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Seismic evaluation and retrofitting of structures in Switzerland using Swiss Standard SIA 269/8

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ETH zürich

Civil Engineering Master
Major in Structural Engineering

Course: Seismic Evaluation and Retrofitting of Existing Structures

Seismic evaluation and retrofitting of structures in Switzerland using Swiss Standard SIA 269/8

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Spring Semester 2020
February 25, 2020

Overview

- Introduction
- From SIA 2018:2004 to SIA 269/8:2017
- Compliance factor
- Seismic evaluation
- Individual and collective risks to persons
- Safety costs
- Efficiency of interventions
- Risk reduction of structural damage
- Infrastructure functions
- Seismic retrofitting
- Recommendation of measures
- Concept of non-deterioration
- Case studies
- The lecture is mainly focused on the assessment based on individual and collective risks to persons

Introduction

- **In general, existing structures do not meet the new seismic requirements even in zones of low seismicity.**
- **Attaining a certain seismic safety level is much more expensive for existing structures than for new structures.**
- **Therefore, the cost of upgrading existing structures to the safety level required for new structures may become disproportionally high in relation to the benefit of the risk reduction.**
- **To avoid inefficient allocation of resources for seismic protection, risk-based rules allowing a lower safety level for existing buildings were introduced in Swiss Prestandard SIA 2018:2004.**
- **This assessment strategy is particularly attractive for regions of low to medium seismicity because it often allows to accept the existing state without any structural intervention.**

[Wenk T. 2008: Seismic retrofitting of structures: strategies and collection of examples in Switzerland. Federal Office for the Environment FOEN, 2008: www.research-collection.ethz.ch/bitstream/handle/20.500.11850/152142/eth-1643-01.pdf

Why special Standards for existing structures?

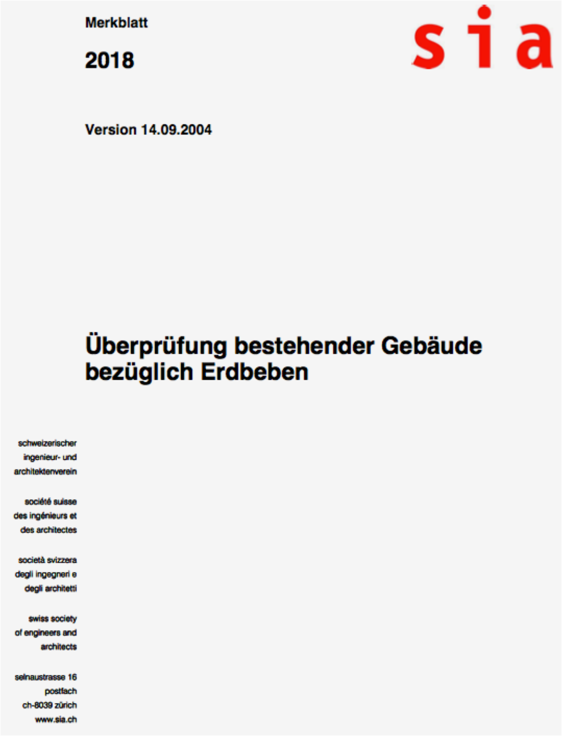
- **General principles:**
  - **Special rules for existing structures only where really justified;**
  - **as little differences as possible between rules for new and existing structures.**

	Seismic design of new structures	**Seismic assessment of existing structures**
Seismic zones and ground types	Discrete number of zones and types according to Structural Standards	Refinement often justified: Microzonation
Importance classes	3 classes	Refinement into 5 classes
Analysis methods	Linear methods according to Structural Standards	Non-linear methods often justified (push-over)
Structural system for horizontal actions	Carefully selected and designed	Often inexistent
Material properties	According to Structural Standards	According to obsolete Standards or unknown
Structural vs. non-structural elements	Clear separation between structural and non-structural	Every element becomes structural
Limit states	Structural safety	Risk-based assessment with compliance factor

[Wenk T. 2005: Erdbebeneinwirkung, Einführung in das Merkblatt SIA 2018, SGEB-Tagung vom 15.3.2005 in Zürich, SIA-Dokumentation D0211: www.research-collection.ethz.ch/bitstream/handle/20.500.11850/152668/eth-2720-01.pdf

Prestandard SIA 2018:2004

- Published in 2004 together with the Swiss Structural Standards SIA 260 to 267 for design.
- Focused on risks to persons in buildings.
- Replaced by Swiss Standard SIA 269/8 in 2017.



Merkblatt

2018

Version 14.09.2004

sia

Überprüfung bestehender Gebäude bezüglich Erdbeben

schweizerischer
ingenieur- und
architektenverein

société suisse
des ingénieurs et
des architectes

società svizzera
degli ingegneri e
degli architetti

swiss society
of engineers and
architects

selnaustrasse 16
postfach
ch-8039 zürich
www.sia.ch

Standard SIA 269/8:2017

- The new Standard SIA 269/8:2017 „Seismic Assessment of Existing Structures“ is part of the standards series SIA 269/x for assessment.
- Improvements to risk-based assessment:
  - Criteria for risks to persons slightly simplified.
  - Additional criteria for material damage
  - Additional criteria for proportional costs of essential buildings and infrastructure networks.

sia

SN Schweizer Norm
Norme Suisse
Norma Svizzera

SIA 269/8:2017 Bauwesen

505 269/8

Ersetzt SIA 2018:2004

Maintenance des structures porteuses – Séismes
Conservazione delle strutture portanti – Terremoti
Existing structures – Earthquakes

Erhaltung von Tragwerken – Erdbeben

269/8

SIA Wenk Erdbebeningenieurwesen + Baudynamik GmbH Wenk Thomas | 13.12.2017

SIA 269/8:2017: Chapters and Main topics

- 1. Terminology
- 2. Basic principles
- 3. Seismic action
- 4. Structural analysis and verifications
- 5. Reinforced concrete structures
- 6. Masonry structures
- 7. Steel and timber structures
- 8. Geotechnical aspects, foundations
- 9. Seismic evaluation and recommendation of interventions
- 10. Proportionality of interventions

Reinforced concrete structures

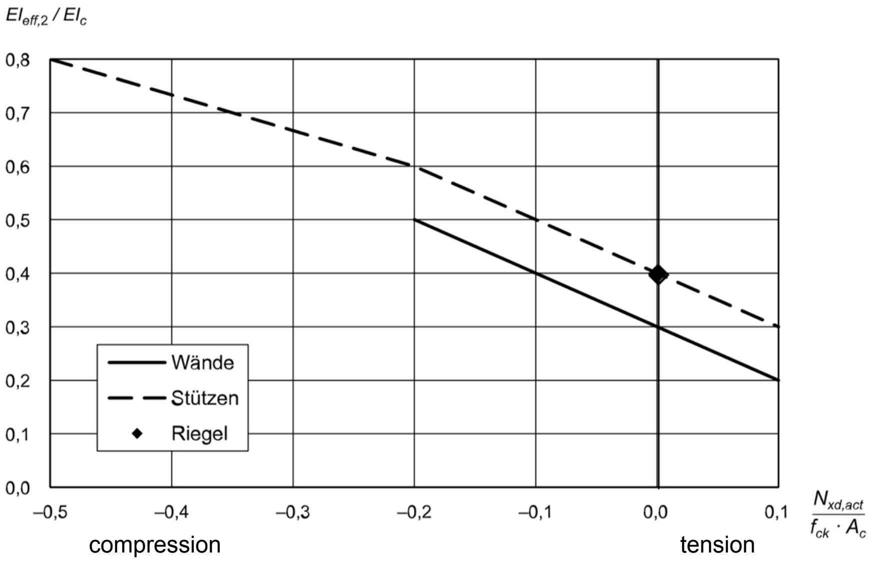
- The reinforced concrete chapter of SIA 2018 has been transferred nearly unchanged to SIA 269/8.
- One minor, but important, new item are the clauses related to the bending stiffness assumptions for elements with plastic deformations.
- As a general rule, the bending stiffness $EI_{eff,2}$ has to be determined by calculating the yield curvature ϕ'_y of the cracked section:

  $EI_{eff,2} = M'_y / \phi'_y$

- As alternative, a approximate values of the bending stiffness $EI_{eff,2}$ can be taken directly from Figure 2 in function of the normal force level.

