EARTHQUAKE RISK MITIGATION IN SWITZERLAND – SUCCESSES, FAILURES AND CHALLENGES IN A COUNTRY OF MODERATE SEISMICITY

B. Duvernay[1]

[1] *Head of the Coordination Center for Earthquake Risk Mitigation, Federal Office for the Environment, Bern, Switzerland, Email: Blaise.Duvernay@bafu.admin.ch, www.bafu.admin.ch/erdbeben*

ABSTRACT :

Switzerland is a small country located in a zone of moderate seismicity in central Europe. It is a federal state with 26 cantons (states) that have a large legislative autonomy in many fields such as construction or education. For the mitigation of most natural hazards on the other hand, the federal authority has a strong legislative competence given by the Constitution. This means it can develop risk mitigation strategies that have to be implemented by the cantons with the help of federal subsidies. This way of doing should insure nationwide protection standards against natural hazards.

Earthquake risk mitigation being a very recent issue in Switzerland, it is not dealt with in the Swiss constitution. Therefore, the federal authority has only limited prerogatives to act in this domain and the responsibility for earthquake risk mitigation is mainly left to the cantons. With this situation, there is a risk to see 26 different solutions being developed by the 26 different cantons. This would mean very different seismic protection standards for the population and the goods across a small nation with only 7.7 million inhabitants. To try to alleviate this potential problem, a constitutional change was proposed in 2003, but refused by a commission of the national parliament.

This paper presents an overview of seismic risk mitigation in Switzerland and discusses the main successes and failures since the starting point of risk mitigation initiatives in Switzerland in the mid-1990s. Difficulties induced by the combination of a federal political system with a strong regional autonomy and the general low awareness due to the low recurrence rate of damaging events are discussed. Actual major challenges and the solutions that are foreseen to effectively reduce the seismic risk in the long term are finally outlined.

KEYWORDS: Earthquake, risk, mitigation, Switzerland

1. SEISMIC HAZARD AND RISK IN SWITZERLAND

1.1. Seismic Hazard

Switzerland is located in the center of Europe in a region of low to moderate seismicity (figure 1). The approximate return periods for different magnitudes are 10 years for magnitude 5 earthquakes, 100 years for magnitude 6 earthquakes and 1'000 years for magnitude 7 earthquakes. A magnitude between 7.0 and 7.4 is the largest expected magnitude in this region.

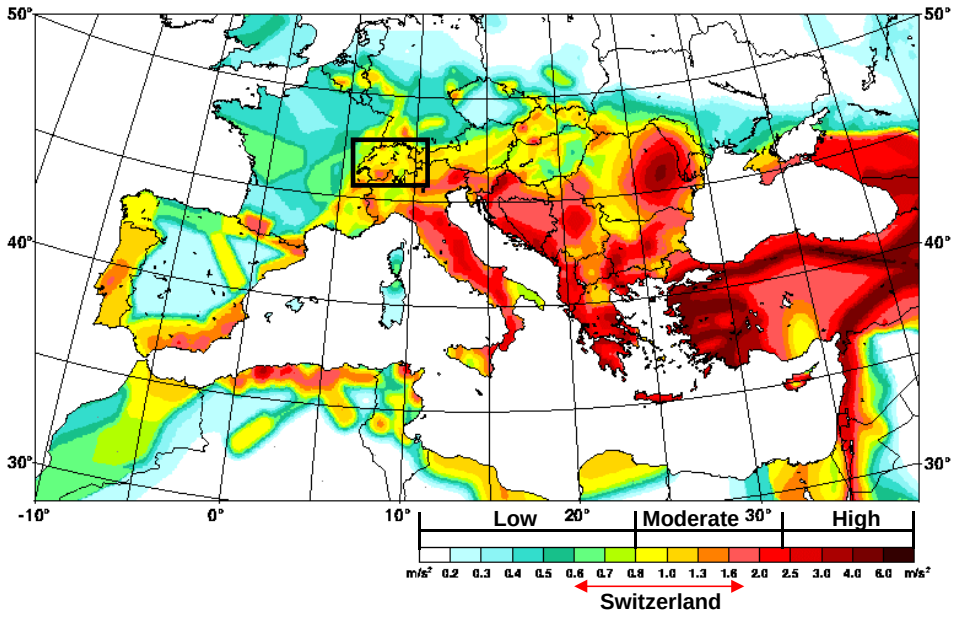

Figure 1: Earthquake hazard in central Europe and around the Mediterranean basin. (Jimenez et al., 2003)

