

## Study of double layer wire mesh ferro cement plate using neutron imaging technique

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### ABSTRACT

Neutron radiography is an imaging technique for visualizing the internal structure of an object by measuring the neutron flux passing through this object in two dimensions. This technique has found more and more applications. In the present study an attempt is made to observe the homogeneity, porosity/voids, initial rate of absorption (IRA) and water absorption behavior of double layer wire mesh (DLWM) reinforced Ferro cement plate. The outcomes of this study prove that the homogeneity of the DLWM Ferro cement is almost in regular manner, although contains large voids/ porosity but fewer amount. Water absorption rate is poorer than the initial rate of absorption. It also complies with the IRA measurement of the sample. The consistent measurements have carried out by determining the gray values/neutron intensity ratio values of the respective neutron radiographic images of the sample at dry and different wet conditions. The objective of this study is to improve the more effective use of Ferro cement plate as a construction material especially as water reservoirs, sculptures, and roofs and also this would further lead to an “eco-friendly” low cost housing without any loss of structural integrity.

Keywords: Neutron radiography, DLWM Ferro cement, Water absorption behavior, IRA

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### 1. Introduction

Neutron imaging is the process of making an image with neutrons. It uses the basic principles of radiography whereby a beam of radiation is modified by an object in its path and the emergent beam is recorded on a photo film (detector). Also it is called a non-destructive testing (NDT) [1] and evaluation technique of non-nuclear, nuclear materials and industrial products. It is completely complementary to the others NDT technique like X-ray, gamma ray radiography because of charge less neutron. Neutron radiograph gives the information of the internal details of an object; can detect light elements, which have large neutron absorption cross-sections like hydrogen and boron. The atoms of the object material scattered or absorbed the radiation and so the beam reaching the detector shows an intensity/gray value pattern representative of the internal structure of the

object [2, 3]. All radiographic methods, whether making use of X-rays, gamma-rays or neutron beams are based on the same general principle that, radiation is attenuated on passing through the sample/object. The object under examination is placed along the incident beam. The beam, which remains after passing through, enters to a detector that registers the fraction of the initial radiation intensity that has been transmitted through each point of the object. Any in-homogeneity in the object on an internal defect (such as voids, cracks, porosity, inclusion, corrosion etc.) will show up as change in gray value/radiation intensity reaching to the detector.

This method is used for determining various types of corrosion on aluminium structure by some workers [4, 5], maintaining of commercial and military aircraft [6],

determining the internal defects in jute reinforced polymer composites [7], ceramics [8], and tiles [9]. The technique is also adopted for the study of water absorption behavior in biopol, jute-reinforced-biopol composite [10], wood plastic composites [11], characterization of single layer wound healing dressing [12], internal defects and water absorption behavior of environmentally friendly brick-MAB [13], the morphological change in plant pod [14], internal structure of electronic components RAM DDR-2 and Motherboard of Nokia-3120 [15], automated machine made environmentally friendly brick (KAB) sample [16], and quality study of handmade brick-DK [17] etc.

Ferro cement is one kind of building construction material which is used widely during from past thirty years and yet has reached a very advanced stage in technique and design for constructing water tanks, roofs and housing wall panel etc. It is very durable, function able, cheap, high tensile strength and versatile material. The use of Ferro cement is also being explored in developing countries day by day in various fields such as for water tanks [18-19]. Two prototype cylindrical water tanks for the collection of rain water were designed, constructed, and tested for using in the rural areas of the Philippines [20]. Small Ferro cement tanks of less than 5000 gal capacity ( $18.3\text{m}^3$ ) was constructed in New Zealand [21]. The further uses of Ferro cement including sunscreens [22-23] and sandwich wall panels [24] for high-rises buildings, permanent forms for conventional concrete construction, biogas digesters, floor decks, swimming pools, water towers, small deck bridges and culverts [25]. Aim of the present study is to determine the elemental distribution such as homogeneity, voids/porosity, water absorption behavior, initial rate of absorption of water (IRA) into the DLWM sample by using the thermal neutron imaging technique.

## 2. Experimental details

### 2.1. Sample collection and curing

The sample DWLM is collected from the Housing and Building Research Institute, Mirpur, Dhaka-1216, Bangladesh. It is manufactured conventionally with the help of very experienced management team consisting of skilled engineers and architects by using raw materials like sand, wire mesh, cement and water. After collection the sample finally it is prepared/polished manually by using series paper and diamond cutter and then the sample is dried at daylight and dryer machine at  $65^\circ\text{C}$  until to get the constant weight. The actual shape, size and weight of the sample are rectangular,  $25.30 \times 7.8 \times 1.4\text{cm}^3$  and 577 gm respectively.

