Analysis of Envelopes Applied To Bioclimatic Architectures.

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Abstract. In the last decade, retrofitting strategies have been reviewed to improve energy efficiency and reduce the environmental impact of existing buildings [1]. A modernization strategy consists of an architectural design based on bioclimatic characteristics. The exploitation of climatic indicators and the use of passive strategies are among the central principles of this design approach [2]. The main objective of this study is to provide an extensive review of the different building envelopes with the adoption of high-performance materials or systems to improve human thermal comfort.

Keywords: Energy saving, Human thermal comfort, Bioclimatic design, Energy Efficiency, Building envelope.

1 Introduction

In 2010, the construction sector consumed 32% of energy, and was responsible for a third of global CO2 emissions [3]. Pérez Lombard et al. [4] identified the increase in energy consumption of the residential and commercial sectors that reached 20-40% of the total world energy use [5], where half of the energy consumption of the building is dedicated to heating systems, ventilation and air conditioning (HVAC), since, both in hot and cold climates, active systems must heat or cool the current building in conditions that are comfortable for the inhabitants [6].

Currently worldwide, the greatest concern for designers and researchers is the environmental issue, especially the excessive consumption of fossil fuels and the consequent danger of climate change. Among the many solutions suggested by global institutions, the use of renewable energy is considered the most suitable factor. These energy approaches can be generalized under the title of sustainable architecture [7], ecological architecture, zero energy [8], passive solar design and bioclimatic design.

Bioclimatic design [9], refers to the architectural design approach that uses both solar energy and related environmental resources to provide thermal comfort indoors and outdoors. According to ASHRAE Standard 55 [10], thermal comfort is defined as: "The condition of the mind that expresses satisfaction with the thermal environment and is assessed by subjective assessment."

The thermal performance of buildings is related to three main categories: microclimate of the building environment, building physics, and required internal thermal comfort [11]. Among these categories, construction physics specifies the building envelope such as roofs, walls, windows, doors
and floors, among its parameters, significantly affecting energy consumption [12], due to the fact that buildings release or obtain heat through of their wraps [13], [14].

Approximately 50% of the total energy consumption of the building is affected by the elements of the building envelope [15]. Therefore, applying enclosures with highly insulated materials [16], [17] or energy efficient equipment such as heat recovery systems [18], can contribute to reducing the energy demand in the home [19], [20].

However, the decision to adopt new envelope systems is difficult because it is a multi-criteria problem that encompasses ecological, economic, social and other dimensions [21]. The downside with modernization also includes limitations such as influences from the existing context [22].

This document provides a review of various envelope alternatives currently applied, such as innovative concepts to replace or retrofit bioclimatic building envelopes. Therefore, this research incorporates as many envelopes as possible as upgrade options into the decision process to optimize the synthesized performance of potential envelopes without subjective material selections.

2 Background of the investigation.

This article reviews the previous studies on the envelopes applied to bioclimatic buildings, determining parameters, as variables to minimize the energy consumption of the house. The studies reviewed include indexed journal articles, conference proceedings, books, dissertations, and reports.

However, during this review, other relevant research is discussed if necessary, to illustrate the idea. The reviewed articles studied the implementation of optimization in the design of building envelopes. In addition, commercial and residential cases are included. Other parameters, such as HVAC systems, controls, renewables, etc., are also included in the reviewed studies as long as the building envelope and energy parameters are primarily considered use / demand.

3 Literature review

To compile the documents, keywords such as 'construction envelope', 'energy consumption' were used. Searches are also carried out with the combination of the main keywords and the different optimization methods. Later in Table 1, the references of the relevant documents that meet the selection criteria are included.

