

Technical Meeting on Research Reactor User Networks:
Standardization of Neutron Imaging for Industrial Applications
23-26 June 2014

ACCELERATOR BASED FAST NEUTRON RADIOGRAPHY SYSTEM FOR THE NON DESTRUCTIVE ANALYSIS AND SOME APPLICATIONS IN TURKEY



Dr. Recep BIYIK

TURKISH ATOMIC ENERGY AUTHORITY

Çekmece Nuclear Research and Training Centre,

34303 Küçükçekmece İstanbul/Türkiye

recep.biyik@taek.gov.tr



Çekmece Nuclear Research Centre (ÇNAEM)

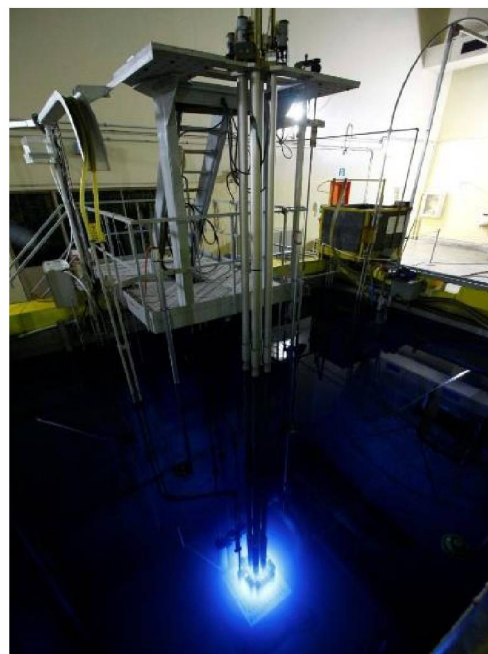
Nuclear Electronic



Nuclear Waste Management



Emergency Response



Research Reactor-TR2



Nuclear Physics





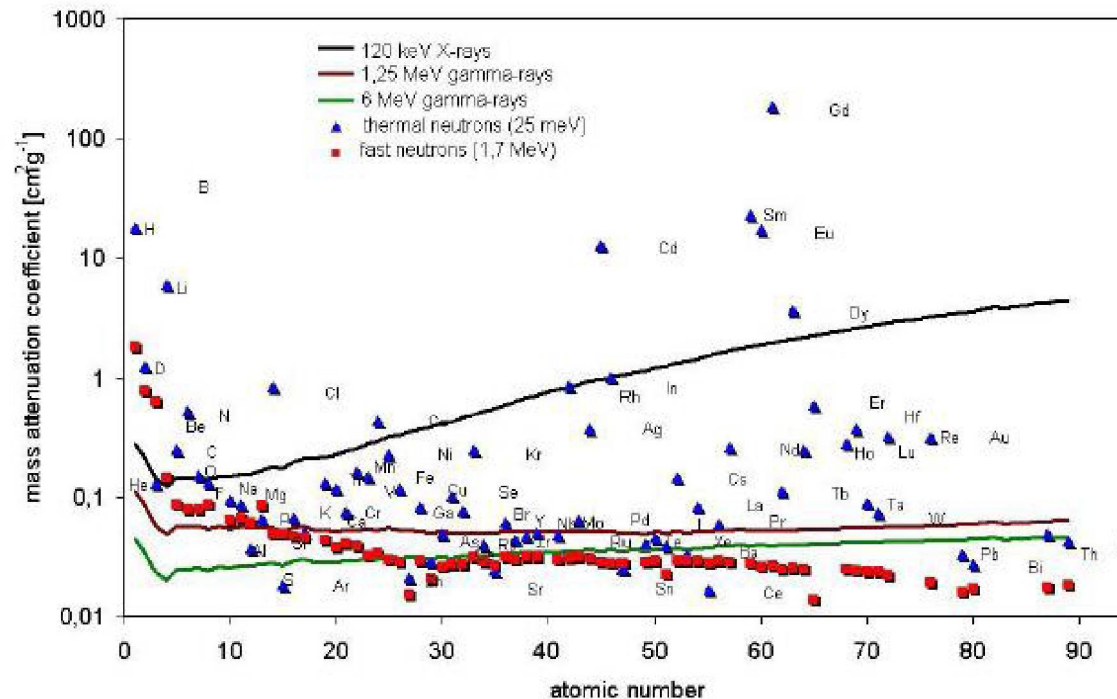
Outline

- Fast Neutron Radiography System (FNR)
 - Neutron Generator
 - Convertor or detector
 - Device to record (CCD-Camera)
- Some Applications of the FNR System
- The NDT Application on the Concrete Samples



Fast Neutron Radiography

Different radiography imaging techniques such as x, gamma and neutron grapy are well established techniques for the non destructive testing (NDT) of materials. But FNR is relatively new and is being developed.

