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Title: Characterization of adobe bricks used in developing countries: Mexico as a case of study

Authors: GUTIÉRREZ-VILLALOBOS, José Marcelino, MORENO-MARTÍNEZ, Jatziri Yunuén, CATALÁN-QUIROZ, Policarpo and GALVÁN-CHÁVEZ, Arturo

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ECORFAN-México, S.C.
143 – 50 Itzopan Street
La Florida, Ecatepec Municipality
Mexico State, 55120 Zipcode
Phone: +52 1 55 6159 2296
Skype: ecorfan-mexico.s.c.
E-mail: contacto@ecorfan.org
Facebook: ECORFAN-México S. C.
Twitter: @EcorfanC

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Introduction

Methodology

Results

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Conclusions

References

Introduction

In Mexico adobe masonry is a traditional common building material in rural areas with low economic development and a high degree of marginalization

Typical adobe house in Mexico

According to the CONEVAL (2015) the population living in poverty in Mexico was 55.3 million people. At the same time, the population in extreme poverty was 11.4 million people, which is equivalent to 44%, and 9% respectively of the total population of the country.

Introduction

For adobe brick constructions, earth is combined with straw and water until a uniform and malleable mixture is obtained.

The mixture is placed in wooden molds to create the pieces of adobe, these are allowed to dry in the open air for approximately 30 to 60 days..

Introduction

Transportation of adobe bricks,

Introduction

The foundation starts between 60 cm to 80 cm beneath the surface and continues up to 30 cm to 40 cm above the ground to avoid weathering of the bottom of the adobe walls (Arroyo, 2010).

The pieces of adobe are joined with a mortar composed of soil, water and dry grass to form a sludge; the joints are approximately 2.5 to 3.5 cm thick. The foundation is usually constructed of basalt masonry and the same mortar that is used for the pieces of adobe.

Introduction

The roof system is either flat or pitched at an inclination anywhere from 15 to 30 degrees. The roof cover is fabricated from annealed clay tile mounted on a robust longitudinal wooden beam that rests on the transverse walls (head walls) and on two wooden struts; the latter are connected to a transverse beam, equally spaced, and resting on the longitudinal walls. Wooden rafters, also known as "madrinas" or battens, are placed approximately 60 cm apart on the walls and longitudinal beam rest

Introduction

Main problems are found in using this material are how to carry out the conservation works of historical buildings, usually adobe masonry and rammed earth, as well as the lack of skilled people to produce adobe, from designer to masons, because it is a forgotten technique.

A new growing interest in adobe masonry has been noticed as an environmentally friendly building material (Laborel-Préneron *et al*., 2016) and the influence of block geometry (aspect ratio), test procedure and basic material parameters (dry density, cement content, moisture content) are also discussed.

Quagliarini and Lenci (2010) investigated the changes in the mechanical properties of ancient roman adobe earthen bricks by varying the percentage of an on-situ soil, straw and coarse sand into the mixture to produce those bricks.

