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Evaluation of mechanical properties of adobe chemically stabilized with "synthetic termite saliva"

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Abstract. The raw mud brick (adobe) is a millenary technology that awakens a wide interest in ecologic and non-conventional constructions. Some advantages are low cost, thermal comfort and minimum environmental impact. For better use, it is important to improve their mechanical properties. Dynasolo DS-328® is a chemical stabilizer used in soil compression for road paving and it is similar to "termite saliva". This composition is based on vegetal oils. It is a high-concentrated liquid product, water soluble, non-toxic, non-corrosive, and non-flammable. The cohesive properties promote the investigation about the incorporation of this product in adobe composition. Therefore, this work aimed to evaluate "synthetic termite saliva" incorporation to adobes at four different concentrations: 1:2000; 1:1500; 1:1000 and 1:500. The reagent is an aluminum sulfate at 1:5000 for all treatments. The soil is a Red Latosol cambisol corrected to 50% fine sand fraction. Soil bulk density, particle density and total pore volume were: Ds = 1.42 kg/dm³, Dp = 2.62 kg/dm³ and VTP = 45.8%. The soil Atterberg limits were: LL (liquid limit) 55.44%; PL (plastic limit) 34.58%; SL (shrinkage limit) 21.67%; and PI (plasticity index) 20.86%. The ideal moisture content was variable, ranging from 50% to 40% according "synthetic termite saliva" increase. Adobes were submitted to compression and bending resistance tests. This research confirmed that "synthetic termite saliva" incorporation improved the adobe compressive resistance and chose the treatment 1:1500 because it increased 20% this property.

1. Introduction

The adobe is an excellent alternative for housing and rural construction, due to the need for environmental quality and thermal comfort in buildings. Although the adobe be a millennial technology, there are still many questions that deserve to be investigated, including the production methodology, normative parameters, and improved mechanical properties. The adobe composition don`t have cement and have no need to be sintered, which are important environmental advantages when compared to other building materials. The artezanal process doesn`t rule adopted science-based procedures that improve the final product. There are several options of products and materials that can be added to soil to improve its properties. Dynasolo DS-328® is a chemical additive similar to "termite saliva" produced in Brazil that has application in road paving. There are studies of its incorporation in construction materials such as compressed rammed earth and BTC-compressed earth block, but are still scarce regarding the adobes. It is a non-toxic product, hydrophobic, and promotes cohesion between the particles. The DS-328® acts as a catalyst, promoting and facilitating ion exchange and allowing for greater cohesion between the fine particles of soil, waterproofing them. Its strong action binding is due to base exchange, causing a greater attraction between the surfaces of the particles of clay, with its consequent flocculation and sedimentation. So no leaching occurs in the structural composition of the treated soil.

Compression resistance is the main measure of quality control adobe. On average varies from 0.6 to 2.0 MPa [1], which shows apparently low values but viable building that has since

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monitoring of professional technical responsibility. Several factors contribute to this variation of resistance: soil characteristics; type of stabilization; craft production; amount of water in the mixture; drying process among others. In research carried out by Piñón et al. [2], compressive strength increased from around 1.2 MPa in normal adobes up to 2.2 MPa when surfactants and emulsified asphalt were added.

Static bending resistance is a parameter that has been little investigated, but it is nonetheless important because it assesses the behavior of adobe in the different treatments proposed giving greater basis for choosing the best. Usually the results are much lower than the compression resistance. In research conducted in Aveiro, Portugal results for static bending were 20% of the results for compression resistance [3]. The adobe mechanical properties depend crucially on soil stabilization and methodology used. Therefore, this work aimed to verify the chemical stabilization with "synthetic termite saliva" incorporation to adobes at four different concentrations: 1:2000; 1:1500; 1:1000 and 1:500 to evaluate the behavior of adobe for compress and bending resistance.