The last damaging earthquake with a magnitude greater than 6 dates back from 1946 and was located in the canton of Valais (figure 2). The 1356 Basel earthquake is the biggest known historical earthquake in central Europe with an epicenter intensity of IX and an estimated magnitude of 6.5 to 7. Hazard studies in Switzerland were mostly based on the analysis of an historical earthquake catalogue of the Swiss Seismological Service (SED, 2002). Based on the hazard studies of SED four seismic zones are defined in the building codes of the Swiss Engineers and Architects Society (SIA, 2003).

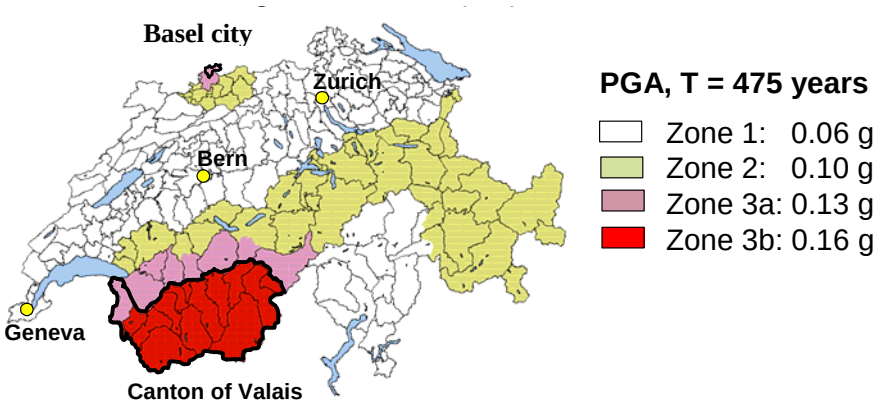

Figure 2: Seismic zones in the building code SIA 261. PGA is given for a rock site with max. 5 m alluvial top soil.

The highest seismic zones (zones 2 and 3) cover the alpine region and the Basel area. The lowest seismic zone covers the plateau (low land) as well as the southern region of the alps. The bigger urban centers are located in zone 1 to the exception of Basel.

1.2. Seismic vulnerability of the built environment

Seismic prescriptions do exist in the swiss building codes since 1970. The edition from 1970 considered a level of earthquake hazard that was very low (PGA of 2%g for most of the country) and in many instances earthquake design loads were comparable to wind design loads. The actualization of the building codes in 1989 contained the first adequate earthquake design provisions with a hazard map, response spectra and material specific parameters. In this edition earthquake design loads became higher than wind design loads for most cases. The building codes have been updated once more in 2003. This new edition is compatible with the Eurocodes. Seismic design loads were once again increased mostly due to a better consideration of the amplification due to the local soil conditions.

Eighty (80) percent of the buildings in Switzerland have been built before 1989. These buildings were designed mostly with wind design lateral loads and their actual seismic safety is largely unknown. The same can be said about many infrastructure elements. Even since 1989, the seismic provisions of the building codes have been largely ignored due to the low awareness of the seismic risk, the insufficient formation of building professionals and the lack of explicit enforcement and control of the building codes by authorities.

The analysis of existing buildings in Switzerland show that they often suffer from typical conceptual problems such as soft storey, very asymmetric bracing, masonry stiffening walls for high buildings, heavy masonry facades without connection to the decks (pre WWII buildings), prefabricated buildings with rudimentary connections. From a global standpoint, most of the building stock would be classified either in the vulnerability class B or in the vulnerability class C according to the European Macroseismic Scale 1998 (Grünthal et al. 1998).