Reinforced concrete structures: Bending stiffness

- **Approximate values of the bending stiffness ratio $EI_{eff,2} / EI_C$ can be taken directly from Figure 2 in function of the normal force level.**
- **This allows a rapid evaluation of the bending stiffness reduction due to cracking.**



[Figure 2 in SIA 269/8]

Masonry structures

- **The masonry chapter of SIA 269/8 has been completely redrafted.**
- **One item of particular interest is the new equation (23) for the out-of-plane examination.**
- **If the wall slenderness h_l / t_w satisfies the criteria in equation (23), a detailed examination of the out-of-plane behaviour under seismic action is not necessary.**
- **Equation (23) serves as an efficient filter to rapidly identify the acceptable walls in the existing state without out-of-plane retrofitting.**
- **Equation (23) is based on a forced-based analysis of the wall.**
- **As in the lower seismic zones equation (23) is in general satisfied, the out-of-plane examination process is greatly simplified.**

Masonry structures: Out-of-plane verification

- **If the wall slenderness h_l / t_w satisfies the following two criteria, a compliance factor $\alpha_{eff} \geq \alpha_{min}$ may be assumed:**

$$\frac{h_l}{t_w} \leq \frac{k\,g}{\alpha_{min}\,\gamma_f\,\alpha_{gd}\,S} \quad \text{und} \quad \frac{h_l}{t_w} \leq \sqrt{\frac{70\,g}{\gamma_f\,\alpha_{gd}\,S}}$$

[Equation (23) in SIA 269/8]

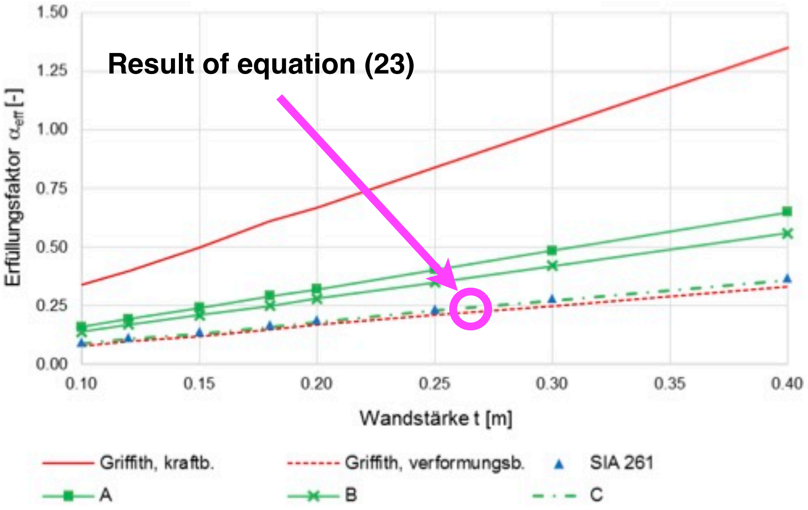
- **If the two criteria are not satisfied, a detailed verification under seismic action is necessary.**

k: factor considering the boundary conditions of the wall:
- **wall top free k = 0,4**
- **wall bottom and top pinned k = 0,8**
- **wall bottom built-in and top pinned k = 1,3**
- **wall top and bottom built-in, loaded by concrete slab: k = 2,0**

h_l: clear wall height between slabs
g: acceleration of gravity
a_{gd}: horizontal ground acceleration
S: parameter to determine the elastic response spectrum
γ_f: importance factor

Masonry structures: Out-of-plane verification

- **Comparison of wall slenderness given by equation (23) with results from non-linear dynamic analyses found in literature.**
- **Perfect agreement for an example wall with slenderness h_l / t_w =11.**



[Lestuzzi P., Mondet Y., et al. 2015: Nachweismethoden für das "Out-of-plane"-Versagen von Mauerwerk bei Erdbeben, SIA-Dokumentation D0255, Zurich.

Seismic evaluation: Compliance factor α_{eff}

- **The seismic evaluation according to SIA 269/8 results in the compliance factor α_{eff}, which describes in one number, how the existing building complies with the requirements for new buildings.**
- **With respect to the ultimate limit state, the compliance factor α_{eff} is defined as the ratio between the seismic action A_R, when the design value of the resistance is reached in a structural or non-structural element, and the design value of the seismic action A_d:**

  $\alpha_{eff} = A_R / A_d$
- **If the compliance factor α_{eff} is equal or greater than 1, then the code requirements for new buildings are fully satisfied.**
- **The critical compliance factor α_{eff} is the minimum value over all sections in the structural system and in non-structural elements.**

Compliance factor α_{eff} vs. Degree of compliance n

- **The compliance factor α_{eff} is suitable for accidental examination situations such as seismic or impact.**
- **For persistent and transient examination situations, SIA 269:2011 defines the degree of compliance n:**

  $n = R_{d.act} / E_{d.act}$

  $R_{d.act}$ **: examination value of ultimate resistance**

  $E_{d.act}$ **: examination value of action effects**
- **Again, if the degree of compliance n is equal or greater than 1, then the code requirements for new buildings are fully satisfied.**
- **But there is a need for two different definitions for α_{eff} and n as well as for two different retrofitting strategies because values below 1,0 are not acceptable for persistent and transient actions.**

[Wenk T. 2019: Grundsätze der Norm SIA 269/8, Tagungsband zum SGEB-Einführungskurs am 13.06.2019 an der ETH Zürich: www.research-collection.ethz.ch/bitstream/handle/20.500.11850/379043/Wenk_Grundsaetze_SIA269_8_2019.pdf]

Seismic evaluation: Importance classes

- More refined division into five instead of three importance classes for existing structures
- IC II is split into three ICs with different minimum compliance factor.

Importance class (IC)	Minimum compliance factor $\alpha_{\min}$
IC I	0,25
IC II (without IC II-i and IC II-s)	0,25
IC II-s (schools and kinder gardens)	0,4
IC II-i (buildings and civil engineering works with important infrastructure functions)	0,4
IC III	0,4

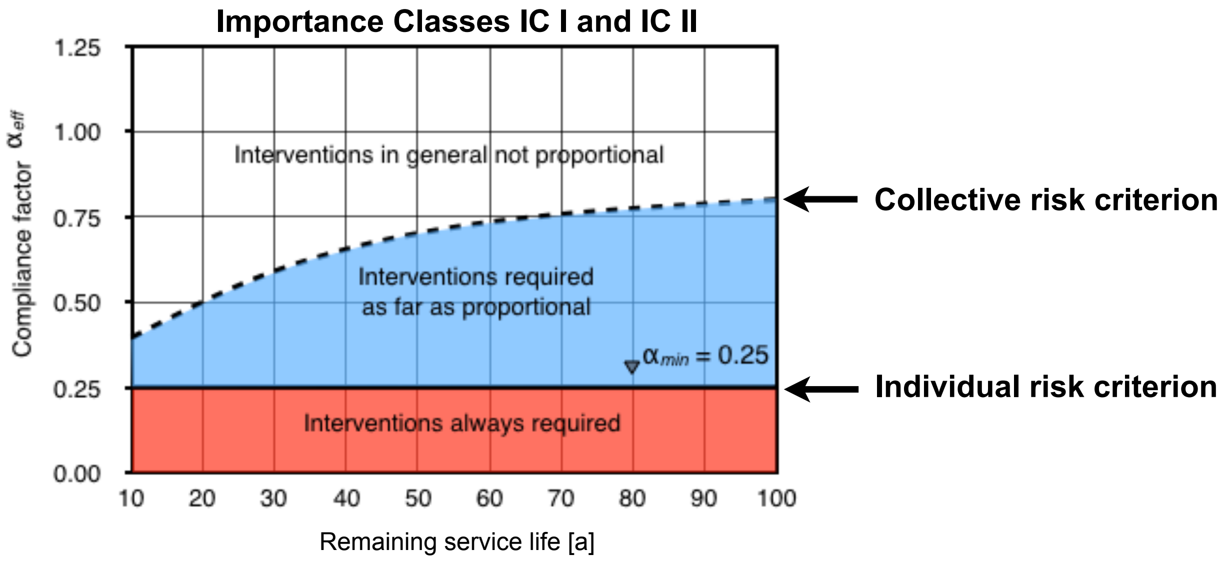
[Table 1 in SIA 269/8:2017]

Seismic evaluation: Remaining service life

- The remaining service life d_r is defined as the time span over which the structural safety has to be guaranteed for the intended building use.
- As a minimum value $d_r \geq 30$ years has to be assumed (SIA 269/8 Clause 10.7.3).
- A typical remaining service life d_r for residential or office buildings is about 40 years:
  - 30 years as minimum value
  - plus 10 years backup time
- At the end of the remaining service life, a new assessment has to be performed.
- Selecting a very short remaining service life usually makes retrofitting measures beyond α_{min} disproportional.
- The remaining service life parameter allows a certain flexibility with respect to the required retrofitting measures.

