



JRC SCIENCE FOR POLICY REPORT

EUROCODES: BACKGROUND & APPLICATIONS

Elaboration of maps for climatic and seismic actions for structural design with the Eurocodes

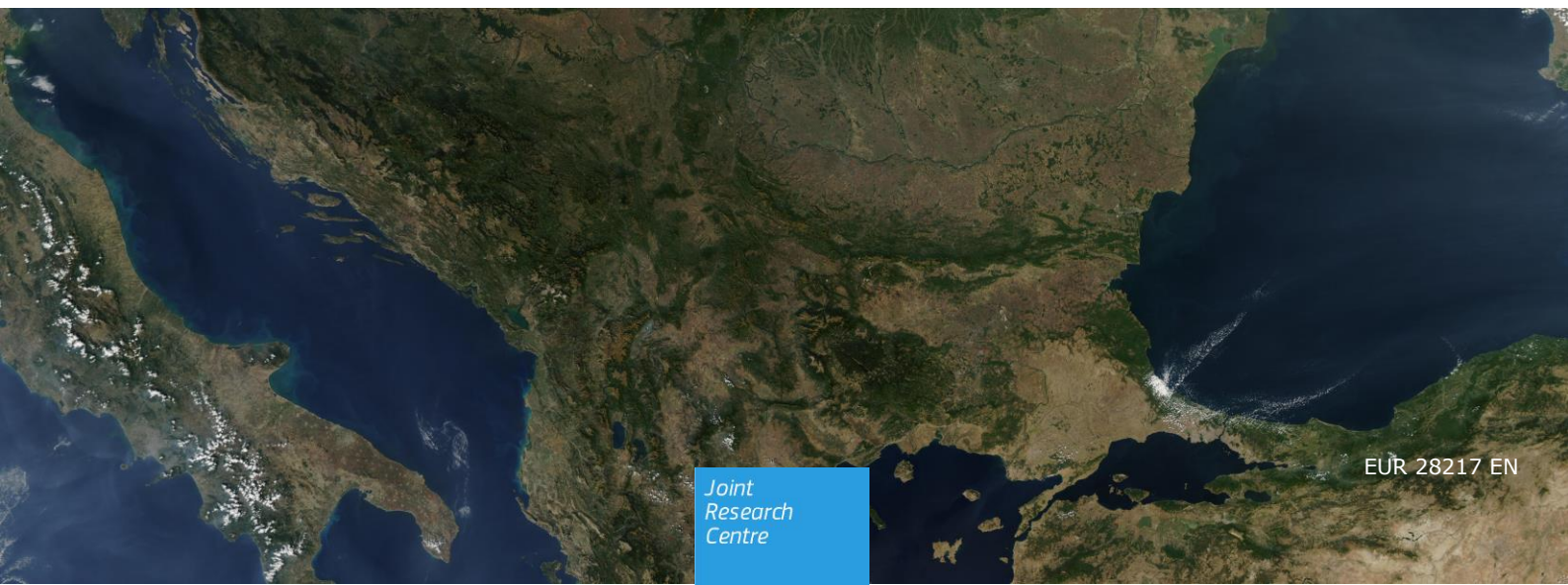
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Title Elaboration of maps for climatic and seismic actions for structural design with the Eurocodes

Abstract

Activities for promotion of policies for sustainable construction in the Balkan region.

Guidance for countries adopting the Eurocodes.

State-of-the-art material to elaborate maps for seismic and climatic actions for structural design.

Experience of the non-EU Balkan countries on elaboration of these maps.

CONTENTS

1	GENERAL PRINCIPLES OF THE ELABORATION OF MAPS FOR CLIMATIC AND SEISMIC ACTIONS.....	3
1.1	Climatic and seismic actions in the Eurocodes.....	3
1.1.1	General	3
1.2	Maps for climatic actions	8
1.2.1	General	8
1.2.2	Ground snow load maps	9
1.2.3	Impact of climate change on climatic actions maps	19
1.3	Maps for seismic actions.....	20
1.3.1	Design values of seismic actions	20
1.3.2	Seismic zonation.....	22
1.3.3	Future evolution of seismic maps	26
1.4	Conclusions	28
 2	 EXPERIENCE OF THE 2013 EUROPEAN SEISMIC HAZARD MODEL: MILESTONES AND OUTPUT	 33
2.1	Seismic hazard harmonization in Europe - the SHARE Project .	33
2.1.1	Introduction	33
2.2	The 2013 European Seismic Hazard Model: highlights and elements.....	34
2.2.1	Cross border harmonization	34
2.2.2	European strong motion database	37
2.2.3	Seismic hazard model uncertainties.....	38
2.2.4	OpenQuake	40
2.3	The 2013 European Seismic Hazard Model: output	41
2.3.1	Engineering requirements	41
2.3.2	Reference probabilistic ground motion maps.....	42
2.3.3	Design spectrum shape parameters from Uniform Hazard Spectra (UHS)	47
2.3.4	Hazard curve elements: <i>k</i> -value	50
2.3.5	Availability	50
2.4	The 2013 European Seismic Hazard Model: summary and further recommendations.....	51

3	REVISED PROBABILISTIC SEISMIC HAZARD MAP OF TURKEY AND ITS IMPLICATIONS TO SEISMIC DESIGN	59
3.1	Introduction	59
3.2	Turkish seismic hazard map Project	59
3.3	Horizontal design spectrum after the revised Seismic hazard maps	61
3.4	Comparison of horizontal design spectrum before and after the revised seismic hazard maps	63
3.5	Conclusions	64
4	EN 1991 – CLIMATIC ACTIONS AND ELABORATION OF MAPS FOR CLIMATIC ACTIONS IN GREECE	69
4.1	Introduction	69
4.1.1	Key items of Part 1-3 “Snow loads” of EN 1991	69
4.1.2	Key items of Part 1-4 “Wind actions” of EN 1991	72
4.1.3	Key items of Part 1-5 “Thermal actions” of EN 1991	73
4.2	Actual situation and near future perspectives concerning Eurocode parts on climatic actions	74
4.3	Elaboration of maps for climatic actions in Greece	75
4.3.1	Snow map for Greece	76
4.3.2	Wind map for Greece.....	78
4.3.3	Temperature maps for Greece	80
4.4	Conclusions	82
5	ELABORATION OF MAPS FOR CLIMATIC ACTIONS IN ITALY	87
5.1	Introduction	87
5.2	Snow map.....	87
5.2.1	Worked examples	93
5.3	Thermal actions.....	93
5.3.1	Worked examples	99
5.4	Wind actions.....	100
5.4.1	Elaboration of wind velocity data in Pisa Airport.....	101
5.4.2	Wind map and terrain categories in Italy.....	103
5.4.3	Worked examples	106
5.5	Concluding remarks.....	107
6	EXPERIENCE FROM THE REGION IN ELABORATION OF MAPS FOR CLIMATIC ACTIONS: BULGARIA.....	111
6.1	Abstract.....	111
6.2	Introduction	111

6.3	Elaboration of the snow load map of Bulgaria	112
6.3.1	Data and preparatory exploration.....	113
6.3.2	Statistical analysis and probability distribution fitting of the data from Bulgaria	114
6.3.3	Estimation of the locations with exceptional snow loads	115
6.3.4	The snow density model in Bulgaria	116
6.3.5	Consistency at the national borders.....	121
6.3.6	The elaborated map for snow load in Bulgaria	121
6.4	Elaboration of the wind load map of Bulgaria	122
6.4.1	The elaborated map for wind load in Bulgaria	123
6.5	Elaboration of the maps for thermal actions of Bulgaria	124
6.5.1	The elaborated maps for thermal action in Bulgaria	125
6.6	Conclusions	127
7	ASSESSMENT AND RETROFITTING OF EXISTING STRUCTURES – HIGHLIGHTS FROM THE SECOND GENERATION OF THE EUROCODES	131
7.1	Policy Framework	131
7.1.1	Strategic importance of construction sector	131
7.1.2	Environmental impact of construction works.....	131
7.1.3	Basic requirements	132
7.2	Assessment of existing structures	133
7.2.1	Existing structures and sustainability.....	133
7.2.2	Potential for future development.....	134
7.3	CEN/TC250 initiative / Mandate 515	134
7.3.1	Background an justification	134
7.3.2	Approach to execution of the Mandate	135
7.3.3	JRC Science and policy report.....	136
7.4	Prospect for CEN Guidance	136
7.4.1	Scope.....	136
7.4.2	Contents.....	137
7.4.3	Basic requirements	137
7.4.4	Procedure for assessment and retrofitting	138
7.4.5	Investigation and updating information.....	138
7.4.6	Structural analysis and verifications	139
7.4.7	Interventions.....	140
7.5	Conclusions	141

8	EN 1998-3: SEISMIC ASSESSMENT AND RETROFITTING OF EXISTING BUILDINGS	145
8.1	Introduction	145
8.1.1	General	145
8.1.2	Overview of the Chapter	145
8.2	Overview of EN 1998-3:2005 - feedback from its application	146
8.2.1	Introduction	146
8.2.2	Performance objectives - compliance criteria - analysis models	146
8.2.3	Treatment of uncertainties due to limited knowledge of the as-built structure.....	147
8.2.4	Critical comments from the application of EN1998-3.....	148
8.3	First building retrofitted to EN 1998-3 tested by earthquake	149
8.3.1	The backdrop	149
8.3.2	Seismic retrofitting of the building with EN 1998-3:2005	149
8.3.3	Computed response vs actual performance in the M6.1 earthquake of 26-01-2014	152
8.4	The conclusion: assessment and retrofitting in the next generation of EN-Eurocodes	153
8.4.1	The context.....	153
8.4.2	The forthcoming new version of EN 1998-3 "Seismic Retrofitting of Structures"	153
9	SEISMIC PERFORMANCE ASSESSMENT AND REHABILITATION OF EXISTING RC BUILDINGS IN TURKEY	159
9.1	Seismic performance assessment procedures	159
9.1.1	Detailed assessment procedures in Turkey	160
9.2	Seismic rehabilitation of existing RC buildings in Turkey.....	164
9.2.1	Member strengthening.....	164
9.2.2	System strengthening	165
9.2.3	Performance of rehabilitated buildings	168
9.3	Conclusions	170
10	ADOPTION AND IMPLEMENTATION OF THE EUROCODES IN THE NON-EU COUNTRIES IN THE BALKAN REGION.....	175
10.1	Introduction	175
10.2	Building capacities for adoption of the Eurocodes in the non-EU countries from the Balkan region	176
10.3	Identification of target countries and relevant national stakeholders.....	176
10.4	Workshop on the adoption of the Eurocodes in the Balkan region.....	176

10.5	Workshop on building capacities for elaboration of NDPs and NAs of the Eurocodes in the Balkan region	179
10.6	Workshop on elaboration of maps for climatic and seismic actions for structural design in the Balkan region	182
10.7	State of the progress and views on the way ahead.....	185
10.7.1	State of the progress.....	185
10.7.2	Views on the way ahead	186
11	STATE OF HARMONIZED USE OF THE EUROCODES NATIONALLY DETERMINED PARAMETERS RELEVANT TO THE DEFINITION OF CLIMATIC AND SEISMIC ACTIONS	191
11.1	Introduction	191
11.2	Brief outline of Eurocodes and NDPs	192
11.3	Statistical analysis of the NDPs available in the Eurocodes Database	194
11.3.1	Statistical analysis on the availability of data	194
11.3.2	Statistical analysis of the acceptance of Recommended Values	197
11.4	Statistical analysis of the NDPs relevant to the definition of climatic and seismic actions	199
11.4.1	Data related to the definition of climatic and seismic actions	199
11.4.2	Statistical analysis of the acceptance of NDPs.....	200
11.4.3	Seismic zone maps adopted by EU Member States	207
11.5	Concluding remarks.....	212

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Foreword

The **construction sector** is of strategic importance to the EU as it delivers the buildings and transport infrastructure needed by the rest of the economy and society. It represents **more than 10% of EU GDP** and **more than 50% of fixed capital formation**. It is the largest single economic activity and it is the biggest industrial employer in Europe. The sector employs directly almost 20 million people. Construction is a key element not only for the implementation of the **Single Market**, but also for other construction relevant EU Policies, e.g. **Sustainability, Environment and Energy**, since 40-45% of Europe's energy consumption stems from buildings with a further 5-10% being used in processing and transport of construction products and components.

The **EN Eurocodes** are a set of European standards (Européenne Normes), which provide common rules for the design of construction works to check their strength and stability. In line with the EU's strategy for smart, sustainable and inclusive growth (EU2020), **Standardization** plays an important part in supporting the industrial policy for the globalization era. The improvement of the competition in EU markets through the adoption of the Eurocodes is recognized in the "Strategy for the sustainable competitiveness of the construction sector and its enterprises" – COM (2012)433, and they are distinguished as a tool for accelerating the process of convergence of different national and regional regulatory approaches.

With the publication of all the 58 Eurocodes Parts in 2007, the implementation in the European countries started in 2010 and now the process of their adoption internationally is gaining momentum. The Commission Recommendation of 11th December 2003 stresses the importance of training in the use of the Eurocodes, which should be promoted in engineering schools and as part of continuous professional development courses for engineers and technicians. It is also recommended to undertake research to facilitate the integration into the Eurocodes of the latest developments in scientific and technological knowledge. In light of this Recommendation, DG JRC is collaborating with DG GROW, CEN/TC250 "Structural Eurocodes" and other relevant stakeholders, and is publishing the Report Series 'Eurocodes: background & applications' as JRC Science for Policy Reports.

The activities of promotion of the construction sector outside the EU are part of the JRC efforts to support the **EU policies and standards for sustainable construction**. In line with the Commission Recommendation of 11th December 2003 the JRC activities comprise guidance and training to the countries showing commitment to adopt and implement the Eurocodes and the European policies and tools for sustainable construction.

The present report contains a comprehensive description of the technical papers and examples prepared by the lecturers of the workshop "Elaboration of **maps** for **climatic** and **seismic** actions for structural design in the **Balkan region**". The workshop was held on 27-28 October 2015, in Zagreb, Croatia, and was organised by the JRC, within the framework of the JRC Enlargement and Integration Action, together with the Institute of Earthquake Engineering and Engineering Seismology (IZIIS) of Skopje and the Faculty of Civil Engineering of the University of Zagreb. The organisation of the workshop was supported by CEN TC250 and by the Croatian Standards Institute. The workshop addressed representatives of public authorities, national standardisation bodies, research institutions, and academia aiming at facilitating further **adoption and implementation of the Eurocodes in the non-EU countries in the Balkan region**.

The report contains state-of-the-art material concerning the elaboration of maps for seismic and climatic (wind, snow and thermal) actions for structural design, in order to support non-EU countries in the adoption of the Eurocodes. In these standards national choices should take into account country differences in geographical, geological or climatic conditions. The regional experience is reported and the non-EU Balkan countries progress on the elaboration of the aforementioned maps is presented and analysed. Advanced concepts for the assessment and retrofitting of existing structures are highlighted as new

trends for the next generation of Eurocodes. Finally, the state of harmonized use of the Eurocodes Nationally Determined Parameters (NDPs), relevant to the definition of climatic and seismic actions, is analysed based on the NDPs uploaded on the JRC database by the EU and EFTA Member States.

We would like to gratefully acknowledge the workshop's lecturers for their contribution in building capacities for the elaboration of maps for climatic and seismic actions for structural design in non-EU countries in the Balkan region.

The editors and authors have sought to present useful and consistent information in this report. The chapters presented in the report have been prepared by different authors therefore are partly reflecting different practices in different countries. **Users of information contained in this report must satisfy themselves of its suitability for the purpose for which they intend to use it.**

All the material prepared for the workshop (slides presentations and JRC Report) is available to download from the "Eurocodes: Building the future" website (<http://eurocodes.jrc.ec.europa.eu>).

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CHAPTER 1

GENERAL PRINCIPLES OF THE ELABORATION OF MAPS FOR CLIMATIC AND SEISMIC ACTIONS

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1 General principles of the elaboration of maps for climatic and seismic actions

1.1 Climatic and seismic actions in the Eurocodes

1.1.1 General

Climatic and seismic actions are treated in EN 1991: Actions on structures, Part 1-3 Snow Loads, Part 1-4 Wind Actions and Part 1-5 Thermal Actions, and in EN 1998: Design of structures for earthquake resistance, Part 1 General rules, seismic actions and rules for buildings, respectively. In the analysis of structures and civil engineering works, actions defined according to the above mentioned Eurocodes parts, are combined with other actions (e.g. permanent loads) according the rules provided by EN 1990 Basis of Structural Design, to evaluate, the design effects of actions to be compared with the corresponding structural resistances, determined according to provisions given in the so called "material Eurocodes" (EN 1992 to EN 1999) and the geotechnical code (EN 1997). In the following diagram, which shows the links between the Eurocodes, they are highlighted the Eurocodes addressed in the present paper.

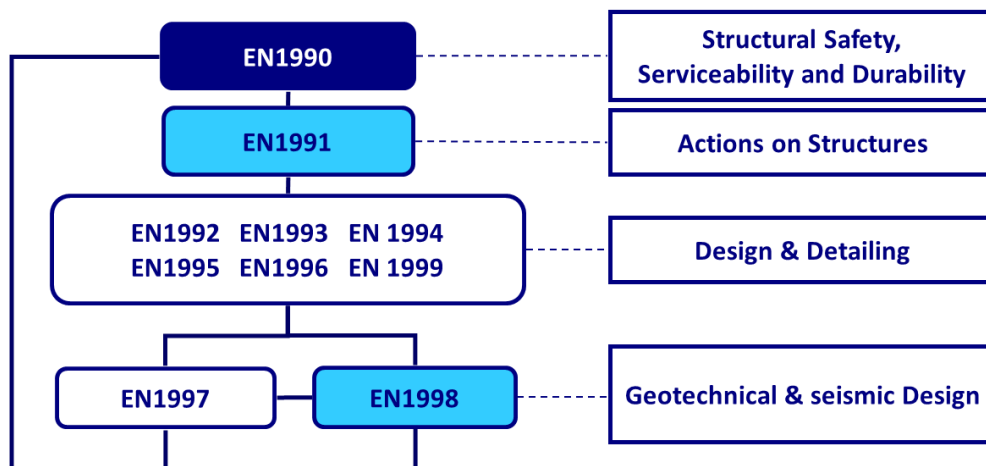


Figure 1.1 Links between the Eurocodes

The Eurocodes recognise the responsibility of regulatory authorities in each Member State of CEN (European Committee for Standardization) and safeguard their right to determine values related to regulatory safety matters at national level, where these vary from State to State. Climatic and seismic actions are a typical example of such determinations and are therefore included in the National Annex to each Eurocode part.

More in detail, according to CEN rules, the National Annex may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters (NDPs), to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e. :

- values and/or classes where alternatives are given in the Eurocode,
- values to be used where a symbol only is given in the Eurocode,

- country specific data (geographical, climatic, etc.), e.g. snow map,
- the procedure to be used where alternative procedures are given in the Eurocode.

The histogram in Figure 1.2 shows the distribution of NDPs in the Eurocode suite, and, as expected, the number of national determinations in EN 1990, the head code, which provides criteria for structural safety, serviceability and durability of structures, in the action code (EN 1991) and in the seismic code (EN 1998) is significant with respect to the total number of NDPs.

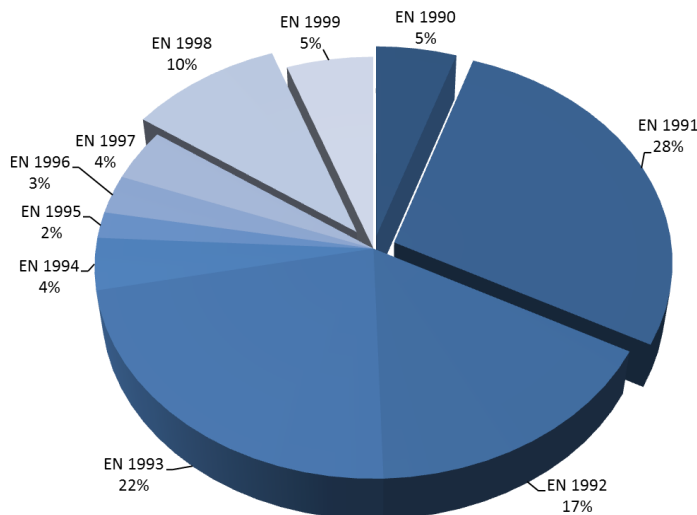


Figure 1.2 Distribution of NDPs in the Eurocodes

General verification formats are specified in EN 1990, which (*cl. 2.1(2)P*) requires that a structure will have adequate structural resistance, serviceability and durability and (*cl. 2.1(1)P*) that a structure shall be designed and executed in such a way that it will, during its intended life, with appropriate degrees of reliability and in an economical way:

- sustain all actions and influences likely to occur during execution and use, and
- meet the specified serviceability requirements for a structure or a structural element.

The above requirements lead to the Ultimate Limit States (ULS) and Serviceability Limit States (SLS) verifications, to be further specified according all possible “design situations” which the structure may experience during its execution, service life time, repair, and eventually during its decommissioning.

In EN 1990 (*cl. 1.5.2.2*) design situations are defined as “sets of physical conditions representing the real conditions occurring during a certain time interval for which the design will demonstrate that relevant limit states are not exceeded”. Generally, three design situations apply for a structure: transient, persistent and accidental (which includes the seismic design situation).

A transient design situation is defined (EN 1990 *cl. 1.5.2.3*) as a “condition that is relevant during a period much shorter than the design working life of the structure and which has a high probability of occurrence”. Typically transient design situation refers to temporary conditions of the structure, of use, or exposure, e.g. during construction or repair, in which

the structural scheme may sensibly differ from that one at final stage (Figure 1.3 a). The Eurocodes allow a reduction of the representative values of climatic actions (e.g wind pressures) to be considered for these short duration design phases, details are given in EN 1991-1-6 (Actions on Structures: actions during execution).



a) Transient design situation



b) Persistent design situation
[source :

<http://www.e-architect.co.uk/>]

Figure 1.3 Examples of transient and persistent design situations

A persistent design situation (EN 1990 cl. 1.5.2.4) is defined as a "situation that is relevant during a period of the same order as the design working life of the structure, and which generally refers to conditions of normal use of the building" (Figure 1.3 b).

The two design situations defined above are usually to be considered in the design of the generality of structures, which, on the contrary, may not necessarily be the case of accidental design situations, which EN 1990 (cl. 1.5.2.5) defines as "*situations involving exceptional conditions of the structure or its exposure, including fire, explosion, impact or local failure*".

Although the verification of structures against exceptional design situations is primarily intended to provide sufficient robustness to prevent disproportionate collapse in case of exposure to those exceptional events mentioned in the definition given above, the Eurocodes include, where allowed by the National Annex, the verification against one climatic action, the snow load, which may be regarded as accidental (i.e. an extreme event associated with an exceptionally infrequent likelihood) for both ground snow load and/or roof snow accumulation patterns (Figure 1.4 a). EN 1991-1-3 gives the details how to detect and to treat the accidental snow loads.

Finally, EN 1990 (cl. 1.5.2.7) defines the seismic design situation as the one involving exceptional conditions of the structure when subjected to a seismic event (Figure 1.4 b).

Following from the above, the definition of climatic actions in the Eurocodes, as well as their representations through national maps, is finalised to the analysis of ULS and SLS for transient, persistent, accidental (only ULS) and seismic design situations, as diagrammatically shown in Figure 1.5.



a) Accidental (climatic) design situation



b) Seismic design situation

[source:

<http://www.primapaginamolise.it/>]

Figure 1.4 Examples of accidental (climatic) and seismic design situations

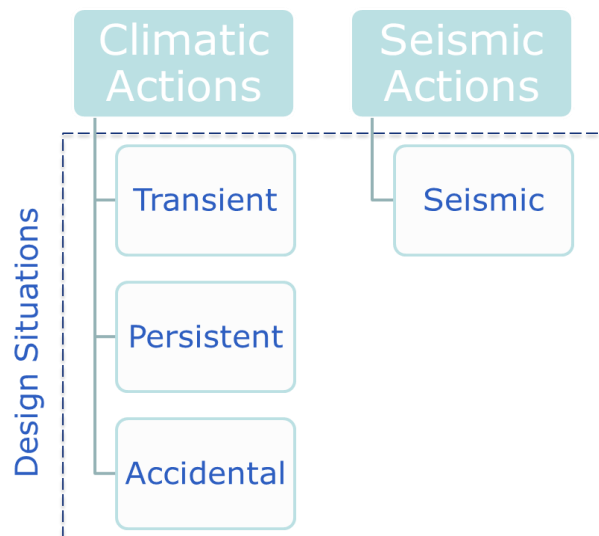


Figure 1.5 Climatic and seismic actions for different design situations in the Eurocodes

Once identified the needed verifications to encompass all the possible conditions (design situations) that will be likely to occur during execution and use of the structure, associated with the corresponding limit states requirements, EN 1990 provides the details of the combination rules of different actions (permanent, variable etc.), for each design situation and limit state, according the partial factor method, upon which the Eurocodes are based.

More in detail, in Section 6 of EN 1990, they are given the following well known equations, where they can be clearly identified the contributions of climatic and seismic actions respectively for persistent, transient accidental and seismic design situations.

For ULS persistent and transient design situations:

$$\sum_{j \geq 1} \gamma_{G,j} G_{k,j} + \gamma_P P + \gamma_{Q,1} Q_{k,1} + \sum_{i > 1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \quad (\text{EN 1990, Eq. 6.10})$$

or, alternatively (where allowed by the National Annex) for STR and GEO limit states, the less favourable of the two following expressions:

$$\sum_{j \geq 1} \gamma_{G,j} G_{k,j} + \gamma_P P + \gamma_{Q,1} \psi_{0,1} Q_{k,1} + \sum_{i > 1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \quad (\text{EN 1990, Eq. 6.10a})$$

$$\sum_{j \geq 1} \xi_j \gamma_{G,j} G_{k,j} + \gamma_P P + \gamma_{Q,1} Q_{k,1} + \sum_{i > 1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \quad (\text{EN 1990, Eq. 6.10b})$$

Where, further to partial factors and combination factors, according to the general notation adopted:

$G_{k,j}$ is the characteristic value of the j -th component of permanent actions,

P is the characteristic value of pre-stressing action;

Q_k is the characteristic value of i -th variable action, acting simultaneously on the structure, among which the climatic actions.

For ULS accidental design situations:

$$\sum_{j \geq 1} G_{k,j} + P + A_d + (\psi_{1,1} \text{ or } \psi_{2,1}) Q_{k,1} + \sum_{i > 1} \psi_{2,i} Q_{k,i} \quad (\text{EN 1990, Eq. 6.11b})$$

Where, further to the permanent and pre-stressing actions, the design value of the accidental action A_d (where relevant, accidental snow load) is combined with the frequent ($\psi_{1,1} Q_{k,1}$) or quasi-permanent ($\psi_{2,1} Q_{k,1}$)¹ value of the leading variable action and with the quasi-permanent values of the remaining variable actions.

Finally for seismic design situation the combination format is as follows:

$$\sum_{j \geq 1} G_{k,j} + P + A_{Ed} + \sum_{i \geq 1} \psi_{2,i} Q_{k,i} \quad (\text{EN 1990, Eq. 6.12b})$$

Where A_{Ed} is the design value of the seismic action, which, according EN 1990 cl. 4.1.2(9), should be assessed from the characteristic value A_{Ek} and the importance factor pertinent to the structure in consideration or for individual projects.

Further to ULS, the Eurocode EN 1990 provides, in clauses 6.5.1 to 6.5.3 criteria for the combination of action for the verification of the structural performance in the serviceability limit states (SLS), according the three following combinations:

$$\text{Characteristic: } \sum_{j \geq 1} G_{k,j} + P + Q_{k,1} + \sum_{i > 1} \psi_{0,i} Q_{k,i} \quad (\text{EN 1990, Eq. 6.14b})$$

$$\text{Frequent: } \sum_{j \geq 1} G_{k,j} + P + \psi_{1,1} Q_{k,1} + \sum_{i > 1} \psi_{2,i} Q_{k,i} \quad (\text{EN 1990, Eq. 6.15b})$$

$$\text{Quasi-permanent: } \sum_{j \geq 1} G_{k,j} + P + \sum_{i \geq 1} \psi_{2,i} Q_{k,i} \quad (\text{EN 1990, Eq. 6.16b})$$

It is worth to underline that the formulation of the Eurocodes is such that the characteristic values of climatic actions (in persistent, transient and accidental combination expressions) and for seismic actions is conventionally associated to given probability of exceedance in a reference time period. The adoption of these characteristic values, in conjunction with the partial factors on actions (as recommended in the Annexes to EN 1990), is considered generally to lead to a structure with a reliability index β greater than 3.8 for a 50 years reference period (see EN 1990 Annex B).

¹ The choice between the frequent and quasi permanent value is left to the national determination.

For climatic actions the recommended probability of exceedance is given in Note 2 to 4.1.2(7)P of EN 1990, where it is specified that the characteristic value of climatic actions is based upon the probability of 0.02 of its time-varying part being exceeded for a reference period of one year. This is equivalent to a mean return period of 50 years.

From the above it results clear that the mean return period of the characteristic value for climatic actions is not to be misinterpreted as the design working life of the structure, which is related to the time depending effects of actions and on the durability aspects.

As recalled before, further to the characteristic values of climatic (and other variable) actions, the formulations for combinations at ULS and SLS, include other different representative values, to take account of the reduce probability of contemporary occurrence of characteristic values of different actions from different sources.

The representative values are obtained by multiplication of characteristic values by a reduction, or combination, factors (ψ_0 , ψ_1 , ψ_2), calibrated in such a way to provide different fractiles of the variable actions, as diagrammatically shown in Figure 1.6

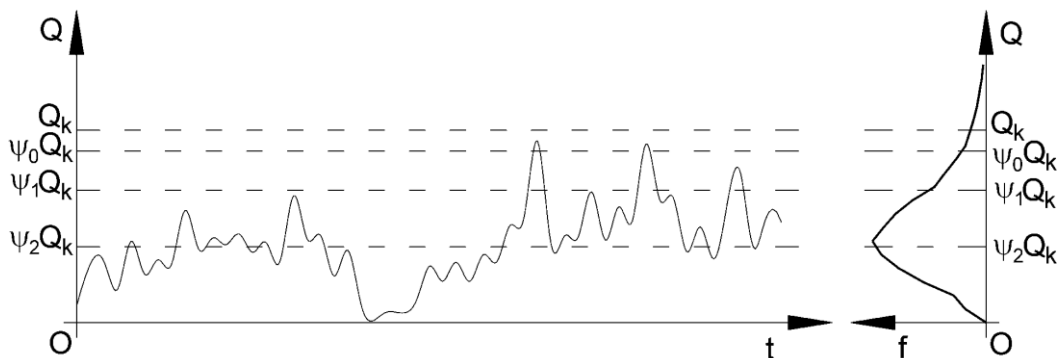


Figure 1.6 Other Representative Values of variable (climatic) actions

As illustrated, the complete set of combination of actions for both ULS and SLS is based upon the characteristic values of permanent, variable and seismic actions, which are to be defined at national level, through NDPs, in the maps. In the next paragraphs they will be illustrated the general principles for the derivation of these maps.

It is worth to underline that what follows is not intended to be a complete description of commonly adopted criteria to derive maps for both climatic and seismic actions for the purposes of structural design. As it is well known, these topics are treated in a huge Literature and the author does not pretend to cover all the issues in this paper, which has to be regarded only as a limited illustration of some general aspects, which may be of interest for those experts involved in the elaboration of maps for climatic and seismic actions at national level in the framework of the Eurocodes.

1.2 Maps for climatic actions

1.2.1 General

As mentioned in the previous paragraph, the Eurocodes recognize the responsibility of National Standard Bodies of CEN Member States for the determination of country specific data, among which they are typically included the maps for climatic actions. It has already been pointed out that these refer to the characteristic values, defined according to the

general provisions given in EN 1990 and in the relevant parts of Eurocode 1: EN 1991-1-3 for snow loads, EN 1991-1-4 for wind actions and EN 1991-1-5 for thermal actions.

If the reason of such differentiation at national level is clearly justified by the need to allow freedom to Member States to establish their own maps on the basis of available data in their territories, the application of this principle led in the past, to a number of inconsistencies among national maps for different climatic actions, particularly evident at borders between neighbouring countries. As it is obvious, the geographical modelling of a physical phenomenon (e.g. the variation of the reference wind speed) should not be influenced by administrative borders between countries. Efforts for a deep harmonization of maps for climatic actions across CEN Member States, have been undertaken, and in many cases still need to be undertaken, by NSBs, on the basis of common approaches set out in the Eurocodes.

The differences observed in the ENV phase of the Eurocodes, i.e. the experimental implementation phase of the codes, terminated with the publication, in the years 2003-2007, of the complete Eurocode suite as EN codes, were due to a number of circumstances, such as:

- the different nature of basic climatic data collected by national meteorological institutes (e.g. in the case of snow loads: snow depths, water equivalent data, direct snow load measures);
- the different statistical treatment of data;
- possible different presentation of maps.

In the specific case of snow loads, the Directorate General III-D3 of the European Commission, funded an important research project, which was carried out by 8 European research Institutes in the period 1996-1999, under the coordination of the University of Pisa (Sanpaolesi et al. 1998, 1999). The aim of the project was to set out a common scientific basis for the elaboration of snow data, to achieve harmonization among CEN members states, preserving their own rights to produce national maps.

The European research project on snow loads, to date, is the only example of scientific activity developed at European scale to serve as a basis to enhance the harmonization of national maps for climatic actions. Since many provisions in the Eurocode EN 1991-1-3 on snow loads are based upon the results of such research work, this specific example will be further illustrated in the following paragraph to illustrate the general principles for the derivation of maps for climatic actions. Further to considerations pertaining to the European scale of the project and to the peculiarities of snow loading, what follows is generally valid for wind velocities and thermal actions (i.e. maximum and minimum air temperatures) as well.

1.2.2 Ground snow load maps

The European research project (Sanpaolesi et al. 1998, 1999), was a pre-normative oriented activity, which aimed to provide sound scientifically based answers to the following fundamental issues, in order to transfer the obtained results in the Eurocode EN 1991-1-3, which in the same period was being converted from ENV to EN. The four research tasks were:

- development of an European Ground snow loads map;
- definition, identification and treatment of Exceptional ground snow loads;
- study of conversion factors from ground to roof loads;
- definition of ULS and SLS combination factors for snow loads (ψ_0 , ψ_1 , ψ_2).

For the purpose of the present paper, the first two activities and their results are of particular interest.

The following illustration of the research results is referred to the CEN Member States at that time, which were in the number of 18, against the current group of 33; as a consequence the geographical coverage of the proposed map results necessarily limited and further studies should be needed to update the map, both by the extension of the snow database to include records from the last 15 years, and more specifically to cover new CEN countries. The procedure developed in the research work has anyway formed the basis for the work of national regulatory authorities in many of the new CEN countries, so that it can be stated that the availability of a common European approach enhanced the harmonization of snow mapping at European scale.

1.2.2.1 Data analysis – characteristic values

The activities for the elaboration of an European ground snow loads map moved from the collection of snow precipitation data across the 18 CEN countries at approximately 2'600 weather stations (Figure 1.7). Data from the selected stations were deeply checked for integrity of the time series, which were generally longer than 50 years and not shorter than 30 years, and for the quality of data themselves (i.e. excluding weather station affected by gross errors in data collection or clearly disturbed by special orographic conditions).

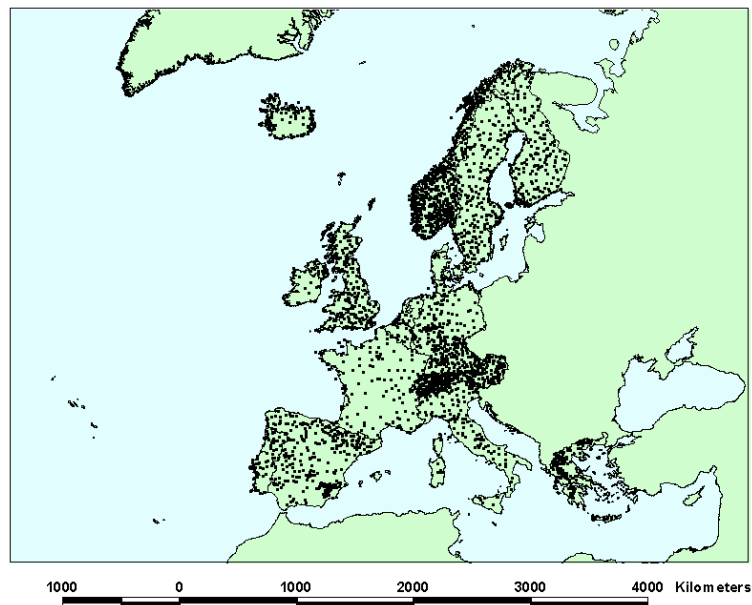


Figure 1.7 Location of the 2'600 weather stations in the European Snow Loads Research Project

Collected data ranged from direct load measurements (only few weather stations and generally for limited time series), to water equivalent and to snow cover depth to be converted into snow load through an appropriate density function conversion factor. From snow data series they were derived the yearly maxima to be statistically processed according a common approach, taking into account both zero and non-zero values, following the so-called "mixed distribution approach".

They were preliminary conducted comparative studies to evaluate the best fitting PDF function in the majority of weather stations, to be consistently adopted for the analysis across the whole European territory. In Figure 1.8 it is shown the distribution of the best fitting PDFs at different weather stations in Germany, which depends on the latitude of the sites: for sites located north to the red dashed line, the best fitting PDF appears to be the Log-Normal, for remaining sites the Gumbel fits better the yearly maxima.

A similar study for Italian weather stations lead to a different conclusion and the correlation in this case is with altitude of sites, as shown in Figure 1.9 (Del Corso and Formichi, 2000). More in detail the best fitting PDF at low to medium altitudes (<1'500 m a.s.l.), which are the most populated areas in Italy, results to be the Gumbel; for sites located at higher altitudes, the Weibull fits better.

From the comparison of results of all the above studies, a common approach was agreed and the Gumbel distribution was adopted as the reference statistical distribution to be adopted in the analysis.