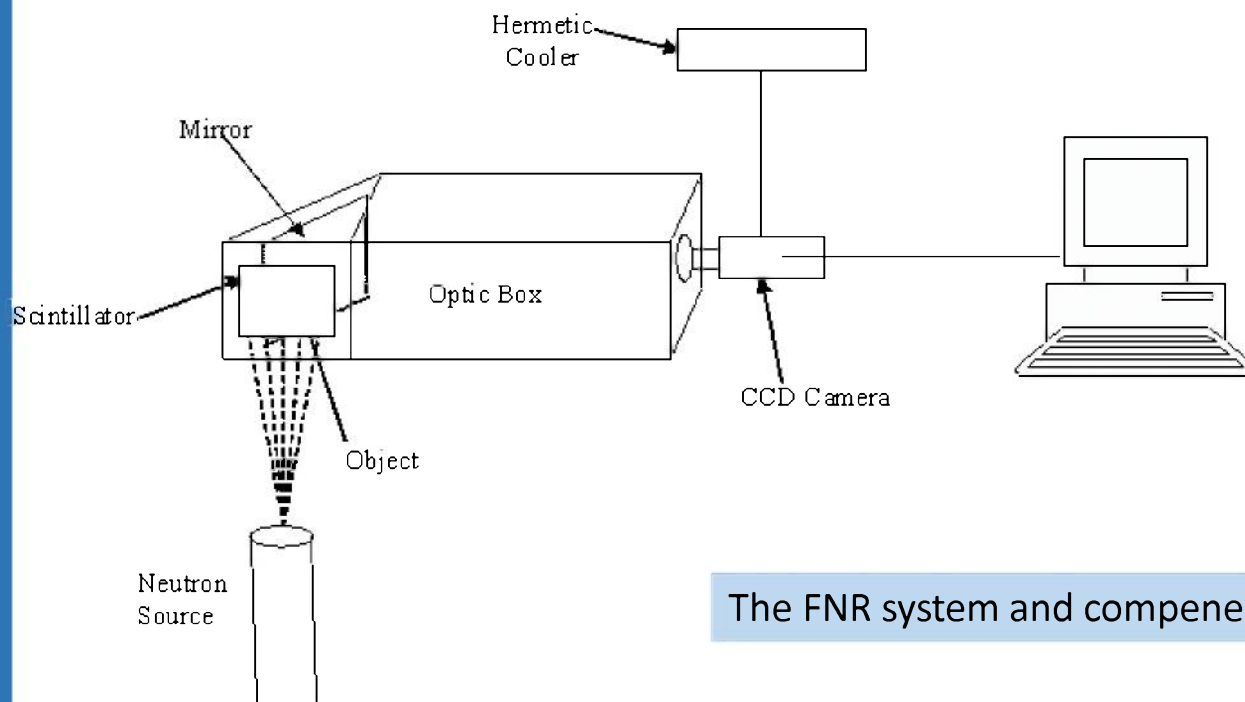


Using this technique all materials such as high density metals, loaded plastics, cadmium, lead, tungsten, concrete etc.. can be analyzed. Compare to the other techniques fast neutrons enable non-destructive testing of thicker object



Fast Neutron Radiography System

The FNR systems in generally consist of three parts,
I- neutron generator (must produce suitable neutron beam),
II- converter or detector (Scintillation screen)
III- a device to record (CCD Camera) the radiation intensity.



The FNR system and components



Fast Neutron Generators



Sames T-400 Low Energy Ion Accelerator (Max 400 kV)



Thermo MP320 Portable Neutron Generator

DT neutron source was used fusion of a deuterium and a tritium atom ($D + T$) results in the formation of a He-4 ion and a neutron with a kinetic energy of approximately 14.1 MeV.



Sames J-15 Low Energy Ion Accelerator (Max. 150 kV)



Am-Be Neutron Source

Experiments were carried out by using fast portative neutron generator Thermo Fischer MP320 and Low Energy Ion Accelerator Sames T-400 at Çekmece Nuclear Research and Training Centre



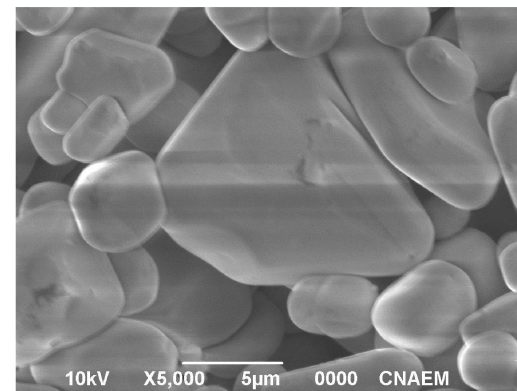
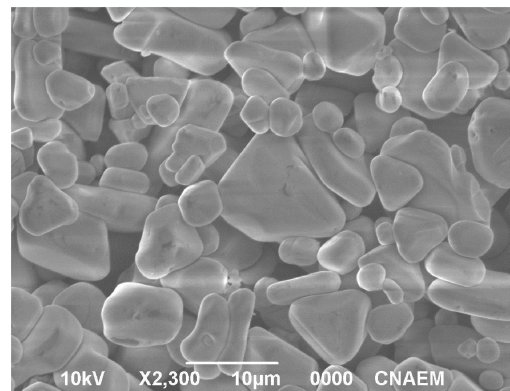
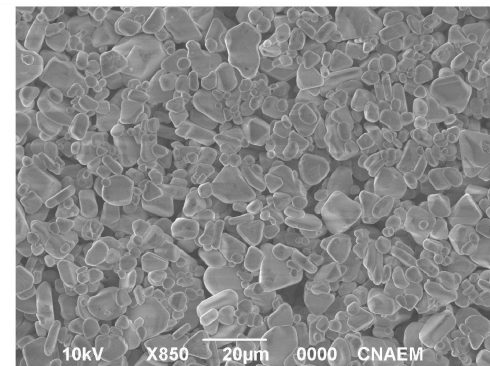
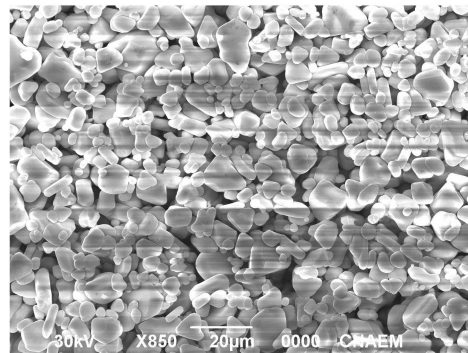
Scintillation Plate (Convertor-Detector)

