



Design of an instrumentation for the automated damage detection in ceilings

B. Belletti, M. Berardengo, L. Collini^{*}, R. Foresti, R. Garziera

Department of Engineering and Architecture, University of Parma, V.le delle Scienze 181/A, 43124, Parma, Italy

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ABSTRACT

A diagnosis method for the detection of detachments occurring in ceilings made with the system beam-and-clay is presented. This analysis is carried out by an innovative, portable instrument. The apparatus is capable of automatically tapping a small area of the ceiling by the shot of a controlled-energy pin, and of simultaneously detecting the out of plane vibration of this area by a low-cost digital accelerometer. Different “levels” in vibration correspond to different movability for the ceiling. By comparing these movabilities, we are able to indicate detachment and its severity/extension. Results of a 1-year experimental campaign in schoolrooms encourage further development and widespread application of the instrument.

1. Introduction

Recent collapses of portion of ceilings occurring in Italian civil structures as schools and hospitals, have generated concern about safety of people. This type of ceilings, was adopted immediately after the Second World War. It was practical and based on cheap technology: the beam-and-clay block floor. This kind of structures represents today more than 70% of the heritage from '50 to '70.

Due to aging, poor quality of material, moisture or unexpected stresses caused by incorrect design and installation, fractures can occur in beam-and-clay block floor systems [1]. This typical detachment, which is shown in Fig. 1, causes the fall of a portion of clay and plaster, whose density can vary 20 and 40 kg/m². Even if these accidents in general do not compromise the bearing capacity of the floor, it can be harmful to people.

Beam-and-clay block floor systems are realized using load bearing beams, also called joists, placed parallel to each other at a distance equal to 50–60 cm. This type of floors can be classified according to their manufacture in fully cast-in-situ and semi-precast structures, as illustrated in Fig. 2. Fully cast-in-situ floor are composed of clay block and reinforced concrete beam assembled in-situ, while semi-precast floor are composed of manufactured precast beams.

Depending on the floor use and destination, cast-in-situ structural topping is generally added. Beams are sometimes reinforced with longitudinal rebars or strands; precast beams are usually reinforced also with lattice girder, while structural topping can be reinforced with a

mesh. Transversal actions are not usually considered, so transversal floor performances should be guaranteed by proper installation.

Since the detachment of clay block shells is a brittle failure mode phenomenon [2–4], it is often hard to predict it. Also the consequences are unpredictable, ranging from the case when collapse makes the rooms unusable, to real emergency situations in which people are involved. Knowing this phenomenon, recognizing it in advance and securing, are the only ways to avoid sudden collapses and to maintain environments safe.

The first step in assessing the tendency to detach of clay block shells from beam-and-clay blocks, is to collect information about the floor type, material defects, inadequate detailing or design: in other words, its history.

Anyway the variety of floor types that can be observed in structures makes it difficult to apply standard procedure in testing. Furthermore interferences, as mechanical appendages and equipment, suspended ceilings and light fixtures can complicate the floor inspection.

A systematic checking is the only reliable way in order to prevent the danger due to a sudden detachment. The manual tapping technique is largely used in these cases, but shows two main disadvantages: firstly it is very time-consuming, and secondly its result is strongly dependant from the technician, being the estimation of the damage based on what he feels and hears. For this reason, automated and high-repeatability systems of diagnosis are highly desirable by safety control authorities.

A deep study of the phenomenon and on its causes is firstly necessary in order to make an effective strategy of design for proper

^{*} Corresponding author.

E-mail address: lucaferdinando.collini@gmail.com (L. Collini).