Seismic evaluation of IC I and IC II

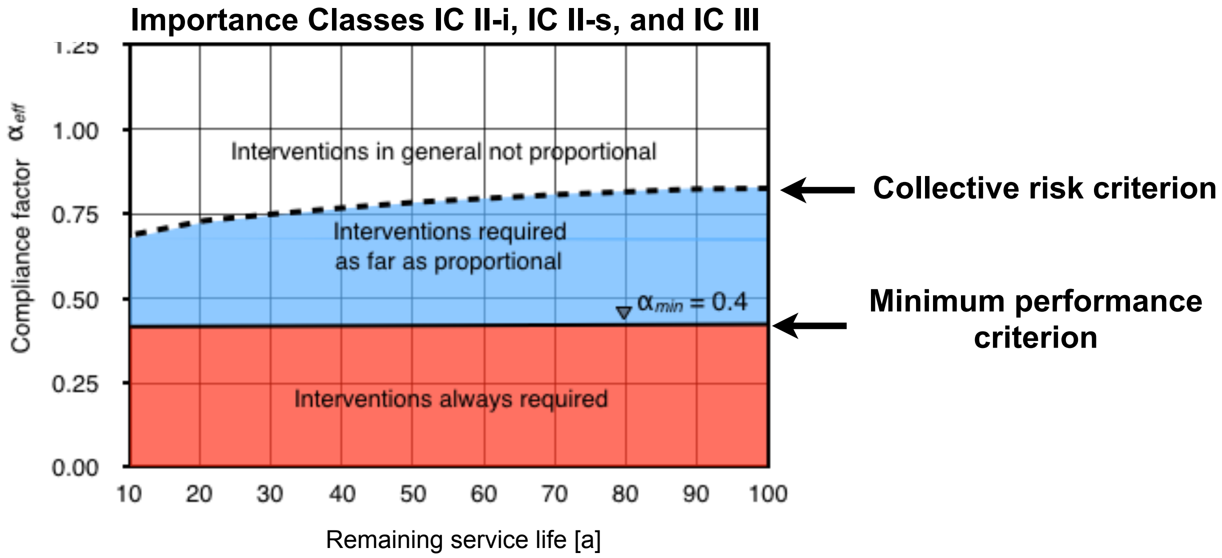
- **The evaluation of existing structures of IC I and IC II distinguishes three cases:**
  - **Red zone: $\alpha_{eff} < \alpha_{min}$ = 0,25: Interventions always required (except very low occupancy building)**
  - **Blue zone: $\alpha_{eff} \geq \alpha_{min}$ = 0,25: Interventions required as far as proportional**
  - **White zone: Interventions in general not proportional**


Importance Classes IC I and IC II

[Wenk T. 2015: Risk-based seismic assessment of existing structures. In 11th Canadian Conference on Earthquake Engineering. www.research-collection.ethz.ch/bitstream/handle/20.500.11850/155204/eth-48018-01.pdf]

Seismic evaluation of IC II-i, IC II-s, and IC III

- **A higher minimum value of α_{min} = 0,4 has to be respected for essential facilities (IC III) , for important infrastructure (IC II-i as well as for schools and kinder gardens (IC II-s):**
  - **Red zone: $\alpha_{eff} < \alpha_{min}$ = 0,4: Interventions always required**
  - **Blue zone: $\alpha_{eff} \geq \alpha_{min}$ = 0,4: Interventions required as far as proportional**
  - **White zone: Interventions in general not proportional.**


Importance Classes IC II-i, IC II-s, and IC III

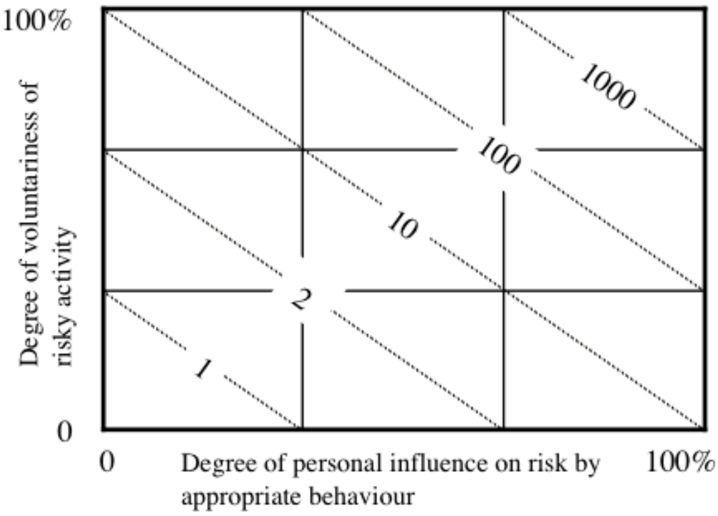
Acceptance criteria for risks to persons

- **In Swiss Standard SIA 269/8 individual and collective risks to persons are considered separately:**
- **Individual risk criterion:**
  - **The individual risk is defined as the probability to be killed by earthquake consequences of an individual person staying all year around inside a building.**
  - **The individual risk is acceptable, if the probability of death does not exceed 10^{-5} per year.**
  - **This requirement is deemed to be satisfied, if the compliance factor is:** $\alpha_{eff} \geq \alpha_{min} = 0{,}25$
- **Collective risk criterion:**
  - **Probability of death caused by collapse of the considered building as integral over all relevant earthquake scenarios.**
  - **Retrofitting costs up 10 million CHF are considered proportional, if one person‘s life can be saved during the remaining service life of the building.**
    The costs of injured persons are included in the 10 million CHF.

Risk acceptance: Individual risks

- **The acceptable level of individual risk depends on the degree of personal influence on the risk and the voluntariness of the risky activity.**
- **For uninvolved individuals, a probability of death of 10^{-5} / a has been adopted as an acceptable individual risk level for natural hazards in Switzerland.**

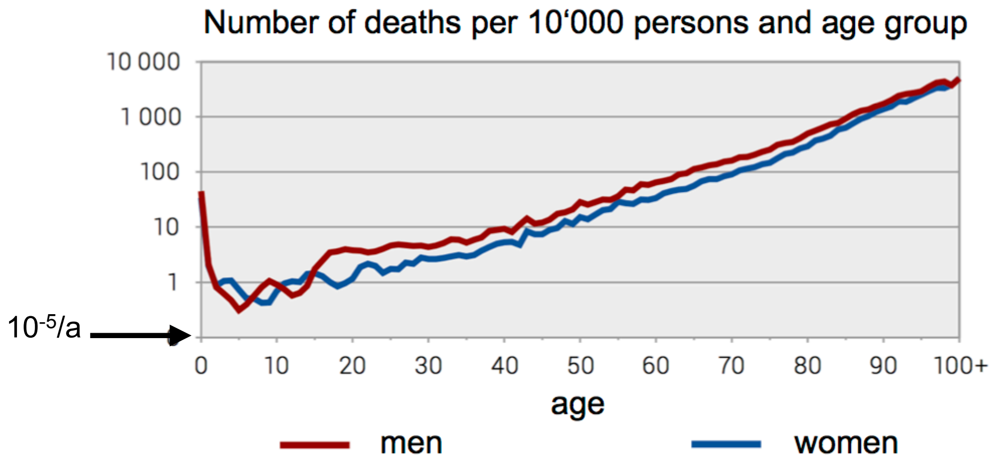
Acceptable risks, per 100’000 persons per year



[Schneider J. 2000: Safety - A Matter of Risk, Cost and Consensus, Structural Engineering International Vol. 10 No. 4]