| Author            | Year | Country  | Summary                                                                 | Doi                        |
|-------------------|------|----------|------------------------------------------------------------------------|----------------------------|
| Piggot, J, et al. | 2019 | Chile    | This research is to analyze the thermal performance of vertical envelope solutions for wooden partition walls used in Canadian establishments and to evaluate how these technologies contribute to reducing the energy demand of educational establishments in Chile. | http://dx.doi.org/10.7764/rdlc.18.1.201 |
| Cassandro, R.     | 2018 | Colombia | A composite panel prototype, type SIP (Structural Insulated Panel), is proposed as a structural thermal panel, as a housing envelope wall made with renewable materials of natural origin, specifically recycled guadua and cardboard. | http://dx.doi.org/10.14718/revarq.2018.20.2.2116 |
| Mazzoco, M. et al.| 2018 | Argentina| In this research the thermal-energy behavior of a social housing in the central region of Argentina is studied. The objective is to energetically evaluate the house for a historical period between 1960 and 2011 and obtain the thermo-physical model through simulation with ECOTECT and SIMEDIF to propose its rehabilitation. | http://dx.doi.org/10.1590/s1678-86212018000400302 |
| Author                  | Year | Country     | Summary                                                                                                                                                                                                 | Doi                                                        |
|-------------------------|------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|
| Osuna, I. et al. [26]   | 2017 | Colombia    | The thermal behavior of an experimental planted roof prototype is determined, which can be installed on inclined roof systems in corrugated sheets of fiber cement, widely used in our environment. | http://dx.doi.org/10.14718/revarq.2017.19.1.1109           |
| Molina, M y Fernández, P. [27] | 2013 | España      | Comparative analysis of the thermal envelope and energy demand between two types of housing, the palloza and the traditional house, in the Os Ancares mountain area, in northwestern Spain. | http://dx.doi.org/10.4067/S0718-915X201300020008            |
| Luciani, S. et al. [28] | 2018 | Colombia    | With the aim of contributing to the reduction of impacts in the construction of buildings, various ventilated and conventional façade systems were designed, involving opaque facades, plant elements and air chambers. | http://dx.doi.org/10.14718/revarq.2018.20.2.1726          |
| Mercado, M., et al. [29] | 2010 | Argentina   | The present work evaluates: (a) the thermal-energy quality of a social housing, by means of in-situ measurements under conditions of real use; (b) the necessary energy requirement through a balance; (c) the simulation of the home in the SIMEDIF program, where the model was adjusted and easy and inexpensive improvements were tested; and (d) a qualitative survey of the thermal sensations. | http://dx.doi.org/10.1590/S1678-8621201000020006            |
| Pérez, N., et al. [30]  | 2018 | Brasil      | The objective of this work is to demonstrate the benefits that building systems with green envelopes can offer to internal environments when temperatures are lower. | http://dx.doi.org/10.4067/S0718-915X20130002000105          |
| Pérez, H. et al. [31]   | 2013 | Chile       | In this study, the analysis on the design and bioclimatic architecture is carried out, taking as a premise the sustainability between user, environment and built space. | http://dx.doi.org/10.4067/S0718-915X20130002000110          |
| Ayelen, M. et al. [32]  | 2018 | Argentina   | The present work proposes as a general objective to carry out a review of the state of the opto-thermal evaluation of materials and components of the urban-building envelope, in relation to the transfer context and the possibilities of regional technological development for the estimation of energy properties and indicators of the urban-building envelope. | https://doi.org/10.2320/07190700.2018.08.02.05             |
| Ramos, A. [33]          | 2017 | Chile       | In the study presented in this article, a mathematical model is developed for the real-time simulation of a winemaking envelope representative of the national winemaking technology - reinforced concrete-, and thermal monitoring of both the wine stored in this interior as in a stainless steel one, with the use of HOBO U-12 temperature sensors. | https://doi.org/10.2320/07190700.2017.07.02.04             |
| Carvalho, C., et al. [34] | 2017 | Brasil      | The objective of this work is to evaluate the thermal comfort of a multi-family housing building using the Mahoney limit values, comparing the results with those obtained from the normative values for each of the bioclimatic zones. | http://dx.doi.org/10.1590/s1678-86212017000100131           |
| Author                        | Year | Country | Summary                                                                                                                                                                                                 | Doi                                                                 |
|------------------------------|------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Balter, J. et al. [35]       | 2016 | Argentina | The objective of the work is to evaluate the energy efficiency and the habitability conditions of housing units in high-rise buildings. Four cases were selected in the City-Oasis of Mendoza, Argentina: two located below and two above the tree canopy. Enclosures of the mass and light type were evaluated. Hygro-thermal measurements were carried out for two years in situ, used to validate models using the Energy Plus simulation program. | http://dx.doi.org/10.1590/s1678-86212016000100059 |
| Matheus, C. et al [36]       | 2016 | Brasil  | This work presents three different studies of thermal behavior with vegetal coatings: 1) a case study with vegetal cover, 2) an experimental study with a living wall and 3) a case study with a green wall, all with comparative and simultaneous measurements between Surfaces exposed and protected by green. | http://dx.doi.org/10.1590/s1678-86212016000100061 |
| Melisa, G. et al. [37]       | 2016 | Chile   | This work proposes the search for alternative materials for thermal insulation of houses, reusing resources. These materials could contribute to both the improvement of the existing home (recycled) and the new one. | http://dx.doi.org/10.4067/S0718-83582016000100004 |
| Schmitt, C. [38]             | 2013 | Chile   | Considerations of environmental responsibility, the search for improvements in the indicators of thermal transmission and infiltrations for glass facades and the existence of new technologies for modeling pieces have stimulated the incorporation of wood in curtain wall structures. | http://dx.doi.org/10.4067/S0717-69962013000200017 |
| Bengochea, M. et al. [39]    | 2011 | España  | The ventilated façade is a building envelope system based on the combination of ceramic panels with the air chamber in order to promote energy savings under appropriate conditions, especially in the face of cooling needs. | 10.3989/cyv.142011 |
| Williamson, J. et al. [40]   | 2016 | España  | Alternative compounds in the envelope sector are obtained by stretch extrusion of narrow interlocking panel sections and profiles. | 10.20868/ade.2016.3195 |
| Varela, S. et al. [41]       | 2018 | España  | In the present work, the thermal behavior of the facade of a typical building from the 1950s that has been rehabilitated with an external thermal insulation system (ETICS) is analyzed. | 10.20868 / ade.2018.3851 |
| Ottelé M, et al. [42]        | 2011 | Italia  | This article discusses a comparative life cycle analysis (LCA) located in the Netherlands for: a conventionally built European brick facade, a directly green facade, an indirectly green facade (supported by a steel mesh), a facade covered with a living wall system based on planters and a facade covered with a living wall system based on layers of felt. | https://doi.org/10.1016/j.enbuild.2011.09.010 |
| Katia Perini & Paolo Rosasco [43] | 2013 | Italia  | This document presents a cost-benefit analysis of different vertical greening systems - green facades and living wall systems - considering the personal and social costs and benefits during their life cycle. | https://doi.org/10.1016/j.buildenv.2013.08.012 |

