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BRAZILIAN SCENERY OF ADOBE: ANALYSIS ABOUT PRODUCTION AND RESEARCH IN THE PERIOD 2008-2018

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ABSTRACT

The use of adobe as an important technique for producing houses goes back to the earliest times and lasts until the present day. In Brazil, the technique was widely used during colonial period, going through several sceneries and tendencies, having its use declined from Industrial Revolution by the offer of new materials more competitive and apparently with more advantage. This paper presents a wide review of the knowledge production about adobe, made by Brazilian academic community, in the past 10 years (2008-2018), aiming a better comprehension of ongoing studies, obtained results and the identification of little explored gaps, besides the proposition of new research lines in the field. From the bibliographic review, it came to light some similarity in regards to the main theme of publications, being proposed a classification in the following categories: stabilizing addition, technique analysis, social view, innovation and technological survey. Results showed a growing in the number of correlates publications in the last years, especially in 2018, besides the occurrence related to events, such as TerraBrasil and SIACOT. In the other hand, it was identified a considerable demand for new researches in adobe, as well as social and political action towards normalization and dissemination of the technique.

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INTRODUCTION

There are adobe constructions in every continent of the planet, in warm and cold weathers, subtropical or temperate climates, in every latitude and almost every culture and civilization prior industrialization used it to build (Dethier, 1985; Minke, 2015). This constructive technique has been adapting itself to human lifestyle since the first habitations, even in the Neolithic period, at least 10 thousand years ago, with the first cultivation systems and animal farming made by men, being it considered one of the oldest, present in most of archeological sites and historical buildings in the world (Dethier, 1985; Mazoyer e Roudart, 2008; Pacheco-Torgal e Jalali, 2011; Minke, 2015). Worldwide, there's a consensus between authors about adobe use's decrease somewhere in the XIX century, due to the fascination with modern materials such as concrete, bricks and steel. Still incipient, the return of this technique's study and interest, amongst other earth building techniques, happens with petroleum crisis in the 1970s.

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Recently, with the increasing sustainability approach, adobe has been drawing interest due to its low consume of energy during its production, low cost, abundant raw material and associated thermal and acoustic properties, especially (Parra-Saldivar e Batty, 2005; Delgado e Guerrero, 2006; José-Sandoval *et al.,* 2018). In the last decade – beginning of XXI century – an increasing attention by the community was registered, which was illustrated by ten times the number of research articles published when compared to the prior century (Pacheco-Torgal e Jalali, 2011). In Brazil, the situation is the same. According to the literature revised in this research, the number of publications about earth as a construction material is increasing. Furthermore, number of scientific (and technical) events about this theme also increased, as well as new construction companies and architecture offices founded to offer specialized services in the field. The creation of professional networks in the 2000s, like TerraBrasil and PROTERRA, both aiming to support construction with earth's discussion and regulation, national and iberoamerican wide, with an expressive number of members in Brazil, is also an evidence. The adobe term can be used to describe different materials and earth building constructions techniques around the planet). However, the most common definition, considered in this research, is similar to several other researchers and refers to adobe as bricks obtained through earth's conformation in the plastic state in shapes with or without stabilizers addition, afterwards dried in air.The use of adobe in emerging countries as a construction technique, such as Brazil, depends mostly on its mechanical resistance, water absorption and chemical stabilization (Millogo*etal*. 2008; Smith, 1982). Furthermore, improvements in mechanical and physical properties of adobe is a growing objective in the national scientific environment, usually proposed through the incorporation of stabilizers additions of the most various natures. In parallel, there's a concern about the preservation, maintenance, conservation and restauration of the heritage built in adobe, based on historical and cultural aspects involved. In some regions, adobe also came up as a technique for social interest constructions, also being considered as a technology for social inclusion, in some cases.This rescue might be justified by several factors, mainly associated with environmental matters, thermal, acoustical and mechanical properties of adobe, as well as social, cultural, economical and historical factors.

Historical process of adobe in Brazil: In Brazil, earth building construction systems were introduced and broadly utilized in the colonial period, between centuries VXII and XVIII, influenced by Portugal's characteristic architecture at the time, and also by African people brought in as slaves, once there are no indications of native people using earth as a construction material (Barbosa e Ghavami, 2007; Salgado, 2010; Silva, 2011). Earth building constructions remnants of Portuguese colonial heritage can be found in several Brazilianregions. Still in colonial period, Reis Filho (1987) registered that adobe was used in simpler constructions, being stone and clay used in more important residences. Other pattern identified by Santos (2008) in the same period, proposed adobe in inward constructions and stone and lime in coastal constructions, based on the availability of local materials. The upbringing of Industrial Revolution, in the XIX century, there was an ascending dissemination of market industrialized materials and techniques, not only drastically diminishing traditional earth building techniques use, but also associating them with pejorative characteristics, as poor, fragile and archaism like. "The elimination of traditional techniques, in the name of hygiene and public health, is a strong trend in urban legislation from the XIX century, with the so called hygienism"(Santos, 2008, p. 246). In São Paulo, Santos (2008) registered that, when turned into XIX century, most constructions were already made of bricks masonry, the technique was born aroundthe 1850s in the state, took in average only 50 years to replace earth building architecture. Other initiative that was more radical was based on forbiddenism, adopted by some of the Brazilian states. In 1984, Sao Paulo state published a law forbidding earth building construction and also every other architecture model resembling the colonial period (Lemos, 1989).From 1930 on, a series of proposals were initiated, that, even if shy and punctual, represent traditional techniques revival. However, it seems to have happened a hiatus regarding adobe use in relevant architectural buildings in this period, once it's highlighted, amongst those initiatives, the use of the mixed technique, monolithic walls of soil cement and rammed earth (Joaquim, 2015; Nito e Amorim, 2015; Pinheiro *et al*., 2016).