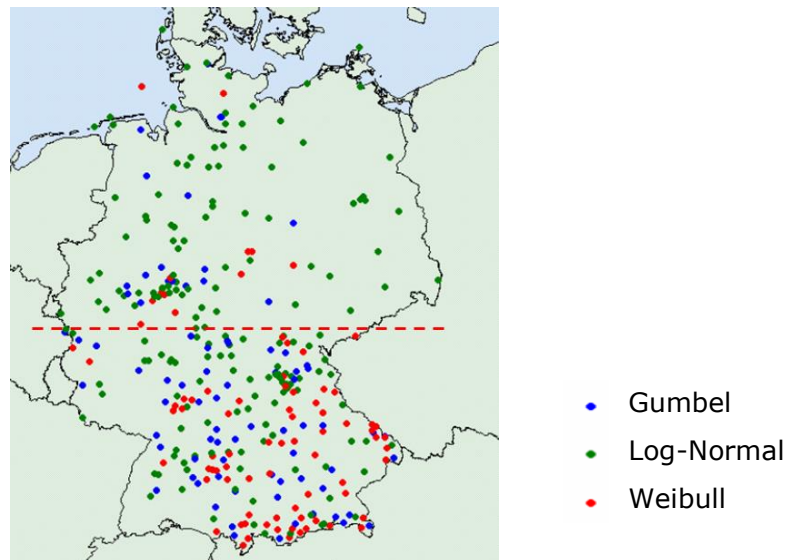


Figure 1.8 Best fitting PDFs for snow loads at weather stations in Germany

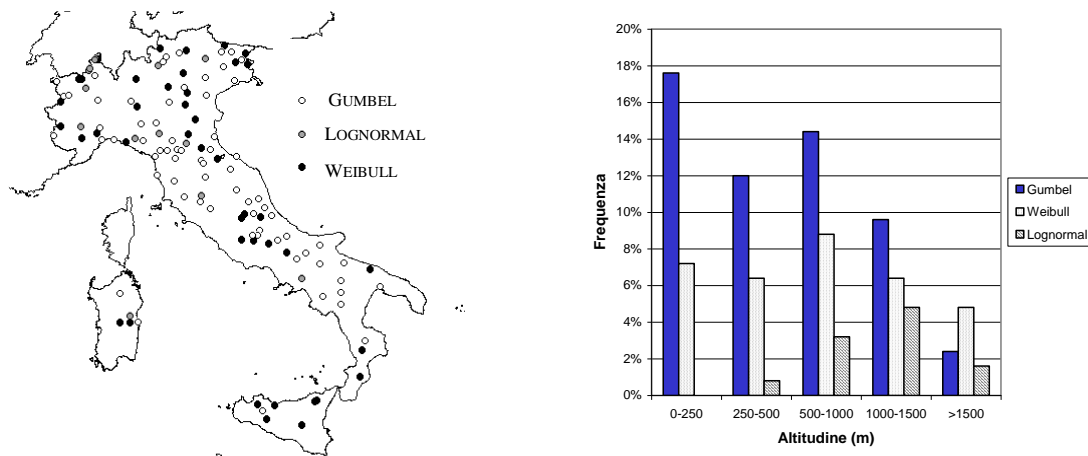


Figure 1.9 Best fitting PDFs for snow loads at weather stations in Italy

The characteristic values (probability of exceedance 0.02 per year) were evaluated at each weather station on Gumbel probability papers by means of least square method regressions.

1.2.2.2 Data analysis – exceptional ground snow loads

In some regions, particularly southern Europe, isolated very heavy snow falls have been observed resulting in snow loads which are significantly larger than those that normally occur. Including these snowfalls with the more regular snow events for the lengths of records available may significantly disturb the statistical processing of more regular snowfalls. On this basis, the following definition of exceptional ground snow loads was agreed during the European research project:

“Isolated and very infrequent snowfalls where the resulting snow load is significantly greater than the loads in the general body of snow load data and its inclusion in that data set distorts the statistical analysis.”

A prime example of exceptional snowfall is Perpignan, France, where a snow depth of 85cm was recorded in 1954 compared with the next largest snow depth value of 46cm. The effects of including this high value in the distribution and on subsequent analysis are discussed in (Sanpaolesi et al. 1995).

Another example is shown the Gumbel probability paper of a weather station in Italy (Pistoia) (Figure 1.10) (Formichi and Del Corso, 2006), where, among the non-zero yearly maxima, an extremely high snow record ($s_{\max}=1.30 \text{ kN/m}^2$) is detected in comparison with the remaining part of the sampled data.

If the extreme event is included in the sample, the regression line is the blue one, leading to an estimate of the characteristic value of 1.00 kN/m^2 ; if the same value is disregarded from the sample (red regression line), the characteristic value decreases to approximately 0.80 kN/m^2 .

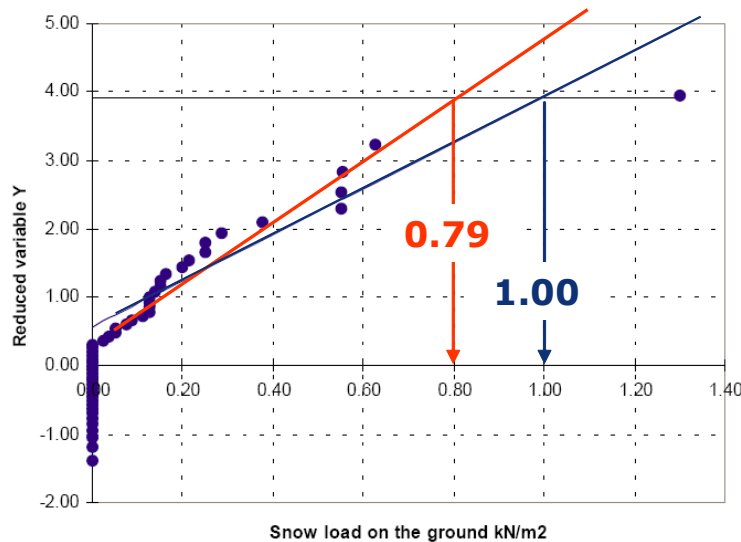


Figure 1.10 Gumbel probability paper: Pistoia (IT)

The criterion identified to detect exceptional ground snow occurrences in yearly maxima data series in the European research work is as follows: “If the ratio of the largest load value to the characteristic load determined without the inclusion of that value is greater than 1.5 then the largest load value shall be treated as an exceptional value”. On this basis, coming back to the example in Figure 1.10, the extreme value can be classified as “exceptional”, since the ratio between s_{\max} (1.30 kN/m^2) and s_k (0.79 kN/m^2), calculated disregarding the maximum value is $1.65 > 1.50$.

Among the 2'600 weather stations examined during the research work, at approximately 160 they were detected exceptional values according the above definition (see Figure 1.11).

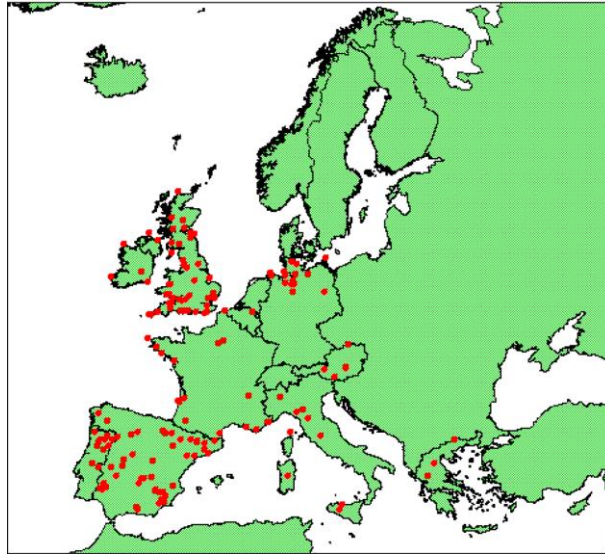


Figure 1.11 Weather stations where exceptional ground snow loads were detected

In paragraph 4.3 of EN 1991-1-3, the treatment of exceptional loads is left open for national determination, based upon the characteristic values of the action, evaluated disregarding exceptional values from the statistical sample.

For locations where exceptional loads may occur (as defined in the National Annex), the ground snow load may be treated as accidental action with the value:

$$s_{Ad} = C_{est} s_k \quad (1.1)$$

where:

C_{est} is set by the National Annex with a recommended value = 2.0

s_k = characteristic ground snow load at the site considered.

Treatment of exceptional ground snow loads is therefore referred to the same characteristic values of the action, elaborated for persistent and transient design situations.

Since the publication of the Eurocode on snow loads (2003), they have been carried out many studies on these extreme events, mainly in countries that joined CEN after that time. An interesting result of such investigation is included in the Slovak National Annex (Sadovský, 2012), which recognises a number of zones where exceptional values are likely to occur, with different intensity with respect to the corresponding characteristic values of the action for persistent and transient design situations.

In Figure 1.12, it is shown the map of Slovakia where they are highlighted four different zones for exceptional values, which can be evaluated by means of C_{est} values, also shown in the same figure. The phenomenon is particularly relevant in some regions, where, probably due to the specific orographic conditions, they are expected values up to approximately 4 times the characteristic value at the site (zone 4: $C_{est} = 3.7$).

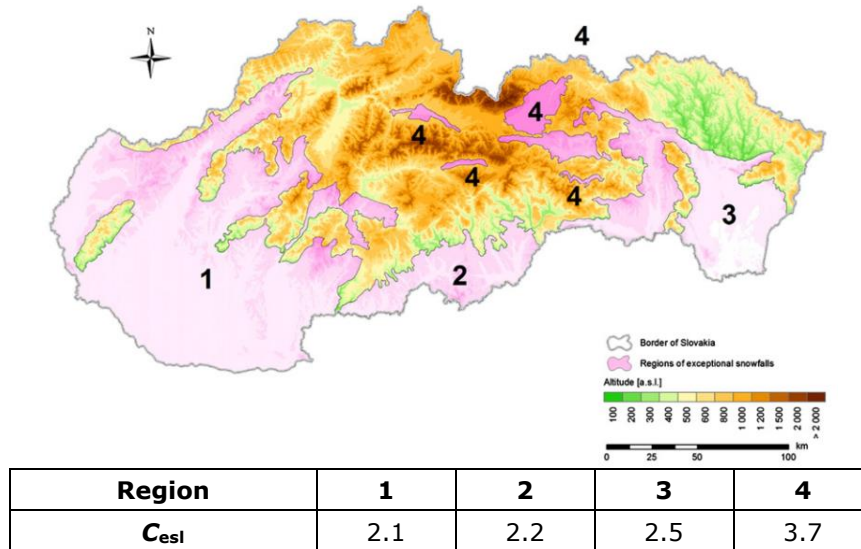


Figure 1.12 Snow map for exceptional values in Slovakia

1.2.2.3 European climatic regions

The availability of characteristic values of ground snow loads, derived according to a common statistical approach, allowed the identification, through an iterative process, of ten different climatic regions, with homogeneous climatic features, also described by means of the correlation of the ground snow load with altitude (Figure 1.13).

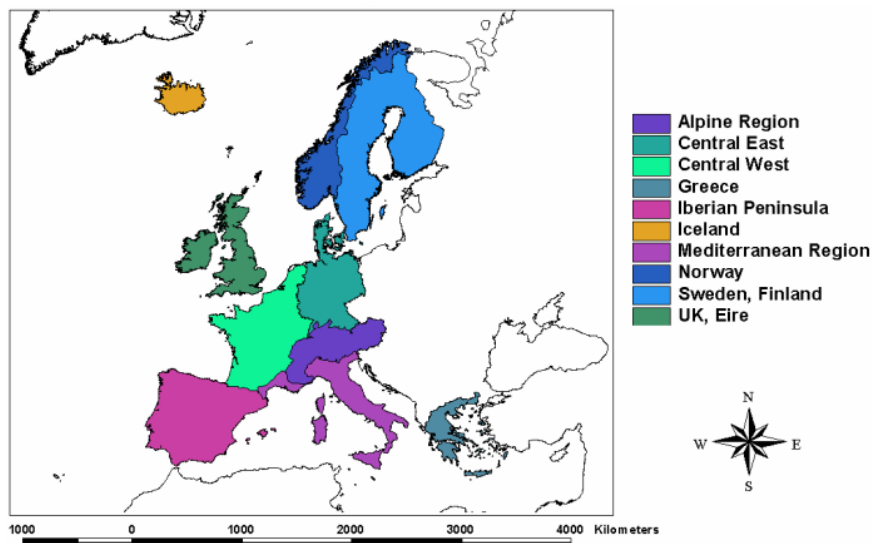


Figure 1.13 Climatic regions (Sanpaolesi et al. 1998 and 1999) [© CEN]

It is worth to underline that the identified climatic regions did not necessarily follow administrative boundaries between countries. A typical example is the Alpine Region, which includes the northern part of Italy, the French Alps, Switzerland, Austria and the southern part of Germany.

For each climatic region characteristic values of ground snow loads were plotted against the altitude of the weather stations, obtaining a scatterplot as illustrated in Figure 1.14 for the Alpine region, where they are also shown the regression curves defined to describe the variation of the ground snow load with altitude in each zone of the diagram (dashed lines).

The load-altitude functions allow to map the ground snow loads at the sea level, obtaining maps not graphically influenced by the terrain orography. Figure 1.15 shows the map obtained for the Alpine region, through interpolation of zone numbers assigned to each weather station where the characteristic ground snow load was calculated.

For each site at a given altitude above the sea level in the map it is thus possible to calculate the characteristic ground snow load through the appropriate altitude function, pertaining to the zone in which the site is located.

Great attention was paid to the discontinuities at borders between climatic regions. The interpolation process of the map for each region was extended to all the weather stations falling into a buffer zone of 100 km depth in the neighbouring regions, in such a way to "smooth" the maps and limit the occurrence of inconsistencies along the borders themselves.

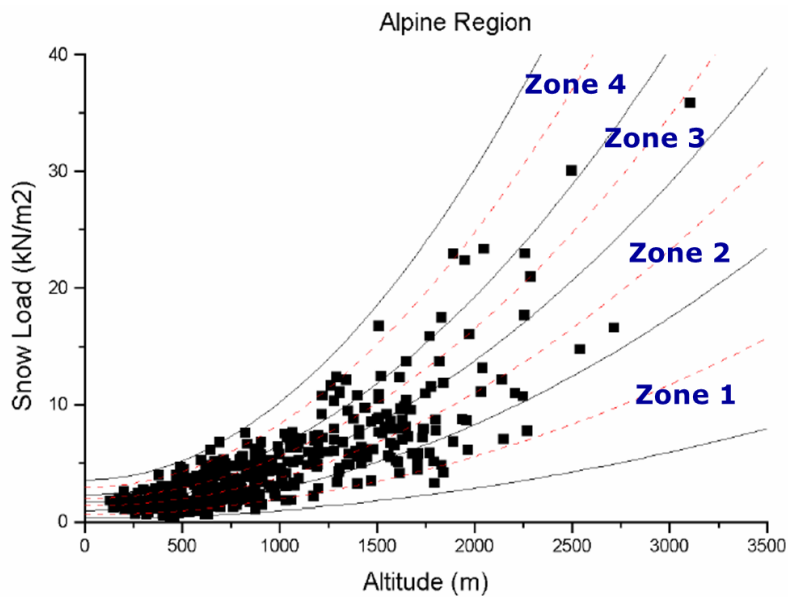


Figure 1.14 Variation of characteristic ground snow loads with altitude in the Alpine Region

Maps derived for the ten climatic region were included in the Annex C to the Eurocode EN 1991-1-3, not to be directly used by designers, but, as stated in clause C(2), with the following objectives:

- to help National Competent Authorities to redraft their national maps;
- to establish harmonised procedures to produce the maps.

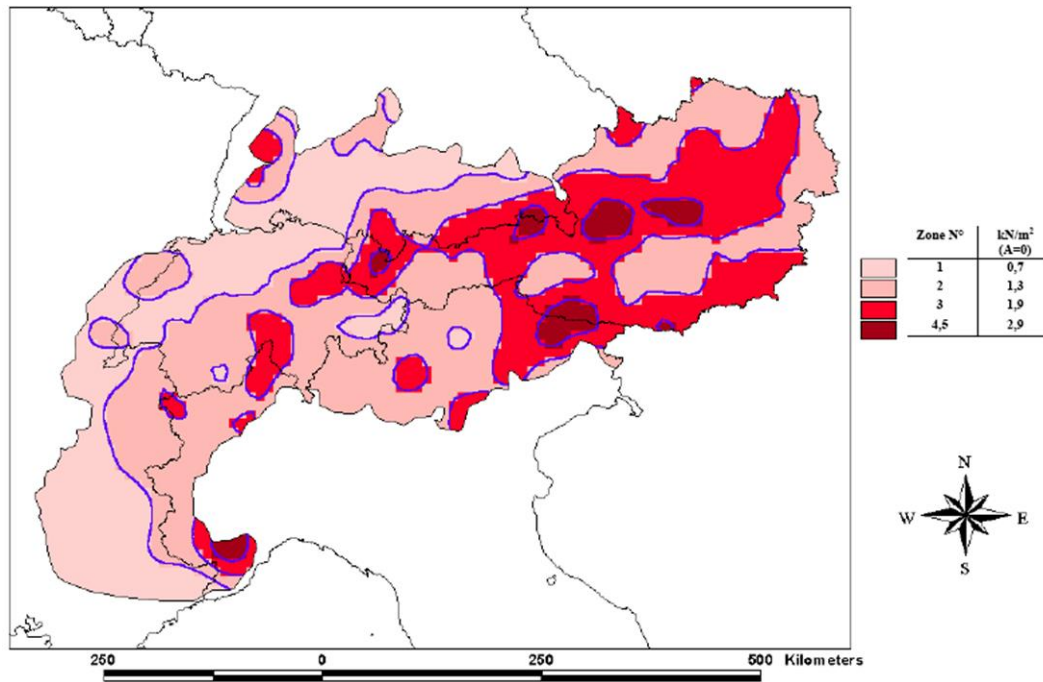


Figure 1.15 Alpine Region (Sanpaolesi et al., 1998 and 1999) [© CEN]

1.2.2.4 National maps

The European ground snow load map developed within the research project illustrated in the previous paragraph formed the basis for National Standard Bodies to prepare their own national maps. This was directly the case of those countries included in the research project; countries which joined CEN after the publication of the Eurocode did have the opportunity to prepare their own maps according to the same general approach followed in the research work and to compare maps at borders with those of the existing climatic regions.

Different ways to present maps were adopted:

- Zones (with administrative or physical contours) of ground snow load reduced at sea level and altitude correlation function, possibly in accordance with the corresponding formulation derived in the research;
- Ground snow loads given at each site in tabular form, where no correlation with altitude is evident, as it is the case of the Norwegian map;
- Ground snow loads given directly at the site of interest (no correlation formula with altitude), presented both through maps with iso-curves or as interactive digital document, as recently done by the Czech standardization institute.

Within the first type of maps there is the Italian ground snow load map, included in the National Annex, which was prepared on the basis of the two maps included into Annex C of EN 1991-1-3, covering the Italian territory: the Alpine and the Mediterranean regions. The following figure illustrates the Italian map compared to that one of the Mediterranean region in the Eurocode. The map in the National Annex presents ground snow loads at sea level and altitude relation functions for four different zones: zone 1 Alpine, Zone 1 Mediterranean, Zone 2 and Zone 3, both Mediterranean. A threshold value has been adopted for location up to 200 m a.s.l., for sites at higher altitudes the altitude correlation functions given in the Eurocode have been adopted. As it results evident, some simplifications have been introduced mainly to fit borders of zones according the administrative borders of Italian Provinces, making the use of the map for design purposes very easy: given the Province of the site and its altitude, the characteristic ground snow

load is directly evaluated by means of the altitude correlation function pertaining to the Province's zone number.

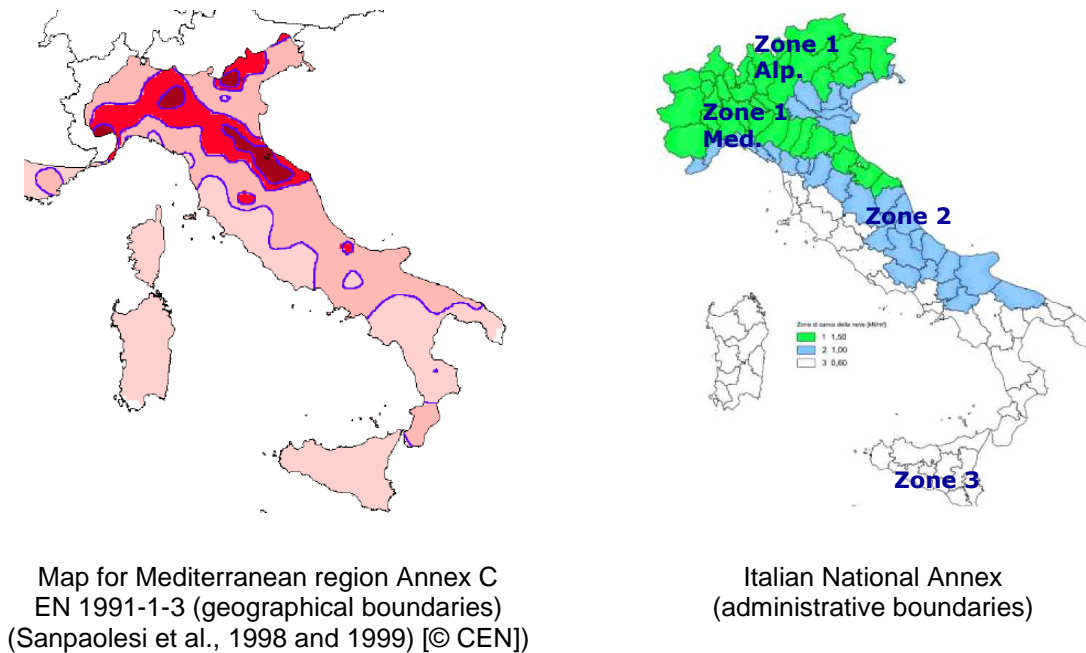


Figure 1.16 Italian ground snow load map

As anticipated, a different approach has been followed in Norway, where the correlation of characteristic ground snow load with altitude is not evident, as shown in Figure 1.17. In the Norwegian National Annex the snow load values are given in tabular form for each municipality.

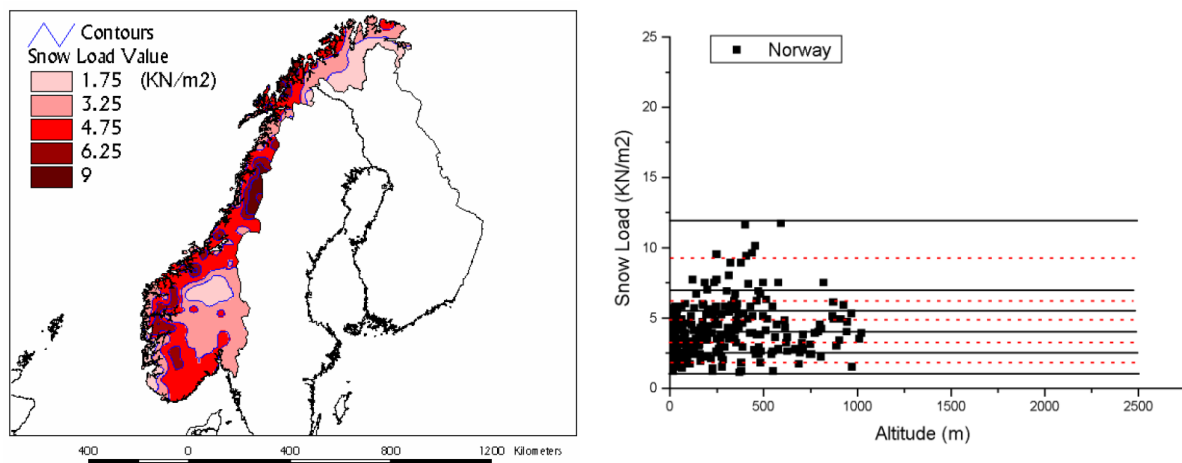


Figure 1.17 EN1991-1-3 Annex C ground snow load map for Norway
(left: Sanpaolesi et al. 1998 and 1999 [© CEN])

Another interesting example of map directly providing ground snow load values at each site, i.e. without making reference to altitude correlation function, is available for Czech Republic, where the national map is provided on a digital interactive form (<http://www.snehovamapa.cz/>), elaborated on a 100x100 m grid basis (Figure 1.18). By clicking on the site of interest, it is possible to get the characteristic ground snow load at

the site and other more detailed information, such as the mean value of the yearly maxima distribution, the standard deviation, the coefficient of variation and the skewness of the distribution, for direct probabilistic verification of structures.

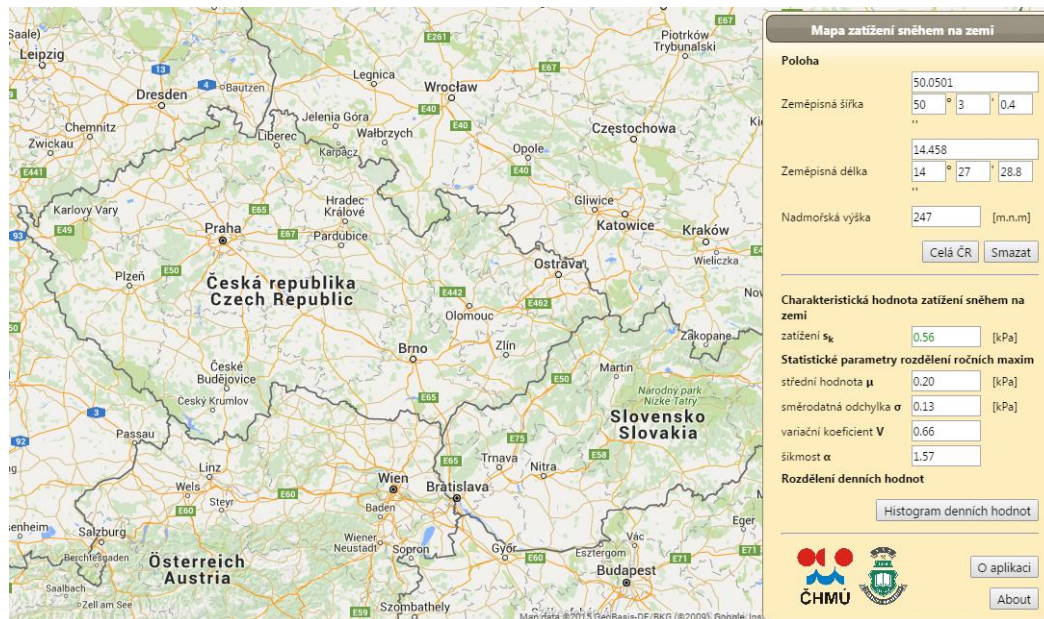


Figure 1.18 Digital map for Czech Republic
[source: <http://www.snehovamapa.cz/>]

1.2.2.5 Consistency at borders of national maps for snow loads

What is the current state of consistency of national maps at borders? Did the effort spent with the European snow loads research (in the years 1996-1999) produce significant improvements in terms of eliminating differences in national maps, towards their harmonization, as it was the original scope of the investigation and of the inclusion of the European snow map in Annex C of the Eurocode published in 2003?

The above questions are on the background of the ongoing revision phase of the Eurocodes with the mandate of the European Commission to CEN (M515 – CEN/TC250 N993, 2013) for the elaboration of the "second generation of the Eurocodes" to be published in 2020.

To give answers to the above questions specific studies are needed and there is not yet available a comprehensive analysis of the National Annexes of different CEN Member States. From some preliminary analysis performed within the Working Group on climatic actions of CEN/TC250/SC1 it can be envisaged that, at least for the case of snow maps, some inconsistencies still exist, but a much better agreement is perceived, thanks to the common basis for the elaboration of maps provided in Annex C of the Eurocode, followed by National Standard Bodies in the elaboration of National Annexes.

As an example, in the histogram in Figure 1.19 they are plotted the ground snow load values, evaluated along a portion (approximately 450 km) of the border between France and Germany, according to the two National Annexes. The comparison shows a lack of full consistency which, further to the difference in the altitude correlation functions adopted in the two countries, is mainly due to the adoption of different minimum threshold values, which can be regarded as a safety related issue, which is left to national determination.

Notwithstanding the above discrepancies, it can be concluded that the availability of a common agreed approach to derive national maps, from the treatment of collected data, their statistical analysis and the interpolation techniques, duly taking into account the effects of extremely infrequent events, constitutes a consolidated background for future

revision of National Annexes, which will further enhance the harmonization of the European snow map.

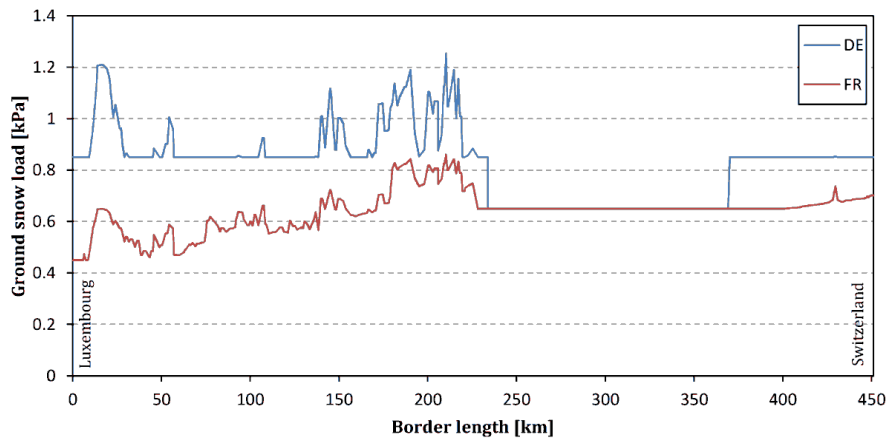


Figure 1.19 Ground snow loads along a part of the border between France and Germany [© Kimbar and Żuranski]

1.2.3 Impact of climate change on climatic actions maps

The evidence of climate change is unequivocal and the consequences are increasingly being felt in Europe and worldwide. In particular, the average global temperature, currently around 0,8°C above pre-industrial level, continues to rise, even more evidently in Europe (European Environment Agency, 2012; European Commission, 2013a; European Commission, 2013b).

Alterations of climatic actions caused by climate change could significantly impact the design of new structures as well as the reliability of existing ones.

This issue is being investigated by different research groups worldwide, particularly aiming to transfer the outputs of global climatological models to predict climate evolution on a suitable scale, to estimate future trends of characteristic values of climatic actions. (Jacob, et al., 2014; Van Vuuren et al., 2011).

Recent studies carried out in Norway (Kvande, et al., 2013) and in Canada (CAN/CSA - S502, 2014) investigate the potential snow load variations due to climate change, particularly focusing on their influence on the reliability of built environment.

Figure 1.20, taken from (Kvande, et al., 2013) illustrates the synthesis of the results of the studies developed in Norway. They are identified different areas in the country, where models for the evaluation of future climate alterations predict variations with respect to the current characteristic values of the ground snow loads. Consistently with the expected global temperature increase trends, in the majority of the country, the projections to the period 2071-2100 of ground snow loads lead to a decrease of the action (light blue zones), with respect to the values currently indicated in the Norwegian National Annex. This trend is not valid for the whole territory, since in some areas (marked in green) the reduction is not expected to take place, and, what is more interesting, in some inner areas (in red), ground snow load is expected to increase. This last circumstance, if it will be confirmed, is of great interest for the evaluation of reliability of existing structures in 2100, i.e. which are being built now or in the near future, which are particularly sensible to the effects of snow loading, such as lightweight long span roofs.

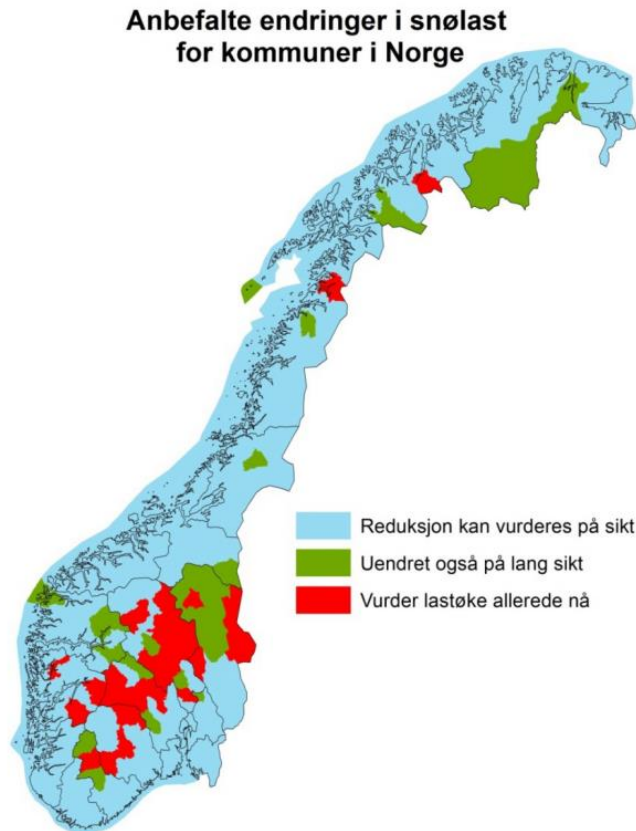


Figure 1.20 Prediction of the variation of ground snow loads in Norway in 2071-2100 (Kvande, et al., 2013) [© SINTEF]

In the mandate M515 for the revision of the Eurocodes (M515 – CEN/TC250 N993, 2013) a particular attention is paid to the effects of the potential consequence of climate change in the field of climatic actions. A specific project team has recently started their activity to report on the impact of climate change on climatic actions in relation to structural design issues and to prepare modified or additional clauses for climatic actions codes in the Eurocode 1 suite (EN 1991-1-3, -1-4, -1-5 and the new EN 1991-1-9 on Atmospheric Icing) and possibly in other Eurocode parts, also providing detailed background documentation.

The aim of the work is to provide increased resilience of long-life structures and infrastructures to climate change consequences, with cost effective benefits avoiding later retrofitting of existing structures.

1.3 Maps for seismic actions

1.3.1 Design values of seismic actions

The purpose of Eurocode 8 (EN 1998-1, 2005) is to ensure, that in the event of earthquakes, human lives are protected, damage is limited, and important structures for civil protection remain operational.

To this aim the Eurocode establish two fundamental requirements:

- No-collapse requirement: the structure should withstand the design seismic action without local or global collapse;

- Damage limitation requirement: The structure should withstand a seismic action with larger probability of occurrence than that of the design seismic action, without the occurrence of excessive damage.

As recalled in paragraph 1, the two requirements are to be verified according the seismic design situation combination equations, where the design value of the seismic action is expressed in terms of the characteristic seismic action, associated with a given probability of exceedance P in a reference period, adequately differentiated for the no-collapse requirement (NCR) and for the damage limitation requirement (DLR) and the importance factor γ_I , which reflects reliability differentiation, according to the following expression:

$$A_{Ed} = \gamma_I A_{Ek} \quad (1.2)$$

The most widely used seismic parameter for the description of the action is the peak ground acceleration (PGA) at the site, which is traditionally and immediately related to the induced seismic forces, which form the basis for current structural design approaches. Though probabilistic procedures, they can be determined values of PGA associated with different probability of exceedance. Target values for the no-collapse requirement P_{NCR} , which is to be established with regard to the reference time of 50 years, is a nationally determined parameter, and the recommended value is set to 0.10, which, under the assumption of a Poisson process, corresponds to a mean return period of the seismic action of $T_{NCR}=475$ years.

Similarly, the probability of exceedance for the damage limitation requirement P_{DLR} , associated with a reference time interval of 10 years, is an NDP as well, and the recommended value is 0.10, which, under the same assumptions above, corresponds to a seismic action with a mean return period of $T_{DLR}=95$ years.

The definition of target probability levels is a matter of optimal allocation of resources and is therefore expected to vary from country to country, depending on the relative importance of the seismic risk, with respect to risks of other origin and on the global economic resources available for the mitigation of this kind of risk.

Further to the probabilities of exceedance, each country is asked to provide criteria for the reliability differentiation of different types of buildings, or more generally, of different civil engineering works, depending on their importance with respect to civil protection, and the consequences of failure. This can be achieved though the modification of the hazard level considered for the design, by varying the return period of the considered action.

EN 1998-1 at cl. 2.1(3)P prescribes that "reliability differentiation is implemented by classifying structures into different importance classes. An importance factor γ_I is assigned to each importance class. Wherever feasible this factor should be derived so as to correspond to a higher or lower value of the return period of the seismic event (with regard to the reference return period) as appropriate for the design of the specific category of structures".

Guidance on how to define the importance factor is provided in the note under cl. 2.1(4) of EN 1998-1, which states that the value of the importance factor γ_I multiplying the reference seismic action (PGA) to achieve the same probability of exceedance in T_L years as in the T_{LR} years for which the reference seismic action is defined, may be computed as $\gamma_I \sim (T_{LR} / T_L)^{-1/k}$. The higher the seismicity of the region, the higher the value of k factor. A value of the order of $k=3$ is assumed as a reference in the Eurocode.

In Figure 1.21 it is shown the variability of the importance factor γ_I with the return period of the action, depending on the value adopted for the parameter k .

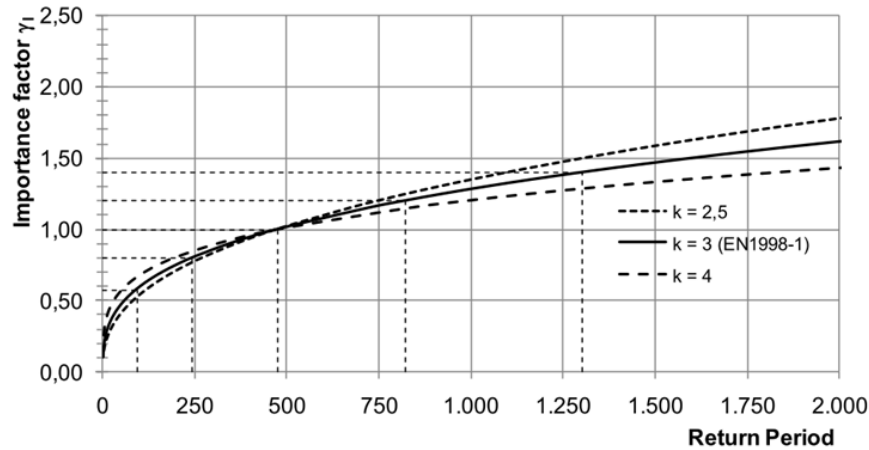


Figure 1.21 Correlation between the importance factor and the return period (Acun et al., 2012) [© European Union]

Coming to the classification of civil engineering works, EN 1998-1 recommends 4 classes, depending on the:

- consequence of collapse for human life;
- importance for public safety and civil protection functions immediately after the earthquake;
- social and economic consequences of collapse.

The recommended criteria for the classification of structures in the four classes are described in the following table, where to each class it is associated the recommended importance factor.

Table 1.1 Importance classes and related recommended values of the importance factor

Importance class	Buildings	Importance factor γ_I (recommended value)
I	Buildings of minor importance for public safety, e.g. agricultural buildings, etc.	0,8
II	Ordinary buildings, not belonging in the other categories.	1,0
III	Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.	1,2
IV	Buildings whose integrity during earthquakes is of vital importance for civil protection, e.g. hospitals, fire stations, power plants, etc.	1,4

1.3.2 Seismic zonation

As synthetically recalled in the previous paragraph, for the purposes of seismic design, the Eurocodes refer to the PGA a_{gR} values for both ULS no-collapse requirement and SLS damage limitation requirement, defined with reference to standard ground type A (rock or rock like geological formation), to be used in conjunction with the importance factor depending on the type of structure under consideration.

As it is well known, further influences to the seismic response of the structure, depending on the soil type and local amplification are taken into account by means of differentiation of response spectra for 5 different soil profiles, ranging from hard or rock soils to soft soils (A to E). This approach, even if it is recognized not to be the best one to describe the severity of an earthquake and its consequences on structures, allows a simplification in the representation of the seismic hazard, which remains fully defined by the specification of the PGA only.

Accordingly, cl. 3.2.1(1)P of EN 1998-1 requires that "national territories shall be subdivided by the National Authorities into seismic zones, depending on the local hazard. By definition, the hazard within each zone is assumed to be constant". Cl. 3.2.1(2) further specifies that "For most of the applications of EN 1998, the hazard is described in terms of a single parameter, i.e. the value of the reference peak ground acceleration on type A ground, a_{gR} . Additional parameters required for specific types of structures are given in the relevant Parts of EN 1998" and that the reference PGA is defined in the National Annex to the code.

Due to the many inherent uncertainties the definition of seismic zones and the related seismic hazard is commonly obtained through a probabilistic approach (Probabilistic Seismic Hazard Analysis), which is based upon three fundamental phases:

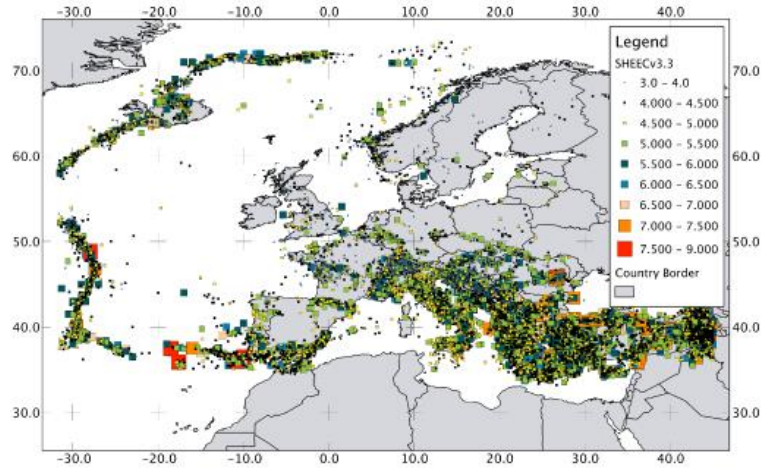
- Specification of the models for the seismic sources, responsible for the seismic hazard;
- Specification of the ground motion models (attenuation relationships);
- Calculation of the reference parameter (PGA) for the reference given probability of exceedance.

