Journal of World Architecture

Research Article

Vernacular Wisdom as a Path Toward Low-energy Ecologically Sustainable Housing and Settlements: Participatory Design and Building to Rehabilitate Local Adobe Bricks in El Salvador

Silvio Cristiano[1,2]*, Camilla Falchetti[3,4]

[1]Department of Science and Technology, Università degli Studi di Napoli 'Parthenope', Naples, 80143, Italy

[2]Department of Molecular Science and Nanosystems, Università Ca' Foscari Venezia, Venice, 30172, Italy

[3]Associazione Labsus – Laboratorio per la Sussidiarietà, Turin, 10100, Italy

[4]Associazione Psicologi nel Mondo Torino, Turin, 10100, Italy

Abstract: Globalized cultures, imaginaries, and economies are often matched to the standardization of building approaches. However, solutions that are not tailored for a specific context tend to entail environmental, economic, and social issues. Throughout human history, vernacular wisdom has produced interesting low-energy and climate-responsive architectures all around the globe: These can be seen as interesting examples in an era of global warming and overall uncertainty; at the same time, they represent accessible sustainable solutions in deprived areas of the world as well as in wealthier areas. The experience of participatory design and building process is here presented, carried on in a rural area of El Salvador, Central America. A sanitary facility for a school is designed and realized after the collectively desired recovery and improvement of one of the fruits of local vernacular wisdom in building design, i.e., the adobe earth brick. Some potentials and limits of such experience as well as of the used technology are reviewed in the perspective of affordable and ecologically sustainable housing and settlements in the area.

Keywords: Bioclimatic buildings, Vernacular architecture, Urban planning, Adobe earth brick, Ecological sustainability

This article belongs to the Special Issue: *Lessons on Climate-Responsiveness Learnt from Vernacular Dwellings-A Global Study*

Received: October 10, 2019

Accepted: October 21, 2019

Publication Online: November 26, 2019

Citation: Cristiano S, Falchetti C, 2019, Vernacular Wisdom as a Path toward Low-energy Ecologically Sustainable Housing and Settlements: Participatory Design and Building to Rehabilitate Local Adobe Bricks in El Salvador. J World Arch, 4(si1): 889. https://doi.org/10.26689/jwa.v4isi1.889

***Corresponding Author**

Dr. Silvio Cristiano,
Email: silvio.cristiano@unive.it

1 Introduction

Globalized cultures and a widely colonized social imaginary[1-3] are often matched to the standardization of building approaches, not necessarily meant as a set of best practices and processes, but rather as the application of general unspecific solutions to different areas: In gene ral, building approaches that were originally thought for the Global North tend to be also applied, unquestioned, in the Global South. Nevertheless, this can entail a range of issues. First of all, such approaches might be technically unsuitable due to some given climate and overall environmental conditions. Second, they might be hardly procured and afforded, if not in their cheap versions, the latter only able to sharpen their performative unsuitability. Third, sometimes, they are not really compatible with local dwelling cultures. Vernacular materials and techniques have been identified as interesting climate-responsive solutions[4,5] inasmuch as closely linked to local climates and socioeconomic contexts. This makes them quite promising for ecologically friendly urban and settlement planning in a challenging century. Some vernacular and bioclimatic building approaches are also interesting when context adapted, affordable, comfortable, and energy performative. This is, for instance, the position of the European Commission[6] promoting mutual knowledge exchange and technology transfer between the old continent and Africa right in these fields. The aim of such European operation falls within the efforts to reach lower energy buildings, according to the Paris Agreement[7]. Sincere researches and applications in construction materials and technologies vernacular wisdom seem to boost even more ambitious actions as called, for example, by Rogelj *et al.*[8] Vernacular building materials and techniques have raised increasing interest in the past decades, with many monographs and papers published throughout the years[9-22]. More recent publications are mostly focused on thematic topics, for example, geographical or technological[23-28]. Much of this literature addresses vernacular building solutions while taking historical and technical aspects into consideration. However, the current compatibility with local markets and especially with local common demand is rarely found. Nevertheless, the acceptability of solutions from the past cannot be neglected; as a matter of fact, progressive levels of cultural and economic colonization have caused many populations to reject their own wisdom and traditions inasmuch as signs of an alleged inferiority, often still marked by less acknowledged Global North-South power unbalance (for a wider discussion on these themes, for instance[3,29]).