The petroleum crisis which started in the1970s, along with increased environmental problems, mainly caused by massive pollutants emitted by industries – culminating in events popularly known as "heat islands" and/or "global warming" – high energy consume required by new technologies, non-controlled extraction of non-renewable materials, frequent economic crisis and accentuated social inequality, earth building construction resurged more significantly, both in the technical and academic field, however, in the decade of 1970 there are no registration of great habitational conglomerates constructed by public initiative with earth building techniques, only private buildings (Revuelta-Acosta *et al*., 2010; Joaquim, 2015; Nito e Amorim, 2015; Pinheiro *et al*.,2016).Only in the 1990s, as registered by Agopyan (2000), Brazil stated to adopt the first more consistent measures aiming for a more sustainable construction, resulting in a considerable advancement in the use of earth, as described by Salgado (2010).

MATERIALS AND METHODS

Aiming to optimize the analysis and understanding every line of study's advancement, it was proposed a classification distributed through the categories that most repeat themselves regarding the main approach of each paper, being: survey, social aim, stabilizer addition, technological innovation and technique analysis.In the "survey" category, it was gathered papers which the objective wereheritage, habitations and/or adobe constructive methods catalog, in a determined region of interest. Papers labeled as "social aim" have a social and cultural approach, usually focused on social interest habitations and adobe construction tradition remanence by craftsman masters. Manypapers aimed to evaluate physical and mechanical properties of adobe with the incorporation of stabilizers additions, therefore, this category was created. Investigative researches aiming to propose other innovations regarding production methodology, evaluation and new constructive practices with adobe were inserted in the "technological innovation" category. The category labeled as "technical analysis" aimed to gather studies were adobe's physical, mechanical, thermal and economic viability without apparent stabilizers' properties were evaluated, based on national norms and/or technical bibliography correlated.

Adobe's State of the Art: Research with adobe has active activity in most Brazilian states. In regions where it was not found recent publications, it was also noted the lack of researchers and / or professionals affiliated to TerraBrasil Network, founded in 2007. It is important to highlight the states of southeast - Minas Gerais and São Paulo - and northeast - Ceará and Paraíba - due to the bigger number of publications. In the other hand, it is noticed adobe's insertion in scenarios with little historical and cultural tradition, acting as a notable technological innovation instrument, through constructive methodologies, architectonic typology, manufacture and dimensional conception methods, especially regarding the composition, evidenced by a higher number of papers focusing on stabilizers additions, which justifies expressive increase on papers related to the theme last year. The upbringing of a higher number of publications in the years even, beginning in 2008, is due mainly, to TerraBrasil[1], a Congress organized by Rede TerraBrasil, as well as the annual

[1]Earth building Construcion and Architechture Congress in Brazil, made every two years.

contribution of SIACOT[2], organized by Red PROTERRA, both in the earth buildingconstruction and architecture area.

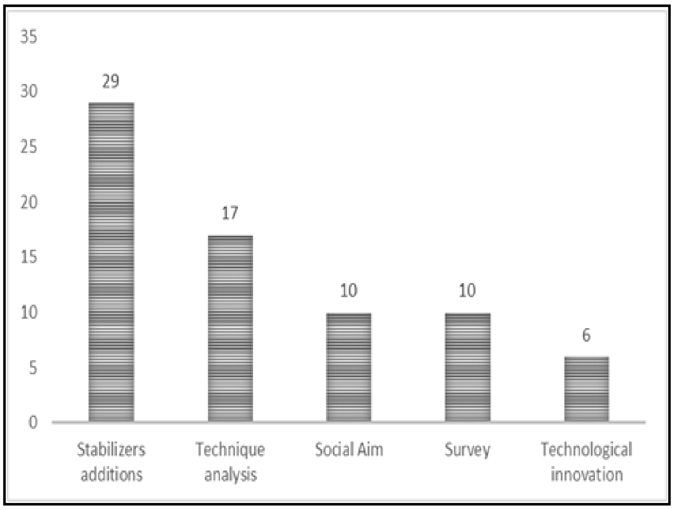

Figure 1. Number of publications versus category of approach

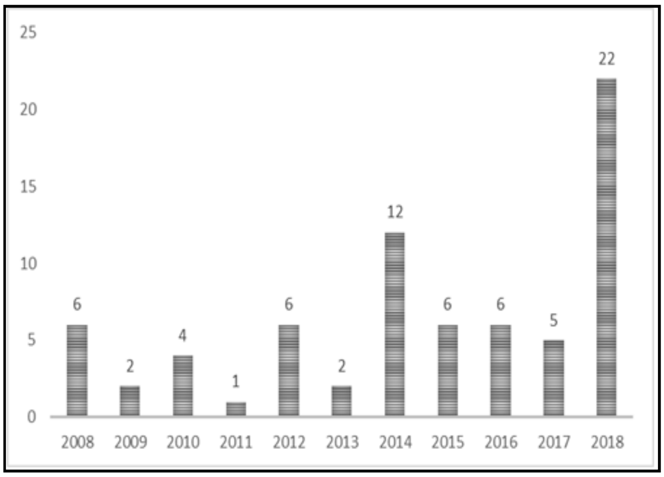

Figure 2. Number of publications versus year of publication in the period 2008-2018