With fast neutron radiographic imaging techniques because of some difficulties encountered an issue which is still in the research and development stage.

Major handicap encountered in this study is the luminescence efficiency of neutron detection efficiency.

For the using FNR system we prepared scintillator screen as a mixed 30 wt% ZnS :Ag and 70wt % in polyester colorless resin.

For this screen, accelerator experiments using Sames T-400 with optimization parameters to give the best image is determined.



SEM Images of scintillation plate



Scintillation Plate (Convertor-Detector)

With 14 MeV neutrons in the R & D department as a result of the test, 0.5 -1 mm thick scintillator efficiency was insufficient contrast was observed. In addition, the contrast between the thickness of 1-2.5 mm thick by now no longer observed. In kalınlılık 2.5 mm-and higher due to the opacity of the material was determined to be an increase in contrast.

All the test results obtained from the 14 MeV neutron scintillator most suitable for the thickness of 2.4 mm - 2.7 mm have been identified as necessary.

Considering these experimental data obtained 27.5 cm x 27.5 cm (756 cm² area) with a thickness of 2.55 mm, made successfully scintillator sheets.



Scintillation Screen
(27.5 cmx27.5cm with thickness 2.55 cm)



CCD Camera (A device to record)

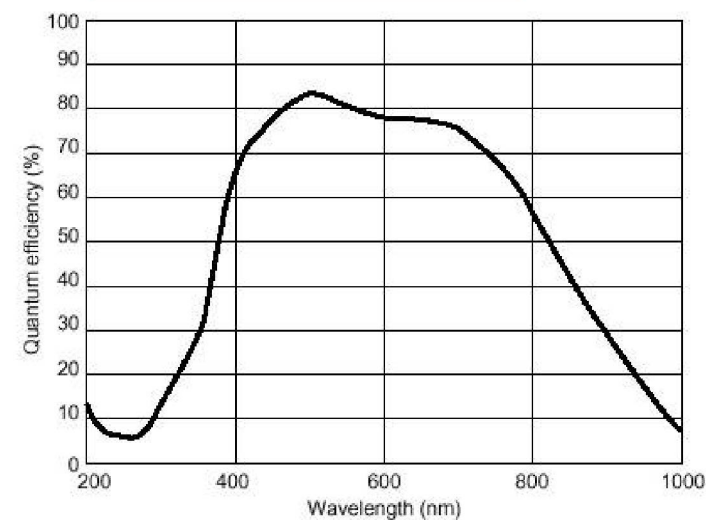
CCD camera system and a scintillator screen, a lens with focal rate 1.2 by the distance the optical path has been designed and is set at 1.7 m.

As a CCD camera the ORCAII -BT-1024G was used with features the well known E2V CCD47-10 chip packaged in a proprietary permanently sealed vacuum chamber evacuated to 10^{-7} Torr. This very high resolution, back thinned, back illuminated, million pixel CCD offers very high quantum efficiency over the spectrum from 350 nm to 900 nm.

L-shaped design to protect from fast neutrons are made. This process is calculated to be 1.7 m mirror is used to change the optical path.



CCD Camera
Hamamatsu ORCAII-BT



Quantum Efficiency of the CCD Camera



Some Applications (1)

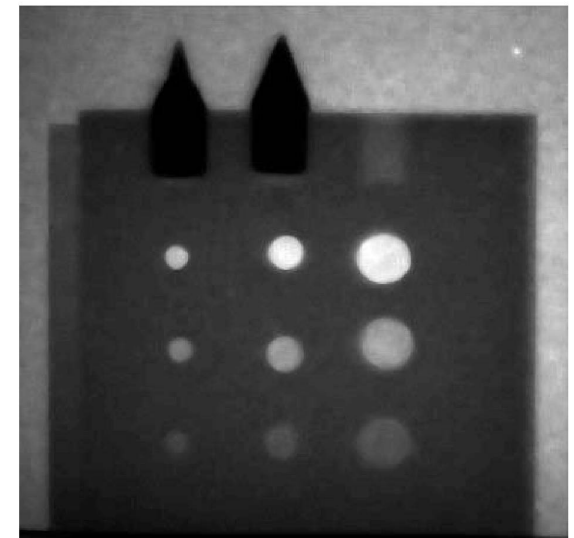
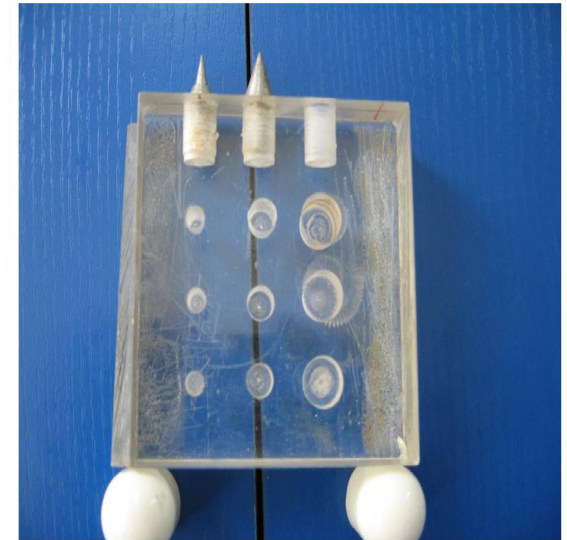
The first tests of the imaging system were performed with plate composed of Plexiglas substances (90x90x20 mm) . Upon the plate different radius and depths holes were formed.

