Study of Single Layer Wire Mesh Ferro Cement Plate Using Neutron Imaging Technique

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ABSTRACT: Neutron radiography (NR), an advanced technique for non-destructive materials testing, utilizes transmission of radiation to obtain visual information on the structure and/or inner processes of a given object and this technique have found more and more applications. In the present study an attempt is made to observe homogeneity, porosity/voids, initial rate of absorption (IRA) and water absorption behavior of single layer wire mesh (SLWM) reinforced Ferro cement plate. The results prove that elemental distribution of the SLWM Ferro cement plate is better, large number of porosity is exist, water absorption rate is very slow than the initial rate of absorption. It also complies with the IRA measurement of the sample. All the measurements have carried out by observation of gray values/neutron intensity ratio values of the respective neutron radiographic images of the sample at dry and different wet conditions. The intent of this study is to promote the more effective use of Ferro cement plate as a construction material especially as water reservoirs, sculptures and also this would further lead to an “eco-friendly” low cost housing without any loss of structural integrity.

Keywords: Neutron radiography, SLWM Ferro cement, water absorption behavior, IRA

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1 INTRODUCTION

Neutron Radiography (NR) is a technique of making a picture of the internal details of an object by the selective absorption of a neutron beam by the object. NR 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). Ingeneral, the radiography technique is nothing but a simple process of exposing some objects to an X-ray, gamma-ray, neutron beam and some other types of radiation and then attenuated outgoing beam from the object is passing through a special type of photographic film to form images of the objects on the radiographic film or detector. Also it is called a non-destructive testing (NDT) [1] and evaluation technique of non-nuclear and nuclear materials and industrial products. NR is an imaging technique which provides images similar to X-ray radiography and complementary technology for radiation diagnoses. Neutron radiograph gives the information of the internal structure of an object; can detect light elements, which have large neutron absorption cross-sections like hydrogen and boron; completely complementary to other NDT techniques, like X-ray or gamma ray radiography.

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]. 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.

In this way this method is used for characterizing the water absorption in building materials both local and some foreign bricks and concrete [3], quality study of rubber and ceramics [4], corrosion of aluminum [5], a series of research works were performed by using different types of samples, such as leather [6], internal defects of 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

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ISSN 2229-5518

machine made environmentally friendly brick (KAB) sample [16], and quality study of handmade brick-DK [17] etc.

Ferro cement is a building construction material which is used mostly in countries with low labor costs, usually for water tanks and houses. The use of Ferro cement is also being explored in developing countries 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 (18.3m^3) was constructed in New Zealand [21]. Ferro cement boats are strong, low maintenance and of similar weight to composite and wooden ones [22]. Many other uses of Ferro cement as a structural material are being explored throughout the world. These include: sunscreens [23-24] and sandwich wall panels [25] for high-rises buildings, permanent forms for conventional concrete construction, biogas digesters, floor decks, swimming pools, water towers, small deck bridges and culverts [26], Ferro cement enclosure for geotechnical centrifuge [27] and Ferro cement overlay for concrete pavement resurfacing [28]. Recently Ferro cement has been used in repair works [29-30]. Aim of the present study is to determine elemental distribution/homogeneity, porosity/voids; Water absorption/penetrating behavior and initial rate of absorption (IRA) of water into the sample by adopting neutron radiography imaging technique.

2 EXPERIMENTAL DETAILS

2.1 Collection and Preparation of SLWM Reinforced Ferro Cement Plate Sample

The sample SWLM is collected from the Housing and Building Research Institute, Mirpur, Dhaka-1216. 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 65ºC until to get the constant weight. The actual shape, size and weight of the sample are rectangular, 25.30×7.4×1.3cm^3 and 544 gm respectively.

2.2 Loading Converter Foil and Film in the NR Cassette

A thin gadolinium metal converter foil of 25 μm thickness was placed at the back of the X-ray industrial film. The loading of the X-ray industrial film (Agfa structurix D_4DW) into the NR cassette (18 cm x 24 cm) is a simple procedure [31] 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 SLWM Ferro cement plate was then irradiated for the optimum exposure time of 04 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 [32]. Developing process is completed at (20-22)^{o}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 a 05 minutes and controlled the fixture temperature at (20-22) ^{o}C.

2.7 Washing

In between developing and fixing the exposure radiographic film must be 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 SLWM reinforced Ferro cement plate sample.

2.10 Methods for Determining 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. Exposure time differs for different samples, depending on the intensity of the neutron beam, density, thickness of the sample and neutron cross-section. The optimum exposure time of the SLWM

Ferro cement plate is determined with trial and error by taking a series of neutron radiographic images at different exposure time (t_i = 2min, 3min and 4min), while the reactor is operated at 2.4 MW. Hence the obtained optimum exposure time is 04 min.

