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APPLICATION OF EUROCODE 8 IN SWITZERLAND

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SUMMARY

In 2003, a new generation of SIA Structural Standards (Swisscodes) based on the Eurocodes were published in Switzerland. Instead of producing an independent seismic document based on Eurocode 8, the European regulations were integrated into the action code as well as into the different material related codes. At the same time, the Eurocode 8 regulations were condensed to the principles and to a minimum of application rules appropriate for a country with low to medium seismicity. The Swiss integration approach allowed to eliminate certain contradictions between different Eurocodes and to produce a user-friendly Standard suitable for practical use.

1. INTRODUCTION

At the beginning of the 1990's when the Eurocode program was started under the guidance of the Comité Européen de Normalisation (CEN), it was planned to publish the Eurocodes by the end of the century. Switzerland originally intended to take over rapidly the definite EN-Versions of the Eurocodes as National SIA Structural Standards with a minimum of changes as soon as they become available. The same procedure was already applied to the ENV-Versions of the Eurocodes (Prestandards) in the early 90's. With time, the delay of the Eurocode program became more and more important and the previous SIA Structural Standards published in 1989 slowly reached the end of their life cycle. In 1999, the development of the so called Swisscodes, a new generation of SIA Structural Standards based on the Eurocodes, was started. The working schedule of the Swisscode program was very tight and already in 2003, i.e. only four years later, the new SIA Structural Standards were published in French and German. The earthquake regulations of the Swisscodes comprise, among other features, a new seismic zoning map, material related seismic rules integrated in the corresponding material codes, and a risk based seismic assessment of existing buildings.

2. OPTIONS FOR IMPLEMENTING EUROCODE 8

Two different options for the implementation of the seismic regulations of Eurocode 8 in the framework of the Swisscodes were evaluated:

1. Self standing document for seismic regulations
2. Integration of seismic regulations in action and material codes

The first option would be in line with the strategy adapted for the other Eurocodes. For each of the Eurocodes from EC 0 to EC 8 a corresponding Swisscode 0 to 8 would have been developed. But it was felt that the primary goal of the Swisscodes project, namely to provide a set of compact and user-friendly Structural Standards to the practicing engineers could not be reached with this option. All actions except seismic being covered in a single action code, it was difficult to justify a separate seismic code for a country with low to medium seismicity like Switzerland.

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Eventually, the second option was selected, i.e. the integration of seismic regulations in action and material codes. It offered the challenge to integrate the ductility enhancing, material specific rules of Eurocode 8 into the corresponding material related Swisscodes SIA 262 to 266 based on Eurocodes 2 to 6 and the geotechnical aspects of seismic design into the Swisscode SIA 267 based on Eurocode 7. At the same time, a certain number of discrepancies between the different Eurocodes could be eliminated, a harmonization task still to be completed at European level. Table 1 presents an overview of the „seismic" content of the new Swiss Structural Standards SIA 260 to SIA 267 (Swisscodes).

Table 1: Integration of seismic rules into Swiss Structural Standards

Standard No.	Title	Seismic Rules	No. of Pages for Seismic Rules
SIA 260	Basis of structural design	basis of design, design equations	0,5
SIA 261	Actions on structures	seismic action, zoning map, response spectra, structural analysis, non-structural elements, importance categories, conceptual design	11
SIA 262	Design of concrete structures	concrete specific seismic rules	4
SIA 263	Design of steel structures	steel specific seismic rules	2
SIA 264	Design of composite structures	composite specific seismic rules	1
SIA 265	Design of timber structures	timber specific seismic rules	2
SIA 266	Design of masonry structures	masonry specific seismic rules	1
SIA 267	Geotechnical design	geotechnical seismic design	4

The main advantage of the integration concept is the improved user-friendliness of the code. The material specific seismic rules are no longer in a separate seismic document but in the respective material code, i.e. where they really should be from the standpoint of the designer. As an example, the rules for ductile reinforced concrete are integrated in the concrete code SIA 262 (2003). At the same time, the integration concept allowed to considerably lower the total volume of the seismic rules.

