Evaluating Linear Attenuation Coefficient for Bio-Shield Concrete using Thermal Neutron Beam Facility at KAERI

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Introduction

- Developing improved bio-shield concrete
  - higher neutron shielding efficiency
    → protecting workers near the reactor
  - lower activation by neutron
    → reducing the highly radioactive wastes from nuclear power plant decommissioning

Neutron Shielding Efficiency

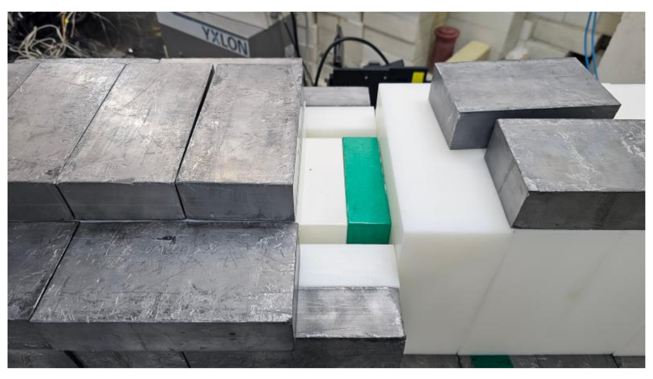
$$\varepsilon_{NS} = \frac{C_0 - C_i}{C_0} = 1 - B \cdot Exp(-\mu d)$$

ε_{NS}: neutron shielding efficiency
Index 0: w/o sample
Index i: i_{th} sample (1-5)
C_0, C_i: neutron count rate
μ: linear attenuation coefficient
d: thickness of the sample
B: build-up factor

Concrete Samples

- Produced by KICT
- Size: $15 \times 15 \times (4, 6, 8, 10)$ cm^3
- Description
  - Ref: normal concrete
  - White: concrete w/ various materials, w/o boron
  - Gray: Ref + boron compound (BN or B_4C)

Concrete samples

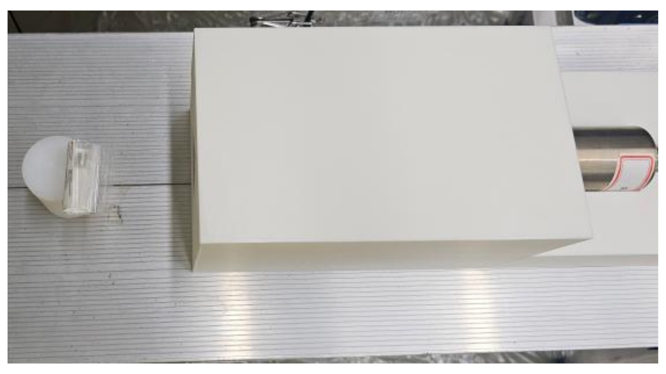


Sample in evaluation system

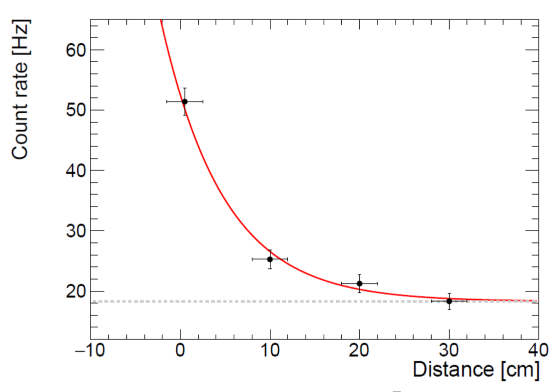
Neutron Detector

- ^{3}He proportional counter
- Plastic holder for positioning detector
- Size: 5 (diameter) × 45 (length) cm^2
- Maximum trigger rate: 916 kHz
- Testing detector using ^{252}Cf source

^{3}He proportional counter w/ plastic holder



Test setup (right: ^{252}Cf)



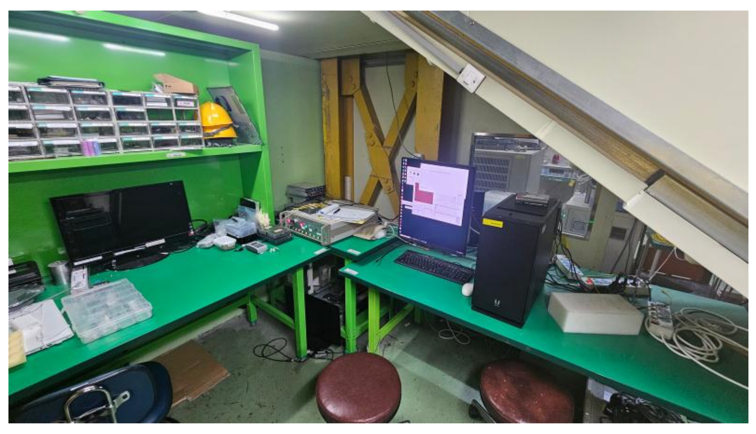
Test result

Neutron Beam Facility at KAERI

- Ex-core Neutron Irradiation Facility (ENF)
- Neutron source: HANARO
- Neutron wavelength: 1-6 Å (~0.002-0.082 eV, thermal & epithermal neutrons)
- Neutron flux: 5×10^8 n/cm^2 @ center of beam port
- Water shutter for shielding neutron beam (consuming 5-6 minutes for on/off)
- Remote control room near the neutron irradiation room