1.3. Seismic risk and its perception

In Switzerland, the seismic risk is comparable to the flood risk. These two risks are the dominant risks associated with natural hazards. The main difference lies in the fact that floods are more frequent than earthquakes but have a lower damage potential. As an example, the floods of 2005 which represent the costliest natural catastrophe in Switzerland caused direct losses of 3 billion US dollars to private property and infrastructures and resulted in 6 casualties. The damage potential for earthquakes is much higher. A typical 100 year event in the canton of Valais with an earthquake magnitude in the order of 6.0 to 6.5 would cost 5 to 8 billion US dollars (basis 1 US dollar = 1 swiss franc) in direct damage to buildings and contents and would cause many tenners to a few hundreds casualties. A repeat of the Basel earthquake of 1356 with an estimated magnitude between 6.5 and 7.0 would cause between 50 and 100 billion US dollars worth of direct damage to buildings and contents and would also cause hundreds to a few thousands casualties. Such an event is statistically very rare with an estimated return period between 1’000 and 5’000 years and is considered as a credible worst case scenario in terms of potential losses. As a reference value, the Gross Domestic Product of Switzerland in 2007 was 480 billion swiss francs.

On the other hand, the perception of the earthquake risk by political authorities, building professionals and the general public shows that is largely underestimated, which is a common fact in countries of moderate seismicity where not each generation has experienced a damaging event. The general public and construction professionals have the impression that the average construction quality in Switzerland is such that earthquakes would not be too much of a problem. They also tend to over evaluate the extra costs to build a seismic resistant building according to the actual building codes. Typically construction professionals think that a 5% to 10% cost increase would result, whereas experience shows that the extra cost should be on average around 1% to maybe 2 to 3% in the zones of highest seismicity.

2. SEISMIC RISK MITIGATION IN SWITZERLAND

2.1 Chronological history of seismic risk mitigation

Table 1 shows key dates in the history of earthquake hazard analysis and earthquake risk mitigation in Switzerland. It shows that seismic safety before the mid 1990s was a concern only for the nuclear power plants and the dam installations which are supervised by the federal state. For most of the other infrastructure (to the exception of bridges of the national roads) and for most of the ordinary buildings seismic safety was usually not an addressed issue. This table gives a sense of the dynamics of earthquake risk mitigation and shows a clear extension and acceleration since the mid 1990s.

Table 1 key dates in the seismic risk mitigation in Switzerland

1878:	**Establishment of the Swiss Earthquake Commission (Swiss Seismological Service since 1913).**
1911:	Installation of the first seismograph (Zürich).
1946:	Magnitude 6.1 earthquake in Sierre (canton of Valais).
1950:	until 1970 construction of most swiss dams (state of the art seismic design).
1969:	until 1984, four nuclear power plants enter service (state of the art seismic design).
1970:	**First building code with rudimentary seismic provisions (largely ignored).**
1978:	First earthquake hazard map of Switzerland in intensity scale.
1978:	Founding of the Swiss Pool for Earthquake Coverage (voluntary pool of cantonal insurances).
1982:	Founding of the Swiss Society for Earthquake Engineering and Structural Dynamics (SGEB).
1985:	until 1993: seismic retrofit of nuclear power plants Beznau and Mühleberg.
1989:	**First modern seismic prescriptions in modern building codes (largely ignored).**
1991:	until 1993: construction of a Strong Motion Network.
1993:	**First canton (Basel-city) begins to evaluate the seismic safety of its critical infrastructures.**
1995:	Kantanos study lists earthquakes as being a major risk related to natural hazards for Switzerland.
1998:	SGEB-publication „Need for action for authorities, universities, industry and private persons,..“.
1998:	Motion Epiney: „call fort the establishment of a clear legal basis for seismic risk mitigation“.
1999:	Concept for a risk mitigation program is addressed to the federal council.
2000:	**Federal council decision : first federal earthquake risk mitigation program (2001-2004).**
2001:	**First canton (Basel-city) modifies its construction law and starts to control the seismic safety of private construction projects.**
2002:	New guidelines for seismic requalification of dams (controls mandated until 2012).
2003:	New seismic hazard map of Switzerland is published.
2003:	Newest generation of building codes with actualized seismic prescriptions.
2003:	**The constitutional modification to establish a clear legal basis for earthquake risk mitigation is rejected by a subcomission of the parliament.**
2004:	The canton of Valais modifies its construction law and starts to control private construction projects.
2004:	**First building code for the seismic verification of existing buildings (SIA, 2004).**
2005:	Federal council decision: federal earthquake risk mitigation program 2005 - 2008.
2005:	**The insurance industry launches a project for a national mandatory earthquake insurance.**
2005:	First conference „Seismic risk mitigation: what can the cantons do“ (organized by the Confederation)
2005:	First continuing education course on earthquake engineering. Demand comes mostly from control procedures implemented in the canton of Valais.
2006:	PSHA Pegasos study for the actualization of the seismic hazard for nuclear power plants.
2006:	The educational shake table of the federal office for the environment enters service.
2008:	Preparation of the third federal program for earthquake risk mitigation.
2008:	Distribution of the federal seismic control procedures for construction projects to all pertinent professional associations and authorities with a call for voluntary application.

