Informes de la Construcción
Vol. 74, 568, e469
octubre-diciembre 2022
ISSN-L: 0020-0883
https://doi.org/10.3989/ic.89959

Analyzing user satisfaction regarding straw bales buildings: A survey study

Análisis de la perspectiva del usuario con respecto a los edificios con fardos de paja: Un estudio de encuesta

Bruno Barzellay Ferreira da Costa (*), Ana Luiza Diminic (**), Samir Jorge Guedes Sias Thompson (***), Assed Naked Haddad (****)

ABSTRACT

The present investigation aims to evaluate straw bales buildings users' satisfaction in terms of product performance. The proposed objective was achieved through a survey applied to a sample of 75 owners around the world. The results indicate that the straw bale technique was chosen by most participants due to the sustainability provided by the system. More than half of respondents said construction was more expensive than expected, but 84% of respondents consider maintenance costs low. External plaster was the constructive element that needed more maintenance over the years. Plumbing was the most outsourced specialized service during construction. All participants reported that they are satisfied with their buildings and 96% said they would use this method again.

Keywords: straw bale; user satisfaction; sustainable materials; online survey; construction system; sustainable buildings.

RESUMEN

La presente investigación tiene como objetivo evaluar la satisfacción de los usuarios de los edificios de fardos de paja en términos de rendimiento del producto. El objetivo propuesto se logró a través de una encuesta aplicada a una muestra de 75 propietarios en todo el mundo. Los resultados indican que la mayoría de los participantes eligieron la técnica del fardo de paja debido a la sostenibilidad que brinda el sistema. Más de la mitad de los entrevistados dijeron que la construcción fue más cara de lo esperado, pero 84% consideran que los costes de mantenimiento son bajos. El yeso exterior fue el elemento constructivo que más mantenimiento necesitó a lo largo de los años. La fontanería fue el servicio especializado más subcontratado durante la construcción. Todos los participantes informaron que están satisfechos con sus edificios y el 96% dijo que volverían a utilizar este método.

Palabras clave: fardos de paja; satisfacción del usuario; materiales sostenibles; encusta online; sistema constructivo; edificios sostenibles.

(*) D.Sc. Engineer. Associate Professor. Federal University of Rio de Janeiro, Macaé (Brazil).
(**) Civil Engineer. Federal University of Rio de Janeiro, Macaé (Brazil).
(***) Statistician. Federal University of Rio de Janeiro, Rio de Janeiro (Brazil).
(****) PhD. Engineer. Full Professor. Federal University of Rio de Janeiro, Rio de Janeiro (Brazil).
Persona de contacto/*Corresponding author*: bruno.barzellay@macae.ufrj.br (B.B.F. da Costa)
ORCID: http://orcid.org/0000-0003-0242-4205 (B.B.F. da Costa); http://orcid.org/0000-0002-2763-931X (A.L. Diminic); http://orcid.org/0000-0003-1280-4981 (S.J.G.S. Thompson); http://orcid.org/0000-0002-4793-0905 (A.N. Haddad)

Cómo citar este artículo/*Citation:* Barzellay Ferreira da Costa, Bruno; Luiza Diminic, Ana; Jorge Guedes Sias Thompson, Samir; Naked Haddad, Assed (2022). Analyzing user satisfaction regarding straw bales buildings: A survey study. *Informes de la Construcción,* 74(568): e469. https://doi.org/10.3989/ic.89959

Recibido/Received: 14/06/2021
Aceptado/Accepted: 09/04/2022
Publicado on-line/*Published on-line*: 10/11/2022

1. INTRODUCTION

The building materials and components industry traditionally faces serious difficulties in the innovation process. Several factors, such as, low investment capacity of small and medium-sized companies linked to the sector, lack of motivation regarding the patent registration process, and even human behavior itself, which by its nature is averse to changes (1), makes it difficult to implement any innovative process. However, development does not wait for the sector to adapt. Since ancient times, people have needed buildings to sustain their lifestyle (2), and continuous and accelerated population growth is constantly putting pressure on the construction industry to produce more and more (3). Currently, 55.714% of the world's population already inhabits urbanized areas, and countries like the United States, England, France, Japan, Brazil, Canada, Chile, Australia, and Denmark already have more than 80% of their population living in urban areas (4).

Therefore, given the rising demand for housing and the high costs of building materials, there is a need to develop alternatives, which have to consider not only technical and economic aspects but also those related to the environment, such as savings of water, energy, and generation of waste in manufacturing and installation; recyclable materials use; durability; use of raw materials reducing; product recyclability; among others (5). In this sense, the possible use of agricultural waste and other biological materials as construction materials has gained attention from researchers, builders, and customers (6). One material that meets with these requirements is straw bale (3), whose application is cheap, readily available, ensure high thermal comfort, and gives flexibility in terms of workability and strength, providing buildings with cleaner, sustainable and responsible production (7-10). In this context, this research seeks to demystify the idea that strawbale buildings, which for decades inhabited the subconscious of children around the world as a kind of fragile building due to the story of the Three Little Pigs, is actually a solid and trustable construction technique, with a high degree of acceptance from its users.

Considering that materials and construction systems are often developed and, for some reasons, are not embraced by consumers in general, this paper's objective is to evaluate strawbale buildings users' satisfaction in terms of product performance. Considering the limited number of studies available on the topic, it will be useful to highlight the advantages and disadvantages of the system, as well as identifying what has hampered this massive application around the world. The proposed objective was achieved through a survey developed and applied in the form of an online questionnaire. From a sample of 75 straw building users, their opinions were analyzed to identify the system's strengths and weaknesses.

Following this introduction, this paper is structured into four additional sections. Section 2 presents the conceptual background of the research based on a review of the available literature, which culminates in research question development. Section 3 describes details of the research methodology procedures, including sampling, data collection procedures, and research tools. Section 4 presents research findings and discusses study implications. Finally, Section 5 summarizes the study conclusions, as well as exposes work limitations and directions for further research.

2. THEORETICAL BACKGROUND

Straw is the dry steam that supports cereal grains like wheat, barley, oats, and rice, left after the seed heads have been removed (3, 11). In other words, it is an abundant natural agricultural waste material that has become a big headache for farmers, since it will not decay easily and, while the grains themselves have a high monetary value, straw does not (3, 11, 12). China and India, for example, the world's largest producers, have not yet figured out how to use this waste productively. As a result, a large amount of residual straw is burned after harvest (3, 10). Therefore, developing solutions for this product use is essential, since burning is a dangerous practice due to the high risk of fire and associated air pollution, which can cause damage to the environment and respiratory diseases in humans and animals exposed to the smoke (3, 11).

