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WHE HOUSING REPORTS - A REVIEW WITH RESPECT TO PAST AND CURRENT EARTHQUAKE DAMAGE OBSERVATIONS

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Abstract

The World Housing Encyclopedia (WHE) can be regarded as the most comprehensive database covering the variation of structural systems for the majority of building typologies in earthquake-affected regions worldwide. Recent efforts of the WHE group have been concentrated on the identification and detailed description of prominent building typologies in various parts of the world that are still missing in the database. Additionally, new paths are entered to improve the accessibility and completeness of the WHE database. There is an ongoing initiative to transfer the existing WHE reports into a knowledge-based website following the wiki template.

An important next step will be the review of existing housing reports with respect to past and current earthquake observations. Thus, former decisions on seismic vulnerability, structural behavior under seismic action, and applied retrofitting strategies will be updated. In doing so the WHE database needs to be linked to the Earthquake Engineering Research Institute (EERI) Earthquake clearinghouse or other freely available resources, such as construction manuals, EERI's Learning from Earthquakes program, or scientific publications.

This paper informs about:

- a strategy for a frequent review of existing WHE housing reports based on the creation of a link to other EERI initiatives like EQ clearinghouse or other freely available resources;
- a guide for the vulnerability rating based on a comparative study with EMS-98 in preparation of the development of an IMS and the GEM building taxonomy.

On this basis, the paper suggests improvements as well as a general procedure for updating the various WHE reports. The purpose of this study is to assess the quality (reliability) of information provided in the WHE reports. Especially, the assignment of the vulnerability will be discussed, whereas the behavior of other building typologies will be taken into consideration. According to the EMS-98 approach which has been followed in this study the vulnerability class of an individual building typology generally depends on the observed earthquake damage for that typology relative to other similar typologies, and is presented as a range rather than a single value.

It is believed that the paper will be relevant to earthquake engineering professionals interested in seismic vulnerability of building typologies, and will support the exchange of experience and link between different international activities like earthquake reconnaissance studies, EQ clearinghouses, etc. In addition, it will support the WHE leadership to encourage proactively authors to update their reports.

Keywords: housing reports; damage observation; seismic vulnerability; earthquake reconnaissance

1. Introduction

1.1 WHE Scope

The World Housing Encyclopedia (WHE) is a collection of resources related to housing construction practices in seismically active areas in the world. The mission is to share information related to different construction types and encourage the use of earthquake-resistant construction technologies worldwide [1].

The WHE Report Database contains reports on housing construction types in seismically active countries. A closer look to worldwide regions of high seismic risk provides a first idea about prevalent building types in these areas and countries [2]. Each housing report contains a detailed description of a specific housing type in a particular country.

WHE can be regarded as the most comprehensive database covering the variation of structural systems for the majority of building typologies in earthquake-affected regions worldwide. Recent efforts of the WHE leadership have been concentrated on the identification and detailed description of prominent building typologies in various parts of the world that are still missing in the database.

This paper informs about:

- a strategy for a frequent review of existing WHE housing reports based on the creation of a link to other EERI initiatives like EQ clearinghouse [3] or other freely available resources;
- a guide for the vulnerability rating based on a comparative study with EMS-98 [4] in preparation of the development of an IMS [5] and the GEM building taxonomy [6].

On this basis, the paper suggests improvements as well as a general procedure for updating the various WHE reports. The purpose of this study is to assess the quality (reliability) of information provided in the WHE reports. Especially, the assignment of the vulnerability will be discussed, whereas the behavior of other building typologies will be taken into consideration. According to the EMS-98 approach which has been followed in this study the vulnerability class of an individual building typology generally depends on the observed earthquake damage for that typology relative to other similar typologies, and is presented as a range rather than a single value.

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1.2 Concept

The description of the structural vulnerability of buildings and the resulting damage predictions for different impact levels are critical aspects of seismic risk studies. The damage analysis after recent earthquakes generally contributes to a better understanding and interpretation of the response of structures and their damage patterns. Additionally, such damage analyses can be performed in comparative studies with respect to the behavior of buildings of different building types.

Thus, there is a continuing need to review the existing WHE housing reports with respect to past and current earthquake observations. Past decisions on seismic vulnerability, structural behavior under seismic action, and applied retrofitting strategies should always be audited and updated, if necessary. In doing so the WHE database should be stronger linked to the EERI EQ clearinghouse or other openly accessible resources, such as construction manuals, EERI's Learning from Earthquakes program, and other scientific publications. In addition, the vulnerability ratings assigned based on past earthquakes need to be reviewed with respect to the observations from recent earthquakes; this will improve consistency to the inherent vulnerability approach.