2.2 Overview of the actual situation

The predominant actual problem for seismic risk mitigation in Switzerland is the lack of a federal law giving the federal state the competence to elaborate and enforce a nationwide seismic risk mitigation strategy. Such a scheme is standard for the management of risks due to natural hazards in Switzerland to the exception of earthquakes. In all other instances, the federal state defines the risk mitigation strategy and the 26 cantons do apply the strategy with the financial support of the federal state. A proposal for a constitutional change in order to set this legal basis for earthquake risk mitigation was refused in 2003 by a commission of the National Parliament. The main reasons for this refusal were unwanted new costs in the federal and cantonal budgets, pressure from the cantons that did not want to loose cantonal autonomy in matters of construction law and building insurance.

Most cantons have developed mitigation strategies for their own building stocks but do not interfere with private construction projects (figure 3). They leave the responsibility of a right and complete building code application to the construction professionals and building owners. Only the cantons of Basel-city and Valais do enforce and control the application of the seismic prescription of building codes for private construction projects. This situation is unsatisfactory as it is observed that the seismic provisions of the buildings codes are still often ignored or misused, mostly in private construction projects but sometimes also in public construction projects. On major contributing problem to this situation is that architects are still reluctant to believe in the necessity of seismic design and are not willing to adapt their technical knowledge in this field despite the organization of seminars and specifically dedicated publications. Knowing the importance of the architect in the overall conception of a building and the usual late involvement of the structural engineer in the process, this situation still leads to less than optimal structural concepts even if the engineer is aware of the problem and willing to apply the building codes. Some cantons prepare legislative changes to introduce controls of private construction projects, but most of them have not planned to do so in the near future.

The federal administration has its own program of mitigation measures since 2000. This program is limited to the legal domain of competence of the federal administration but also aims to motivate the different cantons and private owners to take action. It also aims to develop useful mitigation instruments and standards in order to avoid 26 different solutions to mitigate the earthquake risk in a country of 7.7 million inhabitants.

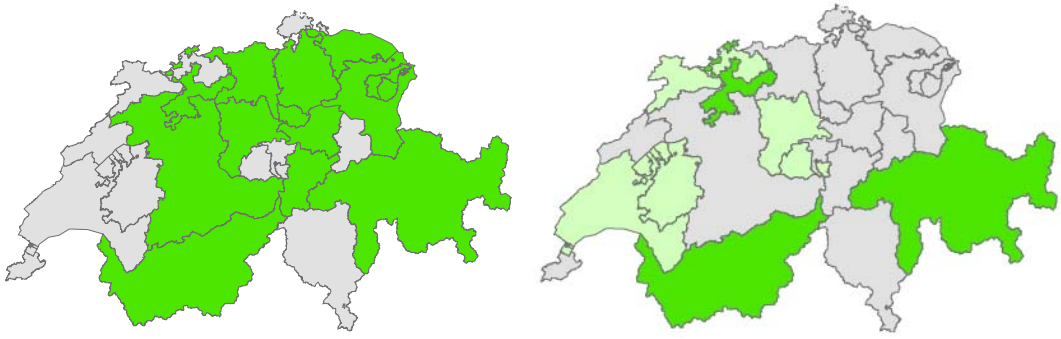

Figure 3: Left: Seismic verification of cantonal important public buildings and enforcement of building codes for public buildings (green = yes, grey = no). Right: Legal enforcement of the building codes for private construction projects (green = yes, pale green= foreseen, grey = not planned)

