

# Non-destructive techniques for characterising earthen structures

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## ABSTRACT

Earthen architecture is one of the most relevant building technologies among heritage structures. It has been used worldwide with particular techniques and performances, which have been extensively documented (see the work by Miccoli et al. [1]). Earthen materials have been characterised from different points of view: composition, mechanical properties, thermal properties or moisture content are sound in the literature. Among them, mechanical properties are the ones which typically include destructive tests. To change this trend, two non-destructive mechanical techniques (ultrasound and modal analysis) are studied to determine their ability at characterising earthen materials. In addition, the possibilities of correlating both techniques are also evaluated, to finally perform an in-depth study about the wide application range of ultrasound transmission technique along all life-cycle of earthen structures, including construction phases.

To achieve these purposes, twenty cubic-shaped earthen specimens were produced for testing the capability of ultrasound transmission method to control moisture content and its evolution during drying process in the construction phase. Clayey-sand soil was used as reference earthen material for this study. Different time of exposition to high humidity environment before drying was also considered. Additionally, a real-scale rammed earth wall was built to assess the feasibility of using ultrasound technique to determine elastic dynamic Young modulus. This analysis was validated by comparison with an experimental modal analysis test also performed on the rammed earth wall. However, this comparison is not direct but based on comparing the experimental results of modal analysis with the numerically calculated vibrational response of the wall which used the dynamic young modulus of the earthen material obtained from ultrasound tests on the wall.

The most important findings are that the relationship between moisture content and ultrasound transmission speed is linear (speed increases with the decrease of moisture content) and the moisture content descends exponentially during drying process, becoming stable at a certain value (1% for the studied soil). This information is useful to control the drying process of earthen materials for new construction but also for conservation or rehabilitation interventions on existing structures using cheap and non-destructive tests. It also allows to control the moisture content distribution on larger in-service structures as it was proved from the tests on the earthen wall.

Additionally, numerical simulation using ultrasound transmission data as input information allow to predict the vibrational response of the tested wall with an error around 3% when comparing with the experimental modal analysis results. Hence, a methodology combining ultrasound transmission method and modal analysis is suitable for determining the dynamic Young's modulus of earthen materials and their corresponding Poisson's coefficient.

## REFERENCES

- [1] Miccoli L, Müller U, Fontana P. Mechanical behaviour of earthen materials: A comparison between earth block masonry, rammed earth and cob. *Constr Build Mater* 2014;61:327–39. doi:10.1016/j.conbuildmat.2014.03.009.