2 Context and case study

El Salvador is the tiniest and most densely populated country in Central America and presents and active volcanic activity, with high seismic and hydrogeological hazards. Salvadoran human development index is 0.674[30], slightly worsening in recent years. Our case study is located in one of the most deprived and densely populated departments of the country, i.e., Cabañas, bordering Honduras [**Figure 1**]. Specifically, the rural area of Santa Marta is addressed, near the town of Victoria. Here, local communities and their related physical, socioeconomic, and cultural dimensions are closely intertwined with Salvadoran recent history, namely, its civil war (1980–1992). Before then, Santa Marta was relatively self-sufficient, settlements were spread out and fragmented, and the land was owned by few latifundists. Farmers would live in conditions of widespread poverty, scarce social rights, and attempts of reforms which were brutally repressed. The civil war originated from increasing awareness and protests throughout the country, experiencing similar issues, with the government using the army against demonstrations. During the war, the governmental army soon adopted scorched-earth policy, and the country was destroyed both physically and psychologically[31] throughout the conflict. When the population from Santa Marta came back to their lands after an exile in Honduras, everything was lost and to be started from scratch, including their houses and settlements. In this area, houses generally consist of one only storey. The shock, the absence, and the international aid contributed to mostly abandon local building materials and techniques during the reconstruction. Some of the local vernacular know-how around the technique of adobe earth brick making and construction were mainly limited to minor structures such as sheds and shelters. Scant attention due to low performances to be ensured summed up to a less frequent use of such approach. As a consequence, quality started to be poorer and poorer, and some earthquakes in the early 2000s caused the abandon of the technique together with some sort of *damnatio memoriae*: The population started to consider adobe as a backward approach to be forgotten. Recent participatory processes facilitated within academically-led Italian-Salvadoran professional

Figure 1. A detail of the local school.

cooperation project *Ma.Sa.Ma.* after local social, economic, and ecological crises had arisen inside the community[32-34], represented a turning point, with some local inhabitants spontaneously urging the recovery of such vernacular building technique. This is at the basis of the following pilot project *Compost(h)emos*[34], aimed at raising awareness around ecological issues, at recovering and improving (hence, culturally and technically rehabilitating) vernacular adobe earth bricks, and finally, at sharing such saved wisdom across the community. This contribution is focused on a critical review of the adobe building technology in that area as well as on the potentials and limits of its use in the Salvadoran context and beyond.