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The following concept is proposed for this task as well as the first step in preparation and submission of new housing reports:

1) Review of existing housing reports for a country or a region;
2) Comparison of currently assigned vulnerability ratings (see section 2.3)
3) Check available damage reports for the building type under consideration from earthquake affected areas of different shaking intensities (different damage grades) → derivation of the typical behavior;
4) Comparison of the observed damage grade with damage grades assigned to other building types;
5) Finalize vulnerability assignments based on typical behavior of building types and recent damage observation;
6) Confirmation or update of the WHE report → amendments or comments to the new WHE WiKi.

Table 1 – Comparison of WHE and EMS-98 building types: Masonry and Timber

Type of Structure				Vulnerability Class					
	WHE housing reports (No. of reports)	No. of stories	EMS-98	A	B	C	D	E	F
Masonry	Adobe (24)	1 - 3	Adobe (earth brick)						
	- Adobe block walls (10)	1 - 2							
	- Mud walls (9)	1 - 3							
	- Mud walls with horizontal wood elements (2)	1							
	- Rammed earth/pile construction (3)	1 - 3							
	Stone Masonry Walls (18)	1 - 7							
	- Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof) (16)	1 - 7	rubble stone, fieldstone						
	-		simple stone						
	- Massive stone masonry (in lime/cement mortar) (2)	1 - 4	massive stone						
	Unreinforced Masonry Walls (22)	1 - 6							
	- Brick masonry in lime/cement mortar (13)	1 - 6							
	- Brick masonry in mud/lime mortar (9)	1 - 5							
	-		unreinforced, with manufactured stone units						
	-		unreinforced, with RC floors						
	Confined Masonry (13)*1	1 - 6	Reinforced or confined						
	Reinforced Masonry (3)	1 - 4							
Timber	Load-bearing Timber Frame (13)		Timber structures						
	- Post and beam frame (no special connections) (2)	1 - 3							
	- Stud wall frame with plywood/gypsum board sheathing (3)	1 - 3							
	- Walls with bamboo/reed mesh and post (3)	1							
	- Wood frame (with special connections) (3)	1 - 8							
	- Wooden panel walls (2)	1 - 2							

Legend: see Table 2

*1 Brick and concrete block masonry are combined, because many reports cover both material types!

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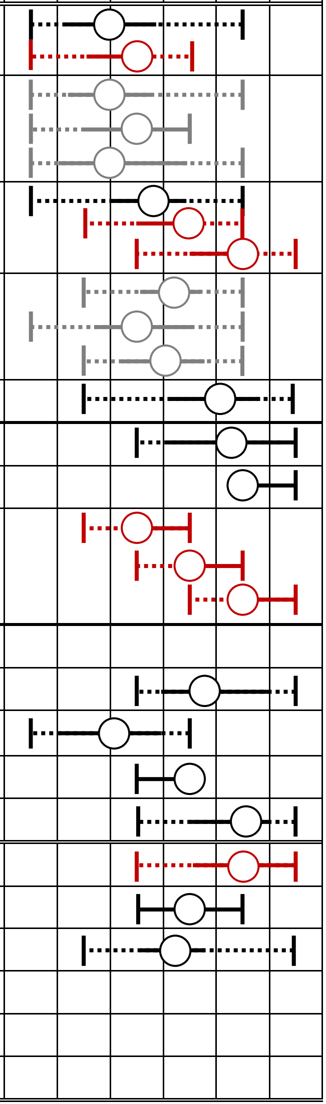
Table 2 – Comparison of WHE and EMS-98 building types: Reinforced concrete and steel