Individual risks by age

- **Individual risks are dominated by age dependent quasi-natural factors.**
- **The death rate of children in Switzerland dropped in recent years to a minimum of about 2 · 10^{-5} / a.**



[Bundesamt für Statistik BFS 2017: Sterblichkeit und deren Hauptursachen in der Schweiz, 2014, Bern]

Individual risks by different activities

- **Occupational risks depending on the professional activity may be an important factor.**
- **In addition, risks related to personal lifestyle and various individual activities may become the dominant factor**

Probability of death in 10^{-5} / a	Activity
400	Smokers: 20 cigarettes a day
300	Drinkers: 1 bottle of wine a day
150	Drivers: Sports motor cycling
100	Flyers: Delta flying or paragliding as hobby
20	Car drivers (20–24 years old)
10	Pedestrians, household workers
10	10,000 km/year car travellers
5	Hikers in the mountains
3	10,000 km/year motorway drivers
1	Flying: Plane crash per flight
1	Living in buildings: Death by fire
1	10,000 km/year train travelling
0,2	Death by earthquakes in California
0,1	Lightning strike

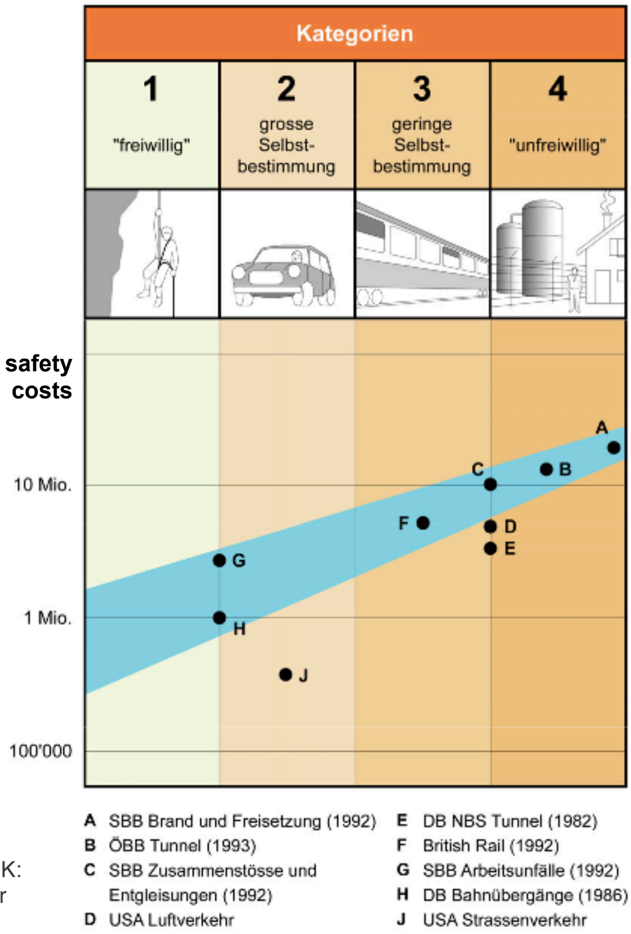
Based on [Schneider J. 2000: Safety - A Matter of Risk, Cost and Consensus, Structural Engineering International Vol. 10 No. 4]

Risk acceptance: Collective risks

- **For the case of major accidents or natural disasters, not the individual but the collective risks are of primary concern to society.**
- **Large collective risks should be reduced as long as intervention costs are proportional.**
- **Remaining small risks are acceptable as long as interventions become too costly.**
- **For non voluntary risks, safety costs in the range of 10 to 100 million CHF per life saved are considered justified for man-made disasters.**
- **For natural disasters, safety costs in the range of 3 to 10 million CHF per life saved are considered justified, i.e. values at the lower end of the range for man-made disasters [SIA 269].**
- **Safety costs reflect a „willingness to pay“ of society to avoid deaths. They do not correspond to real costs or to insured values**

Risk acceptance:
Collective risks
Man-made disasters

- **Acceptable safety costs depend on how voluntarily one is subjected to the risk (Categories 1 to 4 in figure).**
- **In Category 4 „involuntarily“, safety costs in the range of 10 to 100 million CHF per life saved are considered justified for man-made disasters.**



[Bundesamt für Bevölkerungsschutz BABS 2003: KATARISK: Katastrophen und Notlagen in der Schweiz, Erläuterung der Methode, Bern]

Comparison of safety costs

CHF per life saved	Interventions
100	Multiple vaccine in the 3rd World
2000	Installation of x-ray equipment
5000	Wearing motorcycle helmet
10000	Providing cardio-equipped ambulance
20000	Tuberculosis screening
50000	Deployment of rescue helicopters
100000	Seat belts in cars
200000	Rehabilitation of road crossings
300000	Providing kidney dialysis units
500000	Building structures
5000000	Tunnel safety in new Swiss alpine tunnels
10000000	SIA Seismic Standards
20000000	Mining safety USA
50000000	DC-10 grounding
100000000	Tall building regulations UK
1000000000	Asbestos removal in school buildings

[Schneider J., Schlatter H.-P. 2007: Sicherheit und Zuverlässigkeit im Bauwesen: Grundwissen für Ingenieure, vdf Hochschulverlag AG an der ETH Zürich]

Seismic evaluation of IC I and IC II

- **The evaluation of existing structures of IC I and IC II distinguishes three cases:**
  - **Red zone: $\alpha_{eff} < \alpha_{min}$ = 0,25: Interventions always required (except very low occupancy building)**
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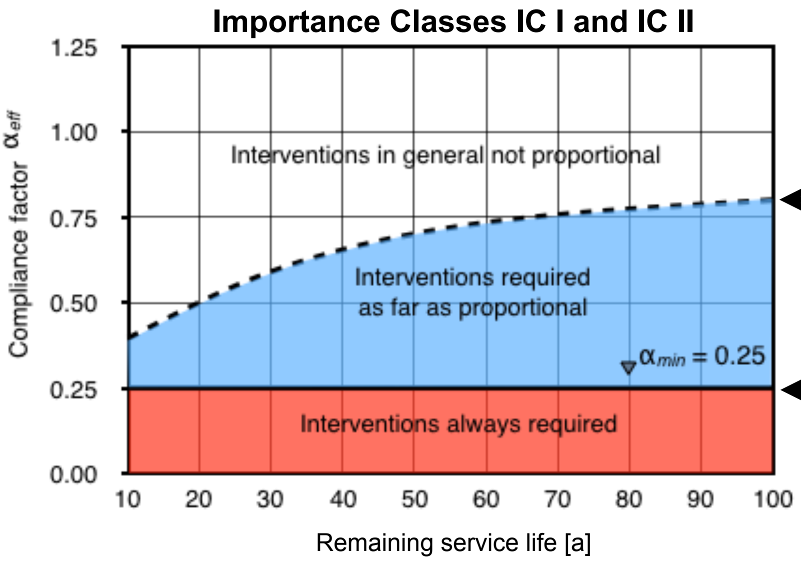


Collective risk criterion based on 10 million CHF life safety costs

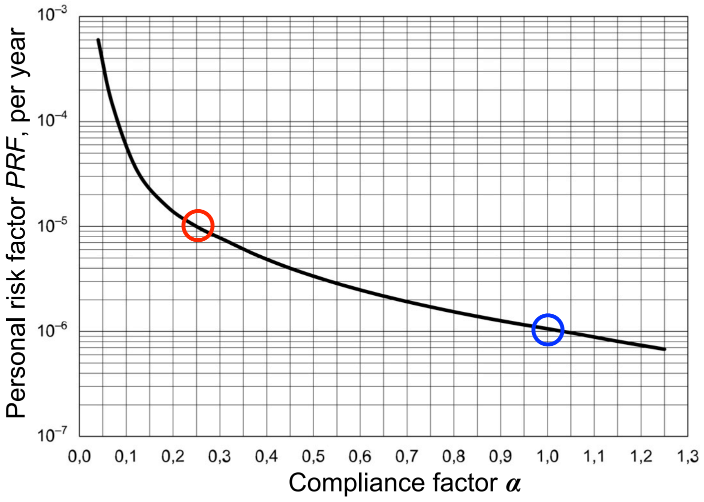
Individual risk criterion based on probability of death of 10^{-5}