3 The adobe brick and its adaptation through participatory design and building

Dating back to nearly 9000 years ago in Russian Turkestan[19] or even earlier in the Neolithic period (Brown and Clifton, 1978), the word adobe means "mud brick," although it is currently also used for architectural styles in North American desert climates[18]. Adobe is usually associated with raw earth as a building material, which was after all the most used building material ever in many hot arid and temperate climates[19]. Earth was at the basis of shelters at the early stages of human development, often combined with brush and tiny wood pieces "covered with mud for waterproofing"[35]. Besides, being a widely available material in many places in the world, it was mostly useful in supporting climate-responsive energy performance even in the absence of heating and cooling systems: Indeed, thick adobe walls are able to absorb heat during the day, keep it for several hours, and release it at night[18]. This provides thermal mitigation, which is particularly suitable in winter. Depending on the local climate, ventilation might be required. Vernacular adobe technologies can be found in Africa, Asia, and America. In New Mexico, the first adobe building wisdom was developed between 700 and 1500 C.E., mostly used for making one-storey houses out of dried mud or stones and adobe mortar, without windows, and with flat roofs[18]. Throughout the centuries and across the continent, the adobe brick making technique was refined, and sun started to be used for the hardening of compressed bricks made of sand and/or clay. There and in other countries such as Iran, entire villages and even cities were built with adobe constructions[18]. In Mali, the Djenné Mosque[36], with its 75-m^2 blueprint and 20-m height, represents the largest adobe building in the world. About earth building, extensive literature has been published in the past 50 years. Among this, Boudreau[37] provides practical guidelines for adobe brick making; Brown and Clifton[38] and Brown *et al.*[39] focused on the properties and durability of adobe; Austin[40] reviewed types of adobe, thermal properties, geology and basic materials, building codes and tests, energy usage, and starts in general to highlight the contemporary dignity of adobe building; the earthquake responses of adobe structures are investigated in Cao and Watanabe[41]. Rodríguez and Saroza[42] identified the optimal composition of adobe as a building material for a school if Cuba, which is particularly suitable for our case study. It is in the past decade, however, that energy and sustainability issues start to be discussed more explicitly and comprehensively: Revuelta-Acosta *et al.*[43] associated them with adobe's thermal performances; other authors calculate the embodied energy[44] and the cradle-to-cradle life cycle assessment[45] of adobe. In recent years, more studies also address the physical and thermal properties of adobe bricks with a focus on their binding materials[46-50]. Nowadays, "advanced earth building techniques demonstrate the value of earth not only in do-it-yourself construction but also for industrialized construction involving contractors"[19].

In the community of Santa Marta, El Salvador, the adobe earth brick technology was recovered and refined while being employed in participatory design and building process for the construction of compost toilets for the local high school[34] [**Figures 1 and 2**]. The participatory design at hand is a form of codesign[29]. A preliminary concept mainly regarding the function and features of the structure (i.e., a compost toilet) is enriched and completed based on the directions emerged from the previous participatory planning project and thanks to the involvement of local expertise (recovery and adaptation of local vernacular techniques). These codesign steps were facilitated by special figures in an open ongoing learning and creative process. The process was framed in the aforementioned independent Salvadoran-Italian cooperation project

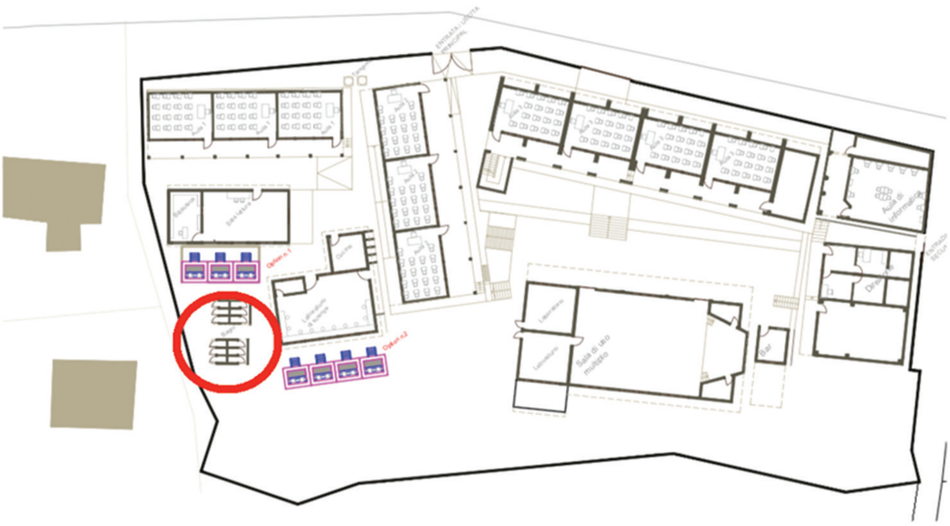

Figure 2. Map of the school complex, with the position chosen for the compost toilets (in the circle).

Compost(h)emos[34], and involved nearly 200 people from the community, including local expert masons, in addition to Salvadoran and Italian practitioners (architects and engineers). This way (and with these numbers in a community of nearly 3000), the impact of mutual technology transfer was maximized[34] both for the building techniques and for the eco-friendly sanitary facility.