### 2.2. Loading converter foil and film in the NR cassette

A thin gadolinium metal converter foil of 25  $\mu\text{m}$  thickness was placed at the back of the X-ray industrial film. The loading of the X-ray industrial film (Agfa structurix D<sub>4</sub>DW) into the NR cassette (18 cm x 24 cm) is a simple procedure [26] which requires a darkroom.

### 2.3. Placing of sample and the NR cassette

The sample is place in close contact with the NR cassette and directly on the sample holder table. The NR cassette is placed on the cassette holder table. Both of NR cassette and sample are placed in front of the neutron beam of diameter 30 cm.

**2.4. Irradiation of the test sample:** After completing the procedures of sections 2.1-2.3 neutron beam was opened by removing the wooden plug, lead plug and beam stopper from the front side of the collimator. The DLWM Ferro cement plate was then irradiated for the optimum exposure time of 05 min respectively.

**2.5. Developing:** Development is an image processing technique by which the latent image recorded during the exposure of the material is converted into a silver image [27]. Developing process is completed at (20-22)°C for 07 minutes.

**2.6. Fixing:** The fixation solution will dissolve the unexposed silver-halide crystals leaving only the silver grains in the gelatin. The fixing is completed within 05 minutes and controlled the fixture temperature at (20-22)°C.

**2.7. Washing:** In between developing and fixing the exposure radiographic films were washed for 1 minute at flowing tap water.

**2.8. Final washing:** The silver compound which was formed during the fixing stage must be removed, since they can affect the silver image at the latter stage. For this reason the film must be washed thoroughly in flowing tap water for 15 minutes after completion of developing and fixing process.

**2.9. Drying:** After the final washing, the radiographic films were dried by clipping in a hanger at fresh air and in a drying cabinet to obtain the final radiographic images of dry and wet DLWM reinforced Ferro cement plate sample.

#### **2.10. Determination optimum neutron exposure time**

Exposure means passing of neutron beam through a sample and holding it onto a special film (X-ray industrial film) in order to create a latent image. Different samples having different exposure time depending on the neutron beam intensity, density, thickness of the sample and neutron absorption cross-section. The determined optimum exposure time of the DLWM Ferro cement plate is 5min from the trial and error by taking a series of neutron radiographic images at different exposure time ( $t_i = 2\text{min}, 3\text{min}$  and  $5\text{min}$ ) while the reactor is operated at 2.4

MW. Hence the obtained optimum exposure time is 05 min.

#### **2.11. Immersion procedure of the sample**

The DLWM Ferro cement plate is placed in a plastic pan and a constant 2.0 cm height of water level is maintained at every immersion time of the sample. The water level is observed very carefully and added extra water to maintain water level at 2 cm height during each immersion time. After time of interest (TOI) such as 5, 10, 15 and 20 minutes this Ferro cement plate is removed from the pan and extra water of outside of the sample is removed by using the tissue paper.

#### **2.12. The NR images of wet DLWM ferro cement plate**

The NR images of DLWM reinforced Ferro cement plate at different immersion time like 5min, 10min, 15min and 20min is obtained by using NR facility of 3MW BTRR. One of these radiographic images of DLWM Ferro cement plate is shown in Fig. 1.



**Fig. 1 NR image of DLWM for  $t_w = 5\text{min}$**

### 3. Mathematical formula of

#### NR images

The neutron radiographic image represents the attenuating behavior of thermal neutron beam due to dry and wet sample. The attenuation of thermal neutron beam is mainly due to scattering and absorption interactions of neutrons with atomic nuclei. This attenuating response for dry sample can be written as following equation [28].

$$I = I_0 e^{-\mu_s t_s} \quad (1)$$

Here,

$I$  and  $I_0$  are the attenuated and incident neutron intensities respectively,  $\mu_s$  is the attenuation coefficient of the sample and  $t_s$  is the corresponding thickness. For water uptake by the sample the above equation can be written as follows:

$$I' = I_0 e^{-(\mu_s t_s + \mu_w t_w)} \quad (2)$$

Where,

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

From equations (1) and (2) the thickness of the absorbed water by the sample can be calculated as follows:

$$t_w = -\ln(I'/I) / \mu_w \quad (3)$$

The gray value/neutron intensity of the radiographic images of the sample is changed with the increasing of water absorbed by the sample. The attenuated neutrons beam enter to the detector that resists the fraction of initial radiation intensity that has been transmitted by each point of the object and is then recorded by the radiographic film i.e. image detector.