Type of Structure	WHE housing reports (No. of reports)	No. of stories	EMS-98	Vulnerability Class A	B	C	D	E	F
RC Moment Resisting Frame	Designed for gravity loads only, with URM infill walls (17)	1 - 18	frame without ERD						
	- Story class I (6) - Story class II (6) - Story Class III (5)	1 – 3 4 – 6 > 6							
	Designed with seismic effects, with URM infill walls (9)	1 - 20	frame with moderate level & frame with high level of ERD						
	- Story class I (3) - Story class II (4) - Story Class III (2)	1 – 3 4 – 6 > 6							
	Dual system Frame with shear wall (4)	4 - 30							
RC Structural Walls	Moment frame with in-situ shear walls (7)	1 - 35							
	Moment frame with precast shear walls (1)	5 - 10							
			walls without, walls with moderate level & walls with high level of ERD						
RC Precast			Still to be introduced!						
	Large panel precast walls (3)	2 - 9							
	Moment frame (5)	5 - 18							
	Pre-stressed moment frame with shear walls (1)	1 - 12							
	Shear wall structure with precast wall panel structure (4)	1 - 18							
Steel			Steel structures						
	Bare frame | Concentric connection in all panels (1)	4 - 6							
	Moment Resisting Frame (6)	1 - 5							
	- With cast in-situ concrete walls (2)								
	- With brick masonry partitions (2)								
	- With lightweight partitions (2)								



Legend:

○ Most likely vulnerability class —— probable range ········ less probable range, exceptional cases

—— Vulnerability Table of the EMS-98 (empirical based)

—— Transformed vulnerability ratings from the different WHE reports [2]

—— Transformed vulnerability ratings with distinction of up to three story classes [2]

2. WHE Housing Types and Vulnerability Rating

2.1 WHE vs. EMS-98 and GEM Building Types

WHE housing reports distinguish nine subtypes of reinforced concrete, thirteen subtypes of masonry buildings, four subtypes of steel and five subtypes of timber buildings. EMS-98 considers seven subtypes of masonry, six subtypes of reinforced concrete structures and one building type each for steel and timber

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structures (see Table 2 and 3). Whereas the EMS-98 vulnerability ratings (shown in *red*) as well as the given scatter are based on observed damages caused by different earthquakes in different countries. The WHE vulnerability ratings (shown in *black and grey*) are analytically derived from the original ratings. The original WHE vulnerability ratings are transformed into the original "Vulnerability Table" of the EMS-98 by determining the most likely vulnerability class as well as its probable and less probable ranges based on the original ratings as well as an upper (worst) and a lower (best possible) bound [7].

The comparative study shows, that conceptually a similar typology is followed, whereas WHE distinguishes more subtypes, especially for steel and timber structures, and considers the number of stories as another parameter. However, the study also indicates the differences in considered and described building types, which might be added in the further development of the EMS-98 [2]. EMS-98 is principally well-placed for its development into an International Macroseismic Scale (IMS), especially when the building types of the updated vulnerability table cover the WHE building types and vulnerability ratings. WHE housing reports provide a very useful background for the introduction of subtypes for steel and timber structures, due to limited empirical data related to these typologies.

