International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 2
ISSN: 2088-5334

Addition of Sawdust and Polystyrene in the Elaboration of Adobe Blocks for Single-Family Homes and its Effect on Temperature Variation and Acoustic Conditioning in Ambato, Tungurahua

A. López [a,*], D. Chérrez [a], G. Núñez [a], J. Guevara [a]

[a] *Universidad Técnica de Ambato, Av. Los Chasquis y Río Payamino, Ambato, 180206, Ecuador*
*Corresponding author: *ds.cherrez@uta.edu.ec*

***Abstract*—This experiment evaluates the use of sawdust and expanded polystyrene (EPS) in the elaboration of adobe blocks as thermal and acoustic constructive elements with low environmental impact. To begin with, a soil selection and analysis process were carried out based on E-080 standard, then traditional adobe blocks with a percentage of 5%, 10% and 15% of sawdust and EPS were added in each mix. A suitable chamber was built to carry out the tests, based on specific standards, the chamber was divided into two rooms by a wall of the abode block with the addition of sawdust and expanded polystyrene using a 5mm layer of mortar to correct joint errors, this was considered appropriate for making temperature and sound measurements with the SPARK LXi Data logger (PS-3600A). Based on the Ecuadorian Construction Standard, comfortable reference values were determined for the measurements. After 28-day elaboration, the blocks were tested under compression. This test showed that all the analyzed samples exceeded the minimum resistance of 1MPa established in the E-080 standard. It was the highest compressive strength obtained in blocks with 5% of sawdust and EPS with a maximum resistance of 2.66 MPa. In addition, it was obtained that the wall made of 10% and 15% of adobe sawdust and EPS present the best performance to thermal variation and acoustic conditioning based on the standards NCh 352, NCh 851 - NCh 849 and NCh 2865.**

***Keywords*—Adobe; resistance; sawdust; polystyrene; thermal; acoustic.**

Manuscript received 20 Jul. 2021; revised 18 Nov. 2021; accepted 12 Dec. 2021. Date of publication 30 Apr. 2022.

I. INTRODUCTION

In the Andean area, traditional techniques and materials in construction are frequent. Adobe is a constructive technique that uses resources close to a population, used by the community for several centuries ago. It is estimated that land use as a building material dates back to approximately 5000 years BC in South America [1], [2]. Currently, 30% of the world population lives inland housing. In the case of underdeveloped countries, about 50% of the rural population and 20% of the urban population live inland housing [3].

Several investigations determine that adobe is a friendly material with the environment and that it can be used easily in construction, allowing sustainable proposals in the elaboration of blocks and similar, due to the reduction of the environmental impact produced by man in the carbon footprint by carrying large volumes of materials not typical of the area[4], [5].

In Ecuador, waste generation in 2014 was 4.18 million metric tons, according to the National Program for the Integral Management of Solid Waste. According to the Ministry of the Environment of Ecuador (MAE), the main solid wastes are organic, cardboard, paper, and plastic [6]. For this reason, it decided to include wastes such as sawdust and EPS in the elaboration of adobe blocks as additives to improve the characteristics of mechanical, thermal, and acoustic resistance for the use of single-family homes.

Expanded polystyrene has enormous potential to be recycled and reused in various areas because it can be found in large quantities. |It also has a low density and can easily be separated from other wastes. However, it has little demand for recycling due to its low cost, so we generate an ecological and innovative initiative by reusing it as an addition to the mixture of adobe blocks [7]-[9]. According to the Metropolitan The Public Company for Solid Waste Management of the Metropolitan District of Quito, in October 2013, it carried out the characterization of urban solid wastes, in which it determined the percentages of the average composition of solid wastes, which indicates that the waste of polystyrene has a percentage of 1.132% in the north station and 0.92% in the south station, likewise, the wood waste has 0.833% in the north and 0.877% in the south[10].

The development of new research on adobe at an international level has allowed the establishment of regulations in several countries such as the United States, Colombia, Spain, India, Nigeria, New Zealand, Peru, etc, to maintain a correct construction technique in the development of adobe blocks and buildings[11]-[13]. In addition, an attempt has been made to improve the operational characteristics of the adobe blocks by adding natural and/or industrialized raw material to the original mixture (clay, sand, and water) in order to give the blocks stronger resistance, durability, and characteristics that optimize construction to avoid their deterioration and reduce environmental impact [14]. This study aims to use mixing tests with stabilizers such as sawdust, plaster, or asphalt to elaborate adobes to increase their resistance to compression bending and improve their durability against humidity [15], [16].

Other studies have shown that the equilibrium in heat loss and gain of a material is by maintaining a normal temperature, that is, when the thermal equilibrium is reached, for which the EPS material is suitable to improve habitability conditions due to its suitable thermal and acoustic properties [16], [17]. On the other hand, the land is an element that thermal balances the humidity of the air and allows the storage of heat. In addition, it is a material with effective conductivity in the construction of houses[18].