Source: Authors.
The building envelope parameters that cause energy consumption in a building include architectural features and construction materials. The relationship between the design of the building envelope and the energy consumption data can be identified by iteration changing the variables [44, [45]. Based on the studies, the influencing variables are listed below:

- Orientation of the building [46], [47], [48], [49], [50].
- Building geometry: aspect ratio and compactness ratio (SA / V) [51], [52], [53], [54].
- Construction materials for building envelopes [55], [56], [57].
- Geometric position and density of fenestrations [wall-window relationship (WWR)] [58], [59], [60].
- Sun protection devices [61], [62], [63], [64].
- Type, size and schedule of the heating, ventilation and air conditioning system (HVAC) [65], [66], [67], [68], [69].
- Management of energy storage. (thermal storage with phase change materials) [64], [70], [71].
- Lighting schedules and indoor lighting power density (LPD) [63], [72], [73], [74].
- Location and weather [75], [76], [77].

4 Results

The environmental impact and energy consumption of conventional materials for construction, according to Diulio, et al, [78], such as cement, concrete, clay and PVC, represents one of the great global concerns, which makes it necessary to rethink the architecture of the building going back to its origins in the construction sector, using local materials with low energy costs and minimal environmental impact. The research made it possible to evaluate through the impact of the envelope on the demand for heating energy, how the thermal behavior of recycled-type envelope materials make a significant saving (18.89%) that generates a reduction of the thermostat temperature by one degree from 21 °C to 20 °C. It shows that without thermal improvement in the envelope that covers the masonry, this is not possible since in previous years the user had to set the thermostat at 24 °C to obtain poor thermal comfort with high specific energy consumption. This caveat is important since if the recommendation is proposed to society to lower the thermostat for buildings that have central air conditioning by one degree, it will only be effective in enclosures that have a sufficient level of thermal insulation in order to increase the interior surface temperature in enclosures, opaque and transparent, thus helping to subtract from large amounts of thermal contamination.

Given these provisions for the minimization of environmental impacts product of conventional architectures, Escorcia et al. [79] in their research to validate the thermal reconditioning of homes for Chile, recognizes effective actions to reduce consumption through passive strategies and the development of clean energy and renewable policies that also coincide with the thermal improvement of envelopes (walls, windows, roofing and floors. Estimates of energy consumption for heating using the classic methodology, annual consumption equation, which contains the degrees- annual days of the respective climatic zone and the characteristics of the home, that is, its volumetric transmittance and the volume of the home.

However, in a proposal for thermal reconditioning of homes in Chile, Pavez and Meza [80] concluded that, although different factors could explain this phenomenon of temperature increase; however, higher thermal resistance is the most likely alternative and so is the use of the thermal inertia of the masonry as the envelope material for insulation. Although it could also be the case of concrete as a coating, probably due to its second highest thermal resistance; but the authors' choice that the thermal inertia of concrete is taken advantage of, apart because economically it has the characteristic that it is achieved as a disused material.

In Colombia, social housing presents a problem associated with the selection and use of a materiality consistent with climate change and the conditions of thermal and light comfort. Therefore, Medina and Escobar [81] present a case study with 114 thermal and 18 light simulations to have a support in their recommendations on which ones establish the envelopes as the barriers between the
interior and exterior of the houses that, therefore, Therefore, they have a great implication in terms of comfort and, as a consequence, play a key role in the harmony between the climate of the place and the comfort conditions in the spaces. They are efficient envelopes with respect to environmental conditions. The authors affirm that, with the aggravation of ignorance or the scarce application of passive strategies of adaptation to climate in architecture, and the absence of notions of control of thermal and light comfort, which exacerbates the problem of comfort and low ventilation, because the envelopes are a much more complex element, which goes beyond a functional value, since they are the components with the largest area and incidence in the thermal and light control of the building.

They summarize everything in their analysis on envelopes, categorizing the materials in such a way that they were applied to simulations divided into the following three groups:

a) Traditional materials, which correspond to those commonly used in construction in Colombia, such as: concrete, brick, wood, plaster, concrete blocks, aluminum, 3 mm glass, clay tile, PVC tile, zinc tile, cement, rubber, asphalt.

b) Avant-garde materials, which correspond to materials that have evolved their usual use such as: double glazing or glass with an air chamber, lightweight aggregate concrete, plasterboard, fiberglass polyester, fiber-cement, polycarbonate, glass wool and galvanized steel.

c) Innovative materials that offer quite significant positive impacts, based on chemistry and state-of-the-art technology to obtain them: expanded polystyrene, porous aluminum, polyethylene airgel, ETFE, glasses with argon gas and glasses with solar panels.

The materials that are usually used in the construction of Colombia do not present an unfavorable thermal and light behavior in cold conditions, but if it is to comply with the conditions in cold and hot climates and apart from the economic conditions in the use of materials non-conventional, Cassandro [24] in his analysis of the thermal envelope material, points out that the envelope of a building has as its main function to maintain a constant thermal insulation and includes all the elements that divide or separate the exterior from the interior; Its main purpose is to maintain the average internal comfort climate between 18 and 20 °C. Then, it shows that in the country there are materials such as guadua waste chips and recycled cardboard; where its results of resistance to compression, thermal and acoustic insulation prove to be a viable and competitive product compared to those currently marketed and show that it is a sustainable alternative within the principles of passive energy.

