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THE WORLD HOUSING ENCYCLOPEDIA ONLINE DATABASE: A RESOURCE ON HOUSING CONSTRUCTION PRACTICES IN EARTHQUAKE REGIONS

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Abstract

The World Housing Encyclopedia (WHE) online database constitutes over 160 housing reports from 44 seismically active regions of the world. The WHE development efforts have been primarily supported by the Earthquake Engineering Research Institute (EERI) as well as the International Association of Earthquake Engineering (IAEE) since its inception in 2000. The database is the result of an enormous amount of volunteered time and expertise provided by engineering professionals from around the world. Each report contains an in-depth description of a specific housing typology within a given region or a country, which is described by the more than 150 attributes/features. The attribute information captured through each report falls into six broad categories: general information, structural features, construction process, socio-economics, earthquake performance, and retrofitting techniques. In 2013, the WHE housing report database was updated to an interactive web-based online system giving users more flexibility in accessing the reports. The new system allows users to search all reports by keywords and to filter the list of reports by specific attributes. Additionally, each report now contains high-resolution images showing typical housing construction, structural details, building plans (if available), and access to photos of typical building performance after earthquakes. The repository now serves as a valuable tool for understanding the exposure of physical building assets, their structural and occupancy characteristics and further informs better selection of vulnerability models for the estimation of earthquake-induced losses after an earthquake, e.g., the U.S. Geological Survey's Prompt Assessment of Global Earthquakes for Response (PAGER) system (http://earthquake.usgs.gov/data/pager/) or the efforts related to the Global Earthquake Model (GEM) development (http://www.globalquakemodel.org/). The online database further enables quick access to detailed engineering information and lessons related to earthquake-resistant design and construction. This paper elaborates on a broad coverage of these reports, various new features of the online database, and discusses how the engineering information contained within each report can be used to improve construction practices in areas with vulnerable housing construction types.

Keywords Housing, Physical seismic vulnerability, Online database

1. The World Housing Encyclopedia

1.1 Background

The World Housing Encyclopedia (WHE) is an encyclopedia of housing construction practices in seismically active areas of the world, hosted and primarily supported by the Earthquake Engineering Research Institute (EERI) and the International Association for Earthquake Engineering (IAEE). The WHE project was inaugurated in January 2000 at the 12th World Conference on Earthquake Engineering in Auckland, New Zealand. Since that meeting, volunteer participants have designed the website, contributed information, and promoted the use of the site with colleagues. For some construction types, this initiative is one of the few, if not the only place where such detailed information is available in English. The goals of the WHE are: to share knowledge on housing construction practices; to encourage use of earthquake-resistant construction technologies; to develop guidelines and technical resources for improving seismically vulnerable construction; and to offer services and technical support to communities across the world on earthquake-resistant housing technologies [1].

The WHE web-based repository now helps to efficiently disseminate earthquake-resistant construction practices from different parts of the world. The database helps to highlight the examples of construction types that perform well during an earthquake, and to also bring attention to the specific seismic deficiencies associated with certain construction types that lead to poor performance and hence contribute to damages and loss. The housing reports are also designed to be region- or country-specific, thereby addressing the influence of local culture, building design and construction technologies, locally available work materials, and the skill level of those involved in the various construction phases of these housing types.

1.2 Housing Report Overview

The original housing report form was developed as a standardized questionnaire with over 60 questions, covering relevant aspects of housing construction, e.g., architectural features, structural systems, seismic deficiencies and strengths, performance during past earthquakes, available strengthening technologies, building materials used, the construction process, and insurance. The attribute information captured through each report falls into six broad categories: general information, structural features, construction process, socio-economics, earthquake performance, and retrofitting techniques. The general information provides background about the regions where the construction type is found, how long it has been in practice, and a general summary. The structural features section contains information on the housing type's structural system, i.e., roof, floors, walls, etc. The construction process section provides insight into the housing type's building materials as well as the design/construction process, building design codes and permit process, building maintenance processes, and construction cost. The socio-economic section looks beyond the building's structure and focuses more on the demographics and socio-economic conditions of building owners and/or occupants. The earthquake performance section details seismic resistant features, if any, of the housing type as well as documented performance of the housing type during previous earthquakes. Finally, the retrofitting section describes any seismic strengthening provisions that have been applied to the construction type. An important feature of the WHE report is that it is able to describe features of both non-engineered rural housing (e.g., adobe masonry) and urban high-rises (e.g. concrete shear wall buildings, prefabricated concrete panel buildings, etc.) in a structured and consistent way.

