EUROCODES AND STRUCTURAL SAFETY OF THE EXISTING BUILDINGS – CONSIDERING THE PUBLICATION OF THE DUTCH NEN 8700

Dr. Nico P.M. Scholten, PhD
Expertcenter Regulations in Building (ERB)
Email: n.scholten@bouwregelwerk.org
Prof.Ton C.W.M. Vrouwenvelder
TNO Built Environment and Geosciences
E-mail: ton.vrouwenvelder@tno.nl

ABSTRACT

Since 1992 there have been a number of proposals to renew calculation methods available to assess the structural safety of the existing buildings. But without operational results.
Upon publication of the Eurocodes NL decided to renew and to include them in the Dutch building regulations. The question was how.
It was decided to develop a new Dutch national standard: NEN 8700. That shows how, in conjunction with the 58 Eurocodes, an expert opinion can be assessed on the structural safety of an existing building.
The Building Decree 2012 refers to this standard for load actions that have to be taken into account, the response of the structure and the required strength of structure, and references to the Eurocodes. The set up of the new standard is explained.
A building is classified as an existing building after it has been completed.
So the standard applies to all building stock, but the owner primarily must ensure that during the design working lifespan the legally required performance for newly built buildings remains satisfied except accidents.
The safety assessment of an existing building differs from that of a new one in ways that are elaborated:

- *cost in relation to safety;*
- *safety in relation to the reference period;*
- *availability of the actual status data versus the design data.*

Unlike the regulations that apply to new buildings the new standard includes for the judgement of the lower limit of safety of the existing structures (the moment that the use immediately has to cease):

- *probability theory;*
- *harmonisation of the Eurocodes with safety of the existing building constructions on an arbitrary moment;*
- *acknowledgement of durable safety requirements other than a 1 year period;*
- *exclusion of requirements pertaining to the uncertainties that may arise during the theoretical design life;*
- *amendment of determination methods for the properties of the structural materials used;*
- *ability to review at any time the actual constructed situation.*

The new standard also establishes the lowest limits of safety levels in the renovation, alteration or enlargement of an existing building.
Reliability and load factors are summarized extracted from the underlying TNO report.

Keywords: safety assessment, regulation, existing building, renovation, standard, Eurocodes, NEN 8700

INTRODUCTION

On October 1, 1992 the Building Decree came into force together with some 6 Ministerial Orders. As from that moment quantifiable calculation methods became available to assess the structural safety of the existing buildings as laid down in the Building Decree and later the Building Decree of 2003 and the Building Decree 2012.
These calculation methods were based on the well-known Dutch TGB standards series together with the more detailed regulations in the Ministerial Order on structural and user safety. This Order has been legally and administratively simplified a number of times but the content is unchanged till April 1, 2012. This Order was originally based on the TNO Building Research report B-91-832. After April 1, 2012 reference is made to the Eurocodes.
There have been a number of standardisation proposals since to publish a separate TGB series to deal with the existing buildings, but this has not come to anything.
The above-mentioned TNO report was issued in 2004 and published as TNO B&O report 2004-CI-R0159.
After the publication of the Eurocodes and the decision to include them in the Dutch building regulations (following the introduction of the third

issue of the Building Decree in 2003) the question arose of what to do about the regulations concerning the structural safety of the existing buildings. The choice was not difficult because making 58 standards to cover the existing buildings or alternatively making 58 sets of follow-up regulations to cover the existing buildings in the 58 Eurocodes was not an option. The choice was made to develop a new Dutch standard: NEN 8700. This standard shows how, in conjunction with the 58 Eurocodes, an opinion can be arrived at on the structural safety of an existing building.

The following research questions are solved for the Dutch situation:

1. What are the differences between the public requirements for structural safety between newly built buildings and existing buildings?
2. What are the backgrounds of the safety philosophy to motivate these differences and how can the assessment of the safety of the existing buildings be used in practice?
3. What are the logical structural safety requirements by renovation of the structure of the existing buildings?

In a national or international perspective the research can be placed as following:

New Eurocodes for the assessment of newly built buildings are introduced in the European Union. In the Dutch building regulations also requirements are given for the minimum performance of the existing buildings. So the existing regulations have to be changed to bring them in line with the 58 Eurocodes parts. In 2010 the Eurocodes will be compulsory. At that moment also the requirements for existing buildings and renovation should be available.