Based on the choice of efficient envelopes, after carrying out thermal and light simulations [28] the simulations to recognize the performance of PVC material compared to conventional materials such as masonry, it was recorded that PVC reduced the temperature, on July 21, which is a day of extreme temperature, compared to the masonry that reduced the internal temperature of 2.2 °C, that is, the model composed of PVC presented better performance. If the base of the envelope is in PVC, the discussion should also focus on the cost-performance ratio, considering that, although the ventilated façade system can decrease the interior temperature in the building.

Analyzing the situation of envelopes in Argentina according to Ayelen [32], infrared thermography is used as a method to estimate the surface temperature of the components of the envelopes of a building from data taken indoors. Through in situ measurements of temperatures and heat fluxes in the envelopes of houses and buildings.

For high-rise buildings, Balter, et al., [35] responds with respect to materiality to the conception of a building with a concrete structure and glass skin, and although the structure is significant due to the seismic nature of the region, it predominates a transparent aesthetic. It has 76% of transparent materials in its envelope and the average thermal resistance of the total envelope is 0.26 m² °C / W. Then, as the improvements in the materials were studied with respect to the known variables, it is suggested that you select for these large buildings an opaque 0.25m solid brick envelope with 0.05m expanded polyurethane insulation (K = 0.78 W / m² °C), and in the light case, work continues with an opaque reinforced concrete envelope of 0.40 m (K = 2.54W / m² °C). In both buildings, the transparent envelope selected is hermetic double glazing (DVH) of 6 mm with a low emissivity interior face (K = 1.80 W / m² °C).

A study that evaluates alternative thermal insulation with cheap materials is that of Melisa [37] who recommends plastic bottles, recycled expanded polystyrene, corrugated cardboard, wheat straw and
recycled polyethylene, as the materials that comprise a feasible alternative for replication by family farmers, since the parameters analyzed in the feasibility study determine that they are easy to implement, very low cost and with an optimal response in terms of thermal insulation. Although the analysis of the life cycle of these materials must be taken into account, although it is a task to be considered in the future, it would allow to specify the feasibility of their use from an integral point of view.

According to Ramos [33], energy efficiency in the envelopes used in Argentine industries is characterized by few specific solutions. The definition of efficient enclosure prototypes from the rational use of energy is a task under development in numerous published works.

Taking buildings with natural conditions in climates of high temperature and high humidity in Brazil, Carvalho, et al [34] exposes that the heat exchange occurs in fluctuating conditions, since the components of the envelope are periodically heated and cooled due to variations in external temperature and incident solar radiation. Under such conditions, the thermal capacity becomes a property with a decisive effect in determining the internal thermal conditions.

Matheus, et al [36] with vegetal coatings and evaluate their ability to mitigate undesirable heat gains in the indoor environment. It is expected, through the results, to indicate the potential of integrating vegetation in buildings and developing projects that use this resource as a passive conditioning strategy. The case study showed that green roof compared to ceramic tiles causes thermal lag, resulting in a more stable temperature for the built environment. According to the temperature data of the surface of the green roof, in relation to the ceramic tile roof, there is an average thermal damping of 9ºC at the hottest times of the day, and an average delay of 2 h.

In recent years, several studies in Spain have addressed this issue, based primarily on obtaining the energy consumption and CO2 emissions of the existing building stock and its possibilities for improvement. Kurtz, et al [82] study the thermal envelopes of old Spanish houses, then the author resolves that his architecture must reform the envelopes in the blind part of facades with solid brick, which is the most used solution or solid concrete block. It has a high insulating capacity suitable for all or almost all levels of Ld. Hollow brick facades are not always sufficient, depending on their thickness and Ld of the site.

Pérez [83] states that when the conditions of Spanish buildings are subjected to moderate or high temperatures, and the interior conditions of comfort close to 20ºC, the materials that make up the enclosures are usually found at temperatures above 10ºC. , taking into account the relative humidity of 55%, which is within the range of interior spaces without high humidity production and the even higher values of environmental relative humidity that Spain handles, make it not realistic to consider that the enclosures that are going to handle have a 50% resistance percentage. The thermal calculation carried out in this way can cause inadequate and insufficient designs of the thermal envelope, energy losses higher than those initially foreseen and a higher energy consumption associated with the air conditioning installations.

Finally, Williamson, et al [40] implemented two varieties; an expanded polystyrene bead insulation with a bonding agent, installing them in Edinburgh properties, using a white bead with a thermal conductivity value of 0.040 W / (m · K).

5 Conclusions
This work has carried out considerable research to investigate different building envelopes. Therefore, it provides an overview of the research developments by various authors in different countries, reviewing related literature available from 2001 to 2020, to highlight the requirement of the document selection criteria, where it was found that:

The studies reviewed confirm that building envelope measurements have the potential to significantly reduce the energy footprint of the built environment. Heat transmission through opaque building enclosures has been shown to be a significant energy loss mechanism, particularly in residential buildings, as they exhibit lower sell-to-wall ratios than glass-dominated office skyscrapers. This is why adding insulation to walls that are not otherwise insulated is very effective; All the studies reviewed indicate improvements by adding insulation or increasing the insulation thickness, albeit with decreasing returns as the insulation thickness increases.
In order to reduce the heating of external surfaces, two primary strategies have been reported: the use of external cladding systems that reduce solar absorption (reduction up to 1.9% in building cooling) as well as the use of vegetation both as shadow generators as detached from the building to green the roof and walls.