A thorough analysis of the context, started with the previous cooperation project *Ma.Sa.Ma*., was, therefore, enriched with some local wisdom emerging from the codesign process. As a consequence, the solvable flaws of the impoverished adobe brick technique – only approximately used in recent years and damaged by the earthquakes until overall abandonment – were overcome. Adobe bricks were now employed for the walls of the sanitary facility building. Tailored adaptation and improvement for the local context are summarized as follows.

First of all, the site was chosen in a slightly sloping area so as to avoid the accumulation of rainwater at the bottom of the walls. Moreover, a base was laid down, made of local stones bound with hydraulic mortar, for an average thickness of 60 cm (i.e., 2 feet), also useful for the lodging of the compost toilet tanks [**Figure 3**]. This way, the adobe brick walls are not in direct contact with the ground nor with the toilets, so as to cut down the risk of being affected by moisture and insects.

Second, high-quality adobe bricks were realized manually after choosing and testing samples of local suitable earth specially riddled and selected to ensure an adequate variety in its composition (grain assortment), and maximize mechanical performances. In addition to such earth mix, locally available forage (*zacate*) was used as binding fiber so as to improve the mechanical performances of the bricks. Forage was specially harvested when still flexible and thin, then dried for four through 7 days. For the brick making, special wooden molds were manufactured by local woodsmiths, allow to shape, and compress four bricks at a time. Controlled natural drying happened in dry and sunny flat paved areas of the community, to reduce their moisture content [**Figure 4**]; their average drying period was 3 weeks, slightly varying depending on the blowing of the prevailing north winds.

Figure 3. The building site, with a focus on the base of the structure.

Third, high attention was paid to building joints; hence, adequate frame and bracing were designed and later constructed, while ensuring static conditions. The frame at issue is a hybrid one, conceived to employ non-alien technologies: In addition to local earth, also locally grown bamboo and widely used sheet metal[34]. To minimize moisture also in exercise, thus protecting the adobe bricks, a ventilated roof was designed and installed[34], large enough to limit the dampening from rain [**Figure 5**].

4 Discussion

4.1 Potentials and limits for El Salvador and beyond

The canniness dedicated to the recovery and improvement of the vernacular adobe brick in the Salvadoran rural area at hand allowed for overcoming recent issues due to technologic flaws. Its low technology allows adequate climate and mechanical performances for the Salvadoran case study. A design and construction inspired by minimum building technologies are essential in any structure in any part of the world. In particular, the following expedients proved to be valid in terms of higher performances and durability for the structure at issue:

a. The top protection from rainwater;
b. The isolation from the ground and its associated surface (rain) water flows;
c. The thick base to decrease the risk of moisture and bacteria in the adobe walls;
d. Varied grain assortment in the earth used for the compressed bricks;
e. Locally available vegetal fibers (forage) specially selected to ensure correct binding;
f. Adequate drying conditions (namely, controlled natural drying on sunny paved surfaces);
g. Building joints, frame, and bracing;
h. Indoor ventilation to reduce winter moister and heat in summertime.

Thermal mitigation for Salvadoran warm climate is quite promising; this is particularly interesting if we consider the affordability of the adobe brick together with its easy design and manufacturing. At the same time, water protection is crucial in rainy contexts like this. The absence of special innovations and strong mechanical performances for buildings higher than one or two stories is acceptable for the local Salvadoran culture, especially in rural areas like Santa Marta. However, some limits are suggested for higher buildings in similar rainy contexts. In general, the need for more demanding energy and mechanical performances requires a case-by-case analysis for

Figure 4. The controlled natural drying of a stock of adobe bricks.

