Available online at www.sciencedirect.com
ScienceDirect
Infrared Physics & Technology 49 (2007) 243–248
INFRARED PHYSICS & TECHNOLOGY
www.elsevier.com/locate/infrared

In situ assessment of structural timber elements of a historic building by infrared thermography and ultrasonic velocity

A. Kandemir-Yucel, A. Tavukcuoglu *, E.N. Caner-Saltik

Middle East Technical University, Department of Architecture, Inonu Bulvari, 06531 Ankara, Turkey

Available online 20 July 2006

Abstract

The infrared thermography (IRT) and the ultrasonic velocity measurements (UVM) promise to be particularly important to assess the state of deterioration and the adequacy of the boundary and microclimatic conditions for timber elements. These non-destructive methods supported by laboratory analyses of timber samples were conducted on a 13th century monument, Aslanhane Mosque in Ankara, Turkey. The combined interpretation of the results was done to assess the condition of structural timber elements in terms of their state of preservation, the dampness problems and the recent incompatible repairs affecting them. Results indicated that moist areas in the structure were associated with roof drainage problems and the repairs undertaken with cement-based mortars and plasters and oil-based paints. Juxtaposition of the IRT and UVM together with laboratory analyses was found to be useful to assess the soundness of timber, enhanced the accuracy and effectiveness of the survey and facilitated to build up the urgent and long-term conservation programs.

Keywords: Infrared thermography; Ultrasonic velocity measurement; Non-destructive testing; Moisture content analyses; Historical timber structures; Aslanhane Mosque

1. Introduction

The survival of historical timber structures for a long period of time is related to the use of compatible materials, the adequacy of construction technologies used in the past and the natural characteristics of older wood [1–3]. The assessment of the state of preservation of timber elements is essential to establish their maintenance and conservation works. The state of preservation of timber elements has to be evaluated together with the microclimatic conditions and the compatibility of the neighbouring materials in touch with them. Unconscious removal of timber elements or the use of new materials that are incompatible with old timbers would be dangerous for both durability and authenticity of the historic structures.

Non-destructive testing (NDT) methods are being developed for maintenance, monitoring and conservation studies of structures with timber elements [4–11]. Among these, infrared thermography (IRT) and ultrasonic velocity measurements (UVM) promise to be particularly important to assess the state of deterioration and the adequacy of the boundary and microclimatic conditions for timber elements.

In this study, a historic structure with timber elements was investigated in situ by IRT and UVM together with laboratory analyses.

2. Materials and methods

A historic structure, 13th century mosque, Aslanhane Camii, belonging to Seljuks Period was examined as a case study (Fig. 1). Its walls were constructed with stone masonry. Its roof and timber ceiling structure were supported by 24 timber pillars (Fig. 2a) and stone masonry walls with timber lintels and bond beams (Fig. 2b).

The structure was examined to find out the moisture distribution in the structure and boundary conditions for

* Corresponding author. Tel.: +90 312 2106214; fax: +90 312 2107966.
E-mail address: tayse@metu.edu.tr (A. Tavukcuoglu).

1350-4495/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.infrared.2006.06.012

Fig. 1. General view of Aslanhane Mosque.

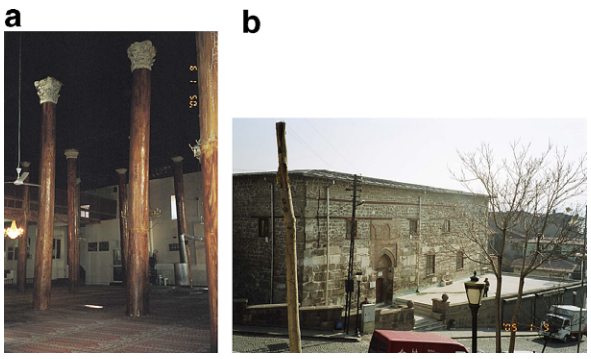

Fig. 2. The roof and timber ceiling structure of Aslanhane Mosque were supported with 24 timber pillars (a) and stone masonry walls with timber lintels and bond beams (b).

timber elements and to assess the state of deterioration of structural timber elements. The in situ survey was done by the use of IRT and UVM. The IR images were taken from the interior and exterior surfaces of the walls, the timber ceiling, floors and timber pillars twice a day, once in the morning and once at night in winter. UVM were taken from some of the timber pillars. Old and new timber samples with different physical and mechanical properties were examined in laboratory to determine the changes in ultrasonic velocity values with varying moisture content. These values formed the reference data to compare the moisture content and UVM taken in situ [8,12,13]. The procedure of each survey phase was briefly explained below.

2.1. In situ infrared thermography

An AGEMA, model 550 thermovision camera was used to produce thermal maps for the interior and exterior surfaces of the walls, timber pillars, timber ceiling and the floor. The camera was given inputs on ambient temperature, relative humidity, distance to target area, and a relevant emissivity of target surfaces [14,15]. Target surfaces mainly consisted of stone masonry walls, oil painted timber pillars, unpainted timber ceiling, plastered and oil painted walls. Climatic data were obtained by use of an environmental meter, Kestrel 3000. IR images were then analysed by using IRwin 5.1 software. Infrared images of the subject areas were taken in segments together with their visible-light photographs. During the survey, the distance between camera and target area was calculated from the measured plan and section drawings for each exposure.

2.2. In situ ultrasonic velocity measurements

A portable PUNDIT Plus CNS Farnell Instrument with 54 kHz transducers were used in the direct transmission mode (cross direction) to produce ultrasonic velocity data of the timber pillars, K1, K2, K3, K5, and K7 (Fig. 3). Each column was examined in east–west and north–south cross directions by taking measurements at five different levels with 30 cm height intervals. For accurate measurements, ultrasound couplant gel was used to provide good contact between the timber surfaces and transducers. Special care was given to take cross measurements at the same level. All measurements were taken perpendicular-to-fiber direction and five readings for each point were recorded to get reliable data. The column diameters were used to calculate the distance traversed by the wave for each measurement. The diameter of each pillar decreased with height. During the survey, the RH and ambient temperature data were taken by the use of an environmental meter, Kestrel 3000. The moisture content of the timber pillars were measured by means of a protimeter, Surveymaster SM.

2.3. Laboratory analyses

During the laboratory analyses, fifteen old and new timber samples were studied consisting of some pine, linden, horn-beam, poplar, walnut, olive and willow samples. Their equilibrium moisture content (EMC) and ultrasonic velocity values were examined for 56%, 75% and 90% RH conditions during the periods of moisture absorption and desorption. EMC of timber samples was determined by recording the increase and decrease in weight. A Protimeter Surveymaster SM was used to get data about the moisture content at their surfaces. UVM of laboratory samples were taken in the direct transmission mode when the sam-

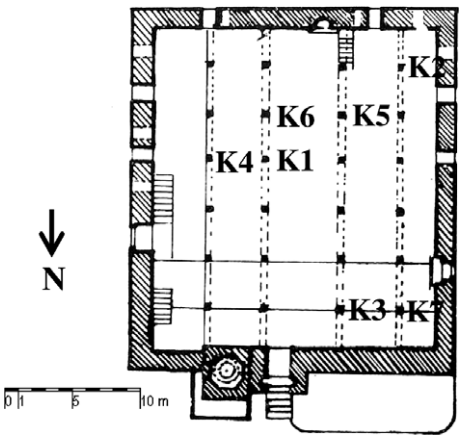

Fig. 3. Plan of the Aslanhane Mosque (source: [16, p. 346]).