### 4. Optical density measurement

The neutron intensity before reaching to the Ferro cement plate sample (object) is different from the intensity of the neutron after passing through the sample. The relationship between these two intensities is expressed through the equation (1). On the other side of the film, a light sensor (photocell) converts the penetrated light into an electrical signal. A special circuit performs a logarithmic conversion on the signal and displays the results in density units. The primary use of densitometers in a clinical facility is to monitor the performance of film processors. Actually, optical density is the darkness or opaqueness of a transparency film and is produced by film exposure and chemical processing. An image contains areas with different densities that are viewed as various shades of gray.

### 5. Result and discussion

In the present investigation NR technique is adopted to study the internal defects such as homogeneity, voids/porosity, initial rate of absorption (IRA) and water penetrating behavior into the sample. The NR imaging method is allowed to comment on the quality of the DLWM Ferro cement plate from the measurement of the gray values/optical densities of their neutron radiographic images.

**Homogeneity:** The quality of a Ferro cement plate depends on the proper elemental distribution of the contents, porosity, hardness, water absorption behavior etc. In this section, porosity, elemental distribution of the sample is described by measuring gray values/intensity ratios from the NR images of the sample. Variation of gray values of the radiographic images of the plate indicates the presence of homogeneous distribution of the contents and the presence of porosity.

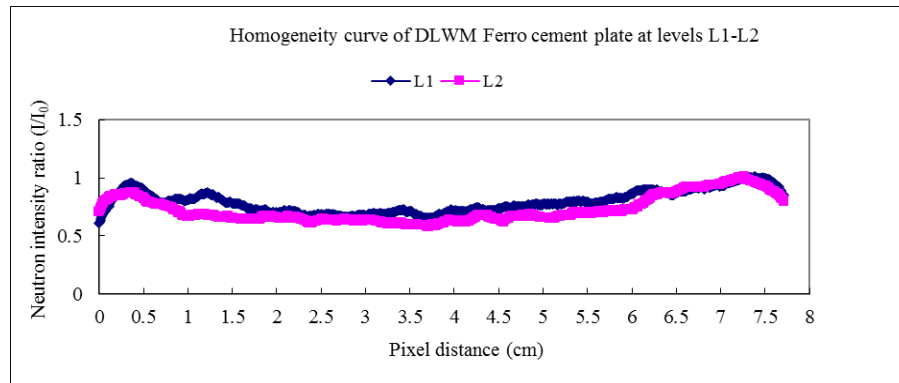


Fig. 2

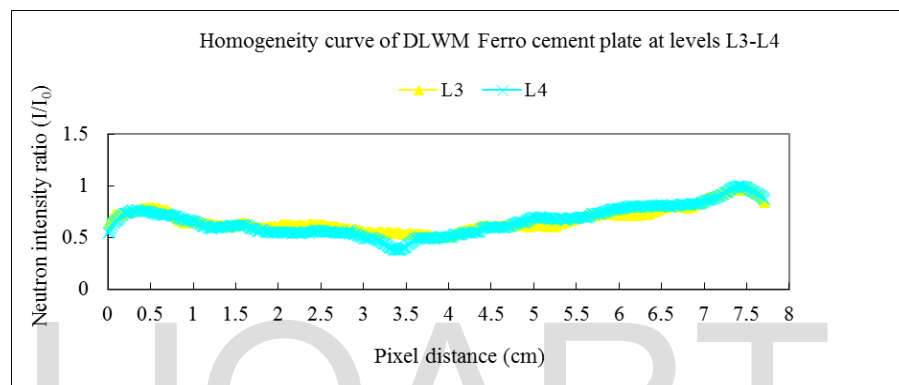


Fig. 3

Fig. 2–Fig. 3 shows the gray value/intensity ratio versus pixel distance plot of radiographic images of DLWM Ferro cement plate. The gray value/intensity ratio is determined by drawing line profile of 50 X 1016 pixel area at different 4 levels on the NR images of DLWM Ferro cement plate using Image J soft ware [29].