Stabilizers additions: Earth building construction techniques, like any other construction material, may be tested in order to characterize and better understand its behavior and performance (Guillaud, 2008). Furthermore, papers focused on stabilizer addition was evidenced. The diversity of additions proposed by authors reinsures the wide associative flexibility of adobe.Amongst short fibers, coconut fiber presented less tensile strength and lower elasticity module, however, due to high amount of lignine, it has more durability compared to other natural fibers with a durability of 4 to 10 years (Mota e Agopyan, 2007; Hejazi *et al.,* 2012). Due to the high consume of green coconut water and the unappropriated discard of its shell, which corresponds to 85% of its total raw weight, green coconut has become an environmental problem, especially in north and northeast regions, who are the biggest consumers of coconutof the country (Martins e Jesus, 2011; Corradini*et al.,* 2009). Santos e Sousa (2018) obtained 8% lighter adobes and with a reduction of 35% in average relative linear retraction with the addition of 25% of coconut fiber, reducing, however, in 17% compressive strength. Costa *et al.* (2014) obtained similar results, by adding 1%, 3% and 5% of coconut fiber in adobes, reducing compressive strength, but in the other hand it was identified an improvement in the durability with the presence of water with the addition of 1% and 5% of fiber, as well as with Ferreira *et al.* (2012) obtained improvements with water absorption by addition of 10% of coconut fiber. Ferreira *et al.* (2012) and Soares *et al.* (2008) registered, however, also an increase in adobe's compressive strength with the addition of 10% of coconut fiber. Linear retraction of adobes was evaluated in none of the three papers last mentioned. Yetgin*et al.* (2008), when evaluating the effects of fiber addition in adobe mechanical properties, concluded that fiber addition increase, reduces the compressive and tensile strength, in other hand, also reducing linear retraction.Millogo*et al.* (2014) explain that, the higher the lignine rate present in the fiber, the higher the associated impermeability, which justifies the results obtained regarding less water absorption cited by papers, with the incorporation of fiber with a high rate of lignine.

Other fibers and some vegetable particles were also utilized by authors. In Piauí, Carvalho e Carvalho (2016), came to reduce the specific gravity of adobes as they increased the incorporated volume of Carnauba fiber (*Coperniciaprunífera (Miller) H. E. Moore*). So, they obtained, as a result, reduction in retraction, increase in compressive strength and the reduction of loss of mass in testswith adobes. Corrêa*et al.* (2015a) obtained a bigger elasticity module and smaller bulk density by adding up to 6% of sugar cane bagasse ash and increasedcompressive strength to 60%, as well as Corrêa*et al.* (2015b) produced adobes with bamboo (*Bambusa vulgaris vittata*) particles addition,and verified an increase of 90% in compressive strength for the addition of 6%, reducing linear relative retraction, water absorption and loss of mass under water action. In both papers, adobe was chemically stabilized with "synthetic termite saliva" in different proportions.Parisi*et al.* (2008) evaluated the compressive strength in adobes with addition of 25% rice shell, obtaining an increase of up to 26.6%, however the addition of 10% of brachiaria reduced it in 11.36%. Gandia*et al.* (2018c) evidenced reduction in bulk density in adobes with addition of 10% of Glass Fiber Reinforced Polymer (GFRP); Silva e Barros (2014) produced adobes with addition of 35% of cellulose fibers, obtaining compressive strength of 1,9 MPa, value superior to what's required by NBR 15270:2017 for ceramic blocks for non load-bearing masonry.

However, as for the water absorption, adobes obtained 133% index, which is over the allowance of NBR 15270:2017. Therefore, is noted that fibers diminish the values of bulk density, linear retraction and water absorption of adobes, increasing, in some cases, compressive strength, once they act in the interruption of cracks formed during compressive tests (Corrêa*et al.*, 2015b, Ghavami *et al.,* 1999). Solutions for problems on destination and/or reuse of various wastes, commonly generated in direct or indirectly by industries, human consume, thermoelectric power plant and water treatment stations, were proposed by incorporating in adobes, in order to improve its properties. Santos e Prado (2018) proposed adding expanded polystyrene (EPS) in adobes, obtaining smaller specific gravity, in the other hand, not influencing in a positive way in other evaluated properties – compressive strength, linear retraction and water absorption. Gandia*et al.* (2018a) came to an increase of 13% in compressive strength in adobes with addition of 3% of sludge

[2]Earth building Construction Ibero-american Seminar, made every year.

