WHY ARE EARTHQUAKES STILL SO DEVASTATING

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ABSTRACT :

Potential earthquake regions are well known and construction techniques are available in order to build earthquake resistant buildings. Regulations taking the seismic action into account are implemented. Despite a large understanding and knowledge earthquakes are, and will be devastating for the following reasons: a) Earthquakes do not occur often. Events not occurring regularly at short intervals do not influence the construction technique of non-engineered constructions. Design rules are not applied because of the absence of an imminent danger. b) Design rules established by the scientific community are not understood by the builders and are not applied. c) Houses are often built by tradesmen without any knowledge of seismic design. Simple design rules are not known by individual builders and are therefore not applied.

KEYWORDS: Seismic hazard, construction technique, non-engineered construction, damage

1. INTRODUCTION

Several million earthquakes occur every year, but most earthquakes are not strong enough to be detected and do not cause any damages to the surrounding buildings. As many as 150 earthquakes occur each year with a magnitude higher than 6.0 [USGS, 2008]. Strong earthquakes occur also in uninhabited regions or the epicenters are too deep and do not harm people or damage buildings. The fact remains that there will always be devastating earthquakes with huge losses (Life and property).

1.1. Recent devastating earthquakes

On December 26, 2003 at 5:26 the Iranian City of Bam was destroyed by an earthquake which killed many people (estimates indicate the number of victims between 25'000 and 80'000. The most cited number is about 27'000). 10'000 to 50'000 people were injured. The magnitude of the quake was 6.6 and the slip occurred at a depth of 2 to 7 km. The fault line was already well known for earthquakes [Zare, 2003].
On October 8, 2005, at 08:50 Kashmir was hit by an earthquake with a magnitude of 7.6. This disaster is also known as the South Asian Earthquake or the Great Pakistan Earthquake. More than 70'000 people were killed and about 3.3 million people were left homeless. The severity of the damage caused by the quake is attributed to severe up-thrust, coupled with poor construction. The seismicity in this region is caused by the collision between the Eurasian and the Indian tectonic plate [Kashmir Earthquake, Wikipedia, 2008]. This is a region with a well understood seismic activity.
On August 15, 2007 at 18:40 an earthquake devastated the cities of Pisco, Chincha and Ica in Peru. The magnitude of the quake was 8.0. About 500 people were killed and more than 58'000 homes were destroyed. Up to 80 % of the city of Pisco was destroyed. The earthquake occurred early in the evening meaning the death toll was not as high as it would have been [Peru Earthquake, Wikipedia, 2008]. Extensive damage was observed in rural regions. This quake also occurred in a region known for its seismic activity, at the boundary between two tectonic plates.
The locations of the earthquakes are well known because most earthquakes occur at plate boundaries of the tectonic plates. Maps are available that show these locations.

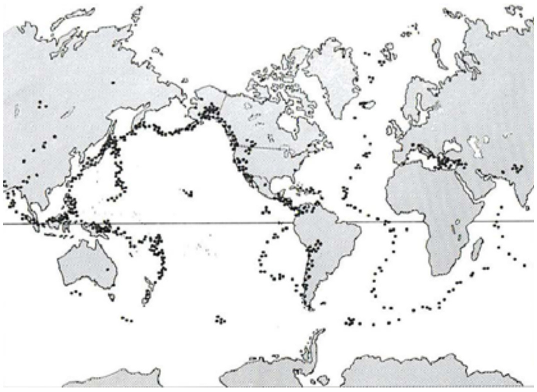

Figure 1 Location of earthquakes [Weidmann, 2002]

1.2 Codes and construction technique

Over the last decades reliable codes were developed and implemented in order to build earthquake resistant buildings. Many countries do have such regulations. If the regulations are properly applied buildings are constructed which resist earthquakes. These design regulations were established by the scientific community and are exchanged during conferences. It is therefore possible to build earthquake resistant buildings.
Recently strong earthquakes have hit well populated regions. Well designed buildings did not suffer earthquake damage.
It was also observed that during the Peru 2007 earthquake several buildings showed almost no

damage whereas adjacent buildings were completely destroyed. In the village of San José de Los Molinos the schoolhouse, a reinforced concrete structure, did not suffer damage whereas the individual buildings, made of adobe, were destroyed.

1.3 Observations

Despite the fact that earthquake hazards are well known and reliable construction techniques exist there were, and will be earthquakes with huge losses of life and destruction of property. Here the causes are examined:

- Earthquakes do not occur often
- Earthquake hazard is not a visible threat
- Empirical design rules are not applied
- The seismic action on a building is not understood (non-engineered constructions)
- The design regulations are not understood
- Many buildings are non-engineered constructions and therefore not designed against earthquake actions

In the following these observations are explained.