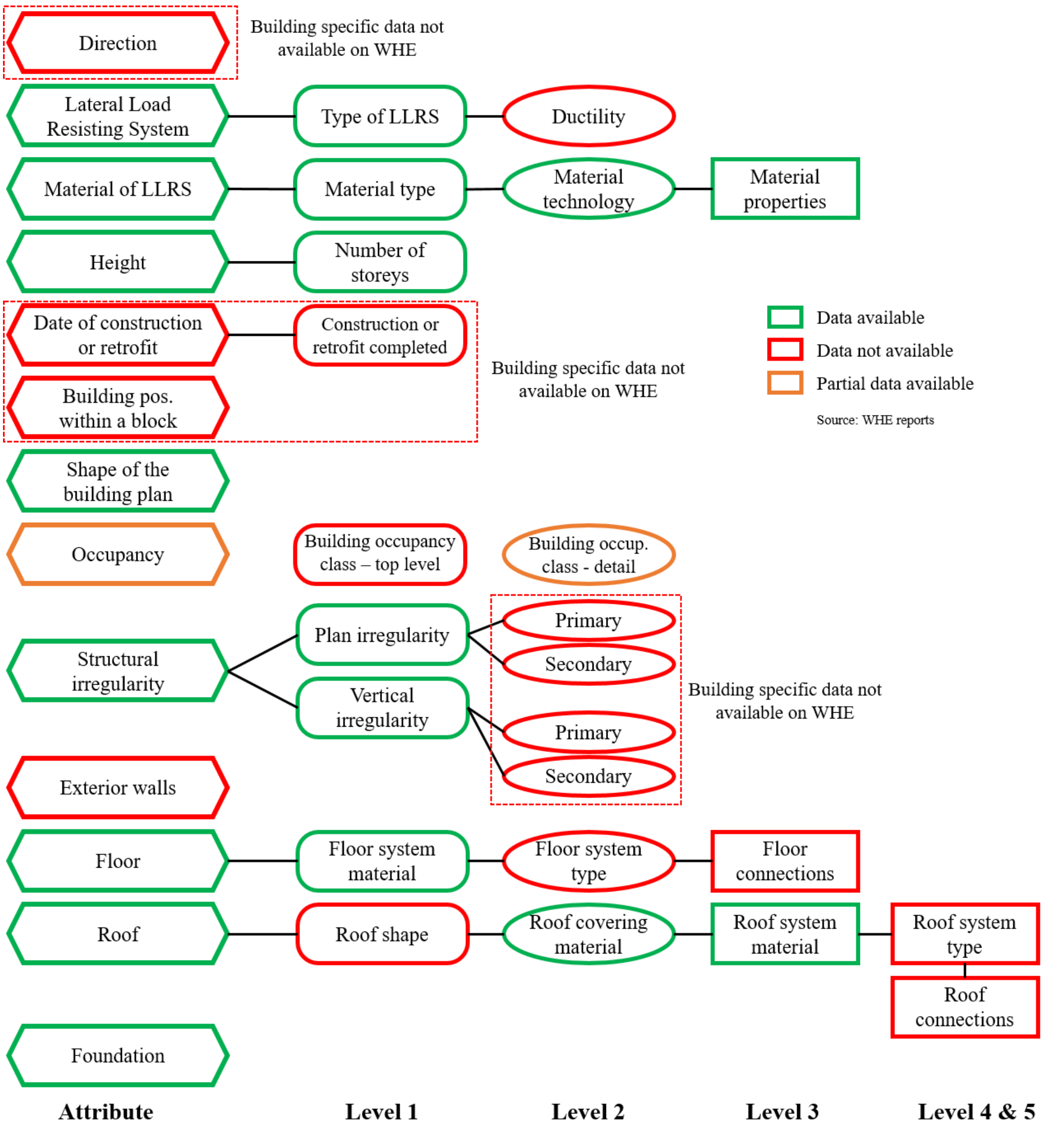

Fig. 1 – Comparison of building attributes from the GEM taxonomy and the WHE housing reports.

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The question of how many building types are really necessary in order to perform a macroseismic survey and to assign an EMS intensity is currently under discussion [7]. The answer to this question might support the tendency to concentrate on the relevant (i.e., the quantitatively dominating) types and on those types which are indicating a small variation of vulnerability classes, provided that the buildings of this type could be identified by structural (primary) and non-structural (secondary) characteristics (i.e., unreinforced masonry structures). Also, the review of subtypes, which are currently included in the WHE shows that too many subtypes do not necessarily lead to an improvement if the assignment of the appropriate vulnerability classes itself is not easy in use.

Another aspect of importance is probably the relationship to the EMS-98 and the target of a consistent handling of building types and corresponding vulnerability ratings. Steel typology should be subdivided into two subtypes, i.e., as a function of Earthquake Resistant Design (ERD) similar as it is done with existing RC frame and RC wall types. Separate types for mixed steel-masonry structures as well as mixed masonry-concrete structures are still missing.

In summary it can be stated that the WHE database provides an excellent entry in the assessment of worldwide building stock and provides valuable information about the housing construction practices in worldwide seismically active regions. Few of the reports assign unrealistically high or low vulnerability classes compared to the expected assignments and therefore should be revised. The establishment of the link between WHE housing reports, EERI earthquake clearinghouse, evaluated and assessed damage reports as well as regular amendments to existing reports will support the development and refinement of IMS.

Additionally, WHE housing reports can be used for the validation of assigned building vulnerabilities, derivation of expert based building vulnerabilities, or provision of additional building stock data for seismic risk studies all over the world. Here, WHE housing reports are compared with SERA building type definition [6] to support the "Level of Sub-structuring" - approach according to [7] as entry to a "Level of Knowledge" for the uncertainty quantification of the vulnerability estimation for seismic risk studies, as one task in the TURNkey project [8]. Figure 1 shows the data given in the WHE housing reports according to the GEM scheme. The WHE housing reports cover most of the GEM building type attributes and support the assignment of either vulnerability class or the selection of an appropriate fragility function.

The following conclusion can be drawn based on the comparison between WHE housing reports, EMS-98 and GEM building taxonomy:

- A proper building taxonomy should distinguish between major building types based on primary structural system and subtypes based on secondary structural system, and in some cases storey class.
- An excessively sophisticated taxonomy does not automatically reduce the uncertainty in the vulnerability assignment.
- The quantification of uncertainty is of high interest for the support of an easier application.

