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Artículo

Construction or Building Techniques in Housing: A Literature Review

Técnicas de Construcción o Edificación en Vivienda: Una Revisión de la Literatura

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Abstract: This study aims to identify the recurring construction techniques used in buildings for residential use. The methodological procedure adopted was the systematic literature review based on the Prisma 2020 flow diagram. The searches were carried out on the following data base platforms: Google Scholar, Science Direct, Scopus, and Web of Science. The results showed a map of the most used processes and materials, such as masonry with different kinds of blocks, timber, and metallic structures. The results presented herein provide bibliographical references to help researchers and professionals.
Keywords: housing; building systems; literature review; masonry; construction system

Resumen: Este estudio tiene como objetivo identificar las técnicas constructivas recurrentes utilizadas en los edificios de uso residencial. El procedimiento metodológico adoptado fue la revisión sistemática de la literatura con base en el diagrama de flujo Prisma 2020. Las búsquedas se realizaron en las siguientes plataformas de bases de datos: Google Scholar, Science Direct, Scopus y Web of Science. Los resultados mostraron un mapa de los procesos y materiales más utilizados, como albañilería con diferentes tipos de bloques, madera y estructuras metálicas. Los resultados presentados aquí proporcionan referencias bibliográficas para ayudar a investigadores y profesionales.
Palabras clave: vivienda; sistemas constructivos; revisión de literatura; albañilería, sistema constructivo

1. Introduction

The production chain of the construction industry spans a set of activities and agents aiming to materialize a certain design. The design quality and the final success of a construction depend on proposals that meet in the best way the many determinants and circumstances of the project. Choosing one construction system over another is a process that includes environmental, social, economic, cultural, and political assessments, and the performance of what has been designed is conditioned by the specifics of labor, materials and equipment. This whole set can be called the building process.

The construction industry accounts for more than one third of the global consumption of final electric power and almost 40% of all direct and indirect CO2 emissions. The electric power demand to construct and maintain buildings is constantly growing, fostered by the easy access to electric power in developing countries, by the increase of built areas and the use of building-support equipment and machinery, such as air-conditioning systems (International Energy Agency, 2020).

Studies on building technologies in housing production, both the most used ones or the exceptional cases, are significant for providing data and analyses on the impact of the construction industry.

Thanks to the need of investigating building processes in housing, Systematic Literature Mapping became an efficient tool to create a ranking scheme of the processes used in the global context. The main objective of this article is to identify the recurring construction processes used for residential-use buildings.

2. Literature Review

We have developed a systematic narrative review in order to document the state-of-the art of the literature on this subject and to examine the main approaches and types of analyses. The literature mapping was based on the PRISMA2020 flow diagram which was developed for systematic reviews (Page et al., 2021). This flow diagram comprises three main stages: identification, screening and included.

An analytical model of each stage was developed to allow the aforementioned stages to be completed (see Table 1). Three phases were proposed for the identification stage, three phases for the screening stage, and for the final stage we quantified the articles that were singled out to be part of this article. We chose to focus on studies developed in articles due to the fact that data included in articles were already synthetized in these articles. The literature review was completed on December 3rd, 2020 with the terms “constructive system” AND “housing”, on the following databases: Google Scholar, ScienceDirect, Scopus and Web of Science. The results are presented in Table 2. Table 2 also shows the available filters in the four databases.

Table 1 - Analytical Model for each stage:

<table>
<tr><th>STEP 1 - IDENTIFICATION</th><th>STEP 2 - SCREENING</th><th>STEP 3 - INCLUDED</th></tr>
<tr><td>The article identification stage can be divided into the following phases:</td><td>The stage of sorting articles can be divided into the following phases:</td><td rowspan="8">The article inclusion stage is the final phase of the systematic research, where the full text articles that passed in the initial stages were placed.</td></tr>
<tr><td>1. Identification of the search term and date.</td><td>1. Compiling all articles identified in the previous phase.</td></tr>
<tr><td>“constructive system” AND “housing”;
Dec.12, 2020.</td><td>2. Exclusion of duplicate articles.</td></tr>
<tr><td></td><td>3. Selection of full-text articles assessed for eligibility.</td></tr>
<tr><td>2. Identification of the research bases.</td><td rowspan="4"></td></tr>
<tr><td>Google Scholar;
Science Direct;
Scopus;
Web of Science.</td></tr>
<tr><td>3. Identification of search filters.</td></tr>
<tr><td>Type of document: article;
Languages: English, Spanish and Portuguese.</td></tr>
</table>

Source: Authors, 2022.