The use of straw as a building material began many years ago, initially applied alone as a roofing component and insulation material. Afterwards in the form of adobe, a piece formed by dried mud together with straw. This material in particular has gained prominence in different cultures, as it does not require any special treatment to be manufactured, and is still used today (13). It is estimated that around 30% of the world population lives in this type of structure, mainly in Africa (14). But it was in the late 19th century, with the invention of the bailing machine, that straw began to be compressed in dense packages to allow construction of support walls consisting only of this material (11, 12, 15, 16). Therefore, straw bale is a compressed bundle of straw and air assembled in a square, rectangular, or round shape, and attached with wire (11, 17).

There are two constructive systems concerning straw bale buildings. In the case of the non-supporting wall system, the bales have no structural responsibility. Thus, it is necessary the presence of structural elements that support and transmit the loads to the foundations. These elements can be made of wood, concrete or even metallic. It is a simple system as the bales only have a sealing function. After fixing the structure to the slab, the bales are fitted to the desired height. Smaller bales, with a final density between 80 and 120 kg/m^3 are common in this solution (18). In the load-bearing wall system, the bales are responsible not only for sealing but also for the stability of the building. In this case, wider bales are more common, with a height-to-thickness ratio equal to or less than 5:1, and final density between 180 and 200 kg/m^3 (18). The construction process itself is very similar to that of masonry, with the installation of alignment guides and alternating positioning of the bales between one layer and the layer above.

The earliest straw bale constructions were built in Nebraska, USA, taking as an example the Burke home, in Alliance, built in 1903 (3, 17, 19-21), and according to Pritchard and Pitts (12), "the development of strawbale building technology resulted from the colonization of North America by Europeans and the lack of availability of construction materials for building". However, the first European straw bales building was built only in 1921, by Émile Feuillette, in Montargis, France (17, 21), indicating that knowledge migrated from America to Europe. These buildings, still in use, were erected more than a century ago and demystify the image of fragility and instability that the mention of straw as a building material can evoke (19).

The construction sector has the potential to cause positive social and economic impacts, but it is also responsible for negative environmental impacts (15). Therefore, there is an incessant search for natural materials that have less embodied energy, such as straw and earth, thus contributing to urban sustainability (17), and according to Adedeji and co-workers (7) "one method of building energy-efficient structures is through straw bale construction". Since the material is obtained from renewable sources, it has greenhouse gas emissions close to zero, consumes little energy to maintain thermal stability, is biodegradable and the environmental impact during its use in construction can be considered low (15, 16, 19, 22). Below, some articles that obtained interesting results on the topic are highlighted. In this study, was chosen to include data as a percentage in most citations, since that way the reader can obtain a reasonable parameter regarding the performance of the straw bale.

Gharaibeh and co-workers (23) concluded that straw bale buildings have a potential to reduce energy consumption up to 25% due to their thermo-energetic characteristics. In a similar study, Wang and Zhang (24) stated that a brick-masonry building requires 60% more energy to be heated than a straw bales building, due to the exceptional insulating properties of the bales (11). Wall and co-workers (25) performed an acoustic test in a prototype house of straw bales, according to the ISO 140-3: 1995 standard. A noise of 100 dB was emitted from the outside and a noise drop of 44% was recorded, an excellent result compared to a 30% reduction estimated in a brick-masonry building. Gupta (11), stated that straw bales walls are lightweight, weighing only 35% that equivalent brick walls, and 38% that concrete block walls, allowing a considerable cost reduction in foundation elements. Yin and co-workers (26) concluded that prefabricated straw bale construction (PSBC) have a high degree of insulation and can reduce thermal loads on the building.

D'Alessandro and colleagues (27) performed a Life Cycle Assessment (LCA) analysis of a 1 m² straw bale wall and, among other results, concluded that straw behavior as an insulator reached satisfactory levels. Sabapathy and Gedupudi (28) measured the thermal transport properties of a straw bale sample for three different orientations in relation to the heat flow, and concluded that the thermal conductivity values obtained for "perpendicular and random orientation were approximately 1.7 times lower compared to the parallel case". In similar research, Platt (29) used computer tomography scanning to investigate the internal structure of straw bales, and found that the production of fiber-oriented bales can improve thermal resistance by 28%. This result is in agreement with the research by Costes and co-workers (30), which concludes that the bale density can modify the thermal transmission coefficient by up to 25%. Yin (31) monitored an experimental straw bale building for 12 months to demonstrate the potential degradation of this material in China's climate. Results demonstrated that straw bale walls are resistant to agents of decay and that existing evaluation methods may overestimate the potential for straw degradation. These are relevant data since straw durability has been a major concern in straw bale buildings (32). Gallegos-Ortega (33) developed a similar study, where the temperature of a straw bale building was monitored for sixty-six days in Mexico. The results showed that the indoor temperature was maintained practically constant, between 25ºC and 26ºC, while the external temperatures varied from 14ºC to 28ºC. Finally, Garas and colleagues (34) concluded that building a straw bale house can be up to 40% cheaper than using cement blocks.

Although the topic has aroused the interest of researchers and gained attention in the last decades after a period of abandonment (27), there is still scarce consistent data about straw bales properties (17), especially in the characterization of these constructions envelope, which includes the analysis of their thermal and acoustic performance, that is hindered "due to the wide variety of characteristics that this material itself presents" (35). According to Koh and Kraniotis (36), "an adequate technical dataset of straw bale and standardized procedures of construction are essential for further spread to wider audiences".

However, a theme to which researchers have devoted even less attention is the perception of end-users towards this constructive system. To the authors' knowledge, over the past 20 years, there is only one study that addresses the topic from this perspective. Ehrenzweig (37) analyzed which factors affected users' level of acceptance regarding straw bale buildings, and concluded that innovativeness and household income were the most significant elements. This shortage of studies indicates a large gap in this knowledge area and makes it difficult to map and assess the real diffusion of straw bales buildings around the world.

To overcome this problem, several associations have emerged over the past three decades intending to spread construction with straw. Among them, the National Straw Bale Research Advisory Network, the Fachverband Strohballenbau Deutschland (Germany Straw Bales Association), and the European Straw Building Association. These associations, however, aimed to analyze the topic only from a local or regional perspective, and this contributed to the creation of voluntary organizations, such as Sustainable Sources, which started to develop mechanisms for registration about straw bale buildings globally, and whose data will be used to carry out this work.

Thus, the research aims to analyze the perception of straw bales buildings users about the product and the experience they had during its construction and operation. To achieve this objective, it was necessary to answer the following research questions (RQ) using a survey study, as outlined in the next section.