Within the EU discussion is opened to develop also Eurocodes for the existing buildings. The Dutch NEN 8700 and background report can be a good starting point.

The main conclusions and recommendations of the project are:

a) The safety philosophy of newly built buildings can also be used for existing buildings and renovation.
b) The reliability-index can be decreased for the assessment of the existing buildings and for buildings in renovation, because economical aspects have to be dealt with in another way than by newly built buildings. Because of another reference period the actions can be decreased. Also durability aspects are not the same. The way safety figures of the structure itself may be used gives also a different assessment.
c) The study and standards provide a direction how to judge in a practical way whether the minimum safety requirements are fulfilled.

THE STRUCTURE

The intention is that the Building Decree 2003 will refer to NEN 8700 for load actions that have to be taken in account, the response of the structure and the required strength of the structure. The new standard will make reference to the Eurocodes.

Purpose of the standard

The standard applies to all existing buildings, regardless of their age. A building is classified as an existing building after it has been completed.

The owner of the building must ensure that during the reference period the legally required standards are or remain satisfied other than caused by an accident. The legally required standards are the safety standards required by legislation at the time of construction, unless a building permit as defined in the article 40 of the Housing Act has expressly permitted a lower standard (for example, in the case of renovation) or if knowingly or unknowingly an incorrect building construction is approved. The legal regulations that determine new structural safety standards apply to the entire reference period, which is defined as the design working life of the building.

If the legally required safety level at the moment of erection is not met, then the article 13 of the Housing Act may on request of the Authority require the building owner to modify the building construction. Whether this is invoked depends amongst others like on the timing of the infringement in relation to the remaining service life of the building. The Municipal authorities have the discretion to accept a certain degree of deviation from the regulations.

A separate issue is the private relationship between contractual parties. If a contractual agreement has not been met then the disadvantaged party has the right to a civil law process and the other party is liable for not fulfilling the contractual obligations.

MAIN CONTENTS

The safety assessment of an existing building differs from that of a new one in a number of essential ways:

- Firstly, increased safety levels usually involve more costs for an existing building than for buildings that are still in the design phase. The safety provisions embodied in safety standards have to be set off against the cost of providing them, and on this basis these costs are more difficult to justify for the existing buildings. For this reason in certain circumstances a lower safety level is acceptable.
- Secondly, the remaining lifetime of an existing building is often different than the standard reference period of 50 years or 15 years that applies to new buildings. This aspect plays an important role in determining if the building construction is still adequately safe.