A major concern was the enormous size of 638 pages for all 6 Parts of Eurocode 8 together (see Table 2). More than 600 pages of seismic rules were considered too much for a country with low to medium seismicity. All seven structural Swisscodes together reach only about 650 pages. Therefore, it was necessary to drastically reduce the seismic rules of Eurocode 8 to an absolute minimum by eliminating among others, alternative application rules, textbook like clauses, and clauses for special structures like towers, masts, silos, tanks and pipelines. Finally, it was possible to compress the seismic rules to a total of only 26 pages including the new seismic zoning map of Switzerland (see Table 1).

Table 2: Parts of Eurocode 8

EC 8 Part	EN-No.	Title	No. of Pages
1	EN1998-1	General rules, seismic actions, rules for buildings	229
2	EN1998-2	Bridges	146
3	EN1998-3	Assessment and retrofitting of buildings	90
4	EN1998-4	Silos, tanks, pipelines	83
5	EN1998-5	Foundations, retaining structures, geotechnical aspects	44
6	EN1998-6	Towers, masts, chimneys	46

3. STRUCTURAL BEHAVIOUR CLASSES

In the Swisscodes, the number of ductility classes is limited to only two for all structural materials, namely *ductile structural behaviour* or *non-ductile structural behaviour*. There is a fundamental difference in the design procedure between these two classes. For non-ductile structural behaviour, the design for earthquake forces is performed conventionally like for wind forces without respecting any ductility enhancing rules, whereas for ductile structural behaviour capacity design including its detailing rules have to be applied.

3.1 Non-ductile structural behaviour

If non-ductile structural behaviour is selected, the material specific seismic rules in SIA 262 to SIA 266 (2003) do not have to be respected. Design and structural detailing can follow conventional rules as in the previous Swiss Structural Standards from 1989. As a consequence, the behaviour factor is limited to a relative small value of in general q = 1,5 with the exception of q = 2,0 for concrete with reinforcing steel of the more ductile classes B or C. The behaviour factor considers here mainly overstrength and only little ductility. Table 3 summarizes the q-factors for non-ductile structural behaviour and horizontal seismic action. For vertical seismic action, the behaviour factor has be assumed q = 1,5 independent of ductility class. Non-ductile structural behaviour is usually suitable for structures in the lower seismic zones combined with favorable ground types, when seismic requirements usually do not govern design. In the other cases, non-ductile behaviour may lead to uneconomically designed structure and ductile behaviour should be selected.

Table 3: Behaviour factors q for non-ductile structural behaviour

Structural and material type	Behaviour factor q
Concrete structures with reinforcing steel of class A or prestressed structures	1,5
Concrete structures with reinforcing steel of classes B or C	2,0
Steel structures	1,5
Composite structures	1,5
Timber structures	1,5
Unreinforced masonry structures	1,5

3.2 Ductile structural behaviour

Ductile structural behaviour corresponds to DCM (ductility class medium) according to Eurocode 8 (2004) for concrete, steel, composite, and timber structures. Reinforced masonry according to Eurocode 8 is considered as ductile structural behaviour for masonry structures. When ductile structural behaviour is selected, the ductility enhancing seismic rules in the material Standards SIA 262 to SIA 266 (2003) have to be respected. Seismic design has to follow capacity design principles. The range of applicable behaviour factors is given in Table 4. The behaviour factor depends on the class of reinforcing steel (B or C) for concrete structures, on the structural system (frame or truss) and on the cross-sectional class for steel and composite structures, as well as on the ductility and the distribution of the connections for timber structures. For masonry structures, reinforced masonry with q = 2,5 is considered to be the ductile behaviour class.

A higher ductility class corresponding to DCH (ductility class high) according to Eurocode 8 is in general not necessary for low to medium seismicity. The larger behaviour factors allowed for DCH compared to DCM would in most cases not lead to savings in the design. The reference value of the peak ground acceleration reaches only 16% g in the highest seismic zone in Switzerland (zone 3b in the Wallis). For this level of seismicity, an economic design can be obtained with a behaviour factor in the range of 3,0 to 5,0 as it is available for ductile structural behaviour (see Table 4). As a consequence, material specific seismic rules could be limited to only one class (ductile structural behaviour) in the Swisscodes allowing to considerably reduce the number of seismic clauses in SIA 262 to SIA 266 (2003).