Evaluation of risks to persons

- **SIA 269/8 provides the quantitative values necessary for a rapid evaluation of the risks to persons of a structure:**
- **Individual risk criterion:**
  - **The probability of death is given in function of the compliance factor (Figure 7 in SIA 269).**
  - **If the compliance factor in the existant state α_{eff} or after intervention α_{int} is equal or greater than 0,25 then the individual risk criterion of 10^{-5} is satisfied.**
- **Collective risk criterion:**
  - **The risk calculation is based on the compliance factor in the existent state α_{eff} and after intervention α_{int}, the occupancy *PB*, the remaining serve life d_r, and the life safety cost limit of 10 million CHF.**

Personal Risk factor *PRF* in function of the compliance factor

- **The personal risk factor *PRF* is equal to the probability of death per year of a person staying permanently in a building.**
- **The two anchor points of the *PRF* vs. α curve are:**
  - **For α = 0,25 the factor *PRF* corresponds to the minimum value for an acceptable individual risk of 10^{-5} per year: red circle.**
  - **For α = 1,0 (requirement for new buildings), the factor *PRF* is assumed to be 10^{-6} per year: blue circle.**



[Figure 7 in SIA 269/8]

Efficiency of an intervention

- **To determine the efficiency of an intervention or measure, the ratio between safety costs and risk reduction over a time span of one year is calculated.**
- **The reduction of personal risks ΔPR_M is calculated as follows:**
  $\Delta RP_M = \Delta PRF_M \cdot PB \cdot GK$ [CHF per year]
  where ΔPRF_M *is the* difference of risk factors PRF_M before and after execution of the considered measure (index $_M$), PB is the occupancy, and GK are the life safety costs of 10 million CHF.
- **The efficiency EF_M of an intervention is determined as follows:**
  $EF_M = \Delta RP_M \,/\, SC_M$
  where SC_M are the yearly safety costs of the measure in CHF per year.
- **To determine SC_M, the total investment costs of a measure SIC_M will be amortised over the remaining service life d_r of the building considering a discount rate of 2 %:**
  $SC_M = DF \cdot SIC_M$ [CHF per year]
  where DF is the discount factor given in Table 4 of SIA 269/8.
- **If $EF_M \geq 1$ the measure is considered proportional.**

Occupancy *PB*

- **The occupancy PB is the average number of people who are staying in the building.**
- **People in the area of rubble of the building have to be included.**

Building type	**Specific occupancy in persons per unit**	**Specific building unit**
Residential	0,2 – 0,6	per room
School	1 – 5	per classroom
Office	0,5 – 3	per 100 m^2 net floor area
Assembly	0,003 – 0,3	per seat
Hospital	1,5 – 2,5	per bed
Shopping	7 – 18	per 100 m^2 gross shopping area

[Table 2 in SIA 269/8:2017]

Very low occupancy buildings

- **For very low occupancy buildings a compliance factor $\alpha_{eff} < 0{,}25$ can be accepted as an exception to the general rule α_{eff} and $\alpha_{int} \geq 0{,}25$.**
- **The following four conditions have to be fulfilled for a low occupancy building (SIA 269/8 Clause 9.3.4):**
  - **occupancy $PB < 0{,}2$**
  - **not more than 10 Persons in the building: occupancy: $PB_{max} < 10$**
  - **organisational measures guaranteeing the above two assumptions concerning the occupancy**
  - **negligible threat to other protected assets (environment, cultural heritage, infrastructure function).**

Additional criteria for evaluation proportional costs

- **The total risk reduction ΔR_M by a measure can be represented as sum of the following parts:**
  $\Delta R_M = \Delta RP_M + \Delta RB_M + \Delta RS_M + \Delta RU_M$ in CHF per year
  - **ΔRP_M Risk reduction to persons: dominant in the case of normal buildings**
  - **ΔRB_M Risk reduction of damage to the structure**
  - **ΔRS_M Risk reduction to valuable goods in the structure**
  - **ΔRU_M Risk reduction of interruption of production in the structure**
  - **ΔIS Risk reduction of interruption of infrastructure function**
- **As an example, the calculation of the risk reduction of damage to the building ΔRB_M is explained on the following slide.**

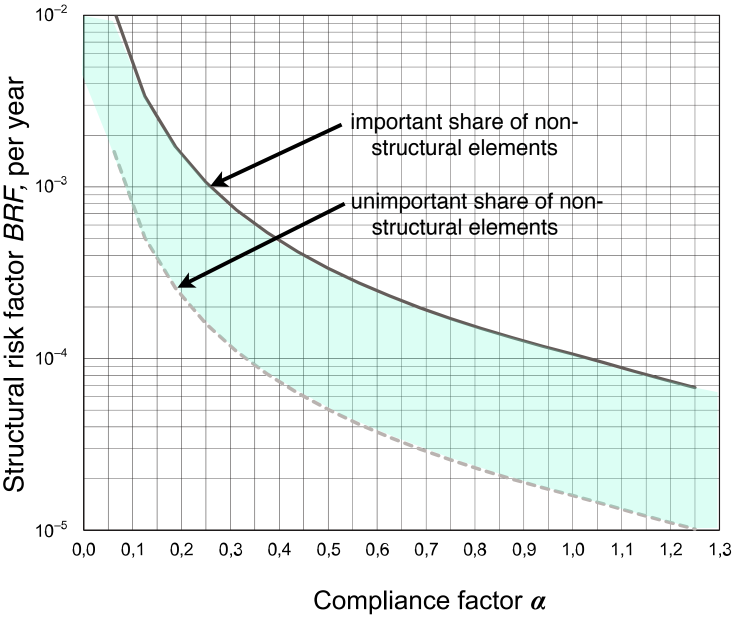
Risk reduction of damage to the structure

- **Informative annex E of SIA 269/8:2017 provides additional information how to calculate the risk reduction of damage to the structure in function of the compliance factor before and after execution of a retrofitting measure.**
- **Risk reduction of damage to the structure ΔRB_M:**

  $\Delta RB_M = \Delta BRF_M \cdot BW$

  ΔBRF_M : difference of structural risk factors, per year.

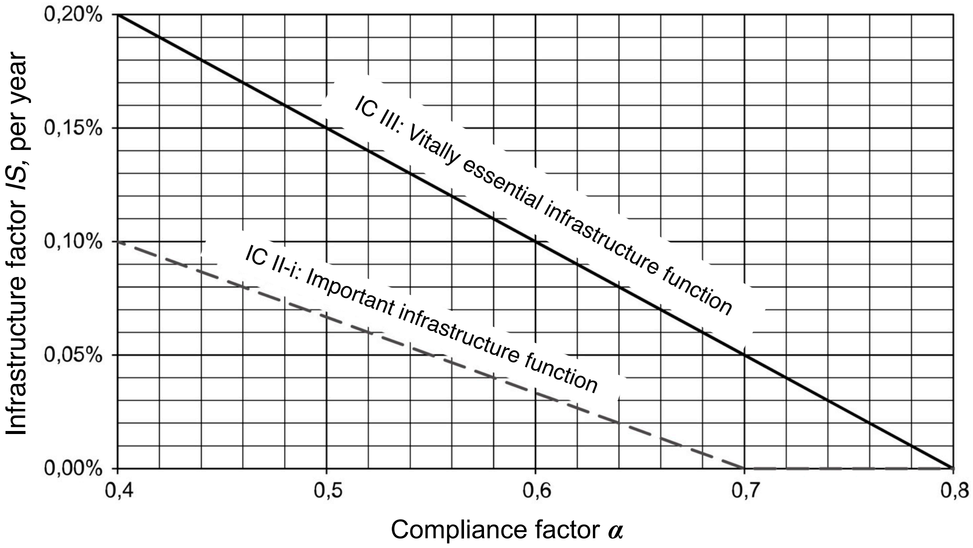
  BW: building value
- **In buildings the share of non-structural elements is in general high:**
  > solid upper curve
- **In civil engineering works the share is often small**
  > dotted lower curve



[Figure 16 in SIA 269/8:2017]

Structures with infrastructure functions

- **Risk criteria based on persons are not suitable for structures with infrastructure functions.**
- **SIA 269/8:2017 provides a simple approach based on a infrastructure factor difference *ΔIS* before and after execution of a retrofitting measure.**



[Figure 8 in SIA 269/8:2017]

Structures with infrastructure functions

- The readiness of society to pay for the protection of infrastructure functions ΔZI_M is calculated as follows:

  $\Delta ZI_M = \Delta IS \cdot BSW$

  ΔIS: difference of infrastructure factor before and after execution of a retrofitting measure per year.