RQ 1: What is the motivating factor for choosing to build with straw bales at the expense of the several existing building systems that are already technically and culturally consolidated?

RQ 2: Owners who choose to build with straw bales had specialized technical assistance?

RQ 3: Do straw bales have special maintenance needs throughout their life cycle?

RQ 4: Do the advantages of using straw bales as a constructive method outweigh the disadvantages, from the end user's point of view?

3. RESEARCH METHOD

This section presents the research methodology employed in this article and meticulously explains the procedures performed after a brief description of the approach used to answer the research questions. An overview of the steps taken in the study can be seen in Figure 1.

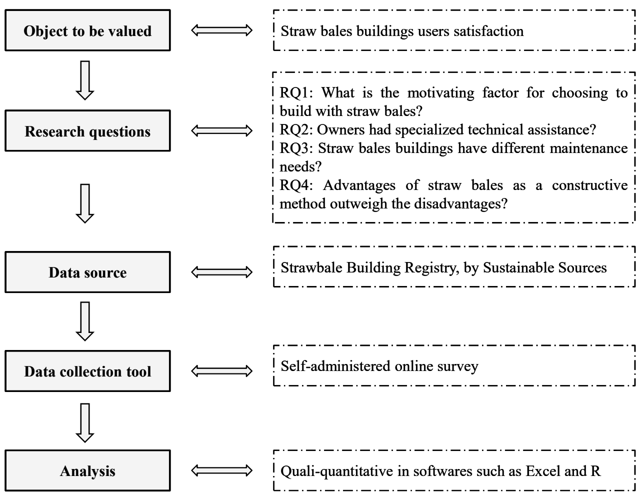

Figure 1. Research framework.

A qualitative-quantitative method was employed in the form of a self-administered online survey for a sample of straw bales building owners (Table 1). This data collection tool is frequently used in this area of knowledge (38) to request the opinion of a group of people on a specific subject and to report physical and social-psychological factors that may impact decision-makers. Since this study aims to collect information from users spread around the world, the application of an online questionnaire was considered suitable since it reduces costs (39, 40), and allows its distribution to a large number of participants across a wide geographical area (41).

Table 1. Survey datasheet.

Universe	Strawbale building owners
Scope	Buildings registered in the Strawbale Building Registry, managed by the voluntary organization called Sustainable Sources
Sampling strategy	Simple random sampling without replacement
Type of survey	Structured questionnaire conducted by email
Questionnaire language	English
Sample size	75 valid questionnaires
Fieldwork period	March and April 2019

A survey instrument was developed and applied to a sample of 75 straw bales building owners from March 13 to April 18, 2019. The 20-question questionnaire included both close-end classifying questions (yes/no) and others with open response fields and comprised three sections. Section 1 was developed to collect demographic information from respondents, such as age, building age and how did they become aware of straw buildings. Section 2 sought to identify the builders' experience with straw construction and its perceived advantages and disadvantages, as well as the difficulties found during the construction process. Finally, in Section 3, respondents were asked to assess the building's performance over the years, indicating their perception about maintenance, construction and operating cost, thermal and acoustic insulation, and their level of satisfaction with the building.

The sampling strategy employed was simple random sampling without replacement, where potential participants were contacted by e-mail and invited to participate in the survey. When conducting a survey, the chance of an individual from the population of interest accepting to answer the questionnaire follows a Bernoulli Distribution, where he can (success) or not (failure) participate in the study. The analysis of this sample leads to a sum of probabilities that result in a Binomial Distribution, Equation [1] and Equation [2]:

[1] $$P(X = x) = p(1 - p)^{n-1}$$

[2] $$\sum_{i=1}^{n} p(1 - p)^{n-1} = \binom{n}{x} p^{x}(1 - p)^{n-x}$$

Through the Central Limit Theorem technique, this Binomial Distribution can converge to a Standard Normal Distribution, helping to calculate the error and sample size that will provide the best representativeness of the population, Equation [3]. The objective is to obtain an approximation of the sample distribution concerning the Standard Normal Distribution, as this is the best way to represent the population. For this to occur consistently and efficiently, a sample greater than 30 is required (42). As the sample size increases, the variability decreases, reducing the sampling error and representing the population reality even better.

$$[3] \qquad P(|X| < x) = P\left(-\frac{\mu - E(X)}{\sqrt{\frac{Var(X)}{n}}} < Z < \frac{\mu - E(X)}{\sqrt{\frac{Var(X)}{n}}}\right)$$

The database used to identify these possible respondents was that of a voluntary organization, called Sustainable Sources, which developed a website for registration and consultation of existing straw buildings in the world, the Strawbale Building Registry. According to the latest update, on July 15, 2019, there are 1676 buildings around the world, spread across 51 countries (Figure 2). The United States leads the list with 786 registrations, followed by China, with 587. Unfortunately, as the record is entirely voluntary, it is believed that the numbers do not fully reflect reality and that they are underestimated (43). For this reason, it is estimated that there are at least ten times more existing structures than those registered.

In addition, despite the over a thousand registrations, they do not necessarily need to be available for consultation due to privacy concerns of the owners. When registering, it is necessary to determine which information will be accessible to the public and which will not, thus reduce the number of possible participants. Then, on March 13, 2019, as a result of the sampling strategies adopted, the survey instrument was directly emailed to 316 straw bales building owners. To improve the response rate, a reminder e-mail was sent two weeks later. The survey was closed on April 18, 2019. Respondents were also informed about the expected average time to complete the questionnaire, around 10–15 minutes. At the end of the collection period, 75 responses were obtained. The confidence interval used was 95%, allowing the calculation of the sampling error according to Equation [4]. In other words, as the sampling error is less than 10 percentage points in a 95% confidence interval, it can be guaranteed that the sampling results represent the population reality.

$$[4] \qquad e = z\alpha_{/2} \cdot \sqrt{\frac{N-n}{N-1}} \cdot \sqrt{\frac{p(1-p)}{n}} = 9.9$$

e = margin of error;
N = 316 (universe) ;
n = 75 (sample);
$z\alpha/2$ = 1,96 (value obtained from the Standard Normal Distribution table);
p = 0,5 (probability of answering the questionnaire);

At this moment, it is important to highlight some relevant aspects of the survey design. First of all, according to Brammer and Walker (41), considering that all participants are volunteers, they are probably more interested in the subject, which may not accurately reflect the opinion of all straw bales building owners. Lastly, only fully completed questionnaires were considered. Two incomplete questionnaires were excluded from the study due to a lack of data. With these exclusions, from the sample data set of 316, 75 were considered valid and usable, resulting in a final response rate of 23,7%. The countries' response rates varied widely and, although the United States' response was relatively low, corresponding to 22.7%, it represents 73.3 % of all responses obtained. The rest varied between countries in Europe, Australia, Japan, Israel, and Canada, according to Table 2. Although Meehan and Bryde (39) claim that response rates are often relatively low for online surveys, the effective rate obtained in this research is considered acceptable since it sought to qualitatively identify the perception of straw bale buildings users regarding their performance. However, according to the table below, the impossibility of individualized analyzes by country was verified, since the margin of error by stratum (country) does not reach a value below 10 percentage points in a 95% confidence interval or the universe do not have statistical relevance for the sample calculation.

