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# A web-information system for housing types in urban areas exposed to strong earthquakes around the world: The World Housing Encyclopedia

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**Introduction**

The Earthquake Engineering Research Institute and the International Association for Earthquake Engineering run the World Housing Encyclopedia (WHE), a contribution to global earthquake risk reduction. Initially (2000-2002), the project was managed by a nine member international steering committee. The project provides a framework which enables sharing information globally on housing construction, using the Internet and modern database technology (www.world-housing.net). The project has made a transition to an Editorial Board that will oversee its future development. The Editor-in-Chief, six regional editors and four Editors at large are in charge of managing the project, providing an overall direction and developing new initiatives. Each regional Editor coordinates the project development within a region and/or continent (Asia, Africa, Europe, North America and Australia/Oceania). The framework is being filled in with information and becoming thus an information system through the volunteer effort of over 180 participants from 47 countries. Three Farzad Naeim awards are given each year for the next five years to the best WHE constributions. The WHE web site is an information system which has received much positive feedback from users around the world: insurers and risk modelers who use the information to refine their models to earthquake engineers and architects who use the information to improve their design and construction practice and academics who use the WHE as a learn-

ing resource for the students. The project's web site had more than 40,000 visitors in 2004 (see www.world-housing.net/statistics/ for details). The Encyclopedia is best illustrated in a multimedia format. The project's first hard-copy publication, entitled *World Housing Encyclopedia: Summary Publication 2004*, was distributed during the 13th World Conference on Earthquake Engineering held in Vancouver, Canada, in August 2004. This publication provides an overview of the project at a glance. Unique to this publication are summaries of the major building technologies found on the web site, followed by one-page excerpts of each report on the web site to these technologies: adobe, stone, brick masonry, confined masonry, reinforced concrete frame and shear wall construction, precast concrete construction, advanced technologies, timber construction, and vernacular construction. A CD is included, containing all the reports as of July 1, 2004, as well as the computer animations and adobe tutorial available on the web site.

**Main features of the WHE web site**

The interactive 'World Map' enables the users to identify all reports from a certain country, listed also in 'Country-Based-Information'. The section 'About the Project' contains the project overview, roster of project contributors and the Editorial Board. All reports comprise a searchable database of global housing construction. The database contains more than 100 contributions, almost half of them from Asia, nearly a third from Europe and most of the rest from Latin America. African housing typologies are also included. Search parametres are various common features for housing construction types: building function, urban vs. rural construction, period of practice, economic level of inhabitants, load-bearing structure, building material, number of stories, seismic vulnerability rating, seismic strengthening technologies, engineered vs. non-engineered construction, building codes/standards, and earthquake insurance. The project steering committee has developed a standardized report format allowing for a comprehensive global categorisation of housing construction types, that is used by project participants to describe individual construction types in their respective countries (Brzev et al, 2002). Following a general information section relevant aspects from architectural and structural features, to socio-economic aspects, construction process and materials, and insurance are included. The characterisation is made through completing check-lists as well as more detailed description, of seismic deficiencies, earthquake resilient features, damage patterns and dedicated strengthening technologies. In addition to the text and numerical information, photos and drawings are included, at least on: exterior view of a typical building, typical plan, key load bearing elements, key sesismic features or defficiencies, critical structural details, typical earthquake damage, seismic retrofit technique. Each report consists of over 60 questions, covering relevant information categories on housing construction. Structural systems have been classified into 30 generic types, covering global hous-

ing construction made out of masonry, concrete, timber, and steel. Currently there are 67 reports describing the engineered construction while the remaining 33 reports are describing nonengineered housing construction practice. Depending on the structural system and the country, each report contains unique information, but the fact that participants all respond to a common set of questions makes comparison possible. There is a 'General Resources' section, containing relevant publications and web links mainly related to the nature of earthquakes, the earthquake behavior of buildings, and the performance of various construction practices in earthquakes. In addition, project participants are working within various WHE collaboration projects on a series of tutorials on various construction materials, like reinforced concrete frame with masonry infill (by EERI/WHE and Virginia Tech and the Bangladesh University of Engineering and Technology; sponsor: USAID) or confined masonry (at PUCP, Lima, Peru; sponsor: EERI Small Grants Program). The first tutorial on adobe construction (developed at the Catholic University of Lima, Peru) is available.

**Housing reports: information categories**

The 'General Information' section includes a summary of the housing construction and information on the typical period of practice and regions of the country where such construction has been practiced. Illustrative may be timber construction in Russia (report #56 by M. Klyachko, A. Benin, Y. Bogdanova), USA (report #65 by C. Arnold), and Japan (report #86 by N. Maki and S. Tanaka).

Some 'Architectural features' relate to the number, size and distribution of openings or to the overall building configuration. Such, steel buildings are illustrated from Iran (report #26 by B. H. Hashemi) and Germany (report #95 by M. Bostenaru Dan).