The importance of studying the elaboration of adobe blocks will allow a sustainable architecture because mud is available in Ecuador and throughout the world, being able to be used without depleting resources, with the advantage that it can be recycled and recirculated. Adobe constructions improve thermal capacity by keeping cool air during the day and warm air at night [19], [20].

II. Material and Method

To carry out the project, a sample composed of several elements were used, among which the following stand out: a) Sawdust, organic material composed of cellulose fibers with small and fine particles smaller than 6 mm, obtained through mechanical processes of wood processing, with a composition of 50% carbon, 42% oxygen, 6% hydrogen and 2% nitrogen; b) Expanded Polystyrene (EPS), foam or cellular plastic material, derived from natural gas and oil, chemically contains 95% polystyrene and 5% gas, reducing the density of the material, it has acoustic, electrical and mechanical insulating properties; c) Land, a non-standardized construction material, its properties vary depending on the production site, but its composition may include different percentages of clay, silt, fine sand, coarse sand and organic matter in some cases[15], [21]-[24].

The methodological approach adopted in this study is the process of soil extraction, making blocks, field and laboratory tests to determine the resistance of the adobe block based on the Peruvian standard E-080 [25]. The plasticity index was carried out through the liquid limit tests, the plastic limit based on the INEN 691 and 692 standards, respectively [26], [27]. The granulometric test was determined for the characterization of the different types of sands and fines based on the INEN 696 standard [28].

III. Results and Discussion

In the first phase, the sample determined a percentage of sand of 70% and fine aggregates in a value of 30%. This consideration is based on the proposal of several research works that recommend the optimal percentages between sand, silt, and clay for the elaboration of adobe blocks. These approaches were tested with different compositions of adobe [24], [29]. Furthermore, for the elaboration of the adobe blocks, an additional percentage of 5%, 10%, and 15% of sawdust and EPS to each mixture was established concerning the weight of the blocks.

Based on the E-080 standard, the size of the adobe block is 40 cm long x 20 cm high x 10 cm wide. Figure 1 shows the preparation of the adobe block mixture. The soil was first screened to remove organic residues, stones, and others, to mix homogeneously with water in a maximum amount of 20% of the weight of the land, as shown in figure 1 (A). Secondly, it was left to rest for at least 48 hours to activate the greatest amount of clay particles before kneading. Finally, coarse sand was added, sawdust as identified in figure 1 (B) and EPS shown in figure 1 (C), according to the quantities of the sample to be tested [7]-[30]-[31].

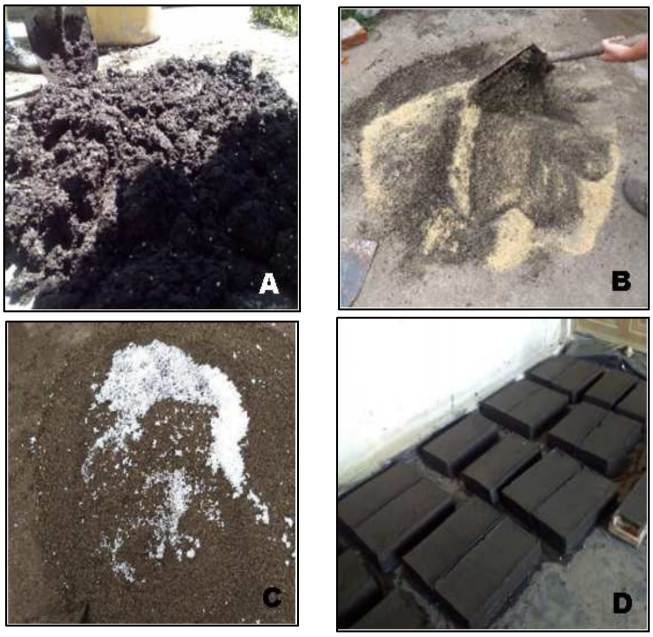

Fig. 1 (A)Sifted land, (B) Adding of sawdust, (C)Adding of EPS, (D) Adobe blocks molding

Figure 1 (D) shows the mixing, shaping, curing, and drying phases of the adobe blocks as recommended by the standard. The blocks were dried on flat surfaces covered from the sun and wind for 28 days [32], and several samples were obtained for the thermal and acoustic tests, in turn of resistance to compression, the samples and their detail are presented in Table I, being six blocks of each type for the compressive strength test and 18 blocks for thermal and acoustic tests.

TABLE I
SAMPLES DETAIL

Test	AS – EPS%	Sand	Fine Material	NS
Thermal and acoustic	+ 0%	70	30	18
	+ 5%	70	30	18
	+ 10%	70	30	18
	+ 15%	70	30	18
Compressive strength	+ 0%	70	30	6
	+ 5%	70	30	6
	+ 10%	70	30	6
	+ 15%	70	30	6

Figure 2 shows the compressive block resistance test. These values were compared based on the requirements of the maximum compressive strength of the E-080 standard, indicated in Table II, in which it can be determined that the maximum compressive strength corresponds to the pressure of 1 MPa (10.19kg/cm^2) [25]. Therefore, the compressive strengths obtained in the tests of traditional blocks and blocks with the addition percentages of sawdust and EPS show a higher resistance than that governed by the regulations [33]-[35].