The detailed illustration of the procedure is out of the scope of the present paper, also in consideration of the fact that other and more specialized contributions in the Workshop, are focused on the this issue; for the purposes of this contribution, they will be briefly illustrated the general basic principles, upon which they are based the three phases.

The first step is to derive the model to describe seismogenic sources: faults and areas of dispersed seismic activity. This is possible through the consultation of seismic catalogues of historical and instrumental seismicity (Figure 1.22). Observations are necessarily extended to short geological periods and additional data are needed to supplement available information. Among these data there are tectonic, geophysical, geological and seismological data such as the results of geodetic monitoring, the determination of slip rates along known faults, deep geologic investigations, etc.

From the collection of all the available information is possible to map the seismogenic sources in a region, as shown in Figure 1.23 (SHARE project, Woessner, 2015).

For each seismogenic idealized area, through statistical analysis of available data, it is possible to derive the upper and lower limits of magnitude of seismic events awaited in the region, an average hypocentral depth and the Gutenberg-Richter correlation function, defining the correlation between the frequency of occurrence of seismic events and their magnitude (Figure 1.24).



**Figure 1.22 SHARE European Earthquake Catalogue: All events of $M_w \geq 3.5$.
[© INGV-DPC]**

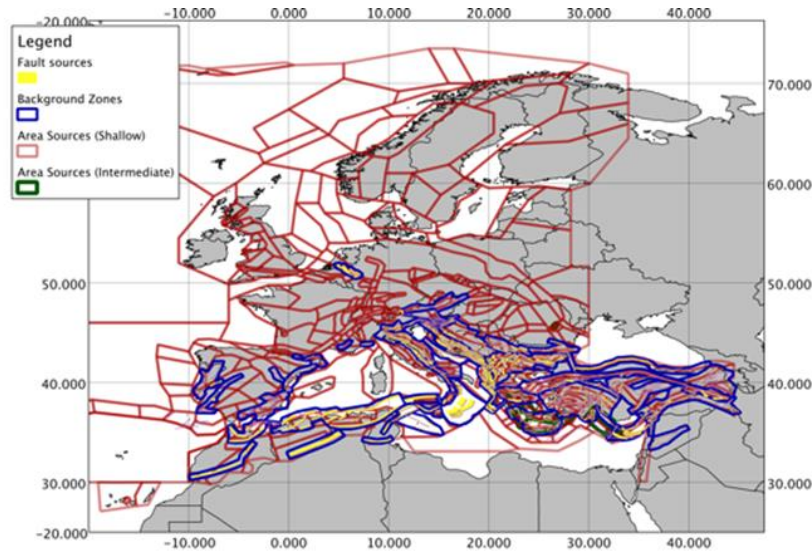


Figure 1.23 Example of European seismicogenic sources [© INGV-DPC]

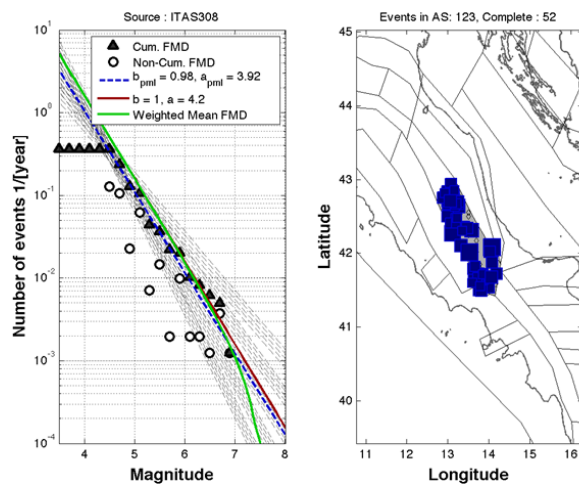


Figure 1.24 Example of Gutenberg-Richter relationship for a seismicogenic zone in Italy [© INGV-DPC]

Once defined the probability density functions describing the probability of seismic events up to a magnitude M in each zone it is necessary to evaluate the effects of the seismic event in the affected regions, by means of models empirically derived, i.e. the attenuation relationships, providing the value of a ground motion parameter (e.g. the PGA) at a given distance R from the source of a seismic event of magnitude M . Figure 1.25 shows a typical example of attenuation relationship, plotted on double logarithmic scale, linking the PGA to the epicentral distance, for various magnitudes (Ambraseys et al., 1996).

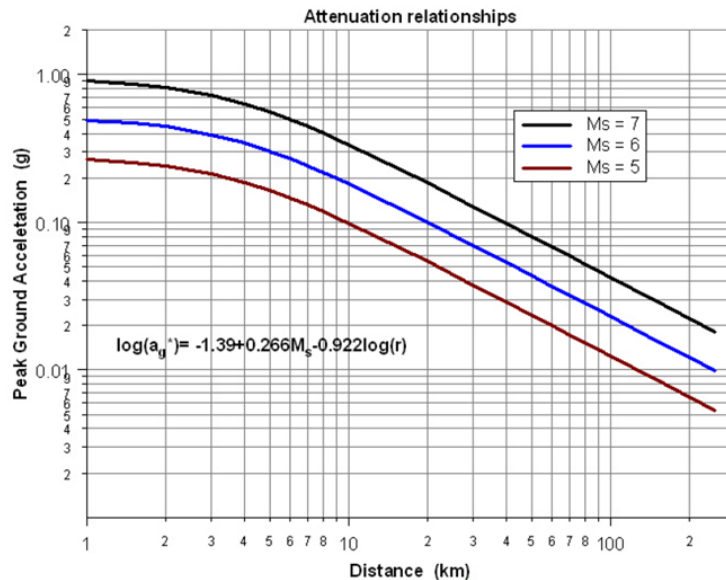


Figure 1.25 Example of attenuation relationship for European area proposed by Ambraseys et al. (1996) [© European Communities]

Uncertainties affecting the prediction of PGA values through the attenuation relationship are treated by means of a probabilistic approach, modelling the actual value of the PGA at a site as a random variable. Under the following assumptions it is finally possible to evaluate the probability of occurrence of a given ground motion parameter at a site for a given time interval:

- each seismic event can take place at any time;
- any seismic event is independent of the occurrence of all others;
- recurrence frequency of seismic events in a given time interval T_d is given by λT_d , being $\lambda = 1/T_r$ the mean recurrence frequency of the seismic event assumed to be constant;
- events follow a Poisson process.

The outcome of this procedure is the hazard curve of a site, correlating the PGA to the exceedance probability for different reference periods. A typical example of an hazard curve is illustrated in Figure 1.26.

It is therefore possible to get the hazard map, where PGAs associated with the required probability of exceedance, e.g. $P = 0.10$ in 50 years, corresponding to the no-collapse requirement, are plotted for each location as illustrated in the following figure for Italy (INGV-DPC, 2006).

Hazard maps are not intended to be directly used for design, but to serve as a basis for the preparation of seismic zonation.

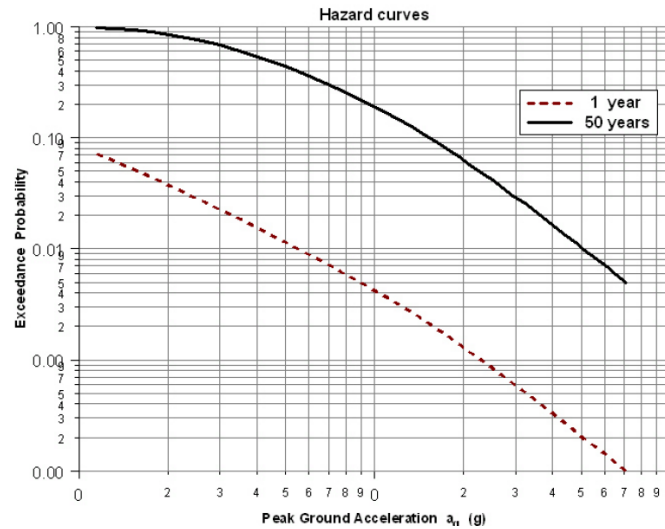


Figure 1.26 Example of hazard curves for a given site, for reference periods of 1 and 50 years (Solomos et al., 2008) [© European Communities]

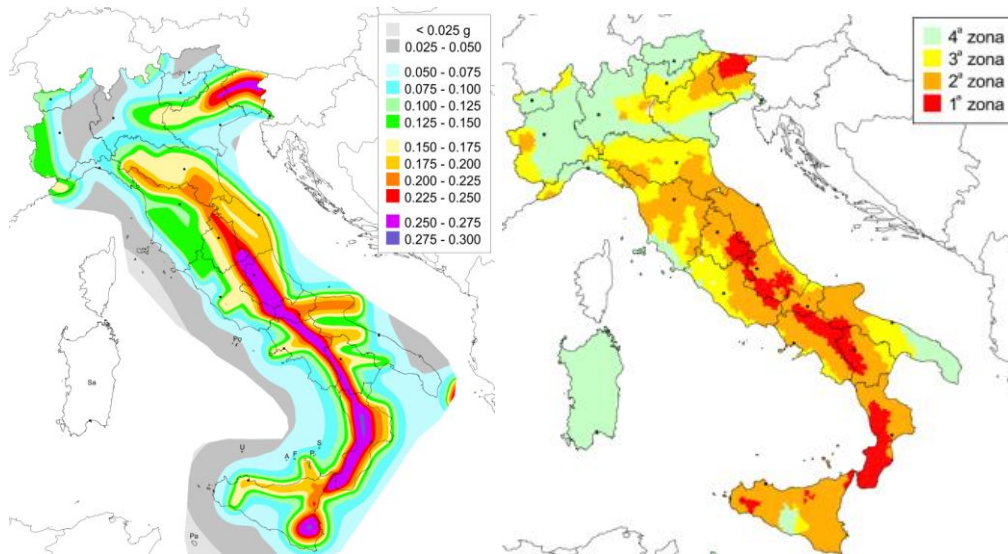
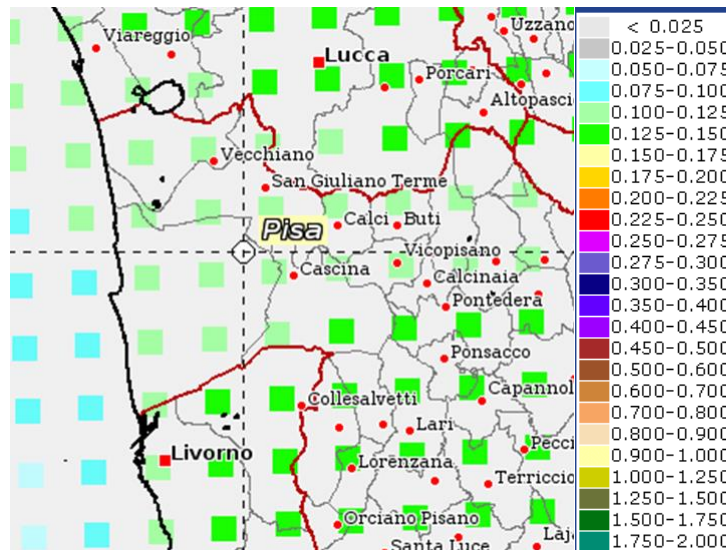


Figure 1.27 Hazard map for Italy ($P=0.10$, ref. period 50 yrs) and related proposed seismic zonation [© INGV-DPC]

1.3.3 Future evolution of seismic maps

As for climatic maps, National Annexes to EN 1998-1:2005 prepared by CEN Member States, still present some inconsistencies at borders between countries. This is mainly due to the different treatment of data from seismic catalogues, attenuation relationships, and statistical processing up to the possible different representation of maps.

As an example, in the recent Italian seismic map (INGV-DPC, 2006), in force since 2008, seismic parameters are defined locally for a network of 10'571 grid points (grid span 5 km), covering the Italian territory. For each grid point they are available the corresponding hazard curves, and PGA (for A type soil) referred to different probability of exceedance and reference time periods (Figure 1.28).



**Figure 1.28 Example of the Italian seismic map. Local definition (grid points) of PGA for 0.10 probability of exceedance in 50 years
[© INGV-DPC]**

As illustrated for the case of snow loads, the publication of EN 1998-1 gave an important contribution to the harmonization, but further efforts are still needed, as recognized by the mandate of the European Commission to CEN (M515 – CEN/TC250 N993, 2013), for the evolution of the Eurocodes to the next generation in 2020, where a specific task on this subject is presented, with the following motivation:

“In the present version of EN1998 the seismic zonation and the definition of the spectral shape of the seismic action for design are Nationally Determined Parameters (NDPs) to be defined in the National Annexes to EN 1998-1. Although EN 1998-1 corresponded to an advancement in terms of harmonization (by establishing a "standard shape" of the design spectra and by establishing the anchoring variable for the definition of the national seismic zonation maps) it is clear that there is a need to pursue further such harmonization in the future revision of EN 1998. Seismic zonation and the definition of the seismic action are key elements for all parts of EN 1998. Its updating fundamentally influences EN 1998 and so this activity should have priority with regard to other changes.”

Recent studies in different countries, mainly those with a high seismicity, suggest different and efficient ways to map the seismic hazard and to define design acceleration spectra for different locations, with a considerable level of detail.

The task for the committee in charge of the evolution of the next generation of EN 1998-1 is therefore aimed to update the way in which the seismic zonation is presented, taking profit of the more recent research in this field, aligning EN1998 with the way in which seismic zonation is presented in other recent national and international seismic codes.

The mandate M515 also specifies that this effect profit shall be taken from recent European research projects, namely the project SHARE, which provided consistent methodologies and tools to support the establishment of a European seismic zonation (Woessner et al., 2015) (see Figure 1.29).

Reference to results of international projects on this specific issue, is very important, since only this approach can effectively contribute to reduce and eventually eliminate inconsistencies in the representation of a phenomenon, like the seismicity, which clearly is not influenced by administrative borders between countries.

The envisaged advancement towards a harmonized seismic zonation, which will be reflected in the redrafting of Section 3 of EN 1998-1, will not prevent Member States, if

required, to establish their own safety levels at different performance levels and for different types of structures (importance classes).

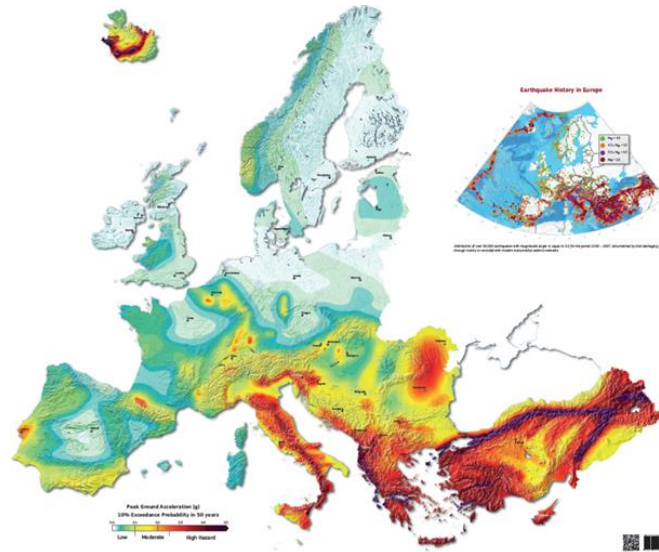


Figure 1.29 The European hazard map (PGA 475 yrs) developed within the SHARE project
[source <http://www.share-eu.org/>]

1.4 Conclusions

They have been illustrated the general principles for the elaboration of maps for climatic and seismic actions in the framework of the Eurocodes. More in detail they have been summarized the general provisions in EN 1990 Basis of Structural Design, regarding design situations for transient, persistent, accidental and seismic situations, and the corresponding combination expressions for both Ultimate and Serviceability Limit States, particularly focusing on the design values of climatic and seismic actions. Reference to Eurocode 1 on snow loads (EN 1991-1-3) has been made to illustrate general principles for the derivation of maps for climatic actions; principles provided in EN 1998-1 for the definition of design values of seismic actions have been recalled as well.

The definition of values for climatic and seismic actions is left to the national regulatory authorities in each CEN member state, as the Eurocodes recognize their responsibility and safeguard their right to determine values related to regulatory safety matters at national level, where these vary from State to State. Climatic and seismic actions are a typical examples of such determinations and are therefore included in the National Annex to the corresponding Eurocode parts.

If, from one side, safety implications of the determination of climatic and seismic actions, fully justify the need to allow freedom to Member States to establish their own maps, the application of this principle led in the past to a number of inconsistencies among different maps for climatic and seismic actions, particularly evident at borders between neighbouring countries, which, in some cases, still exist.

The publication of the complete Eurocode suite in 2007, led to a sensible harmonization in the procedures adopted at national level to derive maps for climatic and seismic actions, but further efforts are needed as recognised by the mandate M515 of the European Commission to CEN, for the evolution of the Eurocodes toward the second generation, to be published in 2020.

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CHAPTER 2

EXPERIENCE OF THE 2013 EUROPEAN SEISMIC HAZARD MODEL: MILESTONES AND OUTPUT

**Contribution to Elaboration of Maps for Climatic and Seismic Actions for
Structural Design in the Balkan Region**

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2 Experience of the 2013 European seismic hazard model: milestones and output

2.1 Seismic hazard harmonization in Europe - the SHARE Project

2.1.1 Introduction

Seismic Hazard Harmonization in Europe (hereafter [SHARE](#)) was founded by the European Commission in the Framework Program 7 (FP7) to generate a community-based probabilistic time-independent seismic hazard model for the Euro-Mediterranean region by 2013, including new data, models and requirements (Giardini et al., 2013). SHARE-Project was the first completed regional effort since the conclusion of the "Global Seismic Hazard Program" – GSHAP (Giardini, 1999) following the ESC-SESAME Unified Hazard Model for the European-Mediterranean region (Jimenez et al., 2003). Also, SHARE was the first contributing the "Global Earthquake Model" (<http://www.globalquakemodel.org/>) initiative.

The main goals of SHARE-Project were:

- To develop a framework for probabilistic seismic hazard assessment (PSHA) across all disciplines, by involving participants, competences and experts spanning all involved fields from seismology, engineering seismology to geology and/or to the earthquake engineering;
- To compile earthquake data and assess seismic hazard without the inconvenience of political constraints and administrative boundaries.

These objectives were successfully accomplished during 3.5-year time span with a consortium of 18 partners in the Euro-Mediterranean region, starting with June 2009. The newly developed pan-European seismic hazard model was built by combining the latest advances on the seismology, geology, geophysics, and tectonics with a comprehensive quantification of the associated uncertainties. SHARE was the only European project, at the date, which explicitly considered the engineering requirements, warranting that the products of SHARE are compatible with current Eurocode 8 requirements and can also form a basis for future developments in Eurocode with respect to seismic input requirements. A specific work-package was established to address several issues in the interface between hazard and engineering design. These included:

- Description of hazard requirements in an engineering context,
- Review of the status of seismic input into building design codes worldwide,
- Investigation into the use of loss assessment for the calibration of performance levels in seismic design codes,
- Survey into the minimum capacity of buildings designed without seismic actions,
- Preliminary pan-European seismic zonation and
- Recommendations to the Eurocode 8 committee for possible short-, mid- and long-term developments in Eurocode.

Although a reference for Europe and Turkey, the output of SHARE project do not replace yet the input to existing national design regulations, which must be obeyed for today's seismic design and construction of buildings (Woessner et al., 2015). Hereafter, the 2013 pan-European Seismic Hazard Model is summarized focusing into the main constitutive elements and output.

Complementary documents and deliverable describing in details the procedures and datasets is online available at <http://www.share-eu.org/>.

2.2 The 2013 European Seismic Hazard Model: highlights and elements

The main highlights of the 2013 European Seismic Hazard Model, hereafter ESHM13, as summarized by (Woessner et al., 2015) are:

- A new European historical and instrumental earthquake catalogue ([SHEEC](#)).
- Novel and a homogeneous database of the seismic faults (over 68000 km of mapped faults) fully parameterized (Basili et al., 2013).
- A new regional reference geodetic mapping (Carafa et al., 2014)
- Generic model for maximum magnitude for the entire region.
- Innovative procedure of characterizing the uncertainties associated to the ground motion (Delavaud et al., 2012).
- Procedures for expert elicitation and the description of modelling uncertainties, enabling with a logic-tree approach.
- Both major components, earthquake source and ground shaking, are described in independent logic-trees and combined for the hazard computation.
- For the first time, a European-wide model considers multiple methods to forecast earthquake activity, all embedded in the earthquake source model. The latter resulted from alternative interpretations of the available tectonic, seismogenic, paleoseismic and geological data.
- Three independent seismogenic models depicting the expected recurrence of earthquakes in the future (based on different combinations of area sources, distributed seismicity and larger events concentrated on faults).
- Novel seismic hazard model parameterization, implementation and calculation (Pagani et al., 2014).

2.2.1 Cross border harmonization

SHARE provided a unified seismic source model and homogeneous assessment of seismic hazard for the whole Mediterranean region, including Turkey. The following datasets are harmonized without country or regional boundaries conditions.

2.2.1.1 Earthquake catalogue

A homogenous earthquake catalogue covering the Euro-Mediterranean region spans the time period 1000-2006 with earthquakes of harmonized moment magnitudes $M_w > 3.5$ was prepared within the three year efforts. The resulting SHARE European Earthquake Catalogue (SHEEC) consists of two sub-catalogues: a historical catalogue covering the time window 1000-1899, compiled by (Stucchi et al., 2012); and an instrumental catalogue spanning across the time window 1000 to 2006 prepared by (Grunthal et al., 2013). Figure 2.1 illustrates the spatial distribution of the SHEEC catalogue as a function of a homogeneous moment magnitude (M_w). The catalogue is open for access online ([SHEEC](#)).

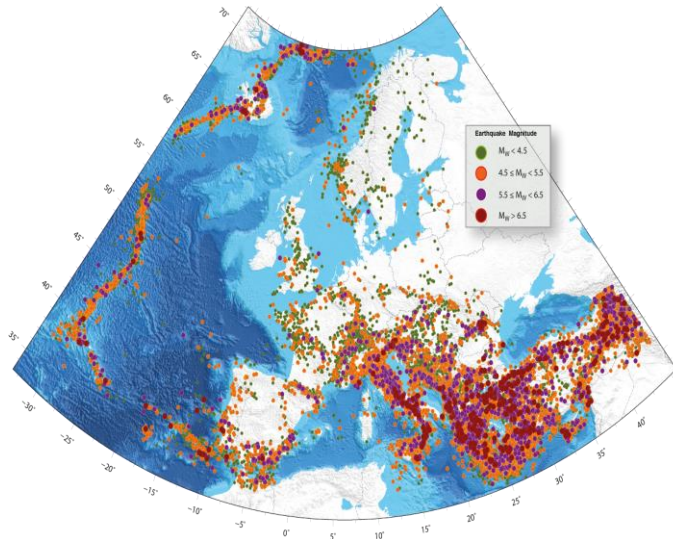


Figure 2.1 Earthquake Catalogue, model harmonized over Euro-Mediterranean Region

2.2.1.2 Fault source database

Fault structures described as composite seismogenic sources (CSS) and subduction zone models for the Calabrian Arc, the Hellenic Arc and the Cyprus Arc, all included in the new European Database of Seismogenic Faults (EDSF, Basili et al., 2013). More than 68000 kilometres representing about 1200 mapped active faults were compiled in the new European Database of Seismogenic Faults. Furthermore, the dataset contains novel subduction zone models for the Calabrian Arc, the Hellenic Arc and the Cyprus Arc. The dataset is open for access online ([EDSF](#)) and illustrated in Figure 2.2.

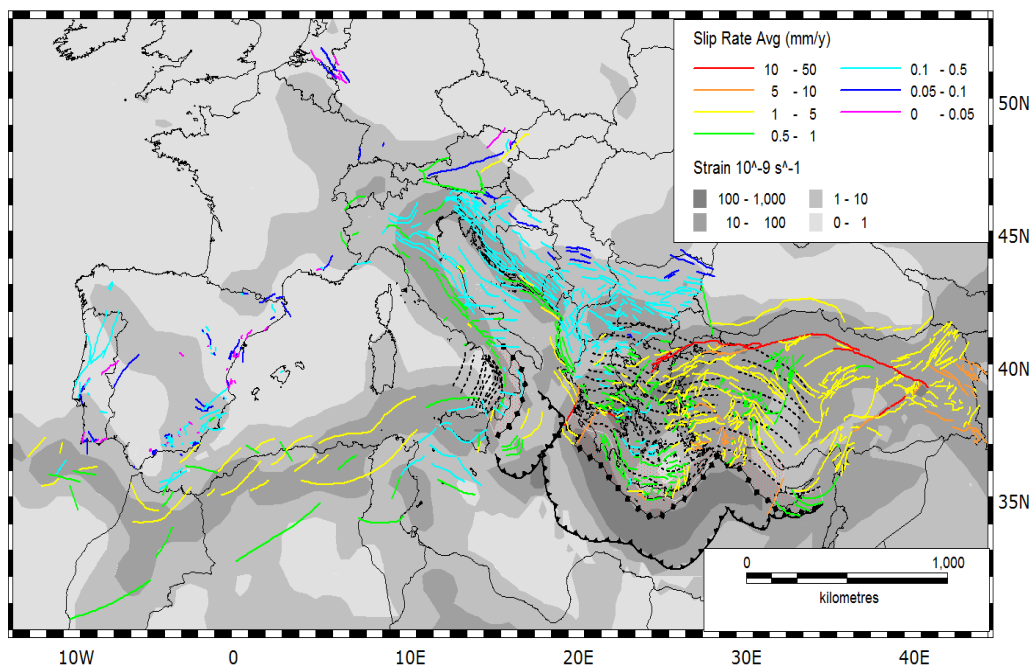


Figure 2.2 Spatial distribution of active faults and subduction zones as compiled within the SHARE Euro-Mediterranean Database of Seismogenic Faults (EDSF). Active faults illustrated by slip rate (mm/y) depicting the rate of deformation of the crust. Black lines indicate subduction zones, whereas the grey background illustrates strain rates in the earth's crust inferred geodetic data

2.2.1.3 Crustal strain rate model

Deformation rates of the Earth's crust recorded by modern Global Positioning System (GPS) networks and geological assessments were used to infer the on-going tectonic movement. This dataset helps identifying the regions where crustal deformation is expected and stress is expected. This stress might be released as earthquakes in the long term (~ 100000 year) or dissipated by other known geological processes. The strain rate model as shown in Figure 2.3 provides the basis for the first homogenized stress field in Europe (Carafa and Barba, 2013).

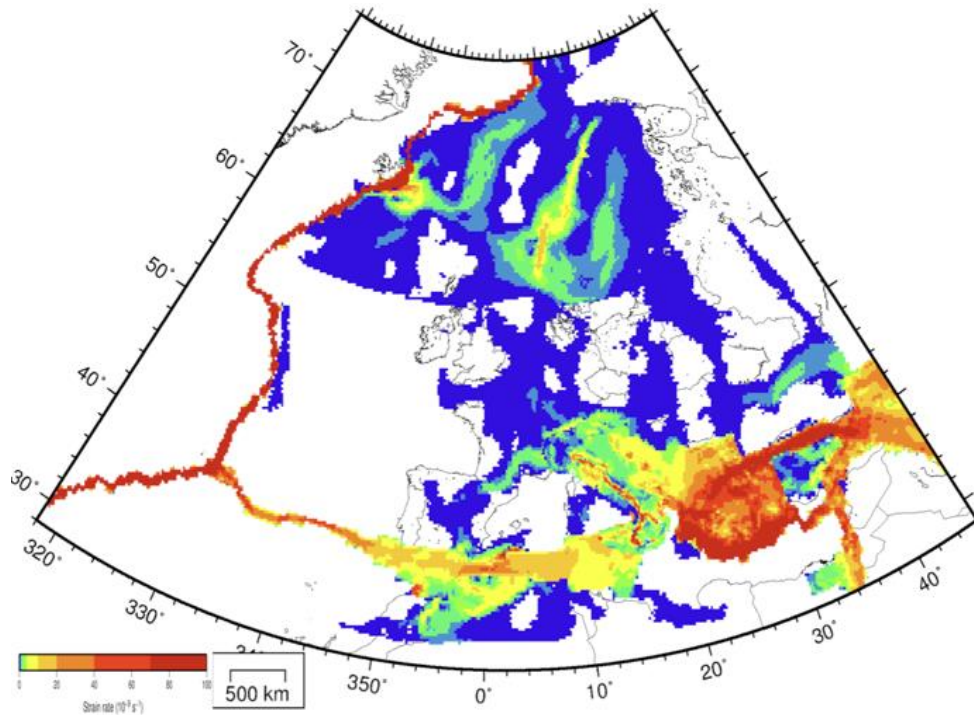


Figure 2.3 Crust strain rate model, model homogenized over Euro-Mediterranean Region

2.2.1.4 Maximum magnitude

The possible maximum earthquake magnitude expected across Europe was derived considering the earthquake history and fault database. Maximum magnitude is defined as the ultimately largest magnitude earthquake that can occur within these regions and an uncertainty add-in. Uncertainty values have been assessed from the earthquake catalogue and they are tectonic dependent. Thus, for active shallow crustal tectonic regimes, the estimation is based on the maximum observed magnitude (M_{obs}) events plus three uncertainty values. For stable continental crust the so-called EPRI approach (Johnston et al., 1994) was considered. The basic concept is to compensate the small seismicity sample of the study area by considering observations from tectonically analogous regions worldwide (Melletti et al 2009–SHARE D3.3). Tectonic regionalization of the maximum magnitude across Europe is shown in Figure 2.4. Details on magnitude values obtained for each super-zone are presented in Figure 2.5.

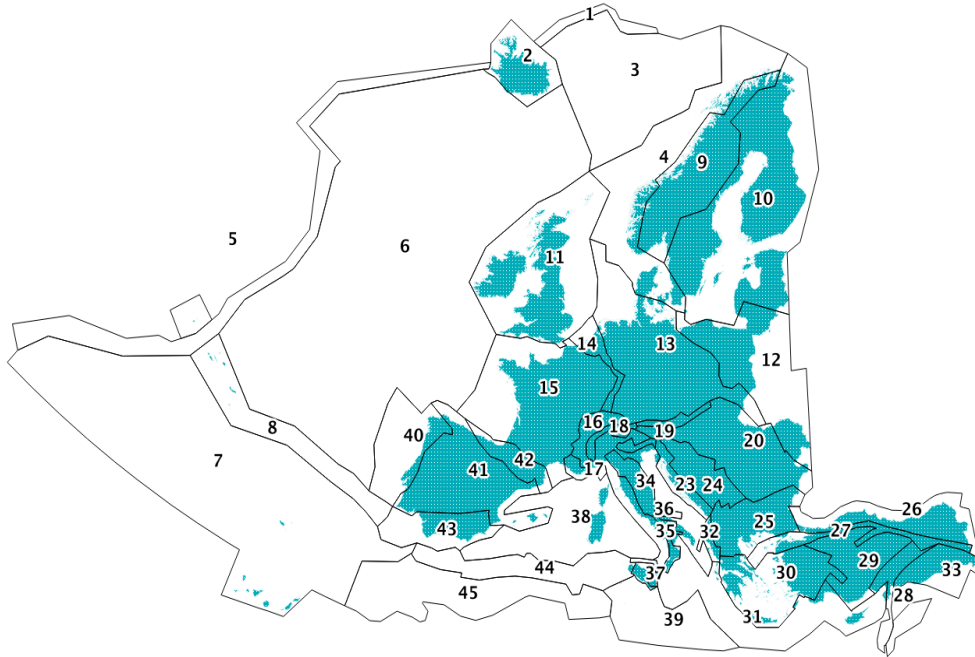


Figure 2.4 Super-zones used to estimate the earthquake maximum possible magnitude

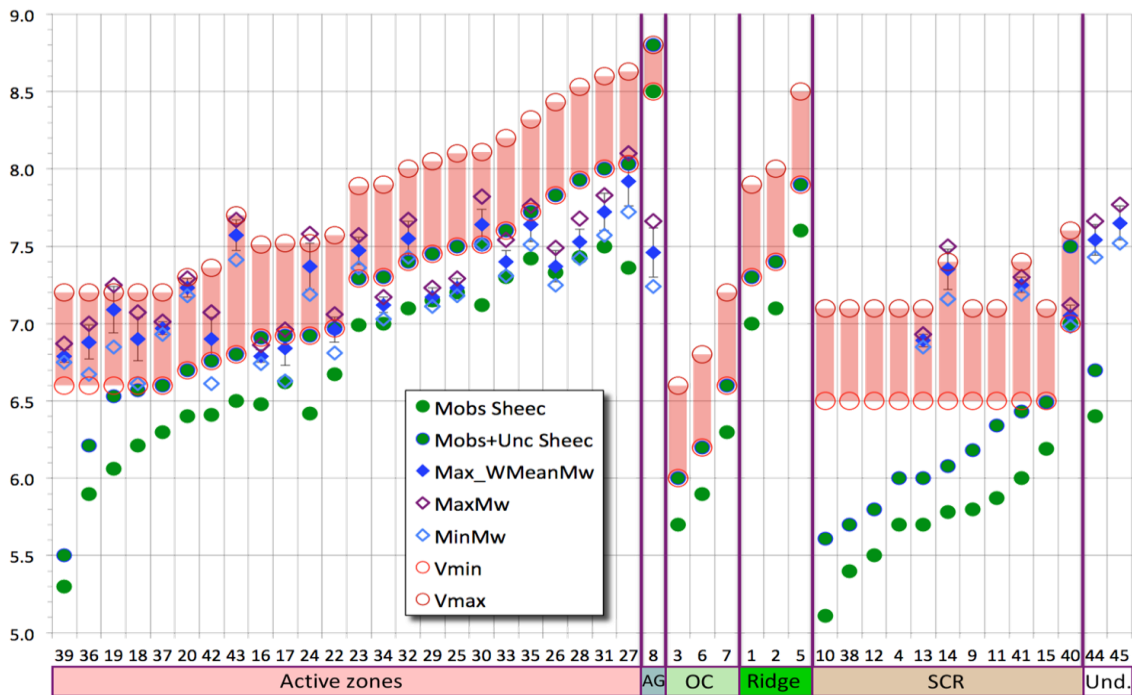


Figure 2.5 Values of maximum magnitude per super-zones as obtained from earthquake catalogue, fault geometry and their uncertainties

2.2.2 European strong motion database

The SHARE strong motion database was compiled from seven different databases: Cauzzi and Faccioli database (C&F), the KIK-Net database, the European Strong-Motion Database (ESMD), the Next Generation Attenuation database (NGA), the Turkish National

Strong-Motion database (T-NSMP), the Internet Site for European Strong-motion Data (ISESD) database, and Italian Accelerometric Archive (ITACA) database. The unified strong-motion databases consist of unique entries described in terms of several seismological parameters i.e. magnitude, depth, faulting style, EC8 site category, various source-to-site distances, filter cut-off frequencies and usable period ranges of ground motions. The major characteristics and constraints of the databank are described according to these seismological parameters. The newly compiled strong-motion database was used to develop a new European ground motion predictive model (Akkar et al., 2014). Additionally, this database was used to test the performance of individual GMPEs to represent the ground motion of different tectonic environments (Delavaud et al., 2012). Further, this database was further extended and is now included in the Reference Database for Seismic Ground-Motion in Europe (RESORCE).

2.2.3 Seismic hazard model uncertainties

2.2.3.1 Source Models

Three independent seismogenic sources were derived to use for probabilistic seismic hazard assessment across Euro-Mediterranean Region:

- Area Source Model
- Smoother Seismicity
- Fault Model

Each model was derived to account and/or to use the homogeneous datasets across the entire region of interest.

Area sources model

Area-sources model was built on local and regional area-source models, eventually cross-border harmonized. Mainly, the new area-sources were delineated following patterns of seismicity, tectonics and geology. The area-sources apply to crustal seismicity considering seismicity to a depth of 40km. Deep non-subduction seismicity in the Vrancea region and in slab seismicity in subduction zones are modelled in volumes considering the specific depth distributions. The area-sources model, consisting of 423 area source zones is available for download at www.efehr.org/share_area_sources/. Data is provided in EPRI Shapefile® format. For each area source zone a mandatory set of parameters were gathered, including the percentage of focal mechanisms, predominant azimuth and dip angle values, hypocentre depth distribution, lower and upper seismogenic depth values, as well as the associated maximum magnitudes. A Gutenberg-Richter distribution of activity rates was assumed to characterize the seismicity potential of area-sources. The activity rate parameters are computed with a Bayesian approach combining a prior b-value and likelihood function for which the parameters of the Gutenberg-Richter distribution is computed with a penalized maximum likelihood method, taking into account various completeness periods (Woessner et al., 2015).

Smoothed seismicity model

This seismogenic model aims to estimate the productivity and magnitude distribution of the entire harmonized catalogue and to spatially distribute earthquake rates according to two weighted spatial probability densities. The later are estimated, one from the seismicity and one from accumulated moment release along faults. The kernel-smoothed stochastic rate considering seismicity and fault moment release (SEIFA) model (Hiemer et al., 2014) was developed upon the pan-European scale considering both the active faults and the subduction zones of the European Database of Seismogenic Faults (EDSF, Basili et al., 2013). Both, the active faults and subduction zones were modelled in the same way as

they are characterized by their size, geometry and slip rate converted to moment release per unit area. The SEIFA model is open for access at www.efehr.org/share_seifa_model/. The smoothed stochastic earthquake rate model considers seismicity and subduction moment release separately. The rate forecasts are derived for seismicity of moment magnitudes $4.5 \leq M_W \leq 9.0$ for depths $D > 40\text{km}$. Data is provided in EPRI Shapefile® format and includes incremental and cumulative earthquake rates.

Faults source model

Faults source model considers identified and mapped geological features to describe the seismically active faults characterized by currently observed deformation as measured by the Global Position System (GPS), geological methods or paleoseismology. The fault source model uses the information of composite seismogenic sources (Basili et al., 2013), to evaluate the earthquake rate forecast from the geological slip rates and the size of the fault sources. Each seismogenic source includes parameters of the geometry, slip rate, moment rate etc. together with uncertainties, defined as maximum and minimum values. A noticeable assumption is that earthquakes of moderate to large magnitudes ($M_W \geq 6.4$) occur on the identified fault sources while smaller events occur in the background sources. Seismicity productivity of individual fault sources is computed by converting the geological slip rates into seismicity via a seismic moment balance. Figure 2.6 shows the comparison of the average annual earthquake rates of the three source models for the shallow crust, together with the declustered cumulative frequency-magnitude distribution of the earthquake catalogue. Details of the model building processes and detailed description of constitutive elements of each source models are summarized in (Woessner et al., 2015).

