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A nondestructive methodology for the testing of fibre cement boards by means of a non-contact ultrasound scanner

Krzysztof Schabowicz *, Tomasz Gorzelańczyk

Faculty of Civil Engineering, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland

HIGHLIGHTS

- A new non-contact ultrasound method to check fibre cement boards are presented.
- An original test methodology developed for testing fibre cement boards are presented.
- The methodology was verified on-site on a real production.

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ABSTRACT

This paper presents a new nondestructive technique using a non-contact ultrasound scanner, suitable for the testing of fibre cement boards. The capabilities of this technique for locating defects in usually unilaterally accessible fibre cement boards during their production are described. An original test methodology developed for this purpose is included. The methodology was verified through laboratory tests on specimens and through trials on a production line. The suitability of this technique for testing fibre cement boards and its reliability have been confirmed.

1. Introduction

In recent years increasingly more building facades have been made of fibre cement boards as the latter became fashionable among architects. Examples of facades made of such boards are shown in Fig. 1. Consistently with the principles of sustainable development, the content of recycled materials in fibre cement boards has been systematically increased, whereby such boards need checking.

This paper presents a new non-contact ultrasound method exploiting Lamb waves to check fibre cement boards for delaminations during production. A delamination (a separation of layers) appears as a result of the improper execution of layered boards, leading to the loss of material continuity, as shown in Fig. 2, due to the absence of bonding between the layers of the material and so causing a reduction in the load-bearing capacity and durability of the board. This defect disqualifies fibre cement boards as a building material, whereby they cannot be put on the market [1–3] since this would significantly affect the reliability of the claddings made of such boards. For this reason fibre cement boards require quality control. So far the control has consisted in the visual inspection of individual boards, which if found defective are removed from the production line. However, this method is inconvenient, causes downtimes and only a small population of the boards can be checked in this way.

A non-contact ultrasound scanner based on Lamb waves, specially designed for the quality control of fibre cement boards is presented in this paper.

2. Literature survey

The identification of delaminations in layered concrete members accessible from only one side has been of interest to, among others, Garbacz [4], Delatte et al. [5] and Oh et al. [6], who proposed a way to produce a "map" of delaminations on the surface of a floor by means of the pull-off method. Ottosen et al. [7], Gar-

* Corresponding author.
E-mail address: k.schabowicz@pwr.edu.pl (K. Schabowicz).

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Fig. 1. Examples of facades made of fibre cement boards.

bacz [4] and Sansalone [8] propose to use the nondestructive impact echo method for this purpose. Hertlein and Davis [9] recommend the modern impulse response method to search for delaminations in concrete flooring. Hoła, Schabowicz et al. [10–14] propose to use jointly the impact response method and the impact echo method to indentify delaminations since they have shown this approach to be more effective. Also Goszczyńska et al. [15] and Ranachowski et al. [16] undertook research in this field. It should be noted that in the above works the tested members were more than 100 mm thick.

The testing of the raw materials used to manufacture fibre cement boards by means of a contact acoustic method was presented by Neithalath et al. [17] and also by Książek [18].

Alleyne and Cawley [19], Kudela and Ostachowicz [20], Su and Ye [21], Wandowski et al. [22], Ambroziński et al. [23], Malinowski et al. [24] and Paćko et al. [25] employed ultrasound Lamb waves to diagnose board construction materials by mainly contact methods, i.e. methods in which a means of coupling with the tested member surface is used. Farlow and Hayward [26], Farlow et al. [27] and Dobie et al. [28] proposed to use Lamb waves in non-contact ways making it possible to test members up to 15 mm thick but small in area (up to a few square centimetres). Information on the possibilities of testing materials by means of Lamb waves can also be found in [29–33].

From the above survey of literature on the investigation of various material imperfections in board members based on the cement matrix by means of nondestructive methods it emerges that there is no work devoted to the testing of thin (up to 15 mm thick) large area board members. Hence this paper proposes a non-contact measuring method specially devised for the testing of fibre cement boards [34,35]. The method exploits Lamb waves which make wave propagation in a large area of the tested thin (up to 15 mm thick) material possible and ensure a short measurement time. Moreover, since this method does not require any coupling between the fibre cement board and the transducers, it and a non-contact ultrasound scanner specially constructed for this purpose could be used directly on the production line of fibre cement boards, making possible the testing and diagnosis of all the boards during their production.

3. Description of non-contact ultrasound scanner

A specially designed and built measuring system in the form of a stationary non-contact ultrasound scanner was used to test fibre cement boards [34,35]. The scanner operates by inducing an elastic wave in the tested member. The technique of a travelling Lamb wave introduced into the tested material via air without contact between the transmitting head (T), the receiving head (R) and the tested material is used here. The two heads are located on the same side of the tested board on its opposite edges, covering the whole width of the board as shown in Fig. 3. Lamb waves are generated by means of longitudinal waves introduced into the board by the transmitting head (T) directed towards the board surface at specific critical angle α_c (see the figure below) determined by the properties of the tested material. The receiving head (registering the wave passing through the material) is inclined to the board surface at the same angles as the transmitting head. The heads are situated at a distance of about 300 mm above the surface of the board which moves on the production line at a speed of about 20 mm/s.

Ultrasound heads (with the basic frequency of 100 kHz) for measurements in air, a system for positioning the heads (the scanner), an arbitrary signal generator with a two-channel oscilloscope

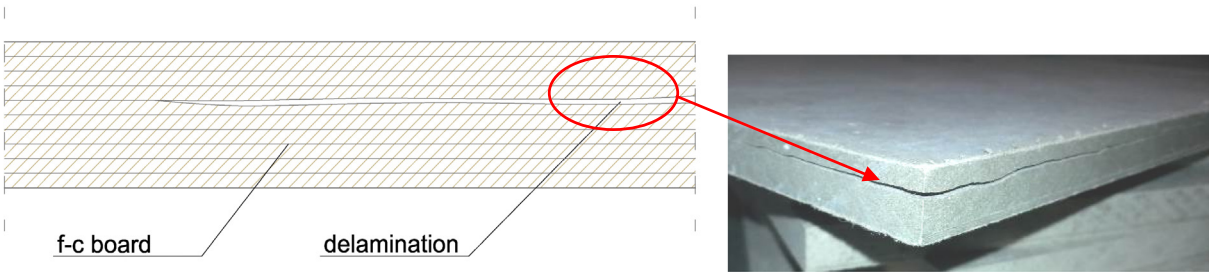

Fig. 2. Fibre cement board with delamination.