The radius and depths of the holes were between 5 to 12 mm and 5 to 15 mm respectively. The numerical gray level of the plexiglass sample was determined and the values of the signal to noise ratio (often abbreviated **SNR**) were shown at Table.

The values of the signal to noise ratio (SNR) of plexiglass sample.

Radius	Deept		
	15 mm	10 mm	5 mm
12 mm	5,31	3,56	2,32
8 mm	5,20	3,39	2,10
5 mm	5,15	2,97	1,94

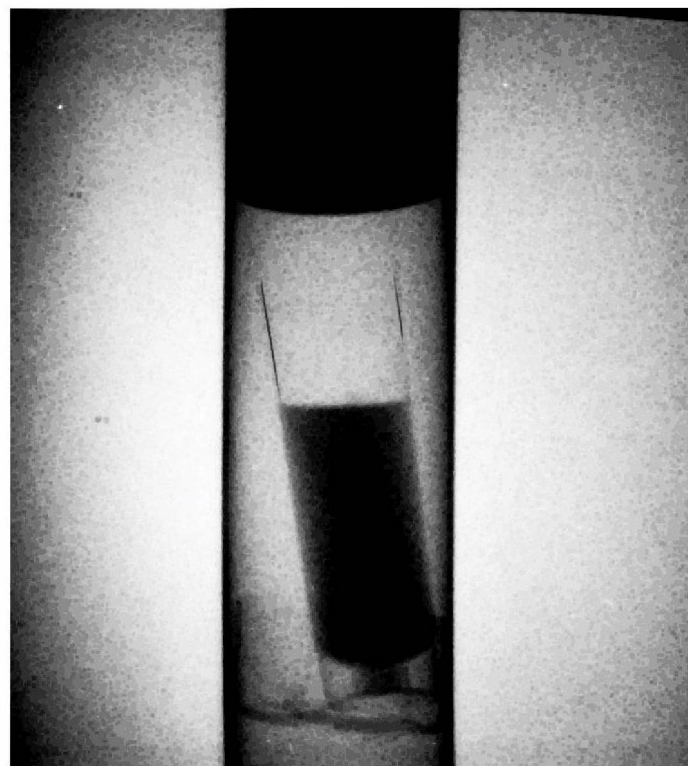
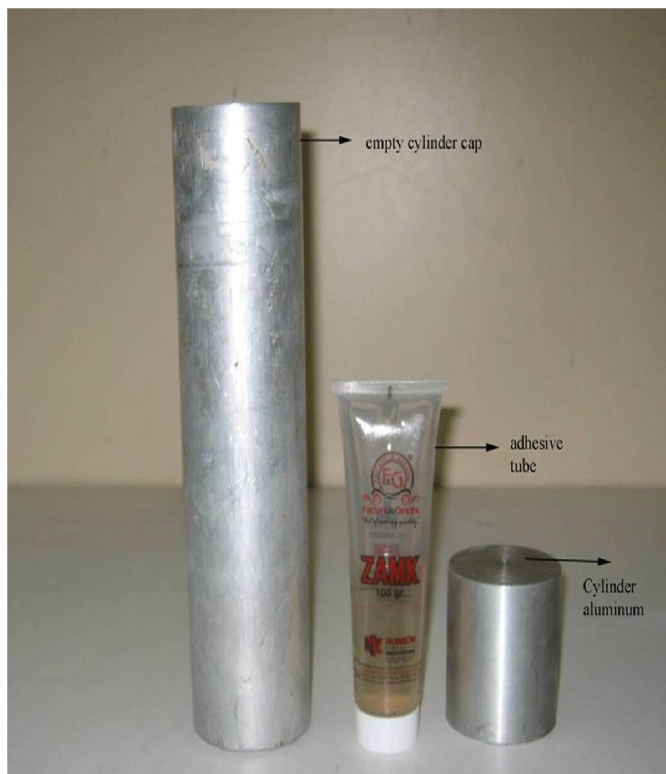
SNR is a measure used to quantify how much a signal has been corrupted by noise. A ratio higher than 1:1 indicates more signal than noise. The higher the ratio, the less obtrusive the background noise is..