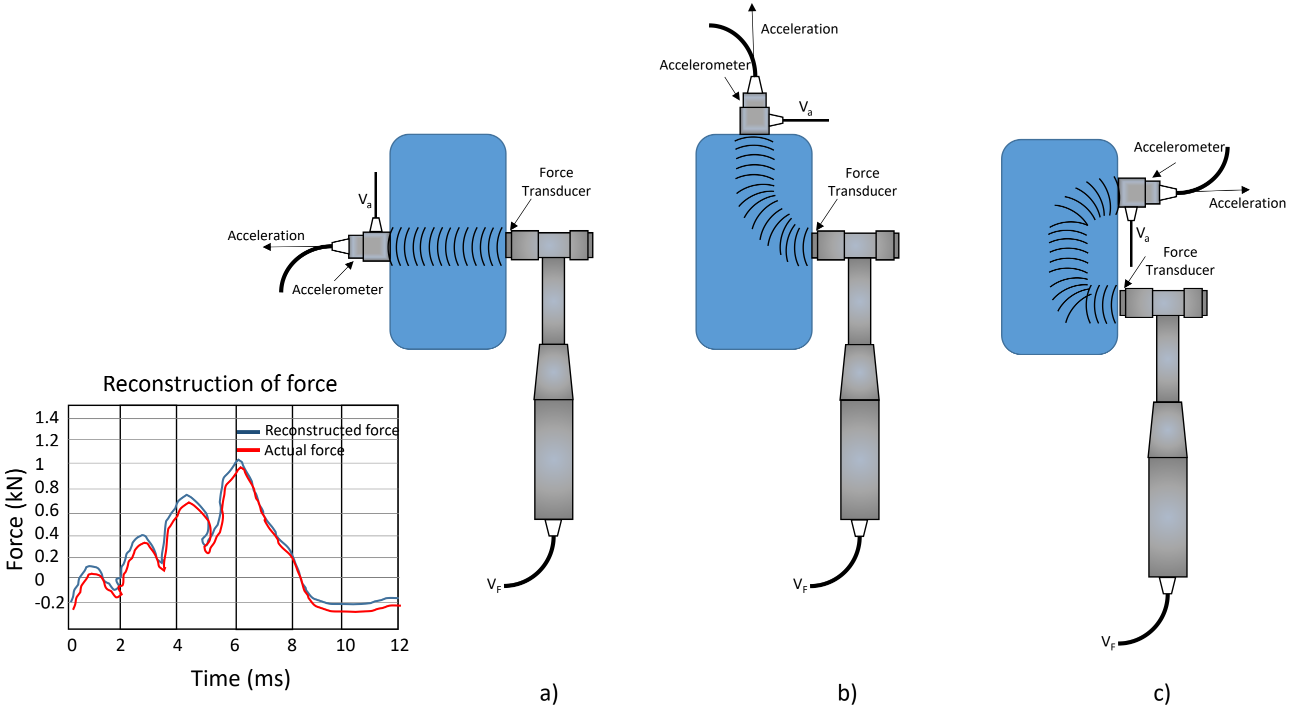
Introduction

Main tests on adobe bricks

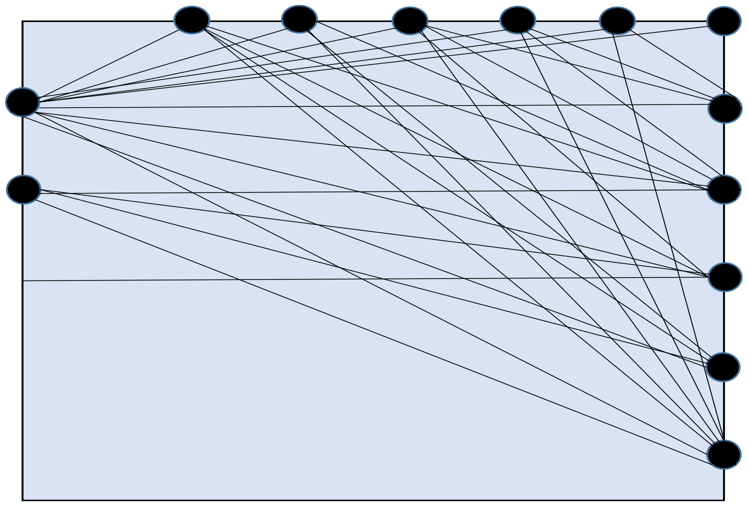
- **Destructive tests**
- **None destructive tests (NDT)**

Introduction

None Destructive Tests



Ways of ultrasonic wave measurement (a) direct, (b) semidirect and c) indirect



Methodology

Destructive Tests

a)

b)

e)

Specimens built for compressive tests: a) construction of pillars; b) planar surface for performing a uniform stress distribution; c) storage of pillars

Methodology

Destructive Tests

Instrumentation for pillars and colocation in the mechanical press

Methodology

Destructive Tests

The elasticity modulus E_m was obtained according to Mexican Norm (equation 1):

$$E_m = \frac{S_2 - S_1}{e_2 - 0.00005} \quad (1)$$

Where:

S_1 = Stress in MPa corresponding to strain e_1 = 0.00005

S_2 = Stress in MPa corresponding to 15-20 % of maximum adobe masonry stress

e_2 = Strain corresponding to S_2

From the measured elasticity in the specimens, average values were calculated (Table 1). The elasticity modulus E_m was 240.94 MPa.