In 2014, the housing report form was updated in order to clarify questions, remove questions that are rarely answered, add questions to provide important additional information, and modify questions to better align the Housing Reports with the GEM Building Taxonomy [2]. The new form contains 80 questions in the categories of: General Information, Structural Features, Building Materials and Construction Process, Socio-Economic Issues, Performance in Earthquakes, and Retrofit Information. More detailed information about the information contained in these sections is presented in section 3 of this article.

As part of the update process, all reports in the database were transferred to the new format. Additionally, during this transfer process, original report authors were contacted to see if they would like to update the

originally provided information in their reports. In the end, over 30 reports were updated with new information, including notes about performance of the building types during earthquakes that had occurred since the reports were originally written.

The compilation of housing reports represents hundreds of hours of volunteer time and expertise by earthquake engineering professionals from around the world. Each report is a comprehensive study of a regional housing construction type completed by, or in collaboration with, regional experts. Once submitted, each report is then peer-reviewed by an international expert who is knowledgeable about the construction type and, preferably, the region addressed in the report. In addition, members of the WHE committee cross-check the report, provide an editorial quality assurance, and assist the authors in preparing the final version which is then published online.

1.3 Short Housing Report

In an effort to increase the number of reports in the WHE database to cover a wider variety of construction types and geographic regions, a shorter version of the housing report form was introduced in 2015. This short version captures the 30 most important fields, thereby drastically reducing the time required to complete a report. As a pilot, the short form was used to document 16 different building typologies in Cuba, which previously had no reports in the database. The availability of the short form should make it easier to contribute to the WHE, which should increase the number of reports in the database.

1.4 Housing Reports Currently Available

New reports are continuously being added to the WHE website [3]. As of September 2016, there were 161 housing reports from 44 countries in the system. Table 1 identifies these 44 countries and shows how many reports are available for each country.

Table 1 – Number of Housing Reports by Country

Cuba	16	Peru	4	Serbia	2	Kazakhstan	1
India	15	Slovenia	4	Palestinian Territories	2	Germany	1
Chile	10	Nepal	4	Switzerland	2	Japan	1
Kyrgyzstan	10	Guatemala	3	Algeria	2	Venezuela	1
Romania	8	Taiwan	3	Nicaragua	2	Trinidad and Tobago	1
Pakistan	8	Greece	3	Belize	2	Indonesia	1
Iran	8	Malawi	3	USA	2	Honduras	1
Italy	7	Bangladesh	2	Mexico	2	Cyprus	1
Russia	6	Turkey	2	Canada	2	Portugal	1
Colombia	5	Syria	2	Pakistan and India	1	China	1
Argentina	5	El Salvador	2	Uzbekistan	1	Malaysia	1

Figure 1 shows the distribution of the housing reports by continent. Figure 2 shows the number of housing reports by building type.