2.2 Relation between Vulnerability and Intensity

Intensity *I* is a qualitative classification of the severity of an earthquake at a location and reflects the impact of the earthquake at that location, due to the earthquake signal and its effect on built environment. The influencing factor is not only the triggering earthquake process itself, but also the factors that affect the wave propagation towards the observation site, such as geology, tectonics, topography, as well as anthropogenic conditions (e.g. population density, building structure, age, construction method and density of buildings) [9].

The development of different intensity scales is outlined in [9]. The scales are compared in terms of their degrees of intensity and the description of observed damage.

The description of the functional relationship between intensity and ground motion quantities needs to be carefully considered. On the one hand, the integer character of intensity has to be correlated with the real ground motion quantities, but on the other hand the intensity is always a descriptive quantity.

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Consequently, the characteristics of the earthquakes, local conditions and the subjective opinion of a person responsible for the macro-seismic evaluation in connection with the choice of the macro-seismic scale have an influence on the intensity assessment.

Vulnerability of structures is one descriptor for the assessment of the intensity especially for higher intensity levels. Observations of the typical behavior of different structural systems under seismic action are critical for assessing earthquake intensity for a specific region.

2.3 Seismic Vulnerability

As stated in the "Seismic Vulnerability Rating – Guideline" [1], "the term vulnerability is used to express differences in the way that buildings respond to earthquake shaking. If two groups of buildings are subjected to exactly the same earthquake shaking, and one group performs better than the other, then it can be said that the buildings that were less damaged had lower earthquake vulnerability than the ones that were more damaged, or it can be stated that the buildings that were less damaged are more earthquake-resistant, and vice versa." (an excerpt from [10]) Note, that the use of word "vulnerability" in this document is not necessarily the same as other uses and definitions of the same word.

The EMS-98 explicitly allows the assignment of transition classes and the consideration of vulnerability-affecting factors. It is one of the inherent advantages of the EMS-98 that the ranges of the vulnerability can be used to indicate the scatter of existing realizations and – by means of simplified graphical elements (horizontal solid and dashed lines) – the probability of expectation. Nevertheless, in many cases only the most-likely rating is applied.

Table 3 shows vulnerability ratings for Chile based on the WHE housing reports and the EMS-98 scale. It can be observed that most likely WHE vulnerability ratings are comparable with the EMS-98 probable ranges whereas the upper/lower bounds only partially correspond to the EMS-98 ratings. Table 3 shows that the WHE vulnerability ratings for the buildings in Chile are generally higher than the proposed EMS-98 ratings. It should be noted that the housing types for Chile covered by the WHE reports (adobe, confined masonry, RC shear wall buildings) are widely used in Chile and have been exposed to numerous earthquakes in the last few decades. Chile experiences on average a magnitude 6 earthquake every 10 years. As a result, there is a significant experience among Chilean engineering experts related to the observed seismic performance of typical buildings. The proposed WHE vulnerability ratings for some Chilean typologies e.g. confined masonry, were confirmed by the 2010 Maule EQ with magnitude 8.8 [10].

Table 3 – Comparison and correlation of seismic vulnerability ratings according to WHE and EMS-98: case study Chile.

	No. of stories	WHE						EMS-98					
		A	B	C	D	E	F	A	B	C	D	E	F
Adobe House	1-2	o						o	-|				
Buildings with hybrid masonry walls	3-4	|-	o	-|				-					
Confined masonry[1)]	1-5				|-	o	-|			|···	o	-|	
Confined block masonry building[1)]	4				|-	o	-|			|···	o	-|	
Reinforced clay/concrete block masonry building	2-4			|-	o	-|				|···	o	-|	
Concrete frame and shear wall building	10-30					|-	o	3)					
Concrete shear walls buildings[1)]	4-30					|-	o	*high level ERD*			|···	o	-|
Reinforced Concrete Shear Wall Houses[1)]	1-3+					|-	-|	*high level ERD*			|···	o	-|
Steel frame buildings with shear walls[2)]	3-5 6-24[2)]					|-	O			|···	···	o	-|
Timber Houses[1)]	1-4					|-	-|		|···	···	o	-|	

[1)] higher vulnerability class than proposed in WHE guideline.
[2)] so far, no recommendation given in WHE guideline [3)] not given as Type of Structure in EMS-98

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Interestingly, WHE reports that describe confined masonry construction in Chile were prepared before the 2010 earthquake [17]. Confined masonry constitutes a significant fraction of Chilean housing stock since the 1930s and thousands of buildings of this type were exposed to the damaging earthquakes. On the other hand, there is no significant evidence of confined masonry exposed to damaging earthquakes in Europe, hence the proposed EMS-98 vulnerability rating for confined masonry may be based on limited experimental studies and damage observations after the European earthquakes. In conclusion, it is expected to observe differences in vulnerability rating between the WHE reports and EMS-98 in this case.