2. OCCURRENCE OF NATURAL HAZARDS

Events not occurring regularly at short intervals do not influence the construction technique. Often housing for the population has to be built quikly and the potential hazards are not taken into account by the individual builders. A hazard is only taken into account when it is known. With what regularity must a hazard occur in order to influence the construction?

Investigations were made into the flooding of the Rhine valley below Basle, Europe. Flooding occurred from time to time and it was investigated for as long as the population remembers these incidents. It was found that already after seven years the hazards were forgotten if no continuous information was given to the population.

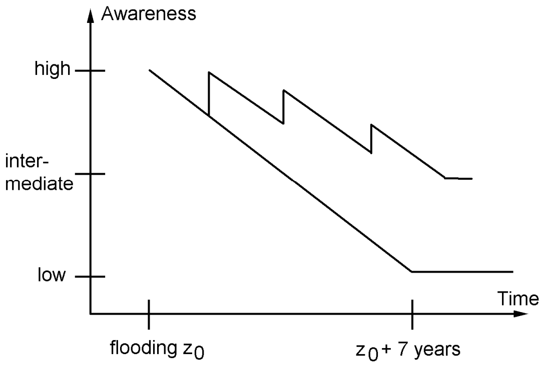

Figure 2 Awareness of natural hazards [Egli, 2002]

Reoccurrence of events over one generation (20 to 30 years) do not influence constructions. Earthquakes which did occur 50 or more years ago will not influence the construction technique of individual builders. They are not aware of these hazards. However, this is different if the buildings are constructed according to standards. In the norm events that reoccur regularly with a long return periods are considered.

2.1 Finding

Only a permanent hazard is taken into account. Devastating earthquakes do not occur often enough at the same location that they are taken into account.

3. VISIBILITY OF HAZARDS

In order to take actions against a hazard, the hazard has to be visible. Everyone can imagine that a river may flood the surrounding land or an avalanche may come down and destroy buildings.
However the earthquake hazard is different from the flooding hazard: The river, the source of the potential hazard, is always visible. Everybody can see the water and is aware that more water may come and flood the land around it.
Earthquake hazard is not visible: people in earthquake regions are not constantly thinking that the ground may shake and destroy buildings. Discussions with victims of the Peru Earthquake indicated that they experienced earthquakes before but they never experienced such a devastating earthquake. Devastating earthquakes occurred in other regions or long time ago.
Not only individuals tend to forget hazards but also the authorities. During summer 2002 parts of Germany were flooded. A village suffering much damage was Röderau Süd. The houses were legally built in the 90's [Berliner Zeitung, 2002] and flooded in 2002. After the flooding the authorities decided to relocate the inhabitants of this village and to use the land again for farming. Authorities forget hazards!

Figure 3 Flooded village (Röderau Süd 2002)

3.1 Finding

Only visible hazards are taken into account. Earthquakes are an invisible threat and are not taken into account by individual house builders without scientific knowledge in earthquake engineering.

4. APPLICATION OF EMPIRICAL DESIGN RULES

Houses in rural areas are often built by tradesmen without scientific knowledge in earthquake resistant design; they are so called non-engineered constructions. Empirical design rules are known which do not require calculations. By simply using proper detailing safe houses can be built. Some times these rules are not even written in the codes, they are just good practise. An example of such a rule is that walls should be linked by bond beams and walls reinforced by simple wire mesh.

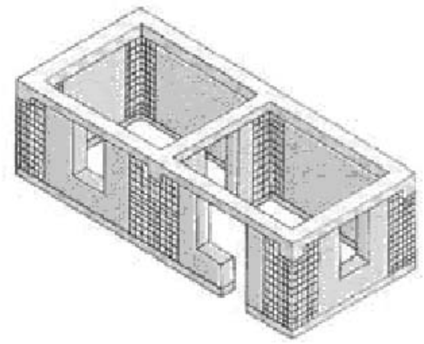

Figure 4 Application of wire mesh and bound beams [Blondet, 2008]

It was shown that by applying these rules even adobe structures resist the horizontal forces during earthquakes. Research was undertaken in Peru to strengthen adobe buildings. It was found that one very effective way to improve the behaviour was to reinforce the walls with wire mesh. The wire mesh may also be applied to existing structures [Auroville. 2008].
The Auroville Earth Institute in India developed design rules for earthquake resistant designs for adobe buildings. These design rules can be applied without extra costs and yield buildings which resist earthquakes. They also observed that in the Gujarat 2001 earthquake some traditional houses made of adobe withstood the seismic forces extremely well. They were simply well designed and well built [Webster, 1995].

