WHE-PAGER PROJECT: BUILDING CONSTRUCTION VULNERABILITY AND INVENTORY

This form is divided into 3 parts:

Part I: **Contributors' Information**
Part II: **Summary of Construction Types, Vulnerability and Population**
Part III: **Colleagues Consulted, Additional Sources of Information Used**

PART I: Contributors' Information

1. Country or Region (if you are only responding for part of a country, please indicate which geographic region.
Note: the WHE strongly prefers national estimates, unless you have data that clearly apply to only one region):

Morocco

2. Name(s) of Contributors

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6. Your self-rating of expertise or confidence: On a scale of 1=low and 5=high, please estimate your level of expertise: 4

7. Referred intensity scale: (MMI/EMS/MSK). If other scale is referred, please specify which one: EMS

Part II: Summary of Construction Types, Vulnerability and Population

	Construction Material (choose from drop down list)	Construction Subtype (Choose from drop-down list)	Probability of collapse (%) of building type when subjected to the specified shaking intensity				Fraction of population who LIVE in this building type		Fraction of population who WORK in this building type		Peak average # of occupants per building
			MMI-IX / MSK-IX / EMS-IX	MMI-VIII / MSK-VIII / EMS-VIII	MMI-VII / MSK-VII / EMS-VII	MMI-VI / MSK-VI / EMS-VI	Urban A	Rural Are	Urban	Rural	
1	Adobe/Mud Walls	Adobe blocks (unbaked sundried mud block) walls	89	45	15	7	2	98			5
2	Stone/Block Masonry	RS1 Local field stones dry stacked (no mortar)	79	40	10	5	5	95			5
3	Stone/Block Masonry	RS3 Local field stones with lime mortar	40	15	5	2	96	4	25		10
4	Stone/Block Masonry	RS5 Local field stones with cement mortar	18	8	2		12	88			10
5	Brick Masonry	UFB3 Unreinforced brick masonry in lime mortar	20	12	5	2	98	2	45		8
6	Reinforced/Confined Masonry	RM2 Reinforced masonry bearing walls with concrete	15	5	2		97	3	65	`	12
7	Reinforced concrete	C Reinforced concrete	4	1			99	1	65		12
8											
9											
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20												

For other combinations (i.e., building types not available in the drop down list):

21												
22												
23												

Part III: Colleagues Consulted, Additional Sources of Information Used

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	Mailing address	
	e-mail	
3	Name	
	Affiliation	
	Mailing address	
	e-mail	

4 Sources of information you used (websites, publications, etc.) Please provide as much detail as possible.

www.mhuae.gov.ma
www.hcp.ma/
www.cnr.ac.ma/

EL Hammoumi, A. Iben Brahim, A. Birouk, E. A. Toto, A. EL Mouraouah, M. Kerroum, K. Gueraoui, M. Kasmi, “Assessment of Seismic Vulnerability of Urban Buildings in Morocco”, Int. Review of Mechanical Engineering, Praise Worthy Prize S.r.l., Vol. 3, n. 1, 2009

Brahim A., EL Mouraouah A., Kasmi M., Birouk A., Toto E. A., Hafid M., EL Harrouni K. “Seismic vulnerability analysis and computer simulations and modelling; case histories”, in PROHITECH 2009, Proceedings, International Conference “Protection of Historical Buildings by Reversible Mixed Technologies”, Rome – 21st to 24th June 2009

5 Additional comments

See the attached draft file

General information on urban population growth, the housing stock, building materials ans construction systems, Morocco's history seismicity, the seismic design code for buildings, and the seismic vulnerability

Background

A high urban population growth

Located on the western shoulder of North Africa, Morocco's coastline borders both the Atlantic Ocean and the Mediterranean Sea. The country is a mixture of high mountains, desert plateaux and rich coastal plains. Morocco has a youthful population, with some 33% under the age of 15 in 2004. However, the growth rate has slowed from a 2,4% high in the 1980s to 1,6% in 2004. Morocco's population was 29,9 million in 2004, giving the country an overall population density of 42 inhabitants per square kilometres, which is very irregularly distributed. The estimated population is 34,4 million in 2008.