In the Fig. 2–Fig. 3, it is also observed that in most of the places the variations of gray values are almost in regular manner. From this point of view it assumes that the distribution of contents in DLWM Ferro cement plate is homogeneous, having slightly larger porosity/voids because of some irregularity of gray value/intensity ratio.

**Water absorption behavior:**

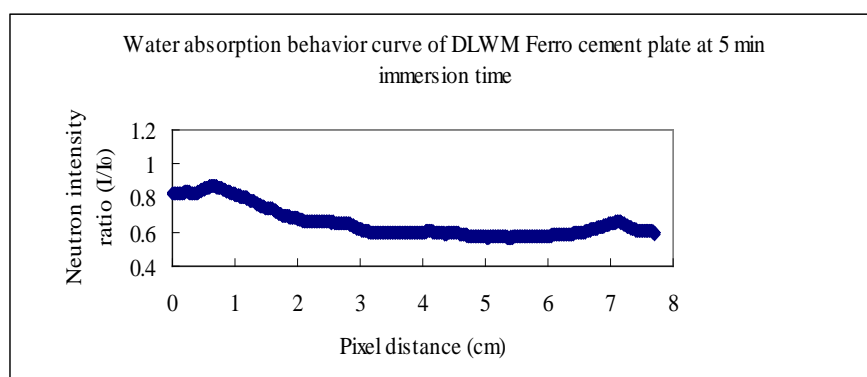


Fig. 4

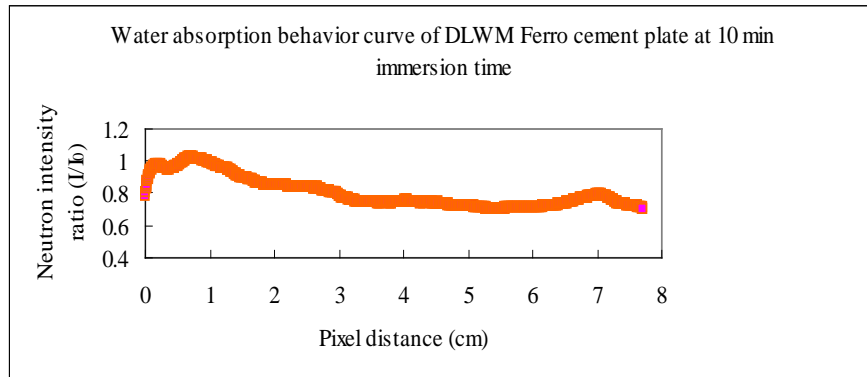


Fig. 5

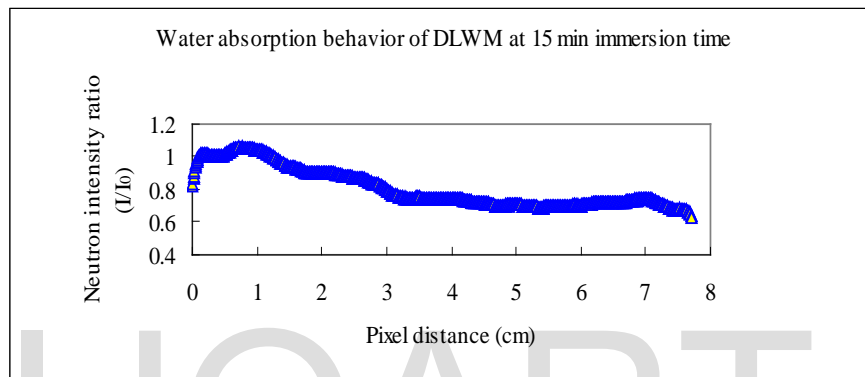


Fig. 6

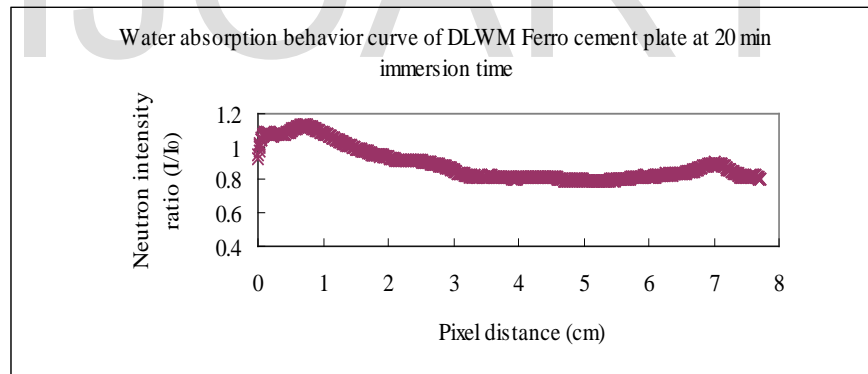


Fig. 7

Water absorption decreased significantly when the temperature increased due to the formation of the amorphous phase at high firing temperature. During the manufacturing time if the clay mixture absorbs more water, brick exhibits a larger pore size, resulting in a lower density. Depending on the H<sub>2</sub>O absorption time of brick, observe differences in capillary absorption [30]. From the present investigation, the water penetrating behavior