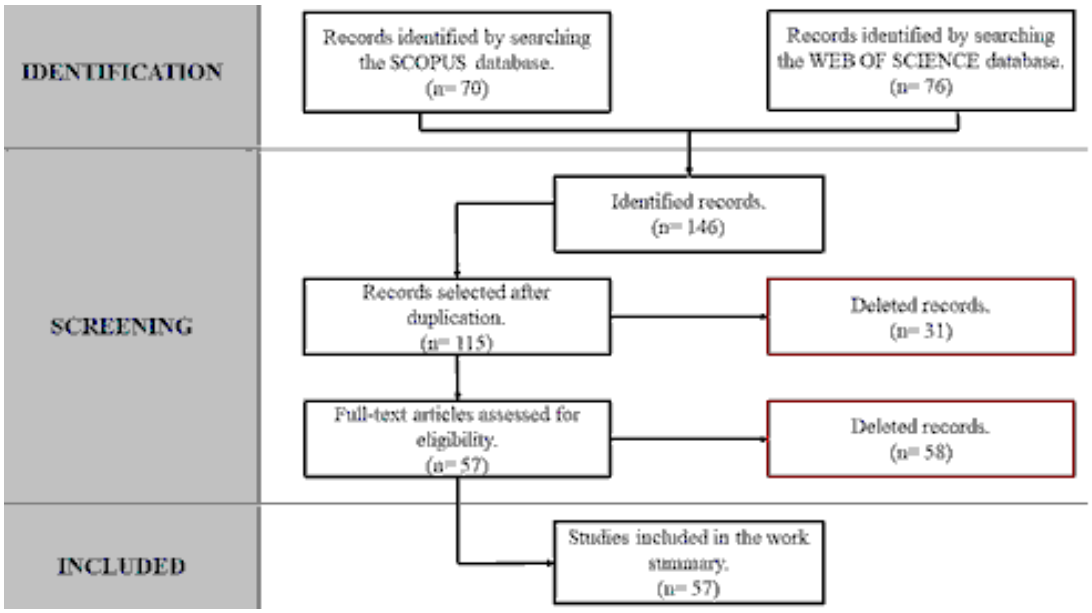
Table 2 - Results of the each of the terms: "constructive system" AND "housing" on the databases

Parameters / Database	Google Scholar	ScienceDirect	Scopus	Web of Science
Link	scholar.google.com	www.sciencedirect.com	www.scopus.com	webofknowledge.com
Search result number	69,100	7,114	160	146
Searched for	All kinds	All kinds	All kinds	All kinds
Order	Relevance or date	Relevance or Date or All types of access or Open access articles or Open file article	Date or Citation or Relevance or First Author or Source Title	Recent or added date or quote or usage count or relevance or first author or source title or conference title
Available filters	• Year	• Year	• Year	• Year
	• Relevance or date	• Publication title	• Author's name	• Web of Science categories
	• Include patents	• Topic	• Subject area	• Types of documents
	• Include citations	• Content type	• Document Type	• Organizations
			• Source title	• Funding agencies
			• Keyword	• Free access
			• Affiliation	• Authors
			• Country/Territory	• Source titles
			• Type of source	• Book series titles
			• Language	• Conference titles
				• Countries / Territories
				• Publishers
				• Group of authors
				• Languages
				• Search area
				• Web of Science Index

Source: Authors, 2022.

Of the four databases used, Google Scholar classifies the articles through an algorithm considering factors such as number of mentions, authors and publisher; ScienceDirect classifies them by date or importance and types of access; Scopus and Web of Science show an option to organize the results by number of mentions. The four databases present as a common trait the possibility of classifying documents according to their significance or date. The authors chose the Scopus and Web of Science databases to proceed with this review due to the amount of documents found and the available filters.
As a result of a general search in the two databases, we found 306 documents in the identification stage. The final phase of this stage used the following filters: type of documents (articles) and language (English, Spanish and Portuguese); other kinds of publications – such as symposium proceedings, books and dissertations – were excluded from the study. In the second stage of the research, the authors excluded duplicate articles and selected articles that were eligible to make up the scope of this study. The third stage presents the number of selected articles, as shown in Figure 1.