Results

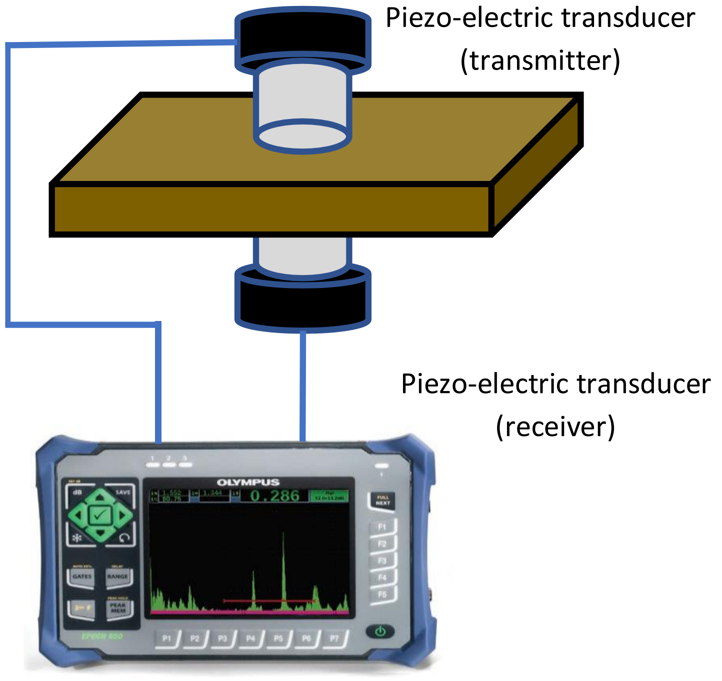
Pruebas destructivas

Table 1 Elasticity modulus (E_m), one of the adobe masonry elastic mechanical properties from the southeastern of Mexico

Specimen (Pillar)	E_m (MPa)
Pillar-1	230.92
Pillar-2	219.24
Pillar-3	275.89
Pillar-4	210.86
Pillar-5	200.94
Pillar-6	197.64
Pillar-7	273.23
Pillar-8	317.67
Pillar-9	242.08
Average values	240.94