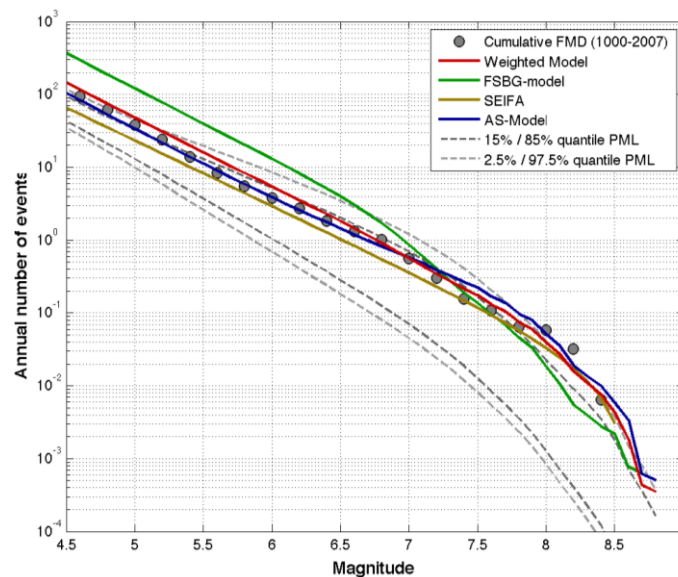


Figure 2.6 Total annual earthquake rate forecast for crustal seismicity for the area source model (blue), the fault source model (green), and the smoothed-seismicity model (dark yellow). Dashed grey lines indicate the uncertainty together with the cumulative magnitude frequency whereas the red curve represents the weighted mean following the preferred weighting scheme (from Woessner et al., 2015)

2.2.3.2 Ground motion models

The inherent variability of expected strong ground motions was quantitatively addressed within the SHARE-project by integrating expert elicitation with data-driven procedures. First, the candidate models were selected and objectively tested and ranked against the European data sets. With this information, a ground motion logic tree was built following

the recommendation of key European experts. This process led to the selection of fourteen ground motion prediction equations (GMPEs) to characterize the expected ground motions for all geological conditions and magnitude, depth, and distance ranges in Europe (Delavaud et al., 2012). The final structure of the logic-tree consists of:

1. Four GMPEs for active shallow and oceanic crust: (Akkar and Bommer, 2010); (Cauzzi and Faccioli, 2008); (Chiou and Youngs, 2008); (Zhao et al., 2006);
2. Five GMPEs for stable continental regions (Akkar and Bommer, 2010), (Cauzzi and Faccioli, 2008), (Chiou and Youngs, 2008), (Campbell, 2003) and (Toro et al., 2002) unpublished update of (Toro et al., 1997). Both, (Toro et al., 2002) and (Campbell, 2003) models were adjusted for the generic rock site condition in Europe, established within the framework of SHARE project that is described with a shear wave velocity of rock = 800 m/s and a kappa value of $\kappa = 0.03$.
3. Two GMPEs, namely (Toro et al., 2002) and (Campbell, 2003) were used for modelling ground motion on Fennoscandian shield;
4. For inslab and interface subduction earthquakes we selected four models (Youngs et al., 1997), (Atkinson and Boore, 2003), (Zhao et al., 2006); (Lin and Lee, 2008);
5. Based on further sensitivity analysis, the logic-tree for the Vrancea region consists of two ground motion models: (Youngs et al. 1997) and (Lin and Lee, 2008).
6. (Faccioli et al., 2010) was preferred to describe the ground motion for volcanic and swarm type areas.

2.2.4 OpenQuake

OpenQuake (Pagani et al 2014) was used to compute of the seismic hazard across Euro-Mediterranean region. OpenQuake is open-source software for computing the seismic hazard and risk, developed and maintained by Global Earthquake Model initiative (<http://www.globalquakemodel.org/>). The hazard library of OpenQuake features state-of-the art seismic source typologies that allow complex representation of the seismogenic sources. The software provides the blueprints to design the source models following the individual seismic source parameterization accordingly to the OpenQuake User's Manual (Crowley et al 2015). According to the software manual, geometry parameters and seismicity occurrence models represent each seismic source. The geometry implies definition of source location, style-of-faulting, and depth. In particular, for the area and point sources, the style of faulting is of significant importance, due to OpenQuake distinctive feature to generate extensive ruptures when area or point sources are defined. The generation of extensive ruptures is controlled by the source related - magnitude frequency distribution, style-of-faulting parameters and magnitude scaling relationships (i.e. Wells and Coppersmith, 1994). Additionally, faults and subduction zones are modelled either as simple faults or complex faults (Crowley et al., 2015). OpenQuake provides standardized input and output file formats based on in-house developed file format: the Natural hazards and Risk Mark-up Language (NRML). The later, is based on a combination of two open-standards: the Extensible Mark-up Language (XML) and the Geography Mark-up Language (GML). The NRML files are both human and machine-readable. Equally important, OpenQuake offers the capability to formally and programmatically define a logic tree (basically through the definition of an input file following the NRML format), without the need of having external tools. Currently the engine allows describing epistemic uncertainties in the source and ground-motion models (Pagani et al., 2014). The input models (NRML file format) and the configuration files as used for the seismic hazard calculation with OpenQuake are available online at www.efehr.org/share_oq_input_files/. The input files reflect the source models and the ground motion logic tree as described in SHARE Deliverable D6.6. OpenQuake software is completely accessible and downloadable through an online repository at www.github.com/gem.

2.3 The 2013 European Seismic Hazard Model: output

2.3.1 Engineering requirements

The engineering requirements were explicitly formulated in the beginning of the SHARE project during a meeting between the Ec8 Committee and SHARE WP2 partners (UPAV, LNEC, METU). These requirements are summarized in the SHARE - document of work and the SAHRE Deliverable D2.1, Table 1. We summarize below the main engineering requirements:

1. *Reference bedrock level described as "Type A" ground rock, and defined as function of V_{s30} – average shear-wave velocity to a depth of 30 m. ($V_{s30} \geq 800$ m/s) (EN 1998-1 3.1.2 (1) – Table 3.1)*
2. *Hazard maps for a range of mean return periods between 25 and 5000 years for the median (from the logic tree) of peak ground acceleration (PGA) at a reference bedrock level.*
3. *Hazard maps for mean return periods between 25 and 5000 years for median spectral ordinates (acceleration and displacement) on type A ground (reference bedrock) for a range of period ordinates (those covered by all GMPEs in logic tree)*
4. *Hazard maps, for aforementioned return periods, of median amplification factor ($F_{0 \sim 2.5}$), T_B , T_C , T_D (if possible) at the reference bedrock level.*
5. *Hazard maps, for the aforementioned return periods, for values of median PGV and median PGD (or appropriate proxies).*
6. *Zonation Map for Europe based on PGA (EN 1998-1 3.2.1 (1)P, EN 1998-1 3.2.1 2), corresponding to the no collapse requirement (EN 1998-13.2.1 3).*
7. *Zonation map for Europe considering both PGA and spectral shape. Zonation may also take into account controlling earthquake scenario as a means of constraining long period motion.*
8. *PSHA disaggregation in terms of PGA and spectral ordinates (i.e. for the results of the maps of output 2). Note, the surface-wave magnitude (M_s) is needed as output of the disaggregation, though this may be obtained from a conversion of M_w .*
9. *Estimation of "k" value (a parameter to allow for the scaling of hazard to intermediate return periods) for median hazard, and indication of uncertainty and applicable return period range.*
10. *Proposals for new spectral shapes for EN 1998-1 for both acceleration and displacement spectra*
11. *Portal with access for engineers to the above output (details to be determined between WP2 and WP6).*

Majority of the above requirements were successfully delivered within the SHARE framework. Yet, due to the considerable computational demands in calculating the disaggregation, it has only been possible within the timeframe of the project to produce the disaggregation for selected sites, and not across the entire region, as was initially envisaged in SAHRE-Deliverable D2.1. In the next sections, relevant examples of the aforementioned requirements are presented in a sequential order. The complete set of results are available online at www.efehr.org.

2.3.2 Reference probabilistic ground motion maps

The reference maps presented in this section are for median value (50th quantile) for reference rock "class A" with $V_{s30} = 800\text{m/s}$ and horizontal components only. The seismic hazard representation for Peak Ground Velocity (PGV) is not directly resulted because the subduction GMPEs does not provide functional forms and coefficients for evaluating PGV. Consequently, the PGV was obtained from the 0.5-second spectral acceleration conversion proposed by (Bommer and Alarcón, 2006).

The spatial variability of the ground-shaking hazard described by PGA, PGV, spectrum accelerations at 1.0s, 2.0s, 3.0s and 4.0s periods for a mean return period of 475 years are shown in the next sections. The reference maps for the listed ground-motion parameters are presented in a sequential order in the next section (Figure 2.7 to Figure 2.12).

Overall, the ground motion hazard maps depict the highest estimates in the southern Europe, in Greece, Italy and Turkey. The largest value obtained are along the North Anatolian Fault, from the northern Aegean and the Marmara Sea, from the South-Western coast of Turkey through Rhodes to eastern part of the Island of Crete, throughout the Gulf of Corinth, and along the western coast of Greece from the Cephalonia fault zone to the Northern coast of Albania.

Consistently high ground hazard values are obtained for Iceland along the plate boundary of the Mid-Atlantic ridge transform faults, from the South Icelandic Seismic Zone (SISZ) to the Tönjes fracture zone in the North. Slightly smaller values, yet high seismic hazard, are mapped throughout the Apennines, Calabria and Sicily in Italy. The deep seismicity in the Vrancea zone (Romania) display the distinct azimuthal dependent high hazard values in North-Eastern Romania declining towards Moldavia and the Black Sea in the East and also west-northwest ward away from the Carpathian Arc.

Moderate ground shaking hazard levels describe all areas along the Mediterranean coast: large parts of Western Turkey, throughout Greece and along the eastern and western Adriatic coast, with the exception of lower values along the northern coast of Croatia, and from the Trentino (in the west) to Slovenia in the east. Such hazard estimates are mapped for well-defined tectonic structures such as the Upper Rhine graben (Germany/France/Switzerland), the Rhone valley in the Valais (southern Switzerland) and the northern foothills of the Pyrenees (France / Spain), where the Western Pyrenees depicts higher hazard values than the Eastern. The entire southern coast of the Iberian Peninsula shows moderate hazard values along mapped fault structures, as well as more punctuated in the greater Lisbon region towards the Targus valley. There are isolated spots of moderate to high hazard, e.g. south of Belgrade (Serbia), northeast of Budapest (Hungary), south of Brussels (Belgium), the region of Clermont-Ferrand (south-eastern France) and the Swabian Alb (Germany/Switzerland). These estimates are consequence of isolated seismicity-based models as the only available information and their assumption that future seismicity will occur close to the historical seismicity.

For the regions in the north that fall into stable continental regions, this effect combined with GMPEs that prescribe a lower attenuation results in relatively high hazard values compared to previous assessments in the long-term geological context. It is therefore instructive to consider the full distribution of hazard estimates at each site.

The uncertainty of the ground shaking hazard estimates are illustrated for PGA in

Figure 2.13 for a mean return period of 475 years, with the quantile estimates (5%, 15%, 85% and 95%) that illustrate the range of values resulting from the seismogenic sources and ground motion models combination within the probabilistic approach.

2.3.2.1 Peak Ground Acceleration – PGA

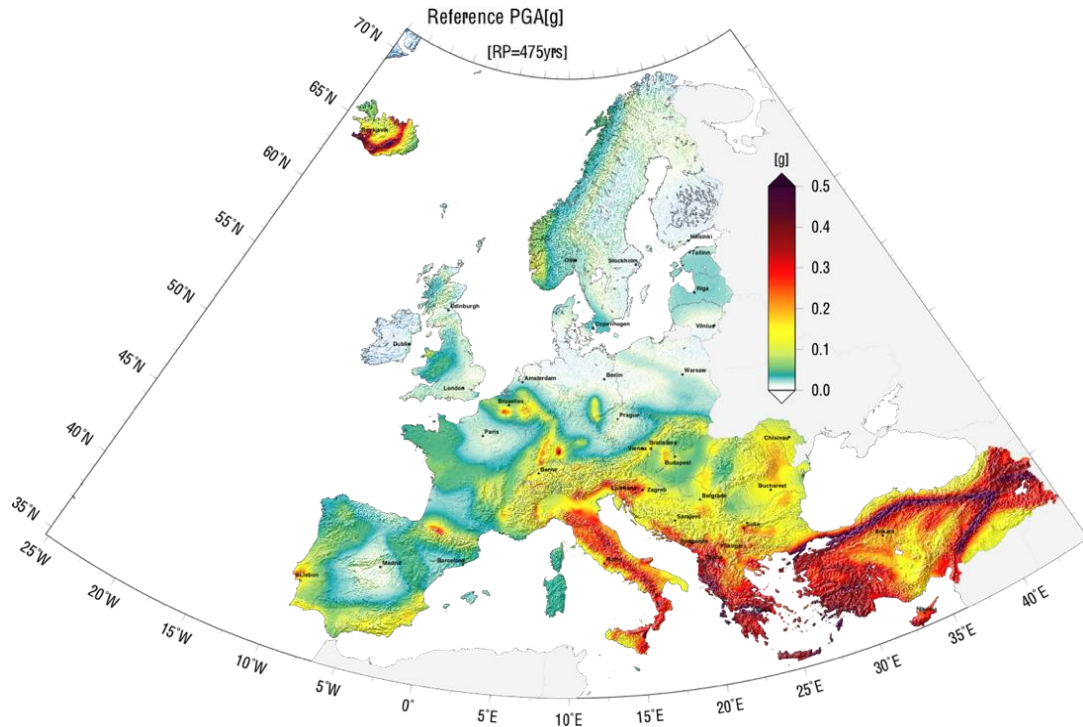


Figure 2.7 Probabilistic map of median PGA for reference rock ($V_{s30} = 800\text{m/s}$) corresponding to a mean return period of 475 years

2.3.2.2 Peak Ground Velocity – PGV

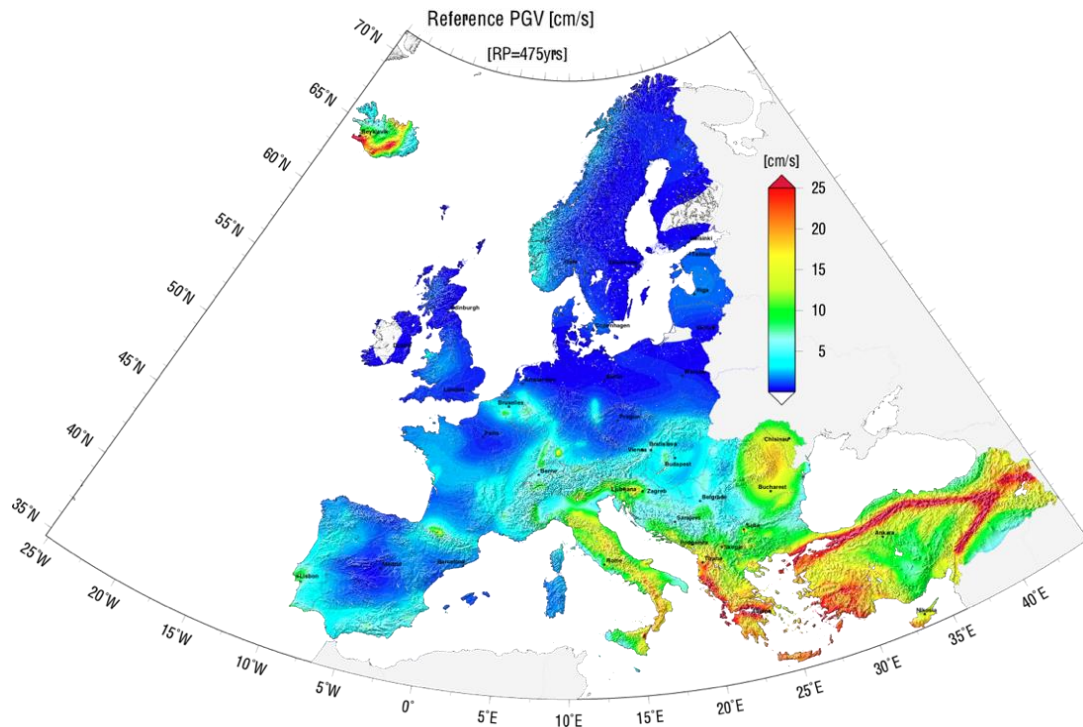


Figure 2.8 Probabilistic map of median PGV for reference rock ($V_{s30} = 800\text{m/s}$) corresponding to a mean return period of 475 years

2.3.2.3 Spectrum Acceleration – SA[1.0s]

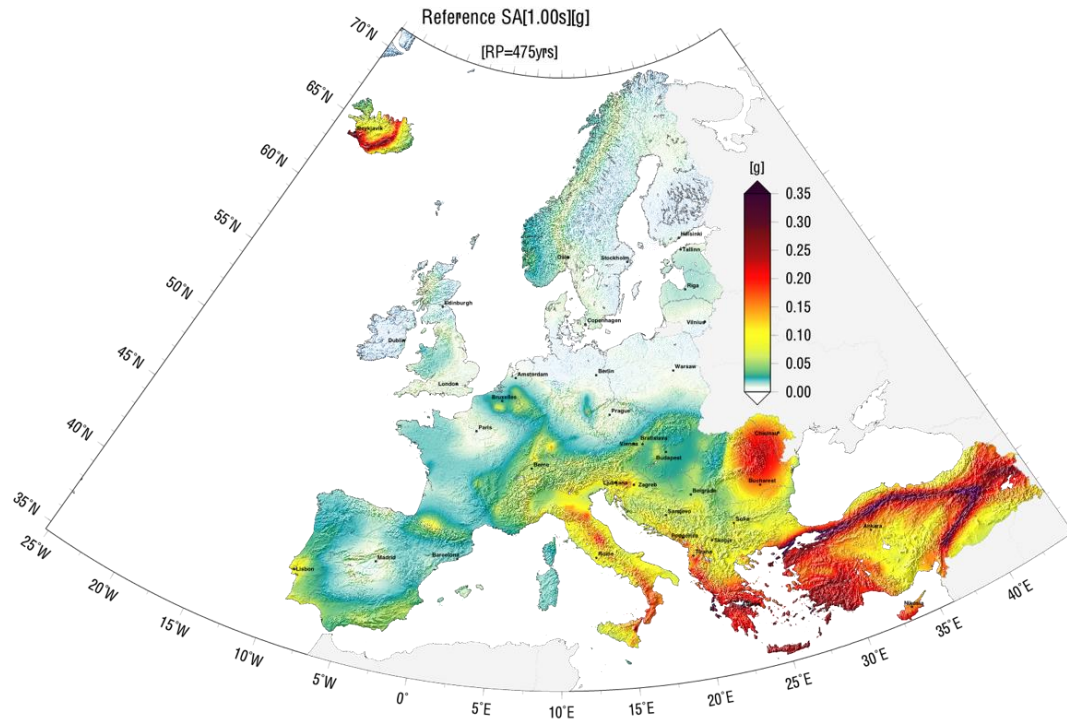


Figure 2.9 Probabilistic map of median SA[1.0s] for reference rock ($V_{s30} = 800\text{m/s}$) corresponding to a mean return period of 475 years

2.3.2.4 Spectrum Acceleration – SA[2.0s]

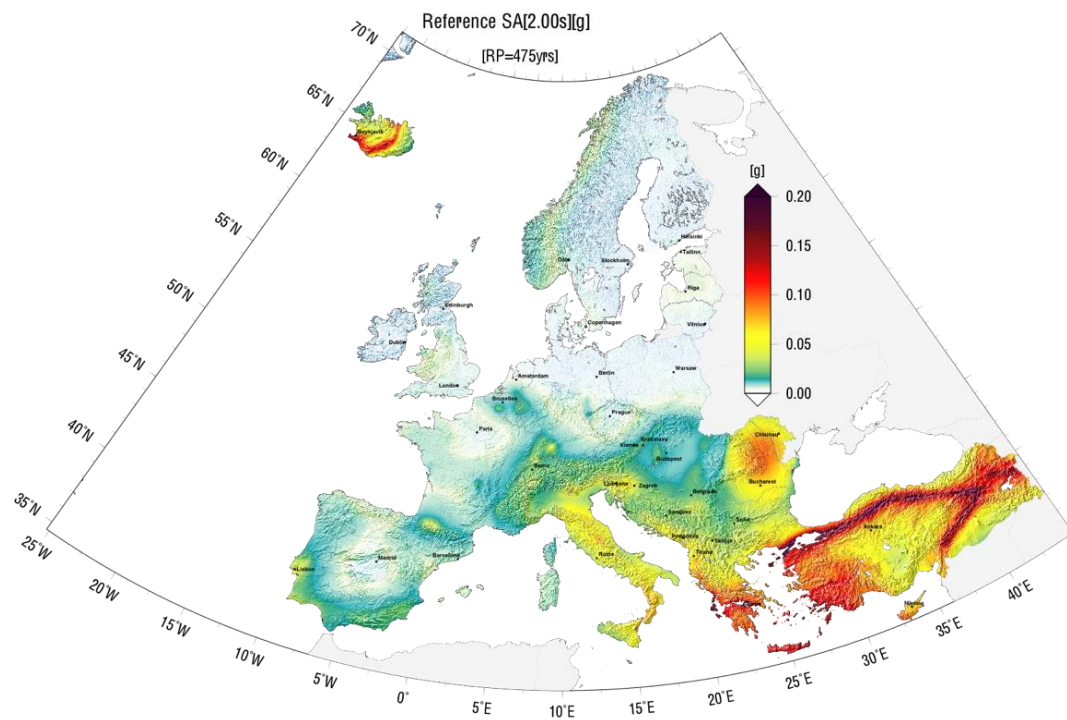


Figure 2.10 Probabilistic map of median SA[2.0s] for reference rock ($V_{s30} = 800\text{m/s}$) corresponding to a mean return period of 475 years

2.3.2.5 Spectrum Acceleration – SA[3.0s]

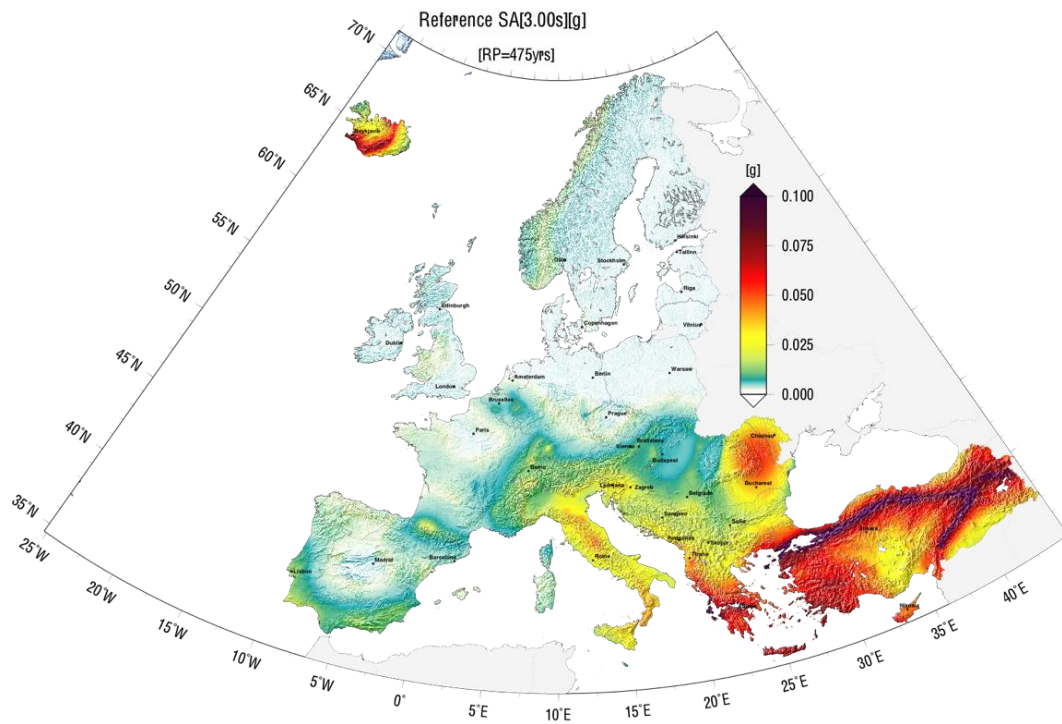


Figure 2.11 Probabilistic map of median SA[3.0s] for reference rock ($V_{s30} = 800\text{m/s}$) corresponding to a mean return period of 475 years

2.3.2.6 Spectrum Acceleration – SA[4.0s]

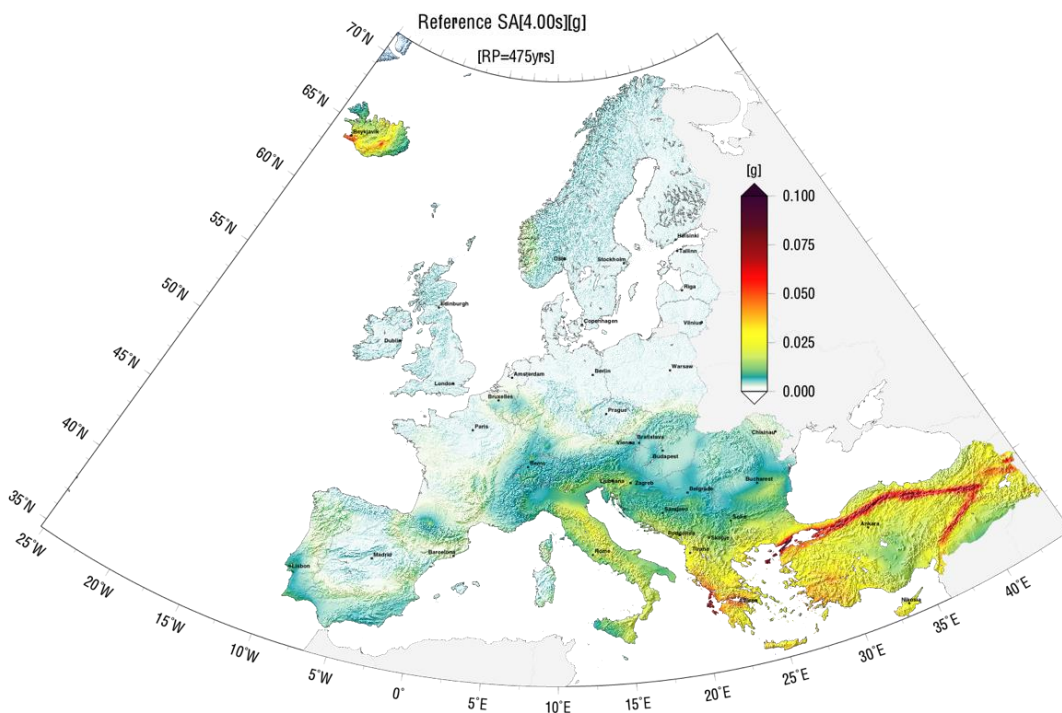


Figure 2.12 Probabilistic map of median SA[4.0s] for reference rock ($V_{s30} = 800\text{m/s}$) corresponding to a mean return period of 475 years

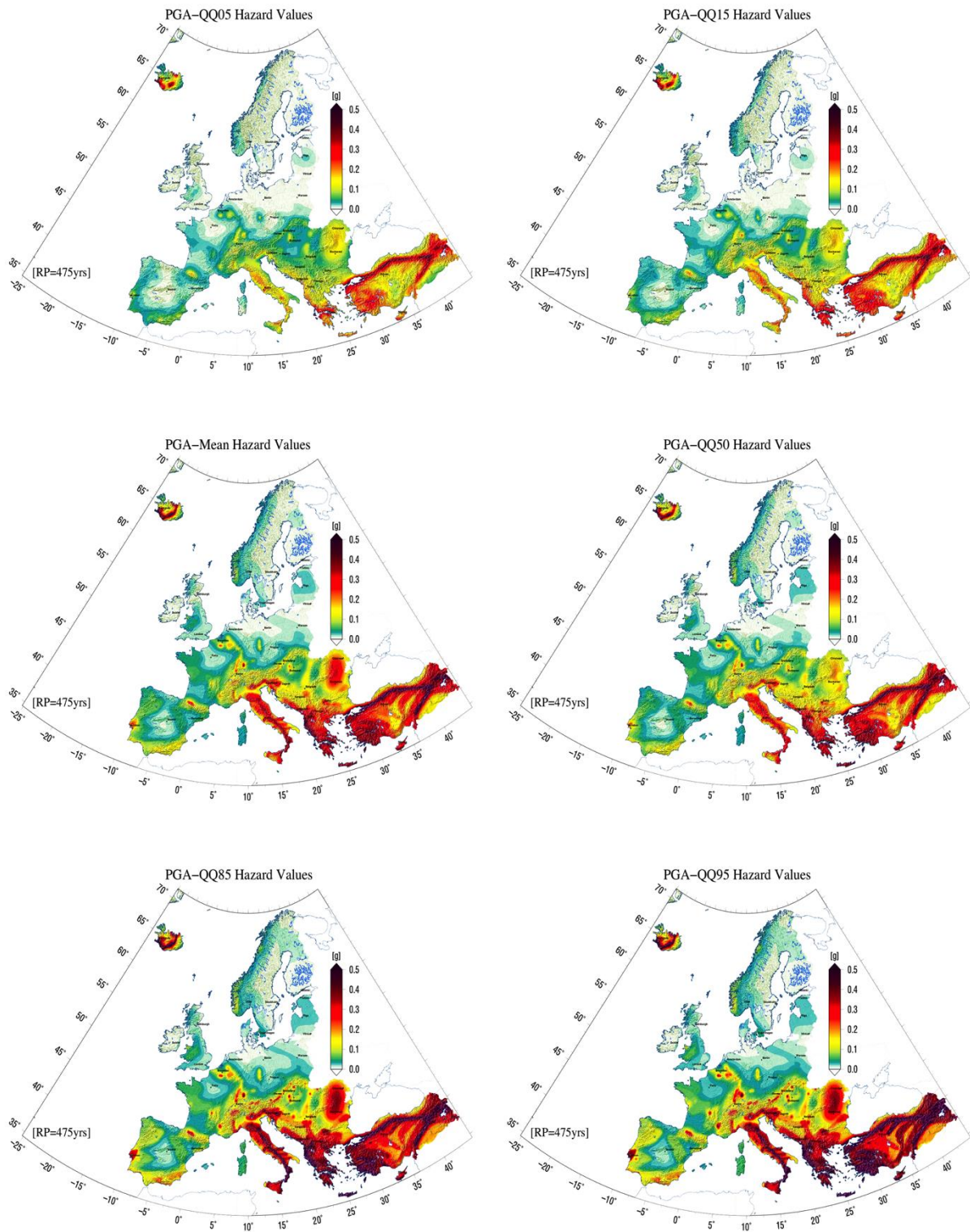


Figure 2.13 Different quantiles map of PGA for reference rock ($V_{s30} = 800\text{m/s}$) corresponding to a mean return period of 475 years

2.3.3 Design spectrum shape parameters from Uniform Hazard Spectra (UHS)

The shape of the design spectrum, as defined by Eurocode 8 vary across Europe, as they are specified as input for seismic design are classed as “Nationally Determined Parameters” and can therefore be subject to modification by each participating country within its own National Annex to the *EN 1998-1*. To evaluate how the shape of the design spectrum may vary throughout Europe, the Eurocode 8 spectrum parameters (F_0 , T_B , T_C and T_D) were optimized to match the spectrum to the UHS. Albeit, the mean return period of 475 years was chosen, the procedure can be applied to other return periods. The procedure for establishing the spectrum parameters from UHS is described in detail by (Weatherill et al., 2013). The resulting shape parameters as shown in Figure 2.14 for F_0 , Figure 2.15 for T_B , Figure 2.16 for T_C and Figure 2.17 for T_D provide a first insights of how the shape of a design spectrum may vary across Europe. The interpretation of these maps is not straightforward and these results should be treated with care, as they are sensitive to the adopted optimization procedures or the sampling resolution of the uniform hazard spectra. Across the Europe the F_0 follow the seismicity patterns and tectonic evidences with distinguish between North-Western Europe (low seismicity) and the Mediterranean (high seismicity), in which higher F_0 values are found in the regions of higher seismicity. The maps of T_B and T_C are particularly difficult to interpret, as the trends are not clearly aligned with major features of the seismicity and tectonics of the region. The spatial pattern of T_D is rather consistent with the regional seismo-tectonics, with the highest values of T_D found in the areas of highest seismic activity and with the potential for larger magnitude ($M_W > 7$) earthquakes. Regardless these limitations, it is recommended that when considering the spatial variation on a more local to national scale it would be preferable to reapply the methodology and investigate the possible influences of the parameter selection or different strategies for optimisation (SHARE – D2.7 – Weatherill et al 2013).

2.3.3.1 Amplification factor (F_0)

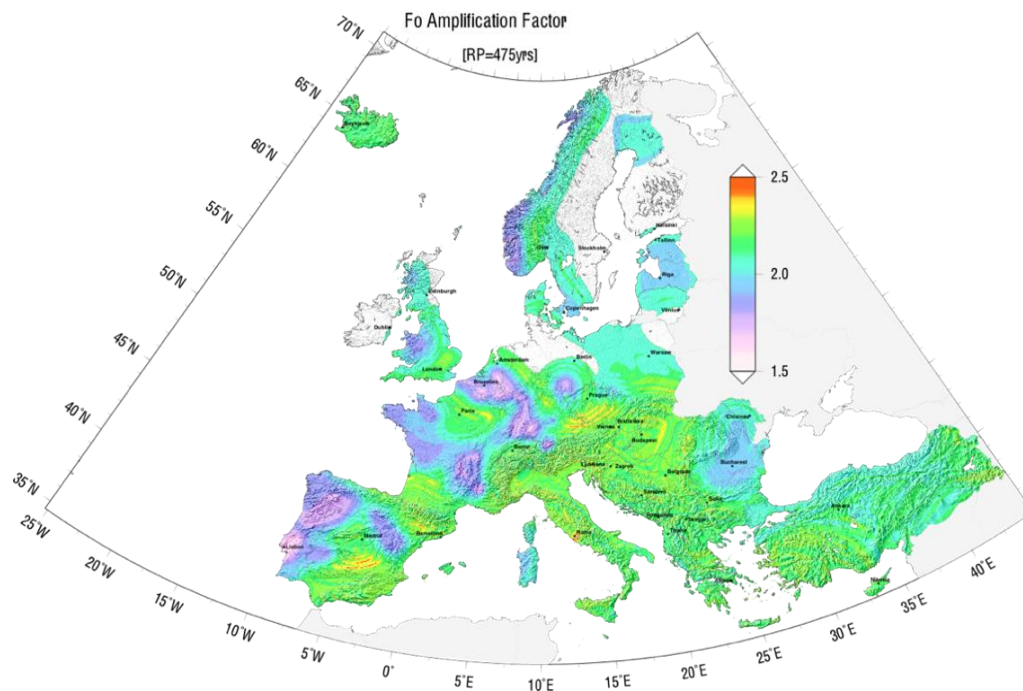


Figure 2.14 Spatial variation of amplification factor F_0 optimized to fit the 2013 European Seismic Hazard Model

2.3.3.2 Constant acceleration corner period (T_B)

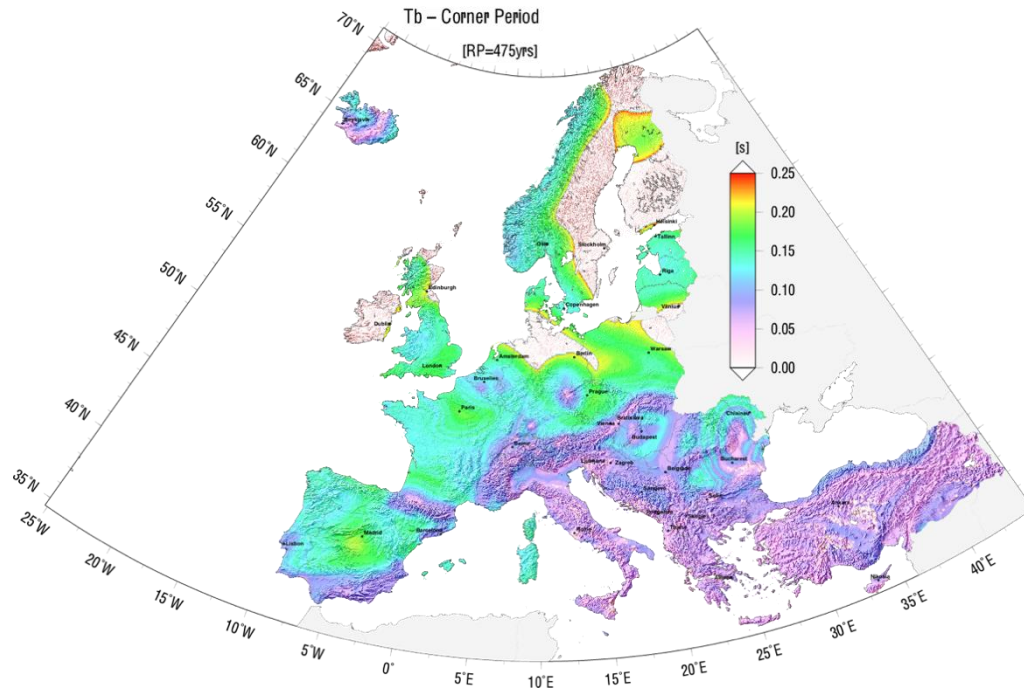


Figure 2.15 Spatial variation of constant corner period T_B optimized to fit the 2013 European Seismic Hazard Model

2.3.3.3 Constant velocity corner period (T_c)

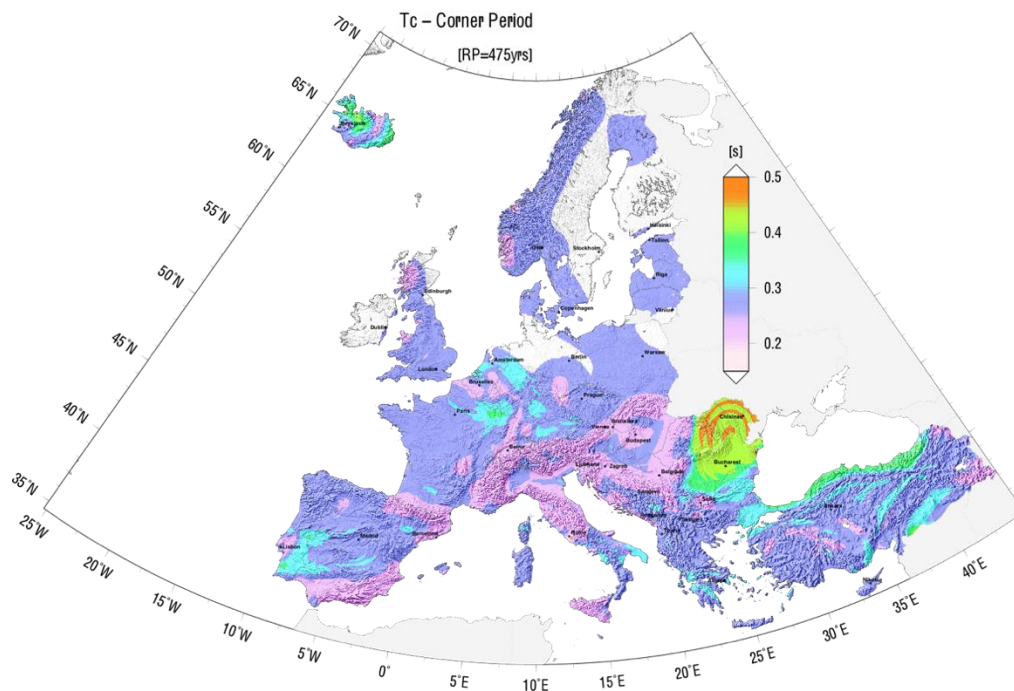


Figure 2.16 Spatial variation of constant corner period T_c optimized to fit the 2013 European Seismic Hazard Model

2.3.3.4 Constant displacement corner period (TD)

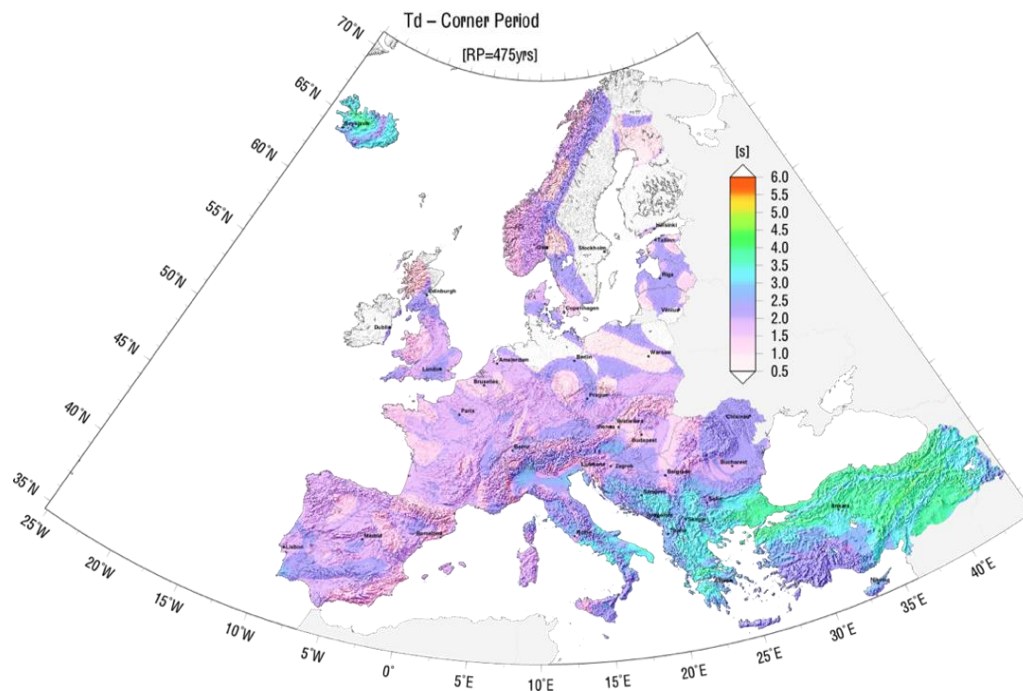


Figure 2.17 Spatial variation of constant corner period T_D optimized to fit the 2013 European Seismic Hazard Model

2.3.3.5 Pseudo-velocity spectrum intensity (VSI) and Acceleration spectrum intensity (ASI)

The spectrum-intensity based parameters provide the basis for a seismic zonation that accounts for both the strength of the ground motion and the shape of the spectrum. In the past, the *effective peak ground acceleration* (EPGA) was considered, but its definition was never standardized (Grunthal and Schwarz, 1996). Two parameters that describe the total energy of the ground motion were adopted: pseudo-velocity spectrum intensity (VSI) and Acceleration Spectrum Intensity (ASI). Whilst these parameters are generally defined for a single record of ground motion, the theoretical principals supporting their usage do not necessarily prevent them from being applied to uniform hazard spectra (UHS). However, one should note the obvious caveat that the UHS in itself is not representative of the spectrum emerging from a single earthquake. The reference maps for a mean return period of 475year ASI and VSI are illustrated in Figure 2.18.