Fig. 2 Compressive strength test of adobe block

A better result in compressive strength is obtained in adobe blocks with 5% sawdust and EPS, while blocks with the addition of 10% and 15% sawdust and EPS represent a decrease in resistance of 12.90 kg/cm^2 at 12.14 kg/cm^2, but higher than the established standard, information that can be seen in figure 3.

TABLE II
AVERAGE COMPRESSIVE STRENGTH

Composition	Average compressive strength (kg/cm2)
Traditional adobe blocks	11.18
Adobe blocks with 5% of sawdust and EPS	21.66
Adobe blocks with 10% of sawdust and EPS	12.90
Adobe blocks with 15% of sawdust and EPS	12.14

In the second phase of the investigation, the blocks that met the minimum compressive strength were evaluated thermally and acoustically. The thermal camera and acoustic evaluation were elaborated based on the standards NCh849, NCh851 and NCh853 [36]-[38]. The dimensions of the thermal chamber and the evaluation of the acoustic insulation are detailed, the measurements of the chamber in landscape view for the tests are detailed in figure 4 A and the measurements inside view are specified in figure 4 B.

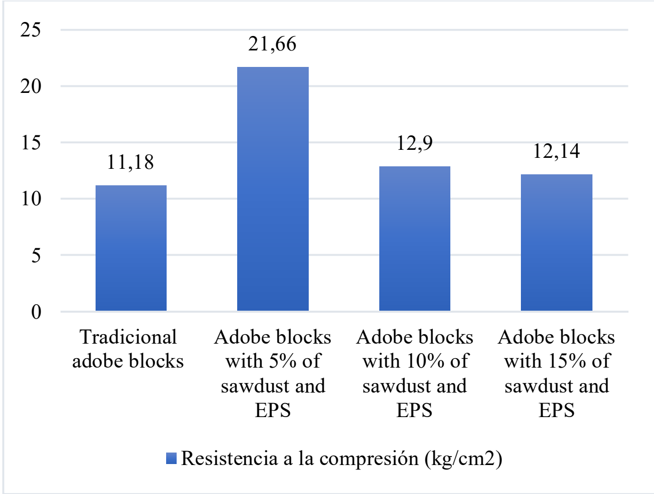

Fig. 3 Average compressive strength (kg/cm2) in blocks with different composition

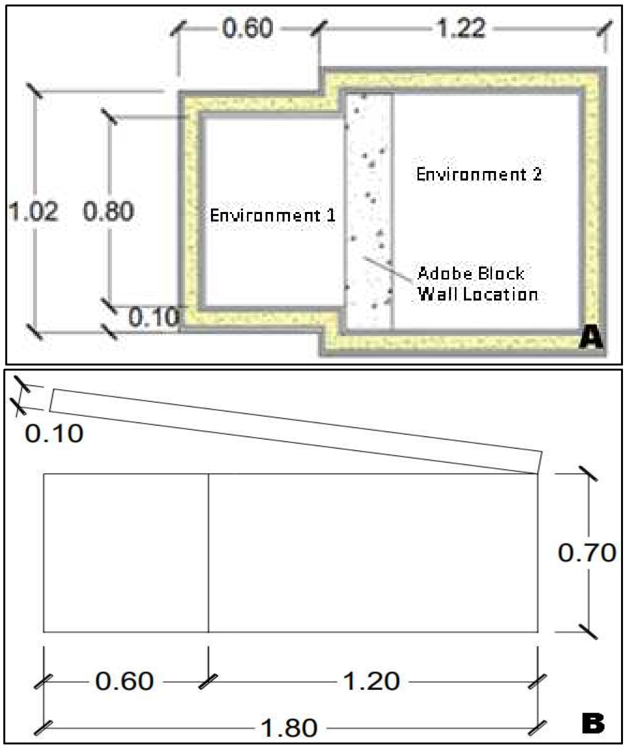

Fig. 4 Dimensions of the test chamber (A) Landscape view and (B) Side View

The thermal chamber was designed based on temperature and acoustic conditioning parameters, using fiberglass panels as insulating material in walls, and according to the specimen to be tested, the finished chamber is shown in figure 5 (A) [39]. An adobe wall was built as a specimen for the thermal and acoustic evaluations. According to the sample, such specimen was made with adobe blocks and joined with a mortar mixture. The detail is visualized in Figure 5 (B). The mortar was made with the same material as the adobe sample blocks, which was tested for crack control and coarse sand dosing; under the E-080 Standard, the mortar layer has a minimum thickness of 5 millimeters.