Windows and glazing are a relevant link to achieve better energy efficiency in building closings. Therefore, changes from single panel glazing to dual panel solar control can have a significant effect (more than 12% in the case of an average residential building). On the other hand, external shading in the form of blinds and / or vegetation has proven to be highly effective (between 28-34% in cooling energy); in addition to improving lighting and solar glare. In addition to the above, the proper orientation of the window reduces energy consumption by up to 55%. Natural ventilation is also a factor that represents a great challenge, however, the use of natural ventilation strategies, present savings of up to 30% in cooling energy savings.

The previous conclusions indicate that very significant energy savings can be achieved in buildings by addressing the building envelope and implementing low-energy ventilation strategies. However, to achieve these savings effectively, it is not only enough to implement these strategies in new construction but also to create awareness and develop modernization measures that can be applied to the various homes built in times when regulations on energy efficiency were scarce or null, being rehabilitated so that they can comply with the current standard parameters in energy efficiency.

References

[1] S. Changa, D. Castro-Lacouture y Y. Yamagata, «Decision support for retrofitting building envelopes using multi-objective optimization under uncertainties,» Journal of Building Engineering, vol. 32, 2020.
[2] A. B. Daemei, S. R. Eghbali y E. M. Khotbehsara, «Bioclimatic design strategies: A guideline to enhance human thermal comfort in Cfa climate zones,» Journal of Building Engineering, vol. 25, 2019.
[3] D. Ü.-V. L. F, C. Susana, S. Camila y B. K. P. Heating, «Heating and cooling energy trends and drivers in buildings,» Renewable and Sustainable Energy Reviews, vol. 41, pp. 85-98, 2015.
[4] LuisPérez-Lombard, JoseOrtiz y ChristinePout, «A review on buildings energy consumption information,» Energy and Buildings, vol. 40, pp. 394-398, 2008.
[5] J. G. Ascanio-Villabona, C. L. Sandoval-Rodriguez, A. D. Rincón-Quintero, B. E. Tarazona-Romero y R. E. Paez-Castro, «Building a prototype for functional analysis of the energy potential of the water flow in pipe ½ “using microturbines applied to Unidades Tecnológicas de Santander,» IOP Conference Series: Materials Science and Engineering, vol. 844, 2019.
[6] S. Gyamfi, SusanKrumdieck y T. Urnee, «Residential peak electricity demand response—Highlights of some behavioural issues,» Renewable and Sustainable Energy Reviews, vol. 25, pp. 71-77, 2013.
[7] G. Farmer y S. Guy, «Reinterpreting Sustainable Architecture: The Place of Technology,» Journal of Architectural Education, vol. 54, nº 3, pp. 140 - 148, 2001.
[8] A. Marszal, P. Heiselberg, J. Bourrelle, E. Musall, K. Voss, I. Sartori y A. Napolitano, «Zero Energy Building – A review of definitions and calculation methodologies,» Energy and Buildings, vol. 43, pp. 971-979, 2011.
[9] D. L. Jones y J. Hudson, Architecture and the environment : bioclimatic building design, United kingdom: L. King, London, 1998.
[10] ASHRAE Standard 55, «Thermal Environmental Conditions for Human Occupancy,» ASHRAE Inc, Atlanta, 2013..
[11] J. S.Gero, NevilleD'Cruz y A. D.Radford, «Energy in context: A multicriteria model for building design,» Building and Environment, vol. 18, pp. 99-107, 1983.
[12] International Energy Agency- IEA, «Technology Roadmap Energy Efficient Building Envelopes,» 2013. [En línea]. Available: https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergyEfficientBuildingEnvelopes.pdf. [Último acceso: 2 08 2020].

[13] S. Jige, Q. Q. Li, G. Augenbroe, J. Brown y P. P.-J. Yang, «A GIS-based Energy Balance Modeling System for Urban Solar Buildings,» Energy Procedia, vol. 75, pp. 2946-2952, 2015.

[14] S.-H. Lee, «Intermittent Heating and Cooling Load Calculation Method -Comparing with ISO 13790,» Architectural research, vol. 14, pp. 11-18, 2012.

[15] L. Mavromatidis, A. Bykalyuk y H. Lequay, «Development of polynomial regression models for composite dynamic envelopes’ thermal performance forecasting,» Applied Energy, vol. 104, pp. 379-391, 2013.

[16] F. P. Chantrelle, H. Lahmidi, W. Keilholz, M. E. Mankibi y P. Michel, «Development of a multicriteria tool for optimizing the renovation of buildings,» Applied Energy, vol. 88, pp. 1386-1394, 2011.

[17] J. G. Ascanio-Villabona, A. D. Rincón-Quintero, C. G. Cardenas-Arias y C. L. Sandoval-Rodriguez, «Incidence of corrosion in low voltage electrical conductor,» IOP Conference Series: Materials Science and Engineering, vol. 844, 2019.

[18] S.E.Chidiac, E.J.C.Catania, E.Morofsky y S.Foo, «Effectiveness of single and multiple energy retrofit measures on the energy consumption of office buildings,» Energy, vol. 36, pp. 5037-5052, 2011.

[19] S. Chang, D. Castro-Lacouture, F. Dutt y P.-J. Yang, «Framework for evaluating and optimizing algae façades using closed-loop simulation analysis integrated with BIM,» Energy Procedia, vol. 143, pp. 237-244, 2017.

[20] T. F. H. Manz, «Thermal simulation of buildings with double-skin façades,» Energy and Buildings, vol. 37, pp. 1114-1121, 2005.