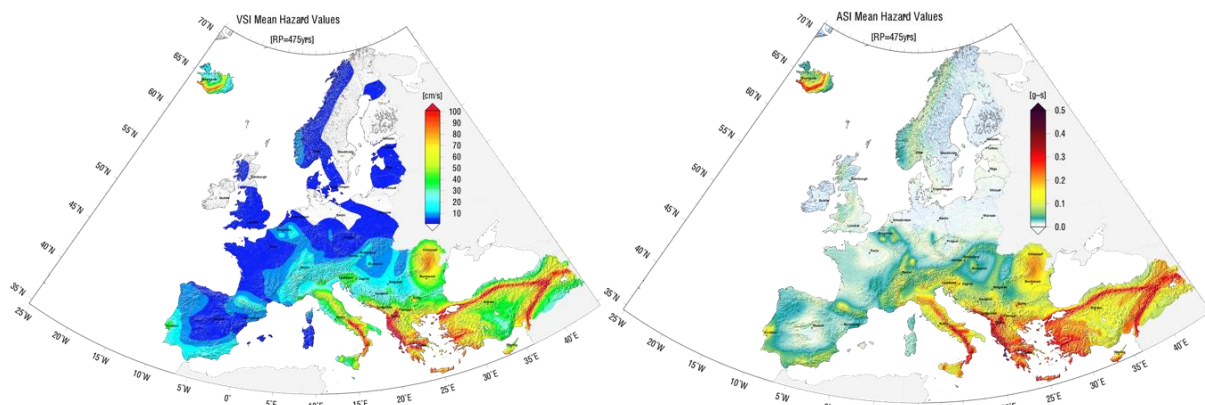


Figure 2.18 Probabilistic map of median Pseudo-VSI (left) and ASI (right) for reference rock ($V_{s30} = 800\text{m/s}$) and mean return period of 475 years

2.3.4 Hazard curve elements: k -value

The term k -value describes the hazard curve decay, is being generally associated to a value of 3 (EN 1998-1 2.1.4). SHARE Deliverable 2.7 (Weatherill et al., 2013) provides the methodology to estimate the k -value from hazard curves, precisely fitting the points between 70 to 5000 years. Where the hazard curves are defined as mean return periods versus ground motion levels. The spatial distribution of k -value shown in Figure 2.19, indicate that whilst there may be a general trend of observing higher k -values (in the range 3.0 – 3.5) in much of the higher hazard region of the Mediterranean, the value itself may depend on many features of the hazard (mainly the nature of the controlling earthquakes) that are specific to each region. Indeed, it is evident that the approximation of $k \approx 3$ is not valid throughout Europe, and that if the use of k -value were to persist in design codes then more care is needed in zoning the value in accordance with the variation seen in a region (SHARE - Deliverable 2.7).

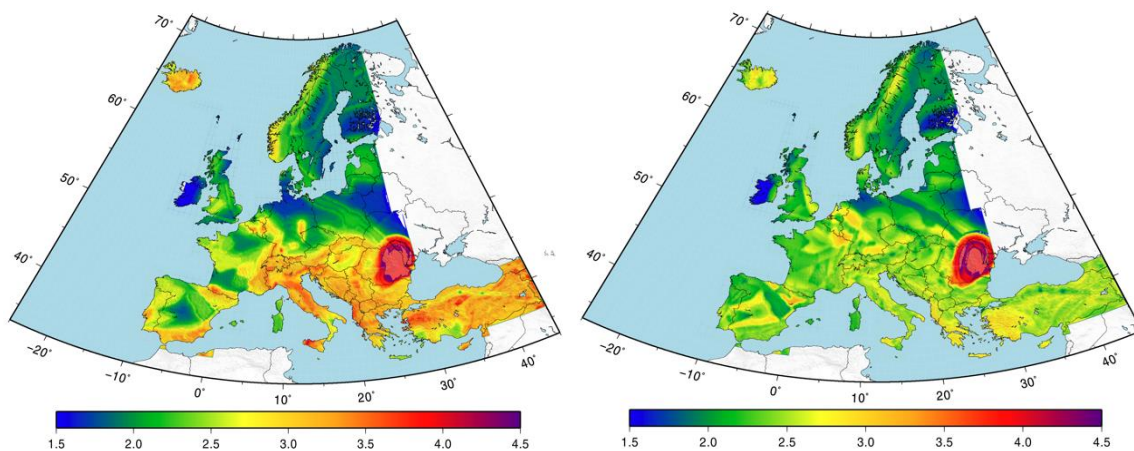


Figure 2.19 Spatial variability in k -value for PGA (left) and 1-second spectral acceleration (right)

2.3.5 Availability

All data, results, references and print material including the official poster of the reference hazard map are freely accessible online at <http://www.efehr.org>, the portal of the European Facility for Earthquake Hazard and Risk and the SHARE project website (www.share-eu.org). ESHM13 results are available for more than 120000 on-land sites equally spaced at 10km across Europe and Turkey. Results are produced for a reference rock condition of Eurocode 8 Type A ($v_{s30}=800\text{m/s}$).

The hazard results are available for ground shaking for frequencies of ground acceleration from 0.1Hz to 100Hz and mean, median and quantile of hazard curves, maps and uniform hazard spectra.

Hazard curves are computed to up return periods of 10000 years – however, caution is to be used when interpreting the curves at very low probability levels because inclusion of very low activity faults that have not entered the SHARE model due to its regional scope or possibly insufficient alternative descriptions in ground motion models may affect the results. We therefore limit result representation for hazard maps to 5000 years - mean return periods.

All SHARE deliverable reports are available online (<http://www.share-eu.org/node/52>). Of particular interest are the deliverable of the SHARE - WP2 Engineering requirements and application:

- D2.1 Hazard output specifications requirements document jointly approved with EC8 Committee
- D2.2 Report on seismic hazard definitions needed for structural design applications
- D2.3 Calibration of Seismic Design Codes using Loss Estimation
- D2.4 Results from study on minimum hazard levels for explicit structural seismic analysis and design
- D2.5 Seismic loss scenarios for sample European cities and regions
- D2.6 Suggestions for Updates to the European Seismic Design RegulationsEuropean
- D2.7 Preliminary Reference Euro-Mediterranean Seismic Hazard Zonation

2.4 The 2013 European Seismic Hazard Model: summary and further recommendations

The ESHM13 represents a turnover for estimating the seismic hazard assessment in Europe. The ESHM13 needs to be understood as a dynamic product, i.e. it is built on the best available science at the time of the project. The ESHM13 provides significant improvement compared to previous efforts mainly due to

- The compilation of homogeneous input databases (earthquake catalogue, active faults and geodetic) required for PSHA,
- The adoption of redefined procedures, especially for expert elicitation and consensus building of hundreds of European experts,
- The multi-disciplinary input from all branches of earthquake science and engineering,
- The full accounting of epistemic uncertainties for model components and hazard results
- Full transparency and open availability of all data, results and methods from the European Facility for Earthquake Hazard and Risk (www.efehr.org). Mainly, the input files are available and allow for full or partial re-generation of the pan-European seismic hazard model.

Moreover, the direct involvement of the European Committee for Standardization, subcommittee for earthquake resistant design (CEN/TC250/SC8), in defining output specifications relevant for Eurocode 8, materialized in a set of recommendations. The later as outlined by the SHARE experts are divided into short-term, mid-term and long-term categories. The recommendation are the results of several activities undertaken including critical overview of recent seismic countries (i.e. Italy, US, New Zealand, Japan and Canada), the use seismic loss assessment in calibration of seismic design codes (SHARE-Deliverable D2.3) and minimum capacity of buildings design without seismic actions to evaluate the minimum hazard level bellow which seismic zonation is not necessary. Hereafter, these recommendations are entirely retained from SHARE - Deliverable 2.6 that also contains the scientific justification and support for these recommendations.

Short-term recommendations implies the direct use of ESHM13 results:

1. *The two spectral shapes (Type 1 and Type 2) anchored to PGA could be removed and replaced by zonation maps of F_0 , T_B , T_C and T_D such that spectral shapes can vary with location and return period.*
2. *The use of site-specific spectral shapes would require a change in the approach to amplify the spectra, which in the short term could be period dependent and derived from current EC8 recommendations.*
3. *Should recommendation 1 not be adoptable immediately, it is recommended that M_w should replace M_s in the definition of Type 1 and Type 2 spectra.*
4. *Explicit recommendations should be provided regarding the means of estimating of the controlling scenario (e.g. disaggregation at the period of vibration of the structure of interest, multiple scenarios where necessary).*
5. *The k -value suggested within EC8 should be revised, and possibly based on the outcomes of SHARE. An upper and lower bound return period that can be estimated with these k -values should also be reported in EC8. As an alternative to this, linear interpolation (in log space) between return periods could be permitted.*

Mid-term recommendations with (with additional research building upon ESHM13 results):

1. *New vertical spectral shapes need to be derived for EC8, building upon the outputs of work-package SHARE-WP4.*
2. *A zonation-based approach should be removed, and the UHS provided and used directly (through a web-portal).*
3. *Amplification factors and site classification table in EC8 could be updated, building upon the research from WP4. Deeper geological characteristics could also be accounted for in the site amplification.*
4. *Displacement spectra require more attention, and the current informative annex should be revised.*
5. *Further consideration on the use of the epistemic uncertainty could be given.*

Long-term recommendations (with more research building upon ESHM13 results):

1. *Significant modifications to the way in which seismic actions are presented within design codes in the future should be investigated, considering the following three suggestions which increasingly depart from current practice:*
 - a. *Risk targeted seismic design actions;*
 - b. *The possible use of aggregate hazard analyses, rather than site specific, for design actions;*
 - c. *A new paradigm for the future of seismic design codes which considers the influence of design choices (in terms of stiffness, strength and ductility) on the aggregate losses to urban areas.*

The requirements as formulated above were presented to, and discussed with, members of the CEN/TC250/SC8 drafting committee.

The ESHM13 provides a full hazard curves and uniform hazard spectra for each site allows for the consideration of spectral parameters and performance-based seismic design requirements within the seismic zonation process. The results are in terms of PGA and Acceleration Spectra (SA) for a wide range of fundamental periods of 0.1 to 4 seconds. The availability of UHS for thousands of site across Europe provides a basis to allow for mapping of the spectrum design controlling ordinates. The first pan-European map of the design spectrum controlling parameters (F_0 , T_B , T_C , and T_D) may help guide National Authorities in the modification of these key parameters to ensure that such modifications are consistent with the seismic hazard in the region of interest. However, mapping the key ordinates poses different challenges of interpretation and application. Further investigations are recommended, particularly for seismically active regions.

Overall, the ESHM13 results provide the basis to aid local experts to extend the approaches to zonation beyond simple consideration of PGA at a fixed mean return period (i.e. 475 years). It is therefore envisaged that future seismic zonation for Europe should be based, not only on PGA, but also on hazard at longer spectral periods. Although, PGA is the parameter required for engineering design purposes in European countries, it was strongly emphasized during various SHARE meetings that for many engineering applications, PGA is not the best suited ground motion parameter and thus the advantage of the ESHM13 is the availability of the entire spectral periods. Moreover, if the seismic action is defined in terms of earthquake time-histories, the newly developed European strong-motion database (<http://www.resorce-portal.eu/>) provides a suitable collection for earthquake records selection.

As it was envisioned within SHARE project, the ESHM13 products shall serve as reference for preparing country specific national annexes with the Nationally Determined Parameters (NDPs), according to different criteria and without the inconsistencies recognized by (Solomos et al., 2008). In this context, the ESHM13 output represents a starting point for developing the national annexes. The first step in pursuing any strategy to incorporate the ESHM13 results is to ascertain what local seismic hazard models already exists. The local experts, earth scientists, seismologists and engineers have to review and evaluate to what extend the datasets, seismogenic models and outputs of ESHM13 can be used to derive national models. It is important to understand the pan European model and point out the differences when compared with the existing country-based models. For instance, the use of different GMPEs might be result in considerable disagreements when compare two seismic hazard models. Another example is the use of active faults for the first time in modelling the seismicity in the Euro-Mediterranean region; or the use of state-of-the art seismogenic source representation. All these assumptions will result in considerable difference when compared with the local seismic hazard models. It is also important to understand the procedures and approaches adopted in ESHM13, particularly on seismogenic data analysis, model uncertainties and seismic hazard aggregation.

It shall be noted, that the outcomes, opinions, findings and conclusions illustrated in this document are resulted of critical investigation into the nature of seismic hazard characterization in Europe. However, the extensive volume of information should not in themselves form a basis for policy without external scrutiny from members of the national authorities responsible for drafting standards in the participating Eurocode countries (Weatherill et al 2013).

Acknowledgments

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- SHARE Deliverable 2.4 "Results from study on minimum hazard levels for explicit structural seismic analysis and design".
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CHAPTER 3

REVISED PROBABILISTIC SEISMIC HAZARD MAP OF TURKEY AND ITS IMPLICATIONS TO SEISMIC DESIGN

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3 Revised probabilistic seismic hazard map of Turkey and its implications to seismic design

3.1 Introduction

The probabilistic seismic hazard map of Turkey is developed with the collaboration of multiple institutes from different disciplines. The project is funded by the Turkish Disaster and Emergency Management Authority (AFAD) as well as the Turkish Catastrophe Insurance Pool (TCIP). AFAD will use the main deliverables of the project (hazard maps of different return periods, T_R) for the new design spectrum definition in the updated Turkish seismic design code. TCIP plans to use the project products for revisiting the earthquake insurance premiums in the country.

This document summarizes the main steps in the seismic hazard map project as well as its effects on the ground-motion definition of the Turkish seismic design code. The revised seismic code in Turkey is expected to be published in 2016 together with the new seismic hazard map.

3.2 Turkish seismic hazard map Project

The revised seismic hazard project follows state-of-the-art approaches in probabilistic seismic hazard assessment (PSHA). The characterization of seismic sources and ground motion as well as computation of hazard are summarized with their full references in the following paragraphs.

The contemporary and historical earthquake catalogues used for developing stochastic earthquake recurrence models in the project include 12674 instrumental (Kadiroglu et al., 2016) and 512 historical earthquakes (Sesetyan et al., 2016a), respectively. Magnitude scales in the contemporary earthquake catalogue are homogenized to moment magnitude (M_w) by using empirical magnitude conversion relationships developed from the same catalogue. The seismic sources including those within a periphery of 200km outside of Turkish territory are modelled as area sources and active fault segments (Demircioglu et al., 2016a; 2016b; Duman et al., 2016; Emre et al., 2016;). Consideration of seismic sources outside of Turkey improves coherency in seismic hazard between Turkey and neighbouring countries. Figure 3.1 shows the simplified geometries of shallow active crustal and subduction seismic sources that are considered in the calculations. The subduction seismic sources are located in the southern part of Turkey. The uncertainties about maximum magnitude, depth, slip rate and source-geometry in seismic source modelling are taken into account by introducing weights to different levels of source parameters via seismic-source logic-tree application (Demircioglu et al., 2016a; 2016b; Sesetyan et al., 2016b).

Ground-motion estimations of future shallow active crustal seismicity are represented by the ground-motion prediction equations (GMPEs) of Akkar and Cagnan (2010), Chiou and Youngs (2008), Zhao et al. (2006) and Akkar et al. (2014). The ground-motions induced by future subduction earthquakes are described by the GMPEs proposed in Lin and Lee (2008), Youngs et al. (1997), Atkinson and Boore (2003) and Zhao et al. (2006). The ground-motion predictive models are selected among a large set of candidate GMPEs by running data-driven and non-data driven tests. Visual inspections of ground-motion trends dictated by candidate GMPEs and PSHA-based sensitivity analyses are also parts of GMPE selection and weighting procedure. The details of ground-motion characterization are

presented in Kale et al. (2016). The ground-motion logic-tree weights used for each GMPE are given in Table 3.1

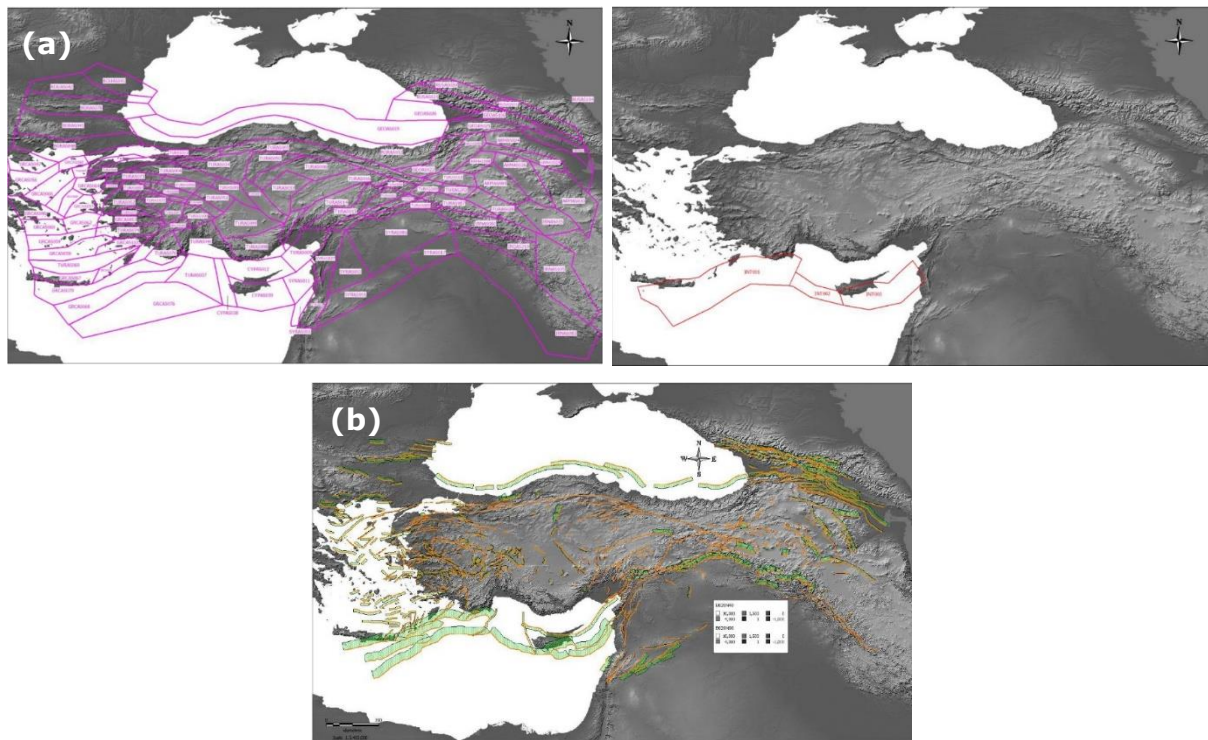


Figure 3.1 (a) left panel shows the 105 area sources representing shallow active seismicity and right panel shows the three area sources of subduction zones, (b) Fault sources of shallow active crustal and subduction seismicity

Table 3.1 GMPEs used in ground-motion characterization and corresponding logic-tree weights

GMPE	Seismotectonic Region	Origin	Logic-tree weight
Akkar and Cagnan (2010)	SACR	Turkey	0.3
Akkar et al. (2014)	SACR	Southern Europe, Balkans, Middle East	0.3
Atkinson and Boore (2003)	Subduction	Global	0.2
Chiou and Youngs (2008)	SACR	Global (mostly Taiwan and California)	0.3
Lin and Lee (2008)	Subduction	Taiwan	0.2
Youngs et al. (1997)	Subduction	Global	0.2
Zhao et al. (2006)	SACR/Subduction	Japan	0.1/0.4

The overall epistemic uncertainty in source characterization is accounted for by modelling the sources as (a) area and (b) fault + smoothed gridded seismicity models. The probabilistic seismic hazard is computed for area source (AS) and fault + smoothed gridded seismicity (FBS) models separately and are combined by equal weights at the end of the calculations. The smoothed gridded seismicity is computed for a Kernel distance of 50km. A total of 64 logic-tree branches are considered in the probabilistic seismic hazard calculations (Sesetyan et al., 2016b). The calculations are done for the entire country at the centres of $0.1^\circ \times 0.1^\circ$ grids for median peak ground acceleration (PGA) as well as 5%-damped spectral accelerations (S_a) at $T = 0.2s$ and $T = 1.0s$. These spectral quantities are used in the new definition of Turkish design spectrum as discussed in the next section. The spectral quantities of interest are computed for generic rock that is defined by $V_{s30} = 760$ m/s. Figure 3.2 shows the PGA map of 475-year return period (10% exceedance probability in 50 years - $10/50$) as a sample case. The project also computes seismic hazard maps for 43-year ($69/50$), 72-year ($50/50$) and 2475-year ($2/50$) PGA, S_a at $T = 0.2s$ and $T = 1.0s$. The horizontal component definition of spectral ordinates is geometric mean in the seismic hazard maps.

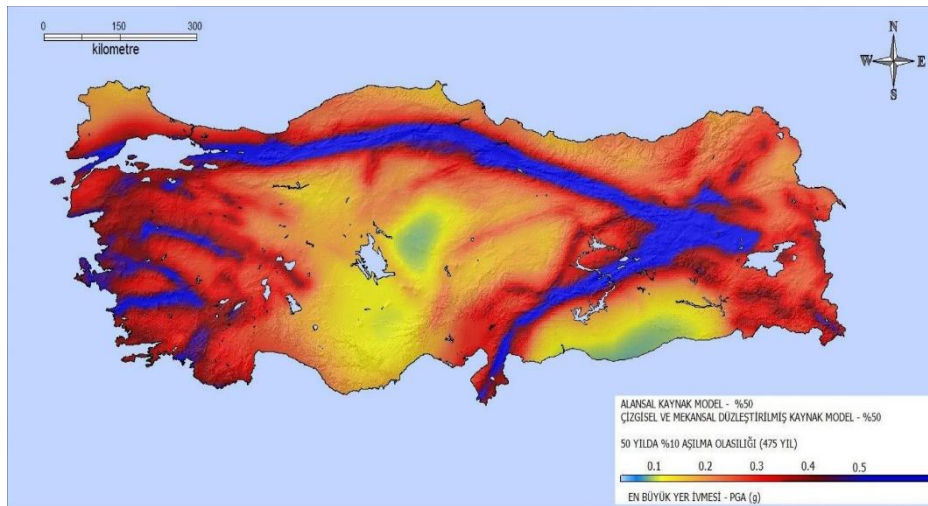


Figure 3.2 Probabilistic PGA distribution (geometric mean) in Turkey for 475-year return period

3.3 Horizontal design spectrum after the revised Seismic hazard maps

The current design spectrum in Turkey relies on Turkish seismic zonation map that is originated from the 475-year return period PGA map of Gulkan et al. (1993). The seismic zonation map divides the country into five zones by simplifying the aforementioned 475-year PGA hazard map. The last zone (Zone V) is described as earthquake-free zone and the other zones attain “effective ground acceleration coefficients” (A_0) ranging from $0.1g$ to $0.4g$. The effective ground acceleration coefficients scale the design-spectrum envelope to describe 475-year target design spectrum. Figure 3.3 shows the Turkish seismic zonation map that is still in force. Figure 3.4 illustrates the design-spectrum envelope as well as the code formulation used for computing the spectral ordinates of 475-year target design spectrum. Modification of design-spectrum envelope from a single spectral period ($T = 0s$ or PGA) would fail to provide reliable information on the equal exceedance probabilities of the spectral ordinates. Design spectral ordinates provided by seismic codes should be a close proxy of target return periods (or exceedance

probabilities). The missing horizontal component definition in A_0 would also lead to a confusion in addressing the directional uncertainty in modern dynamic response spectrum and response history analyses. The current code modifies the 475-year design spectrum to 72-year and 2475-year spectral ordinates via constant factors of 0.5 and 1.5, respectively. This approach would further increase the poor representation of seismic demands for seismic performance assessment in Turkish earthquake resistant design practice. The complex relation between the exceedance probabilities of spectral ordinates cannot be addressed by simple (period independent) constants. Moreover the 475-year target design spectrum is already poorly defined in the current Turkish seismic design code for reasons briefed in the previous lines of this paragraph. The force-based design approach adopted by the current seismic design code of Turkey enforces a slower decay of spectral acceleration ordinates towards longer periods. The decay rate in spectral demands is controlled by $T^{0.8}$ at long periods as shown in Figure 3.4.

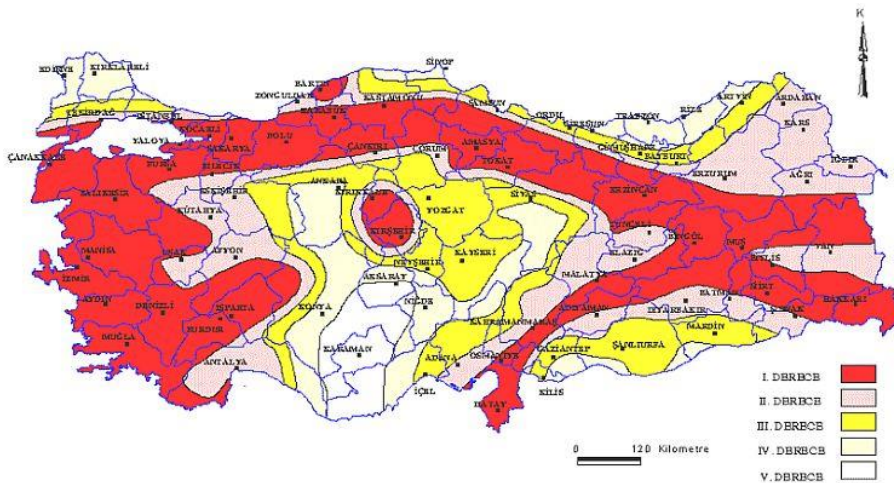


Figure 3.3 Turkish seismic zonation map in effect

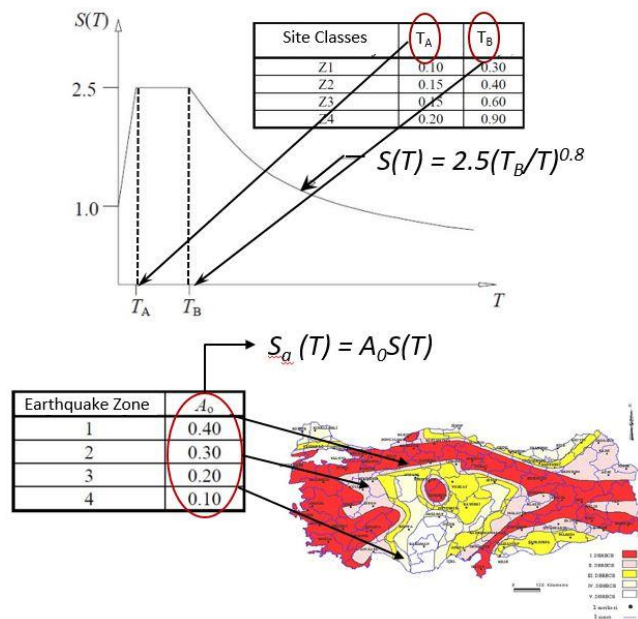


Figure 3.4 Design spectrum via current seismic design code in Turkey. Site class abbreviations represent generic rock (Z1), stiff (Z2, Z3) and soft (Z4) soil conditions

As indicated in the previous section, the revised probabilistic seismic hazard maps describe PGA distribution as well as S_a at $T = 0.2s$ and $T = 1.0s$ for 43-year, 72-year, 475-year (10/50) and 2475-year return periods. Thus, the design ground-motion definition will not be based on seismic zonation concept after the official release of these maps. The zonation map is replaced by the contour maps of different return periods in the definition of design spectrum in the revised Turkish seismic design code. Multiple return periods correspond to different seismic performance levels of new and existing buildings in the earthquake resistant design practice in Turkey. This fact is already indicated in the previous discussions. The use of revised seismic hazard maps in the computation of design spectral demands of different return periods is illustrated in Figure 3.5. The revised Turkish seismic code uses generic rock spectral ordinates of S_a at $T = 0.2s$ and $T = 1.0s$. The generic rock site conditions are modified by code-based site factors and are used in the new definition of design spectrum via expressions shown in the same figure. The computation of design spectrum approach adopted by the revised seismic design code is similar to the current practice in the United States (e.g., ASCE 7-10).

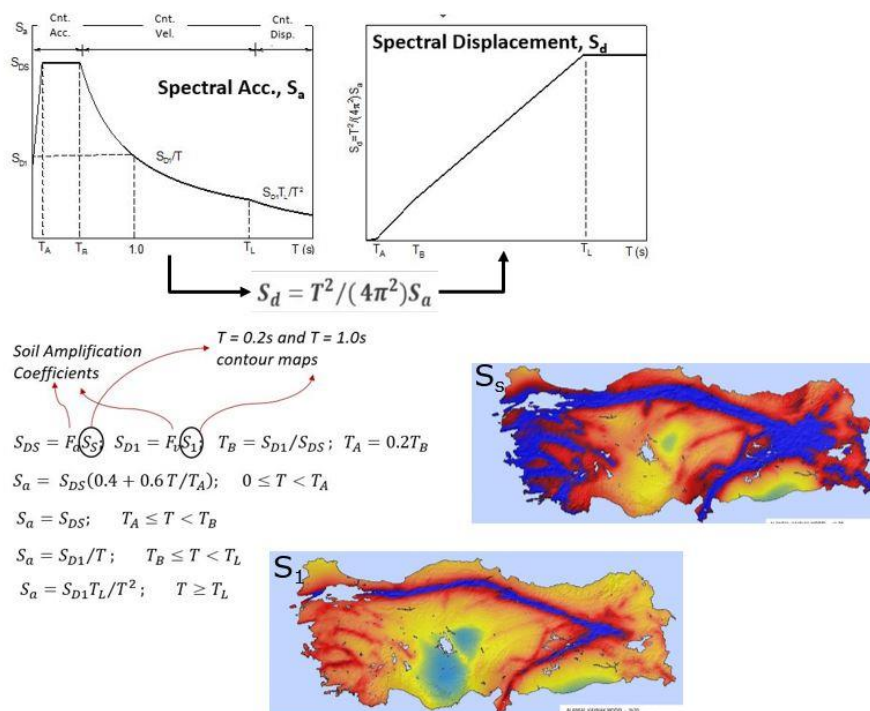


Figure 3.5 The use of probabilistic seismic hazard maps in design spectrum computations dictated by the revised seismic design code. Site factors F_a and F_v change as a function of V_{S30} and the generic rock spectral acceleration levels given by the seismic hazard maps

3.4 Comparison of horizontal design spectrum before and after the revised seismic hazard maps

475-year design spectrum computed from the zone-based approach (current seismic design code as illustrated in Figure 3.4) is compared with the one that will be adopted after the official release of revised seismic hazard maps and seismic design code (Figure 3.5). Comparisons are done for generic rock ($V_{S30} = 760$ m/s) and soft soil ($V_{S30} = 250$ m/s) for spectral accelerations of $T = 0.2s$ and $T = 2.0s$. The selected V_{S30} values can be the

representatives of generic rock and generic soft soil sites in the revised seismic design code. The generic rock and soft soil sites are defined as Z1 and Z3, respectively in the current seismic design code. Figure 3.6 shows the comparisons in terms of ratio plots of “revised” to “current” approach. Here, “revised” represents the revised probabilistic seismic hazard maps and seismic design code whereas “current” stands for zone-based seismic hazard map and current seismic design code.

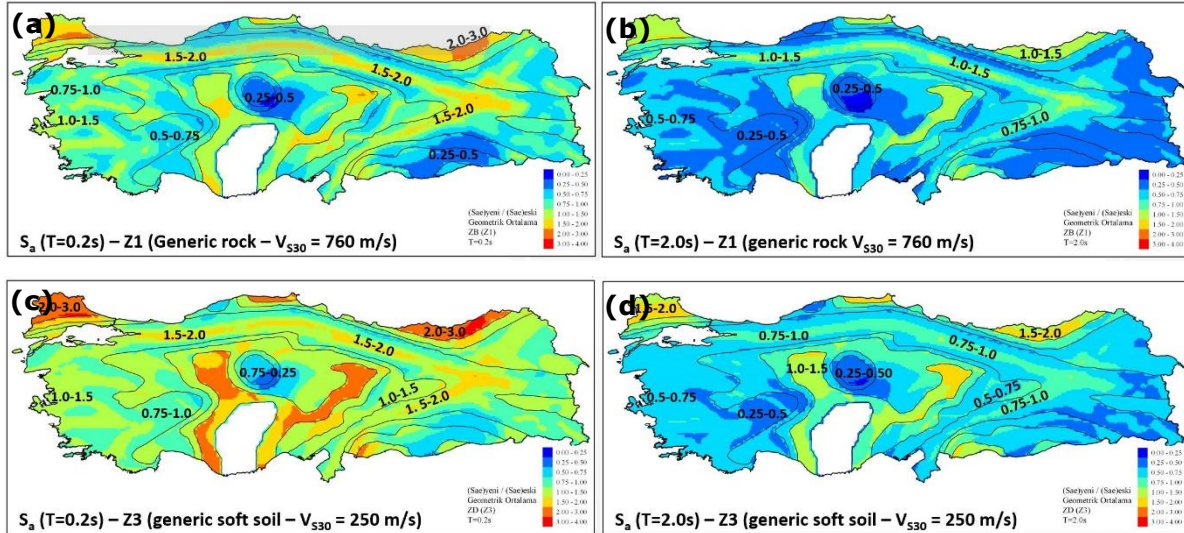


Figure 3.6 Ratios of spectral ordinates computed from “revised” and “current” seismic hazard maps and design codes in Turkey. Spectral acceleration ordinates are computed at $T = 0.2s$ and $T = 2.0s$. Top plots are “revised” to “current” spectral ratios for generic rock (Z1 in the current code) conditions. Bottom plots show the same information for generic soft soil (Z3 in the current code) conditions. First column plots show the ratio distribution for S_a at $T = 0.2s$ and second column plots are the S_a ratios of $T = 2.0s$

The ratio plots indicate that the revised probabilistic seismic hazard maps and therefore the updated design spectrum tend to yield larger spectral ordinates with respect those of current spectrum in the short period range. This observation is more prominent along the North Anatolian and East Anatolian faults. As for the long spectral periods, the difference between the spectral ordinates of “new” and “current” approaches decreases. In general, for softer site conditions, the currently dictated long-period spectral ordinates tend to be equal or larger than those computed from the revised maps and design codes. This trend is reversed in Thrace and at some locations in the Eastern part of Black Sea. Needless to say, modified seismic hazard results, transition from zonation map to contour maps, changes in the computation methodology of design spectrum are the main reasons behind the observations highlighted in Figure 3.6.

3.5 Conclusions

This short paper summarizes the major steps of the recently developed probabilistic seismic hazard map in Turkey. The project is completed by the collaboration of several national governmental institutions AFAD, TCIP, General Directorate of Mineral Research (MTA) as well as universities Bogazici University, Cukurova University, Middel East Technical University and Sakarya University. The implications of probabilistic seismic

hazard maps on horizontal design spectra are also discussed by considering the revisions in the Turkish seismic design code.

The probabilistic seismic hazard maps will be one of the major ingredients of updated seismic design provisions that modify the computation of design spectrum with respect to the current design provisions. The modifications in the computation of design spectrum and transition from earthquake zone concept to spectral contours for certain return periods affect the design spectral ordinates. In general, one would conclude that the design spectral ordinates in the short period range will be larger with respect to those computed from current seismic design provisions and zonation map. This trend is reversed, in particular for softer sites, in the long-period spectral range. This conclusion is confined to the design spectral ordinates of 475-year return period.

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CHAPTER 4

EN 1991 – CLIMATIC ACTIONS AND ELABORATION OF MAPS FOR CLIMATIC ACTIONS IN GREECE

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4 EN 1991 – Climatic Actions and Elaboration of Maps for Climatic Actions in Greece

4.1 Introduction

4.1.1 Key items of Part 1-3 “Snow loads” of EN 1991

As it is known to the engineering community, which is using the EN Eurocodes, there are three Eurocode Parts dealing with climatic actions, namely:

- EN 1991-1-3 for snow loads
 - EN 1991-1-4 for wind actions
- and
- EN 1991-1-5 for thermal actions

Other types of climatic actions, e.g. atmospheric icing, are not for the moment covered by the Eurocodes.

It is also known in principle that during the years following the issuance of the EN Eurocodes, there have been several cases of issuance of additional documents either as corrigenda (essentially editorial and similar errors) or as amendments (technical modifications). In the specific case of snow loads the following documents, cited in the References, have been issued:

- EN 1991-1-3:2003
- EN 1991-1-3:2003/AC:2009
- EN 1991-1-3:2003/A1:2015

As it is stated in its scope, EN 1991-1-3 gives guidance to determine the values of loads due to snow to be used for the structural design of buildings and civil engineering works (for sites at altitudes < 1500m). For higher altitudes advice may be found (if available) in the appropriate National Annex (NA).