Table 4: Behaviour factors q for ductile structural behaviour

Structural type	Behaviour factor q	Criteria
Concrete structures	3,0 – 4,0	Class of reinforcing steel
Steel structures	2,0 – 5,0	Structural system and section class
Composite structures	2,0 – 5,0	Structural system and section class
Timber structures	2,0 – 5,0	Connection type
Masonry structures	2,5	Presence of reinforcing steel

COMPLIANCE WITH EUROCODE 8

In general, the seismic regulations in the Swisscodes are in compliance with Eurocode 8. As an example, for all National Determined Parameters (NDP) the values recommended in Eurocode 8 have been implemented in the Swisscodes. Simple comparative design examples showed that a structure designed according to the Swisscodes will generally present the same level of seismic protection as a structure designed according to the Eurocodes.

Two major deviations from Eurocode 8 are noteworthy:

1. Simplified compliance criteria for damage limitation
2. Simplified combination rules for the effects of the horizontal components of the seismic action.

For importance classes I, II and III it is not required to verify the damage limitation criteria. Example calculations showed that the drift limits specified in Eurocode 8 would in general not govern the design for the range of seismic action in Switzerland. The lower return period of 95 years for the damage limitation requirements compared to 475 years for the no-collaps requirement leads to a really low drift demands in low seismicity. On the other hand, even more stringent interstory drift limits than the recommended values in Eurocode 8 have to be respected for the highest importance category IV (essential facilities), In order to stay fully operational after the design event these facilities should only experience small drifts.

According to Eurocode 8, it has to be assumed that the two horizontal components of the seismic action are acting simultaneously (EN1998-1, clause 4.3.3.5.1 (1P)). It was felt that this rule is too strict for low to medium seismicity. In general, the two horizontal components can be checked separately according to the Swisscodes. This relaxation in the Swisscodes simplifies primarily the equivalent lateral force method, i.e. it allows in many cases to perform a manual calculation instead of a computer analysis. On the other hand, the vertical component of the seismic action has to be taken into account only if the peak ground acceleration is greater than 0,25 g (EN1998-1, clause 4.3.3.5.2 (1)). This would mean for Switzerland that the vertical component could always be neglected. This was considered too optimistic and a clause was introduced into the Swisscodes that at least in special cases like beams supporting columns the vertical component should be checked.

From a legal standpoint, it can be argued that the Swisscodes represent „reduced or simplified seismic design procedures for certain types or categories of structures“ in low seismicity according to Part 1 of Eurocode 8 (EN1998-1, clause 3.2.1 (4)). The National Authorities are competent to select the classes of structures and the seismic zones for which simplified design procedures provisions may be used. The recommended value in Eurocode 8 for the limit of low seismicity is a peak ground acceleration not greater than 0,08 g. The Swiss National Authorities represented by SIA could assign a higher value of 0,16 g to this low seismicity limit with the consequence that „reduced or simplified seismic design procedures“ would be possible for whole Switzerland. Regarded in this manner as simplified provisions according to clause 3.2.1 (4), the Swisscode would be in full compliance with Eurocode 8.

4. CONCEPTUAL DESIGN

Basic principles of conceptual design are given in clause 4.2.1 of Eurocode 8 (2004). It remains unclear if these principles of conceptual design have to be strictly respected or if they are just recommendations in order to achieve „ ... a structural system which, within acceptable costs, satisfies the fundamental requirements (EN1998-1, clause 4.2.1 (1P)).“ In Switzerland, conceptual seismic design measures were already compulsory for structures of higher importance classes in higher seismic zones in the previous Standard SIA 160 (1989). Conceptual seismic design measures can be particularly beneficial in low seismic zones when a structures is accidentally hit by a considerably stronger earthquake than the (low) design event. And for new buildings, respecting conceptual design rules does practically not increase the construction cost.

As a consequence, the previous binding character of conceptual design measures were taken over into the Swisscodes (SIA 261, 2003). The level of the binding character of conceptual design measures depends on importance class (BWK) and seismic zone, in general according to the scheme shown in Table 5. For this particular topic the Swisscodes are more demanding than Eurocode 8.