Fig. 5 (A) Acoustic and thermal test chamber, (B) Adobe block wall inside the test chamber

The SPARK LXi Data logger (PS-3600A) shown in figure 6 A and the temperature, sound, and lighting sensor (PS-2168) shown in Figure 6 B were used for the thermal test. Instantaneous data of temperatures obtained using a thermal source of electrical resistances of 600W was installed properly inside the chamber[40].

(A)
(B)

Fig. 6 (A) SPARK LXi Datalogger (PS-3600A) and (B) Temperature, sound and lightning sensor (PS-2168)

The location of the sensors for the thermal test is shown in Figure 7. Such location allows collecting data and contrasting them with reference values. The source of electrical resistance is located at the end of Environment 1, and through heat transfer, it is measured in Environment 2 [41], [42].

The maximum temperatures, thermal insulation, and the coefficient of thermal conductivity in walls are presented in Table III, which shows that λ is constant in adobe blocks with attachments and has a slight increase in blocks without attachments.

The maximum and minimum temperatures with thermal insulation in environments are presented in Table IV, where the maximum temperature variation is higher in adobe blocks with the addition of 5% and 10% of sawdust and EPS, while in the traditional block, its maximum temperature variation is lower.

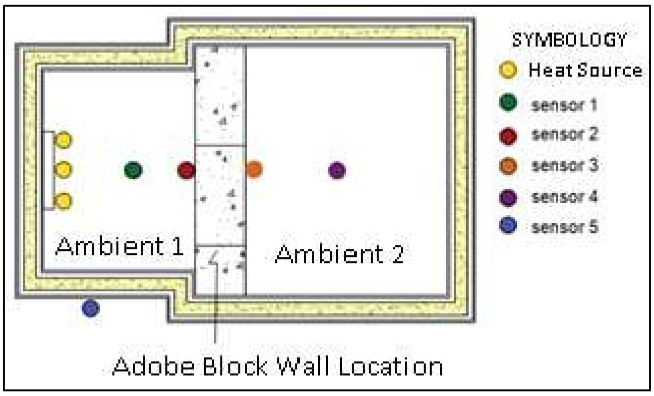

Fig. 7 Location of thermal sensors

TABLE III
MAXIMUM AND MINIMUM TEMPERATURES (°C), THERMAL INSULATION AND COEFFICIENT OF THERMAL CONDUCTIVITY IN WALLS

Block	°C	*Maximum*	*Minimum*	*Max Min*	*ΔT (máx.)*	*Λ (w/m.K)**
Adobe block	1	33.54	14.49	32.69	18.78	0.588
	2	14.75	14.66	1.62		
Adobe block with 5% of sawdust and EPS	1	42.52	14.59	36.21	28.11	0.569
	2	14.41	14.22	1.52		
Adobe block with 10% of sawdust and EPS	1	42.93	15	37.19	28.42	0.569
	2	14.52	14.35	0.97		
Adobe block with 15% of sawdust and EPS	1	44.26	16.48	35.53	29.06	0.568
	2	15.19	14.98	0.36		

In addition, environment 1, where the wall formed with adobe plus 10% sawdust and EPS was experienced, represented a temperature increase of 37.19 ° C, while in environment 2 an increase of 0.97 ° C was obtained. The thermal insulation produced between rooms with this type of wall is 35.30 ° C. Therefore, this block has the highest insulation in rooms, which is displayed in figure 8.

Figure 8 shows the level of thermal insulation in the walls tested and the insulation from environment 2. The adobe wall plus 15% sawdust and EPS being the one that represented a temperature increase value of 29.06 ° C on the face exposed to the source of heat or face 1, while on the back face or face 2. There was an increase of 0.17 ° C, the value of the thermal conductivity coefficient was 0.568 W/mK, being the block with the greatest thermal variation.

TABLE IV
MAXIMUM AND MINIMUM TEMPERATURES (°C), THERMAL INSULATION IN ENVIRONMENTS

Block	Temp Ambient °C	Maximum	Minimum	Mean	Δ Max. Temp.
Adobe Block	1	46.63	13.94	35.69	30.62
	2	16.02	14.39	15.79	
Adobe block with 5% of sawdust and EPS	1	51.04	14.82	38.97	35.22
	2	15.81	14.29	15.49	
Adobe block with 10% of sawdust and EPS	1	52.55	15.36	40.28	35.3
	2	17.25	16.28	16.95	
Adobe block with 15% of sawdust and EPS	1	50.95	15.43	38.69	33.7
	2	17.25	16.89	17.05	

