Boron-Enriched Mortar Panel Applied to the Shielding Wall of the Spectrometer for Reducing Noise Neutron at the BL14 in J-PARC

Ken-ichi Kimura, Masaharu Kinno

Abstract

Boron-enriched mortar panels attached to PC (Precast Concrete) were applied to the shielding structure of the spectrometer of beam line 14 in the J-PARC facility. In collaboration with J-PARC, two kinds of experiments were performed using cold neutron to confirm neutron shielding and reflection performance. The results of the experiments for 19.6 wt% boron-enriched mortar showed a 10-fold improvement in performance compared with the ordinary mortar. The thickness of the mortar in the applied shielding material was 35mm, which was 1/3 thickness materials of the boracic acid resin originally designed. This boron-enriched mortar enables more accurate measurement for most research works in J-PARC and could be applied to any facility where neutrons are generated.

§1. Introduction

Japan Proton Accelerator Research Complex, called J-PARC [1][2], is a new and exciting accelerator research facility in Japan. The Material and Life Science Experimental Facility, (MLF) is one of the main facilities in J-PARC, and has the world's highest intensity pulsed neutron and muon beams in order to promote material science and life science[3].

The neutron facility in MLF utilized a pulsed spallation neutron source based on a high power 3 GeV proton synchrotron. This facility has 23 neutron beam lines with different spectrometers for various research fields[4], such as quantum effects, precise determination of atomic arrangement, surface science, biological molecules, engineering applications, and so on. These researches are for various of subjects, which include super conducting materials, battery anodes, magnets, structures of the earth core liquids, polymers, proteins, and medicines. Some of the expected research results may include understanding the functions and properties of materials through the observation of quantum effects in solid state physics, understanding the precise atomic structure of materials in the indispensable base of material science, biomolecular science for understanding life, and behavior of the materials in high pressure and high temperature for understanding earth science.

These researches are performed by detecting reflected neutron from samples, which are set on the beam line inside of the spectrometer. One of the key factors is how to reduce noise neutron, which come from various component materials for the facilities except samples. On the other hands, the instruments including the spectrometer are covered in concrete or iron materials for the radiation shielding purpose. These shielding materials can be source of the above unexpected reflecting neutron.

Keywords : Boron-enriched; Neutron; J-PARC; PC (Pre stressed concrete); accelerator

So, we developed a new type of shielding materials, which reduced the rate of reflection for the unexpected reflecting neutron by about 10 times compared with ordinary materials based on low-activation concrete and related technologies[5][6], and applied them to the shielding materials in Beam Line 14 (BL14) at J-PARC.

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§2. Experiment

In order to estimate the reduction performance of unnecessary reflection neutron from sources other than the target samples, two kinds of experiments (transmission and reflection in a box) were performed using JRR-3M (Japan Research