  BSW: value of building or civil engineering work and the directly affected objects.

- The efficiency EF_M of a retrofitting measure is determined as follows:

  $EF_M = (\Delta ZI_M + \Delta PR_M) / SC_M$

  where SC_M are the yearly safety costs of the measure in CHF per year.

- The risk reduction of damage to the structure ΔRB_M should not be included in the calculation of EF_M as it is already included in ΔZI_M.

Seismic retrofitting of structures according to SIA 269/8

- SIA 269/8 is focused on the risk-based seismic assessment.
- Seismic retrofitting in SIA 269/8 is limited to the so-called „recommendation of measures“ (Massnahmenempfehlung).
- The recommendation of measures states if measures have to be executed or if the existing state can be accepted as sufficiently safe.
- If measures have to be executed the recommendation specifies the compliance factor α_{int} which has to be reached.
- The general rules for the recommendation of measures are:
  - In principle, $\alpha_{int} \geq 1{,}0$ should be reached.
  - Proportional measures to reach $\alpha_{int} \geq 1{,}0$ must be executed.
  - If $\alpha_{int} \geq 1{,}0$ cannot be reached by proportional measures, all proportional measures to approach 1,0 must be executed.
  - If $\alpha_{eff} \leq \alpha_{min}$ measures to reach α_{min} must be executed independent of costs. (excluded: very low occupancy buildings).

Seismic retrofitting of structures according to SIA 269/8

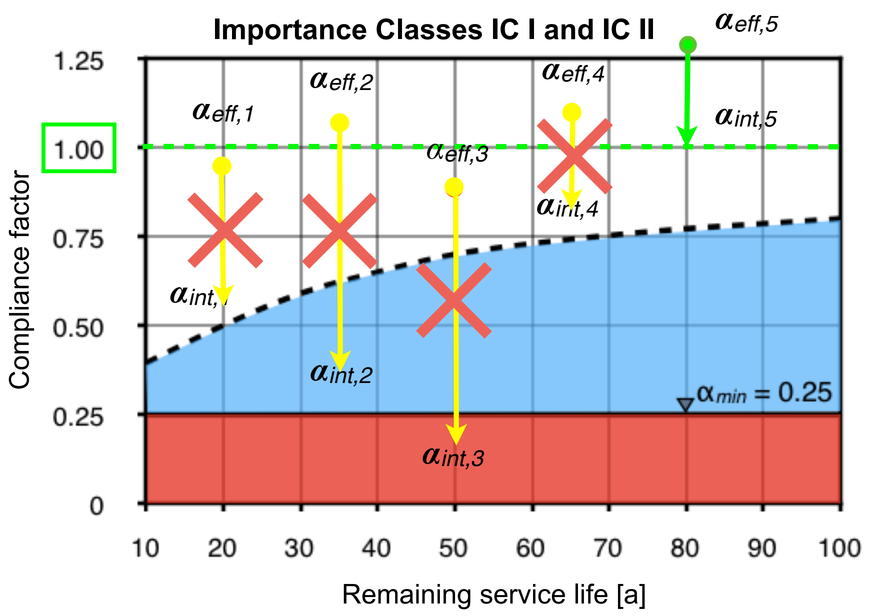
- General rules of application for Swiss Structural Standards:
  - New structures should be designed according to SIA 260 bis 267.
  - Existing structures should be examined according to SIA 269 as well as SIA 269/1 to 269/8.
  - For retrofitting in general, clause 0.1.5 of SIA 269 is applicable: „In the case of modifications, in general new structural components shall be treated according to Codes SIA 260 to 267 and existing structural components according to Code SIA 269 together with Codes SIA 269/1 to 269/8.“
- These simple principles may lead to problems in practical application which should be resolved pragmatically.
- In the case of seismic retrofitting the concept of non-deterioration has to be respected.

Concept of non-deterioration for seismic retrofitting

- The concept of non-deterioration (Verschlechterungsverbot) states that an existing structures may not be weakened to a compliance factor $\alpha_{int} < 1{,}0$.
- The Swiss federal government and the Canton Basel-Stadt already published executive orders explicitly forbidding the deterioration of the seismic safety.
- From the criteria of proportional measures of SIA 269/8, the concept of non-deterioration can be derived indirectly:
- The measure „maintaining the existing state“ is absolutely free. Therefore, it is always proportional and has to be executed as a minimum requirement.

Concept of non-deterioration for seismic retrofitting

- **The compliance factor may not be weakened to $\alpha_{int} < 1,0$.**
- **However, the compliance factor may be weakened to $\alpha_{int} \geq 1,0$.**



[Wenk T. 2019: Grundsätze der Norm SIA 269/8, Tagungsband zum SGEB-Einführungskurs am 13.06.2019 an der ETH Zürich: www.research-collection.ethz.ch/bitstream/handle/20.500.11850/379043/Wenk_Grundsaetze_SIA269_8_2019.pdf]

International Ramifications

- **Austria introduced a similar procedure in the Austrian National Annex to Eurocode 8, EN 1998-3, in 2013.**
- **New Zealand introduced a comparable procedure in 2004:**
  - **There were informal NZ-CH exchanges in 2003 during the drafting of SIA 2018.**
  - **NZ is calling the compliance factor: „% NBS“ (% of New Building Standard).**
  - **α_{eff} = 1,0 corresponds to 100% NBS.**
  - **NZ adopted a lower limit of 34% NBS. It has about the same significance as α_{min} = 0,25 according to SIA 269/8.**
  - **Considering the differences in the shape of the seismic hazard curves, the value of α_{min} = 0,25 for low seismicity in Switzerland corresponds to about 34% NBS for high seismicity in New Zealand with respect to probability of exceedance.**
- **France and Germany showed a general interest in the Swiss approach. But they see legal problems for a lower safety level for existing structures.**
- **In the latest draft of prEN 1998-3:2019, the concept of risk-based assessment can be adopted on a National level, in particular by countries in low seismicity areas, as mentioned in its introduction.**

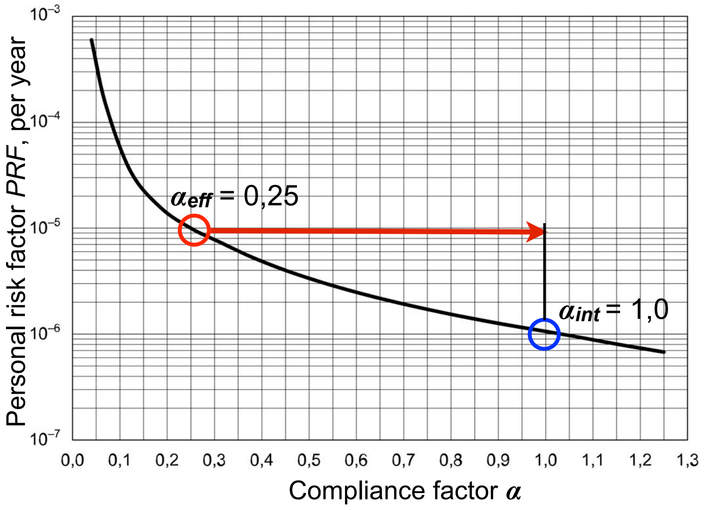
Summary and Conclusions

- **The principal idea of the risk-based seismic assessment procedure according to SIA 269/8 is that existing structures may comply with lower performance limits than new structures.**
- **In essence, the performance state „Post Collapse“ is assessed by personal risk criteria derived from natural and man-made disaster prevention.**
- **Criteria of acceptable individual and collective risks to persons are lower bounds for seismic safety.**
- **The examination procedure acts as an efficient filter to limit interventions to structures with unacceptable high risks.**
- **The concept is focused on regions of low to medium seismicity where it often allows to accept the existing state of a structure as sufficiently safe without any intervention.**

Case study 1: Proportionality of retrofitting measures

- **For a building with a unit occupancy of $PB = 1$ and remaining service life $d_r = 50$ years, determine the proportional costs of seismic retrofitting measures reaching a compliance factor $\alpha_{int} \geq 1{,}0$.**
- **a) For the case that the compliance factor in the existing state is $\alpha_{eff} = 0{,}25$.**
- **b) For the case that the compliance factor in the existing state is $\alpha_{eff} = 0{,}4$.**