Table 1. Stabilized Adobes

Nº	Dimensions (cm)	Compressive strength (MPa)	Soil – Sieveanalysis	Tests	Stabilizer Addition	Authors
1	30 x 15 x 8	-	23% clay, 27% siltand 50% sand.	Water absorption, capillarity and linear retraction	Synthetictermite saliva, Sugarcane bagasse ash	Corrêa *et al.* (2015a)
2	-	-	-	Compressive strength, durability and water absorption	Construction and demolition waste (CDW)	Félix *et al.* (2016a)
3	-	-	-	-	Coconut Fiber – *Cocus nucifera*	Nogueira *et al.* (2016)
4	20 x 9.5 x 5	1.9	-	Compressive strength, water absorption	Cellulose fiber	Silva e Barros (2014)
5	-	1.35 – 4.68	-	Compressive strength, water absorption by capillarity, bulk density and retraction	Carnaubafiber - *Coperniciaprunífera (Miller) H. E. Moore*	Carvalho e Carvalho (2016)
6	24 x 12 x 12	0.92 – 2.85	-	Compressive strength	Mound of Termite	Couto *et al.* (2010)
7	30 x 15 x 8	1.6 - 3	22% clay, 24% silt e 53% sand	Compressive strength, durability	Coconut Fiber – *Cocus nucifera,* Mineral coal combustion ash (MCCA)	Costa *et al.* (2014)
8	-	1.0 - 1.6	36% silt andclay, 67% sand	Compressive strength	Tire rubber waste	Silva *et al.* (2017a)
9	-	-	-	-	Lingocellulose waste	Teixeira *et al.* (2012)
10	20 x 10 x 5	0.7 – 1.0	-	Compressive strength	Coconut Fiber – *Cocus nucifera*	Soares *et al.* (2008)
11	41 x 22 x 7	-	-	-	Caulim waste, Portland cement	Silva *et al.* (2017b)
12	26 x 13 X 8 24 x 12 x 6	1.54 – 2.54	-	Compressive strength, linear retraction	Starch and manioc	Veiga *et al.* (2008)
13	30.5 x 15 x 9.5	1.4-1.9	-	Compressive strength, water absorption, durability (climate action)	Coconut Fiber – *Cocus nucifera*	Ferreira *et al.* (2012)
14	-	1.12 – 2.67	30% clay, 28% silt, 30% sand, 12% rocks.	Compressive strength	Rice shell, Brachiaria and Plaster, Cow dung	Parisi*et al.* (2008)
15	25 x 12 x 10	1.07 – 1.19	-	Compressive strength, linear retraction and absorption, thermal and acoustic performance	Expanded polystyrene	Santos e Prado (2018)
16	30 x 15 x 8	0.67	40% clay, 45% silt, 15% sand	Compressive and tensile strength, specific gravity, contraction, capillarity and water absorption	Synthetic termite saliva	Corrêa *et al.* (2013)
17	30 x 15 x 8	-	23% clay, 27% siltand 50% sand	Specific gravity, linear retraction, water absorption, capillarity	Synthetic termite saliva	Corrêa *et al.* (2014a)
18	30 x 15 x 8	0.6-0.96	23% clay, 27% silt, 50% sand	Compressive and tensile strength	Bamboo particles - *Bambusavulgarisvittata*	Corrêa *et al.* (2014b)
19	-	2.0 – 6.1	13% clay, 27% siltand 60% sand	Compressive strength, water absorption, resistance to water and loss of mass	Alkaline activation	Félix *et al.* (2015)
20	30 x 15 x 8	0.67 – 0.79	40% clay, 45% silt e 15% sand	Compressive and tensile strength, linear retraction, water absorption, loss of mass, capillarity, specific gravity, hygroscopic humidity	Synthetictermite saliva, Bambooparticles - *Bambusavulgarisvittata*	Corrêa *et al.* (2015b)
21	25 x 15 x 10	0.43 – 0.56	-	Compressive strength and water absorption by imersion and capillarity	Palm juice – *Opuntiaficus indica*	Batista e Silva (2016);
22	-	2.0 – 6.0	13% clay, 27% siltand 60% sand	Compressive strength, water absorption, resistance to water and loss of mass	Alkaline activation	Félix *et al.* (2016b)
23	30 x 15 x 8	1.37 – 1.57	-	Compressive strength	ETA sludge	Gandia*et al.* (2018a)
24	30 x 15 x 10	0.57	-	Compressive strength	Cow dung	Vendrami*et al.* (2018)
25	30 x 15 x 10.8	0.67 – 1.55	18% clay, 20% silt, 41% sand and 21% rocks	Compressive strength, linear retraction, water absorption, specific gravity, hygroscopic humidity	CoconutFiber – *Cocus nucifera,* Palm juice – *Opuntiaficus indica and*Cow dung	Santos e Sousa (2018)
26	30 x 15 x 8	-	-	Bulk density	Synthetic termite saliva	Gandia*et al.* (2018b)
27	30 x 15 x 8	-	-	Bulk density, linear retraction, water absorption, loss of mass and capillarity	ETA sludge	Gandia*et al.* (2018d)
28	30 x 15 x 8	-	-	Bulk density	Glass fiber reinforced polymer (GFRP)	Gandia*et al.* (2018c)
29	-	6.3-21.7	17% clay and silt, 33% fine sand, 47% thick sand, 3% rocks	Compressive strength, water absorption, resistance to water and loss of mass	Alkaline activation	Félix *et al.* (2016c)

from water treatment plants.In another approach, Gandia*et al.* (2018d) also evaluated the influence of the same sludge incorporation in regards to physical properties of adobe, which was limited by the author by 3% due to density and water absorption increase, with the addition of incorporated sludge proportion, besides the addition not acting conclusively regarding linear retraction. Costa *et al.* (2014) analyzed the incorporation of mineral coal combustion ashes (MCCA), from thermoelectric power plants in adobes, obtaining up to 18.36% improvement in compressive strength, with addition of 5 and

10%, and higher durability with addition of 20% of MCCA, with a little reduction in compressive strength (2.71%) for this rate. Silva *et al.* (2017a) proposed incorporation of rubber fibers from crushed waste tires, although not presenting quantitative results. Silva *et al.* (2017b) evaluated the compressive strength of adobes with incorporation of waste from kaolin production industries in the northeast region of the country, however, addition of 10%, 20% and 30% reduced considerably the compressive strength of adobes, but, with addition of 30%, it was obtained an average value of 1.6 MPa, value over the minimum allowed by national norm for ceramic blocks for non load-bearing masonry.

Félix *et al.* (2016) proposed the incorporation of construction and demolition waste (CDW) made of masonry and porcelain tile wastes, but conclusive results of such analysis weren't found. Amongst the approaches regarding waste incorporation, it was noted that it's about specific questions about the availability of such waste in a determined region, therefore, due to heterogeneity and origin of these materials, it's necessary not only to evaluate physical and mechanical properties of adobe with those additions, but also the analysis of toxicity, once they may contain substances harmful to humans therefore making the use of the technique a harmful procedure.