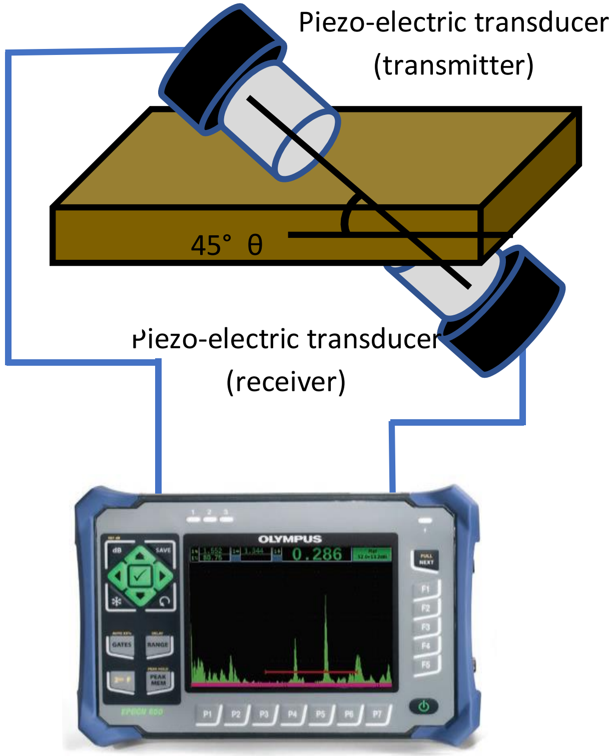
Methodology

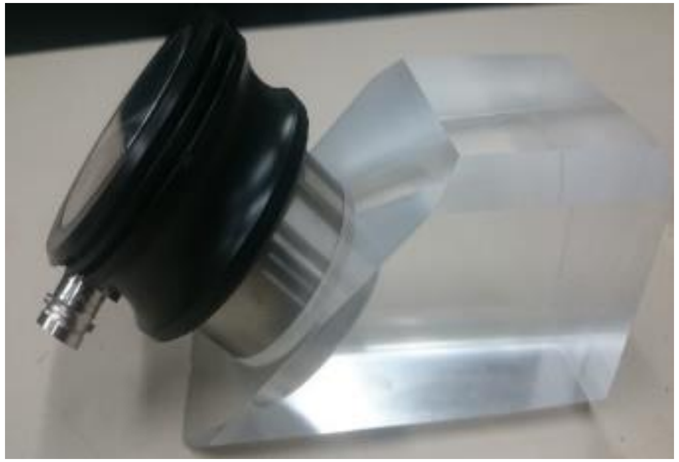
Pruebas no destructivas



Ultrasonic wave emitter-receiver

Longitudinal velocity measurement 5077PR





Methodology

Pruebas no destructivas

Instrumentación de un espécimen para su medición no destructiva

Physical properties	Brick from southeastern of Mexico (half scale)	Brick from central part of Mexico (full scale)
Dimensions (cm)	21.5 x 5.3 x 14.5	30.5 x 7 x 26.5
Mass (kg)	2.175	7.425
Volume (cm^3)	1652.27	5657.75
Density (kN/m^3)	13.16	13.12

a) y b)

a) Pieza de adobe del sureste de México y b) pieza de adobe del centro de México

Methodology

Pruebas no destructivas

Pieza de adobe del sureste de México

T_L (uS)	V_L (in/uS)	V_L (cm/S)	Poisson's ratio v	Elasticity Modulus E_m (MPa)
106.1	0.01885	47879.359	0.44	221.879
T_T (uS)	V_T (in/uS)	V_T (cm/S)		
185.3	15218.565	38655.154		

Methodology

Pruebas no destructivas

Pieza de adobe del centro de México

T_L (uS)	V_L (in/uS)	V_L (cm/S)	Poisson's ratio v	Elasticity Modulus E_m (MPa)
157.2	0.01908	48473.282	0.43	227.385
T_T (uS)	V_T (in/uS)	V_T (cm/S)		
275.1	0.01540	39119.506		

T= sound flying time, *L*=longitudinal, *T*=transversal.

Results

Espécimen	*Densidad* (kN/m³)	Type of test	E_m (MPa)
Southeastern adobe masonry brick	13.16	NDT test	226.54
Central part adobe masonry brick	13.12		231.01
Southeastern adobe masonry brick	13.24	Destructive test	240.94

Annexes

Velocity can be determined from equation (2).

$$V = \frac{h}{t} \qquad (2)$$

Where:

V = velocity

h = Thickness

t = Trip transit time

The units read on the instrument display were in inch/uS. Units had to be converted to cm/uS and multiplied by $1x10^6$ to be expressed in cm/S. starting from this Poisson's ratio v can be calculated using (3).

$$v = \frac{1-2*\left(\frac{V_T}{V_L}\right)^2}{2-2*\left(\frac{V_T}{V_L}\right)^2} \qquad (3)$$

Where:

v = Poisson's ratio

V_T = Shear (transversal) velocity

V_L=Longitudinal velocity

Annexes

Now to calculate elasticity modulus E_m, both velocities are necessary as well. This time density is included. Using equation (4).

$$E_m = \frac{{V_L}^2 \rho * (1+v) * (1-2v)}{1-v} \qquad (4)$$

Where:

V_L=Longitudinal velocity

ρ = Density

v = Poisson's ratio

Conclusions

Mechanical properties of adobe masonry can be obtained using destructive tests in pillars or cylinders (for obtaining elasticity modulus, Poisson’s ratio and tensile and compressive strength) due to the complexity of testing a single brick.

However, in some cases, destructive tests are not possible to apply for obtaining these properties. Such is the case of historical buildings, e.g. constructions carried out with adobe masonry.

The NDT system and the method used in this study to estimate the adobe masonry elastic mechanical properties showed good results compared to destructive tests, the elasticity modulus obtained was closed in both methods (6% of difference between both tests), which validates the alternative method proposed in this research.

It should be noticed that both types of brick coming from different parts of Mexico (southeastern and central part of the country) present approximately the same elastic mechanical properties because of their construction process that is very similar in these two parts of the country.

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