Some Applications (2)

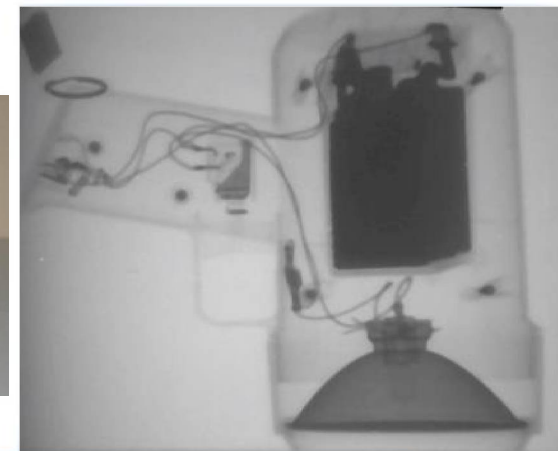
In another test to show the response of the radiographic system against to the different composite materials, different shaped and content materials collected together in a container. For this purpose half full adhesive gum tube and cylindrical shaped aluminium block were placed in an empty cylindrical container. The FNR system did not only distinguished different composite materials but also showed different contrast on the empty side of the half full adhesive gum.



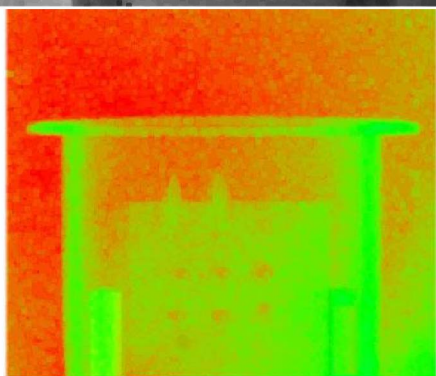
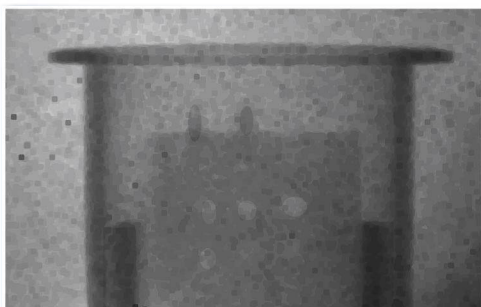


Some Applications (3)

The other example is a lantern (include plastic, copper wire, some metals and lithium battery) and in lead phantom in the stainless steel vessel. The FNR image shows different gray levels against to all different materials in the the samples



FNR image of the lantern



FNR image of the lead phantom in steel vessel



FNR image of the fish, gilt-head bream



FNR image of the radio



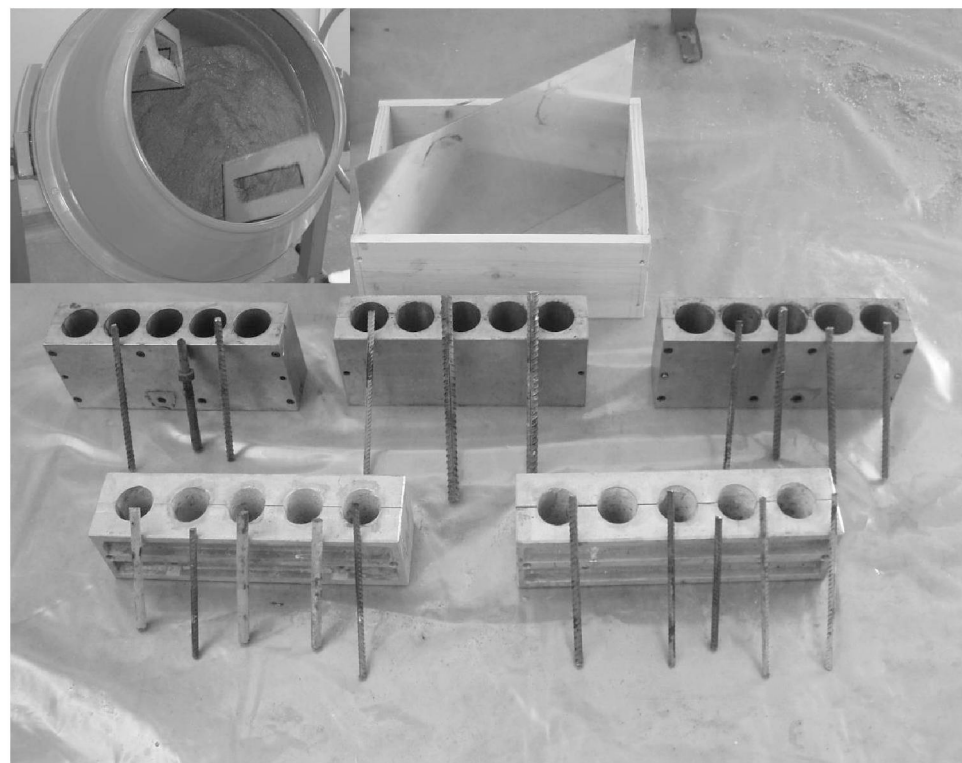
The FNR of the Concrete Samples (1)

It is important point to detect of the soundness of the building with a non destructive way. Using to the FNR system could be determined the iron parts (density, thickness, status) of the concrete blocks.

For this purpose molds were prepared different shape and size. One type is cylindrical (6 cm radius) and the other one is triangle (30x40x50 cm). Iron with different thicknesses and shapes were placed in steel molds.