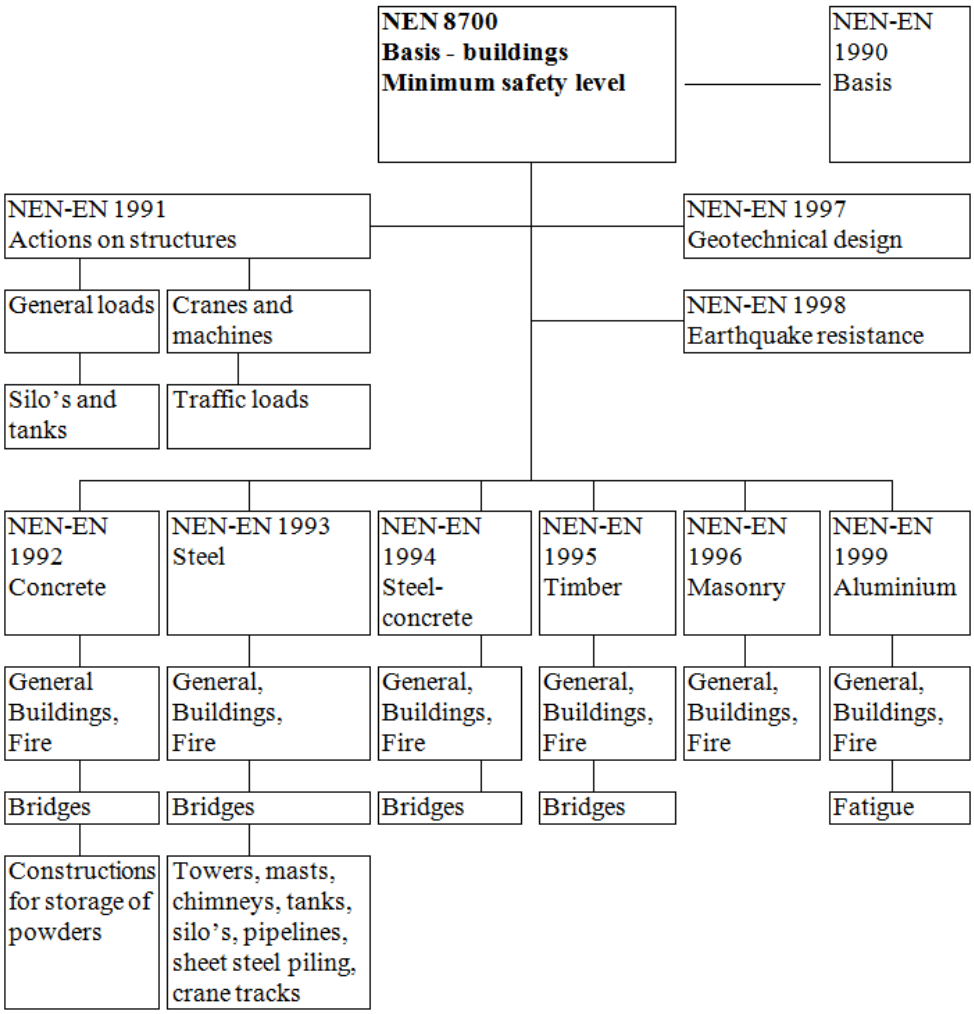


Figure 1. Overview of the standard structure

Table 1

Minimum values for the reliability index β with a minimum reference period (extreme limit) of 15 years for CC1B

Consequence class	Minimum Reference period for existing building	New construc-tion[c] β_n		Repare[d] β_r		Summon[e] β_b	
		wn	wd	wn	wd	wn	wd
1A[b]	1 year	3.3	2,3	2,8	1.8	1.8	0.8
1B[b]	15 years	3.3	2,3	2,8	1.8[a]	1.8[a]	1.1[a]
2	15 years	3.8	2.8	3.3	2,5[a]	2,5[a]	2.5[a]
3	15 years	4.3	3.8	3.8	3.3[a]	3.3[a]	3.3[a]

wn: wind not dominant
wd: wind dominant
[a] In this case the minimum limit for personal safety is normative.
[b] In this case a distinction is made between class 1A (loss of life unacceptable) and 1B (danger of loss of life is small).
[c] For reference period and service life NEN-EN 1990 applies.
[d] For reference period and service life local authority discretion (≥ 15 years) applies
[e] With a remaining lifetime of 1 year.

- Thirdly, in an existing building actual measurement can be made in order to gather the facts.

More information on these aspects and their influence in determining the reliability levels chosen in the standard is contained in a report produced by TNO and the Expertcenter Regulations in Building: TNO-Report 2008-D-R0015/B.

Unlike the regulations that apply to new buildings the requirements of the new standard include:

- The regulations in NEN-EN 1990 which concern probability theory. This pays no attention to individual structural materials but is dependent on the purposes for which the building is used and pays attention to the probability of load stresses occurring over a short reference period. Herewith account is taken of known actions on the building taken place in the past and the probable properties of the building itself and not the structural properties of the building products as products in the market from which the building is made.
- Taking the opportunity to harmonise the Eurocodes with the basic principles on the safety of the existing building constructions on an arbitrary moment. The safety assessment assumes a remaining lifetime of 1 year. Reference periods in determining the size of the load factors are 1 year for buildings in class CC1A and 15 years for buildings in class CC1B, CC2 and CC3. This is therefore a different assumption to the durable safety requirements of a newly built construction.[4] These have in the case of permanent buildings a design lifetime and a reference period of 15 or 50/100 years dependent on the class of the building. For this reason the reliability index β and the load factor γ can be lower than those for a new construction.
- Formal acknowledgement that guarantees on the durable safety requirements need other than to cover a remaining lifetime period of 1 year.
- Excluding requirements that relate to the uncertainties that may arise during the theoretical, paper design of the building.
- Amendment of the methods to determine the properties of the structural materials used in the building; and
- The ability to review at any time the actual constructed situation (a review based on the original design may be sufficient where there are no indications that the actual situation is worse).