Figure 1 - Result of the systematic map developed from the terms "constructive system" AND "housing" on the databases.



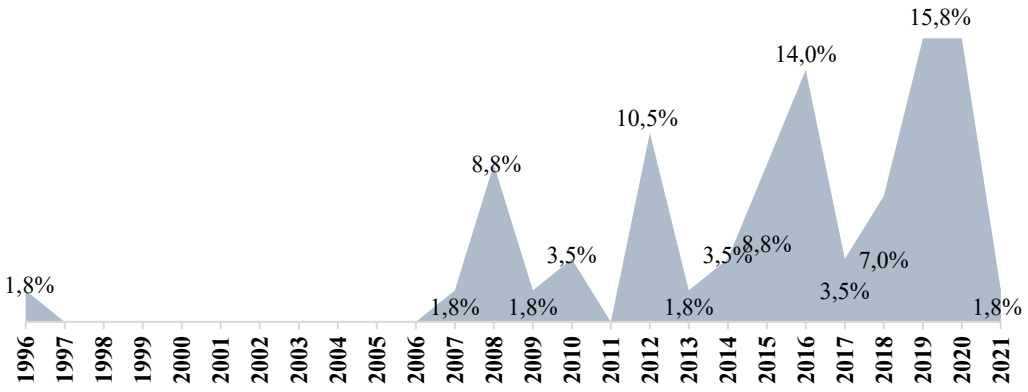
Source: Adapted from Page *et al*., 2022.

The final stage of the systematic review is the inclusion of articles which incorporated the full-text articles that were approved in the preliminary stages. After the selection, 57 articles were included in the last stage (around 49%), and 50.4% were excluded because they did not address the subject and only used the terms of the investigation, which caused them to be selected in the first two stages.
Over 63% of the eligible articles are written in English, 28.1% in Spanish and only 3.5% in Portuguese. This shows that most indexed journals use the English language. Spanish articles were significant, given that Spain has indexed and well-known journals on topics regarding the construction industry.
There are few articles in Portuguese due to the meagre technical and scientific production in this area and also the lack of indexation of many Brazilian journals.

3. Results and Discussion

Interest in studies on housing building systems has increased irregularly since 2007, after almost 10 years without achieving any significant percentage in the total number of publications (Figure 2). In all the works published on the subject in this period, the highest percentage was 15.8% in 2019 and 2020. Even with the restrictions imposed by the coronavirus pandemic (Covid-2019), some studies published in 2020 feature field trips conducted previously. Among them stand out a single-family metallic structure prototype discussion (Campos & Bernardo, 2020a); an analysis of experimental studies on energy efficiency in historical buildings in Seville, Spain; two studies on riverbank landscapes and the loss of different houses due to floods along the Tamsui river in Taipei, Taiwan (Wu et al., 2021) a study on the impact of climate change on the energy performance of residential buildings in order to point to potential design strategies (Soutullo et al., 2020).
The other studies published in 2020, in which field surveys and measurements were not explicitly stated as methods, address subjects such as carbon dynamic life cycle and the costs of residential construction with ceramic-block masonry and prefabricated reinforced concrete panels (González Mahecha et al., 2020), quantification of the impact of climatic changes during the life cycle of the buildings (Rosse Caldas et al., 2020), the work of Ignacio Álvarez Castelao (Salas, 2020) and eight structural systems of prototypes presented in the "Solar Decathlon" competition in 2014 and 2015 (Luna-Tintos et al., 2020).

Figure 2 - Articles published per year.



Source: Authors, 2022.

The identified works published in Portuguese feature studies on the subject in the Brazilian context. The environmental quality and the sustainability of building systems adopted in social vernacular houses (Brandao et al., 2019) are discussed, as well as the relative costs of structural masonry and wood framing in Brazilian house-building through case studies (Silva & Sperandio, 2018).