The chosen language for the questionnaire elaboration was English, considered a universal language. In addition, the

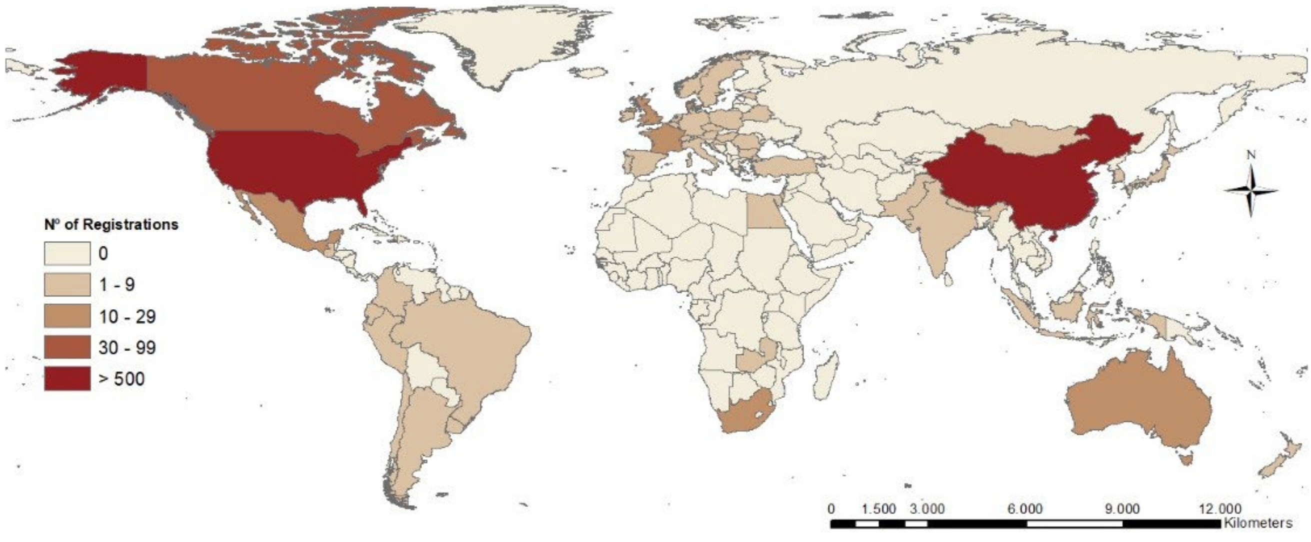

Figure 2. Registrations distribution worldwide.

Table 2. Geographic distribution of study participants.

Country	N	n	e	Country	N	n	e
Australia	8	6	21.4%	Japan	1	1	0.0%
Austria	1	1	0.0%	Mexico	3	0	-
Belgium	2	0	-	Nepal	1	0	-
Canada	32	6	36.6%	Netherlands	3	0	-
Chile	1	0	-	New Zealand	2	0	-
Denmark	4	1	98.8%	Norway	1	0	-
England	1	0	-	Portugal	1	1	0.0%
France	2	0	-	South Africa	1	0	-
Indonesia	1	0	-	Spain	1	0	-
Israel	2	1	98.0%	UK	3	3	0.0%
Ireland	2	0	-	USA	242	55	11.6%
Italy	1	0	0.0%	-	-	-	-
	Total				**316**	**75**	**9.9%**

Table 3. Respondents demographic information.

Age Group	Frequency	Response Rate
18-29 years	0	0%
30-39 years	1	1.7%
40-49 years	13	20.0%
Over 50 years	61	78.3%
Building Age	**Frequency**	**Response Rate**
Up to 5 years	2	2.7%
5-10 years	13	17.3%
10-20 years	46	61.3%
Over 20 years	14	18.7%

website itself from which the information was extracted is originally in English. All contact between the researchers and the respondents was carried out by e-mail, and two survey response methods were offered to each participant. The first option was through an editable PDF attached to the email, in which it was possible to fill in the responses and resend them as an attachment. The second option was through a link that redirected the addressees to a Google Form, from which answers were automatically saved for later consultation. The latter was the option chosen by 77,9% of the participants. The results obtained in the survey stage are presented in Section 4 of this paper.

4. RESULTS AND DISCUSSIONS

After receiving the completed questionnaires, data were treated in the software Microsoft Excel and R and analyzed as follows. The analysis of respondents' demographic information is relevant because it allows the identification of the temporal context in which the building was designed and built, whereas architecture and construction techniques tend to follow trends that constantly evolve. Age was measured by asking participants to choose their age group on a four options scale: 18–29 years old; 30-39 years old; 40-49 years old; and over 50 years old. The same strategy was used to identify the building ages, however, in this case, the options provided were: Up to 5 years; 5-10 years; 10-20 years; and over 20 years. According to Table 3, the majority of participants, 78.3% of the total, are 50 years old or more, and 61.3% of the buildings are between 10 and 20 years old. It can be concluded then that 80% of the buildings surveyed are relatively new since they were built in this century, while the owners were in the age group of 30 to 49 years old. This is valuable information, as it allows identifying the generation of individuals most interested in alternative construction methods, such as construction with straw bales. Furthermore, it illustrates a sharp downward trend in the dissemination of this knowledge.

Another question addressed by the questionnaire was how participants learned about straw bales construction. An open response field was made available, where the respondent was free to describe his first contact with this technique. All 75 responses were then classified and grouped by similarity into categories, whose main ones are shown in Figure 3. Internet and TV were the most effective means of communication, accounting for 38.7% of the total, closely followed by articles from books and magazines (32,0%). Word of mouth communication and workshops held 6 votes each (8,0%). Some participants also reported not remembering how they learned about the technique, others claimed to be builders, but three responses drew attention. A Washington/EUA respondent reported that he received a referral from a local architect who was specializing in straw buildings, which may indicate a local trend towards professionalization of the technique. Two other participants indicated that they had known the technique for years, as they grew up in Nebraska, demonstrating that it is strongly rooted in the region's culture, which is considered the cradle of this methodology.