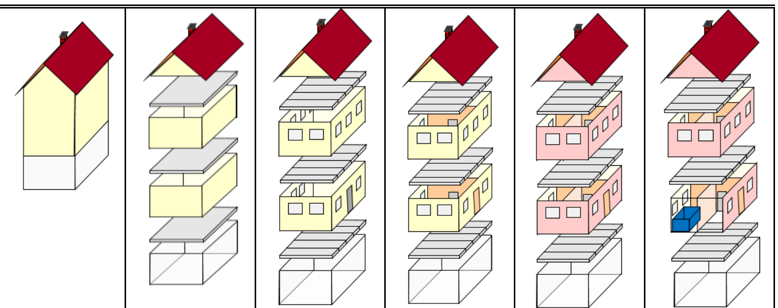
2.4 Level of Sub-structuring

A main task/objective for rapid damage prediction in specific scenarios in the field of natural hazards is to consider the essential data for the assigned main infrastructures/building stocks in the format of the most comprehensive state of knowledge possible and to use them as input for modelling the physical and systematic vulnerability assessment.

The definition of a Level of Sub-structuring (LoS) for the different infrastructure and building types allows a straightforward application for vulnerability, response and damage assessment in pre- and post-disaster scenarios using the main concept of LoS to improve the level of detail [8].

Table 4 compares a scheme for the definition of LoS for buildings [7] with the available information given in WHE housing reports. With increase of knowledge with respect to the secondary and tertiary systems the uncertainty in the vulnerability estimation and thus the certainty in the estimation of probale damage and loss becomes higher and could be quantified in the optimal case (see also Section 3). Note that LoS-1 to LoS-4 are used for regular buildings, while LoS-5 and LoS-6 are typically defined for important buildings like hospitals. Primary elements (P) are the vertical load-bearing members, Secondary elements (S) are the horizontal load-bearing members, while Tertiary elements (T) are the floors and roofs [11].

Table 4 – Comparison and correlation of information provided in WHE housing reports with LoS definition according to [7, 8]



ITEM		LoS-1	LoS-2	LoS-3	LoS-4	LoS-5	LoS-6
No. of stories	P	certain					
Roof & Facade *(Geometry, Material)*	T	certain					
Age *(Year of construction and/or of repair)*	-	partially certain					
Usage *(Residential, Official, etc.)*	-	certain					
Floor - *Geometry, Material* - *Stuctural & non-structural elements*	T		certain	certain			
Wall - *Geometry, Material* - *Stuctural & non-structural elements*	S						
Foundation *(Type, Dimension)*	P		certain				
Structural interior part *(Material, Dimension)*	S				certain		
Ancillary *(Material, Dimension)*	T						certain
Building configuration *(Regularity)*	-			certain	certain		
Lateral load resisting system *(Type)*	P			partially certain	certain		

○ certain ○ partially certain P: Primary elements S: Secondary elements T: Tertiary elements

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By increasing the LoS, more details of information can be attained from building stock survey for both structural and non-structural elements. This information includes lateral-load resisting system, their material and type, aspects of structural irregularity of buildings for ground plane and elevation (comparable to SERA and WHE). It should be mentioned that higher LoS level contains all information that is defined and recognized in previous levels of knowledge, for instance LoS-4 contains all detectable information in LoS-1 to LoS-3. Therefore, a higher LoS (e.g. LoS-4) increases the level of detail for building in comparison with a lower LoS (e.g. LoS-3).

3. Damage Assessment and Vulnerability Studies

3.1 Seismic Vulnerability

As already stated in Section 2.3, conceptually the vulnerability estimations are derived from damage observation and reconnaissance reports. Thus, each earthquake contributes to an improvement and/or confirmation of the vulnerability assignments. For that reason special care should be taken to compare the behavior of the different construction technologies and/or building types in each earthquake.

Therefore, the existing WHE reports should be reviewed frequently based on available damage field reports to keep them updated, to provide feasible/reliable and useful information for the community and carry out a cross-check.