[21] E. Asadi, M. G. d. Silva, C. H. Antunes, L. Dias y L. Glicksmanf, «Multi-objective optimization for building retrofit: A model using genetic algorithm and artificial neural network and an application,» Energy and Buildings, vol. 81, pp. 444-456, 2014.

[22] A. Nutkiewicz, R. K. Jain y R. Bardhan, «Energy modeling of urban informal settlement redevelopment: Exploring design parameters for optimal thermal comfort in Dharavi, Mumbai, India,» Applied Energy, vol. 231, pp. 433-445, 2018.

[23] J. Piggot, M. B. Piderit y P. Blanchet, «Energy assessment of wood-frame vertical envelope solutions applied in educational establishments of southern Chile,» Revista de la Construcción, vol. 18, nº 1, pp. 201-213, 2019.

[24] R. Cassandro-Cajiao, «Muro panel térmico estructural compuesto en guadua y cartón : modelo experimental aplicado al clima de la zona cafetera,» Revista de Arquitectura (Bogotá), vol. 20, nº 2, pp. 90-109, 2018.

[25] M. P. Mazzocco, C. Filippín, H. Sulaiman y S. F. Larsen, «Energy performance of a social dwelling in Argentina and its retrofitting based on thermal simulation,» Ambiente Construido, vol. 18, nº 4, 2018.

[26] I. Osuna-Motta, C. Herrera-Cáceres y O. López-Bernal, «Techo plantado como dispositivo de climatización pasiva en el trópico,» Tecnología, medio ambiente y sostenibilidad, vol. 19, nº 1, 2017.

[27] M. Molina Huella y P. Fernández Ans, «Evolution of Thermal Behavior in Stone and Thatched Roof Traditional Houses. Enhancement of a Sustainable Model in Northwest Spain,» Revista de la Construcción, vol. 12, nº 2, 2013.
[28] S. Luciani-Mejía, R. Velasco-Gómez y R. Hudson, «Ecoenvolventes : análisis del uso de fachadas ventiladas en clima cálido-húmedo,» Tecnología, medioambiente y sostenibilidad, vol. 20, nº 2, 2018.

[29] M. V. Mercado, A. Esteves y C. Filippín, «Thermal-energy efficiency of a social house in the city of Mendoza, Argentina,» Ambiente Construido, vol. 10, nº 2, 2010.

[30] N. P. Gallardo, A. Rogério, G. Z. F. Neves, F. A. Vecchia y V. F. Roriz, «Respuesta Térmica al frío en edificios con cubiertas verdes para clima tropical. Fachadas y cubiertas verdes,» Revista ingeniería de construcción, vol. 33, nº 1, 2018.

[31] H. Pérez Castro, J. Flores y A. López, «Analysys of Ventilation induced in a Livable Space through a hydro-solar Chimney System,» Revista de la construcción, vol. 12, nº 2, 2013.

[32] A. M. Villalba, N. L. Alchapar, E. N. Corre, A. E. Pattini y L. Santoni, «Métodos de evaluación opto-térmica de materiales y componentes de la envolvente edilicia. Situación en Argentina,» Hábitat Sustentable, vol. 8, nº 2, pp. 64-79, 2018.

[33] A. I. Ramos-Sanz, «Potencial de demanda energética cero en envolventes industriales: El caso de la vinificación en zonas de gran amplitud térmica,» Hábitat Sustentable, vol. 7, nº 2, pp. 40-49, 2017.

[34] C. C. Ferreira, H. A. d. Souza y E. S. d. Assis, «Discussion of the limits of the thermal properties of building envelopes according to Brazilian thermal performance standards,» Ambiente Construido, vol. 17, nº 1, 2017.

[35] J. Balter, C. Ganem y C. Discoli, «Heavy and light high-rise buildings in oasis-cities: thermal and energy assessment of apartments above and below the tree canopy in Mendoza, Argentina,» Ambiente Construido, vol. 16, nº 1, 2016.

[36] C. Matheus, F. D. N. Caetano, D. D. d. O. Morelli y L. C. Labaki, «Thermal performance of green envelopes in buildings in the Brazilian southeast,» Ambiente Construido, vol. 16, nº 1, 2016.

[37] G. M. Viegas, C. Walsh y M. V. Barros, «Qualitative and quantitative evaluation of alternative thermal insulation. The case of family-based farming,» Revista INVÍ, vol. 31, nº 86, 2016.

[38] C. Schmitt, «Fachadas vidriadas estructuradas en madera,» ARQ, nº 84, 2013.

[39] M. M. Pérez, G. L. Patiño, M. A. B. Escribano y P. A. L. Jiménez, «Cuantificación de la eficiencia de la fachada cerámica ventilada mediante técnicas de la mecánica de fluidos computacional,» Boletín de la Sociedad Española de Cerámica y Vidrio, vol. 50, nº 2, pp. 99-108, 2011.

[40] J. B. Williamson, J. Stinson, A. Reid y J. Currie, «Improving The Thermal Performance of "Hard-to-Treat" Historic Buildings in Edinburgh’s New Town,» Anales de edificación, vol. 12, nº 1, 2016.

[41] S. Varela, C. Viñas, A. Rodríguez y P. Aguilera, «Analysis of the thermal behaviour of the ETICS system: Rehabilitated building in Madrid,» Anales de edificación, vol. 4, nº 4, 2018.