Stabilization through chemical treatment consists in aggregating to adobe, several substances able to form stable compounds with elements present in the soil, especially with clay fraction (Faria, 2002). In this category, Veiga*et al.* (2008) identified a compressive strength increase in adobes with addition to 10% of manioc starch paste, with 8% of starch concentration, even though they used a soil with granulometry not appropriated for adobe production, based on literature; in the other hand, starch addition induced a higher index of retraction in adobes. Couto *et al.* (2010) evidenced a proportional increase to compressive strength of adobes according to the addition of mound of termite, reaching up to 2.85 MPa. Parisi*et al.* (2008) verified an increase of 71.3% in the values of compressive strengthof adobes with addition to 11% of plaster, however, accelerating considerably the hardening process of the mix. Félix *et al.,* (2015) proposed an adobe stabilization method through alkaline activation, using lab produced solutions, based on metacalcium, active silica, red ceramic waste, and sodium hydroxide. Adding 2% of metakaolin silicate, the best result of compressive strength was obtained with 3% of metakaolin silicate; additionally, less water absorption and volumetric integrity was obtained after the test. In the other hand, Félix *et al.* (2016a) concluded negative influence of the addition of fines to the soil to be stabilized by alkaline activation.

In kaolinitic soils, Félix *et al.* (2016b) proposed the addition of industrialized sodium silicate for alkaline activation of soils for adobe production, obtaining samples with absorption values inside those determined by NBR 8492:2012; also obtained low loss of mass and high water resistance; in every sample it was obtained values way over those recommended by NBR 8492:2012 for cement soil blocks with structural function. Silva *et al.* (2017b) fixed in 9% the incorporation of CP II-Z-32 cement in adobes, however, there were no adobes without incorporation, making impossible to conclude any individual influence in this addition; Parisi*et al.* (2008) produced adobes made with the addition of 6.5% of cement and with compressive strength 100% higher than standard adobes without cement. The addition of 33.33% of cow dung in adobes was proposed by Santos e Sousa (2018), which lead a reduction in water absorption and in the resistance to water, and 17.31% reduction of specific gravity in adobes, however, increasing 48.50% the retraction and reducing 56.77% thevalues of compressive strength, as opposedto Parisi*et al.*(2008) that identified an increasing in the compressive strength of adobes proportionally to the increase of cow dungaddition. Vendrami*et al.* (2018) proposed the utilization of equine excrement, but it wasn't presented any conclusions on this incorporation influence. Despite of the presence of fibers in the excrement, they usually have smaller dimensions and their origin is unknown - varying according to the animal's feeding – therefore being able to present different characteristics, resulting in different influences in adobes' properties (Santos e Sousa, 2018). Corrêa*et al.* (2013) and Corrêa*et al.* (2014a) investigated the behavior of "synthetic termite saliva", chemical stabilizer usually employed in soils and compressed earth blocks (CEB) compaction; authors concluded in the improvement of physical and mechanical properties of adobes with proportions of 1:500 and 1:1500, respectively. In another study, Corrêa*et al.* (2015a) registered the increase of up to 90% in the compressive strength of adobes with addition of "synthetic termite saliva". Corrêa*et al.* (2015a) identified the contribution of "synthetic termite saliva" in 60% on the compressive strengthof adobes, in a proportion of 1:500, also with the addition of sugar cane wastes.

Amongst analysis made by the authors, it's important to highlight the need to include some relevant evaluations, intrinsic to soils for adobe production, such as, the fertility index. According to Malavolta (1967), ideal soil pH for agriculture must be within 5 and 7. Cement additions in the soil makes the environment more alkaline. Batista (2006) evidenced the increase on pH of a soil sample from 7.0 to 10-11 with the addition of only 0.5% of cement, thus, the addition of any percentage of cement increase natural soil's pH value, which is acid, and it become proportionally more alkaline and by consequence, infertile, compromising or limiting its reuse or reinsertion in nature. Some factors like soil granulometry and type of predominant clay are also very relevant to adobe's well performance (Vale *et al.,* 2018), however, about 45% of the authors didn't present clearly the granulometry of utilized soil for adobe production. Amongst those who presented, most of them used sand-clay or sand-silt soil samples, as it is recommended in literature – Minke (2015) recommends an optimized granulometry distribution curve for adobes with 14% of clay, 22% of silt, 62% of sand and 2% of gravel. The influence of stabilizers additions on thermal properties of adobes is also a relevant matter, still poorly discussed by authors. Addition of fibers, for example, reduces adobes' electric conductivity, resulting in higher thermal inertia, by in the other hand, not altering its specific heat (Orui, 2014; Yetgin*et al.,* 2008).