Then C30 type concrete poured. After waiting for the concrete to dry, samples were removed from the mold to take FNR image.

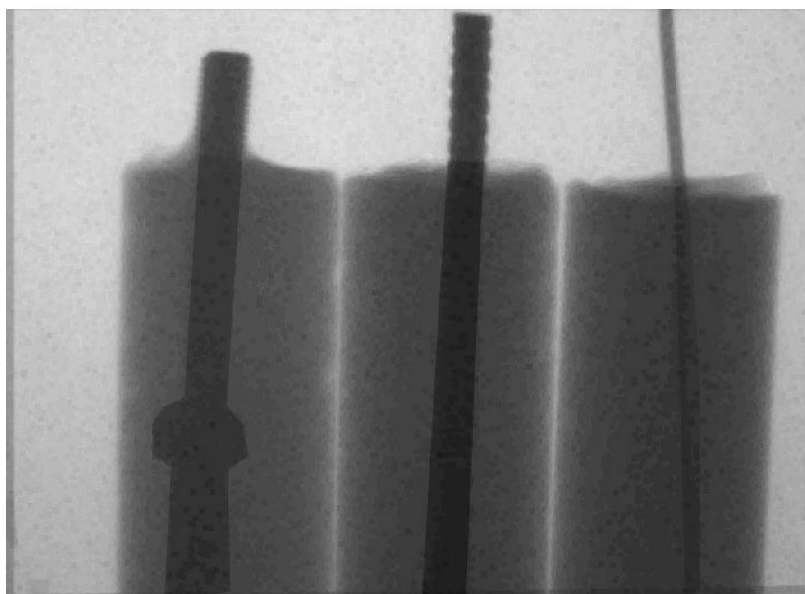
Image processing techniques were applied after the images were taken. Because iron and concrete materials have nearly same neutron absorption coefficients, it is difficult to distinguish contrast.



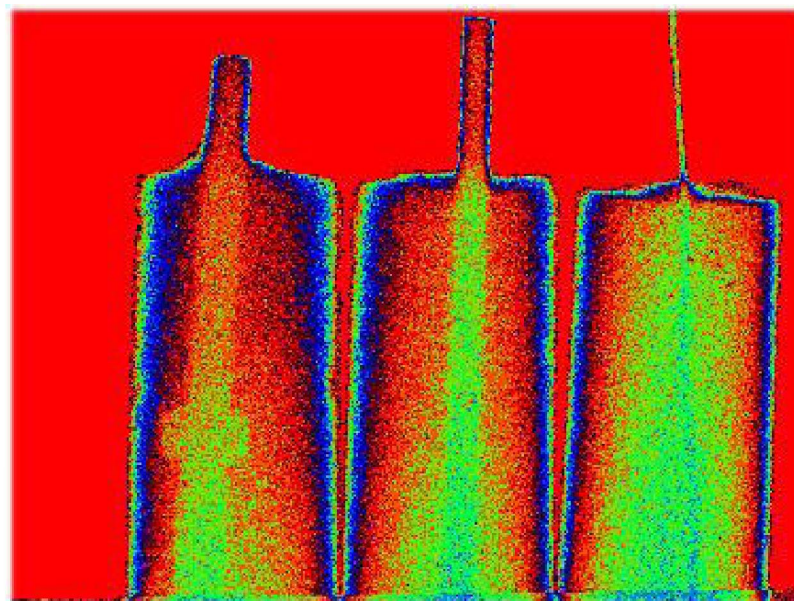


The FNR of the Concrete Samples (2)

Different shaped irons could easily be seen. Moreover even contrast difference of curves of the iron and bolt nut parts were remarkable.



FNR image of the irons in the cylindrical concrete block



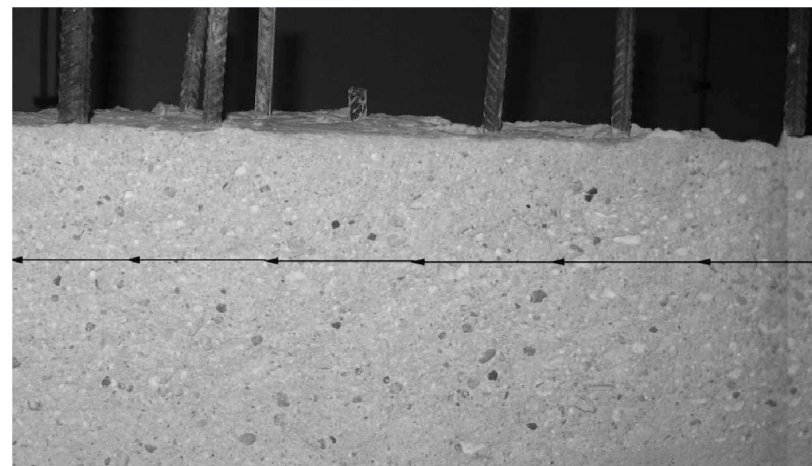
Pseudocolor form of FNR image of the irons in the cylindrical concrete block