Because the introduction of the Eurocode standards NEN-EN 1990 up to NEN-EN 1999 represents a breakthrough in the traditional assessment methods, there is justification for further transforming the old ways of working to the way that has been adopted with the Eurocodes as described above. NEN 6720 assesses concrete on its cube compressive strength, whilst NEN-EN 1992 assesses concrete on its cylinder compressive strength. Timber has now introduced strength classes, whilst for years visual control was the method used despite the need for an objective strength assessment. These are just a few examples.

In the development of the new standard we have tried not to change the confidence levels by which building structures were declared unsafe and were upheld by legal bodies up to the time of publication of the new standard.

In the transition from the TGB 1990 standards to the Eurocodes (NEN-EN 1990 to NEN-EN 1999) the safety classes recognised in NEN 6700 have been transformed to consequence classes. This classifies buildings differently than in NEN 6700. To avoid this having unintended effects for the existing buildings the consequence class CC1 has been split into class CC1A and CC1B. Class CC1A includes buildings that according to NEN 6700 fall in safety class 1 and according to the Building Decree 2003 may be assessed using a reference period of 1 year until the time of the introduction of the new standard. In Class 1A human safety will be subsidiary.

RENOVATION

The new standard also establishes the lowest limits of safety levels in the renovation, alteration or enlargement of an existing building. These limits differ from those which apply to newly constructed buildings and which are laid down in NEN-EN 1990. Note that granting exemptions to a level of the standard that may be below an already legally sanctioned level is not the intention. By doing so the authorities would be accepting a lower standard than they had originally sanctioned. However, the authorities could well take account of the remaining lifespan of the building when granting a permit for renovation, alteration or enlargement. The remaining lifespan can be different from that of an entirely new building. Exceptional circumstances also may occur whereby exemption could be granted, for example, after the occurrence of an accident.

The standard does not contain specific rules relating to minimum safety levels for renovation, alteration or enlargement of a building whereby the remaining lifespan and therefore the reference period of the building to be renovated are taken into account. The

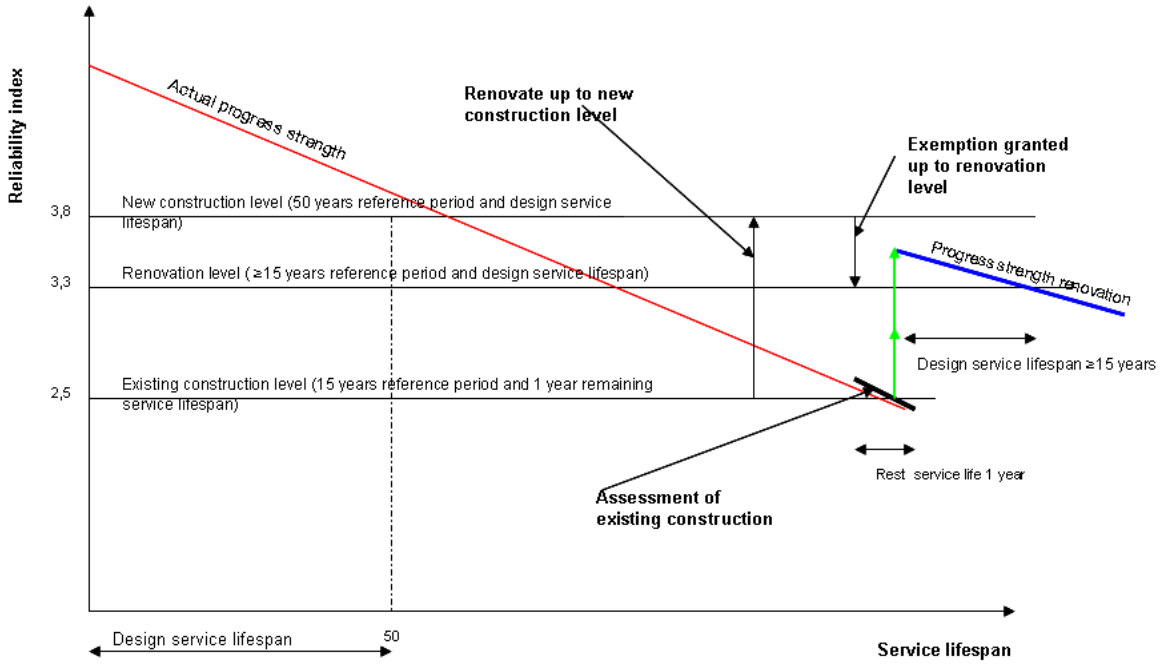
[4] The NEN 8700 and the Eurocodes make a difference between the reference period which expresses the size of the loads to be taken as basis for the calculations and the service life or remaining lifetime. The remaining lifetime is the indicator for the safety of the structure when loads are applied.