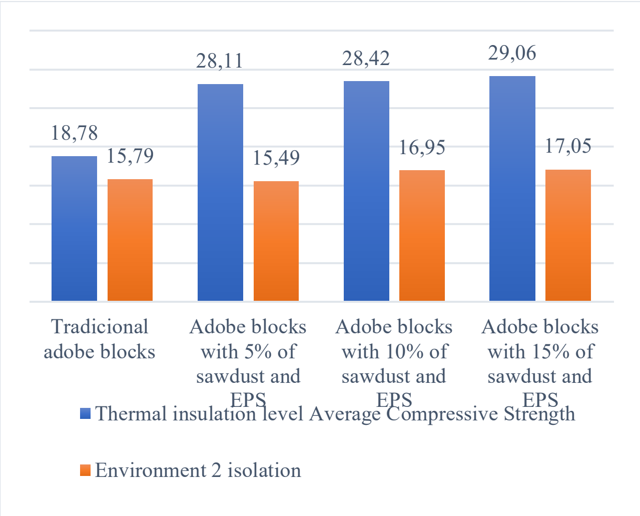

Fig. 8 Thermal insulation level in tested walls and Environment 2 isolation

In the Ecuadorian Construction Standard in the energy efficiency section NEC13, an ideal temperature range allows thermal comfort, which is in the range of 18 to 20 °C[43-45]. Therefore, when analyzing figure 3, the adobe wall plus 15% sawdust and EPS is closer to the said comfort range, and it can be verified that adobe blocks, in general, maintain high thermal insulation.

In the third phase, the acoustic test was carried out based on the NCh2786 standard, in which it specifies a laboratory test method of acoustic insulation for constructing floors, walls, facades, windows, as well as the NCh2864 standard, which specifies the infrastructure requirements for tests in the laboratory for acoustic insulation of building elements.

The location of sensors for the acoustic test is shown in Figure 9, the sound source located at the end of Room 1 and by means of the transmission of sound waves determines the absorption rate of the wall material.

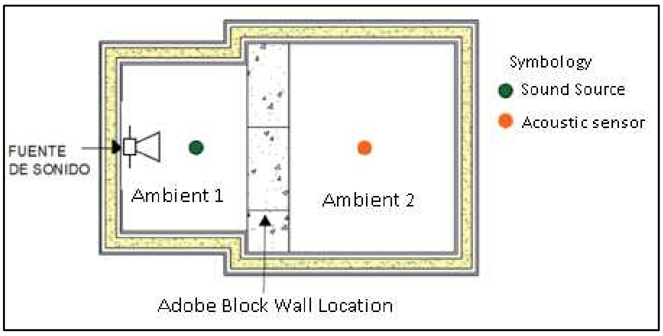

Fig. 9 Acoustic sensor location

Based on the data obtained by the sound level meter and the computer interpretation, comparative parameters were set in each wall tested with the additional material proposed in environments 1 and 2 of the test chamber. Table V shows the sound pressure levels in decibels and acoustic insulation in rooms 1 and 2, being the adobe walls with more than 10% and 15% of sawdust and EPS, the ones with the best insulation. The highest acoustic insulation corresponds to the adobe wall plus 15% sawdust and EPS, the minimum and maximum pressure supplied in room 1 was 82.70 dBA and 85.80 dBA, and in room 2 a minimum value of 38.20 dBA and 39.40 dBA was received as a maximum value.

TABLE V
MAXIMUM AND MINIMUM SOUND PRESSURE LEVELS (DBA), AND ACOUSTIC INSULATION

Block	**dBA**	***Max.***	***Min.***	***Mean***	***Insulation***
Adobe block	Emisor	85.00	82.00	83.65	37.33
	Receptor	48.00	45.10	46.32	
+ 5% of sawdust and EPS	Emisor	84.90	82.70	83.39	41.27
	Receptor	45.20	38.80	42.12	
+ 10% of sawdust and EPS	Emisor	84.40	82.00	83.39	44.85
	Receptor	39.10	38.00	38.55	
+ 15% of sawdust and EPS	Emisor	85.80	82.70	84.22	45.31
	Receptor	39.40	38.20	38.91	

Figure 10 shows an analysis regarding acoustic comfort based on the sound pressure in environment 2 of each wall tested. The ideal sound pressure range based on the NEC13 Standard indicates a maximum sound level for homes, studios, bedrooms, libraries, hotels, living places of 50 dBA, and for school classrooms, a value of 55 dBA. Therefore, the values obtained in all the tests are less than the norm's value. Therefore, while the percentage of sawdust and EPS is greater, the acoustic comfort improves, being the adobe blocks with 10% and 15% of sawdust and EPS with the lowest dBA [46]-[48].

Likewise, the NCh-352 standard allows defining a minimum acoustic insulation range in residential buildings with a minimum insulation value of 40 dBA [49]-[50]. Therefore, the values obtained in the walls with the addition of sawdust and EPS are higher than the proposed minimum requirement, although, the more percentage of addition to the adobe block, its level of isolation increases, with the wall with greater isolation being the more adobe 15% sawdust and EPS with 45.31dBA insulation.

