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Application of the 'World housing encyclopedia'

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1 Introduction

"Risk reduction and sustainable development" is one of the topics concerning the United Nations International Strategy for Disaster Reduction (ISDR). Lessons are being learned, as a recent background paper for the World Summit on Sustainable Development (ISDR, 2002) shows. It is a document developed in participative manner, but today's participation requires more. Getting to its third generation, a new task, innovation, is asked, to deal with complex problem statements, as provision of safe housing in earthquake prone zones is.

A successful example of spreading lessons from pilot and demonstrative projects until they become a better routine, was the International Construction Exhibition Emscher Park in Germany (IBA, 1999). The Encyclopedia, being recognised as a contribution to the ISDR, was managed as a project within the International Decade for Natural Disaster Reduction in its first years of development. Currently the Encyclopedia is managed journal-wise, an editorial board replacing the original steering committee since March 2002. The Encyclopedia project was featured in the United Nations 2001 World Disaster Reduction Campaign launched by the ISDR. It has been listed Aecportico site of the week, in one of the UK's leading directories for architecture, engineering and construction, included in the National Science Digital Library Report for Math, Engineering and Technology. The Encyclopedia project was first presented in 2000 at the 12th World Conference on Earthquake Engineering in New Zealand and from then on at numerous conferences, including a special sessions in 2002 at the 12th European Conference on Earthquake Engineering in London, the UK, and the 7th US National Conference on Earthquake Engineering, in Boston, USA, presentations in 2003 at the 7th U.S./Japan Workshop on Urban Earthquake Risk and Reduction in Maui, Hawaii, and at the Skopje Earthquake – 40 Years European Earthquake

Engineering Anniversary Conference in Skopje and Ohrid, FYR Macedonia. It will be present through an exhibition stand and numerous poster and oral presentations at the 13th World Conference on Earthquake Engineering in Vancouver, Canada, in 2004. The project was reviewed for the “Nature Online” magazine (Whitfield, 2002) in its news “Technology Stories”, highlighting how sparse similar information, like an encyclopaedia on vernacular architecture (Oliver, 1998), is. Oliver’s (1998) work, written by 750 contributors from 80 countries, is a closed, hardcopy static resource. The World Housing Encyclopedia includes to date 94 contributions from 33 countries, and is a growing dynamic resource. As already highlighted by Whitfield (2002) in the title (“Wise man builds his house upon the web”), the Encyclopedia comes close to participative endeavours like Christopher Alexander’s “pattern language” (Alexander, 1977), an early theoretical approach to answer complex environmental problems in providing ways to articulate this answer. An association has been developed based on this seminal work and the innovative, hypertext based work is available online (patternlanguage.com, 2001). A study on the potential lessons to be learned from participative approaches, including historic ones like Alexander’s or new developments like the World Housing Encyclopedia, for building multi-criteria decision models for retrofitting existing buildings was performed (Bostenaru, 2004).

The International Decade for Natural Disaster Reduction (IDNDR) has closed, and the same task arises like after the end of the 10 years long IBA Emscher Park exhibition. The lessons learned from the project have to be transferred into a better routine. The open-end, journal wise management allowing for a dynamic development is a first step. It serves gathering and sharing information. The aim of this paper is to highlight another step, namely the applications of the World Housing Encyclopedia. This step serves to the objectives stated within the ISDR: supporting initiatives in order to reduce human, economic, and social losses due to natural hazards like earthquakes.

2 Comparative analysis application: discussion and results

There are 7 reports on timber based construction in the Encyclopedia, from all parts of the world (Europe, Asia, America and Africa). Examples include typical housing types from countries where wooden construction represents about half of the dwelling stock, like Japan or Canada. Their seismic performance ranges from medium to excellent. While in case of rural traditional buildings like the Kyrgys “yurta” (report 35) or Malawi “nyumba” (report 43) the good performance relies on the lightness of the structure, in case of those following design prescriptions, like Russian (report 56), US American (report 65) or Japanese (report 86) constructions seismic performance depends strongly on the quality of execution and strengthening was needed to improve connections, especially those with foundations. This type of construction is considered to be non-engineered in Canada, and, additionally to seismic deficiencies present in engineered types, efficient shear walls are missing.