Figure 5. Advance of the building site at the end of the 12th week (courtesy of Mr. Justin Bench).

other contexts, strongly depending on local climate and dwelling cultures. Material and technological innovation are also possible and sometimes successful between local vernacular wisdom (such as adobe bricks) and more recent knowledge from other regions; this is for instance the case of a recent study on some Sudanese vernacular innovative building technologies[26]. One last remark might involve the cultural dimension; here, the recovery and improvement of vernacular technologies were encouraged by parts of the population, yet still causing skepticism in some other parts. Skepticism is generally due to the dominant social imaginary, leading to desire exogenous, often Global Northern values and goods, and to reject own ones, sometimes considered as “backward” also in the light of uneven South-North power and economic conditions[3,29]. This of course includes dwelling and its features. In spite of an increasing interest from highly industrialized contexts, as a matter of fact, a major barrier in the application of vernacular building solutions might be paradoxically represented by intangible drivers.

5 Conclusion

While primitive and vernacular wisdom and know-how are often abandoned due to a progressive cultural colonization throughout the world, traditional building approaches still offer some potentials to face context-specific environmental, economic, and social peculiar conditions in many places. This is particularly important in a changing century, with uncertain availability of resources and ongoing global warming. A participatory design and building process in a rural area of El Salvador resulted in the recovery and improvement of local vernacular wisdom around the use of sundried adobe earth bricks. Both local and foreign, professional, and vernacular know-how were used toward a successful collaborative making of a sanitary structure. Crucial expedients were employed and reviewed to stress the important of context adaptation. Among these, the top protection and thick stone-and-mortar ground isolation to minimize the effects of seasonal rains and associated water flows as well as of moisture and insects in general; a selected composition of the compressed bricks, made with highly varied grain assortment in the earth, and binded by locally available vegetal fibers (forage); controlled natural drying conditions for both the fibers and the compressed bricks; and, finally, a special attention paid to building joints, frame, and bracing. In this case study, easy implementation, local materials, and affordability proved to all represent key factors; the demand for ecological sustainability and short houses in the area seems to be positively satisfied by an improved adobe brick technology as illustrated here. This can also be true for other similar climate, socioeconomic, and cultural contexts. Moreover, some features might be used elsewhere, while some other considerations are suggested toward a proper exportability toward affordable and ecologically sustainable housing and settlements in El Salvador and beyond. A not negligible barrier is represented by the social desirability and acceptability of a still valuable wisdom from the past, influenced by cultural and economic factors as well as by their combination. Far from idealization, we suggest that vernacular buildings be, therefore, considered as an important heritage to be studied on a case-by-case basis and with a worldly-wise and open-minded transdisciplinary approach, not forgetting socioeconomic bias on a wider, often international level.

References

[1] Latouche S. Decolonization of Imaginary. In: D"Alisa G, Demaria F, Kallis G, (Eds.). Degrowth: A Vocabulary for a New Era. London: Routledge; 2014. p. 117–20.

[2] Castoriadis C. Radical Imagination and the Social Instituting Imaginary. In: Rethinking Imagination. London: Routledge; 2016. p. 136–54.

[3] Cristiano S. Systemic Thoughts on Ecology, Society, and Labour. In: Cristiano S, (Ed.). Through the Working Class Ecology and Society Investigated Through the Lens of Labour, Ca' Foscari. Vol. 8. Boulder: University Press; 2018. p. 9–23. Available from https://www.edizionicafoscari.unive.it/en/edizioni/libri/978-88-6969-297-0. [Last accessed on 2019 Sep 30].

[4] Rapoport A. House form and Culture. New Delhi, India: Prentice-Hall of India Private Ltd.; 1969.

[5] Rapoport A. Development, Culture Change, and Supportive Design. Habitat Int 1983;3:249–68.

[6] European Commission. LC-SC3-EE-18-2019: Bioclimatic Approaches for Improving Energy Performance in Buildings in Africa and Europe. Horizon 2020, Work Programme 2018-2020, 10. Secure, Clean and Efficient Energ; 2018. p. 50–1.

[7] UNFCCC. Adoption of the Paris Agreement. Report No. FCCC/CP/2015/L.9/Rev.1; 2015. Available from: http://www.unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf. [Last accessed on 2019 Sep 30].

