GAMMA RAY AND NEUTRON ATTENUATION OF PYRITE-POLYMER CONCRETE

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INTORDUCTION

Concrete is one of the widely used shielding materials, but has only moderate shielding properties for neutrons and gamma rays. Its hydrogen content, an element most effective for fast neutron shielding, is very low (~0.56 % by weight). Enriching concrete with hydrogen-containing materials would enhance its neutron shielding properties, while its gamma ray shielding properties as well as its mechanical strength would be improved by using heavy aggregates. Polyethelene $[(CH_2)_n]$ and polyvinyl chloride (PVC) $[(CH2\text{-}CH\text{-}Cl)_n]$ were introduced as part of concrete constituents to improve its neutron attenuation properties. Both of these compounds are rich in hydrogen atoms. Although PVC has less hydrogen density than polyethelene, the chlorine atoms in the polymer have a higher atomic number and a higher neutron absorption cross-section than either hydrogen or carbon atoms.

In order to improve the gamma ray attenuation properties, pyrite (FeS_2) heavy aggregate ore was selected, which has higher density and higher effective atomic number over ordinary concrete. The attenuation properties of Barite heavy aggregates were presented elsewhere(1).

In a radiation field of neutrons and gamma rays, the appropriate concentration of polymer and heavy aggregate can be selected to give the optimum total dose attenuation.

MATERIALS AND METHODS

The polyethelene used was in the form of small balls 3.3 mm in diameter and their specific gravity was 0.95. The PVC was in the form of cylindrical pellets, 3.3 mm in diameter, 3 mm in height, with a specific gravity of up to 1.4. The heavy aggregate ore consisted of up to 90% Pyrite and Pyrrhotite, up to 5% Chalcopyrite, some sphalerite and traces of other minerals. The fine aggregate which was basically feldspar and quartz has apparent, saturated surface dry and bulk specific gravities of 2.706, 2.661 and 2.642, respectively.

Type-1 Portland cement was used. The weight ratios of cement, of fine aggregates:course aggregate:polymer were, 1:1:1:1 (denoted as Py-PVC-1 and Py-Poly-1 for PVC and polyethelene concrete respectively), 1:1:1:1.4 (denoted as Py-PVC-1.4 and Py-Poly-1.4 for the two types respectively) and pyrite polymer free concrete (pyrite conc.). The water to cement ratio was 0.5.

A neutron dosimeter that approximates human body dose-equivalent over a wide neutron energy was utilized (type NM2-NE Technology). The gamma ray exposure was measured by a portable ionization chamber (model 660, Victoreen), with accuracy better than 5% at ^{137}Cs gamma ray energy. The neutron source was ^{241}Am-Be with a neutron emission rate of 6.6×10^6 n/s and a tolerance of 10%. Its neutron dose-equivalent rate at 1 m was 66 μSv/h. The gamma ray source used was ^{60}Co, of 1.4×10^8 Bq activity.
Broad-beam geometry was used, where, in most practical situation, the narrow beam conditions for neutrons do not prevail. The distance between the point source and the detector

was kept constant at 1m. The Lateral dimension of the specimen was selected to give maximum scattering towards the detector. A 60 cm. Lateral dimension was enough to scatter most neutrons and gamma rays.

RESULTS AND DISCUSSION

The natural log of relative neutron dose versus shield thickness is shown in Fig.1. The slope of the lines would be the neutron linear removal coefficient. Clearly the concrete type with higher polymer concentration shows higher attenuation and that polyethylene type exhibits higher attenuation over PVC type. The value of the neutron removal coefficient for Py-Poly-1.4 was approximately twice that of the Pyrite Polymer-free type. The natural log of relative gamma ray exposure rates are shown in fig.2. Unlike neutron attenuation, in this case the pyrite concrete of no polymer shows the highest attenuation followed by ordinary concrete and PVC concrete. The least attenuator was the polyethylene type. This is attributed, mainly, to the high density and the higher effective atomic number of pyrite ore over the rest types. The attenuation coefficients data presented here for pyrite-polymer concrete is close to that of barite-polymer type (1).