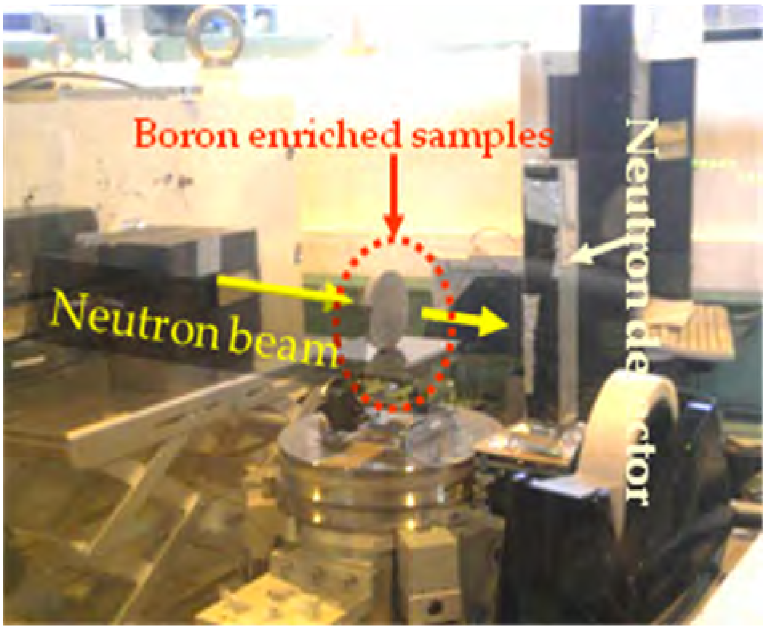

Fig.1 Geometry of the transmission experiment

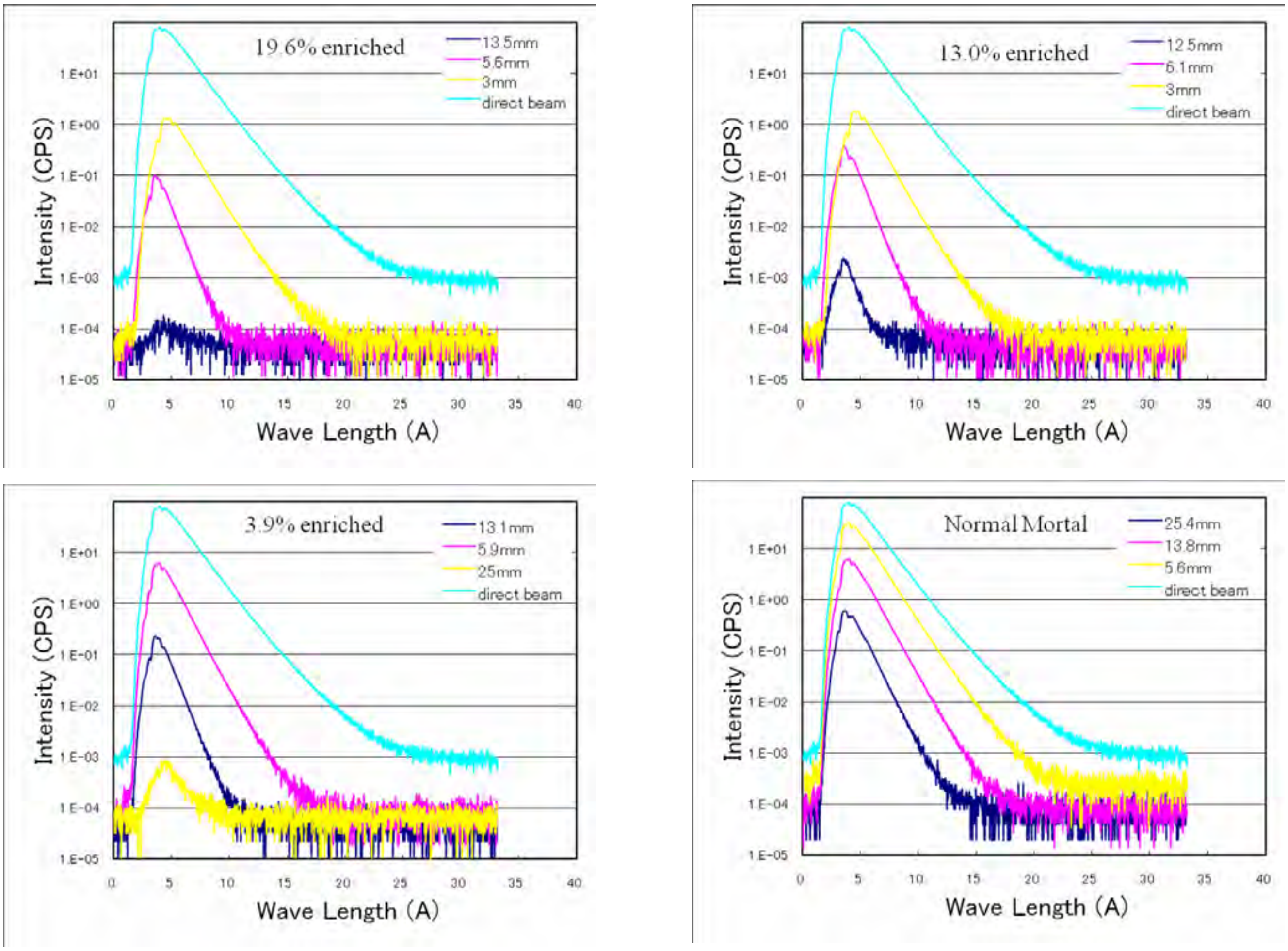

Fig.2 Typical results for the transmission experiment

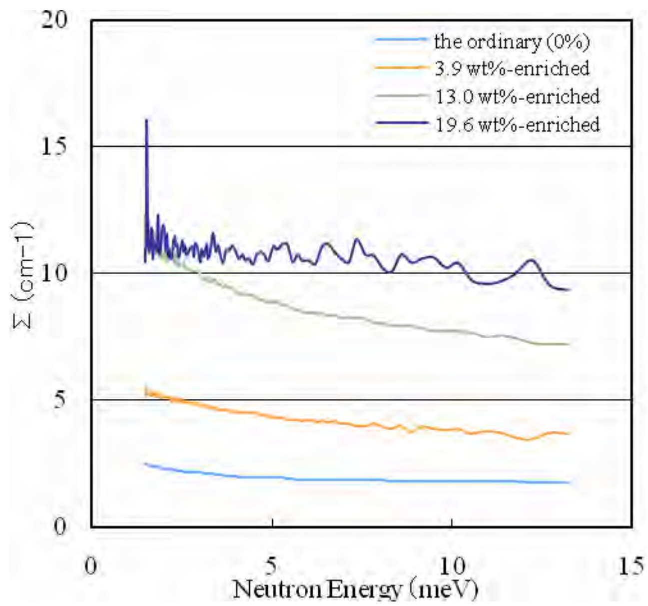

Fig.3 Estimated macro cross section of each boron-enriched samples by transmission experiments

Reactor III in Tokai) [7], in collaboration with J-PARC.

2.1 Measurement of transmission

Transmission experiment is a common procedure to discover the basic of shielding performance against neutron transmission. Ten different concentrations of boron samples with three different thicknesses were prepared for the transmission experiments, and set shown as Figure 1. The neutron beam comes from left side of the figure to the samples set in the center, and only transmitted neutron can be detected by the He-3 neutron detector. The boron concentrations of the samples were from 0.02 wt% to 40 wt%, and the thickness were from 3mm to 25mm. The energy of the neutrons for the experiment were mostly a few meV, up to several tenth meV, which are called “cold” neutrons, because of lower than “thermal” neutron in energy unit, which is equivalent to room temperature.

Figure 2 shows typical results from the experiments. The titles of the each figure indicate the concentration of boron for the sample for the test, which were 0 wt% (ordinary mortar) to 19.6 wt%. The horizontal axis indicates wave length, which could be converted neutron energy, and the vertical axis indicates intensity. Each figure had four curves for three different sample thicknesses and direct beam.