[8] Rogelj J, Den Elzen M, Höhne N, *et al*. Paris Agreement Climate Proposals Need a Boost to Keep Warming Well Below 2 C. Nature 2016;534:631. Available from: https://www.nature.com/articles/nature18307. [Last accessed on 2019 Sep 30].

[9] Fathy H. Natural Energy and Vernacular Architecture. United States: University of Chicago Press; 1986.

[10] Rudofsky B. Architecture Without Architects: A Short Introduction to Non-pedigreed Architecture. Albuquerque: UNM Press; 1987.

[11] Coch H. Bioclimatism in Vernacular Architecture. Renew Sustain Energy Rev 1998;2:67-87. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1364032198000124. [Last accessed on 2019 Sep 30].

[12] Glassie H. Vernacular Architecture. Bloomington: Indiana University Press; 2000.

[13] Ray R. Architecture Without Architects. Glob Built Environ Rev 2002;3:10–4.

[14] Steen AS, Steen B, Komatsu E. Built by Hand: Vernacular Buildings Around the World. Layton: Gibbs Smith; 2003.

[15] Sadler S. Archigram: Architecture Without Architecture. London: MIT Press; 2005.

[16] Asquith L, Vellinga M, (Eds.). Vernacular Architecture in the 21st Century: Theory, Education and Practice. New York: Taylor and Francis; 2006.

[17] Oliver P. Built to Meet Needs: Cultural Issues in Vernacular Architecture. London: Routledge; 2007.