Similar to its neighbours, Algeria and Tunisia, Morocco faces a high urban population growth, with an annual growth rate ranging from 3 to 4% between 1960 and 2004. About 61% of Moroccans are living in urban areas.

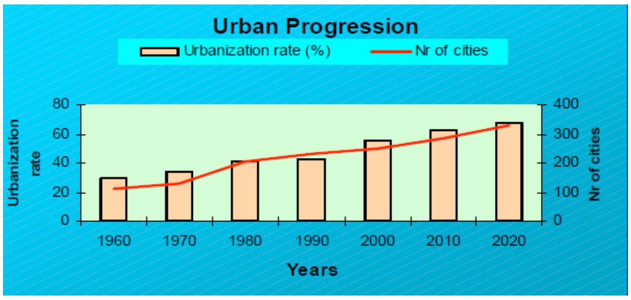

Fig. 1: High rate of urban population

The housing stock: needs in terms of urban housing

The housing stock in Morocco was estimated to 6,2 million units in 2004; the essential of this stock (about 86%) is occupied as a principal residence. The urban housing stock represented 64% of the total stock.

Morocco's annual population growth implies addition every year leading to a requirement of about 110 000 housing units per year. In addition to this, the updated data analysis provided by the 2004 census indicates that the deficit in urban housing is estimated at 1 million. Against the same, the delivery system has been able to produce more than 100 000 units per year. In sum, to be able to absorb and catch up with the housing deficit and meet the new additional needs, the delivery system should be able to produce 200 000 units per year, that is the double of the current production.

The housing stock: classification and characteristics

The housing stock in Morocco can be broken down into tow categories: formal and informal. Formal housing conforms to the law and regulations: the housing unit is built on a properly titled land, in an area zoned for residential construction according to the urban document (master plan), and has a legal construction permit. The formal housing stock is estimated at 80% of the total stock. Informal housing can include two categories: 1) slums (barracks and shacks representing 6% of the stock). For many years the government tried to discourage the development of *bidonvilles* and other spontaneous settlements. More recently, however, the Cities without Slums programme to achieve a slum free target by 2010 is progressing well. 2) the illegal housing, called "habitat non réglementaire" representing about 14% of the stock, in good conditions (good design, good quality construction materials, …), but lacking essential services. The government is seeking ways to regularize this type of housing by bringing it up to an acceptable standard and by providing it with basic services, albeit after construction has occurred

Housing in Morocco can also be ranged from the traditional to the ultramodern, including the following house-types: Villa representing 3,7% of the urban housing stock; Apartment (the contemporary urban apartment block representing 16,4% of the urban housing stock); Modern Moroccan house representing about 61,8% of the urban housing stock (cheap housing built on parcels of between 80 and 120 square meters earmarked for individual housing, but transformed into 2-4 storey urban blocks and comprising one unit housing per floor); Traditional Moroccan house (medinas in urban areas: 7,2% of the urban housing stock, ksour in rural areas); Slum (barrack, shack representing 6,7% of the urban housing stock); Rural house representing 26,0% of the national housing stock; …

Table 1 : National housing stock classification

House-Type	Total %
Villa	2,6
Apartment	10,5
Traditional Moroccan house	6,4
Modern Moroccan house	45,2
Slum	6,2
Rural house	26,0
Others	3,1
Total	100,0

Source : RGPH 2004.

Table 2 : Urban housing stock classification

House-Type	Total %
Villa	3,7
Apartment	16,4
Traditional Moroccan house	7,2
Modern Moroccan house	61,8
Slum	6,7
Rural house	1,0
Others	3,3
Total	100,0

Source : RGPH 2004.

Building materials and construction systems

The most building materials used in the constructions and the common types of structures are:
1. The Earth Architecture using mud brick (adobe), rammed earth (pisé) and compressed earth block.
2. Masonry: Fired bricks, concrete blocks (hollow or solid) performed using cement mortar and natural stone are used for the construction of masonry walls. In all cases the quality of masonry units should comply with the local national requirements with regard to materials and manufacture, dimensions and tolerances, mechanical strength, water absorption, frost resistance, soluble salts content,… .