through the DLWM Ferro cement plate is completely uniform in manner through the all places shown in Fig. 4-Fig. 7. At 5 and 10 minutes water absorption is slightly different but in case of 10-20 minutes water absorption is almost same compare to first 10 minutes water absorption. Finally it is concluded that increasing of water absorption of DLWM with immersion time is poorer. It also complies with IRA measurement.

**Initial rate of absorption (IRA):**

Initial rate of absorption (IRA) is the measurement of the absorption rate that water is absorbed by a porous solid. It is related to the durability, porosity, pore size distribution and water absorption. It is sometimes called rising damp.

The quantity, sizes and connection of pores influence the absorption rate of the sample. The IRA was reported in units of gm/ (30in<sup>2</sup> min) [31]. In our case IRA is measured in units of gm/cm<sup>3</sup>/min. The result of IRA of DLWM Ferro cement plate is shown in Fig. 8.

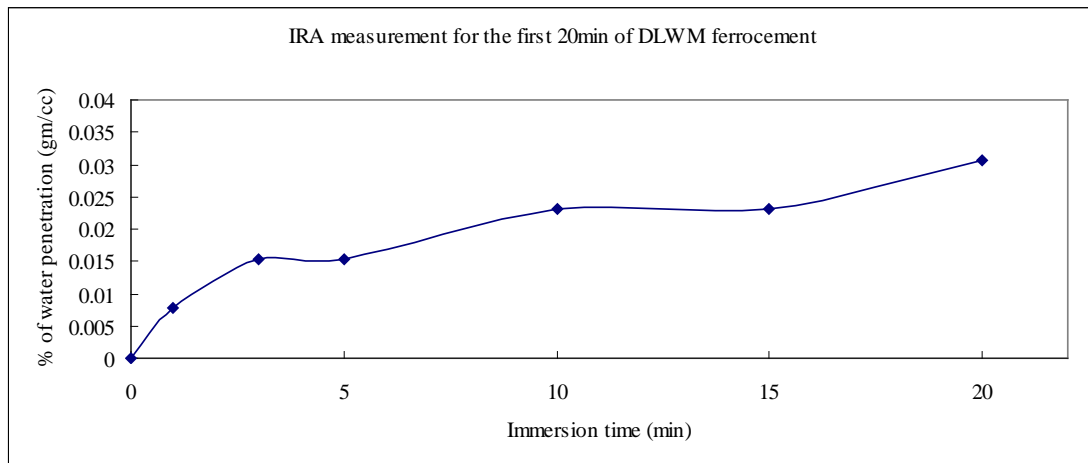


Fig. 8

Fig. 8 shows that at first 5 minutes the rate of water absorption increases slowly with the increasing of immersion time. On the other hand, at 5 to 20 minutes water absorption is continuously increasing but after 20 minutes,

water absorption becomes constant when the sample is immersed into water up to 60 minutes and after 60 to 90 minutes finally the water absorption becomes saturated shown in Fig. 9.