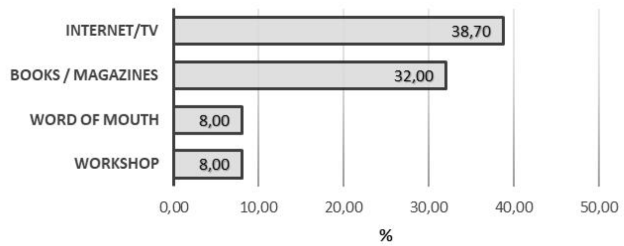

Figure 3. Respondents first contact with straw buildings.

The questionnaire also sought to identify the reason why participants chose to build with straw at the expense of other sustainable construction techniques, thus responding to RQ 1. Just like the question above, all responses were classified and grouped by similarity. Most participants (35%) indicated that the choice for this methodology was due to the sustainability provided by the system. This was followed by a technical feature already mentioned in this work, which is the high thermal and acoustic insulation capacity (26%). Third (15%) is the system's good energy efficiency, which is intrinsically related to its excellent insulating capacity. This gives an interesting and useful perspective to the work because it indicates an alignment of the end-user with the concepts of sustainable buildings. Lastly, participants indicated a desire to build with their own hands (7%), without the need for a formal qualification.

The next stage was the application of closed-end questions. The main purpose of this step was to collect, practically and objectively, more information on the builders' experience with straw construction, allowing responses to RQ 2. Five questions were formulated. The first addressed the type of labor used to carry out the work. Three alternatives were made available: through a builder; by the owners with volunteers' help; or by the owners without help. Results show that 45.3% of the constructions were carried out by the owners with volunteers' help, 36% were carried out by the owners themselves and only 18.7% hired a professional builder.

The other four questions were addressed to the sixty-one owners who directly evolved in the construction, that is, works that were carried out by the owner himself, with or without the help of volunteers. These were formulated with only two alternatives of response each (yes/no), and with that, it was possible to assess how much these owners were committed to learning and specializing in the subject before putting it into practice. The compilation of the answers to these questions is illustrated in Figure 4. Participants were invited to respond to the following questioning:

Question 1 - Did you have any previous construction experience?
Question 2 - Did you participate in any straw bales construction workshop?
Question 3 - Did you use any educational material for support during construction?
Question 4 - Has any activity or service been outsourced?

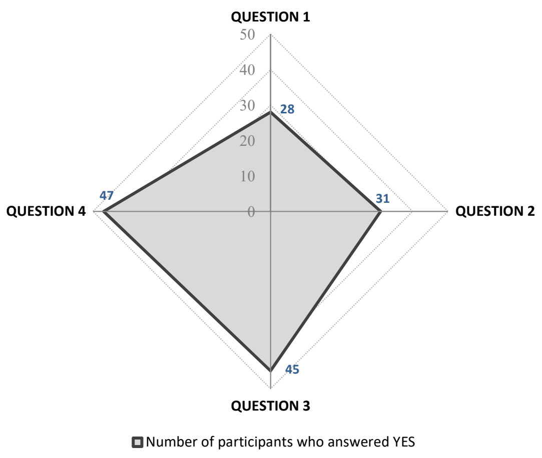

Figure 4. Assessing builder's experience with straw construction.

The responses analysis leads to some important conclusions. First of all, in Question 1, twenty-eight participants (45.9% of the sample) stated that they had some construction previous experience. That is, more than half of the surveyed population had never performed any service related to construction. The answers to Question 2 indicate that only thirty-one participants (50.8% of the sample) received formal training to build straw bale buildings through workshops. This result contrasts with the answers given to Question 3, which indicates that forty-five participants (73.8% of the sample) used technical bibliography to base themselves before starting construction, that is, they understand the importance of technical knowledge. This phenomenon may present two explanations. There is a shortage of courses on the topic or even a perception on the part of the end-user that it is a system that does not require formal qualification to be applied. However, despite having embraced the challenge of building with your own hands, forty seven respondents (77% of the sample) stated that have outsourced specialized labor for at least one specific service, such as electrical installation, plumbing, foundations, among others, according to the results of Question 4. Plumbing was the most sought service, followed by roofing and foundations.

Despite being straw a material generally found in abundance, in some places it may not be so easily available for purchase, directly impacting the viability of this construction method. In this study, among the seventy-five participants, only ten (13.5%) said they had difficulty accessing suppliers of this kind of material in their region, and sixty-five (86.5%) were satisfied with this raw material logistics of purchasing.

This work also sought to assess difficulties encountered by owners during the construction process, to identify which stages of the procedure should be improved. Among all seventy-five respondents, only twenty-six (34.7%) claimed to have encountered some adversity throughout the construction works. Of these, nine (34.6%) reported problems related to the climate, such as rain, humidity, and strong winds. Indeed, these are relevant issues, since straw bale can suffer severe deterioration and even rot if they are wet. Therefore, it must be continuously protected from rain and never left in direct contact with soil moisture until its effective installation. Another four (15.4%) participants mentioned problems related to finishing the walls, more specifically the difficulty in executing or finding a professional with the necessary skill to apply the mortar on the straw bale correctly. This is also a relevant problem since the uniform application of the mortar guarantees the desired thermal and acoustic insulation properties, which can be damaged if cracks appear on the surfaces.

Other mentioned difficulties are not specifically related to straw bale use, but complications that can occur in any construction work, such as inexperienced labor, poorly managed costs, design problems, and the interface to connect straw bales with other materials. Although issues related to inefficient cost management were one of the difficulties experienced by some of the study participants, only three declared that investing in this construction method was not advantageous. In other words, the financial satisfaction degree with the investment was 96%. This is a surprising result, as part of the owners stated that they could have spent less if they had chosen another construction system. In fact, more than half of the respondents (54.7%) stated that the use of straw bales resulted in a more expensive project. That is, despite being more expensive, almost all participants said they were satisfied with the method.