[42] M. Ottelé, K. Perini, A. Fraaij, E. Haas y R. Raiteri, «Comparative life cycle analysis for green façades and living wall systems,» Energy and Buildings, vol. 43, nº 12, pp. 3419-3429, 2011.

[43] K. Perini y P. Rosasco, «Cost–benefit analysis for green façades and living wall systems,» Building and Environment, vol. 70, pp. 110-121, 2013.

[44] S. L. B. &. C. S. Chungloo, «Parametric Analysis of Energy Efficient Building Envelope of Thailand,» Asian J. Energy Environ, 2001.

[45] C.K.Cheung, R.J.Fuller y M.B.Luther, «Energy-efficient envelope design for high-rise apartments,» Energy and Buildings, vol. 37, nº 1, pp. 37-48, 2005.

[46] A. R. G. Carbonari y P. Romagnoni, «Optimal orientation and automatic control of Optimal orientation and automatic control of,» de PLEA 2001- The 18th Conference on Passive and Low: Energy Architecture, Florianópolis, BRAZIL, 2001.
[47] «Cost effectiveness in hvac by building envelope optimization.,» 2012. [En línea]. Available: http://www.redalyc.org/articulo.oa?id=281724144004. [Último acceso: 3 Agosto 2020].

[48] F. Goia, M. Haase y M. Perino, «Optimizing the configuration of a façade module for office buildings by means of integrated thermal and lighting simulations in a total energy perspective,» Applied Energy, vol. 108, pp. 515-527, 2013.

[49] F. Favoino, Q. Jin y M. Overend, «Towards an ideal adaptive glazed façade for office buildings,» de 6th International Conference on Sustainability in Energy and Buildings 2014, SEB-14, 2014.

[50] B. Romero-Tarazona, C. Rodriguez-Sandoval, J. Villabonai-Ascanio y A. D. Rincón-Quintero, «Development of an artificial vision system that allows non-destructive testing on flat concrete slabs for surface crack detection by processing of digital images in MATLAB,» IOP Conference Series: Materials Science and Engineering, vol. 844, 2019.

[51] P. McKeen y A. S. Fung, «The Effect of Building Aspect Ratio on Energy Efficiency: A Case Study for Multi-Unit Residential Buildings in Canada.,» Buildings, vol. 4, pp. 336-354, 2014.

[52] A. Perera y M. Sirimanna, «A Novel Simulation Based Evolutionary Algorithm to Optimize Building Envelope for Energy Efficient Building.,» de 7th International Conference, 2014.

[53] M. Košir, T. Gostiša y Ž. Kristl, «Search For An Optimised building envelope configuration during early design phase with regard to the heating and cooling energy consumption.,» In Presented at the CESB16-Central Europe towards Sustainable Building 2016: : Innovations for Sustainable Future, Prague, Czech Republic., 2016.

[54] S. Kang, S.-g. Yong, J. J. H. Kim, H. Cho y J. & Koo, «Automated processes of estimating the heating and cooling load for building envelope design optimization.,» Building Simulation, vol. 11, nº 2, pp. 219-233, 2017.

[55] S. Manu, J. Wong, R. Rawal, P. C. Thomas, S. Kumar y A. Deshmukh, «An initial parametric evaluation of the impact of the energy conservation building code of india on commercial building sector,» International Building Performance Simulation Association, Sydney, 2011.

[56] R. S. Srinivasan, W. W. Braham, D. E. Campbell y D. C. Curcija, «Building envelope optimization using energy analysis.,» de Proceedings of Building Simulation 2011: 12th Conference of International Building Performance Simulation Association, Sydney, 2011.

[57] O. T. Karaguzel y K. P. Lam, «Simulation based parametric analysis Part-I: One Factor at-a-Time (OAT) Evaluation of Enclosure Measures for building 661,» Centre for building Performance and Diagnostics, Carnegie Mellon University, Pittsburgh, Pennsylvania, 2012.

[58] S. M. Saridar, «The impact of façade design on daylighting performance in office buildings the case of Beirut, Lebano. the case of Beirut, Lebano.,» University of Newcastle, 2004.

[59] N. Ibrahim y A. Zain-Ahmed, «Energy saving due to daylighting: a simplified prediction tool for wall envelope design of air-conditioned office buildings in Malaysia.,» Built Environment Journal, vol. 3, nº 1, pp. 63-75, 2006.

[60] C. Velan, «Evaluation of system design parameters for optimum energy performance of a green IT building. Doctoral thesis,» Dr. M.G.R. educational and research institute, Chennai, 2013.

[61] C.-M. Lai y Y.-H. Wang, «Energy-saving potential of building envelope designs in residential houses in Taiwan,» Energies, vol. 4, pp. 2061-2076, 2011.

[62] M. Ferrara, M. S. E. Filippia y V. Cravinoa, «A simulation-based optimization method for the integrative design,» Energy Procedia, vol. 78, p. 2608 – 2613, 2015.

[63] M. Pesenti, G. Masera y F. Fiorito, «Shaping an Origami shading device through visual and thermal simulations,» Energy Procedia, vol. 78, pp. 346-351, 2015.
[64] F. Ascione, R. F. De Masi, F. R. S. de Rossi y G. P. Vanoli, «Optimization of building envelope design for nZEBs in Mediterranean climate: Performance analysis of residential case study,» *Applied Energy*, vol. 183, p. 938–957, 2016.

[65] Y. Y. R. Pan y Z. Huang, «Energy modeling of two office buildings with data center for green building design,» *Energy and Buildings*, vol. 40, p. 1145–1152, 2008.

