Radiation Measurements 59 (2013) 193–200

Contents lists available at SciVerse ScienceDirect

Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

Monitoring of concrete structures by using the 14 MeV tagged neutron beams

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HIGHLIGHTS

- An underwater inspection system was developed which is able to monitor the state of reinforcement corrosion.
- The system is composed of a remotely operating vehicle (ROV) equipped with the sealed tube neutron generator (NG).
- All measurements could be performed without cleaning the concrete surface from fouling material.

ARTICLE INFO

Article history:
Received 13 February 2013
Received in revised form
8 May 2013
Accepted 5 June 2013

Keywords:
Fast neutrons
Corrosion monitoring
Concrete
Underwater structure

ABSTRACT

The maintenance and repair of reinforced concrete structures, especially those submerged in the seawater require effective inspection and monitoring techniques for assessing the state of corrosion in the reinforcement material. An underwater inspection system was developed which is able to monitor the corrosion of the reinforcement. The system is composed of a remotely operating vehicle (ROV) equipped with the sealed tube neutron generator (NG). By rotating the NG and by using the associated alpha particle technique it is possible to measure the concrete cover thickness together with the reinforcing bar diameter. The possibility of estimating the carbon and chloride contents in the concrete was investigated. Iron plates of different thickness, covered by 6 cm thick concrete block, were successfully detected and the thickness of the concrete cover was estimated. In addition, reinforcing bar of one and 3 cm in diameter were identified and measured. All measurements could be performed without cleaning the concrete surface from fouling material.

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1. Introduction

Recently thousands of structures for the production of oil, gas and electricity have been erected in the coastal seas around the Globe. Those are not the only structures in the sea; sea floor is intertwined by pipes providing water, electricity, gas and communication to the islanders. In addition infrastructure objects like bridges, power stations, ports and dams have critical underwater components. They all need to be inspected for the service, repaired when malfunctioning and kept in the environmentally accepted conditions.

Reinforced concrete deterioration in the concrete structures is a very serious problem. Deterioration is a complicated processes caused by the interaction between the environment and the concrete. There are three main deterioration processes: reinforcement corrosion, frost attacks and alkali-aggregate (silica) reactions (Anders and Nilsson, 1999). Among them the corrosion of reinforcement is the most harmful (Bjegovic et al., 2003; Jones, 1996). It is mainly product of the chloride ions and/or carbon dioxide (in process called carbonation) ingress into a concrete. The high alkalinity of the cement paste, approximately pH 13, results in the passive steel surface protected against corrosion. The presence of chlorides and/or CO_2 reduces pH of the concrete and when its value is below 10.5–9.5, steel surface is no longer protected and starts to corrode. Alkali silica reaction is the reaction of amorphous silica sometimes present in the aggregates with the hydroxyl ions from the cement pore solution. This reaction causes localized swelling responsible for tensile stress and cracking. All three processes depend on concrete moisture (Andrade et al., 1999). The repair costs of the deteriorated concrete nowadays constitute a major part of the infrastructures maintenance. Quality control, maintenance

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1350-4487/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.radmeas.2013.06.001

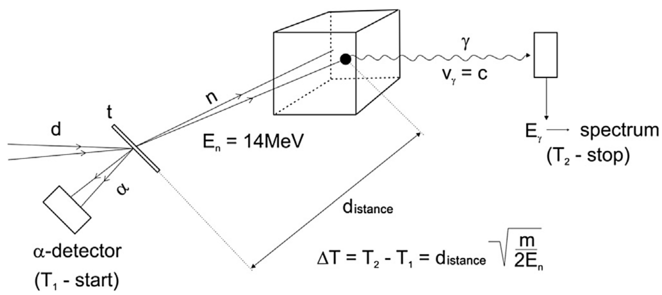

Fig. 1. A schematic representation of the “associated alpha particle technique”. For each characteristic gamma ray measured by the gamma detector and produced by the “tagged” neutron, the time-of-flight of the neutron was also measured. The alpha particle was detected at a time T_1 while the gamma ray at the time T_2. The time difference $T_2 - T_1$ is proportional to the distance traveled by the neutron beam (m is neutron mass, d is deuteron, t is tritium, E_n is neutron energy while E_γ is gamma ray energy).

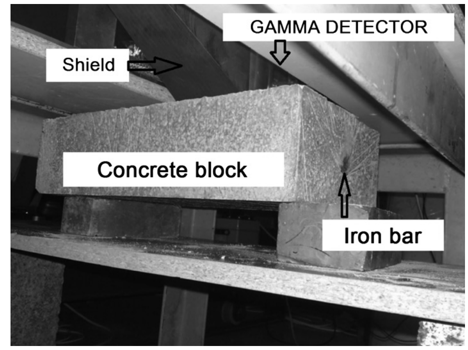

Fig. 4. Concrete block below the gamma ray detector ready to be inspected by the neutron interrogation system.