One of the inherent aims of the WHE leadership is to strengthen/establish a link with the other EERI initiatives, e.g. EERI EQ clearinghouse, which is exemplarily discussed in the next section.

3.2 Recent Damage Observations and Consequences for Vulnerability Assignments

On Nov. 26, 2019 a M6.4 earthquake hit Albania and caused severe damages in the affected regions. Reports [3, 18] show severe damage in multistory reinforced concrete buildings, whereas quite often the primary structural systems just show minor damage, but the secondary infill walls were heavily damaged in in-plane and out-of-plane direction (see Figure 2). Most of these buildings are multi-story buildings with more than eight floors. In contrast, the behavior of medium-size masonry buildings (5-storey high) with RC slabs showed little to no damage (see Figure 3).

Fig. 2 – Observed damages of masonry infill walls in Durrës, Albania due to the Nov. 2019 EQ.
Source photos: left and right - L. Abrahamczyk; middle – S. Brzev.

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Fig. 3 – Undamaged unreinforced multistory masonry buildings in Durrës, Albania after the Nov. 2019 EQ.

Source photo: L. Abrahamczyk

The observation from the 2019 Albania earthquake show that non-structural damage can heavily influence the global damage grade, although the structural damage was more or less negligible and did not affect the safety of the inhabitants. On the other hand, the number of stories primarily influence the building vulnerability – especially in case of RC frame structures – and should be considered as a vulnerability affecting parameter or as criteria for sub-classes, as already suggested [2, 17].

3.3 RC Frame and Infill Wall Robustness

Experience (repeated observations from recent earthquakes, e.g. the Nov. 2019 Albania earthquake) confirm that the behavior of reinforced concrete frame structures under earthquakes is strongly influenced by the presence of unreinforced masonry infill walls. Damage observations lead to the conclusion that the quality of construction and material of the infill walls may have strong influence on the interaction with the primary load-bearing system [12, 13]. At the same time, the infill walls are subject to both in- and out-of-plane seismic effects, which can result in a complex damage pattern [14].

Masonry infills with and without openings generally increase the in-plane strength, and stiffness, and lead to a partly uncontrolled energy dissipation capacity of the reinforced concrete frame structure [15], which in case of an earthquake can lead to an unexpected distribution of horizontal forces and cause localized damage of columns and beams. Especially for reinforced concrete frame structures in low- to medium rise buildings, it is expected that the infill walls at the ground floor level will be damaged first, as they are subject to the highest in-plane demands. However, under the influence of bi-directional loading, where the two components of a floor movement are of similar importance, infill walls at the upper floors may fail under the combination of in- and out-of-plane effects. The magnitude of the loads in-plane decreases at the upper floors, while the forces acting perpendicular to the plane increase due to the increase in acceleration over the height of the building. [Note: This was exactly observed in the Nov. 2019 Albania earthquake [18].]

Figure 4 illustrates a proposed classification for the evaluation of reinforced concrete frames with masonry infills under earthquake effects, which presents the typical damage behavior or damage pattern of reinforced concrete frames depending on the deformability/design levels (*w = weak or s = strong*) of the Primary (structural) elements (P) and the stiffness/strength (*w = weak or s = strong*) of the infill of the Secondary (non-structural) supporting elements (S) [16]. The typical, schematized in-plane damage patterns are derived based on experimental investigations on the behavior of reinforced concrete frames with masonry infill walls and the influence of the material quality. It illustrates (possible) damage patterns in the frame elements and infill walls for the different combinations of material quality for the infills or design levels for the reinforced concrete frame, whereby the focus is limited to fully infilled walls/frames.