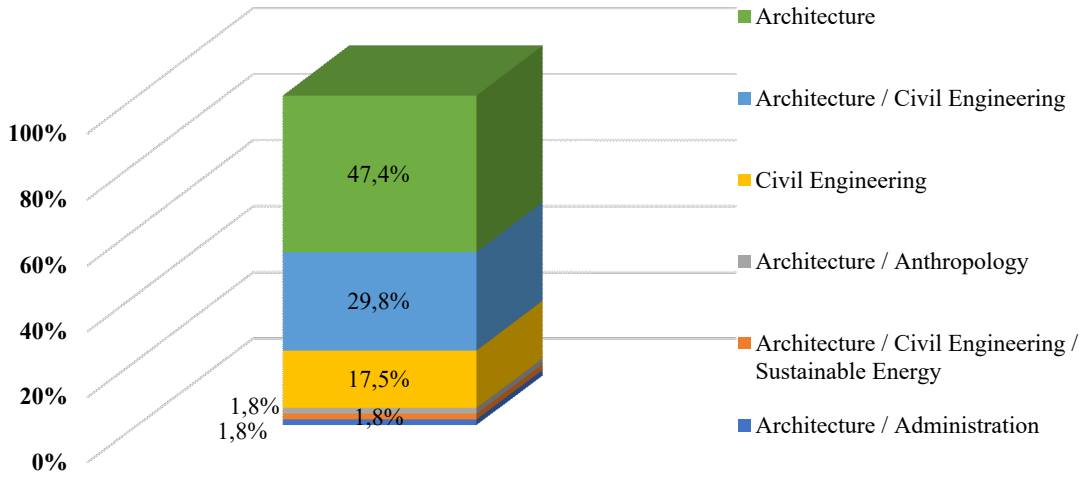
Table 3 - Dimensions of sustainability

DIMENSIONS	%
Policy	8,8
Social	38,6
Economy	43,9
Cultural	47,4
Environmental	98,2

Source: Authors, 2022.

Environmental sustainability is the most addressed dimension (98.2%), both because it is comprehensive and due to contemporary concerns regarding the quality of the built environment for residential use. Cultural and economic aspects are equally addressed (47.4%); social aspects are featured in 38.6% of the articles, and the political aspect was the least pointed out (see Table 3). Although all these aspects are related, this selection tried to pinpoint the specific aspect mentioned in the article.
All selected works that address political aspects have also discussed environmental issues and other subjects (Soutullo et al., 2020)(Goossens & Gomez-Meneses, 2015; Masferrer et al., 2012; Safapour et al., 2019; Zhang et al., 2011). An economic approach was considered in some studies and cultural issues were also included (Masferrer et al., 2012; Safapour et al., 2019), while social topics were addressed in other articles (Goossens & Gomez-Meneses, 2015; Zhang et al., 2011).

Figure 3 – Fields of Knowledge



Source: Authors, 2022.

As expected, the fields of architecture and engineering address the topic the most, although other fields were also present in the final selection, such as administration and anthropology, see Figure 3. During the eligibility selection process, over 80 articles from other areas were removed. They used the designated terms, but with different connotations, without developing any aspect specifically related to the building process. While there is an example of study which lies in the field of administration (Safapour et al., 2019), there is also another that comes from anthropology (Skewes, 2016).
Despite this difference, works that combine architectural knowledge with different areas of engineering have in common a cultural approach.

Regarding funding from agencies of research support, results indicated that only 33.3% of all studies were carried out with some kind of financial aid. This result makes it clear that many researchers rely on the institutions they are related to, which partially or totally fund their studies. This proves the scarce resources that have been invested in academic research in the fields of architecture, urbanism and construction, even prior to the Covid-2019 pandemic.

Brazilian agencies National Council for Scientific and Technological Development (CNPq in the Portuguese acronym) and Coordination for the Improvement of Higher Education Personnel (CAPES in the Portuguese acronym) funded the highest number of studies. The main funding agency was CNPq (González Mahecha et al., 2020; Gonzalez Stumpf et al., 2014; Rosse Caldas et al., 2020; Silva et al., 2016) and Capes stands out in the second place (González Mahecha et al., 2020; Gonzalez Stumpf et al., 2014; Marvila et al., 2019).