The main part of the document, except the foreword it is constituted by the following six sections:

1. General
2. Classification of actions
3. Design situations
4. Snow load on the ground
5. Snow load on roofs
6. Local effects

The document also contains five Annexes with the following subjects:

Annex A gives information on design situations and load arrangements to be used for different locations.

Annex B gives shape coefficients to be used for the treatment of exceptional snow drifts.

Annex C gives characteristic values of snow loads on the ground based on the results of work carried out under a contract by the former DGII/D3 of the European Commission specific to EN 1991-1-3. The aim of this Annex was in fact to give information to the National Competent Authorities of the Member States (MS) to help them in redrafting their

national maps, as well as to help them to make use of the established harmonized procedures for the producing the snow maps for treating their own basic snow data.

Annex D gives guidance for adjusting the ground snow loads according to the return period.

Finally, Annex E gives information on the bulk weight density of snow.

It is also important to clarify that EN 1991-1-3 does not give guidance on specific of snow loading, such as:

- impact snow loads resulting from snow sliding off or falling from a higher roof;
- the additional wind loads which could result from changes in shape or size of the construction works due to the presence of snow or the accretion of ice;
- loads in areas where snow is present all year round;
- ice loading;
- lateral loading due to snow (e.g. lateral loads exerted by drifts);
- Snow loads on bridges.

The research program mentioned previously has been carried out by several European Organisations, namely the University of Pisa (as Co-ordinator) and BRE (UK), CSTB (F), EPFL (CH), ISMES (I), JRC (EU), Sintef (N), University of Leipzig (D) and has led to a final report with annexes (Sanpaolesi et al., 1998).

The main topics in the research programme were:

- the study of the European ground snow loads map;
- the study and definition of exceptional snow falls;
- the theoretical and experimental definition of the shape coefficients for the conversion of ground snow load into roof load;
- the statistical definition of the combination coefficients.

The results of the research work were widely used in drafting EN 1991-1-3 and also to determine national snow maps and combination coefficients for the various National Annexes for those countries that were members of the EU and EFTA in 1998.

The principles of the elaboration of maps for climatic actions and some details on the elaboration of the European ground snow load maps are presented in another chapter of the present report (Formichi, 2016). As an example, the map and relevant data for the case of Greece, as included in the final report with annexes mentioned previously (Sanpaolesi et al., 1998) are presented hereafter.

Greece: Snow Load at Sea Level

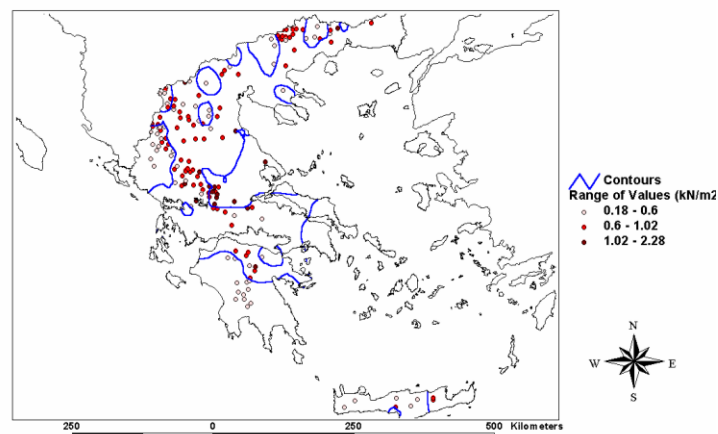


Figure 4.1 Snow load map for Greece – Range of values (kN/m²) [© Formichi]

Greece: Snow Load at Sea Level

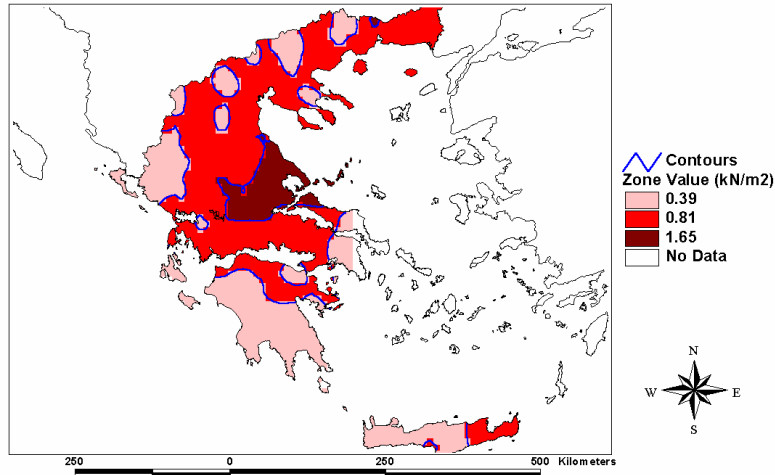


Figure 4.2 Snow load map for Greece – Zone values (kN/m²) (Sanpaolesi et al., 1998 and 1999) [© CEN]

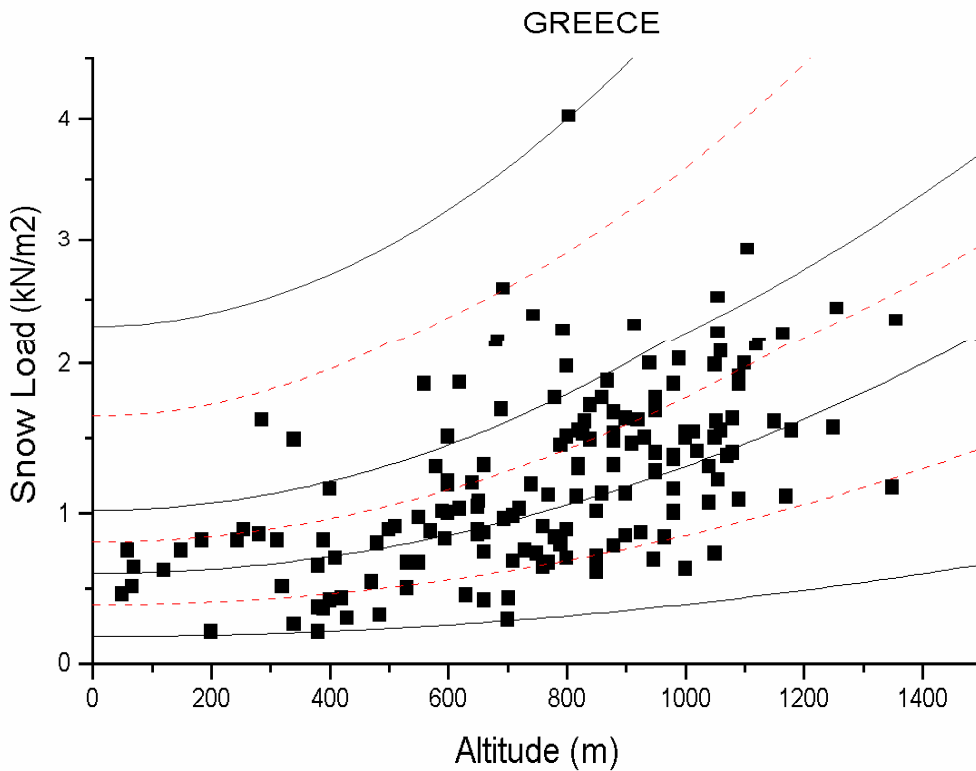


Figure 4.3 Snow load for Greece as a function of the altitude (black line = zone limit; red line = representative snow load – altitude relationship for the corresponding zone) [© Formichi]

The relation between the snow load s (in kN/m²) and the altitude A (in m) is given by the formula:

$$s=(0.18+(Z-0.5)[2.28-0.18]/5)[1+(A/917)^2] \quad (4.1)$$

where Z is the zone number.

It is also worthy to mention that following a number of roof failures in Europe during the winter 2005-2006, attributed to the snow loads, a proposal has been drafted with the following key objectives:

- to examine these failures and determine if they necessitate any addition to EN 1991-1-3 "Snow Loads", and whether any accompanying research will be required;
- to extending Annex C of EN 1991-1-3 for every member state of EU and EFTA in order to ensure sound information on ground snow loads.

More specifically:

- examine the cause of the failures and their implication on EN 1991-1-3;
- determine and compare the values of ground snow loads causing the collapses with the values given in Annex C of EN 1991-1-3;
- if safety implications were detected the following aspects would need reconsideration: snow load on the ground, shape factors and the effects of roof dimension on these factors, effects of melting/freezing of snow and other influences;
- update EN 1991-1-3 to the satisfaction of National Delegations to CEN/TC250/SC1, by incorporating one more decade of data;
- extend Annex C of EN 1991-1-3 to cover all the Member States of the EU and EFTA;
- examine National Annex maps with the maps of Annex C of EN 1991-1-3 as a first step to obtain a harmonized snow map of Europe by ensuring consistency at borders.

The aforementioned proposal unfortunately did not found the necessary financial support and for this reason has not been materialized.

4.1.2 Key items of Part 1-4 "Wind actions" of EN 1991

This Part of EN 1991 on wind actions has proven to be one of the Eurocode Parts for which time and effort have been necessary in order that agreement is reached among the Member States. There is a risk that this situation is somehow repeated, given the important number of comments received during the recent systematic review.

In the specific case of wind actions the following documents, cited in the References, have been issued:

- EN 1991-1-4:2005
- EN 1991-1-4:2005/AC:2010
- EN 1991-1-4:2005/A1:2010

As it is stated in its scope, EN 1991-1-4 gives guidance to determine the natural wind actions to be used for the structural design of buildings and civil engineering works for each of the loaded areas under consideration. This includes the whole structure or parts of the structure or elements attached to the structure, e.g. components, cladding units and their fixings, safety and noise barriers.

This Part is applicable to:

- buildings and civil engineering works with heights up to 200 m;
- Bridges having no span greater than 200 m, provided they satisfy the criteria for dynamic response.

This Part is intended to predict characteristic wind actions on land-based structures, their components and appendages.

The main part of the document, except the foreword it is constituted by the following six sections:

1. General
2. Design situations
3. Modelling of wind actions
4. Wind velocity and velocity pressure
5. Wind actions
6. Structural factor $c_s c_d$
7. Pressure and force coefficients
8. Wind actions on bridges

The document also contains six informative Annexes with the following subjects:

Annex A gives illustrations on the terrain categories and provides rules for the effects of orography including displacements height, roughness change, influence of landscape and influence of neighbouring structures.

Annex B and C give alternative procedures for calculating the structural factor $c_s c_d$.

Annex D gives $c_s c_d$ values for different types of structures.

Annex E gives rules for vortex induced response and some guidance on other aeroelastic effects.

Finally, Annex F gives dynamic characteristics of structures with linear behaviour.

It is also important to clarify that EN 1991-1-4 does not give guidance on local thermal effects on the characteristic wind, e.g. strong arctic thermal surface inversion of funnelling or tornados.

Also it does not give guidance on the following aspects:

- guyed masts and lattice towers which are treated in EN 1993-3-1 and lighting columns which are treated in EN 40;
- torsional vibrations, e.g. tall buildings with central core;
- bridge deck vibrations from transverse wind turbulence;
- wind actions on cable supported bridges;
- vibrations where more than the fundamental mode needs to be considered.

It is clear that there is no provision for maps on wind actions in EN 1991-1-4.

4.1.3 Key items of Part 1-5 "Thermal actions" of EN 1991

In the specific case of thermal actions, the following documents, cited in the References, have been issued:

- EN 1991-1-5:2003
- EN 1991-1-5:2003/AC:2009

As it is stated in its scope, EN 1991-1-5 gives principles and rules for calculating thermal actions for buildings, bridges and other structures including their structural elements. Principles needed for cladding and other appendages of buildings are also provided.

It also describes the changes in temperature of structural elements. Characteristic values of thermal actions are given for use in the design of structures which are exposed to daily and seasonal climatic changes, while structures not so exposed may not need to be considered for thermal actions.

Structures in which thermal actions are mainly a function of their use (e.g. cooling towers, silos, tanks, warm and cold storage facilities, hot and cold services etc.) are treated in Section 7, while chimneys are treated in EN 13084-1.

The main part of the document, except the foreword it is constituted by the following six sections:

1. General
2. Classification of actions
3. Design situations
4. Representation of actions
5. Temperature changes in buildings
6. Temperature changes in bridges
7. Temperature changes in industrial chimneys, pipelines, silos, tanks and cooling towers

The document also contains four Annexes with the following subjects:

Annex A (normative) gives guidance on the isotherms of national minimum and maximum shade air temperatures. It is to note that no maps are provided.

Annex B (normative) gives guidance on temperature differences for various surfacing depths. It is essentially applied to bridges.

Annex C (informative) gives information on the coefficients of linear expansion.

Finally, Annex D (informative) gives information on temperature profiles in buildings and other construction works.

4.2 Actual situation and near future perspectives concerning Eurocode parts on climatic actions

Following the issuance of the EN Eurocodes and their progressive implementation in the Member States it was felt necessary in several cases to establish Working Groups (WG) under CEN rules, i.e. subordinate groups to CEN/TC 250 or its SCs. These WG were intended to support the mother SC by dealing with all matters arising, e.g. preparing/reviewing corrigenda and amendments, considering any comments submitted and more recently proposing the content of the forthcoming future evolution of the first generation of Eurocodes. Most of these activities are usually considered and called as "maintenance" activities. Within this context the following WG have been established by SC1 in order to deal with subjects related to climatic actions:

- WG 01 "Climatic actions" to deal with snow, wind and thermal actions;
 - WG 02 "Atmospheric icing of structures";
- and more recently
- WG 06 "Actions from waves and currents on coastal structures".

A systematic review concerning (among other) the EN 1991-1-3, EN 1991-1-4 and EN 1991-1-5 has been launched and concluded one year ago with the collection of comments. Within the framework of the Mandate 515 (EC, 2012) signed by CEN and EC, the preparation of Phase II calls for tendering has started, in order that Project Teams (PT) be established, among which those to deal with the future development (revision) of the aforementioned climatic actions parts of the EN Eurocodes.

It is worthy to mention that among the sub-tasks of all three future Project Teams to deal with the future development (revision) of snow, wind and thermal parts of the actual EN Eurocodes (EN 1991-1-3, EN 1991-1-4 and EN 1991-1-5, respectively) the following are included:

“Collect snow load on ground based on existing national values and present the values in a snow load map emphasizing differences across borders and revealing the introduction of the exceptional ground snow loads to be dealt with accidental design situations”.

“Collect basic wind velocities based on existing national values and present the values in a wind map emphasizing differences across borders”.

“Collect characteristic temperatures based on existing national values and present the values in a temperature map emphasizing differences across borders”.

In other words it is intended that climatic maps are established, but essentially based on existing maps of the Member States and mainly in view to reach at least “smoothing” of the differences across border areas.

In addition to that the future evolution of ISO 21650 to EN 1991-1-8: General Actions – Waves and currents on coastal structures, as well as of ISO 12494 to EN 1991-1-9: General Actions – Atmospheric icing is scheduled.

At a later stage the interdependence of snow, wind and temperature with atmospheric icing will also be considered, as well as the impact of climatic actions on glass structures.

In the meantime, a Project Team has been established and just started to work with the task of drafting a technical report analysing and providing guidance for potential amendments for Eurocodes with regard to structural design addressing relevant impacts of future climate change (general and material specific). It is intended to include recommendations for modified or additional clauses for EN 1991-1-3, -1-4, -1-5 and EN 1991-1-9 (and possibly other Eurocode Parts) and to provide relevant background documents.

4.3 Elaboration of maps for climatic actions in Greece

The relevant maps, together with the additional NDPs are included in the corresponding National Annexes, cited in the References, namely:

- Greek National Annex (NA) for snow loads (ELOT EN 1991-1-3:2004/NA, issued 2010-11-15);
- Greek National Annex (NA) for wind actions (ELOT EN 1991-1-4:2005/NA, issued 2010-11-15);
- Greek National Annex (NA) for thermal actions (ELOT EN 1991-1-5:2004/NA, issued 2010-11-15).

4.3.1 Snow map for Greece

Snow data were obtained from the archives of the National Electric Company (ΔEH), for a total number of 96 stations. These were chosen for the duration of the period of measurement (longer than 20 years) and to give a reasonably homogenous coverage throughout all of Greece. Stations are located mainly at high altitudes, but there are stations located at low altitudes which have fewer and less reliable data.

The data contain daily measurements indicating the water equivalent of snow fallen in the 24 h period. Measurements are taken at 09:00. For all stations geographical coordinates and altitude were available, as were the following supporting qualitative information: wind presence and sunny or cloudy weather.

The usual practice used for the establishment of the European snow maps consists of the choice of a probabilistic model, the estimation of the parameters and the evaluation of the characteristic value for a 98% fractile. More specifically, the maximum yearly ground level snow load is assumed to follow a type I extreme value (Gumbel) distribution.

The relation established for Greece in the framework of European snow maps project of Pisa University was originally expressed by Eqn. (4.1). The zone values proposed in the same framework for the characteristic snow load s_k (in kN/m^2) at sea level are presented in Figure 4.2. They correspond to zone numbers given in the map with the values 1, 2 and 4, respectively for zones A, B and C(Γ). It should be noted however that while the correlation coefficient for zones A and B ranges between 0.85 and 0.90, its value for zone C (Γ) is only 0.57, i.e. rather low. Furthermore, this approach is on the safe side, as most of the values are lower than the representing function. It should also be mentioned that for coastal zones and most of the islands there are no data points to represent the milder climatic conditions in this area (often with no snow years).

Considering the aforementioned results and the advantage for practical reasons that the limits of the zones coincide with administrative limits (of regions or departments) the following simplified formulation has been adopted in the Greek National Annex:

$$s_k = s_{k,0} [1 + (A/917)^2] \quad (4.2)$$

s_k the characteristic snow load (kN/m^2)

$s_{k,0}$ the characteristic snow load at sea level (kN/m^2) with the values 0.4 (kN/m^2), 0.8 (kN/m^2) and 1.7 (kN/m^2), respectively for zones A, B and C(Γ)

A the site altitude above sea level (m).

The three zones A, B and C(Γ) are shown in Figure 4.4, while in Figure 4.5 the characteristic snow load s_k is plotted for each one of the three zones as a step function of the altitude (every 100 m).

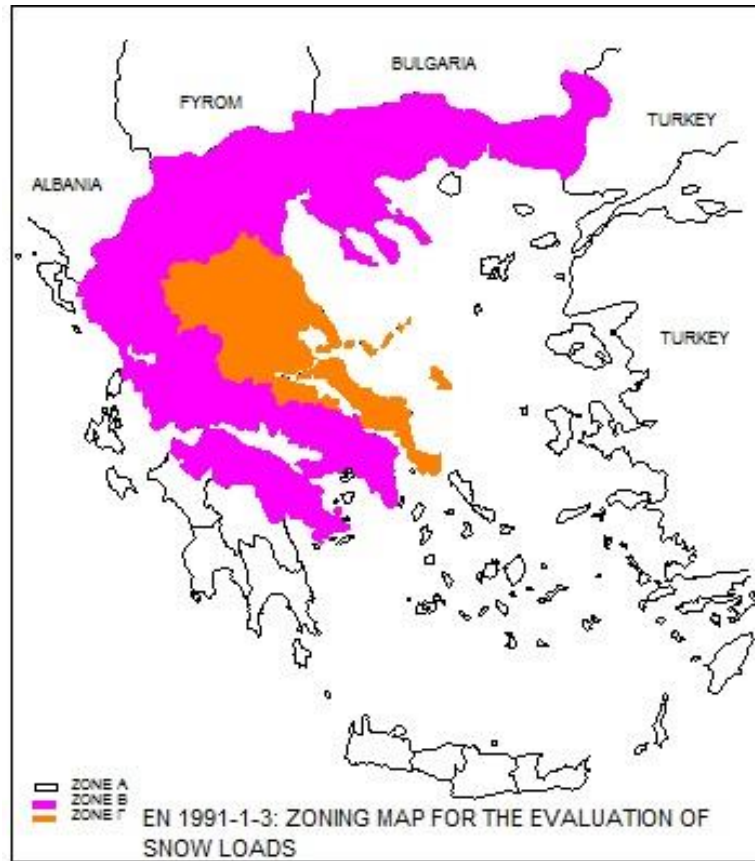


Figure 4.4 Zoning map for the evaluation of snow loads in Greece [© ELOT]

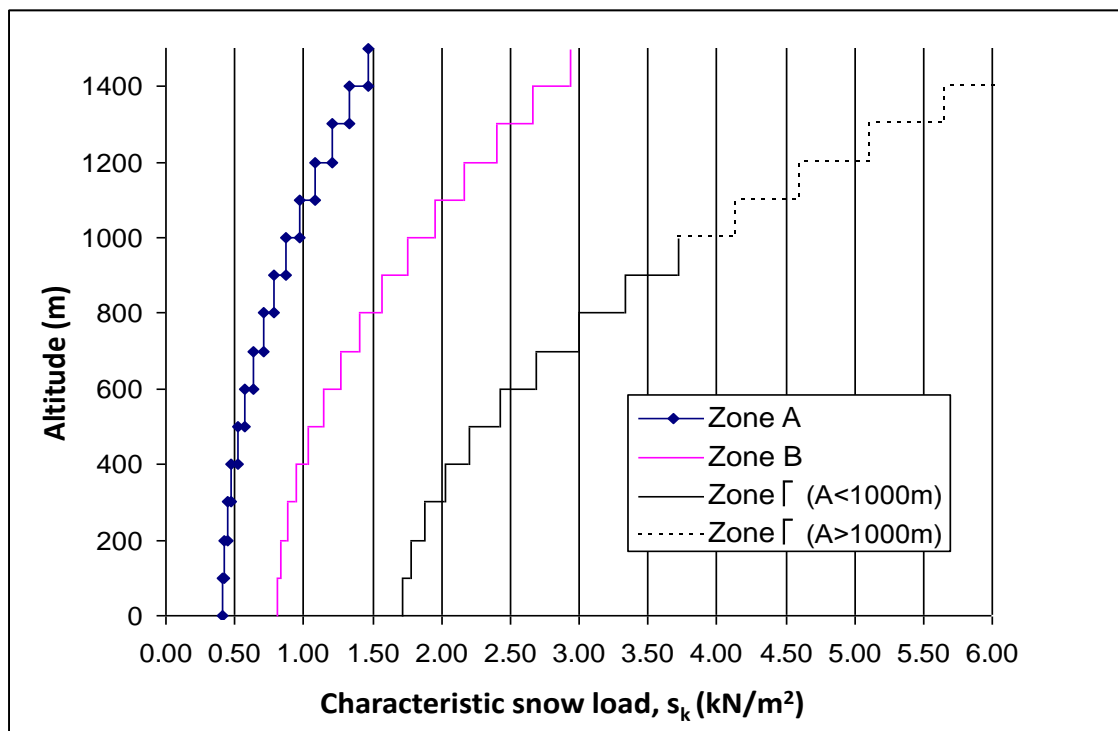


Figure 4.5 Characteristic snow loads in Greece as a function of the altitude [© Trezos]

4.3.2 Wind map for Greece

Until the implementation of the Eurocodes in Greece, initially as ENVs in the late '90ies and later on as ENs, DIN 1055 was being used for the consideration of the wind action in structural analysis. In view of the forthcoming Eurocodes an initial study has been undertaken (Tzanakis and Trezos, 1986), in which the characteristic values of the reference wind velocity were calculated and maps of equal velocity were elaborated. The data that served as a basis for the previous study were of two types: the quantitative data (wind speed in m/s or miles per hour) and the qualitative data (wind speed in Beaufort scale). Quantitative data (in m/s) were few in number (24 stations with an average observation period of 13 years), while qualitative data (in Beaufort) were much more numerous (82 stations with an average observation period of 23 years). Quantitative data were used to calculate characteristic values. According to this study, conservative estimates of the characteristic wind velocity (due to the limited number of quantitative data), were suggested as follows:

- islands and coastal zone of the mainland (within 10 km from the seashore): 36 m/s;
- rest of the Country: 30 m/s.

Several years later, in view of the adoption of the EN Eurocodes and following the gathering of a greater number of quantitative data by the National Meteorological Service, the re-calculation of the characteristic values of wind velocity from the total available quantitative data was decided (Trezos and Babiri, 2001). The data made available referred to the maximum monthly wind velocities in miles per hour and they were gathered from 31 meteorological stations belonging to the National Meteorological Service, within the Greek territory, with an average observation period of 40 years.

Initially the sensitivity of results in relation to the assumed distribution was examined by comparing (for all stations) the Gumbel extreme value distribution, the Weibull distribution, as well as the lognormal distribution.

As it was expected Weibull distribution leads systematically to smaller values, while Gumbel distribution leads to greater values. Gumbel and lognormal distributions have more or less the same results. More specifically, the mean values of the characteristic value of the wind velocity for the 31 stations have been, respectively 25.0 m/s (Weibull), 27.6 m/s (Gumbel) and 26.7 m/s (lognormal). Therefore the Gumbel distribution has been retained.

Given also the fact that the estimated parameter values depend on the method used for their evaluation, the three most common estimation methods, namely:

- Method of moments;
- Least square method (LSM);
- Maximum likelihood method.

As far as the sensitivity of the results on the estimation method was concerned, the least square method gives greater velocities in average, the method of moments gives smaller values, while the maximum likelihood method median values. More specifically, the mean values of the characteristic value of the wind velocity for the 31 stations have been, respectively 29.1 m/s (LSM), 27.6 m/s (Method of moments) and 28.2 m/s (Maximum likelihood method). Therefore the LSM has been retained.

In conclusion, differences associated to the type of distribution and the estimation method are not significant (compared to the location of the station). The results of the 31 stations were used to draw iso-velocity wind maps. The station network is not dense enough, so as to enable the calculation of the characteristic wind velocity in each region. However, by examining carefully the wind map, it allows the distinction of the Country in two or three zones with iso-velocities ranging between 35 m/s and 25 m/s.

The map of equal wind velocities based on the results of the most recent study available is shown in Figure 4.6. One can see that apart the Aegean sea, the zoning based on the distinction between mainland and coastal areas may be acceptable. Therefore, the choice for the Greek National Annex on wind actions was the adoption of the following two zones, shown in Figure 4.7:

- islands and coastal zone of the mainland (within 10 km from the seashore): 33 m/s;
- Rest of the Country: 27 m/s.

This choice practically corresponds to a reduction of the wind values adopted during the ENV phase, by 3 m/s.



**Figure 4.6 Map of equal wind velocities in Greece with return period 50 years
[© Trezos]**

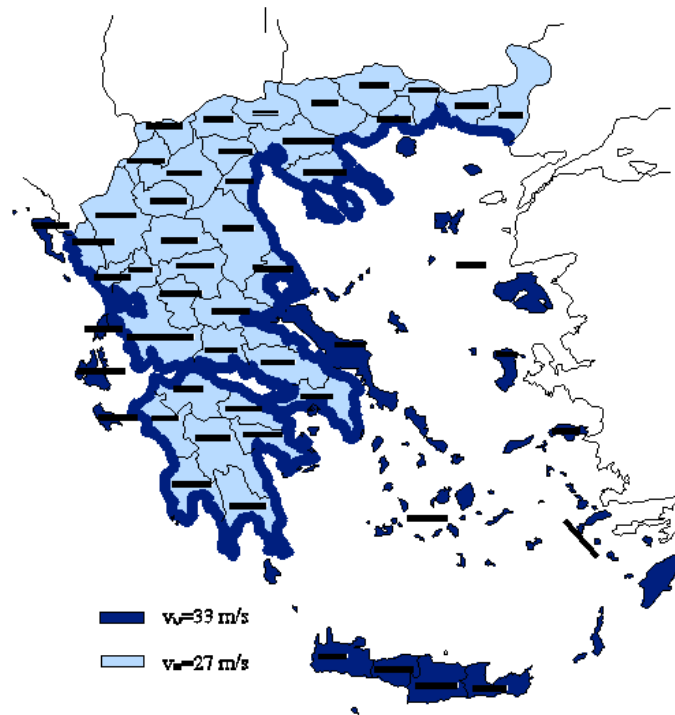


Figure 4.7 Map of wind velocities zones in Greece [© ELOT]

4.3.3 Temperature maps for Greece

The data have been collected from 44 temperature measurement stations in Greece with a satisfactory geographical distribution.

As for snow, a Gumbel distribution has been assumed for the yearly extreme (maximum and minimum) temperatures. Again three methods have been initially used for the assessment of site and scaling parameters, namely: method of least squares, method of moments and method of highest likelihood. As the differences of the results obtained were not significant, the least squares method (LSM) has been selected for the evaluation of the parameters. Subsequently the characteristic values of maximum and minimum temperatures have been established for a return period of 50 years.

Initially isotherm curves have been drawn, naturally following the correction required in order to obtain values at sea level (with a vertical temperature grade of $0.65^{\circ}/100$ m). The number of years of measurements in each station have also been considered as appropriate.

The maximum temperatures vary between approximately 39° and 48° and the isotherm curve of 45° covers practically most of the area of the continental part of the country. This is a reason for selecting only one or two zones.

As far as the minimum temperatures are concerned there is a clear variation from north to south. In most cases minimum temperatures vary between approximately -5° and -20°

A four zone approach associated to the division of administrative regions has been considered as the most sensible choice.

Taken into account some inaccuracy and other inconvenient of isotherm curve drawing, the use of maps with zoning has been considered more appropriate and has been adopted. In the following Figure 4.8 and Figure 4.9 the maximum and minimum, respectively, air shade temperatures for Greece are shown.

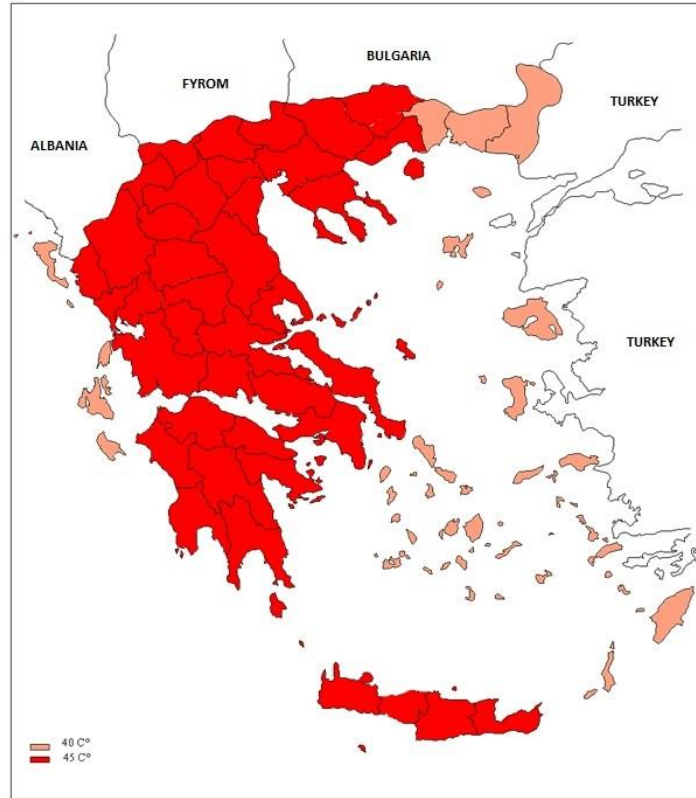


Figure 4.8 Map of maximum air shade temperatures in Greece [© ELOT]

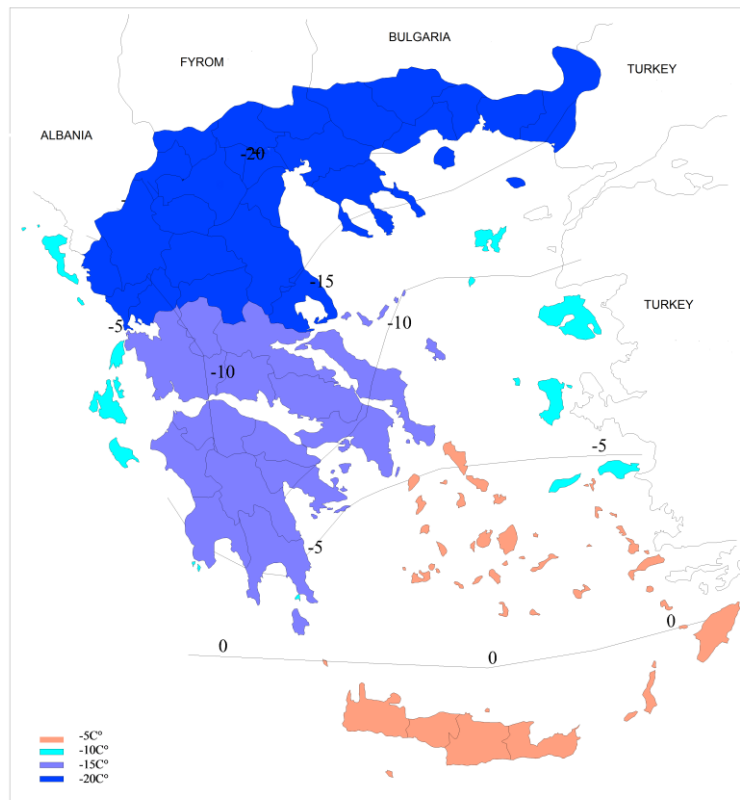


Figure 4.9 Map of minimum air shade temperatures in Greece [© ELOT]

4.4 Conclusions

The present Chapter 4 has a twofold purpose: an overview of the climatic actions as handled by the EN Eurocodes (including the perspectives for the coming years) and an ad-hoc presentation of the elaboration of maps for climatic actions in Greece.

Initially, a summarized general overview focusing on the key items of the three Eurocode Parts dealing with climatic actions, namely EN 1991-1-3 on Snow Loads, EN 1991-1-4 on Wind Actions and EN 1991-1-5 on Thermal Actions has been presented. A special mention has been given to a proposal, almost a decade ago, for an updating and the geographical extension of the European Snow Maps which served as a background for the drafting of EN 1991-1-3.

Subsequently, the existing situation, as per October 2015, as well the perspectives for the revision and possibly further development of the EN Eurocodes on climatic actions, has been outlined. The main tasks of the Project Teams to be established via official calls for tendering, as Phase II within the framework of the Mandate 515 (EC, 2012) have been cited, as well the role of a Project Team on potential impacts of climate change to be addressed by the Eurocodes.

In its second part, the background and the outcome of the elaboration of the snow load, wind actions and thermal actions maps for Greece, as established for being used in the relevant National Annexes of the EN Eurocodes, have been outlined and presented. It was recognized that the results have been unavoidably affected by some inadequacies, including the use of the data base. The Hellenic (Greek) Eurocodes Mirror Committee and the NSO are well aware of the situation and a future revision will hopefully be undertaken, where appropriate, including consideration of border zone issues, once more urgent items concerning the implementation of the Eurocodes are successfully addressed.

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CHAPTER 5

ELABORATION OF MAPS FOR CLIMATIC ACTIONS IN ITALY

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5 Elaboration of maps for climatic actions in Italy

5.1 Introduction

As stated in *Foreword* of Eurocodes, maps for climatic actions are typical country specific data, to be included in National Annex as Nationally Determined Parameters.

According to EN 1990, Sec.4, Clause 4.1.2(7)P, Note 2 "The characteristic value of climatic actions is based upon the probability of 0,02 of its time varying part being exceeded for a reference period of one year. This is equivalent to a mean return period of 50 years for the time-varying part."

Statistical elaboration of climatic data is a very complex procedure, as it should be adapted to specific features of the climatic region under examination.

In effect, aiming to define characteristic values, it is sufficient to analyse the statistics of annual maxima, so focusing on a discrete set, composed by one value per year of observation.

In general, typical steps of the procedure are:

1. selection of meteorological stations granting a sufficiently uniform coverage of the country or of the region in terms of area (longitude and latitude) as well as of altitude for the observed climatic variable (basic wind speed, weight or height and density of snow cover, maximum and minimum temperature), provided that the measurements are available for a sufficiently long time interval (30-50 years);
2. definition of the series of annual extreme values for the variable under consideration;
3. adoption of a suitable extreme value distribution, like extreme values type I distribution (Gumbel), GEV distribution, Weibull distribution, 3-parameters log-normal distribution, generalized Pareto distribution, checking *a posteriori* its aptness to represent the given variable;
4. elaboration of extreme values in order to obtain the characteristic value of the climatic variable (2% upper fractile of annual extrema);
5. definition of climatic maps identifying homogenous climatic areas: each climatic area is characterized by a particular relationship expressing the characteristic value of the climatic variable as function of the altitude of the site;
6. when, like in Italy, climatic variables depend on the altitude, the values previously determined at the actual altitude are modified according to the above mentioned relationship, in such a way that climatic maps are referred to sea level.

In the present chapter, elaboration of Italian maps for climatic actions, snow, wind and temperature, is discussed.

5.2 Snow map

The Italian snow map (National Annex to EN1991-1-3, 2013) is based on the results of a wide research carried out in the late 90th by eight European research institutions (Del Corso

et al. 1995) and promoted by the DG III of the European Commission (DG III European Commission, 1998; DG III European Commission, 1999).

Beside the collection and the processing of a large amount of snow load data for most part of the European territory, the aim of the study was to define common methods to evaluate the ground snow loads in European countries, to be used in developing EN1991-1-3, also in order to reduce inconsistencies of snow load values in CEN Member States and at borderlines between different countries.

In the territory of the 18 CEN countries covered by the above mentioned research, the ten different homogeneous major climatic regions illustrated in Figure 1.1 were identified, each one characterized by a particular snow load-altitude relationship.



**Figure 5.1 Major climatic Regions for snow loads;
(adapted from Sanpaolesi et al., 1998 and 1999) [© CEN]**

As highlighted by the red box in Figure 5.1, Italy belongs to two major climatic regions: the Alpine Region and the Mediterranean Region, which are covered by the weather stations shown in Figure 5.2.



Figure 5.2 Weather stations considered for snow load measurements

In regions having mild climatic conditions, like the Mediterranean one, the snow melts during the period between two consecutive low pressure weather systems. The snow cover is often the result of one single snow event and any following snow event may be

considered to be statistically independent from the first one, even if, in some other case, it can happen that rain accumulates in the snow cover, determining very high density of the snow cover, that can achieve values of 500-600 kg/m³.

On the contrary, in areas with continental climate and in mountains regions, the snow cover is the result of the accumulation of several layers, so that the maximum snow load is registered after several consecutive snow falls. Anyhow, the statistical analysis has been performed taking into account the recorded loads, irrespective of the fact that they are the result of either an accumulation or a single snow event.

In some weather station, the records often contain some years without any snow cover. In these cases a mixed distribution has been used, taking into account the average percentage of snowy years.

They have been also observed in some samples one or more annual maximum values of snow load which do not fit well the remaining data. These values are often observed in Mediterranean Region: a typical example is reported in Figure 5.3, concerning the elaboration of snow load on ground in Pistoia, located in the Italian region of Tuscany. In this Gumbel plot, the annual maximum of 1,3 kN/m² is clearly outside the statistical series: in fact, the dashed line best fitting the whole data set is not able to cover the outlier, so that it cannot be treated as belonging to the statistical sample. For this reason, the outliers are treated as accidental values and disregarded in the analysis of the population of the extreme values. The best fitting of the so corrected population is represented by the continuous line in the graph (see also chapter 1, section 1.2.2.2).