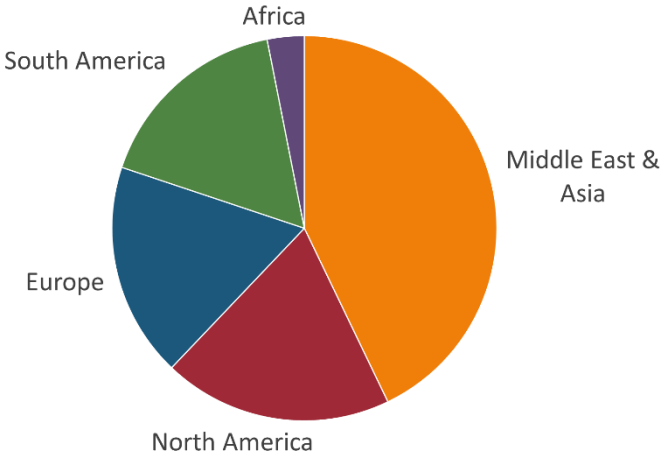

Fig. 1 — Distribution of housing reports by continent

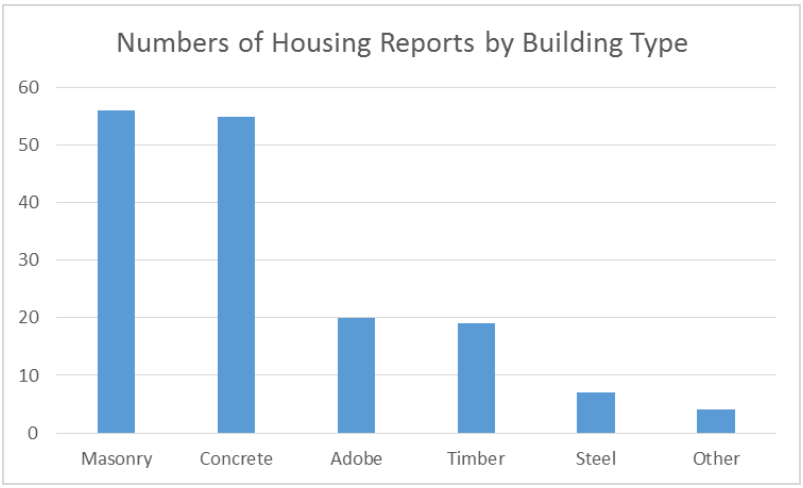

Fig. 2 — Number of housing reports by building type

2. Online Housing Report Database

2.1 Database Features

Along with updating the housing report form, the online database for the WHE was also updated to increase site security and improve the user interface. The new WHE housing report database homepage is shown in Figure 3.