Table 5: Level of binding character of conceptual design measures in SIA 261

	Zone Z1	Zone Z2	Zones Z3a and Z3b
Importance class I and II (BWK I)	Recommended	Recommended	Exceptions to be justified
Importance class III (BWK II)	Recommended	Exceptions to be justified	Compulsory
Importance class IV (BWK III)	Exceptions to be justified	Compulsory	Compulsory

5. EXISTING BUILDINGS

Most existing buildings in Switzerland were not designed for earthquake action. If they are checked according to the Swisscodes, the seismic requirements for new buildings can usually not be satisfied. Existing buildings have to be assigned to the non-ductile structural behaviour class with a q-factor as low as 1,5 leading to high seismic action effects. Seismically retrofitting existing buildings up to the code requirements for new building may be very costly and inefficient compared to the resulting risk reduction. To avoid that huge sums of the national economic are spent inefficiently for seismic risk reduction, a separate Standard SIA 2018 for the assessment of the seismic safety of existing buildings was published in 2004. According to this Standard, lower seismic requirements may apply to existing buildings.
In the first step of the assessment according to SIA 2018, a compliance factor $\alpha_{eff} = R_d/E_d$ is determined, where R_d is the resistance and E_d the action effect of the seismic design situation. Depending on the planning horizon of the building and the value of the compliance factor, three different cases have to be considered as shown in figure 1.

1. If $\alpha_{eff} \geq \alpha_{adm}$ retrofitting measures are not recommended.
2. If $\alpha_{adm} > \alpha_{eff} \geq \alpha_{min}$ the building has to be retrofitted as long as the cost of the structural intervention is proportionate in relation to the achieved seismic risk reduction. A simplified risk analysis based on the average occupancy of the building has to be performed for this purpose .
3. If $\alpha_{eff} < \alpha_{min}$ retrofitting is in general required. If retrofitting costs become excessive, the occupancy of the building may be limited as alternative way for risk reduction.

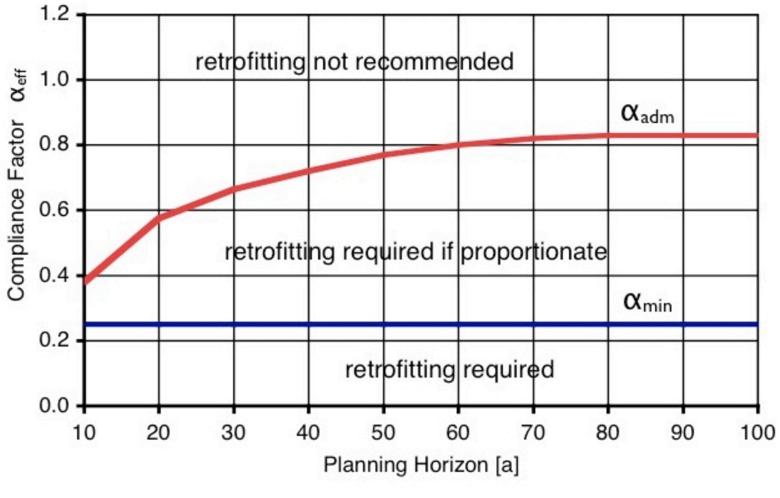

Figure 1: Risk based assessment of retrofitting measures according to SIA 2018

6. NATIONAL DETERMINED PARAMETERS

As soon as a new Part of the Eurocodes becomes available as European Standard, it is completed by a short National foreword according to CEN rules and published as SIA Standard in French and German. By June 2006, all 6 Parts of Eurocode 8 have been published in this manner as SIA Standards. The National foreword states that the Structural Standards SIA 260 to SIA 267 (Swisscodes) represent an adequate National implementation of the Eurocodes in Switzerland. But it does not specify any numerical values for the National Determined Parameters (NDP). Instead, the National Determined Parameters have to be determined by the building owner together with the designer based on the Structural Standards SIA 260 to SIA 267, if a project is designed according to the Eurocodes. The National Determined Parameters used in the design have to be documented in the so-called service criteria agreement of the project.

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