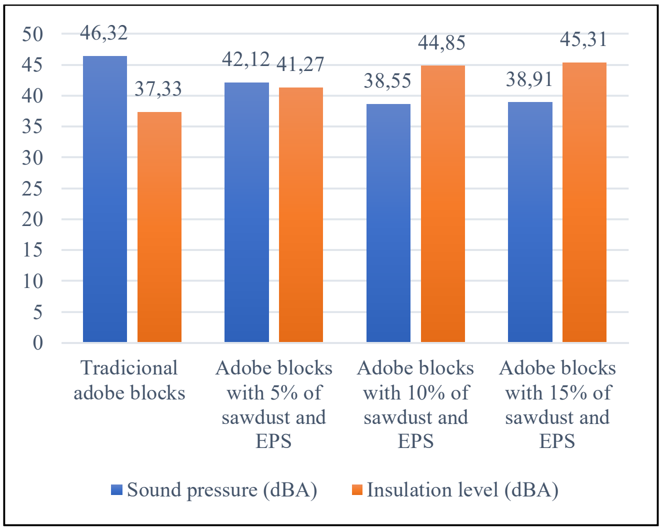

Fig. 10 Sound insulation level

IV. Conclusion

The addition of sawdust and EPS to a traditional adobe block, by 15%, improves its resistance to compression about the E-080 standard with 12.14 kg / cm2, it allows a thermal comfort close to what the NEC13 standard indicates at its minimum value of 18 ° C, and a sound insulation level higher than the NCh-352 standard with a value higher than the recommended value of 5.31 dBA. Therefore, the results of this study indicate that traditional adobe is improved by adding 15% of residues to the adobe composition. This research aims to motivate the implementation of recycled materials such as sawdust and polystyrene in single-family homes with sustainability concepts and energy savings since the resistance to compression of each block exceeds the regulations. Likewise, it maintains good insulation thermal and acoustic comfort.

Acknowledgment

The authors thank the Universidad Técnica de Ambato, and Dirección de Investigación y Desarrollo, for the management in the execution of the Research Project “Cálculo y diseño de vivienda sismo resistente de interés social, auto sustentable con materiales de la zona sierra”, with Resolution 1540-CU-P-2018 and code PFICM18.

References

[1] M. N. Azhar and L. A. Qureshi, "Experimental Study of Structural Behaviour of Chinese Bond Brick Masonry: A New Trend of Durable & Economical Construction in Pakistan," *Journal of King Saud University-Engineering Sciences,* 2020.

[2] A. Gutiérrez, G. Quispe, A. Mendoza, H. Betancur, E. Ramos, "Confort térmico y el riesgo de infecciones respiratorias en los adultos mayores en la sierra rural del Perú," *Revista Española de Geriatría y Gerontología*, pp. 24-28, 2021.

[3] M. Nurain, S. Adnan, S. Shahidan, A. Shah, "Strength and water absorption properties of light weightconcrete brick", *IOP Conf. Ser. Mater. Sci. Eng.* 513 (1) (2019), http://dx.doi.org/10.1088/1757-899X/513/1/012005.

[4] R. S. Argento, J. Ferreyra, A. M. Anderson, M. F. Carrasco, A. González, and R. M. Grether, "Residuos de desmote de algodón aglomerados: su producción y aplicación en la construcción de viviendas," *Ambiente Construído,* vol. 19, pp. 127-145, 2019.

[5] V. Angulo Zavaleta (2020), "Materiales alternativos sostenibles empleados en la construcción: una revisión a la literatura científica," Available: https://repositorio.upn.edu.pe/handle/11537/23755.

[6] A. Michaelowa, A. Galante, L. Lo Re, V. Villa, C. Illueca, P. Gómez, *et al.*, "Concepto de implementación del mecanismo sectorial de mitigación en el sector de los residuos en Ecuador. (Documento principal)," ed: CAF, 2019.

[7] K. Raju and S. Ravindhar, "Multiple categories of bricks used for construction–A Review," in *IOP Conference Series: Materials Science and Engineering*, 2020, p. 012122.

[8] A. Mohajerani, M. Ashdown, L. Abdihashi, and M. Nazem, "Expanded polystyrene geofoam in pavement construction," *Construction and Building Materials,* vol. 157, pp. 438-448, 2017.

[9] S. Siswosukarto, A. Saputra, and I. G. Y. Kafrain, "Utilization of polystyrene waste for wall panel to produce green construction materials," *Procedia engineering,* vol. 171, pp. 664-671, 2017.

[10] T. Bowen, "A Best Practices Manual for Using Compressed Earth Blocks in Sustainable, Home Construction in Indian Country", *University of Colorado Boulder,* (2017), pp. 45

[11] C. Fioriti, R. Segantini, J. Pinheiro, J. Akasaki, and F. Spósito, "Bloques de mampostería de hormigón liviano fabricados con caucho de neumáticos y metacaolín," *Revista ingeniería de construcción,* vol. 35, pp. 295-307, 2020.

[12] C. Ponce-Palafox, J. Carrillo, and A. López-Montelongo, "Fabricación de ladrillos con polvo-residuo de mármol en México Propiedades físicas y mecánicas del polvo-residuo de mármol de la provincia de la Comarca Lagunera, en México," *Revista de Arquitectura (Bogotá),* vol. 22, pp. 106-113, 2020.