Entrance of neutron irradiation room

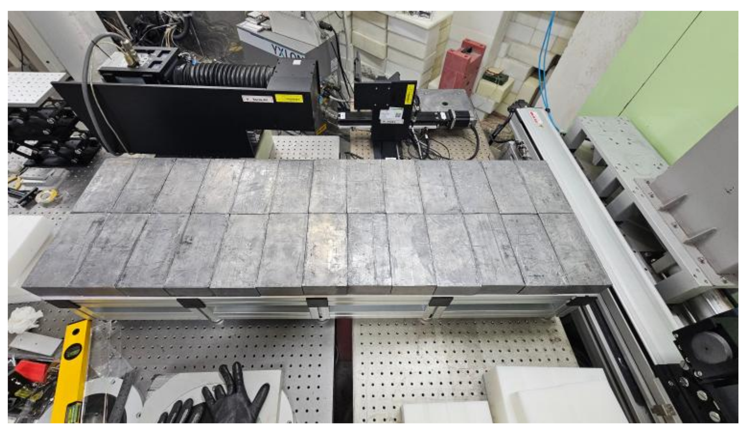
Neutron irradiation room



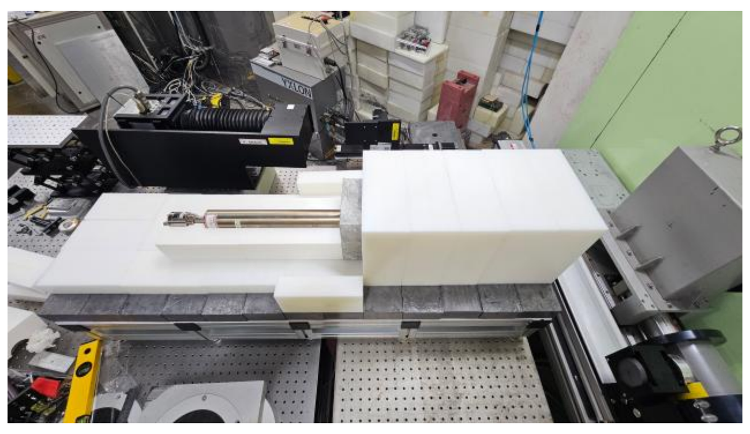
Remote control room

Experimental Setup & Method

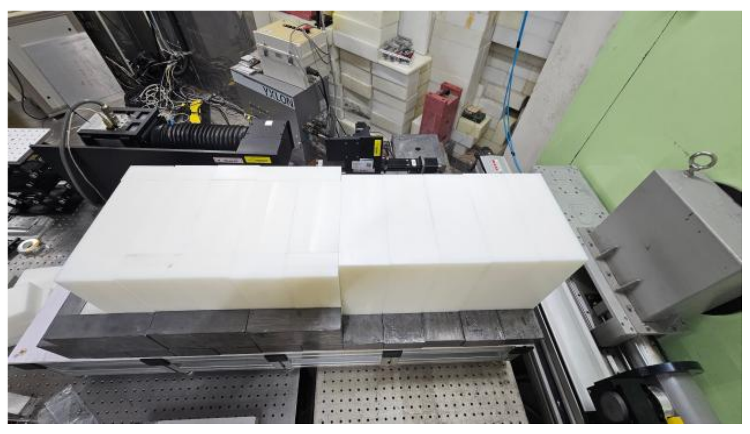
- Optimizing neutron beam flux for shielding efficiency evaluation
  - positioning neutron detector away from the beam port (104 cm)
  - focusing neutron beam using collimators (length: 50 cm, material: HDPE)
- Shielding detector from the external neutrons and gammas (HDPE & lead bricks)
- Alternating measurements of neutron beam w/o and w/ sample