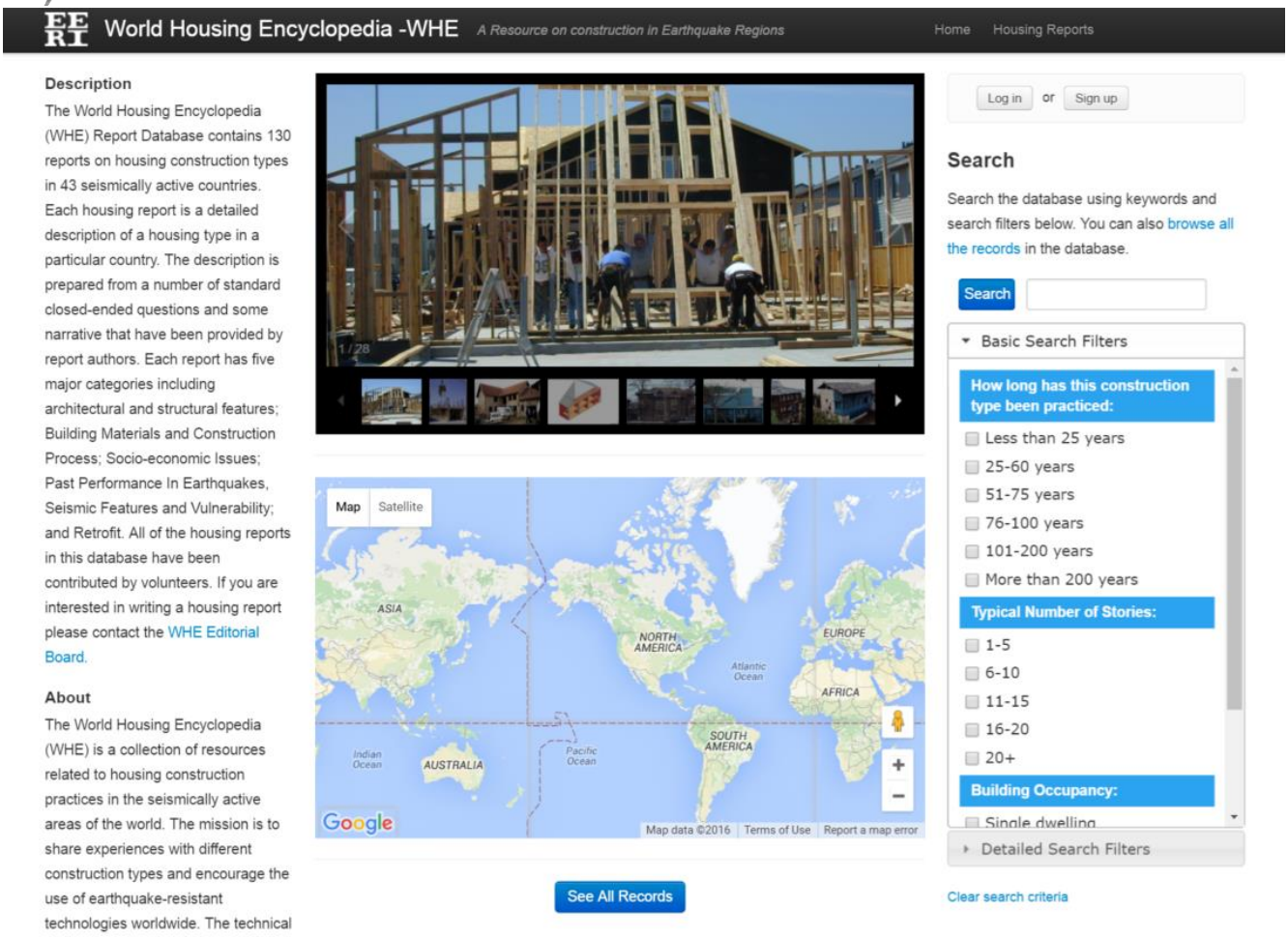

Fig. 3 — A screenshot showing the World Housing Encyclopedia website [3].

The new database has important features that allow the user to search, to make query into, and to filter information from variety of different reports. With the ability to identify and to search for specific sets of parameters, the users can produce contextual summary tables/compilations from the entire repository in a more efficient and quicker way. The information can be sorted or presented by report number, by building type, and (or) by country/region of interest. Additionally, free text search allows users to search all reports for any keywords of interest. Finally, users can further narrow the reports shown in the table using search filters that include: the length of time the construction type has been practiced, typical number of stories, building occupancy, plan shape, typical wall densities, foundation type, roof system, and type of ownership. Figure 4 shows the housing report table sorted by country and showing only reports for single dwelling buildings of construction types that have been practiced for 25-60 years.

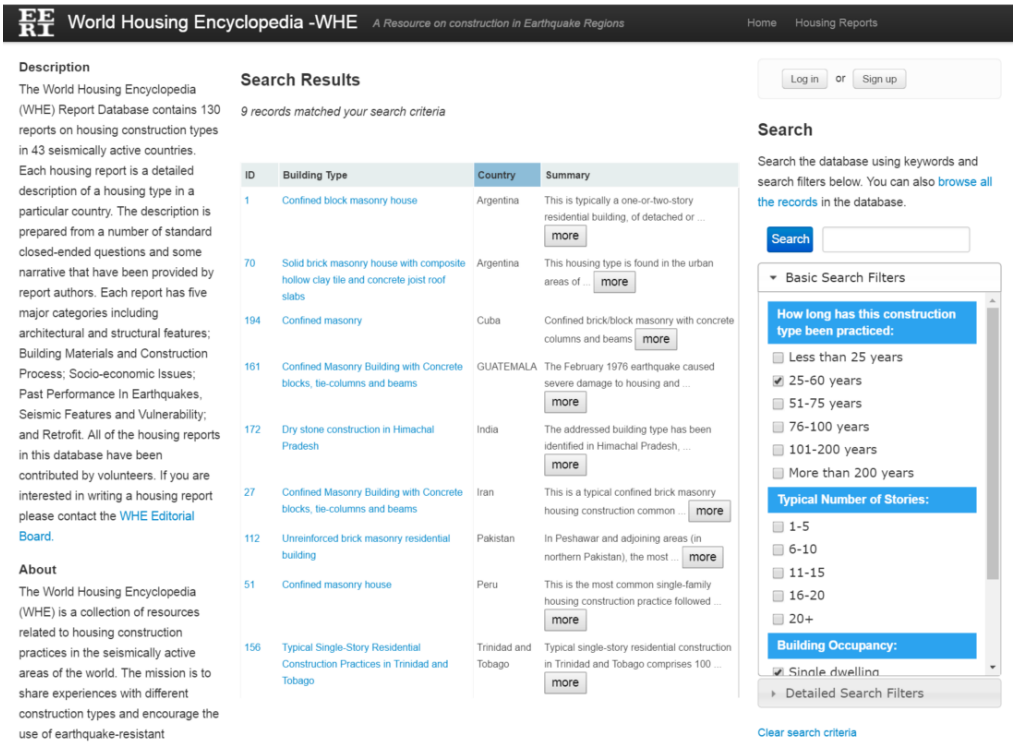

Fig. 4 — Housing report table sorted by country, by building occupancy category and by vintage. In this example, the selection shows reports by each country of single family dwellings that have been built for 25-60 years [3].

2.2 Housing Report Visualization

From the housing report table, an individual housing report can be viewed by selecting the report ID number. Figure 5 shows the layout for housing reports in the new database. The left side of the report shows general information about the building type and the rest of the page shows more detailed information organized in tabbed sections.