[13] M. Premkumar, G. Devi, R. Sowmya, " Design and Implementation of Brick Making Machine Integrated with Smart IIoT Application," *International Journal of Computing and Digital Systems,* vol. 9, 2020.

[14] S. Marathe, I. Mithanthaya, and S. Shetty, "Strength behaviour of masonry blocks produced using green concrete," in *Sustainable Construction and Building Materials*, ed: Springer, 2019, pp. 33-40.

[15] J. Canivell, J. Martin-del-Rio, F. Alejandre, J. García, A. Jimenez, "Considerations on the physical and mechanical properties of lime-stabilized rammed earth walls and their evaluation by ultrasonic pulse velocity testing". *Const. Build. Mater.*, 2018, pp. 826-836.

[16] R. Abid, N. Kamoun, F. Jamoussi, and H. El Feki, "Fabrication and properties of compressed earth brick from local Tunisian raw materials," *Boletín de la Sociedad Española de Cerámica y Vidrio,* 2021.

[17] M. Madrid, A. Orbe, H. Carré, and Y. García, "Thermal performance of sawdust and lime-mud concrete masonry units," *Construction and Building Materials,* vol. 169, pp. 113-123, 2018.

[18] J. Véliz-Párraga and D. González-Couret, "Vivienda de interés social en Portoviejo. Ambiente térmico interior," *AUS [Arquitectura/Urbanismo/Sustentabilidad],* pp. 35-41, 2019.

[19] C.Lima, F. Ribeiro, G. Isaia, M. Mancio, "Concretes with binary mixtures of artificial pozzolans and concrete demolition waste," *Ambiente Construído, vol. 20, pp. 177-188*, 2020.

[20] J. R. Lopez Huaman, "Medidas de atenuación de señal 3G y 4G en estructuras construidas por adobe (measurements of 3G and 4G signal attenuation in adobe buildings structures)," 2020.

[21] V. B. Benites Zapata, "Adobe estabilizado con extracto de cabuya (Furcraea andina)," 2017.

[22] V. A. Chicaiza Llumipanta, "Análisis comparativo de la resistencia a compresión entre bloques tradicionales y bloques elaborados con poliestireno expandido granular y bloques elaborados con tusa de maíz triturado como sustituto parcial del agregado grueso," Universidad Técnica de Ambato. Facultad de Ingeniería Civil y Mecánica, 2017.

[23] J. H. Lazaro Reynoso, J. L. Villalta Preciado, C. E. Colonio Reyes, D. E. Fernandez Quispe, and T. N. Llanos Sanchez, "Casas estructuradas con centro de poliestireno expandido," 2017.

[24] F. Wang, N. Kyriakides, C. Chrysostomou, E. Eleftheriou, R. Votsis, and R. Illampas, "Experimental research on bond behaviour of fabric reinforced cementitious matrix composites for retrofitting masonry walls," *International Journal of Concrete Structures and Materials,* vol. 15, pp. 1-17, 2021.

[25] D. El Peruano, "Ministerio de Vivienda, Construcción y Saneamiento," *Norma E. 080-RNE. Diseño y construcción con tierra reforzada*.

[26] N. INEN, "“NTE INEN 692: Determinación del límite plástico.,” vol. 0818, pp. 1–10, 1982.," 1982.

[27] N. INEN, "“NTE INEN 696: Áridos. Analisis granulométricos en los áridos, fino y grueso.,” Inst. Ecuatoriano Norm., vol. 0696, pp. 1–12, 2011.," 2011.

[28] D. Y. Hernández Endara, "Determinación de las características físicas y mecánicas del suelo para implantación de edificaciones de categoría baja en la ciudadela 24 de Mayo, ciudad Jipijapa," JIPIJAPA-UNESUM, 2018.

[29] A. D. Ortega and H. Gil, "Estudio del comportamiento mecánico de morteros modificados con fibras de aserrín bajo esfuerzos de compresión," *Revista Científica Ingeniería y Desarrollo,* vol. 37, pp. 20-35, 2019.

[30] B. Zviagina, V. Drits, O. Dorzhieva, "Distinguishing features and identification criteria for K-dioctahedral 1M Micas (illite-aluminoceladonite and illite-glauconite-celadonite series) from middle-infrared spectroscopy data," *Minerals*, vol. 10, p. 153, 10.3390/min10020153, 2020.

[31] C. Costa, D. Arduin, F. Rocha, and A. Velosa, "Adobe blocks in the center of Portugal: Main characteristics," *International Journal of Architectural Heritage,* vol. 15, pp. 467-478, 2021.

[32] Y. Qin, Y. He, J. E. Hiller, and G. Mei, "A new water-retaining paver block for reducing runoff and cooling pavement," *Journal of Cleaner Production,* vol. 199, pp. 948-956, 2018.