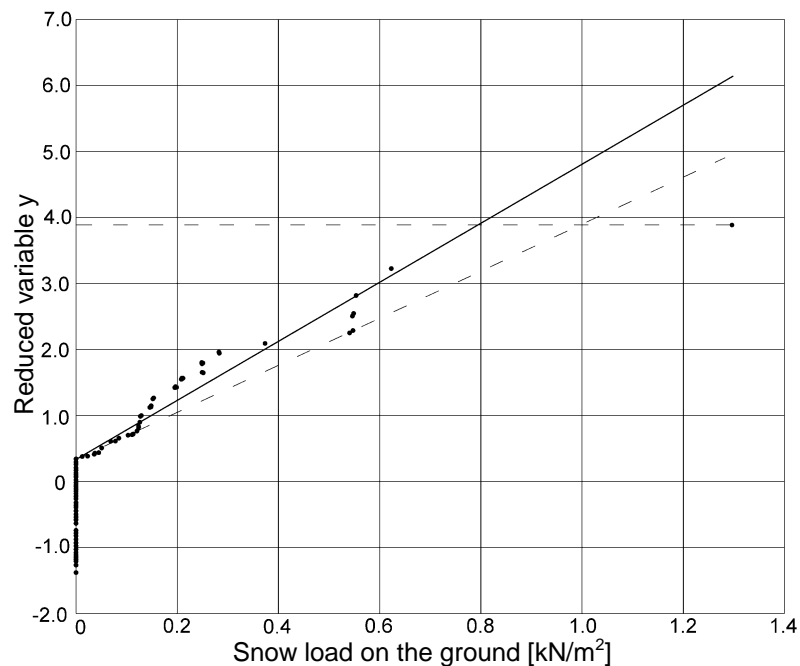


Figure 5.3 Elaboration of snow load data on the ground (Pistoia)

The regression analyses carried out in the aforesaid research showed that in Alpine Region (see Figure 5.4) and in Mediterranean Region the characteristic value of the snow load, s_k , depends on the square of the altitude A , according to Eqn. (5.1)

$$s_k = z \left[1 + \left(\frac{A}{b} \right)^2 \right], \quad (5.1)$$

where z and b are suitable parameters, depending on the climatic zone.

It must be pointed out that Eqn. (5.1) holds also for other European climatic Regions, except Central West Region, Sweden and Finland, UK and Eire, where s_k depends linearly on A and for Norway, where s_k is independent on A .

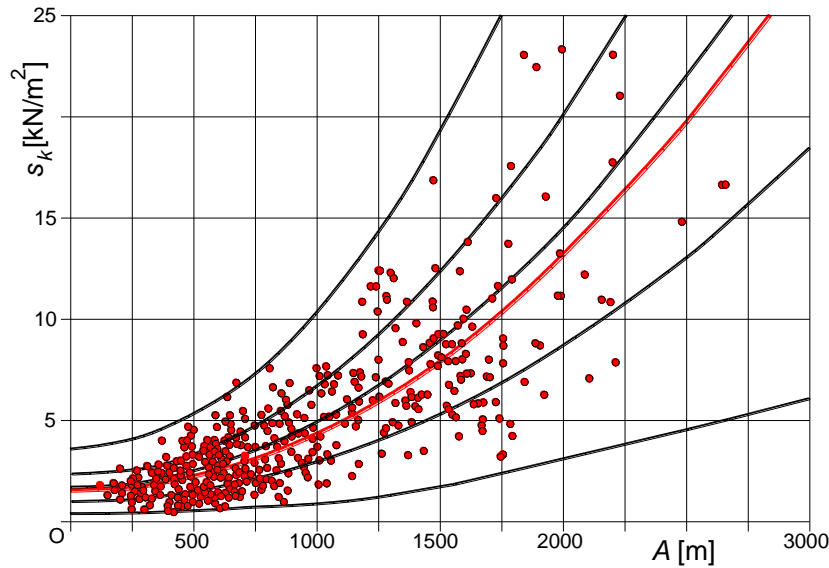


Figure 5.4 $s_k - A$ plot for the Alpine Region

Concerning Italy, the final outcomes of the study were local maps indicating the s_k values at the sea level, for the Alpine Region (Figure 5.5) and for the Mediterranean Region (Figure 5.6), from which it is possible to identify three different Zones, which have been considered as basis for the definition of the Italian snow map, reported in the Italian National Annex (NA) to EN1991-1-3 (Figure 5.7). In the map, Zone I is represented in green, Zone II in light blue and Zone III in white.

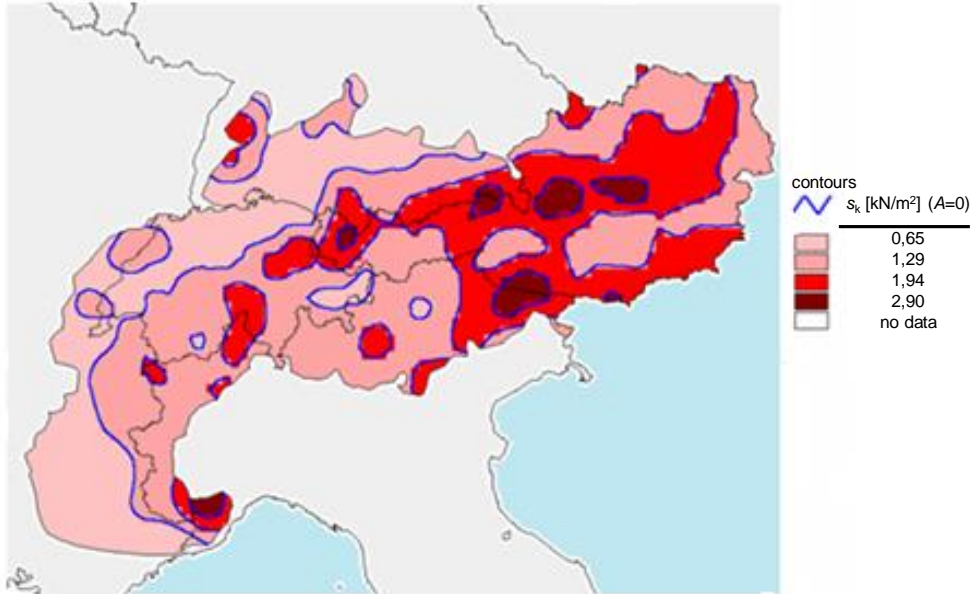


Figure 5.5 Characteristic values of snow load at the ground at sea level in Italy (Alpine Region) (Sanpaolesi et al., 1998 and 1999) [© CEN]

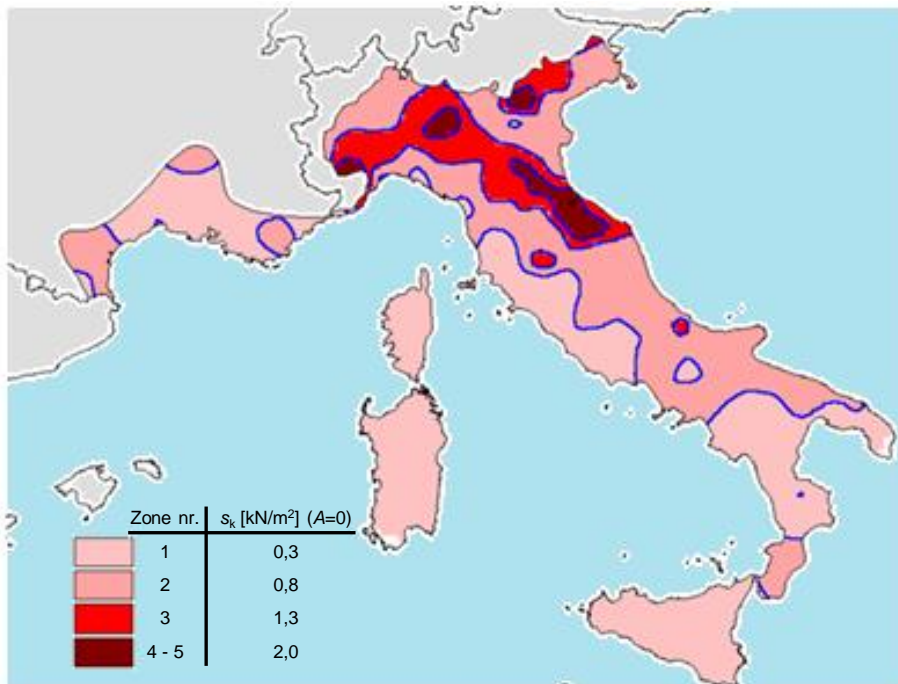


Figure 5.6 Characteristic values of snow load at the ground at sea level in Italy (Mediterranean Region) (Sanpaolesi et al., 1998 and 1999) [© CEN]

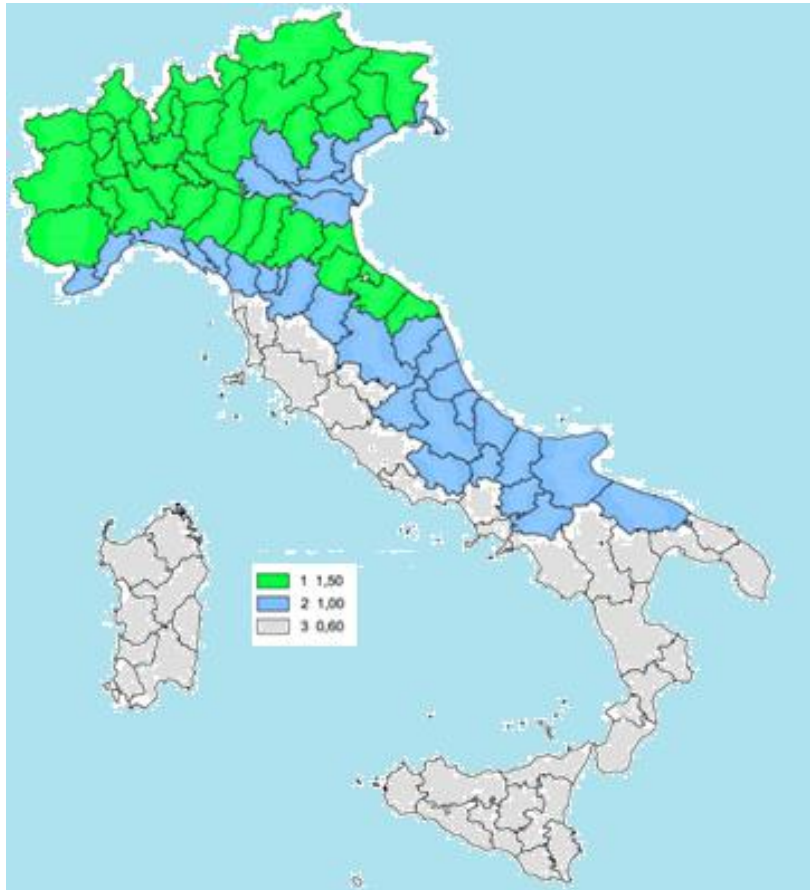


Figure 5.7 Italian Map for snow load at sea level [kN/m]

It must be stressed that the separations between Zone I and Zone II and the separation between Zone II and Zone III correspond to administrative borders of provinces and that map in Figure 5.7 is updated taking into account the most recent amendments to Italian NA.

The $s_k - A$ relationships in the three Zones are expressed, respectively, by

$$\begin{aligned}
 s_k &= 1,50 \text{ kN/m}^2 && \text{if } A \leq 200 \text{ m} \\
 s_k &= 1,35 \left[1 + \left(\frac{1}{602} \frac{A}{\text{m}} \right)^2 \right] \text{ kN/m}^2 && \text{if } A > 200 \text{ m},
 \end{aligned}
 \tag{5.2}$$

in Zone I, by

$$\begin{aligned}
 s_k &= 1,00 \text{ kN/m}^2 && \text{if } A \leq 200 \text{ m} \\
 s_k &= 0,85 \left[1 + \left(\frac{1}{481} \frac{A}{\text{m}} \right)^2 \right] \text{ kN/m}^2 && \text{if } A > 200 \text{ m},
 \end{aligned}
 \tag{5.3}$$

in Zone II and by

$$s_k = 0,60 \text{ kN/m}^2 \quad \text{if } A \leq 200 \text{ m}$$
$$s_k = 0,51 \left[1 + \left(\frac{1}{481 \text{ m}} A \right)^2 \right] \text{ kN/m}^2 \quad \text{if } A > 200 \text{ m}, \quad (5.4)$$

in Zone III.

Use of Eqns. (5.2), (5.3) and (5.4) is allowed only for altitudes $A \leq 1500$ m. For $A > 1500$ m *ad hoc* studies are required, but in this case $s_k = \max [s_k(A=1500 \text{ m}); s_k(A)]$.

The coefficient of variation for snow loads is around 0,3 in the Alpine Region, while in the Mediterranean Region is usually 0,7, but it can attain values around 1,0.

5.2.1 Worked examples

In the following, the practical application of the snow map is illustrated, evaluating the snow load at the ground in three different sites: Novi Ligure (AL), San Marcello Pistoiese (PT), Avigliano (PZ).

5.2.1.1 Snow load at the ground in Novi Ligure

Novi Ligure is in Piedmont, in province of Alessandria, at an altitude $A=150$ m above sea level.

It belongs to Zone I, therefore, as $A < 200$ m, it follows from Eqn. (5.2) $s_k = 1,50 \text{ kN/m}^2$.

5.2.1.2 Snow load at the ground in San Marcello Pistoiese

San Marcello Pistoiese is in Tuscany, in province of Pistoia, at an altitude $A=623$ m above sea level.

It belongs to Zone II, therefore, as $A > 200$ m, it follows from Eqn. (5.3), that $s_k = 0,85(1 + (623/481)^2) = 2,28 \text{ kN/m}^2$.

5.2.1.3 Snow load at the ground in Avigliano

Avigliano is in Basilicata, in province of Potenza, at an altitude $A=867$ m above sea level.

It belongs to Zone III, therefore, as $A > 200$ m, it follows from Eqn. (5.4), that $s_k = 0,51(1 + (867/481)^2) = 2,17 \text{ kN/m}^2$.

5.3 Thermal actions

The Italian thermal map (National Annex to EN1991-1-5, 2013) is based (Froli and al., 1994) on the results of the elaboration of the databank of measurements of the air temperature in shade, collected by the Information service of the Italian Ministry of Forestry, Agricultural and Food Resources in about 370 weather stations across Italy, which are summarized in Figure 5.8. The databank contains information coming from different sources, and in particular from the Italian Air Force.



Figure 5.8 Weather stations for measurements of air temperature in shade

Assuming Gumbel-type distribution of extrema, the data collected, elaborated again according the general procedure recalled before, allowed to determine for each site the characteristic values of the maximum and minimum air temperature in shade, T_{\max} and T_{\min} , respectively, as well as four homogenous climatic region, each one characterized by suitable $T_{\max}-A$ and $T_{\min}-A$ relationships, obtained by means of regression analysis. The results, summarized in Figure 5.9 for Zone I, North, in Figure 5.10 for Zone II, West, in Figure 5.11 for Zone III, East, and in Figure 5.12 for Zone IV, South, clearly demonstrate that T_{\max} and T_{\min} depend linearly on A , and that the slope of the lines depends on the climatic zone.

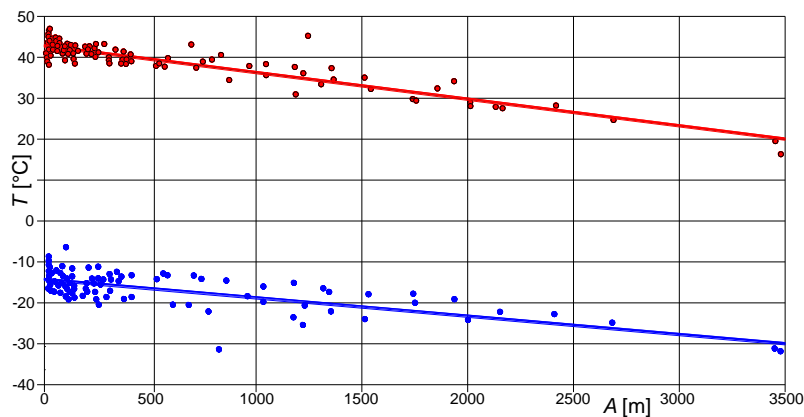


Figure 5.9 $T_{\max}-A$ and $T_{\min}-A$ plots for Zone I (North) in Italy

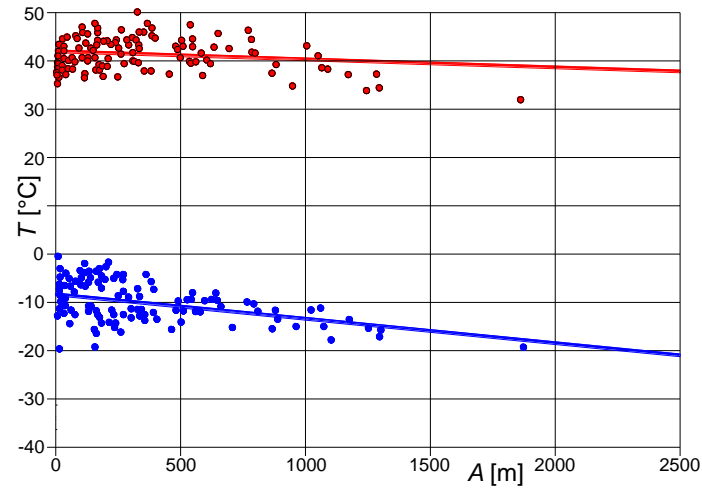


Figure 5.10 T_{\max} - A and T_{\min} - A plots for Zone II (West) in Italy

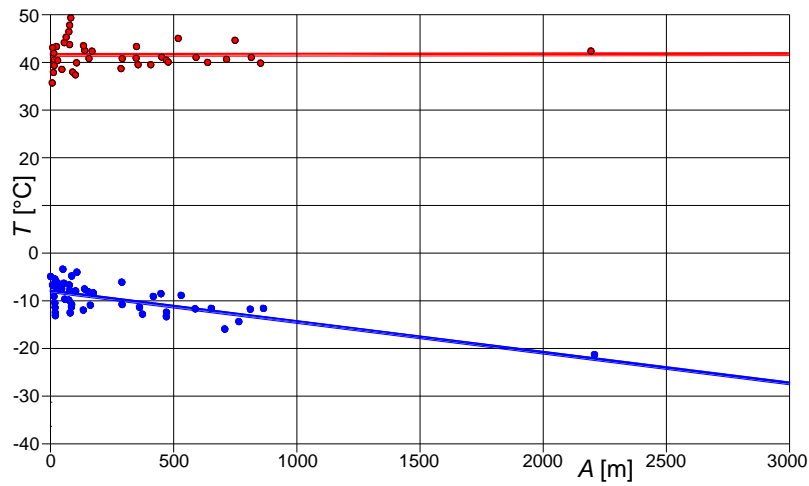


Figure 5.11 T_{\max} - A and T_{\min} - A plots for Zone III (East) in Italy

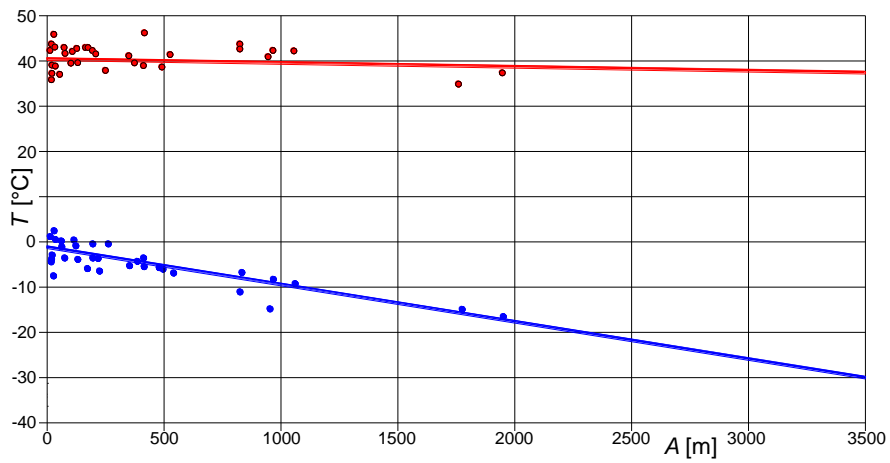


Figure 5.12 T_{\max} - A and T_{\min} - A plots for Zone IV (South) in Italy

Comparison of different curves, illustrated in Figure 5.13, demonstrates that:

- at the sea level, the mean characteristic value of T_{\max} can be assumed around 42 °C independently on the Zone, while the mean characteristic value of T_{\min} is around -15 °C in Zone 1, -8 °C in Zones II and III and -2 °C in Zone IV;
- the slope of the T_{\max} -A line is more pronounced in Zone I than in Zones II and IV, being practically zero in Zone III, while,
- on the contrary, the T_{\min} -A lines characterized by maximum and minimum slope pertain to Zone IV, and Zone I, respectively.

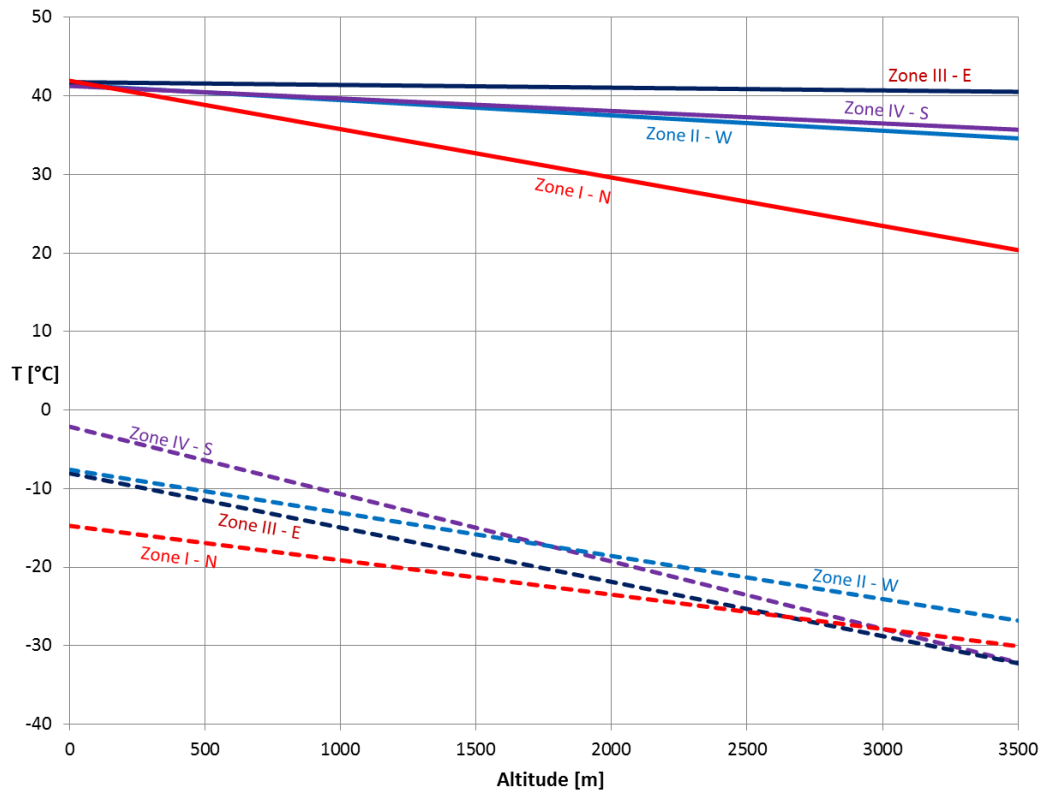


Figure 5.13 T_{\max} -A and T_{\min} -A curves in the four climatic Zones

The upper limits of T_{\max} derived from data elaboration are around 48 °C in Zone I and in Zone IV and around 50 °C in Zones II and III, while, considering sites with $A < 1000$ m, the lower limits of T_{\min} are below -30 °C in Zone I, around -20 °C in Zone II, and around -16 °C in Zones III and IV. It must be highlighted that, in some cases, these values do not correspond with the highest and lowest temperatures actually measured; in effect, the maximum temperatures ever recorded in Italy are around 48 °C in Zones II, III and IV and around 42 °C in Zone I; the minimum temperatures recorded at low altitudes are around -25 °C in Zone I, -23 °C in Zones II and III and -15 °C in Zone IV. Anyhow, these discrepancies are much less significant than it might appear at first sight, since it must be considered that, as well as with snow and wind actions, results are averaged and normalized at regional level, so that very extreme values can be considered as outliers, to be taken into account in accidental design situations.

Reduction at the sea level of the above mentioned data allowed to determine the contour maps of T_{\max} and T_{\min} , reported in Figure 5.14 and Figure 5.15, respectively, leading to the climatic map of Figure 5.16, where separations between adjacent Zones correspond to administrative Regional borders.

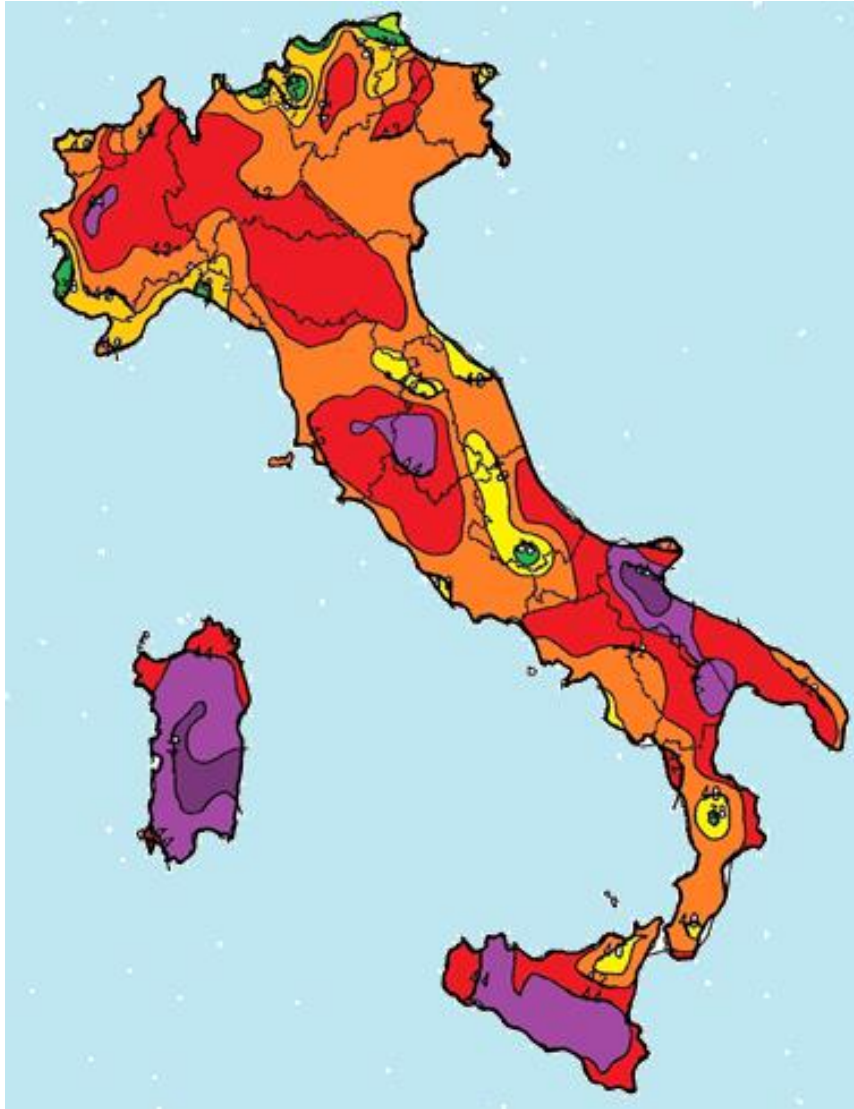


Figure 5.14 T_{max} ($t_R=50$ years) contours in Italy



Figure 5.15 T_{\min} ($t_R=50$ years) contours in Italy



Figure 5.16 Climatic Zones for temperature in Italy

The $T_{\min} - A$ and $T_{\max} - A$ relationships in the four Zones are expressed, respectively, by

$$T_{\min} = \left(-15 - \frac{4}{1000} \frac{A}{\text{m}} \right) ^\circ\text{C}, \quad (5.5)$$

$$T_{\max} = \left(42 - \frac{6}{1000} \frac{A}{\text{m}} \right) ^\circ\text{C},$$

in Zone I,

$$T_{\min} = \left(-8 - \frac{6}{1000} \frac{A}{\text{m}} \right) ^\circ\text{C},$$

$$T_{\max} = \left(42 - \frac{2}{1000} \frac{A}{\text{m}} \right) ^\circ\text{C}, \quad (5.6)$$

in Zone II,

$$T_{\min} = \left(-8 - \frac{7}{1000} \frac{A}{\text{m}} \right) ^\circ\text{C},$$

(5.7)

$$T_{\max} = \left(42 - \frac{0,3}{1000} \frac{A}{\text{m}} \right) ^\circ\text{C},$$

in Zone III, and

$$T_{\min} = \left(-2 - \frac{9}{1000} \frac{A}{\text{m}} \right) ^\circ\text{C},$$

(5.8)

$$T_{\max} = \left(42 - \frac{2}{1000} \frac{A}{\text{m}} \right) ^\circ\text{C},$$

in Zone IV.

5.3.1 Worked examples

In the following, the practical application of thermal map is illustrated, evaluating T_{\min} and T_{\max} in four different sites: Sasso Marconi (BO), Ceprano (FR), Santa Croce di Magliano (CB) and Zafferana Etnea (CT).

5.3.1.1 Thermal actions in Sasso Marconi

Sasso Marconi is in Emilia Romagna, in province of Bologna, at an altitude $A=128$ m above sea level.

It belongs to Zone I, therefore, it follows from Eqn. (5.5) $T_{\min} = -15 - 0,004 \cdot 128 = -15,5$ °C and $T_{\max} = 42 - 0,006 \cdot 128 = 41,2$ °C.

5.3.1.2 Thermal actions in Ceprano

Ceprano is in Lazio, in province of Frosinone, at an altitude $A = 105$ m above sea level.

It belongs to Zone II, therefore, it follows from Eqn. (5.6) $T_{\min} = -8 - 0,006 \cdot 105 = -8,6$ °C and $T_{\max} = 42 - 0,002 \cdot 105 = 41,8$ °C.

5.3.1.3 Thermal actions in Santa Croce di Magliano

Santa Croce di Magliano is in Molise, in province of Campobasso, at an altitude $A = 608$ m above sea level.

It belongs to Zone III, therefore, it follows from Eqn. (5.7) $T_{\min} = -8 - 0,007 \cdot 608 = -12,3$ °C and $T_{\max} = 42 - 0,0003 \cdot 608 = 41,8$ °C.

5.3.1.4 Thermal actions in Zafferana Etnea

Zafferana Etnea is in Sicily, in province of Catania, at an altitude $A = 574$ m above sea level.

It belongs to Zone IV, therefore, it follows from Eqn. (5.8) $T_{\min} = -2 - 0,009 \cdot 574 = -7,2$ °C and $T_{\max} = 42 - 0,002 \cdot 574 = 40,8$ °C.

5.4 Wind actions

The Italian wind map (National Annex to EN1991-1-4, 2013) is based on the results of the elaboration of the wind measurements mainly made by the meteorological service of the Italian Air Force.

According the EN1991-1-4, Sec. 1, Def. 1.6.1 the fundamental basic wind velocity is "the 10 minute mean wind velocity with an annual risk of being exceeded of 0,02, irrespective of wind direction, at a height of 10 m above flat open country terrain and accounting for altitude effects (if required)".

Elaboration of data has been carried out again according the procedure recalled before, generally hypothesizing type I Gumbel distribution of annual extrema.

It must be pointed out that recently the ability of the Gumbel distribution to fit wind data has been questioned, appealing that, especially in Northern European Countries, Gumbel distribution overestimates the fundamental basic wind velocity and that three-parameter log-normal distribution or Weibull distribution lead to more realistic values.

One typical example is reported in Figure 5.17 representing in a Gumbel plot the annual maxima of the basic wind velocity recorded in Schipol Airport (NL) in years 1950-2002.

In Figure 5.17, the Gumbel distribution fitting the experimental data is represented by the red line, leading to a fundamental value around 29 m/s.

In the author opinion, various extreme value distributions, that differ in some way only in the upper tail region, could fit satisfactorily the measurements. In effect, it must be highlighted that, since measured annual maxima falling in the upper tail are very few and that some values can be regarded as outliers, usually, the amount of measured extreme values available does not allows to select the "best" extreme distribution, also because the fundamental wind velocity is no high enough to be excluded for physical reasons.

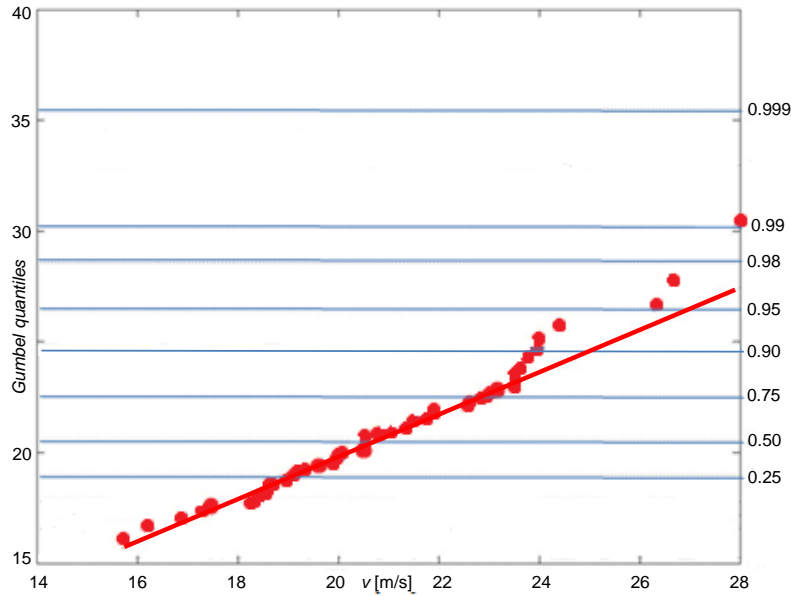


Figure 5.17 Gumbel plot of annual maxima of wind velocity in Schipol Airport

Considering as representative parameter of a given data set its skewness, an alternative way has been suggested to establish what kind of extreme distribution best fit the data; in fact, the Gumbel distribution is characterized by $Sk=1,14$, the Weibull distribution is characterized by $Sk<1,14$ and the Fréchet distribution by $Sk>1,14$. But, also this criterion is questionable, as it results excessively sensitive to the available data, as it can be easily demonstrated, referring to a real case study (see §5.4.1).

5.4.1 Elaboration of wind velocity data in Pisa Airport

In the present paragraph, it is discussed the elaboration of the annual maxima of wind velocity, measured in Pisa Airport in the period 1973-2015 and reported, year by year, in Figure 5.18.

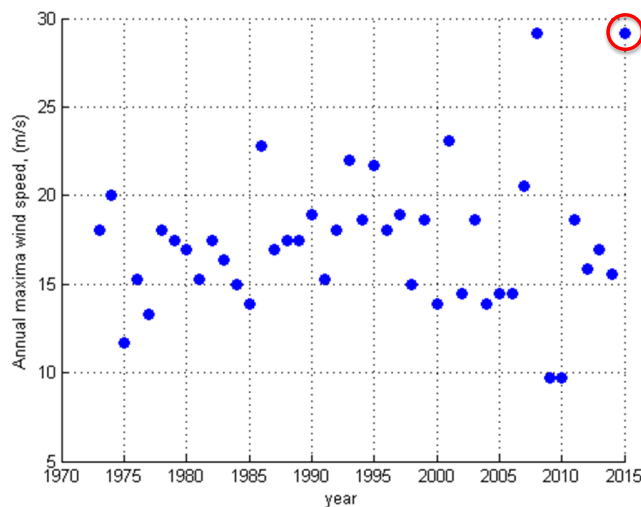


Figure 5.18 Annual maxima of wind velocity in Pisa Airport

From the diagram it is evident that the absolute maximum of the measured wind velocity, 29,2 m/s around, occurred twice, in 2008 and the 5 March 2015, when a very strong northeast wind storm (Gregale) occurred in Tuscany coastal areas.

To evaluate as the content of data set influences the results, data have been elaborated including or neglecting the latest datum, referring to 2015, highlighted with the red circle in Figure 5.18.

The results of the elaborations are illustrated in the Gumbel plot of Figure 5.19 for the period 1973-2014, so neglecting the information regarding year 2015, and in the Gumbel plot in Figure 5.20 for the period 1973-2015. In both diagrams they have been drawn the Gumbel lines obtained by means of the method of moments (red line) and by the method of maximum likelihood (blue line), as well as the skewness (Sk) of the distribution and the fundamental basic wind velocities (characteristic values, v_k) derived by means of the above mentioned methods.

As expected, these outcomes clearly demonstrate that the characteristic basic wind velocity depend of the method used to fit the data and are strongly influenced by the highest recorded values. In effect, the method of moment gives a value of 27,45 m/s for v_k , disregarding 2015, which becomes 28,97 m/s including 2015, while the method of maximum likelihood gives a value of 27,10 m/s, for v_k , disregarding 2015 and again 28,97 m/s including 2015.

Moreover, the influence of the 2015 measurement on skewness is even stronger, in fact, including 2015, it is $Sk=0,929$, while, disregarding 2015, it is $Sk=0,463$, so indicating that skewness is a very weak indicator of the ability of the extreme value distribution to fit experimental data.

In conclusion, as inherent uncertainties are comparable with differences in estimates obtained with different distributions, it is confirmed that setup of objective criteria for the choice of the distribution is very hard.

Anyhow, the results match with the assumption that extreme wind data in Italy are usually described by Gumbel distribution, with coefficient of variation $CoV \approx 0,2$.

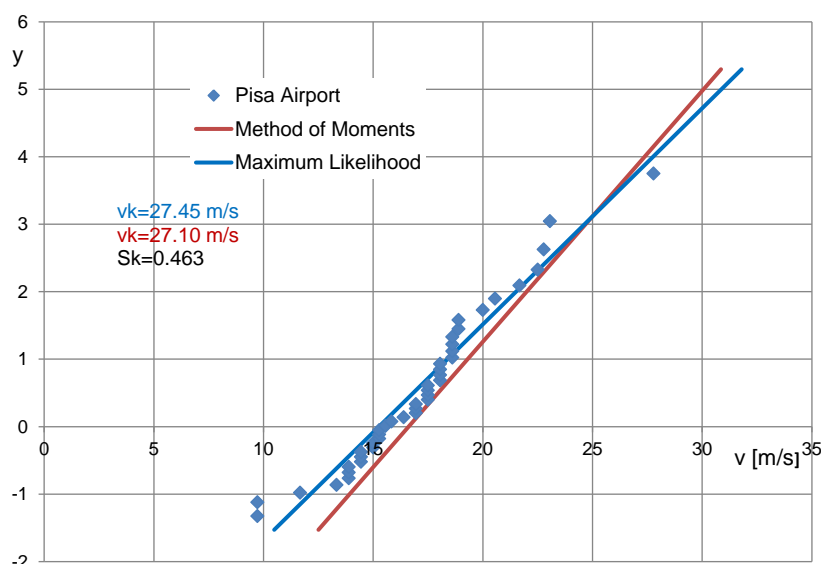


Figure 5.19 Gumbel plot of wind velocity in Pisa Airport (1973-2014)

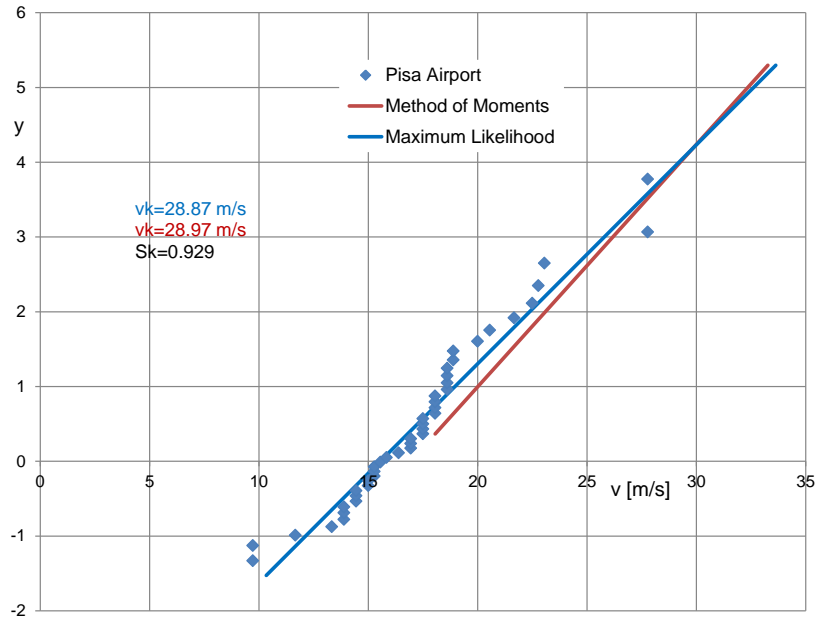


Figure 5.20 Gumbel plot of wind velocity in Pisa Airport (1973-2015)

5.4.2 Wind map and terrain categories in Italy

The regression analysis allowed to determine 9 Zones for fundamental basic wind velocities, illustrated in Figure 5.21.