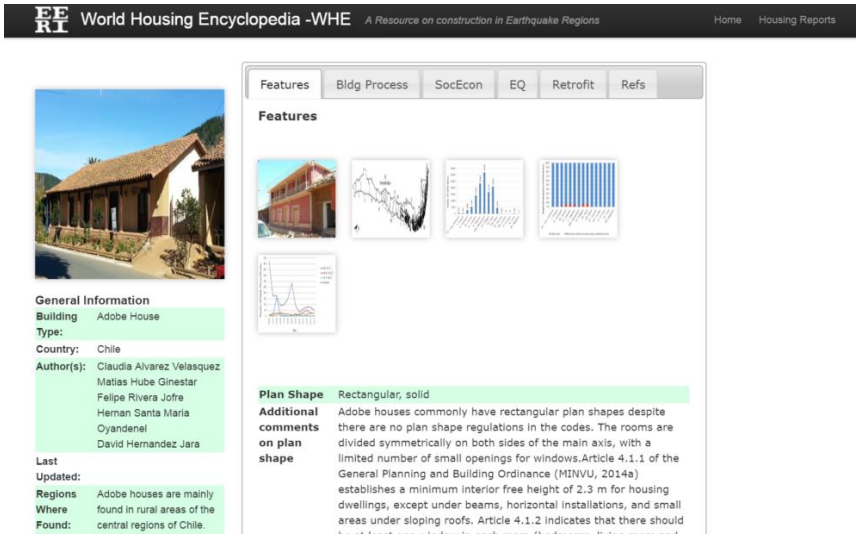

Fig. 5 — View of housing report #179 in the online database

By default, the "Features" tab appears first. Each section of the housing report contains photos and figures relevant to that section of the report. Thumbnails of each image are shown on the page and by selecting a thumbnail, users can see high-resolution versions of these images.

2.2.1 General Information

The "General Information" section is presented on the left side of the report window as shown in Figure 5 for Report 179. The General Information section includes the following information:

	Long Report	Short Report
Building Type	✓	✓
Country	✓	✓
Report Authors	✓	✓
Regions Where Found	✓	✓
Summary of Housing Type	✓	✓
Length of time construction type has been practiced	✓	✓
Whether the construction type is still being practiced	✓	
Building Occupancy	✓	✓
Typical Number of Stories	✓	✓
Terrain where construction type is built	✓	

2.2.2 Features

The "Features" section of the report contains information about the building type's structural system. The Feature information is shown when a housing report is first opened. Figure 5 shows the Feature information of Report 179. The Feature section includes the following information:

	Long Report	Short Report
Plan Shape	✓	✓
Plan Dimension	✓	
Structural System	✓	✓
Gravity Load-Bearing and Lateral Load-Resisting System Types	✓	✓
Wall Densities	✓	
Wall Openings	✓	
Adjacency	✓	
Building Modifications	✓	
Foundation Type	✓	✓
Floor System	✓	✓
Roof System	✓	✓
Type of infill wall material	✓	✓

2.2.3 Building Materials and Construction Process

The second tab in the housing report is the Building Materials and Construction Process section. This section contains information about building materials, the design and construction processes, building codes and standards, building permits, building maintenance, and construction economics. Figure 6 shows the Building Materials and Construction Process section of Report 181. The Building Materials and Construction Process section contains the following information:

	Long Report	Short Report
Description of building materials of walls, foundations, floors, and roofs	✓	
People involved in the design process and their role and expertise	✓	
People involved in the construction process and their role and expertise	✓	
Information about the construction process, phasing, and related issues	✓	
Information about Building Codes, standards, and enforcement	✓	✓
Information about building permits and development control rules	✓	
Typical problems associated with construction type	✓	
Information about building maintenance	✓	
Unit construction cost	✓	✓
Construction labor requirements	✓	