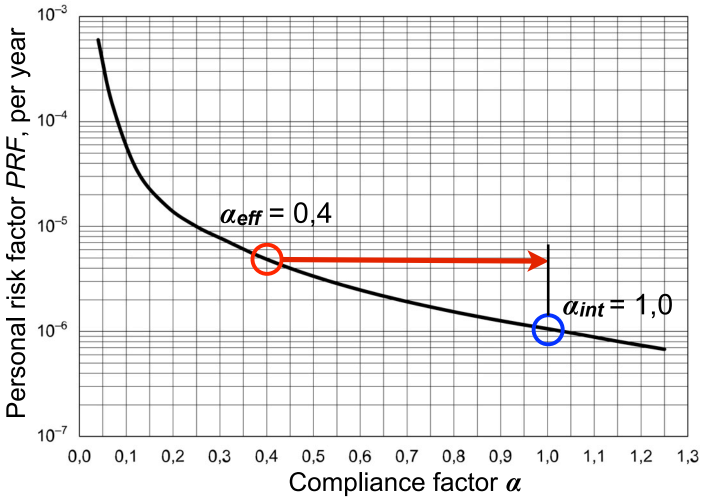
Case study 1a): Proportionality of retrofitting measures



[Figure 7 in SIA 269/8]

- **Initial state: α_{eff} = 0,25**
  $PRF_M(\alpha_{eff}) = 10^{-5}$
- **Retrofitted: α_{int} = 1,0**
  $PRF_M(\alpha_{int}) = 10^{-6}$
- **$\Delta PRF_M = 10^{-5} - 10^{-6} = 9 \cdot 10^{-6}$**
- **The reduction of personal risks:**
  $\Delta RP_M = \Delta PRF_M \cdot PB \cdot GK$, with
  $PB = 1$ and GK = 10 million CHF
- **$\Delta RP_M = 9 \cdot 10^{-6} \cdot 1 \cdot 10$ million =**
  90 CHF per year
- **For a proportional measure:**
  $EF_M = 1$ and hence $SC_M = \Delta RP_M$ = 90 CHF per year
- **The total investment costs of a measure SIC_M will be amortised over the remaining service life d_r = 50 years considering a discount rate of 2 % and a discount factor DF = 0,032**
  $SIC_M = SC_M / DF$ = 90 CHF / 0,032 = 2800 CHF

Case study 1b): Proportionality of retrofitting measures



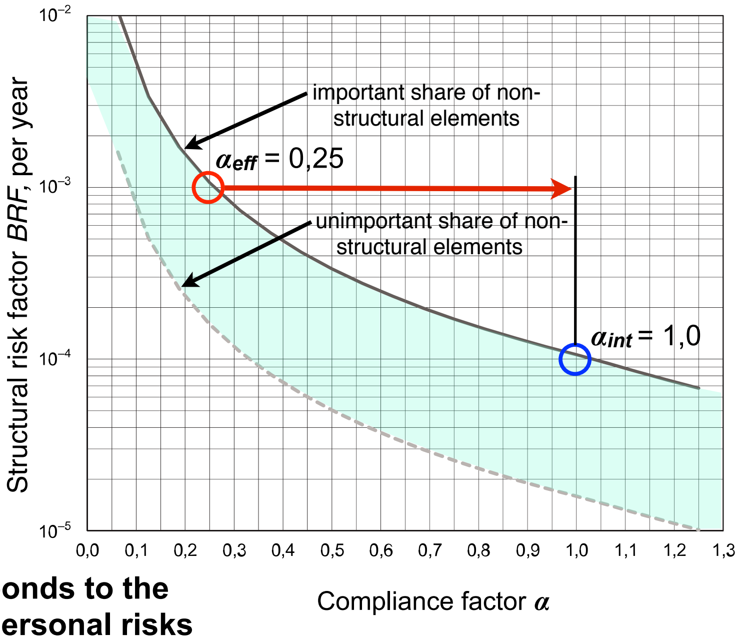
[Figure 7 in SIA 269/8]

- **Initial state: α_{eff} = 0,4**
  $PRF_M(\alpha_{eff}) = 5 \cdot 10^{-6}$
- **Retrofitted: α_{int} = 1,0**
  $PRF_M(\alpha_{int}) = 10^{-6}$
- **$\Delta PRF_M = 5 \cdot 10^{-6} - 10^{-6} = 4 \cdot 10^{-6}$**
- **The reduction of personal risks:**
  $\Delta RP_M = \Delta PRF_M \cdot PB \cdot GK$, with
  $PB = 1$ and GK = 10 million CHF
- **$\Delta RP_M = 4 \cdot 10^{-6} \cdot 1 \cdot 10$ million =**
  40 CHF per year
- **For a proportional measure:**
  $EF_M = 1$ and hence $SC_M = \Delta RP_M$ = 40 CHF per year
- **The total investment costs of a measure SIC_M will be amortised over the remaining service life d_r = 50 years considering a discount rate of 2 % and a discount factor DF = 0,032**
  $SIC_M = SC_M / DF$ = 40 CHF / 0,032 = 1200 CHF

Case study 2: Risk reduction of damage to the structure

- **For a building with a building value *BW* = 1 million CHF and an important share of non-structural elements, determine the risk reduction of damage to the structure by a seismic retrofitting measures reaching a compliance factor $\alpha_{int} \geq 1{,}0$.**
- **a) For the case that the compliance factor in the existing state is $\alpha_{eff} = 0{,}25$.**
- **b) For the case that the compliance factor in the existing state is $\alpha_{eff} = 0{,}4$.**
- **Assuming a remaining service life $d_r = 50$ years, determine the additional occupancy *ΔPB* which would lead to the same proportional costs as the damage reduction.**

Case study 2a): Risk reduction of damage to the structure

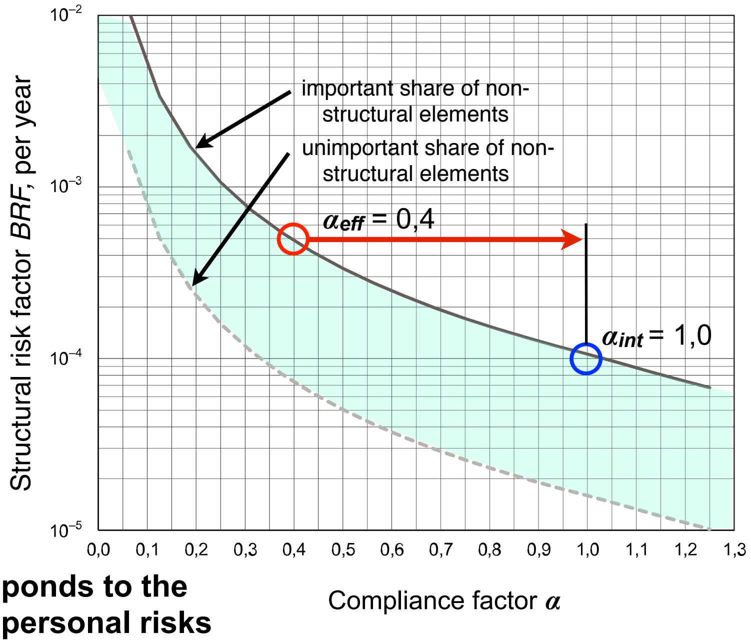


[Figure 16 in SIA 269/8:2017]

- **Initial state: $\alpha_{eff} = 0{,}25$**
  $BRF_M(\alpha_{eff}) = 10^{-3}$
- **Retrofitted: $\alpha_{int} = 1{,}0$**
  $BRF_M(\alpha_{int}) = 10^{-4}$
- **$\Delta BRF_M = 10^{-3} - 10^{-4} = 9 \cdot 10^{-4}$**
- **Risk reduction of damage to the structure ΔRB_M:**
  $\Delta RB_M = \Delta BRF_M \cdot BW$, with $BW = 1$ million CHF
- **$\Delta RB_M = 9 \cdot 10^{-4} \cdot 1$ million CHF = 900 CHF per year**
- **ΔRB_M = 900 CHF per year corresponds to the tenfold value of the reduction of personal risks $\Delta RP_M = 90$ CHF per year calculated in case study 1a) for *PB* = 1.**
- **Therefore, an additional occupancy *ΔPB* = 10 persons would lead to the same proportional costs as the damage reduction.**