It may be concluded that in a mixed field of neutron and gamma rays, the appropriate concentration of polymer or heavy aggregate can be selected to give the highest attenuation of the total dose.

REFERENCES

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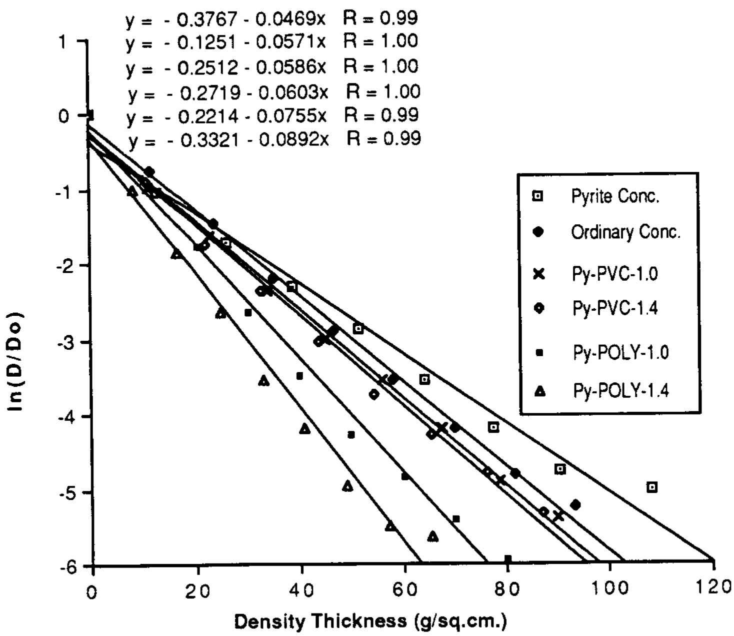

Fig.1. Natural log of relative neutron dose rate in broad beam geometry of pyrite concrete loaded with either polyethylene or PVC, shown with the sraight line fitting equations.
The source-to-dosimeter distance was 1 meter.

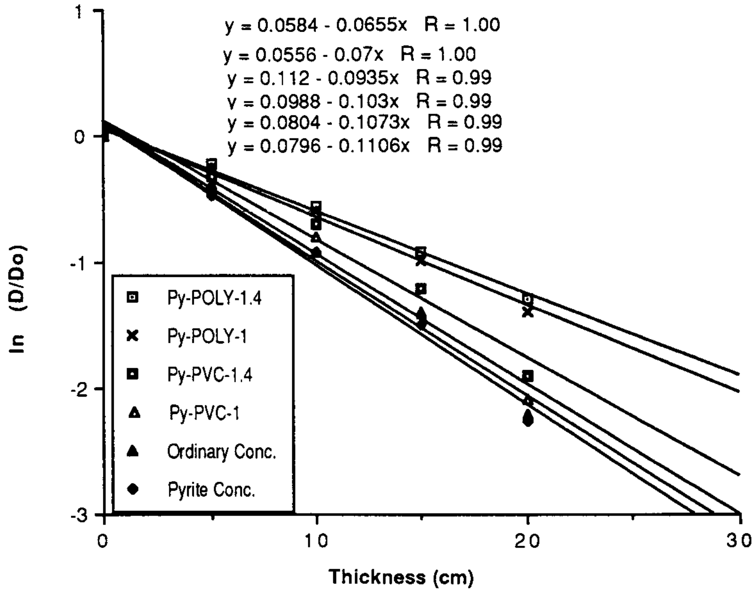

Fig.2. Natural log of relative gamma ray exposure dose rate versus thickness of pyrite concrete loaded with either polyethylene or PVC, shown with the straight line fitting equations. The source-to-detactor distance was 1 meter.