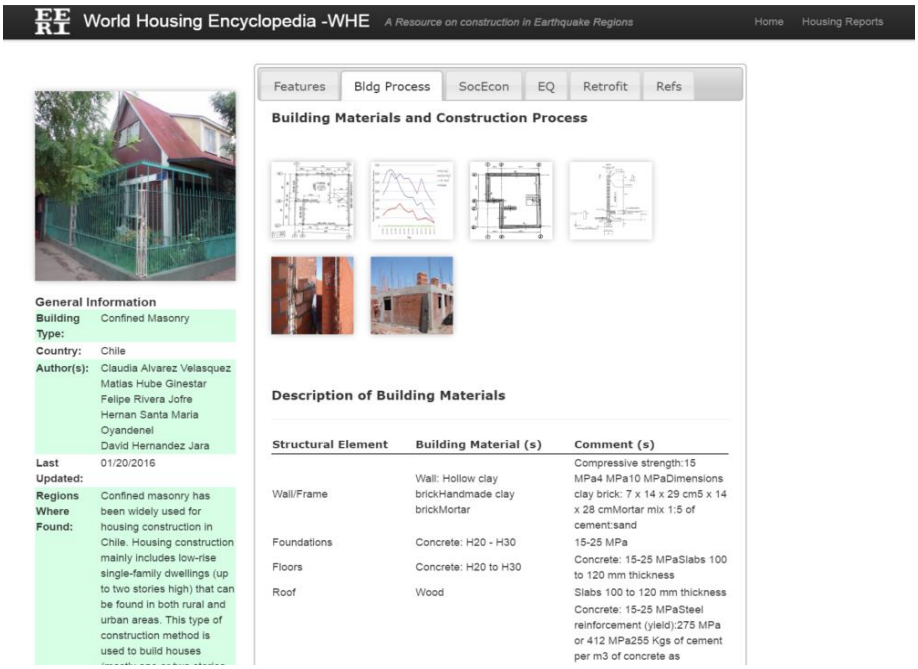

Fig. 6 — Building materials and construction process section of housing report #181

2.2.4 Socio-Economic Issues

The Socio-Economic Issues section includes information about the building type's patterns of occupancy, economic level of inhabitants, building financing and ownership, and earthquake insurance. Figure 7 shows the Socio-Economic Issues section of Report 18. The Socio-Economic Issues section contains the following information:

	Long Report	Short Report
Patterns of occupancy	✓	
Typical number of inhabitants during day and in evening	✓	✓
Economic level of inhabitants	✓	✓
Typical source of financing for this building type	✓	
Type of ownership for this building type	✓	
Availability of earthquake insurance	✓	
Earthquake insurance coverage and cost	✓	✓
Earthquake insurance cost comparison for new and retrofitted buildings	✓	

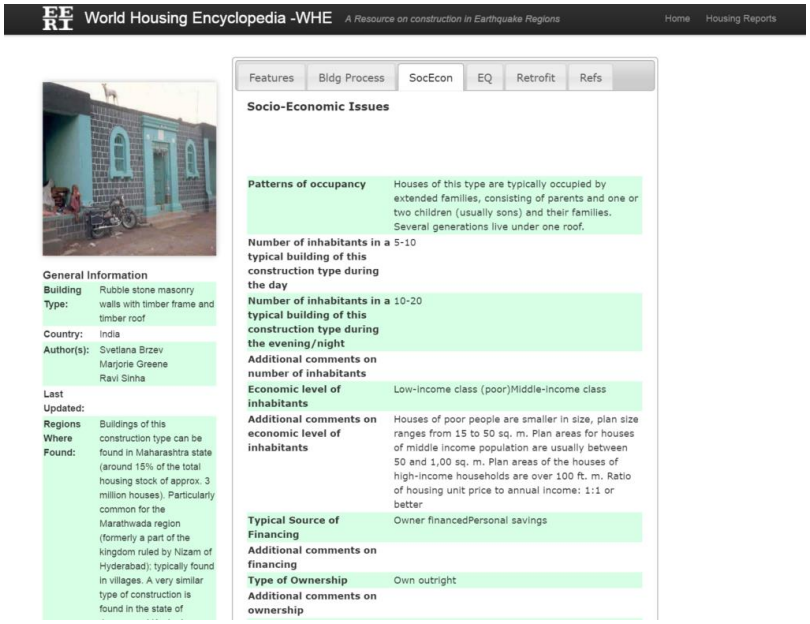

Fig. 7 — Socio-economic issues section of housing report #18

2.2.5 Earthquake

The Earthquake section includes information about the building type's past performance and damage patterns in earthquakes that have affected the building type, structural and architectural features for seismic resilience, and the seismic vulnerability rating. Figure 8 shows the Earthquake section of Report 179. The Earthquake section contains the following information:

	Long Report	Short Report
Earthquakes that have affected the building type	✓	
Information about observed damage patterns	✓	✓
Structural and Architectural features for seismic resistance	✓	
Vertical and horizontal irregularities	✓	
Seismic deficiencies and resilient features of walls, beams, columns, roofs, floors, and the foundation	✓	✓
Seismic vulnerability rating	✓	✓

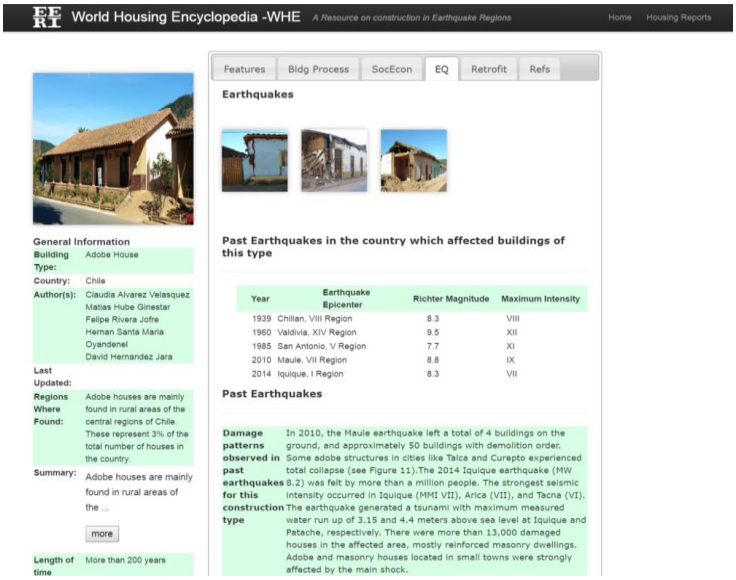

Fig. 8 — Earthquake section of housing report #179

2.2.6 Retrofit Information

The Retrofit Information section includes information about seismic strengthening provisions for the building type. Figure 9 shows the Retrofit Information section of Report 82. The Retrofit Information section contains the following information:

	Long Report	Short Report
Structural deficiencies and typical seismic strengthening provisions to address them	✓	
Documentation of implemented seismic strengthening	✓	
Whether seismic strengthening was mitigation or repair	✓	
Inspection of seismic strengthening	✓	
Individuals involved in the construction aspects of seismic strengthening	✓	
Performance of retrofitted buildings in earthquakes	✓	

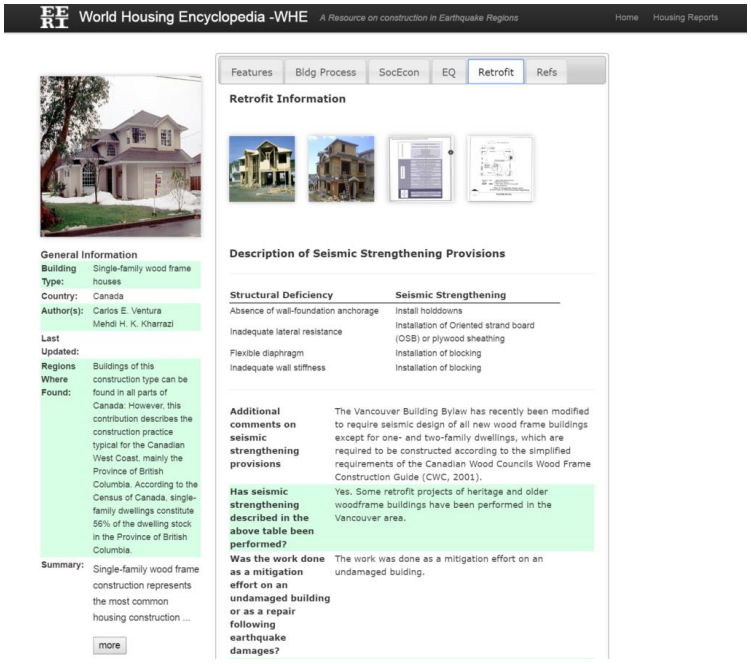

Fig. 9 — Retrofit information section of housing report #82

2.2.6 References, Authors, and Reviewers

The final tab in the report is the References section. This section lists all the references for the report, including a link when references are available online, the author information and reviewer information. Figure 10 shows the References section of Report 11.