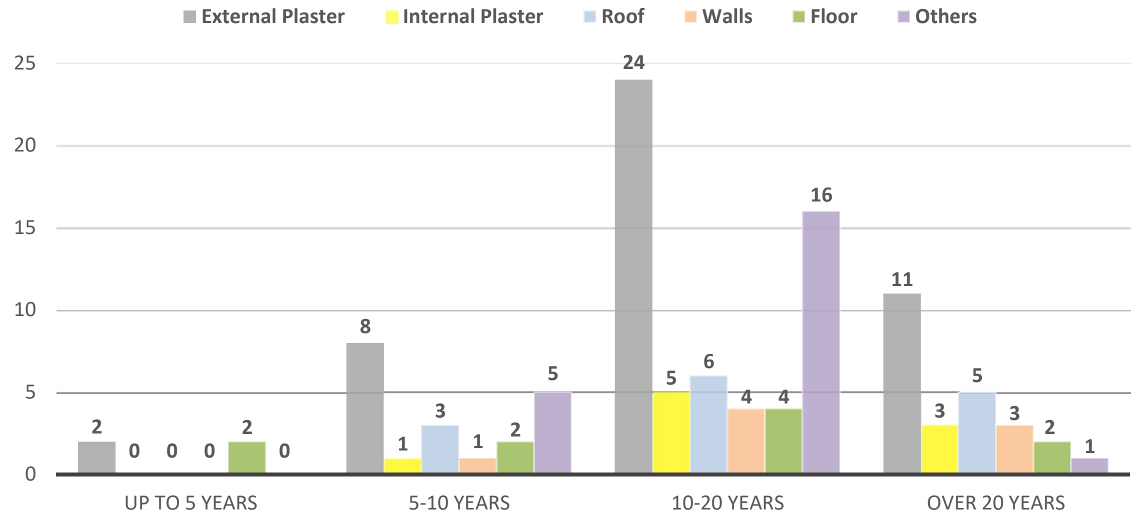

Figure 5. Pathologies identified during the operation period.

Considering the building life cycle concept, it is especially important to evaluate pathologies that arose during its operation period. Cracks in concrete and plaster, infiltrations in walls and roofs, were some of the problems mentioned by the fifteen owners (20% of the sample) who reported the appearance of pathologies in their buildings. Among them, 86.7% reported knowing the causal factors, such as rains, failures in the waterproofing service, poorly executed applications, and even earthquakes. Thus, based on the previous answers, six alternatives were provided for participants to point out in which region of the structure it was necessary to carry out some kind of maintenance, whether preventive or corrective, throughout the existence of the building: Internal plastering; External plastering; Roof; Wall structure; Floor structure; and Others. Each participant was free to select as many responses as he deemed necessary. Considering that buildings of different ages have different maintenance needs, Figure 5 relates the above constructive elements with the life span of the building.

Based on the graph above, it can be concluded that external plaster is the constructive element that needed more maintenance among the results of the studied sample, followed by roofing. It is noticeable that the end-user, in general, understands maintenance of the building systems as essential for their longevity, regardless of the construction method used, thus the relevant factor is the conservation cost impact for these owners. In this context, the survey reveals that 84% of participants consider maintenance costs to be low, which is an expressive positive result, allowing us to answer RQ 3.

Finally, participants were asked to indicate the greatest advantage of this construction method, as well as its greatest disadvantage. Figures 6 and 7 illustrate these consultation results, where it can be seen that the most cited advantage was the system's high insulating capacity. 98.7% of respondents stated that are satisfied with the thermal confort. In addition, 92% of the participants consider themselves satisfied with acoustic insulation. Among responses classified as

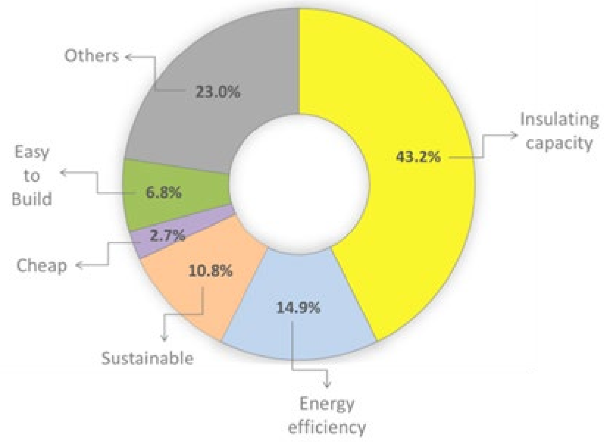

Figure 6. Straw bales construction method advantages.

"Others", are questions such as high durability and natural aesthetics.

Regarding the disadvantages observed, it is clear that there was no consensus compared to the mentioned advantages. Responses varied widely, from the lack of skilled labor to the vulnerability of the straw bales during the construction period, that is, before they were properly installed. The highest percentage of responses was concentrated in the "Others" option, where difficulties were reported in complying with local building codes, the considerable width of the walls, and the complexity in changing the layout after construction.

However, despite the mentioned disadvantages, 100% of the owners said they were satisfied with their buildings, and 96% said they would use this method again and/or recommend it to others. This has made it possible to answer RQ 4. So, it can be concluded, through the sample population degree of unanimous satisfaction, that straw bales use is a great option, at least according to this group of real users.

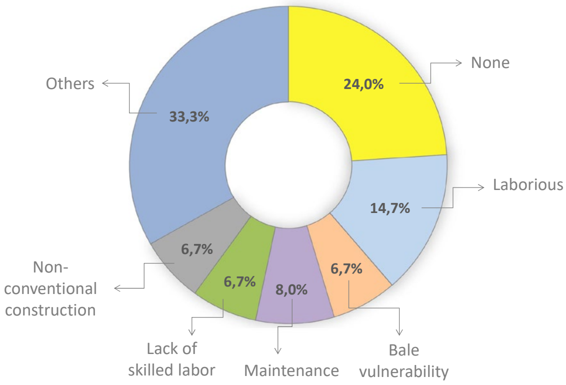

Figure 7. Straw bales construction method disadvantages.

5. CONCLUSIONS

Currently, there are several construction systems available in the construction market. However, there is a worldwide trend to search for increasingly sustainable construction methodologies, and a large number of scholars have dedicated themselves to the study of these systems. On the other hand, scientific production on the subject is still scarce.

The main results obtained indicate that 61.3% of the buildings are between 10 and 20 years old. That is, they are relatively new buildings. Internet and TV were the most effective means from which respondents learned about straw bales (38.7%). Closely followed by Books and Magazines (32.0%). Emphasizing the relevance of digital media in knowledge dissemination. A total of 35.0% of participants indicated that straw bale technique was chosen due to the sustainability provided by the system. Followed by its high thermal and acoustic insulation capacity (26.0%) and good energy efficiency (15.0%), which could demonstrate a paradigm shift for the construction sector, historically concerned only with the financial cost.