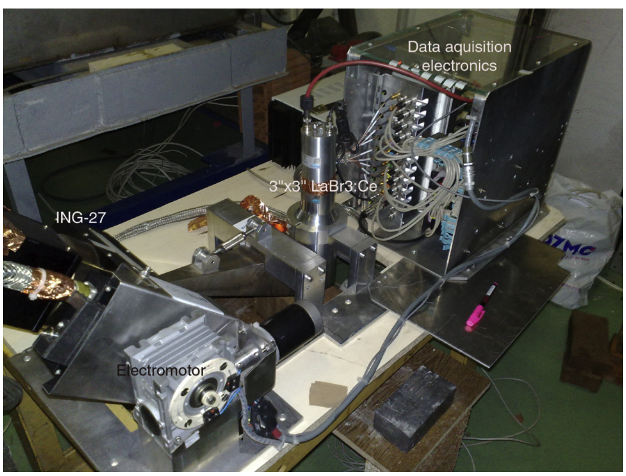

Fig. 2. Experimental setup.

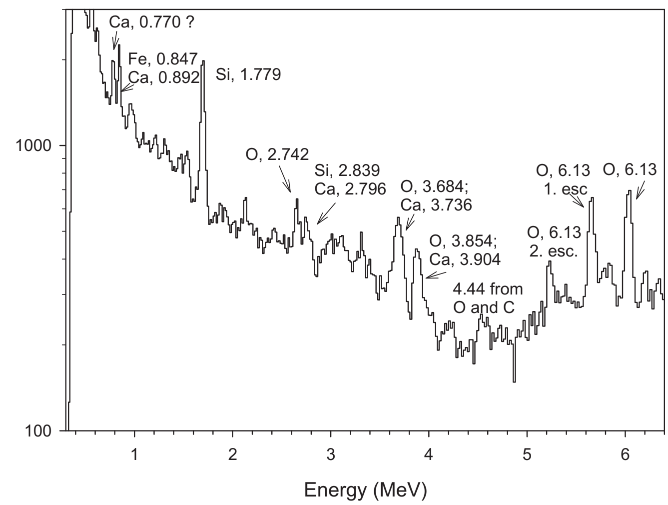

Fig. 5. The gamma ray spectrum of concrete.

and restoration planning need non-destructive inspections and monitoring techniques that detect corrosion at an early stage (Song and Saraswathy, 2007), preferentially without cleaning concrete surface by removing fouling material.

Devices which can perform without cleaning the structure could substantially reduce time and, ultimately, costs. Detecting a crack that is covered by a four to 6 cm-thick coating of organisms is a challenging task; with present techniques detecting an internal flow under these conditions is seemingly impossible. A capability of this type is very desirable not only to detect the crack but to quantify it as well. None of the present crack detection techniques, except acoustic emission, seem suitable for this task. A feasibility program to assess the possible means of addressing this problem should be undertaken. Active corrosion zones on the structure should be sought, as well as the cracks or failures.

In this paper we present a neutron-based technique able to inspect underwater components of concrete structures and to monitor concrete deterioration.

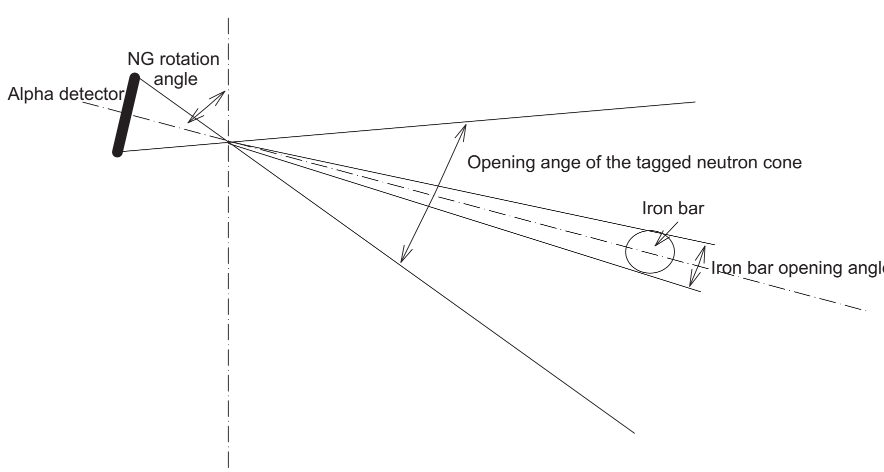

Fig. 3. A schematic representation of the experimental setup from Fig. 2.

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