[18] May J, Reid A. Architettura Senza Architetti: Guida Alle Costruzioni Spontanee di Tutto il Mondo. Milano: Rizzoli; 2010.
[19] Minke G. Building with Earth: Design and Technology of a Sustainable Architecture. Walter de Gruyter; 2012. Available from: https://www.pure.iiasa.ac.at/id/eprint/13307/1/nature18307_proof1.pdf. [Last accessed on 2019 Sep 30].
[20] Fernandes JEP, Mateus R, Gervásio HM, *et al*. The Importance of Vernacular Strategies for a Climate Responsive Building Design. SBE16 Braz Port Sustain Urban Communities Towards Nearly Zero Impact Built Environ 2016;1:429–38. Available from: https://www.repositorium.sdum.uminho.pt/handle/1822/43169. [Last accessed on 2019 Sep 30].
[21] Heynen H. Vernacular Architecture and the Uses of the Past. Bauhaus Imaginista; 2019. Available from: http://www.bauhaus-imaginista.org/ARTICLES/3150/VERNACULAR-ARCHITECTURE-AND-THE-USES-OF-THE-PAST. [Last accessed on 2019 Sep 30].
[22] Nguyen AT, Truong NSH, Rockwood D, *et al*. Studies on Sustainable Features of Vernacular Architecture in Different Regions Across the World: A Comprehensive Synthesis and Evaluation. Front Archit Res 2019. Available from: https://www.sciencedirect.com/science/article/pii/S2095263519300603. [Last accessed on 2019 Sep 30].
[23] Carabbio R, Pieraccini L, Silvestri S, *et al*. How can Vernacular Construction Techniques Sustain Earthquakes: The Case of the Bhatar Buildings. Front Built Environ 2018;4:18. Available from: https://www.frontiersin.org/articles/10.3389/fbuil.2018.00018. [Last accessed on 2019 Sep 30].
[24] Gautam D, Rodrigues H. Seismic Vulnerability of Urban Vernacular Buildings in Nepal: Case of Newari Construction. J Earthq Eng 2018;1–22. Available from: https://www.tandfonline.com/doi/full/10.1080/13632469.2018.1498411. [Last accessed on 2019 Sep 30].
[25] Indraganti M. India: Bio-Climatism in Vernacular Architecture. In: Sustainable Houses and Living in the Hot-Humid Climates of Asia. Singapore: Springer; 2018. p. 47–58.
[26] Cristiano S, Gonella F. Learning from Hybrid Innovative-Vernacular Solutions in Building Design. Systemic Evaluation Through Emergy Synthesis of Technologies for Energy Saving in Sudan. J Environ Account Manage 2019;7:209–23. Available from: https://www.lhscientificpublishing.com/journals/JEAM-Download.aspx. [Last accessed on 2019 Sep 30].
[27] Ismail M, Singh H, Teeli MA. An Analysis of House Type Transformation from Vernacular Buildings to Modern Houses in Mountainous Region of Guraiz Valley. Res J Soc Sci 2019;10. Available from: http://www.aensi.in/assets/uploads/doc/479dd-390-395.14565.pdf. [Last accessed on 2019 Sep 30].
[28] Valinejadshoubi M, Heidari S, Zamani P. The Impact of Temperature Difference of the Sunny and Shady Yards on the Natural Ventilation of the Vernacular Buildings. J Build Eng 2019;26. Available from: https://www.sciencedirect.com/science/article/pii/S2352710218314384. [Last accessed on 2019 Sep 30].
[29] Cristiano S, Falchetti C, Miacola F, *et al*. Cooperation Beyond Development. Rethinking International aid for the Self-Determination of Recipient Communities. J Univ Int Dev Coop 2018;1. Available from: http://www.ojs.unito.it/index.php/junco/article/view/3661. [Last accessed on 2019 Sep 30].
[30] United Nations Development Programme. Human Development Indices and Indicators: 2018 Statistical Update; 2018. Available from: http://www.hdr.undp.org/en/content/human-development-indices-indicators-2018-statistical-update. [Last accessed on 2019 Sep 30].
[31] Mela A, Chicco E. Comunità e Cooperazione. Un Intervento Sul Benessere Psicologico Nel Salvador: Un Intervento Sul Benessere Psicologico Nel Salvador. Milano: Franco Angeli; 2016.
[32] Cristiano S, Falchetti C, Vasilescu V, *et al*. Effective Participatory Processes and Multi-Disciplinary Approaches for the Analysis of a Territory and the Fostering of Durable and Sustainable Self-Managed Strategic Planning: the Ma.Sa.Ma. Project, a Rural Case Study in El Salvador. Abstract Proceedings of the IV Congress of the University Network for Development Cooperation (CUCS), Brescia; 2015. Available from: https://www.docplayer.it/6705218-Rinforzare-il-capitale-umano-nei-paesi-a-risorse-limitate-health-and-wealth-for-all-by-the-year-2030-proceedings-of-the-iv-congress.html. [Last accessed on 2019 Sep 30].
[33] Ciaffi D, Mela A. El Salvador Verso la Pianificazione di Città e Territori: Un'esperienza Partecipativa Pilota a Santa Marta. Visioni LatinoAmericane; 2015. p. 12 Available from: https://www.openstarts.units.it/bitstream/10077/10664/1/Ciaffi_Mela.pdf. [Last accessed on 2019 Sep 30].
[34] Falchetti C, Cristiano S, Mela A. Failing While Succeeding? On the Delicate Effects of a Yet Sincere Cooperation. J Univ Int Dev Coop 2018;1. Available from: http://www.ojs.unito.it/index.php/junco/article/view/3663. [Last accessed on 2019 Sep 30].
[35] McHenry PG. Adobe and Rammed Earth Buildings: Design and Construction. Tucson: University of Arizona Press; 1989.
[36] Marchand TH. The Djenné Mosque: World Heritage and Social Renewal in a West African Town. In: Verkaaik O, (Ed.), Religious Architecture: Anthropological Perspectives. Amsterdam: Amsterdam University Press; 2013. p. 117–48.
[37] Boudreau EH. Making the Adobe Brick. Berkeley (CA): Fifth Street Press; 1971.
[38] Brown PW, Clifton JR. Adobe I: The Properties of Adobe. Stud Conserv 1978;23:139–46. Available from: https://www.tandfonline.com/doi/abs/10.1179/sic.1978.019. [Last accessed on 2019 Sep 30].
[39] Brown PW, Robbins CR, Clifton JR. Adobe II: Factors Affecting the Durability of Adobe Structures. Stud Conserv 1979;24:23–39. Available from: https://www.tandfonline.com/doi/abs/10.1179/sic.1979.003. [Last accessed on 2019 Sep 30].
[40] Austin GS. Adobe as a Building Material. NM Geol 1984;6:69–71. Available from: https://www.geoinfo.nmt.edu/publications/periodicals/nmg/6/n4/nmg_v6_n4_p69.pdf. [Last accessed on 2019 Sep 30].
[41] Cao Z, Watanabe H. Earthquake Response Prediction and Retrofitting Techniques of Adobe Structures. In: Proceedings of the 13th World Conference on Earthquake Engineering, Paper No. 2594; 2004. Available from: http://www.iitk.ac.in/nicee/wcee/article/13_2594.pdf. [Last accessed on 2019 Sep 30].
[42] Rodríguez MA, Saroza B. Identificación de la Composición Óptima del Adobe Como Material de Construcción de Una Escuela en Cuba. Mater Constr 2006;282:53–62. Available from: https://www.dialnet.unirioja.es/servlet/