A portion of 45.3% of the constructions were carried out by the owners with volunteers' help; 36% were carried out by the owners themselves; and only 18.7% hired a professional builder. Among them, 45.9% of respondents stated that they had some construction previous experience; 50.8% received formal training through workshops; and 73.8% used technical bibliography to base themselves before starting construction. At least one specialized service was hired by 77% of the participants. Plumbing was the most voted. However, it should not be forgotten that the construction of a building is an activity of great responsibility and that it needs to be supervised by a legally qualified professional. Access to straw bale suppliers was not a problem for 86.5% of respondents. However, this may not reflect the reality in other regions.

Adversities during the construction were reported by 34.7% dos owners. The most voted were climate issues, which is normal, as straw bales are susceptible to bad weather before they are properly installed. Finishing the walls was the service indicated as the most complicated execution for 15.4% of participants, and external plaster was the constructive element that needed more maintenance over the years. This was an expected response, as the outer walls are the most exposed to the weather. 54.7% of participants stated that the construction was more expensive than expected, but 84.0% of them consider maintenance costs to be low. This was a surprising conclusion, since in the case of an organic element, a higher maintenance cost was expected. A total of 98.7% of respondents stated that are satisfied with the thermal confort provided by the building, and 92.0% consider themselves satisfied with acoustic insulation. There was no consensus on the disadvantages of the system. Finally, 100% of the owners said they were satisfied with their buildings, and 96.0% said they would use this method again and/or recommend it to others.

This research is subjected to some limitations that should be considered, and some may serve as a stimulus for future work. The research design provides a snapshot of the opinions of this specific group of volunteers. Thus, the results may or may not represent the entire population of straw bales users. The research findings are limited in terms of sample size since the database that was used does not provide a considerable amount of information about its records. A larger sample may be considered in future studies to overcome this problem. Finally, current research can be extended in several directions. Research related to building standards, maintenance costs, safety, comfort and habitability levels in accordance with local, regional and international codes should be improved. However, it is always interesting to highlight the importance of considering the end-user perspective, since the vast majority of studies address only the system technical characteristics. Therefore, it is relevant to carry out the study by stratum, that is, to concentrate the sampling to obtain inputs that are closer to the reality of each country. This can be an interesting approach to make buildings more sustainable, which meets the users' expectations, ensuring cleaner production and more responsible consumption in the housing sector.

REFERENCES

(1) De Bes, F.T.; Kotler, P. (2011). *Winning at innovation: The A-to-F model*. London: Palgrave Macmillan.
(2) Yilmaz, M.; Bakis, A. (2015). Sustainability in construction sector. *Procedia – Social and Behavorial Sciences*, 195: 2253-2262. https://doi.org/10.1016/j.sbspro.2015.06.312.
(3) Hall, M. (2019). Counting straw: the capacity of New Zealand's grain growing sector to supply straw for construction. In A. Agrawal and R. Gupta (Eds). *Revisiting the Role of Architecture for Surviving Development* (pp. 1-10), 53rd International Conference of the Architectural Science Association (ANZAScA).
(4) The World Bank (20 August 2019). *The United Nations Populations Division's World Urbanization Prospects - Indicators*. Retrieved from http://data.worldbank.org/indicator.

(5) Navacerrada, M.Á.; De la Prida, D.; Sesmero, A.; Pedrero, A.; Gómez, T.; Fernández-Morales, P. (2021). Comportamiento acústico y térmico de materiales basados en fibras naturales para la eficiencia energética em edificación. *Informes de la Construcción*, 73(561): e373. https://doi.org/10.3989/ic74558.
(6) Burroughs, S.; Ruzicka, J. (2019). The use of natural materials for construction projects – Social aspects of sustainable building: Case studies from Australia and Europe. *IOP Conference Series: Earth and Environment Science*, 290: 012009. https://doi.org/10.1088/1755-1315/290/1/012009.
(7) Adedeji, A.A.; Ibiyeye, A.; Adedeji, A.M. (2018). Effect of temperature on strawbale wall rendered with laterite and clay nanoparticle. *MATEC Web of Conferences*, 165: 22008. https://doi.org/10.1051/matecconf/201816522008.
(8) Adedeji, A.A.; Ibiyeye, A.; Adedeji, A.M. (2018). Hysteresis analysis of prestressed brick frame with strawbale masonry infill subjected to seismic loads. *MATEC Web of Conferences*, 165: 22009. https://doi.org/10.1051/matecconf/201816522009.
(9) Douzane, O.; Promis, G.; Roucoult, J.; Le, A.T.; Langlet, T. (2016). Hygrothermal perfomance of a straw bale building: In situ and laboratory investigations. *Journal of Building Engineering*, 8: 91-98. https://doi.org/10.1016/j.jobe.2016.10.002.
(10) Chaussinand, A.; Scartezzini, J.L.; Nik, V. (2015). Straw bale: A waste from agriculture, a new construction material for sustainable buildings. *Energy Procedia*, 78: 297-302. https://doi.org/10.1016/j.egypro.2015.11.646.
(11) Gupta, M.S. (2015). Straw bale construction: A revolutionary building material in low cost housing. *International Journal of Recent Advances in Multidisciplinary Research*, 2(7): 0583-0587.
(12) Pritchard, M.B.; Pitts, A. (2006). Evaluation of strawbale building: Benefits and risks. *Architectural Science Review*, 49(4): 372-384. https://doi.org/10.3763/asre.2006.4949.
(13) Vega, P.; Juan, A.; Guerra, M.I.; Morán, J.M.; Aguado, P.J.; Llamas, B. (2011). Mechanical characterisation of traditional adobes from the north of Spain. *Construction and Building Materials*, 25(7): 3020-3023. https://doi.org/10.1016/j.conbuildmat.2011.02.003.
(14) Parisi, F.; Asprone, D.; Fenu, L.; Prota, A. (2015). Experimental characterization of Italian composite adobe bricks reinforced with straw fibers. *Composite Structures*, 122: 300-307. https://doi.org/10.1016/j.compstruct.2014.11.060.
(15) Marques, B.; Tadeu, A.; Almeida, J.; António, J.; De Brito, J. (2020). Characterisation of sustainable building walls made from rice straw bales. *Journal of Building Engineering*, 28: 101041. https://doi.org/10.1016/j.jobe.2019.101041.
(16) Yin, X.; Dong, Q.; Lawrence, M.; Maskell, D.; Yu, J.; Sun, C. (2020). Research on prediction model for durability of straw bale walls in warm (humid) continental climate – A case study in Northeast China. *Materials*, 13: 3007. https://doi.org/10.3390/ma13133007.
(17) Cornaro, C.; Zanella, V.; Robazza, P.; Belloni, E.; Buratti, C. (2020). An innovative straw bale wall package for sustainable buildings: experimental characterisation, energy and environmental performance assessment. *Energy and Buildings*, 208: 109636. https://doi.org/10.1016/j.enbuild.2019.109636.
(18) Minke, G., Mahlke, F. (2005). *Manual de construcción con fardos de paja – Fundamentos – Construcciones - Ejemplos*. Montevideo: Editorial Fin del Siglo.
(19) Elias-Ozkan, S.T., Summers, F. (2013). Thermal performance of three different strawbale buildings at the Kerkenes Eco-center. *Journal of Green Building*, 8(4): 110-126. https://doi.org/10.3992/jgb.8.4.110.
(20) Cascone, S.; Evola, G.; Gagliano, A.; Sciuto, G.; Parisi, C.B. (2019). Laboratory and in-situ measurements for thermal and acoustic performance of straw bales. *Sustainability*, 11: 5592. https://doi.org/10.3390/su11205592.
(21) Mutani, G.; Azzolino, C.; Macrì, M.; Mancuso, S. (2020). Straw buildings: A good compromise between environmental sustainability and energy-economic savings. *Applied Sciences*, 10: 2858. https://doi.org/10.3390/app10082858.
(22) Chiras, D.D. (2000). *The natural house: A complete guide to healthy, energy efficient and environmental homes*. Vermont: Chelsea Green Publishing Co.
(23) Gharaibeh, N.G.; Valenzuela, B.; Machado, J.; Cook, S. (2009). Green approach for coping with the high cost of infrastructure services in U.S. colonies. *Journal of Infrastructure Systems*, 15(4): 417-424.
(24) Wang, J.; Zhang, X. (2005). Analysis on residential energy conservation for straw-bale building: Jianzhu Cailiao Xuebao. *Journal of Building Materials*, 8(1): 109-112.
(25) Wall, K.; Walker, P.; Gross, C.; White, C.; Mander, T. (2012). Development and testing of a prototype straw bale house. *Proceedings of the Institution of Civil Engineers - Construction Materials*, 165: 377-384. https://doi.org/10.1680/coma.11.00003.
(26) Yin, X.; Dong, Q.; Zhou, S.; Yu, J.; Huang, L.; Sun, C. (2020). Energy-saving potential of applying prefabricated straw bale construction (PSBC) in domestic buildings in northern China. *Sustainability*, 12: 3464. https://doi.org/10.3390/su12083464.
(27) D'Alessandro, F.; Bianchi, F.; Baldinelli, G.; Rotili, A.; Schiavoni, S. (2017). Straw bale constructions: Laboratory, in field and numerical assessment of energy and environmental performance. *Journal of Building Engineering*, 11: 56-68. https://doi.org/10.1016/j.jobe.2017.03.012.
(28) Sabapathy, K.A.; Gedupudi, S. (2019). Straw bale based constructions: Measurement of effective thermal transport properties. *Construction and Building Materials*, 198: 182-194. https://doi.org/10.1016/j.conbuildmat.2018.11.256.
(29) Platt, S.; Maskell, D.; Walker, P.; Laborel-Préneron, A. (2020). Manufacture and characterisation of prototype straw bale insulation products. *Construction and Building Materials*, 262: 120035. https://doi.org/10.1016/j.conbuildmat.2020.120035.
(30) Costes, J.; Evrard, A.; Biot, B.; Keutgen, G.; Daras, A.; Dubois, S.; Lebeau, F.; Courard, L. (2017). Thermal conductivity of straw bales: Full size measurements considering the direction of the heat flow. *Buildings,* 7(1): 11. https://doi.org/10.3390/buildings7010011.