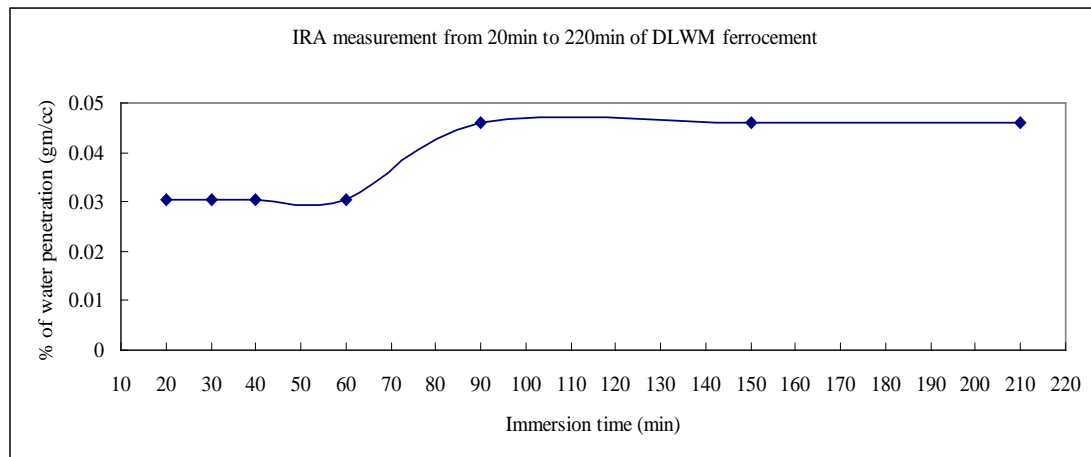


Fig. 9

Generally, the Ferro cement layers showed good stiffness, ductility and impact resistance, the thickness of the slabs increases the absorbed energy, the impact resistance of Ferro cement is improved with increase in number of meshes/layers [32].

The widespread use of Ferro cement has begun only in the past two decades due to its proper advantages in terms of lightness of weight (since its thickness is usually between 13mm and 15mm), less shrinking, high tensile strength, ease of handling and low labor cost in its production. It is recognized that the economics importance of Ferro cement is depends on several factors such as costs of raw materials and labor, and the relative cost of competitive materials. Ferro cement is ideally suited for thin structural elements because of the uniform distribution and dispersion of reinforcement, which provides higher durability, tensile strength and tensile ductility. The results clarify that the uses of double layer wire mesh (DLWM) reinforced Ferro cement plate improve the service and brittleness due to less water absorption. The results also clarify that the Ferro cement wire mesh reinforcement layers improves the ductibility because of less water absorption and used as well as have the ability to reduce cracks.

## 6. Conclusion

From the above observations it is concluded that, the direct film NR imaging technique is powerful tool for non destructive testing to investigate the quality of DLWM reinforced Ferro cement plate. This method is very helpful to observe different characteristic such as homogeneity, voids/porosity, water absorption/penetrating behavior and initial rate of absorption of the desired sample. This DLWM Ferro cement plate sample can be used especially as water reservoirs, sculptures housing wall panel, sunscreens and roofs.

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## References:

- [1] Berger H (1965), Neutron radiography, Elsevier, Amsterdam Berger H, ANL-6846 (1964).
- [2] Hardt, Von der P and Rotterger H (1981) (edditor), Neutron radiography hand book, D. Reidel Publishing Company, Dordrecht, Holland.
- [3] Harold, Berger (1965), Neutron radiography methods, capabilities and applications, Elsevier Publishing Company.
- [4] John J (1970), Californium based neutron radiography for corrosion detecting air-craft, Practical application of neutron radiography and gauging, ASTM STP 586, American Society for Testing and Materials, pp 168.
- [5] Dance WE, Neutron radiographic non-destructive evaluation of aerospace structure, Ibid pp 137.
- [6] Jhon J (1979), Neutron radiographic non-destructive testing, Proc. conference on non-destructive evaluation of materials, (Burke JJ and Weiss Eds V) Plenum Press, New York, pp 151.