Dimensions used by authors have some variability, being more common adobes with 30 cm of length, 15 cm of wide and height varying between 8 cm and 10.8 cm. However, Vendrami*et al.* (2018) registered that according to masonry norm named "Adobe – terminology, requisites, production, masonry execution and test methods", running in Technical Norms Brazilian Association (ABNT), for a height of 10 cm and vertical join of seating in the order of 1.5 cm, adobe's wideness must be of 20 cm and the length equivalent to 41.5

Table 2. Thermic properties in adobe walls

Nº	Characteristics of the wall	Thermic conductivity W/m.K	Thermic transmittance W/m².K	Adobe's thickness (cm)	Thermic delay (h)	Author
1	Adobe wallwithplaster	0.98	3.02	13	4.24	Faria e Neves (2013); Faria *et al.* (2014)
2	Adobe wall without fiber, without plaster	0.56	1.13-2.28	15-40	12-19	Orui (2014)
3	Adobe wall with fiber, without plaster	0.35	0.76-1.67	15-40	9-15	Orui (2014)
4	Adobe wall	0.42-0.67	2.5-3.7	10-27	-	Dal Soglio*et al.* (2018)
5	Adobe wall with addition of equine excrement	0.46-0.63	2.5-3.7	10-25	-	Dal Soglio*et al.* (2018)
6	Adobe wall with lime and earth covering (thick.: 2 cm)	0.8-1.0	2.39-2.59	15	-	Peixoto e Leite (2018)
7	Adobe wall with lime and earth covering (thick.: 3 cm)	0.8-1.0	2.24-2.41	15	-	Peixoto e Leite (2018)
8	Adobe wall without addition and without plaster	-	2.49	12	4.1	Santos e Prado (2018)
9	Adobe wall with EPS (0.1%-0.3%), without plaster	-	2.35	12	3.9	Santos e Prado (2018)

cm, which can make more common dimensions used by authors in the last decade wrong. Generally, stabilizers additions incorporation improved properties evaluated by authors. In other hand, in some cases, improvement of a certain property, due to incorporation of an addition, compromised other's performance. Therefore, it's highlighted the importance of proposing the right amount of each addition, in a way that it doesn't influence the performance of adobe's intrinsic properties without stabilization and/or the possible contribution of improvement of other incorporated addition associatively.

Technique analysis

When associated with environment satisfactory architectonic solutions, the building raise with earth building construction techniques may present a good thermal performance, depending on adopted walls' thickness (Peixoto e Leite, 2018; Faria e Neves, 2013). Notwithstanding, analysis about thermal properties of adobes based on national regulation of performance, presents itself as a wide interest factor amongst authors in this classification. Usually, it's common between authors the affirmation that earth building walls provide better thermal comfort when compared to other materials', however that advantage is directly connected to higher thickness adopted in earth walls and not only for the material intrinsic properties, conferring it more thermic inertia (Silva *et al.,* 2018; Faria e Neves, 2013; Orui, 2018; Peixoto e Leite, 2018). Dal Soglio*et al.* (2018) verified that adobe has high thermic capacity, being the requisite met in vertical seals, with, at least, 11 cm of thickness, but, in order to attend to every requisite of thermic performance in every Brazilian bioclimatic zone, it's recommended to apply internal and external coverings with 3 cm of thickness, for adobes with 15 cm wide (Peixoto e Leite, 2018). Amongst evaluated papers that focused on thermal properties of adobe, thermic conductivity of adobes without additions, when determined, was between 0.56 and 1.0 W/m.K. Confirming conclusions obtained by Yetgin*et al.* (2008), incorporation of fibers and excrement resulted in the reduction of this property, as stated in Orui (2014) and Dal Soglio*et al.* (2018). Thermic transmittance (U), for being proportional to thermic conductivity, presented the same behavior. Thermic delay of walls varies proportionally to adopted thickness and is directly connected to adobe's thermal performance, the higher its value, the better the thermic isolation of the wall. In this matter, Orui (2018) obtained adobes with thermic delay of up to 19 hours, adopting 40 cm thickness; in less thick walls, with 12 cm and no plaster, Santos e Prado (2018) obtained adobes with thermic delay of 4.1 hours – what according to NBR 15220:2005, is classified as a light seal. Therefore, it becomes relevant to highlight that, in most cases, superiority of adobe walls in terms of comfort, is also directly connected to the adopted walls' thickness, when compared to other conventional construction techniques (Faria*et al.,* 2014). In regards to the granulometric analysis of the soil for adobe production in different regions of the country, Corrêa*et al*. (2012) analyzed soils collected in the city of Lavras – MG for its granulometry and ideal humidity, validating the soil's potential for adobe construction in the region. Gonçalves (2018)validated, through field tests, the use of different soils in the city of Pouso Alegre – MG for the production of adobes without stabilization. In the other hand, when evaluating compressive strength of adobes which the fabrication soil possessed granulometric composition not matching those indicated in literature, Rezende *et al.* (2014) obtained an average of 1.99 MPa, value over the recommended by national regulation for concrete blocks for non load-bearing masonry. Vale *et al*. (2014) reported the same fact, once, when mechanic characterizing adobes produced by locals in the city of Vitoriano Veloso – MG, results presented average compressive strength of 2.05 MPa – acceptable value for seal masonry in national regulation – even as the soil used as raw material possessing granulometric proportions very controversial to those indicated in related literature. Therefore, it is highlyimportant to also evaluate the type of predominant clay and not only proportions of minerals presented in the soil, as proposed by Vale *et al.* (2018), when suggesting methylene blue test as a complementary tool for characterizing the soil for adobe producers, allowing the identification of the type of predominant clay. Other authors analyzed constructions in adobe through the architectonic perspective, evaluating physical and mechanical properties of adobes, constructive characteristics of residences and pathological anomalies. Alcântara *et al*. (2018), Moreira e Rezende (2018a,b) e Delmonaco*et al*. (2018) analyzed vernacular constructions in adobe in the city of Ibiapina – CE, Santana do Riacho – MG e Pedro II – PI, respectively, where it was identified pathological anomalies made mainly by bad execution, negligence and especially by the wrong use of materials associated with adobe, such as cement in walls' coverings, once this union presents low cohesion, provoking detachment of the plaster from the masonry, as well as the lack of maintenance in buildings, especially of the historical housing, which also infers to public politics neglecting heritage preservation.