3. Reinforced concrete: reinforced concrete frames with concrete beam-hollow block slabs and masonry infill walls. This construction system represents about 83% of the constructions

The confined masonry, a construction system where masonry structural walls are surrounded on all four sides with reinforced concrete, is also used. In order to ensure structural integrity, vertical confining elements are located at all corners and recesses of the building, and at all joints and wall intersections.

The principal traditional building materials used in some medinas include the earth blocks, as well as the plaster, the wood and the stone. Traditional ceramic tiles, *zelij*, or cedar woodwork are the common finishing materials. Indeed, one of the constructive typologies of the structure load-bearing wall is the masonry carried out with local stone or earth bricks, and bound by a loam mortar or lime, between which are intercalated wood elements of cedar. This provision of two materials, one rigid and the other flexible device, allows an absorption of the seismic horizontal loads.

Morocco's historic seismicity

The geological position of Morocco at the encounter of several interacting tectonic plate is the raison that, historically, Moroccan cities were repeatedly destroyed by several strong earthquakes. Some cities were partially or totally destroyed. It was only at the beginning of the twentieth century that one started to have reliable and scientific information about the earthquakes in Morocco; the first scientific studies of 1904 had shown that Morocco, like the other Mediterranean countries, was exposed to the seisms. From 1932, macro seismic investigations were organized by the Cherifien Scientific Institute (become Scientific Institute) thanks to the weather observation network. Indeed, the seismic events in Morocco were seldom reported in the historical and archives documents, as well in those which treat the World Islamic history as those specific to the history of Morocco. The information recorded on the seisms in Morocco missed chronological and space details. In addition, the foreign sources which studied the history of Morocco have been much interested in the seisms. Several earthquakes have been mentioned there whereas they were not quoted in the Moroccan historical sources. Certain seisms were quite detailed but in general there was confusion of events and an exaggeration of the material and human losses. El Mrabet's work (2002) largely contributed to the study of this historic seismicity by using the maximum of available sources, Arab, Spanish, Portuguese or French. The richness of these data depended on the intensity of the seism and the proximity of the epicentre to the historical, cultural and political cities, like Fez, Marrakech, Meknes in the centre of Morocco, or to the economic centres like the Atlantic harbours of Tangier in the north and Agadir in the south. From the 9th to the 11th century, the earthquakes were described in a brief way: the writings referred to the destruction of constructions without other precise details. The description became relatively more detailed as from the 15th century, for example the place is quoted clearly, but the objective remained purely informative. It was at the 17th century that one found the details of the 1624 and 1663 seisms reported in a particular mail: the damages which affected the buildings in Fez were mentioned in a detailed way. The extent of the destruction of the 1755 seism, Lisbon earthquake, was mentioned by several sources: the destruction concerned even the palaces and the mosques in Meknes while the damage was less impressive in Fez.
In addition, a chronology of the great earthquakes in Morocco since year 881, is presented according to the Grande Encyclopédie du Maroc (1987):
-In May 28, 881, an appalling seism affected the two banks of the Detroit.

