# A Study of the Viniard Board Quality Using Neutron Radiography Technique

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Film Neutron Radiography (NR) imaging technique was employed to study the quality of viniard board used as building materials collected from the Partex group company of Bangladesh. Samples of viniard board to be studied were irradiated with thermal neutrons of 3 MW TRIGA MARK-II Research Reactor at Atomic Energy Research Establishment (AERE), Savar, Dhaka, Bangladesh. Measurements were carried out to determine the defects and the water absorption behavior of the studied material. The optical density of neutron radiographs was determined for both cases and it was found that there were no defects in the sample as well as the structural constituents of the material were distributed uniformly. The water absorption over a period of time for the same sample was found to be negligible.

## 1. Introduction

Neutron Radiography (NR) is a non-destructive technique for testing nuclear and non-nuclear materials as well as industrial products. It is a powerful tool for non-destructive inspection of materials and also a complementary technique to X-ray radiography [1-5]. Neutrons are attenuated by the interaction with nuclei of the sample material and its image contains the information about the material and the structure inside the sample. On the other hand, the attenuation of X-rays depends on the charge density of the electron cloud and increases with the atomic number of the sample material. Contrary to X-rays, neutrons are also well attenuated by light materials such as hydrogen due to its large scattering and absorption cross-section. The total neutron cross-section depends on the properties of nuclei and varies from element to element, even from isotope to isotope. Therefore, neutron radiography can be used as a tool for non-destructive inspection of materials.

In Bangladesh, NR was first used in the laboratory of AERE, Savar, Dhaka, to study building materials such as bricks and concretes. Later, this technique was further employed for quality control tests of some industrial products like leather, rubber, plastics, ceramics, and composites materials containing wood and plastic. Wood and its associated industrial raw material technology has been changing mainly due to a rapidly evolving economic situation. An example of such change is a recent invention by Partex group of Bangladesh, a kind of wood like material called 'Viniard board', which is now being used for various purposes. It has been used especially by the housing construction industry in rural areas during the last decade. However, there has not been any published study on the quality of Viniard board either in our laboratory or elsewhere in the country. The present study was undertaken with a view to check the defects and the water absorption of viniard board by NR technique.

## 2. Experimental Procedure

### 2.1 Sample collection and neutron beam facility

Samples of viniard board were collected locally from the Star Particle Board Mills Ltd., a unit of Partex group, with the aim to detect its internal defects and water absorption behavior using the direct film NR technique. Neutron radiography was performed using the thermal neutrons facility at 3 MW TRIGA MARK II Research Reactor of the Atomic Energy Research Establishment, Dhaka, Bangladesh. In this experiment, the tangential beam port of the reactor has been used for thermal NR because it provides good contrast of images due to its sufficient amount of thermal neutron flux as compared to gamma – rays, which is not the case of other three port lines. Neutrons obtained from this source were processed before the use of this source for the Neutron Radiography. A detailed description of the reactor (TRIGA MARK-II) construction and its facility can be found in [6, 7]. Some relevant features of its thermal beam line are shown in Table 1.

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| Neutron flux ($\phi_{th}$) at sample position: | $1.13 \times 10^6$ n cm$^{-2}$ sec$^{-1}$ |
|---|---|
| Diameter of the entrance aperture: | 2.34 cm |
| Length of the collimator: | 140 cm |
| L/D: | 60 |
| Gamma ($\gamma$) dose: | 0.5055 mR/sec |
| Effective beam area: | 30 cm$^2$ |
| Cd ratio: | 10.51 |
| $\phi_{th} / \gamma$: | $2.23 \times 10^6$ n cm$^{-2}$ mR$^{-1}$ |

Table 1.  Important features of the tangential beam line of the Research Reactor.

### 2.2     Methods and Analysis

Gadolinium (Gd) metal foil converter of 25 µm thickness and Agfa D4P DW industrial X-ray films were used as detector in the NR camera. The films have emulsion only on one side. The NR camera is a tight device for holding both the film and the converter foil in close contact during exposure. The film was loaded into the NR camera in such a way that the emulsion surface of the film was kept in contact with the converter foil. These procedures were carried out in a dark room to take the radiography of experimental objects. The sample was placed at the surface of the NR camera by using the aluminum tape and then placed on the neutron beam line. In order to obtain the high-resolution neutron radiographic images, the samples were exposed for an optimum time, which was determined by a series of experiments, each with a different exposure time. By observing the brightness and the homogeneity of radiographic image of samples, which has the task of collecting the signal emitted by the converter during the exposure time, the optimum exposure time was determined to be 40 minutes.