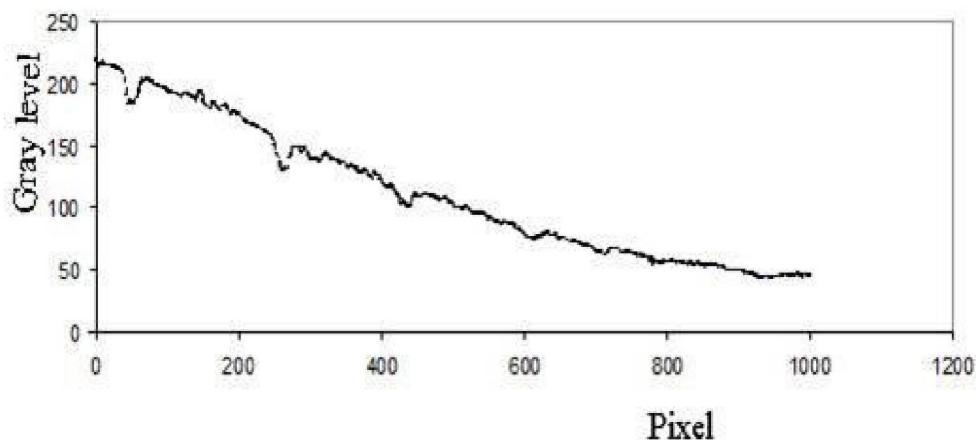
The FNR of the Concrete Samples (3)

The image of the triangle sample (30x40x50 cm) also has an important value. The thickness of the concrete block started from 2 cm and ended 30 cm. Almost all of the iron rods were seen from FNR image.

This result demonstrates that iron rods in concrete structures can be seen with non destructive FNR techniques.



concrete blocks in a delta configuration
30x40x50 cm



The FNR image of concrete blocks in a delta configuration





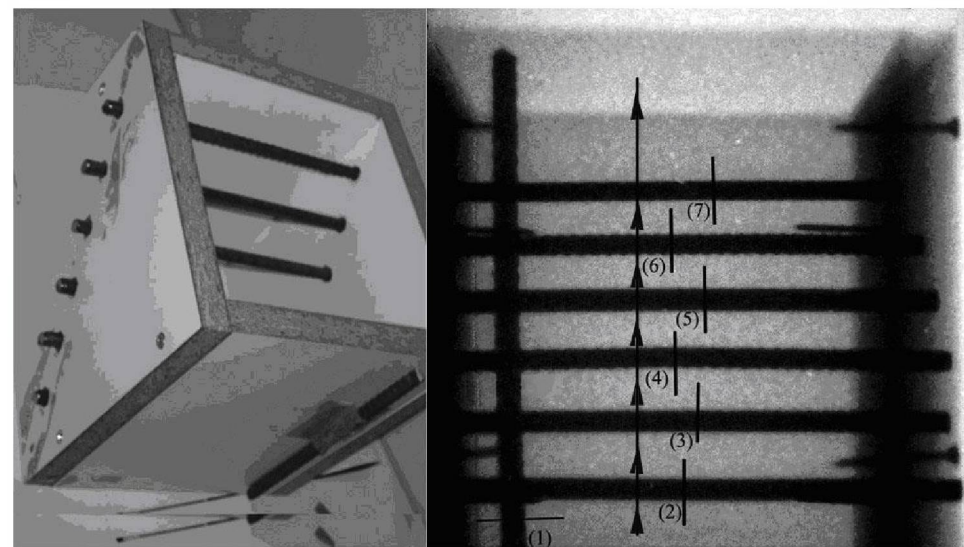
The FNR of the Concrete Samples (4)

The detection of the changing thickness of the iron due to corrosion in concrete , it is important for the construction industry and construction safety

In this part of the study in 8mm thickness iron placed in to mold with regular interval and take a FNR image,

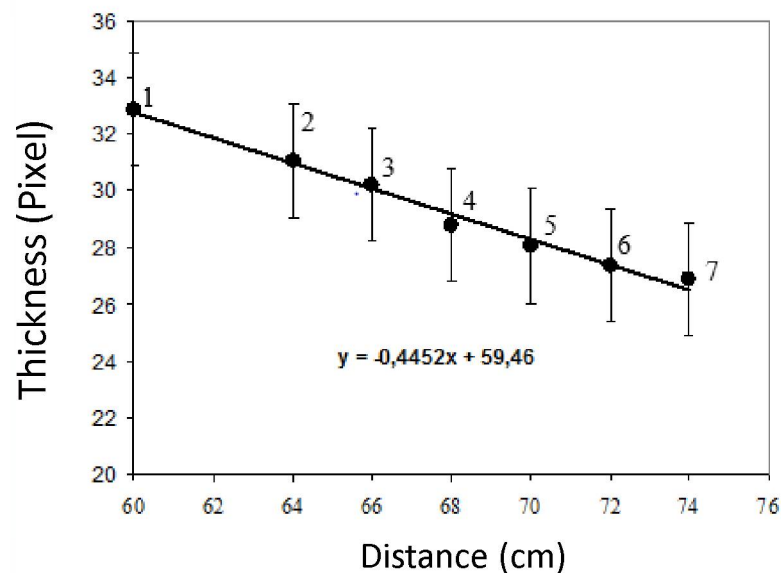
At the digital image of the mold thickness of the iron were determined depending on the distance.

In this way the same thickness of the iron changing with dept were obtained as pixel unit.



