TIME VARIATIONS OF EXPOSURE RATES FROM RESIDUAL RADIOACTIVITIES PRODUCED IN SHIELD CONCRETES

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ABSTRACT

The concrete constituent (magnetites ore, pyrites ore, marble, gravel and Portland cement) were irradiated by secondary particles at the slow extracted beam line of the KEK 12 GeV proton synchrotron, and the levels of photon exposure rates from these constituents were estimated on the basis of the saturated activities for individual nuclides produced. It is suggested that the use of marble concrete in the inside walls at high energy accelerator tunnels can reduce markedely the exposure doses to the accelerator operating crew and maintenance workers, compared with heavy and ordinary concretes commonly used.

INTRODUCTION

The tunnel shielding of the slow extracted proton beam line of the 12-GeV proton synchrotron at the National Laboratory for High Energy Physics (KEK) is composed of magnetite heavy concrete. After about six year's operation, the induced radioactivities in the concrete have been one of te major causes of radiation exposure to the operating crew and maintenance workers, and is so great as to sometimes restrict their work.[1] The residual activities produced in an accelerator enclosure are widespread and in practice it is very difficult to control the radiation dose from activated shielding concretes, while control of the photon exposure rates from locally hot machine components is usually accomplished by shielding and/or periodic replacement. Thus it is very important in designing high energy accelerator shielding to choose the shielding materials which are less susceptible to activation.

In this paper, Magnetite ore, pyrites ore, gravel cement and marble were irradiated by secondary particles produced by the primary beam at KEK 12-GeV proton synchrotron, and the time variations of exposure rates from these concrete constituents were examined extensively. A discussion on the optimum shielding materials at high energy accelerators is given on the basis of the above results.

EXPERIMENTAL

The powdered (40 ~ 80 mesh) concrete consituents of magnetites ore, pyrites ore, gravel, marble and Portland cement are packed in acrylic case (25 mm diameter, 2 mm thick), and te stacked samples are irradiated by secondary particles at EP2. The samples were irradiated for 201.5 hours at the position on the EP2 floor about 5.5 m downstream from the K2 target (Pt : 1 cm diameter, 4 cm long) and at about 30° to the beam direction. The 12-GeV proton beam intensity hitting the Pt target was about 5.49×10^{11} protons/s during the cycle of machine operation. The flux of high energy hadron (≥ 30 MeV) was determined to be (1.01 ± 0.07) particles/$cm^{-2} \cdot s^{-1}$ from the ^{22}Na yield in the irradiated Al disc (2.0964g), using the value of 9.85 mb for the spallation reaction of ^{27}Al. High energy neutrons are considered to be principal particles for this reactions. The measurement of radioactivities and calculation of saturated activities were made in a similar manner as those previously reported.[2]

RESULTS AND DISCUSSION

The exposure rates due to the residual activities is calculated by the following equation:

$$\dot{X} = \sum_i \Gamma_i \cdot A_i \cdot (1 - e^{-\lambda_i \cdot T_{irr}}) \cdot e^{-\lambda_i \cdot T_w}$$

where

$\dot{X}$ = photon exposure rate [(R/h) g^{-1} per seconddary particles: ≥ 30 MeV /s)] at 1 cm from the sample,

Γ_i = specific gamma-ray constant ($R/h \cdot C_i^{-1}$) at 1 cm for the ith nuclide,

A_i = saturated activity of the ith nuclides [Ci· g^{-1} per(secondary particles: ≥ 30 MeV /s)],

λ_i = decay constant of the ith nuclide

T_w = cooling time,

The published values of Ai[2] were used in the calculation. As an example, Fig. 1 shows the time variation of exposure rates thus calculated for the concrete constituents irradiated by the secondary particles for one week. Except for the cement, the exposure rates rank in the following order; magnetite ore > pyrites ore > gravel > marble, regardless of irradiation time and decay time. The exposure rates of the marble are about one-tenth of those of the gravel and one-hundredth of those of the magnetites and pyrites ores at Tw ≈ 10^4 hours. Furthermore the ratios of exposure rates of irradiated concrete constituents to those of the marble become greater with an increse in irradiation time and in decay time. Fig. 2 shows the time variations of exposure rates for various type of concretes, here the mixing ratios of aggregate to cement were assumed to be (by weight): 11.5 for magnetite and pyrites heavy concretes, 5.25 for ordinary concrete and 5.67 for marble concrete. These ratios are commonly used in making concretes. As Fig. 2 shows, the overall variation of exposure rates are essentially similar to those for individual aggregates.

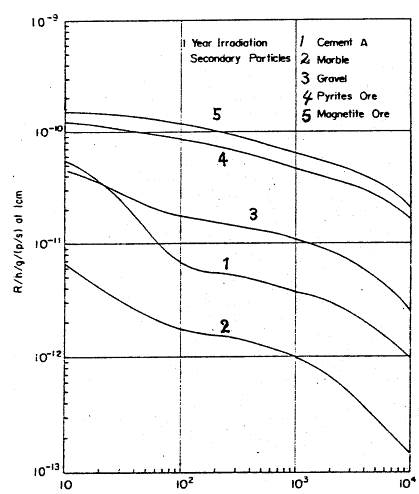

Fig. 1 Time variations of exposure rates [$(R/h) \cdot g^{-1}$ per (secondary particle/s) from the concrete constituents irradiated by the secondary particles (E≳30 MeV) (1-yr irradiation).