To determine the water absorption behavior of Viniard board samples, the neutron radiographs were first obtained in dry condition. Then, the same samples were immersed in water for different duration of time and again the radiographic images were taken. The immersion periods were chosen to be 10, 20, 40, and 60 minutes.  After performing the irradiation with thermal neutrons, the film was separated from the camera in a dark place and the following steps were taken to make visible images of the irradiated samples:  developing, washing, fixing, final washing and drying.

Developing ensures better contrast of photo-

images produced during the irradiation process of samples. Kodak D-19 developer was used in the developing procedure. We kept the film in the developer for 5 minutes at temperature of 22°C. After the completion of development, the activity of remaining developer in the emulsion was neutralized by rinsing the developing film and vigorous agitation in flowing water for one minute. Then the developed film was immersed in the fixer chemicals (Kodak Unifix powder) for 5 minutes at 22°C to obtain clear neutron radiographic images. Silver compounds formed during the fixing stage must now be removed to reduce or cancel any effect they may have later on images. For this reason, the film was washed thoroughly in running water for 15 minutes at 22°C. After final washing, the film was dried by flowing fresh air from the air-cooler.

In order to inspect the quality of the studied samples, the optical density (D) of the images was determined by the densitometer using the following mathematical expression as [8]:

$$D = \log \frac{A_0}{A} \qquad (1)$$

Here, $A_0$ represent the response of densitometer without any image, and A represents the response of densitometer with images.

The fractional change in image density $\Delta D$ is calculated using the formula:

$$\Delta D = \frac{(D_c - D_n)}{D_c} \qquad (2)$$

Here, $D_c$ is the optical density at the center and $D_n$, the optical density at different positions of the

sample. Radiographic images (or converter signals) can be read out digitally. We measured the optical densities of radiographic images of samples using a digital densitometer, model 07-424, S-23285 of Victorian. Inc., U.S.A. [9, 10]. The fractional change in image densities at eight different positions with respect to the central position was calculated using equation (2). The sensitivity of the used densitometry was checked with a standard sample and its error was found to be 3.94%.

The neutron radiographic image represents the attenuated response of thermal neutrons, which is mainly due to the scattering and absorption interactions of incident neutrons with various constituents of the Viniard board samples. The attenuated response for the dry sample can be written as:

$$I = I_0 e^{-\mu_s t_s} \tag{3}$$

Here, I and $I_0$ are the attenuated and incident neutron intensities, respectively, $\mu_s$ is the attenuation coefficient, and $t_s$ is the thickness of the studied samples under dry condition.

For water absorbed samples, the above equation can be written as:

$$I' = I_0 e^{-(\mu_s t_s + \mu_w t_w)} \tag{4}$$

where, $I'$ is the attenuated neutron intensity in wet sample, $\mu_w$ is the attenuation coefficient and $t_w$ is the thickness of the absorbed water by samples.

From equations (3) and (4), the thickness of the absorbed water by the sample is:

$$t_w = -\ln \frac{\left(\dfrac{I'}{I}\right)}{\mu_w} \tag{5}$$

### 3. Results and Discussion

In the present investigation, the NR technique has been adopted for the inspection of internal defects and water absorption behavior of the Viniard board. Therefore, the experimental outcome can be divided into two parts as:

- Densitometric study of defects in Viniard board;
- Water absorption behavior of samples.

### 3.1 Densitometric study of defects in Viniard board

The optical density values at eight different positions of the sample with reference to the central one is shown in Table 2. This method allows us to comment on the quality of the studied samples from the measurements of the optical density obtained by the NR images. If the optical densities of the samples are different at different positions, then the component within samples are not uniformly distributed. Hence, the fractional change in image density at different positions from that at the centre is the measuring standard for the quality of a sample. The absence of fractional changes in images ensures uniformity of composite materials of which samples under consideration are made of.

### 3.2 Water absorption behavior of samples

The optical density of NR images of samples changes with water absorption. Its value is related to the transmitted neutron that passes through the sample. So, the density is directly related to the quantity of water absorbed by the sample. The densitometric optical densities in dry and wet samples at different values of immersion time period are shown in Table 3. It is observed that the water absorption by the Viniard board samples is negligible.

A series of neutron radiographs were performed and the corresponding radiographic images were taken in a 25 μm thickness of Gd metal foils as converter. The optimum neutron irradiation/exposure time of Viniard board is found to be 40 minutes. The result shows that the density values for different positions do not differ significantly. This confirms the uniform distribution of associated components of the viniard board.