2. Methodology

The experiment was conducted at the Experimental Unit Wood Panels (UEPAM) and Forest Sciences Department laboratories in Federal University of Lavras. The soil sample was collected in BC horizon in Lavras, Brazil. The characterization was made by field tests: visual and tactile identification, linear shrinkage, soil washing, and laboratory testing: X-ray diffraction, particle size analysis, textural classification by Atterberg triangular diagram and consistency limits [4]. After investigation, the soil was classified as Red Latosol cambisol, clayey silt [5] with high clay bit expansive with kaolinite. Soil bulk density, particle density and total pore volume were: Ds = 1.42 kg/dm³, Dp = 2.62 kg/dm³ and VTP = 45.8%. The granulometric correction was made by dry mass with fine sand. The amount of sand was determined by mathematical calculation: for one kilogram of natural dry soil were added 412 grams. The granulometric composition after correction was 23% clay, 27% silt and 50% sand. The initial amount to the composition of adobes was the result of plastic limit.

In the chemical stabilization were used four different concentrations of the product: 1:2000; 1:1500; 1:1000 and 1:500. The reagent was an aluminum sulfate at 1:5000 for all treatments according manufacture instructions. The added dosage was proportional at dry soil mass. The adobe produced without DS328® was compared with four others treatments as reference. Table 1 shows the materials quantities used in this experimental stage and adobe production.

Table 1. Materials quantity and adobe production.

Treatments	DS328®	DS328® (%)	DS328® 10% (ml)	Water (l)	Soil (kg)	Adobes (units)
T1S	-	0	0	50	143,136	26
T2A	1:2000	0.05	613	40	122,688	23
T2B	1:1500	0.07	818	35	122,688	23
T2C	1:1000	0.10	1.431	46	143,136	25
T2D	1:500	0.20	2.862	32	143,136	22

The ideal moisture was determined by field test [1,6] and timber shapes were castings with dimensions 30x15x8cm according relative ratio of length, width and height [7]. The shapes were previously wet and immersed in the sandbox to facilitate demolding.

The production of adobes had the following procedures: weighing the soil, placed on the wooden platform; addition of the solution of *DS328*; homogenization; addition of the reagent solution; homogenization, addition of water until the ideal moisture [8]. The homogenization was done with feet and "maromba" (Fig. 1). The adobes were produced on flat surface with a thin layer of sand. They were done in the shade until they were completely dry for 25 to 30 days.

Fig.1. ”Maromba” and adobe production.

Compression [7] and three point static bending resistance [9] tests were done to five treatments with six and four replications respectively after forty days of drying. The compressive strength tests were performed in Universal Machine EMIC. The adobe were weighed and measured before the test. These were sawn in half and joined with lime soil mortar, also used for the regularization of the contact surface with the test machine (Fig. 2). The load cell used was 100 kN at a speed of 1.2 mm/min. We evaluated the following parameters: modulus of elasticity (MOE), resistance (σ_{max}) and maximum force (F_{max}). The three point static bending resistance tests were performed in Universal Machine EMIC. The adobe were weighed and measured before the test. The distance between two points used was 240 mm. The load cell used was 20kN with a speed of 1.2 mm / min. We evaluated the following parameters: modulus of elasticity (MOE), resistance (σ_{max}) and maximum force (F_{max}). The experimental data were analyzed by analysis of variance, considering completely randomized design. The Tukey test was applied to differences in the level of 5%. The software used was 4.2 SISVAR [10].

Fig.2. Samples preparation for compression resistance test.

3. Results and Discussion

The results presented below compare the adobes produced with limed soil T1S (control) and with incorporation of the stabilizer *DS-328*® in the treatments T2A, T2B, T2C, and T2D to evaluate mechanical and physical properties.

3.1. Compression resistance

The stabilizer *DS328*® was studied in BTCs - compressed earth blocks, in a proportion of 0.1% (1:1000) by weight of dry soil. The granulometric composition of the soil was 18.2% clay, 5.3% silt and 76.5% sand. Analyzing the results, the authors [11] infer that there was a considerable increase in compressive strength with the use of chemical additives. This increase approached 125% to 1% cement and 35% to 3% of cement.The lack of results by incorporation of “synthetic termite saliva" in adobes not allow a comparison. The addition of the stabilizer DS-328® this research was significant at the 5% maximum. The results (Table 2) were superior to T1S (control), except for the modulus of elasticity (MOE). Treatment T2A and T2B showed the best results (Fig. 3). The NTE E.080 (2000) establishes compressive strength > 0.7 MPa, so the treatments T2B met the specifications.