(31) Yin, X.; Lawrence, M.; Maskell, D.; Chang, W. (2018). Construction and monitoring of experimental straw bale building in northeast China. *Construction and Building Materials*, 183: 46-57. https://doi.org/10.1016/j.conbuildmat.2018.05.283.
(32) Yin, X.; Lawrence, M.; Maskell, D.; Ansell, M. (2018). Comparative micro-structure and sorption isotherms of rice straw and wheat straw. *Energy and Buildings*, 173: 11-18. https://doi.org/10.1016/j.enbuild.2018.04.033.
(33) Gallegos-Ortega, R.; Magaña-Guzmán, T.; Reyes-Lópes, J.; Romero-Hernández, M.S. (2017). Thermal behavior of a straw bale building from data obtained in situ. A case in Northwestern México. *Building and Environment*, 124: 336-341. https://doi.org/10.1016/j.buildenv.2017.08.015.
(34) Garas, G.; Allam, M.; El Dessuky, R. (2009). Straw bale construction as an economic environmental building alternative – a case study. *Journal of Engineering and Applied Sciences*, 4 (9): 54-59.
(35) Cascone, S.; Rapisarda, R.; Cascone, D. (2019). Physical properties of straw bales as a construction material: A review. *Sustainability*, 11(12): 3388. https://doi.org/10.3390/su11123388.
(36) Koh, C. H., Kraniotis, D. (2020). A review of material properties and performance of straw bale as building material. *Construction and Building Materials*, 259: 120385. https://doi.org/10.1016/j.conbuildmat.2020.120385.
(37) Ehrenzweig, D. (1999). Consumers acceptance of straw-bale housing. *International Journal for Housing Science and Its Applications*, 23(1): 69-77.
(38) Ruparathna, R., Hewage, K. (2015). Sustainable procurement in the Canadian construction industry: current practices, drivers and opportunities. *Journal of Cleaner Production*, 109: 305-314. https://doi.org/10.1016/j.jclepro.2015.07.007.
(39) Meehan, J.; Bryde, D.J. (2014). Procuring sustainability in social housing: The role of social capital. *International Journal of Purchasing and Supply Management*, 20: 74-81. https://doi.org/10.1016/j.pursup.2014.01.002.
(40) Meehan, J.; Bryde, D.J. (2015). A field-level examination of the adoption of sustainable procurement in the social housing sector. *International Journal of Operations & Production Management*, 35: 982-1004. https://doi.org/10.1108/IJOPM-07-2014-0359.
(41) Brammer, S.; Walker, H. (2011). Sustainable procurement in the public sector: an international comparative study. *International Journal of Operations & Production Management*, 31: 452-476. https://doi.org/10.1108/01443571111119551.
(42) Bolfarine, H.; Bussab, W.O. (2005). *Sampling elements*, São Paulo: Blucher.
(43) Beaudry, K.; MacDougall, C. (2019). Structural performance of non-plastered modular straw bale wall panels under transverse and gravity loads. *Construction and Building Materials*, 216: 424-439. https://doi.org/10.1016/j.conbuildmat.2019.04.186.