The optical density of radiographic images represents the attenuating behavior of thermal neutrons when passing through the samples under study. This value depends on the thickness of the absorbed water by the same kind of samples. Figs. 1a -1d show that the radiographic image for dry sample has better contrast than other images obtained for immersion times at 10, 20 and 40 minutes. Here, the image for the first 10 minutes of immersion is slightly deviated than the dry one due to the water uptake by the sample and then it is almost constant (Fig.1c and d) for the remaining immersion time periods.

| Sample | Optical density at the center | Average density ($D_c$) | Optical density at different positions ($D_n$) | Fractional change in image density $\Delta D = (D_c - D_n)/D_c$ |
|--------|------|------|------|------|
|        |      |      | 1.81 | 0.000 |
|        | 1.81 |      | 1.81 | 0.000 |
|        | 1.82 |      | 1.82 | 0.005 |
| Viniard | 1.81 | 1.81 | 1.81 | 0.000 |
| board   | 1.81 |      | 1.81 | 0.000 |
|        | 1.81 |      | 1.81 | 0.000 |
|        | 1.81 |      | 1.82 | 0.005 |
|        |      |      | 1.81 | 0.000 |

Table 2. Densitometric data for the study of quality of Veniard board samples.

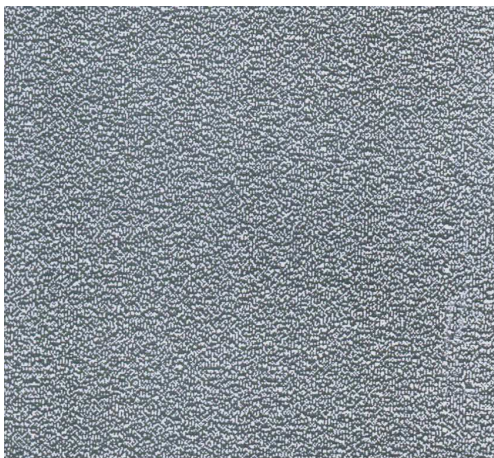| Sample conditions | | Optical density |
|------|------|------|
| Before water absorption (dry condition) | | 1.81 |
| After water absorption | 10 min | 1.47 |
|  | 20 min | 1.40 |
|  | 40 min | 1.40 |
|  | 60 min | 1.40 |

Table 3. Densitometric data of Viniard board before and after water absorption.
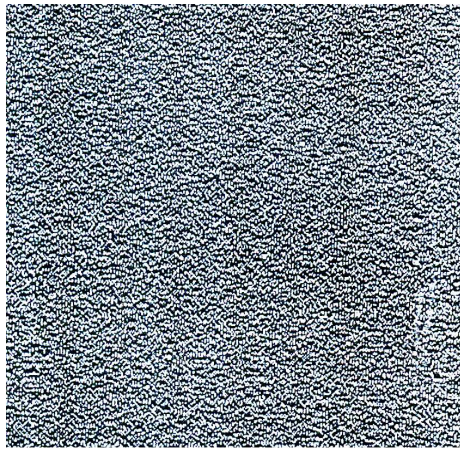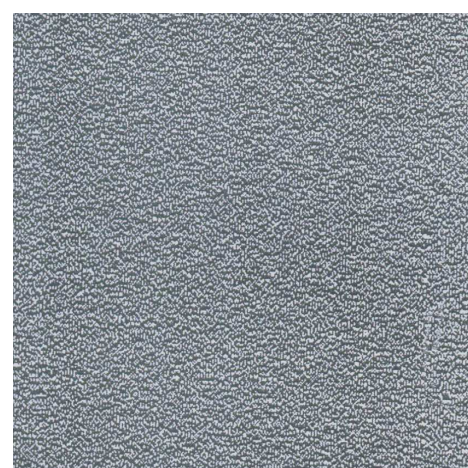
(a) Dry sample.
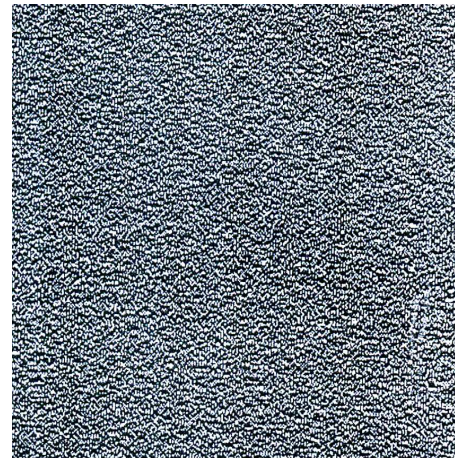


(b) Water absorption for 10 minutes.



(c) Water absorption for 20 minutes.



(d) Water absorption for 40 minutes.

FIG. 1: Neutron radiographic sample images (positive prints) for (a) dry sample and various periods of water absorption as shown above in (b), (c) and (d).

## 4. Conclusion

In the present investigation, NR technique has been adopted to investigate the internal defects and the water absorption behavior of Viniard board samples. Densitometric optical densities were measured for both cases and it was found that the associated constituents of samples were uniformly distributed. This confirms that there was no defect inside the same samples.

Water absorption for the dry as well as wet samples (at different immersion time periods) was carried out and the results of radiographic images showed that the viniard board is a good wooden material even if it is exposed to rain water.

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