[66] W. Xu, K. P. Lam, A. Chong y O. T. Karaguzel, «Multi-Objective Optimization of Building Envelope, Lighting and HVAC Systems Designs,» ASHRAE and IBPSA-USA., Salt Lake City, UT, 2016.

[67] A. D. Rincón-Quintero, L. A. D. Portillo-Valdés, A. Meneses-Jacomé, C. G. Cárdenas-Arias, C. L. Sandoval-Rodríguez, J. G. Ascanio-Villabona, B. E. Tarazona-Romero, J. A. Sandoval-Baldión1, J. C. Ortiz-Rios1 y R. A. Mantilla-Olejua, «Manufacture of hybrid pieces using recycled R-PET, polypropylene PP and cocoa pod husks ash CPHA, by pneumatic injection controlled with LabVIEW Software and Arduino Hardware,» *IOP Conference Series: Materials Science and Engineering*, vol. 844, 2019.

[68] CIBSE, «Environmental Design: CIBSE Guide A,» seventh ed, Bros, Great Britain, 2006.

[69] C. L. Sandoval-Rodríguez, J. G. A. Villabona, C. G. Cárdenas-Arias, A. D. Rincon-Quintero y B. E. Tarazona-Romero, «Characterization of the mechanical vibration signals associated with unbalance and misalignment in rotating machines, using the cepstrum transformation and the principal component analysis,» *IOP Conference Series: Materials Science and Engineering*, vol. 844, 2019.

[70] A. A. Chernousov y B. Y. Chan, «Numerical simulation of thermal mass enhanced envelopes for office buildings in subtropical climate zones,» *Energy and Buildings*, vol. 118, p. 214–225, 2016.

[71] C. L. Sandoval-Rodríguez, J. G. A. Villabona, C. G. Cárdenas-Arias, A. D. Rincon-Quintero y B. E. Tarazona-Romero, «Characterization of the mechanical vibration signals associated with unbalance and misalignment in rotating machines, using the cepstrum transformation and the principal component analysis,» *IOP Conference Series: Materials Science and Engineering*, vol. 844, 2019.

[72] M. Mayhoub y R. Labib, «Towards a solution for the inevitable use of glazed facades in the arid regions via a parametric design approach,» The Proceedings of CIE, Manchester, UK.

[73] A. Kirimtat, B. K. Koyunbaba, I. Chatzikonstanti y S. Sariyildiz, «Review of simulation modeling for shading devices in buildings,» *Renewable and Sustainable Energy Reviews*, vol. 53, p. 23–49, 2016.

[74] C. G. Cárdenas-Arias, A. D. Rincón-Quintero, A. Santos-Jaimes, C. L. Sandoval-Rodríguez, D. F. Rojas-Gomez y S. J. Ardila-Galvis, «Elasticity modulus variation of the AISI SAE 1045 steel subjected to corrosion process by chloride using tension test destructive,» *IOP Conference Series: Materials Science and Engineering*, vol. 844, 2019.

[75] I. Da-Silva y E. B. Ssekulima, «In International conference, towards sustainable energy solutions for the developing world,» de *Domestic use of energy conference. Cape Peninsula University of Technology, Cape Town, South Africa*, 2011.

[76] T. M. Echenagucia, A. Capozzoli, Y. Cascone y M. Sassone, «The early design stage of a building envelope: Multi-objective search through heating, cooling and lighting energy performance analysis,» *Applied Energy*, vol. 154, pp. 577-591, 2015.

[77] F. D. Luca, H. Voll y M. Thalfeldt, «Horizontal or Vertical? Windows’ layout selection for shading devices optimization,» *Management of Environmental Quality: An International Journal*, vol. 27, nº 6, pp. 623-63, 2016.

[78] M. d. l. P. Diulio, G. R. Netto y R. a. C. J. D. Berardi, «Impacto de la envolvente en la demanda de energía en calefacción residencial de la región metropolitana de La Plata, tomando como
caso testigo el reciclado energético de una vivienda,» Ambiente Construido, vol. 16, nº 1, pp. 55-70, 2016.

[79] O. ESCORCIA OYOLA, «Validación del reacondicionamiento térmico de viviendas para la reconstrucción pos-terremoto 2010: Dichato, Chile.,» Revista de la construcción, vol. 12, nº 2, pp. 54-71, 2013.

[80] D. PAVEZ-GALLEOS y L. MEZA-MARIN, «Aplicación de un subsidio de reacondicionamiento térmico de viviendas en la Región Metropolitana de Chile.,» Revista de la Construcción, vol. 17, nº 3, pp. 401-411, 2018.

[81] M.-P. N y E.-S. J, «Envolventes eficientes : relación entre condiciones ambientales espacios confortables y simulaciones digitales,» Revista de Arquitectura, vol. 21, nº 1, pp. 90-109, 2019.

[82] F. Kurtz, M. Monzón y B. López-Mesa, «Obsolescencia de la envolvente térmica y acústica de la vivienda social de la postguerra española en áreas urbanas vulnerables. El caso de Zaragoza,» Informes De La Construcción, vol. 67, nº 1, 2015.

[83] J. L. P. Galaso, «Simbiosis entre clima, lugar y arquitectura. Desarrollo de estrategias bioclimáticas aplicadas en la Costa del Sol Occidental. Tesis doctoral,» Universidad de Málaga, Málaga. España, 2015.