There are 23 reports on reinforced concrete (RC) frame construction, spread among American (Chile, Colombia, Venezuela), European (Cyprus, Greece, Italy, Turkey, Romania, Serbia and Montenegro), Asian (India, Kyrgyzstan, Malaysia, Syria, Taiwan, Uzbekistan) and African (Algeria) examples. Most of them predate seismic codes, which are from the most vulnerable types. An extensive comparison on reinforced concrete construction based on the information contained in the Encyclopedia would not fit into the frame of this paper. Instead, cross-continentally selected types will be compared exemplary. Such examples are the differences in reinforcement in detailing Colombian and Greek buildings. Greek buildings of this type (report 15) are addressed by the Greek Code for Earthquake Resistant Design (NEAK) from 1995 and showed an overall satisfactory behaviour during the 1999 Athens earthquake. However, the column confinement is not satisfactory and strengthening measures are addressing particularly this deficiency. Colombian buildings of this type are addressed by codes since 1984. This first code was, so the report 11, updated in 1998 in order to address buildings constructed prior to 1998, which represent 60% of the building stock. Seismic deficiencies are numerous, and include unsatisfactory sections of concrete members, poor anchorage due to absence of lap splicing, and generally poor quality of workmanship. Strengthening measures concentrate therefore on reinforcement addition. If key seismic features or deficiencies were given for these two cases by structural details, it is the overall distribution of structural members which determines it in case of Taiwanese (report 61) and Romanian examples in the encyclopedia. Typical deficiencies for Taiwanese street front buildings with arcade at the first floor are the soft storey, the unidirectional architectural layout and the extra rooftop additions. Related deficiencies characterise this Romanian building type: soft storey, bad architectural layout, through irregularity as in other Romanian types, and set back upper storeys. Thus in both cases the retrofit strategy consisted in redesigning the structure: installation of new walls for these Taiwanese housing units and transforming into moment resisting frame with lightweight infill in case of the Romanian ones, and column jacketing (steel or fibre wrap in Taiwan; concrete jacket in Romania).

Reinforced concrete structural wall structures are represented in the Encyclopedia, through 12 reports. Most examples from countries with formerly centralised economies (Kazakhstan, Kyrgyzstan, Russia, Romania), where series of buildings with a typical plan were built, are prefabricated panel constructions, and those which have cast in place reinforced concrete structural walls show a related typology, lacking any frame elements (Romanian and Kyrgys examples). Other examples are variations of a “tube in tube” layout, meaning that a core and a border out of reinforced concrete structural walls are created in order to deal with special requirements to build high-rise up to 30-35 storeys (report 79/Canada, report 4/Chile) or earthquake resistant (report 101/Turkey). Although seismic performance of reinforced concrete structural wall buildings is very good, among these examples there are some which presented considerable damage: in Romania, due to the presence of a single longitudinal wall. Pre-cast structural wall construction presented none to slight damage in strong earthquakes (Romania 1977, Armenia 1988, Uzbekistan 1966, Turkey 1999 and 2003) as far as reports in the Encyclopedia document. It is nevertheless to be highlighted that these constructions were characterised by the presence of two longitudinal load-bearing walls, a layout which protected also cast-in-situ construction types from damage (report 87/Romania, report 109/Colombia). New solicitations on pre-damaged structures leaded to damage in the Gazly (Uzbekistan) earthquakes (1976, 1984). Turkish "tunnel" type buildings performed very well in recent damaging earthquakes. In Chile a severe damage and partial collapse were reported.

Housing construction with steel frame structure is rare. Nevertheless, such examples are included in the Encyclopedia (report 25 and 26/Iran, report 4/Chile), while a report for early 20th century construction in Germany is currently in work. The Chilenian type is one of high-rise buildings, with up to 24 storeys. Iranian steel frame buildings are mid-rise (2-6 storeys), like the German ones. The most vulnerable part in these Iranian buildings are the walls, not properly connected to the steel frame, followed by improper column-beam connections,. Soft storey failure is common (report 25), and occurred also in the 2003 Bam earthquake (EERI, 2004b). Chilenian steel buildings don't have any seismic deficiencies, connections did not fail in earthquakes reported to affect this type (in 1960 and 1985).