Social Aim

Papers gathered in this classification focus on the use of adobe as a solution instrument for social demands, through Social Interest Habitations (SIH), built heritage preservation and/or educational methodology. Thus, it could be verified that initiatives proposed by authors in this approach foresaw its utilization as an instrument of community participation for the construction of habitations in every social substrate, as much for rescuing the traditional technique as for its insertion on this scenarios, from local raw material and workforce, converting this process in benefit for all of people involved, using it as a vector for waste encapsulation, giving them useful and last longing destination, allowing adobe, in some cases, to be considered as a social inclusion technology.Barreto e Ino (2010a) embraced project development processes about HIS in rural settling through variables that influenced the constructive process of three SIH in adobe, in the state of São Paulo, seeking improvements in constructive processes for SIH projects, promoting effective solutions for people in this context's needs. Variables which may influence in this aspect where then defined, such as project conditions, culture, physical-natural, constructive steps and interrelation. Research showed the importance of context influence in the determination of those variables' specificities, once each dweller determined the house's constructive process.

Still in São Paulo, Faria (2010) presented results of two research projects of training in adobe production and SIH construction in the same region; author registered that despite of the difficulties in the use of earth building construction techniques in São Paulo's acceptance, generated products were positive and promising for the deconstruction of this prejudice. Pereira *et al*. (2014) proposed, through bibliografic review, a project for adobe masonry for SIH in the state of Paraíba, obtaining ideal adobes for the region with 30.5 cm x 15 cm x 9.5 cm, seeking thermal comfort and construction easiness. Klein e Bueno (2012) registered the process of adobe production used in quilombola community's habitations in the state of Tocantins as a method of teaching math, aiming to show students the correlation between day to day traditional activities and math learning and other subjects taught during materials collection and adobe production, such as geography, biology, chemistry and physics. Joaquim e Lopes (2012) made a qualitative analysis from interviews with workers that participated in adobe production in construction sites in Piracaia – SP; authors highlighted a bad remuneration of the workers, based wrongfully on the premise that adobe is an alternative technique and, therefore, should be less expensive; furthermore, it was also shown the exhaustive physical effort of the workers, which don't have any technological aid to execute any of the construction steps. It's important to highlight that those problems may result in chasing away adobe use in determined situations, as for the contractor's view – when using the technique focusing in the economics – as for the contracted, that, in light of the above cited lack of stimulation, ends up surrendering to traditional techniques, usually more valued.

Pachamama (2018) tried to encourage a self-construction using earth building construction techniques – adobe and wattle and daub – in low income communities in the city of Belo Horizonte, MG, by means of a manual with accessible language and good constructive practices. Braga (2016) analyzed adobes and their relation with cultural landscape preservation in Santana do Riacho – MG, praising the importance of this heritage's preservation and the lingering of the technique amongst craftsman masters, perpetuating and improving its use between future generations. Vale e Rezende (2017) analyzed the adobe use in the district of Vitoriano Veloso – MG, as for transformations suffered by vernacular architecture since the foundation and associated socio-cultural impacts; authors identified a vernacular techniques' process of rescue in the region from the 1990s, not only influenced by tourism, but also with the arrival of handcrafts workshops in the city, which started to revalue the manual activities and esthetics for culture value and for local identity. Braga e Nascimento (2018) registered the knowledge and the understanding of the territory in a quilombola community in the state of Maranhão, though its citizens narrative and observation; authors identified the use of adobe's tradition of the community, focused on self-construction, from predominant local soil's collection, making photographic registration and interviews, and seeking data surveying in order to incentive a future extension project with the community. When evaluating construction sites with adobe in the state of São Paulo, Joaquim e Lopes (2018) registered human participation as workforce in heavy labor and bad remuneration in the region, what sounds like a paradox, once this kind of service doesn't require specialized knowledge, resulting in a lack of stimulation of workers to keep working with the technique. As for the sites, in general, have the same dynamic as conventional sites, with a very well separated work division and a little to none social mobility. These practices end up for making it difficult adobe's insertion in the construction market, especially in urban sites, where availability and supply of industrialized materials is abundant, as well as specialized workforce.

Survey

Papers gathered in this classification sought to make quantitative documentation in a determined urban context, focused on adobe-based constructions, involving both built heritage and contemporary constructions. Alexandria e Lopes (2008) surveyed adobe constructions in the city of Pedro II – PI, raised during state's colonization, identifying used techniques and constructive procedures; authors verified the presence of earth building architecture since the state's colonization, in the XVII century, through visited farm houses. In the same way, Carvalho *et al*. (2010) surveyedadobe constructions in north and northeast regions of Ceará state as a contribution for the traditional constructive system and also in the search for technical possibilities reevaluation to the typical house of Ceará's dry climate, authors concluded that the concept of an adobe habitation is already a concept accepted for many years and disseminated amongst the population, which empirically already understands concepts and properties related to the technique, such as thermic inertia. Figueiredo*et al.* (2011) surveyed and characterized dwellings built with earth building construction techniques, amongst those adobe, in the XVII and XIX centuries in São Luís – MA's historical center, however, authors identified adobe use only in rare cases of some structural walls. Carignani e Reis (2014) pointed out a historical survey made through bibliographic and iconographic review of traditional construction techniques in the city of Barra dos Burges – MT, aiming to keep adobe's preservation and rescue in local self-construction. In the same state, authors registered population interest's increase in participating and know about earth building architecture, demystifying unfunded prejudices, as well as highlighting the importance of registering and getting to know local historical and cultural heritage, seeking for popular awareness.Enoré (2018) surveyed houses made with adobe in the city of Várzea Grande – MT, and identified residences' blueprints, constructive methodology, utilized materials and preservation aspects; the author identified the need to create preservation politics due to increasing alteration in historical buildings. In the state of Bahia, Romero *et al.* (2015) surveyed adobe constructions, comparing the used construction method in the region with recommendations of Peruvian norm – NTE E.080:2000; authors identified that, construction techniques used by workers in the state of Bahia, mostly met the norm's recommendations, however highlighting the need for understating and applying the norm in order to reduce pathological manifestations in the buildings. Silva *et al.* (2018) surveyed the existence, distribution and models of earth building architecture production, amongst those, adobe, in the metropolitan region of São Paulo – SP; authors identified problems with occluded earth elements, due to the phenomena known as jacket with more recent techniques, however this paper aimed to act in the reversibility of the material and immaterial heritage's devaluation process, promoting its rescue, maintenance and study, for future and current generations. These papers result in a contribution for the use of adobe as a construction technique mapping in the country, allowing to identify the need for built heritage's preservation and perpetuation of traditional knowledge and cultural goods associated, as well as make possible the identification of architectonic typologies used in the country, as contribution for constructive aspectsand Brazilian vernacular architecture's understanding.