-In December 1 and 30, 1079, a devastating seism destroyed towers, minarets and buildings. Many people perished under the ruins.
-In 1276, a violent earthquake caused the destruction of Larache town located on the Atlantic coast, causing several deaths.
-In September 22, 1522, Fez and the villages of the surrounding area were completely destroyed; the seism caused also several damages in Tetouan in the north of Morocco.
-In January 26, 1531, a violent seism was felt in Morocco but this event is unknown in Moroccan literature.
-The earthquake recorded on March 1, 1579 in Mellilia destroyed tens of houses and part of the ramparts of the city.
-In May 11, 1624, a catastrophic seism destroyed most of the Moroccan towns of Taza, Fez and Meknes. This earthquake is relatively well documented.
-In August 5, 1660, the town of Mellilia was affected by a violent seism causing considerable damages.
In July 1719, the Moroccan coastal towns recorded a violent seism which has also destroyed part of the town of Marrakech.
-In December 27, 1722, a devastating seism caused large damages in the Moroccan coastal towns.
-In 1731, another seism destroyed the town of Santa Cruz (Agadir).
-In November 1, 1755, the seism which struck Lisbon destroyed the majority of the Moroccan coastal towns from Tangier to Agadir. At this epoch the large cities were especially located inside of the country like Fez, Meknes and Marrakech. One of the well documented destructive tsunamis in the Atlantic Ocean. The Arabic and European archives deal us with so important information concerning the event.
About 26 days after Lisbon earthquake, a seism more stronger and violent affected city of Fez after the last prayer of the day: many minarets and mosques were destroyed in different places in the city and about 10 000 persons were killed.
-In April 15, 1757, a violent seism destroyed several buildings of Sale town.
-In April 12, 1773, a devastating seism almost destroyed all the town of Tangier and several houses in Fez were collapsed. This earthquake was also felt in Sale town.
-In August 31, 1792, Mellilia was again shaken by a violent earthquake causing the destruction of several buildings.
-In February 11, 1848, a disastrous earthquake was felt in Morocco causing of large damages in Mellilia town.
-In January 21 and 22, 1909, a seism destroyed rural agglomerations located at 5 km from Tetouan town and maked hundred victims (between dead and wounded).
-In January 4, 1929, an earthquake caused damages in Fez and villages of the surrounding area.
-In February 29, 1960, a devastating earthquake of magnitude of 5.7 on Richter scale, destroyed the Agadir city causing 12000 died; the damages estimated at that time to 290 million dollars.
-In February 28, 1969, a violent seism which had his epicentre in the same area as that of 1755 (Lisbon), was felt in almost all Morocco, but it was on the Atlantic Littoral that this seism reached its stronger intensity.
-In May 26, 1994, an earthquake of magnitude of 5.7 on Richter scale shook the town of Al Hoceima.
-It February 24, 2004, the Al Hoceima province recorded a violent seism of 6.3 on Richter scale causing the collapse of 2539 houses including 2498 in rural areas.

The May 26, 1994 (Mw = 5.7 , EMS92 +7) and February 24, 2004 (Mw = 6.3 , EMS92 +8) earthquakes that affected the Al Hoceima region of northern Morocco are the two strongest events recorded in this region.

Ten months after Al Hoceima earthquake, there was an important but largely ignored event characterized by a vigorous seismic series with a magnitude from 4.3 to 5.3, located about 100 kms SE from Al Hoceima. However, its proximity to large population centre (Nador city, 109 000 inhabitants) was important. A maximum intensity of EMS 7 was observed in Douria village, with widespread damage of grade 3 to vulnerable buildings (Source: Patrick Murphy Corella).

CNRST's recent studies (Centre National de Recherche Scientifique et Technique, Morocco) have given two principal results:
-70% risk for the occurrence of a Magnitude 7.0 earthquake within a period of 100 years for some regions;
-more than 20% of total population live in seismically active geographical areas where moderate earthquake hazards to major damaging earthquake can occur at least once in a lifetime.