Table 2. Medium results of compression resistance tests.

Treatments	MOE (MPa)	σ_{max} (MPa)	F_{max} (N)
T1S (control)	43,42	0,60	11256
T2A 1:2000	37,30	0,70	13014
T2B 1:1500	58,06	0,72	13005
T2C 1:1000	37,41	0,64	11993
T2D 1:500	52,93	0,67	12264
General medium	45,83	0,67	12306
CV_e^*(%)	43,58	11,52	8,81

* CV_e is the experimental variation coefficient

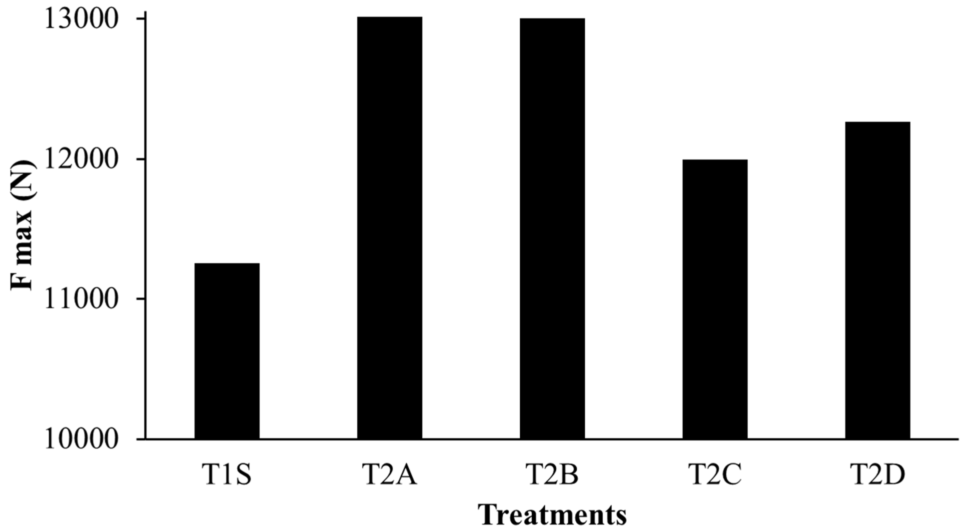

Fig.3. Medium results of maximum force in *DS 328®* treatments

3.2. Bending resistance

The addition of stabilizer DS-328® was not significant for any of the parameters analyzed at 5%. The trend of increasing modulus of elasticity (MOE) was the highest concentration of additive and the results were superior to the compression test, ranging from 112 MPa to 164 MPa and 43 MPa to 53 MPa respectively. The results of the maximum bending resistance corresponded to 67 to 78% of the compression obtained (Table 3). This correlation is higher than in the NZS: 4298 [12] determines that 10 to 20%. Silveira et al. [13], results obtained below 30% for adobes.

Table 3. Medium results of bending resistance tests.

Treatments	MOE (MPa)	σ_{max} (MPa)	F_{max} (N)
T1S (control)	111,89	$0,47_{(0,094)**}$	977
T2A 1:2000	133,74	$0,47_{(0,049)}$	951
T2B 1:1500	148,13	$0,47_{(0,049)}$	1034
T2C 1:1000	150,39	$0,47_{(0,049)}$	1038
T2D 1:500	164,25	$0,44_{(0,057)}$	984
General medium	141,68	0,46	997
CV_e^*(%)	22,06	13,45	9,99

* CV_e is the experimental variation coefficient
** standard deviation

4. Final remarks

This ongoing research confirmed that “synthetic termite saliva" incorporation improved the adobe compressive resistance and chose the treatment 1:1500 because it increased 20% this property.

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