2.11 Immersion Procedure of the Sample

The SLWM 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 during each immersion time. After time of interest (TOI) such as 5, 10, 15 and 20 minutes Ferro cement plate is removed from the pan and extra water of outside the sample is removed by using the tissue paper.

2.12 The Radiographic Images of Wet SLWM Ferro Cement Plate

The radiographic images of SLWM 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 SLWM Ferro cement plate is shown in Fig. 1.

Fig. 1 NR image of SLWM for t_w=5min

3 MATHEMATICAL FORMULATION 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 [33].

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

Here,

I and I_0 are the attenuated and incident neutron intensities respectively, μ_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, μ_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 MEASUREMENTS

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 RESULTS AND DISCUSSIONS

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

ISSN 2229-5518

From the investigation of different neutron radiographic images of dry SLWM Ferro cement plate sample, it is observed that at 4 minutes exposure time radiographic image of SLWM looks best.

Homogeneity:

The quality of a Ferro cement plate depends on the proper elemental distribution of the contents, porosity, hardiness, 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.

The Fig. 2-Fig. 3 shows the gray value/intensity ratio versus pixel distance plot of radiographic images of SLWM Ferro cement plate. The gray value/intensity ratio is determined by drawing line profile of 50 X 804 pixel area at different 5 levels on the NR images of SLWM Ferro cement plate using Image J soft ware [34]. In the Fig. 2-Fig. 3, it is also observed that in most of the places the variation of gray value is almost in regular manner. From this point of view it assumes that the distribution of contents in SLWM Ferro cement plate is homogeneous and contains little porosity because of some irregularity of gray value/intensity ratio.

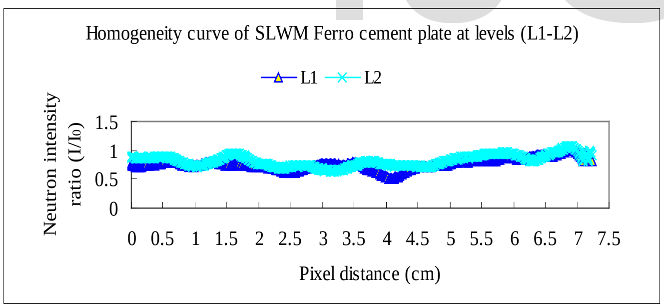

Fig. 2

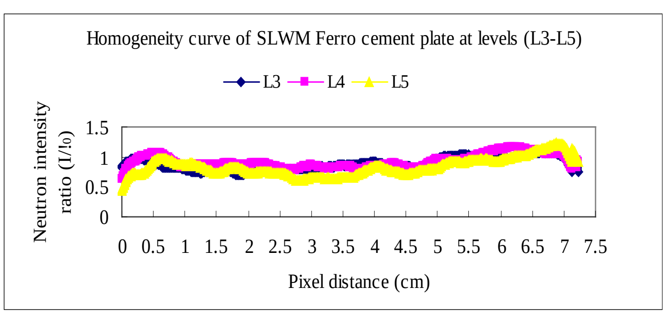

Fig. 3

Water absorption behavior:

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_2O absorption time of brick, observe differences in capillary absorption [35]. From the present investigation it also shows that the water penetrating behavior through the SLWM Ferro cement plate is completely uniform in manner (Fig. 4-Fig. 7) through the all places. Fig. 4-Fig. 7 also shows that 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 SLWM takes water with immersion time slowly. It also complies with IRA measurement of SLWM Ferro cement plate respectively (Fig. 8- Fig. 9).