Adobe housing has been reviewed mostly in Latin American countries (Argentina, El Salvador, Peru) in frame of the World Housing Encyclopedia project, but also reports on housing in India, Kyrgyzstan, Malawi and Iran are available. In most of the cases these are residences of poor people, but this is not the case for Iran (report 104). However, while this type performed poorly under earthquake impact, an Indian type, a traditional rural house called "bhonga" (report 72), performed very well. Another rural mud building type, "nyumba", performed reasonably well in Malawi (report 45). This type was mentioned above as a timber structure, as it contains a timber core. The timber-adobe combination proved as particularly seismic resistant for the so-called "Fachwerk" (half-timbered) house in Germany and neighbouring countries, for which a report is in work. An Argentinian type, built after the Adobe Construction Regulations from 1948 (report 2) had a satisfactory performance. Other adobe building types documented in the Encyclopedia were destroyed in earthquakes to large amounts: in El Salvador in 2001 (report 14), India in 1997 (report 23), Kyrgyzstan in 1992 and 1986 (report 42), Argentina in 1894, 1944, 1952 and 1977 (report 89), and in Iran in 2003 and before (report 104). Some Malawian and Peruan types are also assessed as highly vulnerable, but detailed information on earthquake damage is missing. Causes were poor quality of walls, big openings and poor wall-roof connections. For some of these types seismic strengthening provisions were developed in form of retrofit or new construction (report 89/Argentina).

The Encyclopedia differentiates between several types of masonry construction: stone masonry (9 reports), unreinforced brick masonry (15 reports), confined masonry (10 reports), and concrete block masonry (5 reports). Due to this high number of relevant examples, an extensive comparison of all masonry construction types regarding their seismic performance would go beyond the scope of this paper. Instead, strengthening provisions for European stone brick masonry wall buildings will be compared. Such nonengineered unreinforced brick structures are, along with reinforced concrete schelet structures designed for gravity loads only, most vulnerable. Seismic features of an Italian stone masonry building type (report 28) are regular arrays of floor ties in one unit, irregular distribution of wall ties in the next one and corner return stones in the third unit. Corner returns between perpendicular walls made of large stone blocks are a significant earthquake resilient feature. In case of these constructions replacement of the original roof structure by a reinforced concrete slab with ring beam leaded to earthquake damage, as stiffness increased. Portugal's "Pombalino" buildings present a particular case of stone masonry, with an embedded three-dimensional timber structure ("gaiola"). The architecture of their structure comes close to that of the "Fachwerk" houses, with the difference, that the stone infill does not have adobe's elasticity and thus these residences, built in the city of Lisbon during the reconstruction after the 1755 earthquake, present seismic deficiencies of low strength connections between "gaiola" and the masonry walls, additionally to the typical out-of-plane failure vulnerability of the later. Urban non-engineered brick masonry structures are exemplified by a single family house typical for Italian town centres (report 29). Vertical extension of the building induced seismic deficiencies. Brickwork frame around windows is seismic resilient. Although horizontal arch effect in the vertical addition to the building followed earthquakes, the most common damage was collapse of interior floors. It was observed that RC strengthening, a common provision for European brick masonry structures with flexible floors (reports 84 and 85/Romania) could seriously damage the walls of this type. Better results were achieved through provision of metal ties in two orthogonal directions. An example of a non-engineered rural brick masonry structure is given by a farmhouse to be found in Italy regions of moderate seismicity. In the rare cases of retrofit on buildings of this type, metal ties are employed to improve the wall performance. Metal ties reinforcement proved also appropriate for low-rise stone masonry buildings (report 58/Slovenia, report 16/Greece). A Slovenian confined brick masonry house (report 88) was practiced after the first national seismic code was issued (1964). These buildings, like other confined masonry buildings (report 69/Serbia and Montenegro), have shown a good seismic performance. Deficient is the absence of top bond-beams along the gable walls, leading to earthquake damage. Retrofitting consists in temporary lifting the structure and constructing bond beams atop all walls at the attics level. Different from mid-rise stone masonry and low-rise unreinforced brick masonry buildings, in this case retrofit with reinforced concrete bond beams, being in accordance with the original structure stiffness, proved successful. For the Serbian type mentioned carbon fibre diagonals on the walls retrofit was also employed, apart of reinforced concrete overlay, the later being another measure practiced in Slovenia.

3 Conclusions

The cross-comparison examples shown prove that the structure of the World Housing Encyclopedia meets its scope of transforming specific data on seismically vulnerable or resistant housing into valuable information which can be shared between housing experts like architects, structural engineers, and construction managers.

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