From the three different curves shown in Figure 2, a macro cross section can be calculated for each sample with different boron concentrations, which was shown in Figure 3. The horizontal axis of Figure 3 is the neutron energy and the vertical axis is the macro cross section. This figure indicates that higher boron concentration have higher macro cross sections. The rough curve for 19.6 wt%-enriched samples is caused by low intensity of transmission data with the thicker samples in Figure 2, while the other three curves have higher intensities. This figure shows that the 19.6 wt%-enriched data has the highest macro cross section for all neutron energies among the four smples, while the difference to the 13.0 wt%-enriched data around a few meV is small and the tendancy of the curve for the 19.6%-enriched data is different from other three curves. This difference may cause low intensity for the 19.6%-enriched samplse, so more data should be collected for better understanding.

2.2 Evaluation to measure reduction of reflected neutrons

In the 2.1 section, the basic properties for the transmission were taken from the simple experiment. However, the data required was the reduction of neutrons reflected by materials other than the target. So, a new type of experiment was carried out for the evaluation of the boron-enriched mortar applied to the shielding wall of the spectrometer at the Beam Line 14 in J-PARC.

Measurement of only reflected neutrons was required in order to evaluate the reduction performance. So 400mm cubic boxes with 300mm cubic inner space and 50mm of wall thickness, which were manufactured by 19.6% boron-enriched mortar and ordinary mortar, were prepared.