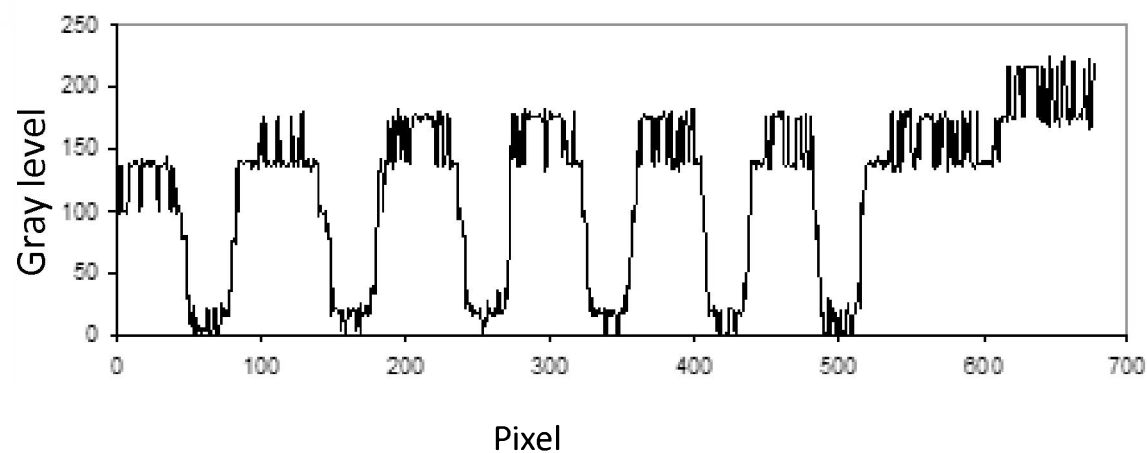


The FNR of the Concrete Samples (5)



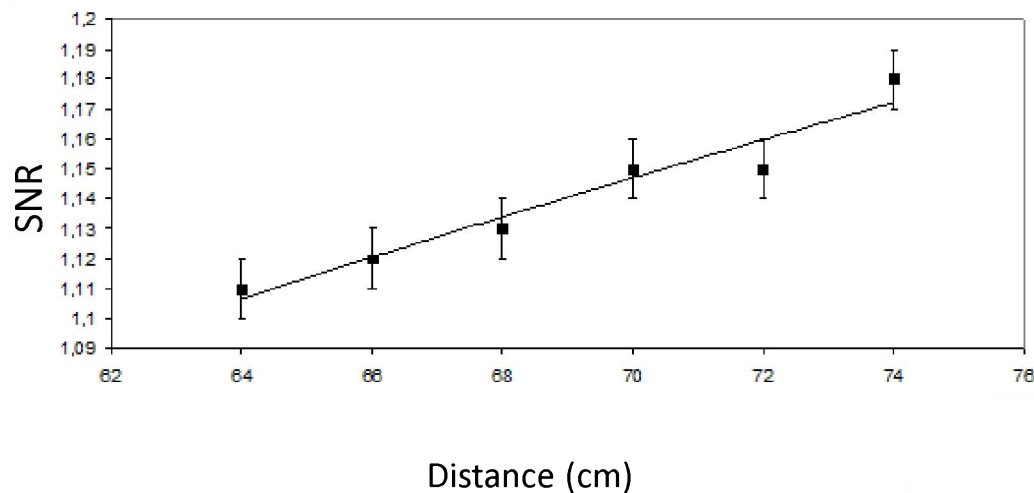
The change of the thickness of the iron depend on the depth of concrete block (from the FNR images).

Grayscale chart of the concrete mold from below to upwards.



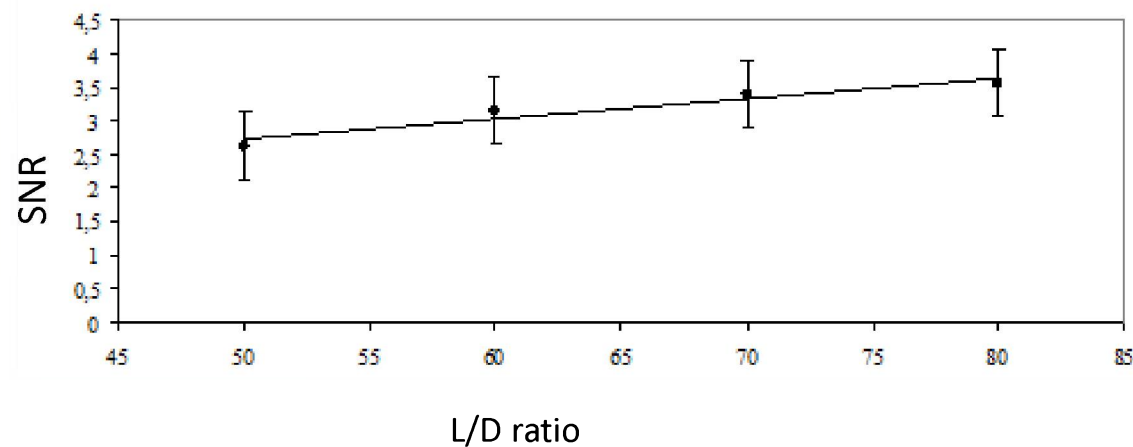


The FNR of the Concrete Samples (6)



In three different regions and depths of iron peers SNR values

Different L/D (the distance between the source and the sample material) exchange rate with the SGO.





Thank you

...thank you for your attention