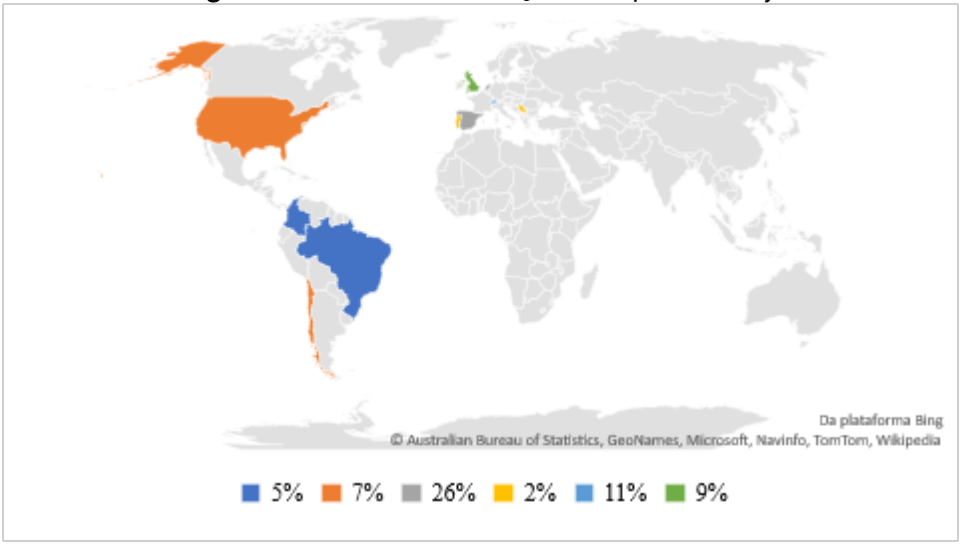
As for the journals with more published works, the authors have noted that in the first place comes Energy and Buildings, whose main goal is to present new research data and new practices aimed at reducing buildings' energy needs and improving the quality of buildings' internal environment. This piece of information indicates that one of the greatest concerns regarding contemporary building systems is the assessment of energy expenses during the life cycle of the buildings (see Table 4).

Table 4 - The ten journals that published the most on the subject

JOURNALS	%
Energy and Buildings	12
Informes de la Construcción	9
Journal for Housing Science	5
Construction and Building Materials	5
VCL arquitectura	4
Sustainability	4
Revista de la Construcción	4
Journal of Building Engineering	4
Indoor and Built Environment	4
Energies	4

Source: Authors, 2022

Figure 4: Distribution of the journals per country



Source: Authors, 2022.

Spain and Netherlands had 26% of the selected articles, followed by Switzerland with 11%, United Kingdom with 9%, Brazil and Colombia with 5% and finally Portugal and Serbia with 2% (Figure 4).

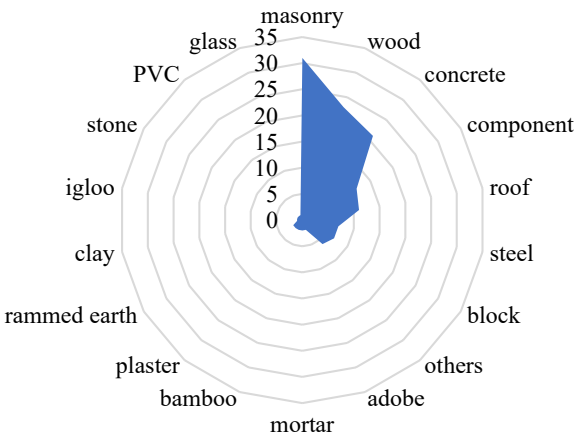
Figure 5 shows an analysis produced from the keywords of eligible articles. The authors have observed that the term "constructive system" is not much used, whereas "housing" is the most recurrent term in the articles. Chile stands out because many case studies were conducted in the country. However, what Figure 5 may suggest is that the terms used in the research on construction processes differ depending on the specific journals and countries involved, so that research conducted prior to the search for specific keywords is an essential step to achieve satisfying results.

Figure 5 – Keywords cloud.

Source: Authors, 2022.

Figure 6 presents the most recurring construction systems in the analyzed articles and shows that masonry-related studies occupy the first place in terms of published topics. Next come timber structure articles, then studies related to reinforced concrete, and in the fourth position are articles focusing on several specific housing components, followed by items related to roofing. Last in this list was glass.

Figure 6 – Distribution by systems.



Source: Authors, 2022.