[33] C. Babé, D. K. Kidmo, A. Tom, R. R. N. Mvondo, R. B. E. Boum, and N. Djongyang, "Thermomechanical characterization and durability of adobes reinforced with millet waste fibers (sorghum bicolor)," *Case Studies in Construction Materials,* vol. 13, p. e00422, 2020.

[34] S. P. Cabrera, Y. G. Aranda-Jiménez, E. J. Suárez-Domínguez, and R. Rotondaro, "Bloques de Tierra Comprimida (BTC) estabilizados con cal y cemento. Evaluación de su impacto ambiental y su resistencia a compresión," *Revista hábitat sustentable,* vol. 10, pp. 70-81, 2020.

[35] R. Suda, T. Kiefer, C. Schranz, and J. Füssl, "A finite-element-based approach to quantify the impact of bed joint reinforcement on the compressive strength of vertically perforated clay block masonry," *Engineering Structures,* vol. 239, p. 112277, 2021.

[36] E. A. Paguay Córdova, "La adición de botellas plásticas PET en la elaboración de bloques alivianados para viviendas unifamiliares y su efecto en la variación de temperatura y acondicionamiento acústico en el cantón Ambato, provincia de Tungurahua," Universidad Técnica de Ambato. Facultad de Ingeniería Civil y Mecánica, 2019.

[37] S. R. Cabay Cepeda, "La adición de bolsas plásticas en la elaboración de bloques de adobe para viviendas unifamiliares y su efecto en la variación de temperatura y acondicionamiento acústico en el cantón Ambato, provincia de Tungurahua," Universidad Técnica de Ambato. Facultad de Ingeniería Civil y Mecánica, 2019.

[38] C. N. Orcaistegui Venegas, "Evaluación técnica y económica de aplicar medidas de reacondicionamiento en viviendas existentes," 2018.

[39] A. Ullauri, N. Friend, and J. Barzola, "Análisis físico-mecánico de morteros asfálticos compuestos a partir de materiales reciclados," *Revista Universidad y Sociedad,* vol. 10, pp. 245-254, 2018.

[40] A. Marquínes, E. Tejeira, E. Aulestia, M. Lezcano, S. Franco, J. Peren, "Evaluación del nivel de iluminación natural en una oficina del edificio 3835 del International Business Park,". *SusBCity, vol. 2(1), pp. 1-8,* 2020.

[41] R. M. Gandia, F. C. Gomes, A. A. Corrêa, M. C. Rodrigues, and D. B. Marin, "Physical, mechanical and thermal behaviour of adobe stabilized with the sludge of wastewater treatment plants," *Engenharia Agrícola,* vol. 39, pp. 684-697, 2019.

[42] H.-Y. Liu, H.-S. Wu, and C.-P. Chou, "Study on engineering and thermal properties of environment-friendly lightweight brick made from Kinmen oyster shells & sorghum waste," *Construction and Building Materials,* vol. 246, p. 118367, 2020.

[43] MIDUVI, "NEC-HS-EE: Eficiencia energética en la construcción en Ecuador," 2018.

[44] X. B. Castillo Izurieta, "La importancia de la aplicación de las normas NEC-norma ecuatoriana de la construcción, en la utilización del vidrio en la construcción," Universidad de Guayaquil Facultad de Ciencias Administrativas, 2020.

[45] V. G. Chimbo Andy, "Análisis de la resistencia a la compresión de ladrillos prensados interconectables elaborados de barro, cangahua y puzolana, con adiciones de cemento, cumpliendo la norma ecuatoriana de la construcción (NEC 2015)," Universidad Técnica de Ambato. Facultad de Ingeniería Civil y Mecánica, 2017.

[46] R. M. Garay and N. Pino G, "Proyecto Vivienda de Emergencia, Parte 3, Comportamiento acústico," *Revista de la construcción,* vol. 18, pp. 96-110, 2019.

[47] M. Machimbarrena, B. Rasmussen, and C. R. Alves Monteiro, "Regulatory sound insulation requirements in South America-Status for housing, schools, hospitals and office buildings," in *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*, 2019, pp. 7470-7481.

[48] Y. Rodríguez Cisneros and W. Baldeón Quispe, "Evaluación del ruido y el confort acústico en la Biblioteca Agrícola Nacional. Lima, Perú," *Medicina y Seguridad del Trabajo,* vol. 64, pp. 17-32, 2018.

[49] C. INN | Instituto Nacional de Normalización, "NCh352.Of2000-Aislación acústica - Parte 1: Construcciones de uso habitacional - Requisitos mínimos y ensayos (extracto)," 2000.

[50] H. A. Pino Escobar, "La adición de aserrín y poliestireno en la elaboración de bloques de adobe para viviendas unifamiliares y su efecto en la variación de temperatura y acondicionamiento acústico en el cantón Ambato, provincia de Tungurahua," Universidad Técnica de Ambato. Facultad de Ingeniería Civil y Mecánica …, 2019.