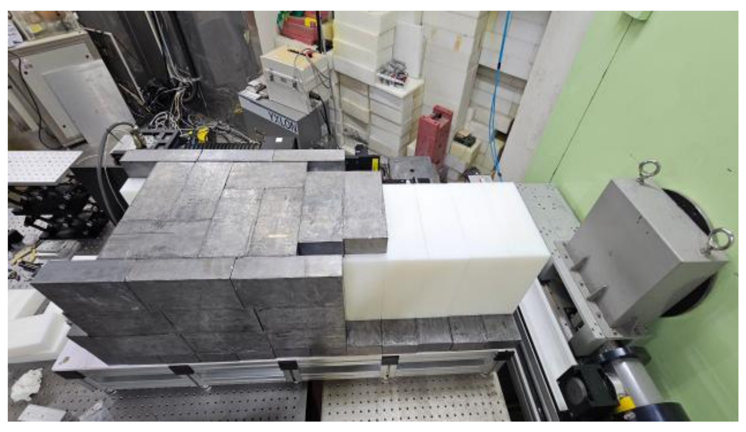
1. Pb shielding at bottom



2. Positioning collimators & detector



3. Covering detector



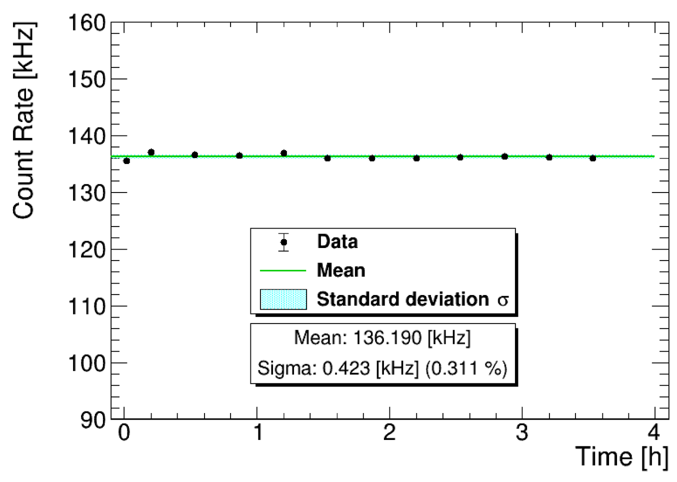
4. Shielding detector w/ HDPE/Pb

5. Loading sample in the system

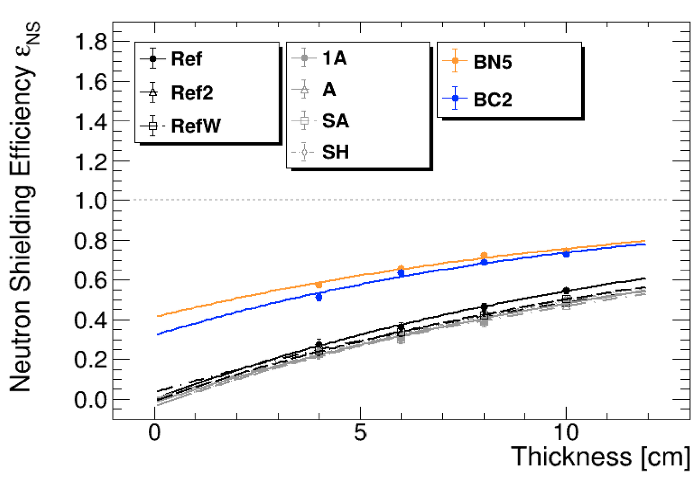
6. Ready for measurement

Results: Evaluation of Neutron Shielding Efficiency

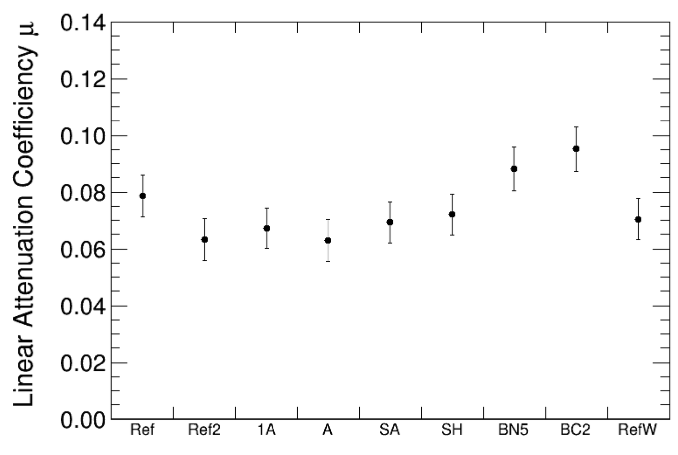
- Checking neutron beams stability using data w/o sample
  → neutron count rate: 129-136 kHz w/ 0.3% fluctuation for 108-114 cm distance from neutron beam port
- Comparing neutron shielding efficiency / linear attenuation coefficiency w/ various materials, compositions, and thicknesses (4-10 cm)
  - doping boron compounds → increase of neutron shielding efficiency ε_{NS} and linear attenuation coefficiency μ
  - comparing boron compounds (5% BN or 2% B_4C) → similar in error range but concrete w/ B_4C is more efficient



Neutron beam stability



Neutron shielding efficiency



Linear attenuation coefficiency

- Study plans
  - Simulating neutron shielding tests → evaluating buildup factor & estimating neutron shielding efficiency for actual concrete thickness (~2 m)
  - Analyzing uncertainties for neutron shielding efficiency evaluation