3.1 – Masonry-Based Systems

Figure 6 shows the distribution of structural systems and materials pointed out by the studies, the most frequent being masonry systems. Studies can be classified according to their different approaches:

A. Environmental Impact and Comfort:
- Incorporated energy in masonry housing, as compared to reinforced concrete structures (Gonzalez Stumpf et al., 2014);
- Energy efficiency in: houses (Silva et al., 2016) and masonry houses in hot and humid climates (Y. García et al., 2019); in historical buildings made of ordinary solid brick masonry (Caro & Sendra, 2021); in 17 different typologies of housing in the South of Portugal (Brás et al., 2014); in ceramic-block double masonry (Figueiredo et al., 2016);
- Assessment of environmental impact from: masonry as compared to alternative systems (Rosse Caldas et al., 2020); ceramic block masonry with PVC membranes (Mendonça et al., 2017); comparison of several masonry building systems (Soutullo et al., 2020); comparative analysis of pre-fabricated systems in reinforced concrete and structural masonry (González Mahecha et al., 2020);
- Thermal comfort evaluation (Brumaru & Cobârzan, 2008); thermal performance of a house model with England's eight most common building systems, including different kinds of masonry (L. Rodrigues & Gillott, 2013);
- Life Cycle Assessment – CLA (ACV in the Portuguese acronym) of two structural systems (traditional masonry and steel structure) of a building in three different cities in Belgium, Portugal and Sweden (Rossi et al., 2012);

B. Historical Approach: historical houses in the North of Spain (Salas, 2020); production of popular building culture and heritage in Caracas (Rosas Meza, 2009); historical and cultural factors of traditional construction (Orta et al., 2016) and analyses of traditional houses with vaulted roofs made with ceramic brick masonry (Masferrer et al., 2012);

C. Comparative assessment of performance in earthquakes in two house designs, one with adobe masonry and the other with ceramic block masonry (Orta et al., 2016);
D. Alternative materials: experimental masonry with adobe-and-reed blocks (Prado García & Illanes Garat, 2008); bio-concrete and bamboo masonry (Rosse Caldas et al., 2020);
E. Analyses of composite systems of prefabricated concrete and structural masonry (González Mahecha et al., 2020);
F. Assessment of mechanical resistance: Physical and mechanical performance of soil-cement blocks to be used in houses (Bedoya-Montoya, 2018) and destructive tests of resistance to compression in ceramic-block structural masonry (Marvila et al., 2019).

The most addressed topic refers to the environmental impact of single-mode or combined masonry techniques, either by themselves or compared to other building systems. The studies indicate that different kinds of masonry, whether of ceramic hollowed blocks or solid mud bricks, are less impactful than reinforced concrete systems.

3.2 – Timber Structural Systems

Timber structures were the second most quoted category, whether massive, laminated, glued, OSB or others. The approaches of the articles referring to these structures can be classified in:

A. Historical: Japanese traditional house in timber structure and its possibilities of disassembly and reuse (Caparrós & Astarloa, 2017); vernacular construction in the Midwest of Brazil with timber structure and wattle-and-daub enclosures (Brandao et al., 2019); historical buildings in cities in the North of Spain (Salas, 2020); Danish architect Knud Peter Harboe's 1950's timber structure houses (Ferrer Forés, 2017b); studies of half-timbered structures in buildings from the 17th and 18th centuries in Madrid (González-Redondo, 2019); indigenous dwellings of the Mapuche territories in Chile (Skewes, 2016) and analyses of timber structure vernacular constructions in Portugal, Turkey, France, England, Greece, Romania, Italy, Spain, Germany, and Scandinavia (Dutu et al., 2012);
B. Comparative Assessment: when comparing the costs of the wood frame building system with conventional masonry, the wood frame was pointed out as the cheaper system (Silva & Sperandio, 2018);
C. Contest Proposals: Design description and analyses for the Elemental Chile contest using a industrialized timber building system (Bonet Miró & Brunelli, 2007);
D. Technological Innovation: innovative proposal of building with timber with the Hybrid Timber Frame (HTF) Cross Laminated Timber (CLT) (Casagrande et al., 2021).

Research on timber structural systems emphasizes analyses of vernacular/historical buildings; only one work addresses a proposal for a competition, and only one article deals with technological innovation.