The heart of each report and of the encyclopedia itself is the on on 'Structural Features'. The information on the structural system can be summarized by including information on the material, the load bearing structure (type and subtype), the foundation type and description, the floor and roof system, the typical number of stories and the typical wall density. The prevalent building materials include concrete (9 systems), steel (5 systems), masonry (13 systems), and timber (6 systems). For example, reinforced concrete frames with masonry infills have been recognized as one of the most vulnerable housing construction practices in Europe, and were affected by the 1999 Athens (Greece) earthquake and the 1999 Izmit (Turkey) earthquakes. This type of construction was also affected by the 1999 Chi Chi (Taiwan) and 2001 Bhuj (India) earthquakes. As of this writing, the WHE contains 25 reports on moment resisting concrete frames, out of which 19 describe concrete frames with masonry infill, including those affected by the earthquakes mentioned above. Illustrative are: Turkey (report #64 by P. Gülkan, M. Aschheim, R. Spence), Colombia (report #11 by L.G. Mejia), Taiwan (report #61 by M.S. Sheu, G.C. Yao), Romania (report #71 by M. Bostenaru Dan, I. Sandu), and Greece (report #15 by T.P. Tassios, K. Syrmakezis).

'Problems', in form of 'seismic deficiencies', and 'opportunities', in form of 'earthquake resilient features', are illustrated in tabular form in the section 'Evaluation of seismic performance and seismic vulnerability'. This section includes the estimate of the seismic vulnerability rating for the housing construction under discussion. Most of the reports (39 in total) currently available in the database describe the highly vulnerable construction (EMS, 1998, vulnerability Classes A and B) that has performed poorly in earthquakes, such as unreinforced masonry construction and non-ductile concrete construction, however there are 19 reports on 'success stories', describing earthquake-resistant construction (Classes E and F per EMS, 1998, scale). For each past earthquake affecting the building type, a table lists year, epicenter, Richter magnitude, and maximum intensity (noting scales used) in the section 'Earthquake Damage Patterns'. The damage patterns are linked over the 'element' key to the previous section and illustrated with pictures. Reports on housing construction affected by the 2003 Boumerdes (Algeria) and 2003 Bam (Iran) earthquakes are also included in the encyclopedia. Information across countries can be compared, for example, to evaluate the seismic performance and seismic vulnerability, reflected in earthquake damage patterns of reinforced concrete shear wall buildings in Romania (report #78 by M. Bostenaru Dan, I. Sandu), Chile (report #4 by O. Moroni and C. Gómez) and Russia (report #55 by M. Klyachko, I. Mortchikchin, I. Nudga).

Linked again over the 'element' key, the section 'Building materials and construction process' includes 'urban mineralogy' details: a description of the characteristic strength of the building materials. The section also adresses design and construction expertise, as are building codes, building permits and development control rules, the role of engineers and architects, the phasing of construction, building maintenance, the process for building code enforcement, typical problems associated with a particular construction practice. For example, a report on the historic timber frame reinforced masonry buildings 'Pombalino' from Portugal describes the process of building code enforcement after the 1755 Lisbon earthquake. Illustrated was the section with interior views of adobe or adobe infill building types in Iran (report #104 by M. Mehrain and F. Naeim) and Switzerland (report #108 by M. Bostenaru Dan).

The section 'Seismic Strengthening Technologies' is linked over the 'element' key to the seismic defficiencies. In some cases, no strengthening was needed or tried; in other cases a range of available strengthening techniques are summarized in text and figures. Technologies tested in real earthquakes are identified. The masonry construction type was chosen to illustrate effective seismic retrofit technologies used worldwide in: Portugal (report #92 by R. Cardoso, M. Lopes, R. Bento, D. D'Ayala), Algeria (report #75 by M. Farsi, F. Lazzali, Y. Ait-Méziane), Italy (report #31 by A. Goretti, D. Malvolti, S. Papa), India (report #21 by R. Sinha, S. Brzev), Slovenia (report #88 by M. Lutman, M. Tomazevic), Romania (report #85 by M. Bostenaru Dan, I. Sandu).

**Conclusions**

The purpose of the encyclopaedia is to enable sharing of information on both vulnerable and earthquake resilient housing types among housing experts: earthquake engineers (structural engineers and engineering seismologists) and architects/urban planners, providing them with the opportunity to perform worldwide comparison. A powerful feature of the web site is the ability to search mono- or multiparametrical, globally or by continent (geographical distribution), like urban vs rural construction, or building codes versus seismic vulnerability rating. Also possible is to browse conventionally: for a selected country, the user can view **'**Country-Based Information':

- The seismic hazard map for the country, adapted from the Global Seismic Hazard Assessment Program (seismo.ethz.ch/GSHAP/);
- General country-related information, including documents and web links related to housing and seismic risk information for most countries. Some typical statistics are also included, such as the size and general rate of increase in urban/rural housing stock in the country and the density of urban/rural housing.

A report is able to describe features of both nonengineered rural housing (ex adobe masonry) and urban highrises (concrete shear wall buildings, prefabricated concrete panel buildings, etc.). Several features are useful for urban earthquake risk assessment. The vulnerability rating is determined according to the EMS scale (EMS, 1998). Examples of earthquake-resistant construction include urban engineered structures to vernacular construction. The reports contain information on past earthquakes that have affected the discussed building type. Further figures relating to the text, such as on recent earthquakes affecting, may be included. Some reports contain very interesting historical information on building code enforcement. The Encyclopedia is the most comprehensive global project of this type and, for several construction types, one of the few or only place, where such detailed information is available in English. The project continues to grow and new participants are welcome.

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