- [7] Islam MN, Khan MA and Zaman MA (2005), Study of the defects and water absorption behavior in jute reinforced polymer composites using film neutron radiography. *Journal of Reinforced Plastics and Composites.*, **24(16)**: 1697.
- [8] Alam MK (2005), Comparative study of internal defects in ceramic products using CCD-camera based digital neutron radiography detector. *Bangladesh J. Sci. Ind. Res.*, **40(3-4)**: 169.
- [9] Alam MK, Islam MN and Zaman MA (2007), Study of internal defects and water absorption behavior of single layer Italian tiles using neutron radiography facility of 3 MW TRIGA MARK-II research reactor. *Journal of Bangladesh Academy of Sci.*, **31(2)**: 213.
- [10] Alam MK, Khan MA and Lehmann EH (2006), Comparative study of water absorption behavior in biopol and jute reinforced biopol composite using neutron radiography technique. *Journal of Reinforced Plastic and Composites.*, **25(11)**: 1179.
- [11] Islam MN, Khan MA, Alam MK, Zaman MA and Matubayashi M (2003), Study of water absorption behavior in wood plastic composite by using neutron radiography technique. *Journal of Polymer Plastic Technology and Engineering.*, **42**: 925.
- [12] Alam MK, Islam S, Saha S, Islam MN, Khan MA, Islam JMM and Islam SMA (2014), Characterization of single layer wound healing dressing by using different techniques. *Journal of the African Review of Phys.*, **9**: 95-102.
- [13] Alam MK, Islam MR, Saha S, Islam MN and Islam SMA, (2014), Internal defects and water absorption behavior of environmentally friendly brick-MAB using film neutron radiography technique. *Journal of Bangladesh Academy of Sci.*, **38(1)**: 1-6.
- [14] Rahman MM, Saha S, Islam MN, Alam MK, Rahman AKMA and Islam SMA (2013), A study of the morphological change in plant pod by using direct film neutron radiography technique. *The African Review of Phys.*, **8**: 239-242.
- [15] Mia S, Rahaman MH, Saha S, Khan MAT, Islam MA, Islam MN, Alam MK and Ahsan MH (2013), Study of the internal structure of electronic components RAM DDR-2 and motherboard of nokia-3120 by using neutron radiography technique. *International Journal of Modern Engineering Research (IJMER).*, **3(6)**: 3429-3432.
- [16] Alam MK, Islam R, Saha S, Islam N, Islam SA (2013), Quality study of automated machine made environmentally friendly brick (KAB) sample using film neutron radiography technique. *Journal of Building Construction and Planning Research.*, **1(4)**: 141-152.
- [17] Alam MK, Islam MR, Saha S, Islam MN and Islam SMA (2013), Quality study of hand made brick-dk using neutron radiography technique. *Bangladesh Journal of Scientific and Industrial Research.*, **48(4)**: 237-246.
- [18] Paramasivam P and Nathan GK (1984), Prefabricated ferro cement water tanks. *ACI JOURNAL*, Proceedings, **81(6)**: 580-586.
- [19] Paramasivam P, Nathan GK and Lee SL (1979), Analysis, design and construction of water tanks. *Journal of Ferro cement (Bankkok).*, **9(3)**: 115-128.

- [20] Paramasivam P, Ong KCG, Tan KH and Lee SL (1990), Rainwater storage using ferro cement tanks in developing countries. *Journal of Ferro cement* (Bangkok), **20(4)**: 377-384.
- [21] Ferro cement tanks and utility buildings (1968), Bulletin No. CP-10, New Zealand Portland cement Association, Wellington, 5.
- [22] Mansur MA, Paramasivam P and Lee SL (1987), Ferro cement sunscreens on high-rise buildings. *Concrete International: Design and Construction.*, **9(9)**: 19-23.
- [23] Paramasivam P, Ong KCG, Tan KH, Somsak S and Lee SL (1990), Long-span precast ferro cements sunscreens in public housing. *Concrete International: Design and Construction.*, **12**: 33-36.
- [24] Lee SL, Mansur MA, Paramasivam P, Ong KCG and Tam CT (1986), A study of sandwich wall panels. *Journal of Ferro cement* (Bangkok), **16(3)**: 295-313.
- [25] Proceedings, 2nd International Symposium on Ferro cement (1985), Asian Institute of Technology, Bangkok, 788.
- [26] Bouma AH (1969), Methods for the study of sedimentary structures. A text book, Publisher by John Wiley and Sons and the author Arnold Bouma, New York, pp. 140.
- [27] Bjelkhagen HI (1993), Silver-Halide recording materials, Springer Verlag, pp. 128-151.
- [28] Fischer CO, Stade J and Bock W (1997), Neutron radiography (5), Proceedings on the fifth world conference, Berlin, Germany, June (17-20), (1996), DGZFP Publ. Berlin.
- [29] Collins TJ, Image for Microscopy. *BioTechniques* **43**, 1 Suppl., July, (2007) pp. 25- 30. doi: 10.2144/000112517. PMID 17936939.
- [30] Weng CH, Lin DF and Chiang PC (2003), Utilization of sludge as brick materials. *Adv. Environ. Res.* **7**, 679-685.
- [31] Sanders J and Frederic J (2011), Structural clay products division meeting. *The national brick research center.*
- [32] Eltehawy E, Effect of using ferro-ement on the mechanical properties of reinforced concrete slabs subjected to dynamic loads, Pro. 13<sup>th</sup> International Conference on Aerospace Sciences & Aviation Technology, ASAT-13, May (26–28), (2009).