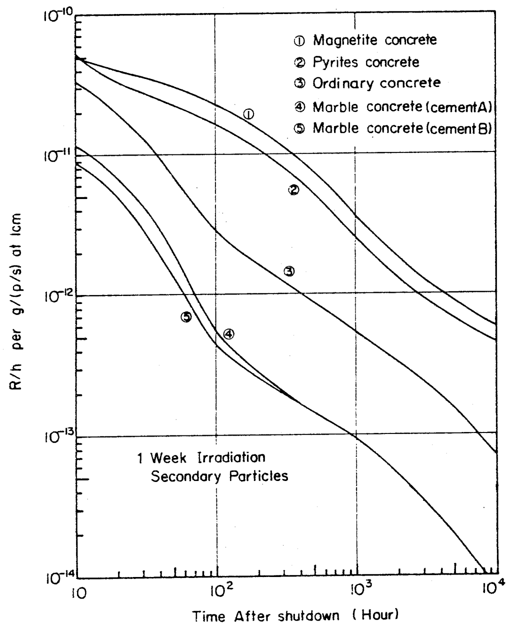

Fig. 2 Time variations of exposure rates [(R/h) g^{-1} per (secondary particle/s) from heavy, ordinary and marble concretes irradiated by the secondary particles (E $\gtrsim$ 30 MeV) (1-week irradiation).

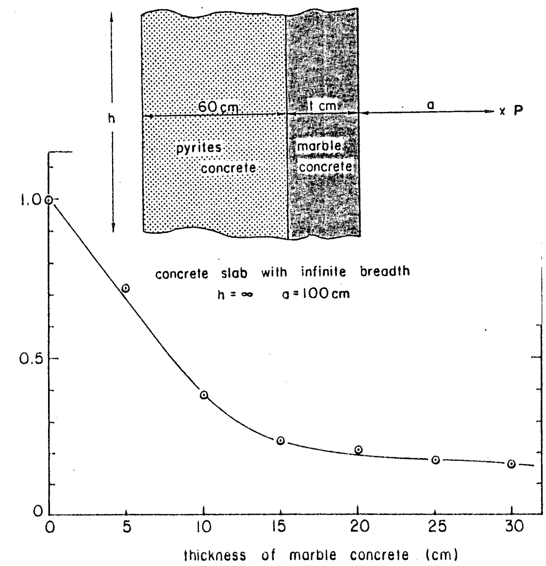

Fig. 3 Relationship between thickness of marble concrete and exposure rates at the position P

These results are suggesting that the use of marble concrete for the inside walls of accelerator tunnels can reduce markedely personnel doses of accelerator maintenance workers. The complex concrete block of pyrites and marble concretes shown in Fig. 3 was devised in order to reduce radiation doses from te activated concretes as low as possible. Exposure rates at the position P are shown in Fig. 3 as a function of the thickness of marble concrete, by assuming that only Mn is present and distributed uniformly in the pyrites concrete, and linear attenuation coefficients for marble and pyrites concretes are 0.185 cm^{-1} and 0.274 cm^{-1} for 0.83 MeV gamma-ray of ^{54}Mn. About 15 cm thickness is enough to shield the radiations from heavily activated pyrites concrete. The concrete block thus designed was made actually to examine the compressive strength. Fig. 5 shows the cross-sectional view of the complex concrete thus made. After standard curing and aging to 28 days, its strength was more than 235 kg/cm^2[3], being about the same as those of ordinary and heavy concretes.

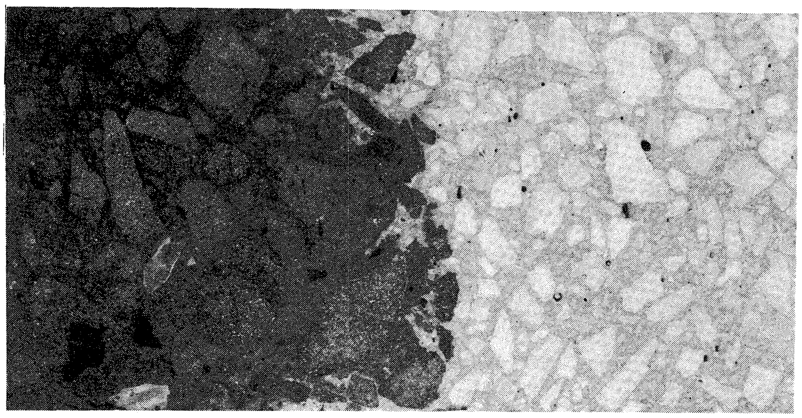

Fig. 4 The complex concrete block composed of pyrites and marble concretes
left: pyrites concrete, right: marble concrete

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3. M. Kawada, Private communication, 1982, Dowa Mine Co., Tokyo, Japan.