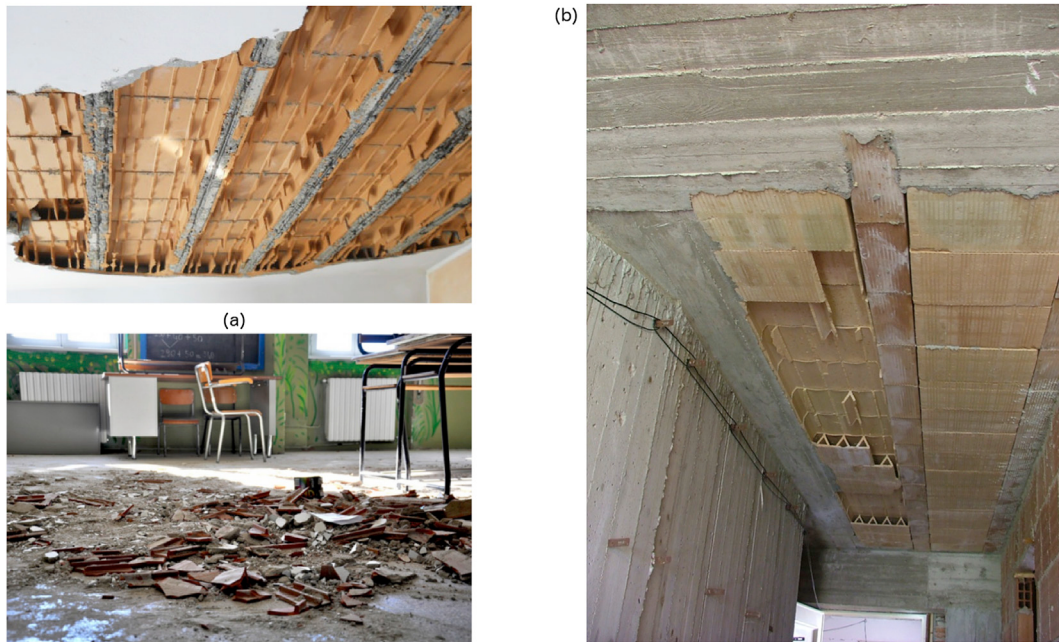


Fig. 1. Detachment of ceiling block shells a) in a school class and b) in a residential building.

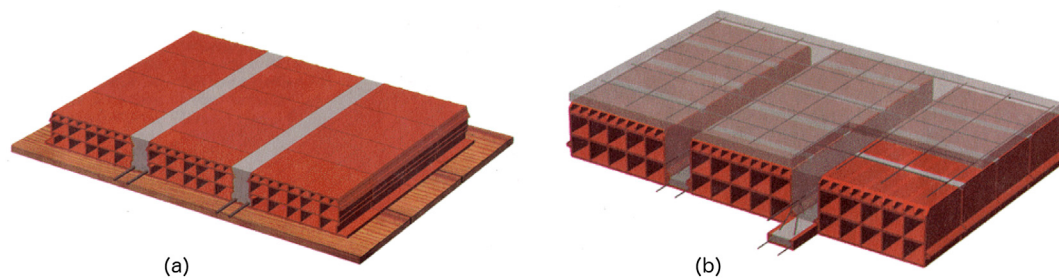


Fig. 2. (a) Fully cast-in-situ; (b) semi-precast beam-and-clay block floor system.

instrumentation and method.

2. The detachment phenomenon of clay block shells

The detachment of clay block bottom shells from beam-and-clay block floor systems can be due to several causes:

a. Mechanical properties of the system components (clay, reinforced concrete, plaster)

Cracking of clay blocks causing the bottom shells detachment is strongly depending on tensile strength and fracture energy of clay shells and webs of block. Experimental studies carried out using Moiré interferometry technique showed that the fracture energy value of sand and clay mixture is much higher than that of clay alone [5].

b. Shape and dimensions of components (beam, clay block, topping slab)

High span/depth ratios can cause deflection of beam-and-clay block floor systems involving damages like cracking, debonding, etc. Detachment failure mode can be also activated by longitudinal rebar debonding due to lack of web thickness of beams, clear cover and bar distance with respect to the maximum aggregate size of concrete.

c. Poor conceptual design of floor system

Poor conceptual design of floor system can generate high transversal stress values on clay block, e.g. clay blocks supported by beams having different lengths or different stiffness, interaction at floor edge in presence of balcony or stiff members (like reinforced concrete walls).

d. Installation and erection

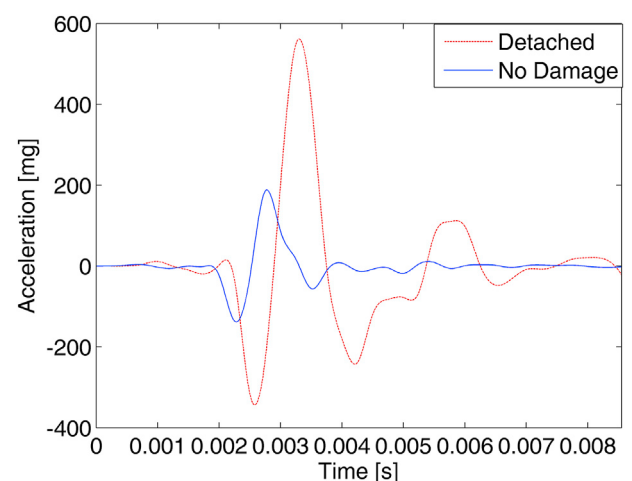


Fig. 3. Local acceleration of healthy vs. detached points.

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