Case study 2b): Risk reduction of damage to the structure

- **Initial state: α_{eff} = 0,4**
  $BRF_M(\alpha_{eff}) = 5 \cdot 10^{-4}$
- **Retrofitted: α_{int} = 1,0**
  $BRF_M(\alpha_{int}) = 10^{-4}$
- **$\Delta BRF_M = 5 \cdot 10^{-4} - 10^{-4} = 4 \cdot 10^{-4}$**
- **Risk reduction of damage to the structure ΔRB_M:**
  $\Delta RB_M = \Delta BRF_M \cdot BW$, with
  BW = 1 million CHF
- **$\Delta RB_M = 4 \cdot 10^{-4} \cdot 1$ million CHF = 400 CHF per year**



[Figure 16 in SIA 269/8:2017]

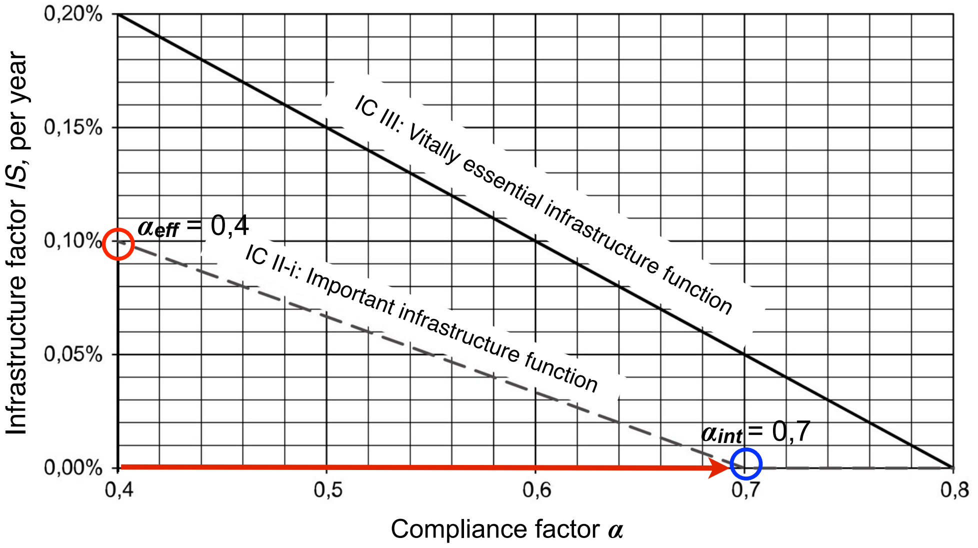
- **ΔRB_M = 400 CHF per year corresponds to the tenfold value of the reduction of personal risks ΔRP_M = 40 CHF per year calculated in case study 1b) for PB = 1.**
- **Therefore, an additional occupancy ΔPB = 10 persons would lead to the same proportional costs as the reduction of damage to the structure.**

Case study 3: Structures with infrastructure functions

- **For a bridge in importance class IC II-i, with a value BSW = 10 million CHF, and a remaining service life d_r = 50 years, determine the proportional costs of seismic retrofitting measures reaching a compliance factor $\alpha_{int} \geq 0{,}7$.**
- **a) For the case that the compliance factor in the existing state is α_{eff} = 0,4.**
- **b) For the case that the compliance factor in the existing state is α_{eff} = 0,6.**
- **The reduction of personal risks ΔPR_M may be neglected.**

Case study 3a): Structures with infrastructure functions

- **Initial state: α_{eff} = 0,4 $IS(\alpha_{eff})$ = 0,10 %**
- **Retrofitted: α_{int} = 0,7 $IS(\alpha_{int})$ = 0,0 %**
- **$\Delta ZI_M = \Delta IS \cdot BSW$ = (0,10 % - 0,0 %) · 10 million CHF = 10‘000 CHF per year**
- **For a proportional measure: $EF_M = 1$, hence $SC_M = \Delta ZI_M$ = 10‘000 CHF per year**



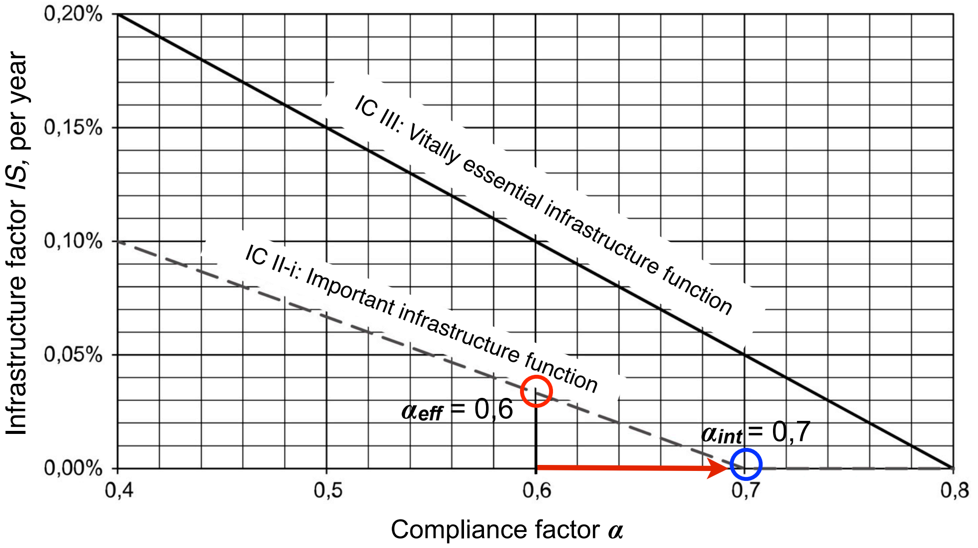
[Figure 8 in SIA 269/8:2017]

Case study 3a): Structures with infrastructure functions

- **$\Delta ZI_M = \Delta IS \cdot BSW$ = (0,10 % - 0,0 %) · 10 million CHF = 10‘000 CHF per year**
- **The total investment costs of a measure SIC_M will be amortised over the remaining service life d_r = 50 years.**
- **At a discount rate of 2 %, the discount factor becomes DF = 0,032 for d_r = 50 years (Table 4 in SIA 269/8:2017).**
- **For a proportional measure: $EF_M = 1$, hence $SC_M = \Delta ZI_M$ as the risk reduction to persons ΔPR_M is neglected.**
- **$SIC_M = SC_M / DF = \Delta ZI_M / DF$ = 10‘000 CHF / 0,032 = 312‘000 CHF**
- **Therefore, measures up to costs of about 3 % of the value of the bridge are proportional.**

Case study 3b): Structures with infrastructure functions

- **Initial state: α_{eff} = 0,6 $IS(\alpha_{eff})$ = 0,044 %**
- **Retrofitted: α_{int} = 0,7 $IS(\alpha_{int})$ = 0,0 %**
- **$\Delta ZI_M = \Delta IS \cdot BSW$ = (0,044 % - 0,0 %) · 10 million CHF = 4‘400 CHF per year**
- **For a proportional measure: $EF_M = 1$, hence $SC_M = \Delta ZI_M$ = 4‘400 CHF per year**



[Figure 8 in SIA 269/8:2017]

Case study 3b): Structures with infrastructure functions

- **$\Delta ZI_M = \Delta IS \cdot BSW$ = (0,044 % - 0,0 %) · 10 million CHF = 4‘400 CHF per year**
- **The total investment costs of a measure SIC_M will be amortised over the remaining service life d_r = 50 years.**
- **At a discount rate of 2 %, the discount factor becomes DF = 0,032 for d_r = 50 years (Table 4 in SIA 269/8:2017).**
- **For a proportional measure: $EF_M = 1$, hence $SC_M = \Delta ZI_M$ as the risk reduction to persons ΔPR_M is neglected.**
- **$SIC_M = SC_M / DF = \Delta ZI_M / DF$ = 4‘400 CHF / 0,032 = 138‘000 CHF**
- **Therefore, measures up to costs of about 1,4 % of the value of the bridge are proportional.**