articulo?codigo=2126380. [Last accessed on 2019 Sep 30].
[43] Revuelta-Acosta JD, Garcia-Diaz A, Soto-Zarazua GM, *et al*. Adobe as a Sustainable Material: A Thermal Performance. J Appl Sci (Faisalabad) 2010;10:2211–6. Available from: http://www.scialert.net/abstract/?doi=jas.2010.2211.2216. [Last accessed on 2019 Sep 30].
[44] Shukla A, Tiwari GN, Sodha MS. Embodied Energy Analysis of Adobe House. Renew Energy 2009;34:755–61. Available from: https://www.sciencedirect.com/science/article/pii/S0960148108001729?via%3Dihub. [Last accessed on 2019 Sep 30].
[45] Christoforou E, Kylili A, Fokaides PA, et al. Cradle to site Life Cycle Assessment (LCA) of Adobe Bricks. J Clean Prod 2016;112:443-52. Available from: https://www.sciencedirect.com/science/article/pii/S0959652615012378. [Last accessed on 2019 Sep 30].
[46] Lertwattanaruk P, Choksiriwanna J. The Physical and Thermal Properties of Adobe Brick Containing Bagasse for Earth Construction. Int J Build Urban Interior Landsc Technol BUILT 2011;1:57–66. Available from: https://www.pdfs.semanticscholar.org/a2db/dd2c4c1f0643d3a7f635f64d217b3810da14.pdf. [Last accessed on 2019 Sep 30].
[47] Parisi F, Asprone D, Fenu L, *et al*. Experimental Characterization of Italian Composite Adobe Bricks Reinforced with Straw Fibers. Compos Struct 2015;122:300–7. Available from: https://www.sciencedirect.com/science/article/pii/S0263822314006412. [Last accessed on 2019 Sep 30].
[48] Abanto GA, Karkri M, Lefebvre G, *et al*. Thermal Properties of Adobe Employed in Peruvian Rural Areas: Experimental Results and Numerical Simulation of a Traditional Bio-Composite Material. Case Stud Constr Mater 2017;6:177–91. Available from: https://www.sciencedirect.com/science/article/pii/S2214509516300900. [Last accessed on 2019 Sep 30].
[49] Gandia RM, Corrêa AA, Gomes FC, *et al*. Physical, Mechanical and Thermal Behavior of Adobe Stabilized with "Synthetic Termite Saliva". Engenharia Agrícola 2019;39:139–49. Available from: http://www.scielo.br/scielo.php?pid=S0100-69162019000200139&script=sci_arttext. [Last accessed on 2019 Sep 30].
[50] Costa C, Cerqueira Â, Rocha F, *et al*. The Sustainability of Adobe Construction: Past to Future. Int J Archit Herit 2019;13:639–47. Available from: https://www.tandfonline.com/doi/full/10.1080/15583058.2018.1459954. [Last accessed on 2019 Sep 30].