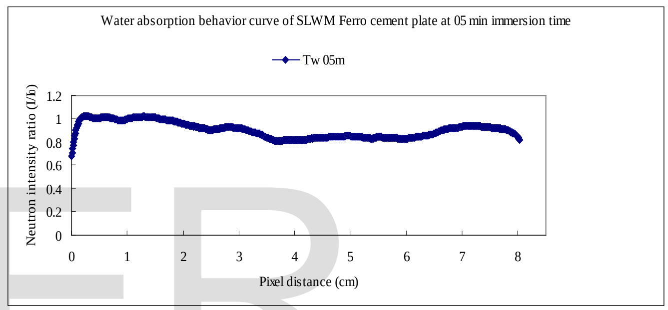

Fig. 4

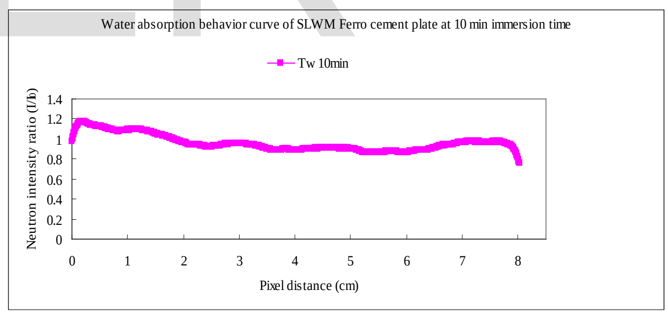

Fig. 5

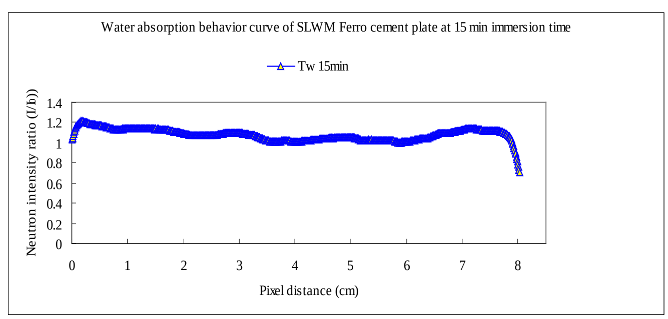

Fig. 6

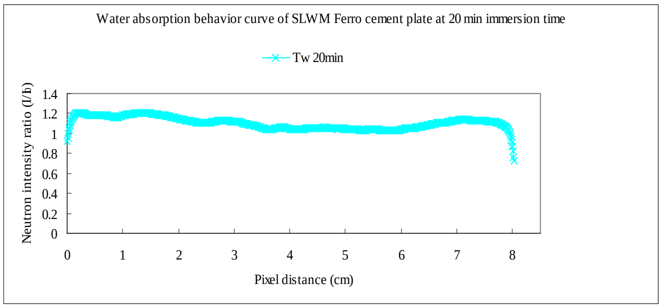

Fig. 7

Initial rate of absorption (IRA):

It 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 is reported in units of gm/ (30in^2 min) [36]. In our case IRA is measured in units of gm/cm^3/min. The results of IRA measurement for SLWM Ferro cement plate is shown in Fig. 8.

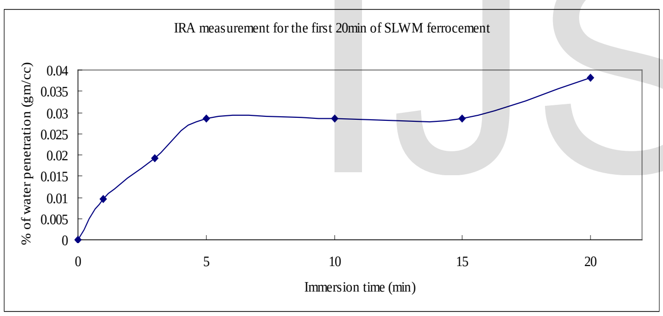

Fig. 8

Fig. 8 shows that at first 5 minutes the rate of water absorption is higher. On the other hand, at 5 to 20 minutes water absorption is almost constant. After 20 minutes immersion water absorption becomes constant when the sample is immersed into water up to 60 minutes and after 60 to 90 minutes the water absorption slowly increases with increasing immersion time but less amount shown in Fig. 9.

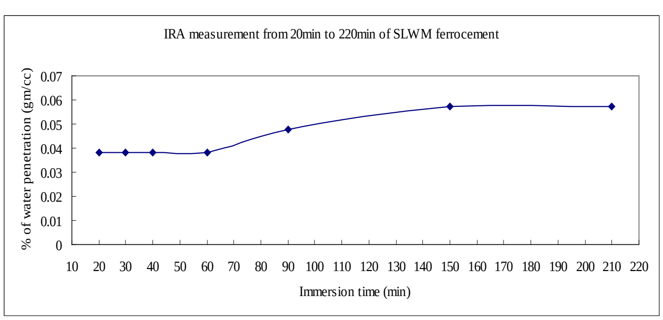

Fig. 9

In general, 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 [37].

The use of Ferro cement in pre-fabricated buildings provides many advantages in terms of lightness of weight (since its thickness is usually between 13mm and 15mm), ease of handling, low labor cost in its production and a durable material requiring little maintenance. Saving in cost is one of the several reasons for the popularity of Ferro cement. It is recognized that the economics of Ferro cement is dependent 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 SLWM Ferro cement wire mesh reinforcement plate improve the service and brittleness due to slowly and less amount of water absorption. The results also clarify that the Ferro cement wire mesh reinforcement layers improves the ductibility because of slowly and less amount of water absorption and used as well as have the ability to reduce cracks.

6 CONCLUSIONS

NR technique is powerful method to determine the quality study of wire mesh Ferro cement plate like as single layer wire mesh reinforced Ferro cement plate (SLWM). This method is very helpful to observe different characteristics such as porosity/voids, homogeneity, water absorption or penetrating behavior and initial rate of absorption of the sample. This SLWM Ferro cement plate sample can be used as water reservoirs, sculptures and also this would further lead to an “eco-friendly” low cost housing without any loss of structural integrity.

ACKNOWLEDGEMENT

Authors would like to thanks to the Ministry of Science & Technology (MOST) for their financial aid in order to completion of my MS thesis work.

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