Technological innovation: In this category, authors proposed innovation through the investigation of test method's standardization, dimensional attributes and adobe production models. Neves e Faria (2008) presented the development of adobe compressive strength determination test's procedure, as a step of Interlaboratorial Program PROTERRA, through cubic test samples, as a method to be adopted during lab tests made by researchers, allowing to improve, standardize and compare knowledge over adobe's physical and mechanical characteristics. Faria*et al*. (2008) made tests of physical characterization of soils, with adobes originated with a mixture with soils from Bauru-SP and Americana-SP resulting in a soil with 29.5% of clay, 9.0% of silt and 61.5% of sand. Authors proposed that, with the adoption of the procedure for compressive strength in adobe test by several labs, a collection of data from different locations is obtained, allowing to improve knowledge about physical and mechanical characteristics of adobes. Therefore, the adoption of this method by the scientific and academic community is paramount for the evolution on adobe properties' knowledge, once, in the lack of a national standardized method, application of different analysis for the same variable makes unviable to direct compare the authors and, thus, the identification of improvement and gathering of more consistent, broad and assertive results. Pereira e Bezerra (2012) analyzed the variables of influence in the process of technological innovation in the city of Palmas – TO, identifying possible competitive advantages of adobe produced with aquatic macrophytes insertion in local construction, basing on possible motivations of the environment in which innovation promotion occurs. It was noticed the difficulty of inserting the technology in the lack of interlocution of the technological innovation process mobilization agents (authorities, public institutions, society and productive sector companies), especially in the coordination between actions of different spheres of the process, worsened by the lack of compromise of the constructors in knowledge improvement, to promote technological innovations not only with economic value, but also social. Joaquim e Lopes (2014) proposed the partial mechanization of adobe production with the use of machinery utilized in traditional construction, considering comfort and safety evaluation of workers and necessary investment value for these production means, they formulated a previous evaluation of which equipment may be incorporated in light of the difficulty to insert social advancements caused by financial costs. Riva e Ribeiro (2014) proposed a vegetated adobe model, ring shaped, as a technique of soil bioengineering for short slope's contention; authors concluded that proposed adobes had mechanical resistance and behavior coherent, thus, verifying the possibility of adobe utilization, in the conditions of the research, to contain short slopes. Barreto e Ino (2010b) presented proposals of interface between electrical installations and adobe walls, through different concepts of adopted adobes' shapes and dimensions. Adobes were molded and adapted with holes, considering installations vertically in the walls; authors concluded to be possible to develop a technical solution along with dwellers, using few resources to reduce and perfect interface execution stages and difficulties, resolving them in aneasier way.

Conclusions

Academic community interest – which is also based on popular expectation – for adobe study, among other earth building construction techniques, has increased considerably in Brazil in the last decades. The presented literature review allowed some conclusions over the theme, as follows:

- Events such as TerraBrasil and SIACOT, are presented as indispensable initiatives for the continuity of already published researches and also as an incentive for new publications on the theme.
- Stabilizer additions in adobe have been the focus of most of the publications of the last 10 years. Addition of synthetic and natural fibers present as allies for adobes' relative linear retraction decrease, reducing cracks and contributing for the improvement of thermic, acoustic and even mechanical resistance matters, as evidenced in some cases.
- Adobe's compressive strength is practically a solved problem, in most of the approaches. Expertise in the elaboration, especially based on technical manuals and also the right choice of soil, through field and lab tests, allow to obtain satisfactory results for these properties in most cases.
- Water absorption by adobes already have some solution proposed by authors, which allows to solve a big problem related to earth building construction: water. Therefore, when reaching satisfactory patterns of absorption, adobe then acts similarly to other techniques – ceramic brick and concrete block – especially with cow dung insertion, by the method of alkaline activation and also by adding "synthetic termite saliva" as recommended by respective authors. In the other hand, a gap is identified for new additions more effective and accessible in this

process, incentivizing adobe use in every social subtract on a larger scale.
- Proposals for technological innovation are mainly presented as a rescue lever for the production of large-scale adobe and also in consonance with other areas of knowledge, inserted in the construction field. These initiatives are relevant precisely for the upbringing of hybrid and functional initiatives, allowing adobe to insert itself in an active and long-lasting way in the architectonic landscape and contemporary technological scenario.
- Cataloging adobe buildingheritage is also an important tool to bring value to the technique nationwide, as much as in urban historical centers as in communities where adobe still acts as a construction technique.

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