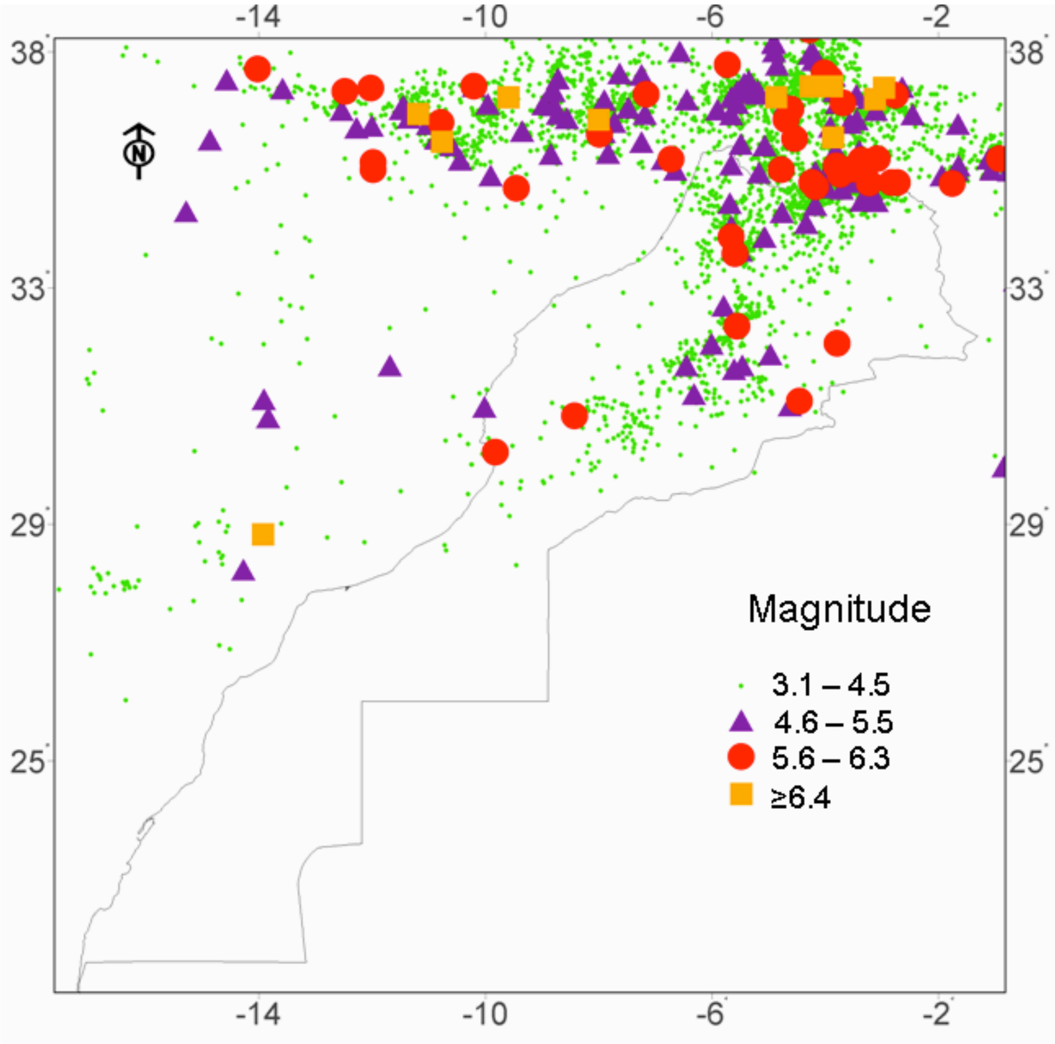

Fig. 2: Morocco's seismicity map (1900 – 2007)
(Source: CNRST, Morocco)

The seismic design code for buildings

Morocco is exposed to a number of natural hazards such as earthquakes, but the regulatory framework for risk management has not been yet fully established. Recent even (the earthquake of February 2004, Al Hoceima in the northern region) demonstrated the lack of preparedness of the country to cope with natural disasters. This earthquake was however the occasion for strengthening the efforts to apply the national building code requirements for earthquakes (RPS2000), to create a new approach to civil protection and the recent creation of the National Committee of Earthquake Engineering.

The different structures concerned by the Code include RC frame and wall bearing structures. The Code is used for new constructions and great modifications of existing buildings. However, it is not applied to bridges, dams, industrial buildings such as nuclear and electric units, and buildings realized by materials or systems not stipulated by the standards.

After 7 years of existence, the RPS 2000 does not seem to achieve all the goals initially discounted at the time of its elaboration due to a mentality problem, a professional engagement problem, but also due to some difficulties of application and comprehension. Some of architects and Engineering Offices were not prepared with the application of this law and the computational tools were not standardized. Fortunately, this Code is improving.