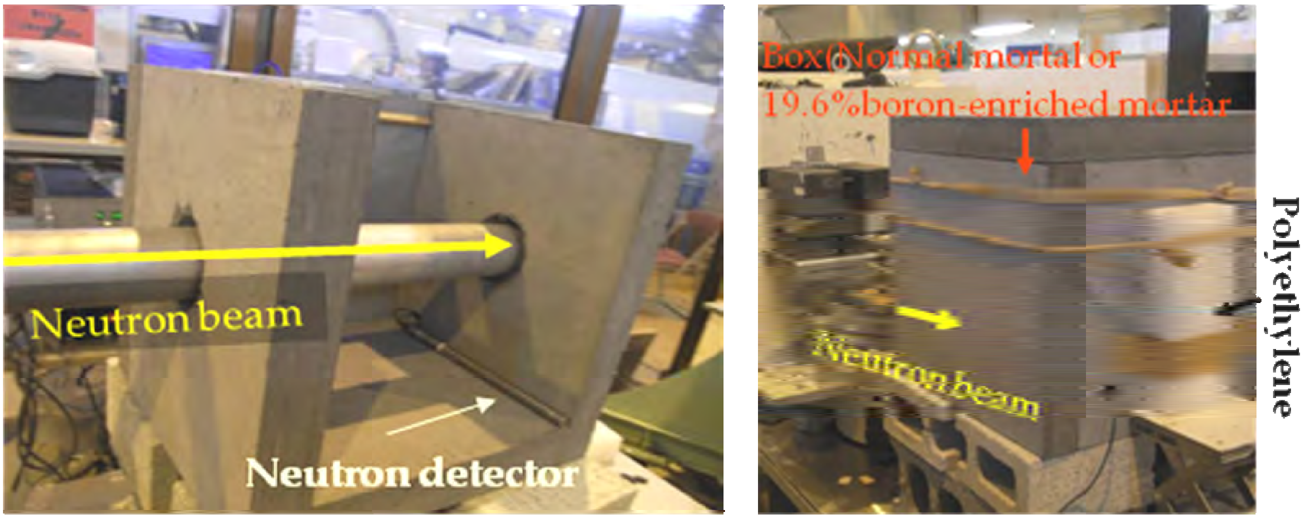

Fig.4 Geometry for the experiment of the reduction performance of the reflected neutron

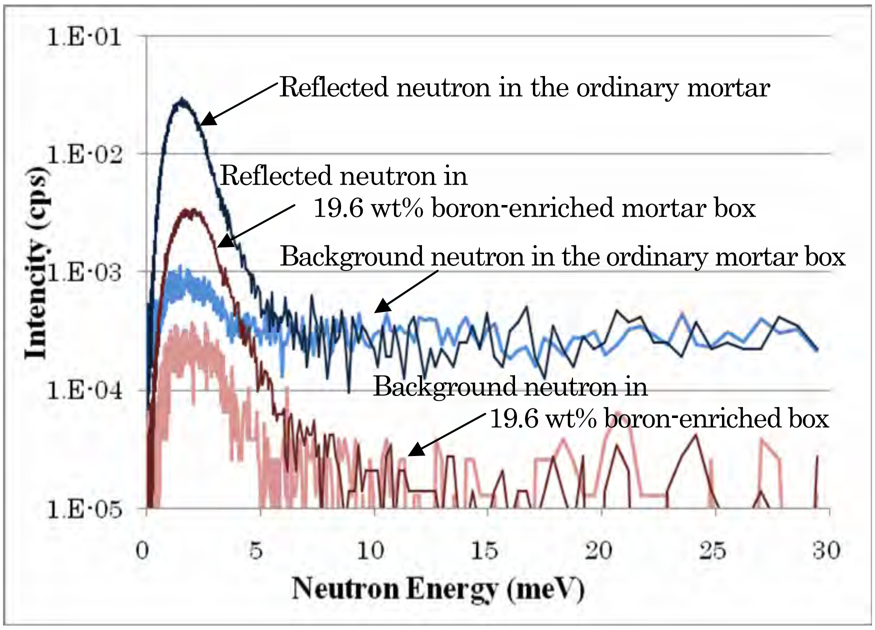

Fig.5 Comparison of neutron reduction performance of 19.6 wt% boron-enriched mortar to the ordinary mortar

The neutron bean, which was the same as above transmission experiment, was guided inside an evacuated aluminum pipe in the box. The guided neutron went through the inside of aluminum pipe, and irradiated the polyethylene set at the end of the pipe facing the outside box. As polyethylene is reflect-able material to neutrons, some neutrons were reflected by the polyethylene set facing the outside box wall toward inside the box. These neutron were reflected more than one time to the inside wall, which was 19.6% boron-enriched mortar or ordinary mortar and were detected by the HE3 neutron detector, because the wall thickness was 50mm and the neutron detector was set where the neutron directly reflected by the polyethylene could not be reached. Figure 4 shows the geometry for the experiment of the reduction performance of the reflected neutron.

The measurements were carried out two times each (measurement of the reflected neutron and background) for two materials, which were 19.6% boron-enriched mortar and the ordinary mortar. Figure 5 shows a comparison of neutron reduction performance of 19.6% boron-enriched mortar and the ordinary mortar. The peak value of the reflected neutron for the boron-enriched mortar was 10 times smaller than that for the ordinary mortar and background neutron for the boron-enriched mortar was also about 10 times smaller than that for the ordinary mortar. The two peaks in the figure show the quantities of the reflected neutrons and the difference of the two peaks shows the reduction performance of the reflected neutron for the boron-enriched mortar to the ordinary mortar. While background of the difference for the two boxes was also indicated the reflection performance of the neutron for boron-enriched mortar to the

Fig.6 Sckematic veiw of the BL14 (dot circule indicate the spectromater sheilding which inside wall is covered by boron-enriched mortar)