As for the coverage of financial losses, earthquake damages to buildings and contents are not covered in the mandatory insurance for buildings. This mandatory insurance covers losses from fire and other natural hazards to the exception of earthquakes. It is provided by monopolistic cantonal building insurances in 19 cantons and by private insurances in 7 cantons. Since 2005, a project to extend this insurance to cover earthquake losses is in preparation. This project is a joint project of the cantonal building insurances and of the private insurances. It is supervised by the

federal office for private insurances. One major challenge for this project will be to get approval from the federal administration as well as well as all the necessary legislation adaptations in the cantons in order to extend the policy coverage of the actual insurance system. If things go according to plan, this national mandatory coverage should start in 2010. Premium should be set at 0.01% per year with a deductible of 10% (minimum 50'000 US dollars). Such an insurance product would be a major step in reducing the financial risks for private building owners. It is also hoped it will help to harmonize the earthquake risk mitigation and promote a more widespread control of the seismic provisions of the building codes.

2.3 The federal seismic mitigation program

In December 2000, the Federal Council decided to start a federal earthquake risk mitigation program. To implement and manage the program, it has created the Coordination Center for Earthquake Risk Mitigation (CCERM) at the Federal Office for the Environment (see also http://www.bafu.admin.ch/erdbeben). The measures of this program are summarized in the following paragraphs:

2.2.1. Enforcement of building codes for construction projects

For all federal construction projects and projects that have to be approved or subsidised by the federal administration, standardized control procedures have been put in place in order to enforce, control and document the application of the seismic provisions of the building codes. These procedures have been developed since 2005 and are now implemented as standard procedures.

2.2.2. Seismic control and retrofit of important federal buildings

For all important and critical federal buildings, a systematic inventory of the seismic safety runs since 2001. The goal is to identify the buildings with a high risk potential and to retrofit them if necessary. About 800 buildings have been screened so far and around 160 of them will have to be evaluated in detail and reinforced if necessary within the next 20 years. All 4'200 bridges of the national road have also been screened. 20% of them will have to be evaluated in more detail and retrofitted if necessary in the next 15 years.

2.2.3 Seismic safety of infrastructure systems

The aim of this measure is to develop the necessary technical documents and procedures to control construction projects of infrastructures that are in the domain of competence of the Confederation. Another goal is to sensitize infrastructure owners outside the domain of competence of the Confederation. The infrastructure sectors that have been handled in priority since 2005 are the national roads, the electric power substations and the essential communication systems.

2.2.4 Development of seismic safety concepts for cultural heritage of national importance

The aim of this measure is to develop applicable methodologies for the seismic verification and strengthening of vulnerable historical structures, taking into account the conflict between intervention and preservation. At this stage most of the activity is restricted to research activities and the development documentation standards for cultural heritage structures.

2.2.5 .Legislation enhancements

The aim of this measure was to establish a legal basis for a nationwide strategy to be implemented by the cantons. A proposal to modify the Constitution in order to give the federal administration strategic prerogatives for earthquake risk mitigation was refused by a commission of the Parliament in 2003. This was a major drawback in the mitigation program.

2.2.7 Development and implementation of an intervention concept at the federal level

In Switzerland, cantons and communes have the operational lead in case of natural catastrophes. The confederation will engage its resources only if requested by the cantons. In case of an earthquake the resources of the cantons would be clearly insufficient and the federal state would have to take an active supportive role. This measure aims to develop the necessary procedures and instruments to be able to provide an effective support and coordinate international help efficiently.

2.2.8 actualization of hazard models

The main mission of the swiss seismological service (SED) is to record the seismic activity and update the earthquake hazard model according to the current state of knowledge. The renewal of the swiss strong motion network that is planned between 2009 and 2016 aims to provide essential data for these future hazard maps revisions.