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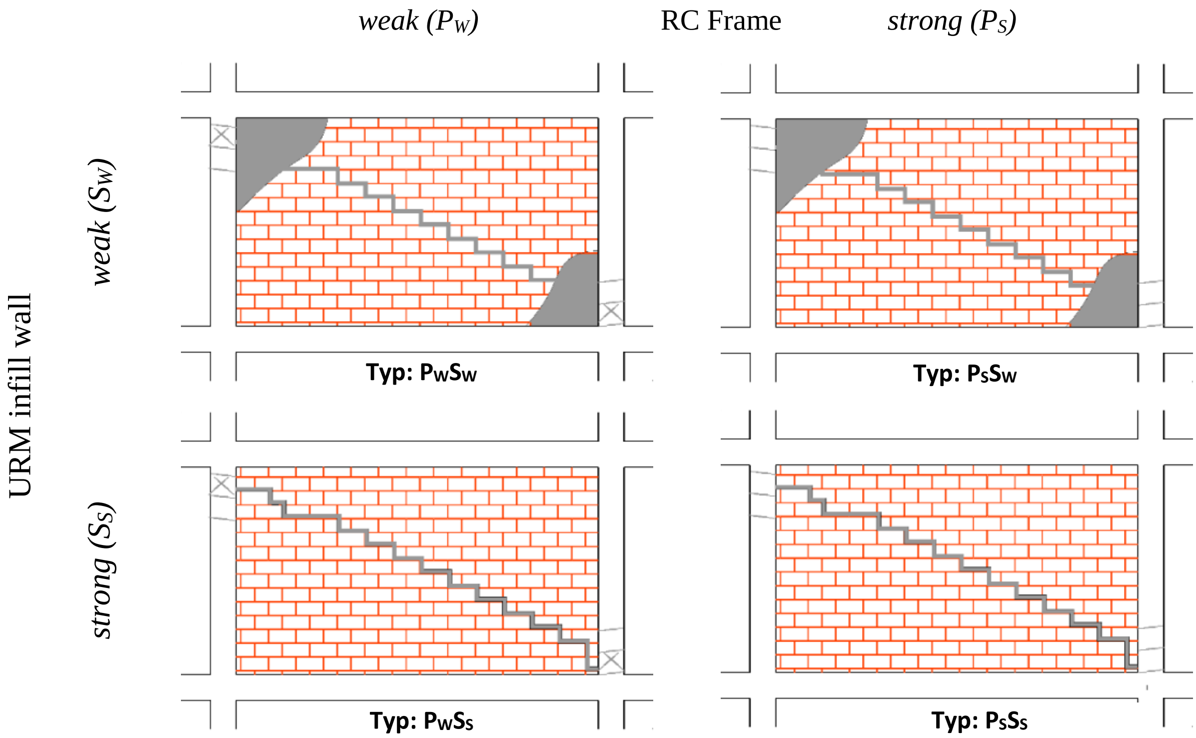

Fig. 4 Typical schematized damage patterns for reinforced concrete frames with masonry infill walls depending on material quality, relative strength and stiffness [16].

It can be seen that in the case of stable/robust (*s* = *strong*) frames and soft/weak (*w* = *weak*) infills (type P_SS_W), a damage pattern occurs in which the infills fail and the frame only shows cracks (minor damage). On the other hand, in the P_WS_S case, the frame experience flexural and shear cracks (large structural damage) and the infill mainly shows diagonal cracks (small to medium damage).

With the introduction of analytical localized damage grade descriptions [14], the prerequisites are created for further supporting analytical investigations to work out the ***most likely*** vulnerability for reinforced concrete frames with infill walls - categorized in terms of material quality, design levels or relative strength and stiffness, and number of stories.

4. Summary and Outlook

Damage observations from recent earthquakes show on one hand the challenges in making vulnerability and damage grade assignments, and on the other hand the continuous changes in construction practice and building stock. Thus, past reports on seismic vulnerability, structural behavior under seismic action, and applied retrofitting strategies should be continuously audited and updated.

A comparative study of the WHE reports with reconnaissance studies (e.g. [12, 13]) with respect to the EMS-98 building type classification scheme as well as vulnerability class definitions reveals common dominant building types as well as sub-types. While the main building types are defined by the material of the primary elements, sub-types are mainly defined by the lateral load-resisting system like frame, wall and/or level of earthquake resistant design (ERD). Recent earthquakes have shown that the behavior of non-structural components can heavily influence the global damage grade. Thus, vulnerability affecting factors like the number of stories and the properties of non-structural elements should be considered as important attributes of a building typology and the corresponding vulnerability table/matrix.

The above considerations lead to the following objectives for the WHE activities: achievement of a living platform and critical review/update of existing reports with respect to future vulnerability ratings.

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WHE leadership supports this development by establishing a link with the other EERI initiatives, e.g. EERI EQ clearinghouse, EERI's Learning from Earthquakes program, and a transition of the WHE housing reports database into a WHE housing reports wiki. New Wiki will easily allow to include amendments and comments to existing reports and facilitate development of new reports. With the establishment of the WHE housing reports Wiki, authors of the existing housing reports and other interested parties will be invited to verify the existing data based on recent earthquake damage observations and vulnerability rating concept discussed in this paper.

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