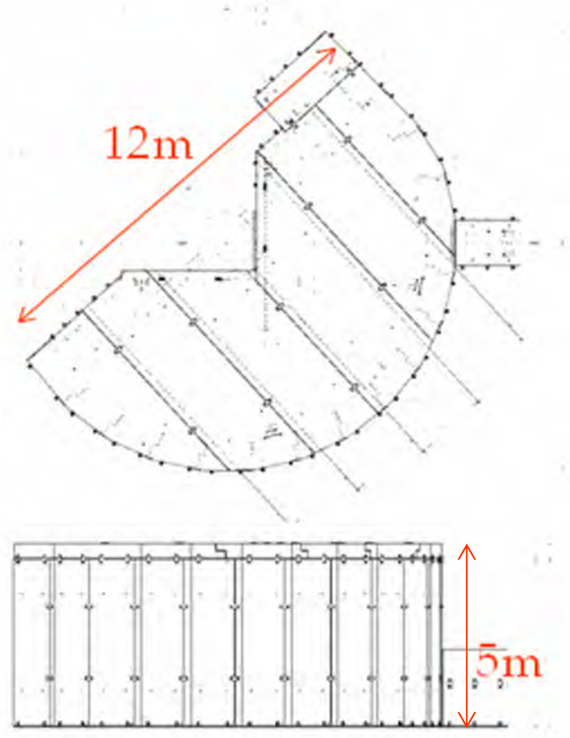

Fig.7 design sketch of the spectrometer shielding

ordinary mortar.

The neutron reduction performance of the 19.6% boron-enriched mortar shows a 10-fold reduction in the peak value of the reflected neutrons and background. This shows that the 19.6% boron-enriched mortar walls have 10 times better performance in reducing the reflected neutron comparing to the ordinary mortar walls.

§3. Apply to the BL14

The above evaluated 19.6% boron-enriched mortar with a 3.5mm thickness was attached to a PC (Precast Concrete) wall with 750mm thickness in order to satisfy the shielding requirement and the reduction of the reflected neutron. This newly developed PC plate, which can be call PC with the boron enriched mortar, was applied to the Beam Line 14 as a shielding structure for the spectrometer, which was called AMATERAS in the Material and Life Facility, in J-PARC[8]. Figure 6 shows the whole shielding structure, which includes the shielding block around target (blue concrete blocks on the right-hand side), the beam transported shielding blocks (light pink concrete blocks in the middle), and the shielding structure for the spectrometer (circled by dash line in the left side).

Figure 7 shows the design sketch for the spectrometer shielding structure, which has a cylindrical shape with 12 m diameter and 5 m height. All of the surface of the inside wall except floor, which area is about 200 m^2, were wearied 19.6% boron-enriched mortar with 3.5mm thickness, which was originally designed 100mm boracic acid resin.

The boron-enriched mortar, with a boron

concentration of 19.6w%, can reduce the unnecessary reflected neutron, which mainly comes from shielding wall, up to 1/10 and the thickness can also reduce 1/3. This makes the inelastic and quasielastic scattering measurement in Bean Line 14 more accurate. The spectrometer of Beam Line 14[9] is called "AMATERAS –Cold Neutron Disk-Chopper Spectrometer" [7], which main features are new fast dick chopper, double chopper spectroscopy with a coupled moderator source, and repetition rate multiplication.

§4. Conclusion

The transmission of the cold neutron experiment for the ten boron-enriched mortar samples was performed in JRR-3, in order to evaluate basic shielding performance of the boron-enriched mortar. The mortar of 19.6w% boron-enriched (19.6 weight %), has best performance of the 10 samples.

To estimate the reduction performance of the neutron reflection, another experiment was performed using a box consisting of 19.6% boron-enriched mortar, compared with the ordinary mortar. The neutron intensity reflected from boron-enriched mortar box was about 10 times less than that from the ordinary mortar. This experiment showed that the reduction of reflected neutrons for the 19.6% boron-enriched mortar is 10 times better than that of the ordinary mortar.

Based on the above 2 undertaken in collaboration with J-PARC, the performance of the boron-enriched mortar was confirmed. So, this newly developed boron-enriched mortar panel was attached to the PC, which was applied to the shielding structure of Beam Line 14 in MLF of J-APRC. The thickness of the boron-enriched mortar was 35mm, which is 1/3 comparing to the designed thickness by boracic acid resin.

This boron-enriched mortar enables accurate measurement for most research works in J-PARC, and also can be applied at any facility where neutrons are generated, such as nuclear facilities, accelerator facilities, and so on.

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Ken-ichi Kimura

short comment The developed boron-enriched mortar is very unique and should be useful. So, I try to proceed to distribute this material every possible market related radiation field.