2.2.9 Information and promotion of risk mitigation initiatives

The goal of this measure is the preparation and distribution of informative material for the public, authorities, building owners and construction professionals, the support of regional initiatives, the support of continuing education and applied research. These activities will have to be intensified in the coming years to compensate for a lack of harmonized mitigation strategy.

2.4 Lessons learned from systematic controls of construction projects in Valais

The canton of Valais has 285'000 inhabitants (3.85% of Switzerland's population) with a concentration of that population in the Rhone alluvial valley on deep sediments with potential important valley amplification effects. The approach of this canton is good example for the right balance between information, organization of continuing education in earthquake engineering and strict control of the enforcement of building codes.

The cantonal authorities have decided to enforce the application of the seismic provisions of the building codes in the process of the revision the cantonal construction law in 2004. All new buildings with more than 2 stories above ground, as well as buildings with high occupancy and critical infrastructure buildings require the submittal of a standardised pre design report which is controlled by a mandated engineer for the issuance of the construction permit. After the construction of the building raw structure, a standardised compliance report has to be submitted for the issuance of the habitation permit. For the rest of the new buildings projects, the compliance with the seismic provisions of the building codes remains mandatory, but no particular documentation has to be submitted for control (self responsibility).

The general acceptance of these controls for new buildings is now good. At the beginning of the controls in 2004, a few projects that were built in non conformity with the pre design reports were stopped and correction measures were forced by the canton. This sent a strong signal to the building owners and construction professionals that seismic safety would be strictly enforced.

Out of the analysis of several hundreds of pre design reports in the first year of application, it was found that approximately 50% of these reports contained basic mistakes. This confirmed that not all engineers are able to apply the seismic provisions of the building codes correctly and that a continuing effort in post formation is necessary. The canton organized seminars and distributed a lot of information to building professionals. To further support the engineers in the application of the buildings codes, a map of the foundation soil classes covering the whole canton has been published. In 2008 the big majority of pre design reports are satisfactory. The canton plans to relax its control procedures within the next two years. This example shows that a very strict control process can also be applied during a finite phase until the construction world gets used to deal with the problem efficiently.

As accompanying measures, the theme of seismic safety was presented at the two most important fairs of the canton in 2006 and 2008. At these occasions, special events were also organized for schools and the educational shake table

test of the federal office for the environment was used to provide a lively experience of earthquake shaking.

3. CONCLUSIONS AND PERSPECIVES

In order to achieve an effective seismic risk reduction in building construction projects in Switzerland, control procedures have been developed and introduced recently. At the time being, such procedures for private sector buildings are only applied in 2 out of 26 cantons (states) as well as for the federal construction projects. These control procedures have proven to be effective at reasonable costs and have also demonstrated that the current average level of proficiency of civil engineers and architects in seismic design needs to be further increased.

Political pressure from the federal administration on the cantons, increasing public awareness, as well as a very likely future (2010 horizon) extension of the mandatory building insurance in order to cover earthquake losses will hopefully contribute to a generalisation of control procedures in the rest of the cantons. Only so will a long term effective vulnerability and risk reduction be achieved. The federal mitigation program and the pioneering experiences in the canton of Valais have shown that success depends on the right balance between information, education of construction professionals, the preparation and distribution of technical information and the strict enforcement of building codes. As a positive signal several other cantons plan to adapt their legislation in order to be able to control private construction projects. As in many countries of moderate seismicity, obtaining the necessary political support to do so remains a challenge.

If the federal state will ever have the necessary legal basis to be able to determine a nationwide strategy for the mitigation of seismic risk is an open question. The actual disparate situation in the 26 cantons regarding regional mitigation strategies show that such a legal basis is an important building block for an efficient and uniform mitigation of the seismic risk. In this context, the federal strategy remains to show a good example, inform and sensitize stakeholders, support the issuance and distribution of all the necessary technical information and motivate cantons and private owners to be more proactive in seismic risk mitigation. Since the mid 1990s, a lot of progress has been made, but a lot remains to be done to cover the last mile towards effective seismic risk reduction.

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