TNO report 2008-D-R0015/B does include recommendations for this.

SUMMARY ON RELIABILITY AND LOAD FACTORS

Extracted from the TNO report and applied to the different situations the reliability indices are shown in Table 1.

Figure 2 illustrates how the regulations are intended to work based on an example in consequence class 2 (with a service life of 50 years for a new construction and 15 years for renovation and in both cases the wind is not taken into account). Table 2 shows the conversion to load factors.



Strictly speaking the reliability indices relating to various lengths of service life and remaining lifetime cannot be captured in a single graph because to do this the β's should be calculated on the basis of 1 year. This has not been done.

Figure 2. Effect of the regulations on structural safety shown in terms of the required reliability of the building against time

Table 2

Overview of load factors

	NEW CONSTRUCTION					RENOVATION					EXISTING BUILDING				
	Load factors ULS, New construction (STR/GEO and extreme)					**Load factors ULS – Renovation (repair)**					**Load factors: ULS – Existing buildings**				
	Reference period is 15/50/100 years; service life is 15/50/100 years					**Reference period: dependent on the situation (≥ 15 years; service life: dependent on the situation (≥ 15 years)**					**Reference period 1 year with CC1A 1 year and with CC1B and 2 and 3 ≥ 15 years; remaining lifetime 1 year)**				
Load combination	Permanent load		Dominant variable load	Other variable load	Extreme load	Permanent load		Variable load	Wind force	Fire	Permanent load		Variable load	Wind force	Fire
	Un-favourable	Favourable				Un-favourable	Favourable				Un-favourable	Favourable			
STR/GEO (6.10a)															
Consequence class 1	1,2	0,9	1,35Ψo	1,35 Ψo	-	1,1	0,9	1.10Ψo	1,10Ψo	-	1,1	0,9	1.00Ψo	1,10Ψo	-
Consequence class 2	1,35	0,9	1,50Ψo	1,50 Ψo	-	1,3	0,9	1.30Ψo	1,30Ψo	-	1,2	0,9	1.15Ψo	1,30Ψo	-
Consequence class 3	1,5	0,9	1,65Ψo	1,65 Ψo	-	1,4	0,9	1,50Ψo	1,50Ψo	-	1,3	0,9	1,30Ψo	1,50Ψo	-
STR/GEO (6.10b)															
Consequence class 1	1,1	0,9	1,35	1,35 Ψo	-	1,1	0,9	1.10*	1,10*	-	1	0,9	1.00*	1,10*	-
Consequence class 2	1,2	0,9	1,5	1,50 Ψo	-	1,2	0,9	1.30*	1,30*	-	1,1	0,9	1.15*	1,30*	-
Consequence class 3	1,3	0,9	1,65	1,65 Ψo	-	1,3	0,9	1,50*	1,50*	-	1,2	0,9	1,30*	1,50*	-
Extreme (6.11)															
All classes	1	1	1		1	1	1	1		1	1	1	1		1

dominant" multiply by Ψo

Dependent on the reference period the following applies for variable loads: If NEN-EN 1991 has no directive, as with floor loads, then the following may apply:

$$F_t = F_{t_0}\{1+\frac{1-\psi_1}{9}\ln(\frac{t}{t_0})\}$$

Where:
is the adjusted extreme value of the variable equally spread load for the remaining lifetime;
is the extreme value of the variable equally spread load for a service life of 50 years;
is the ψ-factor value from table A1.1 in the standard;
is the service life or the remaining lifetime;
t_0 is the service life of 50 years.

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