4.1 Finding

The empirical design rules are not known to the craftsmen.

5. UNDERSTANDING SEISMIC ACTION

During an earthquake the ground moves rapidly horizontally and vertically. Horizontal forces act therefore on the building due to the horizontal accelerations which, with the mass, produce inertia forces. Usually buildings are designed to withstand the vertical actions and the only major horizontal actions on constructions are wind forces. Buildings with great masses, such as adobe buildings with heavy roofs, create huge horizontal forces. The structure may not resist these lateral forces and collapse. It is of importance that the builders understand what happens during the seismic shocks. However it may be rather complicated for non-trained personnel to estimate the magnitude of the horizontal forces.

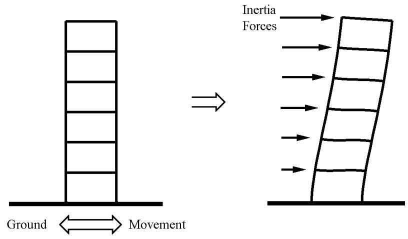

Figure 5 Earthquake action on buildings

5.1 Finding

The average person does not understand the behaviour of structures during earthquakesand may not take into account the horizontal forces due to seismic action.

6. DESIGN RULES ARE NOT UNDERSTOOD OR NOT CORRECTLY APPLIED

For major buildings the earthquake resistance has to be proved by numerical methods. Codes usually require numerical verifications, but conceptual and constructional measures are also very important to improve the behaviour. Simple rules can be easily understood and applied to buildings at no extra costs. However, if these rules are not understood, they can not be applied correctly. Rules are indicated in the literature e.g. [Bachmann, 2002] these rules can be applied at no significant costs. An example is shown in Figure 6.

Figure 6 Design Rule: Avoid «bracing» of frames with masonry infills [Bachmann, 2002]

Design rules established by the scientific community do not reach the housing builders. Research is done in universities and the behavior of earthquake action on buildings is well understood. This research is then taken by the code makers and should be applied to new buildings. Buildings designed and constructed according to these rules behave, in general very well and do not suffer damage.
However, these design rules are not always properly applied. The reasons are:

- The designer does not apply the relevant codes
- The rules are ignored (money and / or time may be saved)
- Lack of proper supervision on construction site

6.1 Finding

Design rules are not understood and are therefore not applied.

7. NON-ENGINEERED CONSTRUCTIONS

There are constructions designed by professional engineers and non-engineered constructions. Non-engineered buildings are erected by local tradesmen and are not designed according to the regulations. The ultimate resistance of structures designed by engineers is usually verified by analytical models. In order to check the resistance codes have to be applied and a margin of safety is granted. Structures built by tradesmen are based on experience with earlier structures. The margin of safety is unknown and may be very small. These buildings may collapse during earthquakes.

During the Peru earthquake many non-engineered structures were completely destroyed, see figure 7. Simple design rules were not applied.

Figure 7 Non-engineered structures in Pisco, Peru 2007 Earthquake

Many of these buildings had adobe walls and lightweight roofs made of timber. Buildings collapsed but did not burry the inhabitants because of the light roof. It is believed that most of these structures were not designed against earthquake actions. The Peru earthquake hit the population in the rural areas. Houses in the rural areas were mostly non-engineered constructions.

7.1 Finding

Non-engineered structures may not be designed against horizontal loads and therefore have an unknown margin of safety. They may not resist to the inertia forces during an earthquake and collapse.

8. CONCLUSIONS

In the future earthquakes will continue to be devastating and will cause much damage to people and property. The following reasons are:

1. Many people live in non-engineered houses, often in adobe buildings. These buildings are built by local tradesmen without training in earthquake design. Experience plays a major role in constructing these buildings. For any given location strong earthquakes do not occur often. After some decades the devastating seismic actions are forgotten and therefore not taken into account anymore.
2. Earthquakes are not a visible threat to a building. Seismic design is forgotten.

3. Simple design rules are not passed on to the builder of rural houses. Construction workers are not aware of the horizontal forces during earthquakes. Buildings are not designed for these horizontal forces.
4. Non-engineered constructions are not verified by engineers with an adequate knowledge in earthquake engineering.
5. Existing design rules have to be understood in order to be applied. Only if the behaviour of structures influenced by horizontal accelerations is understood can these rules can be applied.
6. It is important that buildings in rural regions are also designed against seismic actions and not only major buildings in the cities.

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