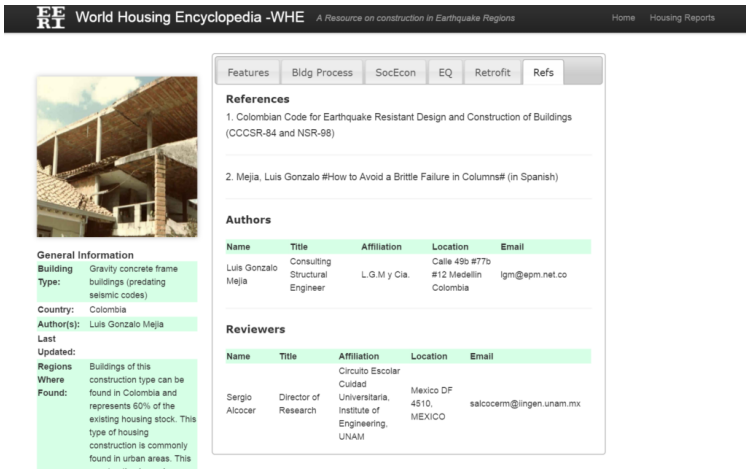

Fig. 10 — Reference section of housing report #11

3. Applications of the Housing Report Database

3.1 USGS PAGER Partnership

The WHE PAGER Project was a collaborative effort initiated by U.S. Geological Survey's PAGER project (http://earthquake.usgs.gov/eqcenter/pager/) and EERI to develop a better estimation of building inventory and its vulnerability worldwide [4]. The effort relied on the collective knowledge of a group of experts associated with the earlier EERI's WHE efforts. The WHE's housing prototype database (readily accessible at

http://www.world-housing.net), covered the residential building types, but lacked the information in terms of (1) nonresidential building types, (2) fraction of building types in rural or urban areas, (3) vulnerability characteristics, and (4) occupancy characteristics (day and night time occupancy pattern). Through its multiple phases, the WHE-PAGER initiative resulted in a significant enhancement of inventory data covering 26 countries, and vulnerability functions for more than 40 non-US structural types [5].

3.2 GEM Projects

The WHE has been used as a resource for many GEM (Global Earthquake Model) efforts. The database of reports helped inform the development of the GEM Building Taxonomy, and after the taxonomy was developed, WHE contributors were asked to evaluate and test the taxonomy. Additionally, information from the WHE was used as a resource for expert elicitation workshops aimed at refining the GEM Vulnerability model.

3.3 International Macroseismic Scale Development

There is an ongoing effort in using the information collected by the WHE and provided in the housing reports in transforming the European Macroseismic Scale [6] into an International Macroseismic Scale (IMS). The starting point for this initiative is the fact that authors of the WHE housing reports were asked to provide a detailed description of the building type's seismic vulnerability features and to quantify this vulnerability by assigning the most likely vulnerability class along with the ranges of probable and less probable (exceptional) cases following the classification table of the European Macroseismic Scale EMS-98. This effort is discussed further in Abrahamczyk et al. [7].

4. Future WHE Efforts

Despite being a largely volunteer effort, the WHE initiative continues to serve as a key resource for enhancing our understanding of housing construction practices in earthquake-prone regions of the world. With over 160 housing prototype reports covering 44 countries, the WHE database basically remains the only publicly available resource that comprehensively illustrates the various types and states of housing in certain countries.

The WHE database continues to grow and the WHE initiative represents a huge leap forward. This effort also demonstrates the enthusiasm that exists among earthquake engineering professionals from around the world in contributing to the understanding of earthquake effects on housing.

New housing reports continue to be developed. The main intention when developing the short housing report form was to encourage more contributions. One of the main purposes is to encourage the preparation of reports from countries that, so far, have not been contributing to the WHE. A further aim is also to complete more reports from seismically affected counties and covering the majority of, if not all, prevalent building types of the respective country. Capturing all prevalent building types in a given area could further assist in developing robust building exposure models for applications in earthquake risk estimation and mitigation initiatives. Additionally, updates to the housing reports are to incorporate the GEM Building Taxonomy and PAGER taxonomy strings. Anyone interested in contributing to the WHE can find out more information at: http://www.world-housing.net/.

In addition to growing and improving the database of housing reports, there is an opportunity to use the information from the reports to support a more active WHE role in increasing seismic safety in developing countries. There is a potential for the reports to be used as a resource to create localized construction tutorials and guidelines as well as public awareness materials. The WHE Committee is considering this and many other ways to increase the dissemination of WHE products especially to individuals/institutions who are expected to benefit from them [5].

5. References

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