3.3. Reinforced Concrete Structural Systems

Concrete construction systems constituted the third most frequent approach in the study. Some articles discuss this topic alongside masonry and timber systems, while others focus on the following aspects:

A. Historical: Analysis of a housing tower-block built with reinforced concrete pre-fabricated components in the European post-World War II context (Braghieri, 2019); description and analysis of designs using reinforced concrete and designed by selected architects such as Antonio Bonet (Torres-Dorado & Añón-Abajas, 2019); Jørn Utzon (Ferrer Forés, 2017a) and Knud Peter Harboe (Ferrer Forés, 2017b);

B. Comparative evaluation: Study of traditional and industrialized concrete construction systems for housing use, indicating that industrialization incorporates a rational dimension in its components and allows an abstract conception with its elements (Pich-Aguilera et al., 2008);
C. Contest and events: Analysis of a multifamily housing project with a mixed (concrete and timber) building system for the Elemental Chile Contest (Bonet Miró & Brunelli, 2007) and description of the logistics of the reinforced concrete prefabricated panels, the relationship between industrialization and modern architecture, and how these aspects could be seen in the Chilean Pavilion at the Venice Architecture Biennale in 2014 (Alonso & Palmarola, 2015);
D. Analyses of compound systems: Study of a proposal developed for the city of Manta, in Ecuador, with a building system comprising compacted BTC15 mud-block structural walls and sugar cane panels, reinforced concrete for specific structural elements such as foundations or floors, and ground-floor walls made with BTC14 blocks (del Caz-Enjuto et al., 2019);
E. Performance: articles assessing the potential for reducing energy demand in residential buildings by intervening in the external envelope (Domínguez et al., 2012); hybrid multifunctional components made with a mix of soil and concrete mortar (Alavéz-Ramírez et al., 2018); and the thermal performance of a prefabricated concrete slab with macroencapsulated PCM (Phase Change Materials) (Navarro et al., 2015);
F. Resistance assessment: analysis of the use of Steel Reinforced Grout (SRG) in the execution of reinforced concrete subject to bending in repair and reinforcement works (Larrinaga et al., 2020).

The two most addressed topics refer to performance evaluation and historical analyses researches. In both cases, there are works that address prefabricated reinforced concrete constructions, as well as other constructive processes.

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3.4. Metallic Structural Systems

Prototypes were employed to conduct several experimental evaluations of metallic structural systems in residential buildings and the results were published in two complementary articles in different journals (Campos & Bernardo, 2020a, 2020b). Two other articles originated from the same investigation discuss metallic structure housing resistant to earthquakes (Morganti & Tosone, 2010), as well as the use of those results to assess houses located in earthquake-prone areas in Italy (Morganti & Tosone, 2008).

The typologies of the designs and the geometry applied to the projects by Antonio Bonet and Josep Puig Torné are analyzed (J. F. R. García, 2015).
In their preliminary assumptions for the research, the authors expected metallic structure housing to be present in more publications, yet this was the least addressed system as compared to masonry, concrete, and timber structures.

3.5. Other works

A set of articles address materials that are less employed throughout the world but that can be used in conjunction with different structural systems, such as cork (García-Pérez et al., 2017); straw, bark, reed (Cook, 1996); and straw with binders (Miličić et al., 2019).

Other authors dedicate themselves to portions or components of the housing building, such as roofing structures (Argüello Méndez & Cuchí Burgos, 2008; F. Rodrigues et al., 2018) and flooring (Soriano et al., 2016); hybrid solutions with several materials (Damico et al., 2012; Zhang et al., 2011) and polystyrene components (Brumaru & Cobârzan, 2008; Cobîrzan et al., 2012).

4. Conclusion

The results have shown that systems using different kinds of masonry, timber structures and reinforced concrete were the most recurring in worldwide investigations on the production of residential buildings. The most frequent objectives were the study of vernacular or historical constructions and analyses of their structural and performance systems, always considered more efficient than contemporary constructions.
The most frequent studies are those which address buildings with hybrid systems and those assessing environmental impact, such as comfort and energy saving. Only very rarely do articles address aspects of technological innovation, in spite of the copious existing innovations in contemporary architecture, engineering and construction industries.
The Systematic Literature Review was the methodology employed in this research and it proved to be an efficient tool to detect topics of production on the subject in three languages, enabling the authors to systematize and list the data found in the international context. Clearly, this topic is not specifically approached by the indexed studies and there are many gaps to be researched on building systems used for housing, especially as regards contemporary production. These results hereby presented can stimulate new investigations in order to deepen the knowledge of the field.

5. Acknowledgment

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