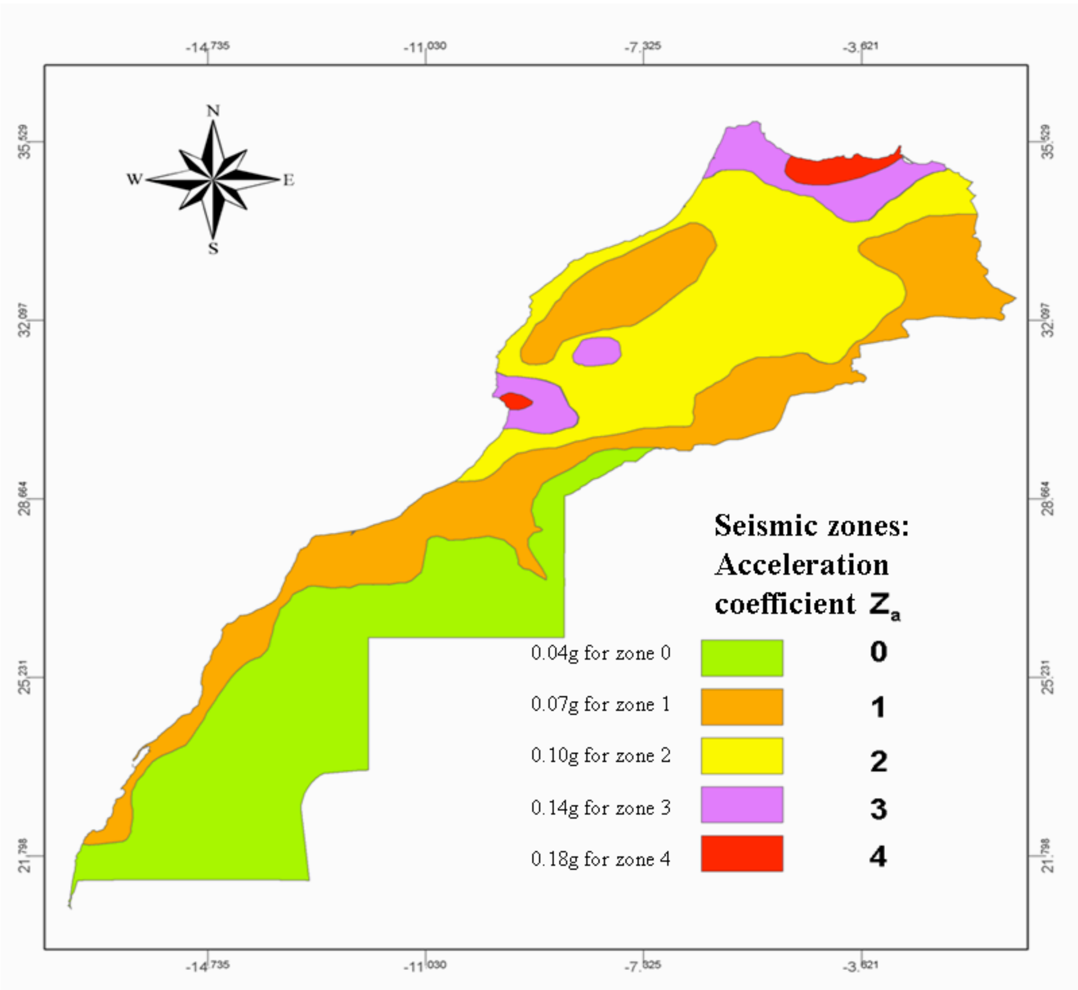

Fig. 3: Seismic zones (5 zones instead of 3 zones in the Codes's first version)
(Source: Revised RPS2000, 2008)

Seismic vulnerability

Seismic vulnerability assessment of constructions in urban areas

The seismic vulnerability assessment of constructions in urban areas was performed using statistics of a survey on the buildings stock in Morocco that was implemented in the year 2000 by the Housing Observatory of the Real Estate Promotion Direction which was under the State Secretariat of Housing. These statistics helped define the different types of housing, and their structures. This information, along with past-earthquakes observed damages allowed to rank the different buildings into vulnerability classes. For the different types of constructions, four vulnerability classes have been found, from class A to D. Then, a semi-empirical method was used for the computation of the buildings vulnerability index and fragility curves for the different vulnerability classes. These fragility curves have been used to simulate the consequences of a seismic intensity IX on the different vulnerability classes. It turns out that the consequences would be catastrophic for class A and would have very little effect on class D buildings.

Fig. 4: Soft storey damage to this RC building in Al Hoceima region. (grade 3 vulnerability C)

Fig. 5: On the right: building with ground floor collapse (grade 5 vulnerability C)
On the left: both ground and first floors failed in this building (grade 5 vulnerability C)


Fig. 6: Damaged column and soft storey damage (grade 4 vulnerability C)


Fig. 7: Shear damage to the hollow brick wall with RC frame (grade 2 vulnerability C)


Fig. 8: Advanced corner failure of traditional masonry. Rural area in Al Hoceima region (grade 4 vulnerability A)

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