In each Zone, the relationship between the altitude and the basic wind velocity v_b is expressed by the Eqns.

$$\begin{aligned}
 v_b &= v_{b,0} && \text{if } A \leq A_0, \\
 v_b &= v_{b,0} + k_a(A - A_0) && \text{if } A > A_0,
 \end{aligned}
 \tag{5.9}$$

where $v_{b,0}$ is the fundamental basic wind velocity at sea level, A is the altitude of the site, in m, A_0 is the reference altitude, in m, and the coefficient k_a , in s^{-1} , is the slope of the line.

For each Zone of the map, the values of the parameters to be introduced in (5.9) are given in Table 5.1.

As known, the variation of the wind velocity profile with the altitude above the ground is influenced by the terrain exposure category, that determines the extension z_g of the atmospheric boundary layer, as shown in Figure 5.22.

In Italy, five terrain exposure categories are identified, depending on the Zone, on the distance from the shoreline, on the altitude above sea level of the building site and on the terrain roughness.

According to Table 5.2, four types of terrain are identified in term of roughness, being the roughness decreasing from A to D.

Once known the terrain roughness and the building site, the terrain category can be derived from Figure 5.23.

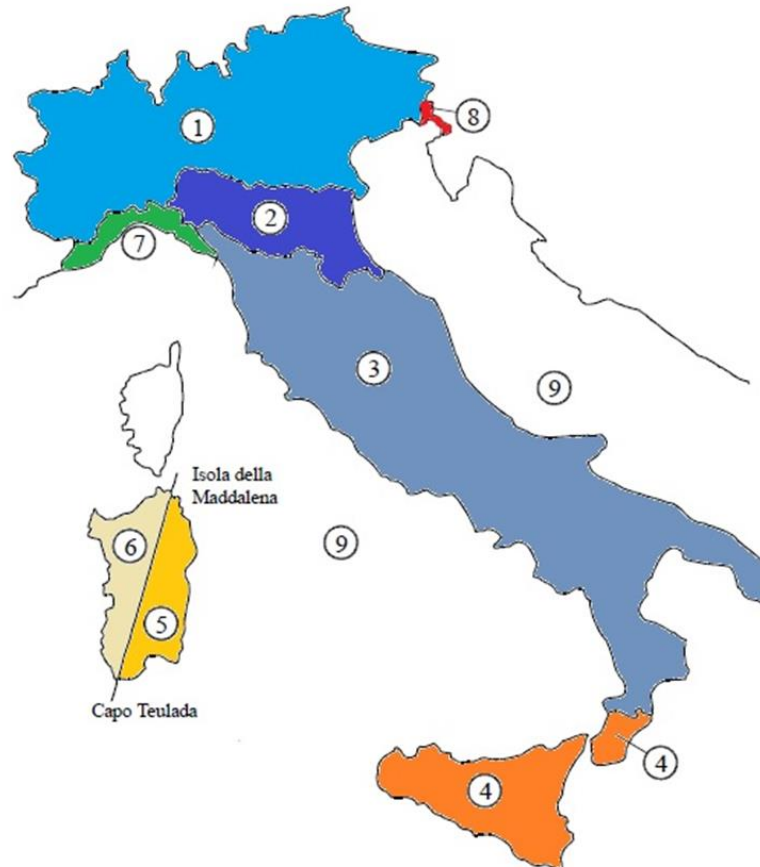


Figure 5.21 Climatic zones for fundamental basic wind velocities in Italy

Table 5.1 Values of parameters of $v_{b,0}$ -A relationship in Italian wind zones

Zone	Description	$v_{b,0}$ [m/s]	A_0 [m]	k_a [1/s]
1	Valle d'Aosta, Piedmont, Lombardy, Trentino Alto Adige, Veneto, Friuli Venezia Giulia except province of Trieste	25	1000	0,010
2	Emilia Romagna	25	750	0,015
3	Tuscany, Marche, Umbria, Lazio, Abruzzo, Molise, Puglia, Campania, Basilicata, Calabria, except province of Reggio Calabria	27	500	0,020
4	Sicily and province of Reggio Calabria	28	500	0,020
5	Sardinia (zone east of the line connecting Capo Teulada with Isola di Maddalena)	28	750	0,015
6	Sardinia (zone west of the line connecting Capo Teulada with Isola di Maddalena)	28	500	0,020
7	Liguria	28	1000	0,015
8	Province of Trieste	30	1500	0,010
9	Islands (except Sicilia and Sardinia) and open sea	31	500	0,020

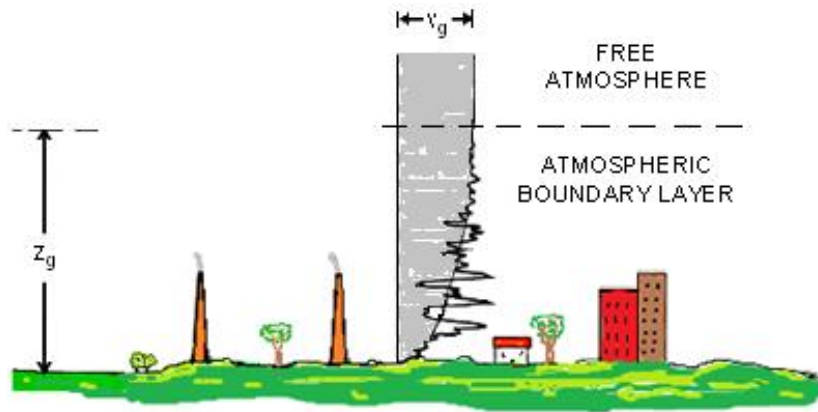


Figure 5.22 Wind velocity profile

Table 5.2 Classification of terrain roughness

Terrain roughness	Description
A	Urban areas with not less of 15% of surface is covered by buildings whose height is bigger than 15 m
B	Urban areas not belonging to class A, suburban, industrial and wooden areas
C	Area with dispersed obstacles (trees, buildings, walls, fences ...); areas with roughness not belonging to classes A, B, D
D	Areas with no obstacles (open land, airports, agricultural areas, pastures, wetlands or sandy lands, surfaces covered by snow or ice, open sea, lakes ...)

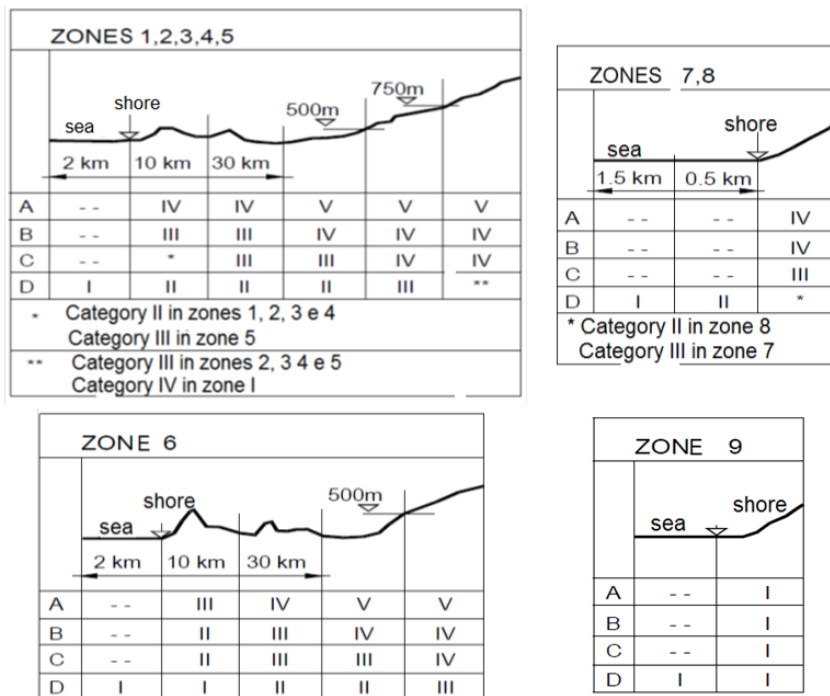


Figure 5.23 Identification of terrain category

Finally, adopting the parameters k_r , z_0 and z_{\min} given in Table 5.3 in function of the terrain exposure category, the exposure factor $c_e(z)$ in terms of wind pressure can be derived from Eqn. (5.10):

$$c_e(z) = k_r^2 c_t \ln \frac{z}{z_0} \left[7 + c_0 \ln \frac{z}{z_0} \right] \quad \text{if } z \geq z_{\min},$$

$$c_e(z) = c_e(z_{\min}) \quad \text{if } z < z_{\min},$$
(5.10)

where, c_0 is the orography factor.

The c_e - z curves for the five terrain exposure categories are illustrated in Figure 5.24.

Table 5.3 Values of parameters depending on terrain exposure category

Terrain exposure category	k_r	z_0 [m]	z_{\min} [m]
I	0,17	0,01	2
II	0,19	0,05	4
III	0,20	0,10	5
IV	0,22	0,30	8
V	0,23	0,70	12

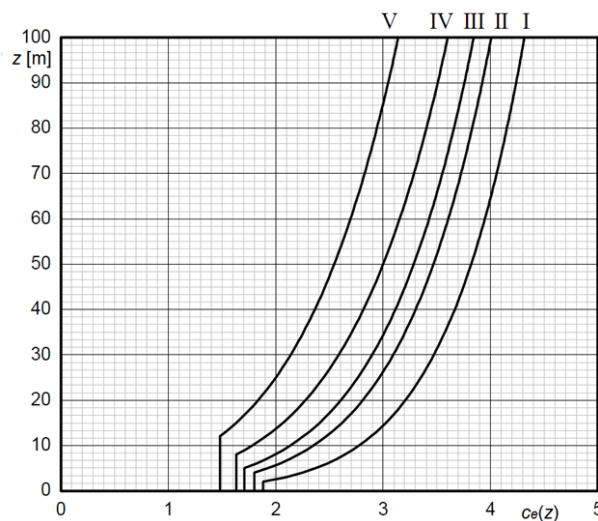


Figure 5.24 c_e - z curves for different terrain categories [© NTC 2008]

5.4.3 Worked examples

In the following, the practical application of wind map is illustrated, evaluating terrain exposure category in four different sites: Pisa, considering urban area of roughness B; Trieste, considering urban area of roughness A; Portoferraio, Tuscany, Isola d'Elba, considering waterfront, open area of roughness D; Santa Croce di Magliano, Molise, considering area with dispersed obstacles of roughness C; Zafferana Etnea, Sicily, considering area with dispersed obstacles of roughness C.

5.4.3.1 Wind actions in Pisa

Pisa is in Tuscany, Zone 3, $v_{b,0}=27$ m/s, $A_0=500$ m, $k_a=0,020$ s⁻¹ at an altitude $A=12$ m above sea level, $v_b=27$ m/s, and a distance from the shore less than 10 km.

With these data and considering urban area of roughness B, from Figure 5.23 it results in a terrain exposure of category III, and, from Table 5.3, $k_r=0,20$, $z_0=0,10$ m, $z_{min}=5$ m.

5.4.3.2 Wind actions in Trieste

Trieste is in province of Trieste, Zone 8, $v_{b,0}=30$ m/s, $A_0=1500$ m, $k_a=0,010$ s⁻¹ at an altitude $A=2$ m above sea level, $v_b=30$ m/s.

With these data and considering urban area of roughness A, from Figure 5.23 it results in a terrain exposure of category IV, and, from Table 5.3, $k_r=0,22$, $z_0=0,30$ m, $z_{min}=8$ m.

5.4.3.3 Wind actions in Portoferraio

Portoferraio is in the Isola d'Elba, Zone 9, $v_{b,0}=31$ m/s, $A_0=500$ m, $k_a=0,030$ s⁻¹ at an altitude $A=4$ m above sea level, $v_b=31$ m/s.

With these data and considering waterfront, open area of roughness D, from Figure 5.23 it results in a terrain exposure of category I, and, from Table 5.3, $k_r=0,17$, $z_0=0,01$ m, $z_{min}=2$ m.

5.4.3.4 Wind actions in S. Croce di Magliano

Santa Croce di Magliano is in Molise, Zone 3, $v_{b,0}=27$ m/s, $A_0=500$ m, $k_a=0,020$ s⁻¹ at an altitude $A=608$ m above sea level, $v_b=29,16$ m/s, and a distance from the shore less than 30 km.

With these data and considering area with dispersed obstacles of roughness C, from Figure 5.23 it results in a terrain exposure of category II, and, from Table 5.3, $k_r=0,20$, $z_0=0,10$ m, $z_{min}=5$ m.

5.4.3.5 Wind actions in Zafferana Etnea

Zafferana Etnea is in Sicily, Zone 4, $v_{b,0}=28$ m/s, $A_0=500$ m, $k_a=0,020$ s⁻¹ at an altitude $A=574$ m above sea level, $v_b=29,48$ m/s, and a distance from the shore less than 10 km.

With these data and considering area with dispersed obstacles of roughness C, from Figure 5.23 it results in a terrain exposure of category III, and, from Table 5.3, $k_r=0,19$, $z_0=0,05$ m, $z_{min}=4$ m.

5.5 Concluding remarks

The present chapter discusses the procedures used to elaborate the maps for climatic actions in Italy, namely the maps for snow load, thermal action and wind actions. Those maps are present in the Italian National Annexes of Parts 1-3, 1-4 and 1-5 of Eurocode 1: *Actions on structures*.

For each climatic action, several worked examples are presented aiming at illustrating the practical application of the climatic actions maps in different Italian sites.

As referred in chapters 1 and 5 of this report, within the framework of the European Commission Mandate M515 for the revision of the Eurocodes, the climate change implications for the Eurocodes should be assessed. In this respect, it is worth mentioning

that a pilot study on the implications of climatic changes on snow loading is being developed by the University of Pisa with the support of the JRC (Croce *et al.*, 2016).

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CHAPTER 6

EXPERIENCE FROM THE REGION IN ELABORATION OF MAPS FOR CLIMATIC ACTIONS: BULGARIA

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6 Experience from the region in elaboration of maps for climatic actions: Bulgaria

6.1 Abstract

This report describes the work done and the encountered difficulties in the project for adoption and implementation of the Eurocode EN 1991, Parts 1-3, 1-4 and 1-5 – for snow, wind and thermal actions correspondingly, in Bulgaria. These Eurocodes give recommendations on determination of the characteristic values of the snow load, wind speed and wind load and maximal and minimal air shaded temperatures.

The project for implementation and adoption of the aforementioned parts of Eurocode EN 1991 started in 2007, shortly after Bulgaria joined the European Union, ended in 2009 and was funded by the Ministry of Regional Development and Public Works. The needed National Annexes (NAs), which include the Nationally Determined Parameters (NDPs), were elaborated at the National Institute of Meteorology and Hydrology by the Bulgarian Academy of Sciences. The NDPs reflect the differences between the countries in regard to the geographical, geological and climate conditions and must be defined by each country.

The elaborated NDPs and maps for climatic actions according to Parts 1-3, 1-4 and 1-5 of the Eurocode EN 1991 were published and officially accepted as National Standards in 2011 by the Bulgarian Institute for Standardization – the Standardization Body in Bulgaria.

Keywords: climatic maps, elaboration and adoption, National Annexes, Nationally Determined Parameters

6.2 Introduction

The EN Eurocodes 1-3, 1-4 and 1-5 are part of a comprehensive set of 10 European Standards (EN 1990 – EN 1999), which covers all of the aspects in structural design of buildings and civil engineering works. They should progressively replace the current national standards throughout Europe and that will ensure a common and coherent approach to all major fields in construction sector. The Eurocodes are also flexible because they offer “the possibility for each country to adapt to local conditions and practices through the so-called Nationally Determined Parameters (NDPs)” (Apostolska et al., 2014) and furthermore they “are a major tool for the successful removal of trade barriers for construction products and services; contribute to the safety and protection of the people in the built environment, on the basis of the best possible scientific advice and are a common basis for technical and scientific collaboration.” (Dimova et al., 2015).

The national project for implementation and adoption of the aforementioned parts of Eurocode EN 1991 started in 2007, shortly after Bulgaria joined the European Union and lasted three years. It was funded by the Ministry of Regional Development and Public Works. The needed National Annexes (NAs), which contain information on the Nationally Determined Parameters (NDPs), were elaborated by a team of scientists, mainly from the Division of Climatology at the National Institute of Meteorology and Hydrology by the Bulgarian Academy of Sciences, led by Prof. Vesselin Alexandrov.

The elaborated NDPs and maps for climatic actions (snow and wind load as well as thermal actions) according to Parts 1-3, 1-4 and 1-5 of the Eurocode EN 1991 were published and officially accepted as National Annexes in 2011 by the Bulgarian Institute for

Standardization. They complemented the National Standards from 2006 and act only together.

6.3 Elaboration of the snow load map of Bulgaria

EN 1991-1-3 gives guidance for the determination of the snow load to be used for the structural design of buildings and civil engineering works for sites at altitudes under 1500 m. Information or recommendation on the values of the snow load above this altitude may be found in the National Annexes.

The standard EN 1991-1-3 is intended to be used with EN 1990:2000, the other parts of EN 1991 and EN 1992 – EN 1999 for the design of structures. It consists of six sections (General; Classification of actions; Design situations; Snow load on the ground; Snow load on roofs and Local effects) and five annexes (A - Design situations and load arrangements to be used for different locations; B - Snow load shape coefficients for exceptional snow drifts; C - European Ground Snow Load Maps; D - Adjustment of the ground snow load according to return period and F - Bulk weight density of snow), the first two being normative and the last three informative. According to EN 1990:2002, 4.1.1(1)P and 4.1.1(4) snow loads in EN 1991-1-3 are classified as variable, fixed and static actions. For particular conditions exceptional snow loads and exceptional snow drifts may be treated as accidental actions, e.g. action, usually of short duration but of significant magnitude, that is unlikely to occur on a given structure during the design working life.

Many clauses of EN 1991-1-3 originate from the results of a research work, carried out between 1996 and 1999 under the leadership of Prof. Luca Sanpaolesi from the University of Pisa. The project was funded by DGIII/D3 of the European Commission. The research was focused on the following four tasks: development of an European ground snow load map; determination of exceptional ground snow loads; definition of appropriate criteria for determination of the serviceability loads and provision of methods and techniques for determination of snow loads on roofs.

The research conducted for the elaboration of the map for snow load in Bulgaria was focused on the following two tasks:

- estimation of the characteristic value of the snow load on the ground – s_k and
- estimation of the locations with exceptional snow loads on the ground.

According to *EN 1991-1-3 Sec.1 (1.6.1)* the characteristic value of the snow load on the ground s_k is the “snow load on the ground based on an annual probability of exceedance of 0.02, excluding exceptional snow loads”, which is equivalent to Mean Recurrence Interval (MRI) of 50 years.

The exceptional snow loads on the ground is the “load of the snow layer on the ground resulting from a snow fall which has an exceptionally infrequent likelihood of occurring” *EN 1991-1-3 Sec.1 (1.6.3)*. The criterion for identifying the last is “If the ratio of the largest load value to the characteristic load determined without the inclusion of that value is greater than 1.5 then the largest value should be treated as an exceptional value”.

The estimation of the characteristic and the exceptionally snow load values and the elaboration of the snow load map of Bulgaria were made according to the methodology recommended in the aforementioned research work and accepted in Eurocode EN 1991 1 3. This methodology has five main steps, which are listed below as follow:

- a) conducting statistical analysis of the seasonal maxima of the snow cover using four different probability distribution functions (PDFs);
 - Extreme value distribution Type I for maximum (Gumbel)

- Extreme value distribution Type II for maximum
 - Weibull (extreme value distribution Type III for minima)
 - Log-normal distribution
- b) using the least square method (LSM) in order to find out which probability distribution function fits the data best;
 - c) estimation and exclusion of the exceptional snow loads
 - d) performing snow density estimations;
 - e) searching for appropriate snow density model and snow load – altitude dependency and
 - f) checking for consistency at the national borders.

6.3.1 Data and preparatory exploration

The elaboration of the snow load map of Bulgaria was based on data for the seasonal snow cover maxima from 126 meteorological stations and the covered period was 1931–2006. Only few of the used stations have continuous record for this whole period, but for all the period with unbroken data is longer than 50 years. Regular information for the snow density from 22 stations was added to the used data base. These stations measure the snow density each five days, when snow is presented. Their names, geographical coordinates and altitudes are given in the Table 6.1. Old archive field measurements of the snow density in the mountain regions complemented the data base and new field campaigns in these regions during the described research were organized.

As a first step this study started with investigation of some characteristics of the snow cover (seasonal maxima with 2, 5, 10, 15, 20 and 25 MRI) for two different periods 1931-1970 and 1971-2000. A general decreasing for the second period was estimated – 10 % for North Bulgaria, 20 % for South Bulgaria and the mountain regions and 30 % for the coastal regions – the last one is presented as example on Figure 6.1.

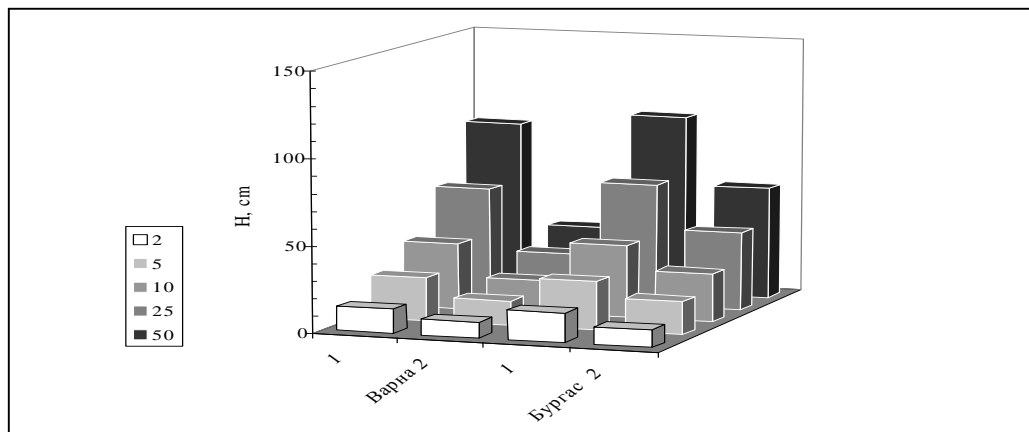


Figure 6.1 Estimated snow maximal heights with 2, 5, 10, 15, 20 and 25 MRI for the coastal stations Varna (left) and Burgas (right) for the periods 1931-1970 (1) and 1971-2000 (2) (after Moraliiski and Dimitrov, 2006)

That is why it was decided to extend the explored period as much as possible.

Table 6.1 Stations in Bulgaria which measure the snow density

Synoptic №	Climatic №	Station name	Latitude	Longitude	Altitude (m)
15502	1020	Vidin	43°54'	22°53'	31
15507	2015	Montana	43°25'	23°13'	202
15505	3010	Vratza	43°12'	23°32'	309
15520	3040	Kneja	43°30'	24°05'	117
15527	4035	Belene	43°38'	25°08'	23
15528	4010	Pleven	43°25'	24°38'	134
15525	5010	Lovech	43°08'	24°44'	220
15530	7010	V. Tarnovo	43°05'	25°39'	195
15530	23010	Pazgrad	43°31'	26°31'	345
15549	28040	Kubrat	42°39'	26°59'	194
15646	25010	Shumen	43°16'	26°56'	218
15640	41010	Sliven	42°40'	26°19'	259
15640	42020	Chirpan	42°12'	25°20'	173
15635	42030	Kazanlak	42°37'	25°24'	392
15637	43010	Haskovo	41°57'	25°34'	230
15734	44010	Kardjali	41°39'	25°22'	331
15734	47010	Ivailo	42°13'	24°20'	212
15628	45120	Rojen	41°42'	24°44'	1750
15726	62010	Kjustendil	42°16'	22°43'	520
15601	64310	Dragoman	42°56'	22°56'	715
15614	64201	Sofia – CMS	42°39'	23°23'	586
15627	46090	Peak Botev	42°42'	24°55'	2376

6.3.2 Statistical analysis and probability distribution fitting of the data from Bulgaria

The snow depth and the snow density depend on many factors and meteorological conditions such as temperature, prevailing wind and prevailing type of precipitation, humidity, relief and exposure to the sun etc. According to the climatic conditions there are two regimes of snow cover – continental (or mountain) and maritime. The first one is characterized by a long period of steadily snow accumulation – until late winter or early spring, followed by a relatively short melting period. The character of the snow cover in second one is not constant, with repeating intervals of accumulation and fully melting and in some winters there may be even not any snow at all. The statistical analysis of the two regimes may require different approaches. In this study the methodology recommended by the team of Prof. Sanpaolesi is followed. Four PDFs were used in the current project for fitting the seasonal maxima of the snow cover. These are the Gumbel, Weibul, Fréchet and the Log-normal distributions. The general procedure for fitting the data and determination of the 50 years MRI is as follows: firstly the extraction and ranking of the seasonal snow maxima is made, then these maxima are plotted based on the length of record, followed by fitting of a PDFs to the tail of the data distribution and determination of the 50 years MRI from a simple formula. The best fit among the used four PDFs is determined by the means of the LSM.

In most of the cases the best results in fitting the data for the snow height in Bulgaria were achieved by the first two distributions. On the next two figures are presented as examples two such fittings for stations Gospodinci and Goleshevo.

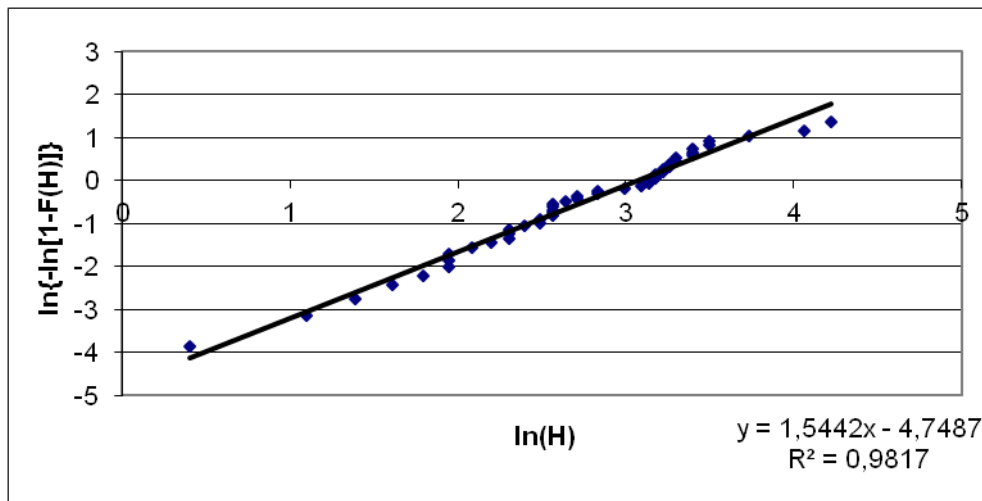


Figure 6.2 Station Gospodinci – Weibull best fit regression line

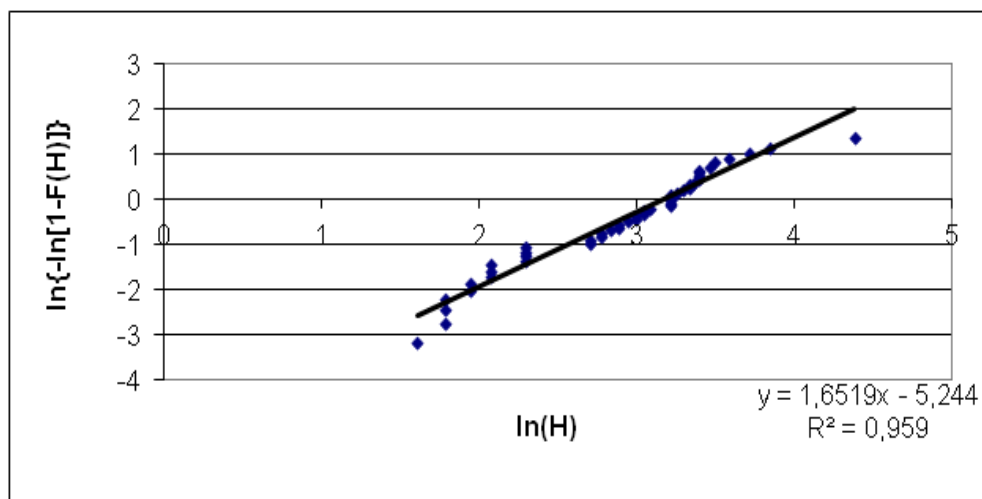


Figure 6.3 Station Goleshevo – Gumbel best fit regression line

6.3.3 Estimation of the locations with exceptional snow loads

Following the simple criterion in the EN 1991-1-3 for finding exceptional snow load - H_{max} to be greater than $1.50 H_{50}$, we encountered only two stations in Bulgaria, which could be characterized as places with exceptionally snow falls – these are the stations Burgas and Shumen. The first one is a coastal station on Black Sea and the second one is in the Northeast Bulgaria. According to the recommendations of EN 1991-1-3 the registered highest values were excluded from the statistical analysis for these two stations. After the removal of the highest value in the data range of Burgas the estimated 50 year MRI snow height dropped with 22%.

6.3.4 The snow density model in Bulgaria

As revealed by the preparatory work of the team of Prof. Sanpaolesi various countries use different models of the snow density for transformation of a measured snow depth into a load. These models were summarized as follow:

- Fixed value for the mean density of snow is used in Belgium, Eire, France, Greece, Luxembourg and Netherlands;
- Density as a function of snow depth due to the compression of snow is used Germany;
- Density as a function of the place of observation is used in Sweden, Spain and Austria. In Sweden different constant values of the snow density are used in different regions of the country. In Spain and Austria the snow density is considered as increasing function of the altitude;
- Density as a function of time of the year is used in Italy, Portugal, Spain, Norway and Switzerland, which depicts the fact that is some regions the accumulation of snow continues for long periods – e.g. in higher altitudes or further north.

The snow density model in Bulgaria may be considered as a mixed one and is based on regular as well as on field measurements for a long period.

6.3.4.1 Fixed density model for the low regions

For the regions up to 1000 m a fixed value of 210 kg/m³ is applied. This value resulted as the average of long-term measurements of the aforementioned 5-days measurements of the snow density. Some of these long-term averages for the winter months for few representative stations are presented in the table below.

Table 6.2 Monthly mean values of the snow density (kg/m³) for some stations in Bulgaria

	I	II	III	XI	XII
Vidin	210	230	260	140	220
Kneja	260	280	230	220	250
Veliko Tarnovo	190	160	200	160	200
Ivailo	160	160	200	180	190

6.3.4.2 The density model for the mountain regions – altitude, time and snow depth dependent

For the density of the snow cover in the regions above 1000 m a mixed approach is applied based on altitude, time and snow depth dependency. The first two dependencies reflect the fact of increasing of the snow cover with elevation of the sites and with the time of the year. The increasing of the snow depth itself enhances the compression of the snow. The deepest snow depths with high densities can be found in the high mountain regions in late winter or in the beginning of the spring. Long-term archive field measurements served for estimation of the snow densities in these places, taking into account also the exposition of the slopes. On Figure 6.4 is depicted one dependency of the snow density on the snow depth for the regions above 1000-1200 m in Bulgaria for month April, resulted from limited number of archive field measurements and in Table 6.3 are summarized the results from the field measurements in West Rhodope, which are relatively close to the border with

Greece. It can be seen that the snow density constantly increases from December till April as well as with the altitude.

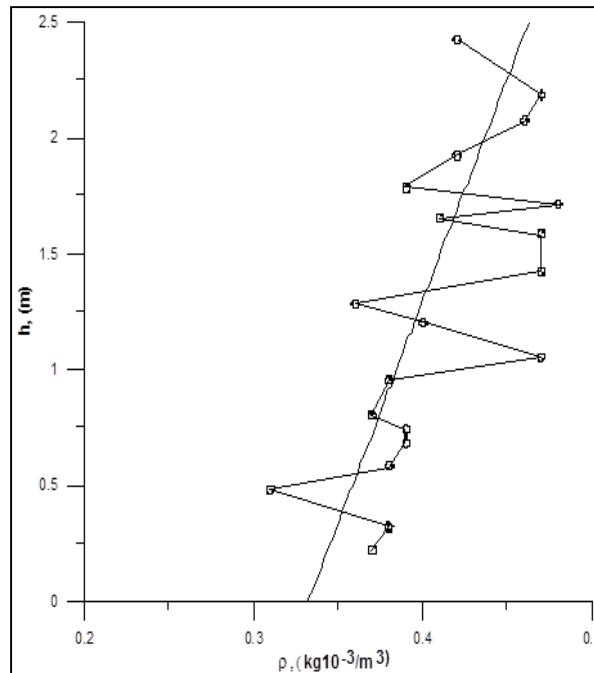


Figure 6.4 Snow density dependency on the snow cover depth

Table 6.3 Number of measurements (1) and averaged values of the snow density (kg/m³) (2) in West Rhodope

Location	Altitude, m		XI	XII	I	II	III	IV
1	1180	1	12	38	58	58	47	5
		2	150	170	190	200	230	230
2	1130	1	4	24	32	36	35	2
		2	110	170	190	240	250	360
3	1200	1	12	79	89	86	61	5
		2	140	210	250	260	240	270
4	1250	1	14	43	78	58	48	8
		2	190	230	240	290	310	310
5	1440	1	10	36	51	56	49	44
		2	160	250	240	260	290	350
6	1531	1	9	24	33	43	37	12
		2	160	260	280	290	290	330
7	1542	1	6	43	54	49	53	38
		2	210	280	250	290	320	400

6.3.4.3 New measurements and finding in the mountainous regions

During the current project for adoption and implementation of the Eurocodes for climatic actions several new measuring activities for assessment of the snow density in the mountainous regions of Bulgaria were arranged. They consist of two groups of activities – daily measurements of the snow density at the high-mountainous meteorological stations of NIMH plus 5-days measurements at two selected high-mountainous huts on the north and south slopes of the mountain Stara Planina beneath the station peak Botev Vrah and field measuring expeditions in mountains.

One new relation between the snow density and the averaged for the previous 24 hours air temperature were found during the special daily measurements at the mountain stations. This relation for peak Murgash is presented on Figure 6.5.

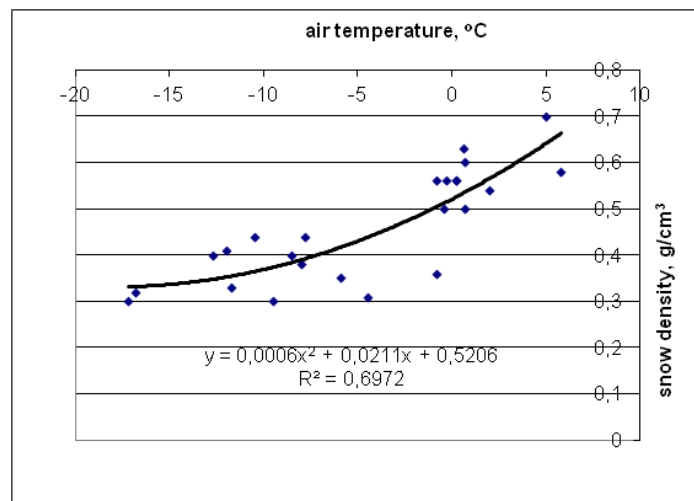


Figure 6.5 Relation between the snow density and the averaged for the previous 24 hours air temperature, data from peak Murgash for the winter 2007/2008

On Figure 6.6 are presented the daily snow measurements at station peak Rojen, in the mountain Rhodope, which is a border zone between Bulgaria and Greece. On next Figure 6.7 is presented the histogram of the density only of the newly fallen snow for the same location for the winter 2008/09.

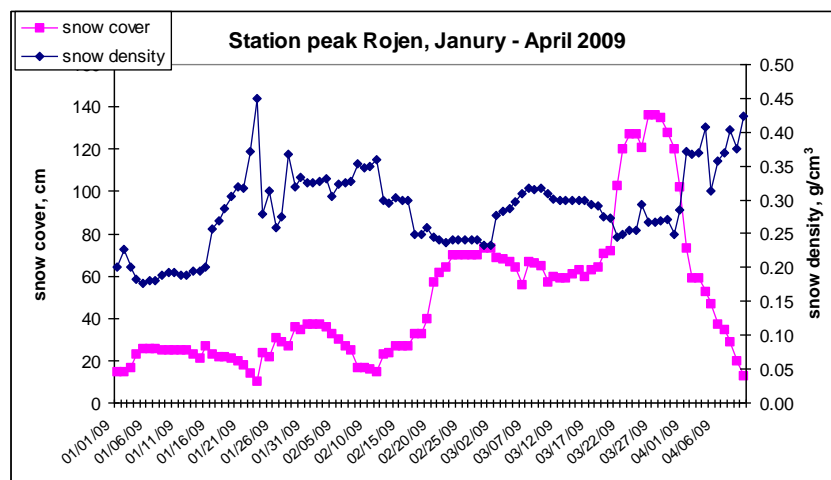


Figure 6.6 Daily snow measurements at station peak Rojen in the Rhodope

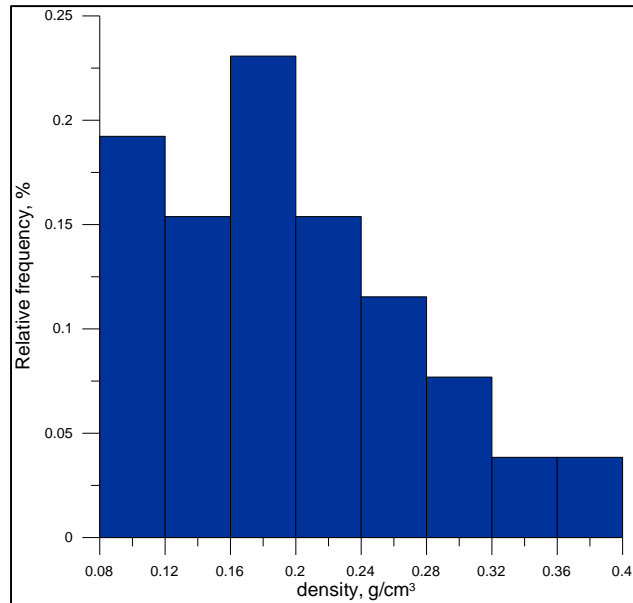


Figure 6.7 Histogram of the newly fallen snow at station Rojen

Both figures and the last table show that the snow density in these regions, which are border zone between Bulgaria and Greece, varies between 120 and 400 kg/m³ depending on the month and the altitude. The mean density of the newly fallen snow is 190 kg/m³, which is higher than the accepted value for Greece – 140 kg/m³.

Beside these daily measurements several expeditionary measuring campaigns in the mountain regions of Bulgaria were carried out. They were arranged in such a way that a vertical gradient of the snow cover and the snow density along a particular slope of the mountain could be made – the measuring team climbed the mountain from the bottom up to the summit, taking snow probes at different altitudes. The profiles of the snow density were also assessed at each measuring point and this procedure is depicted on Figure 6.8.



Figure 6.8 Snow profile measuring procedure

The results from all expeditions in the mountain Pirin are graphically presented on Figure 6.9.

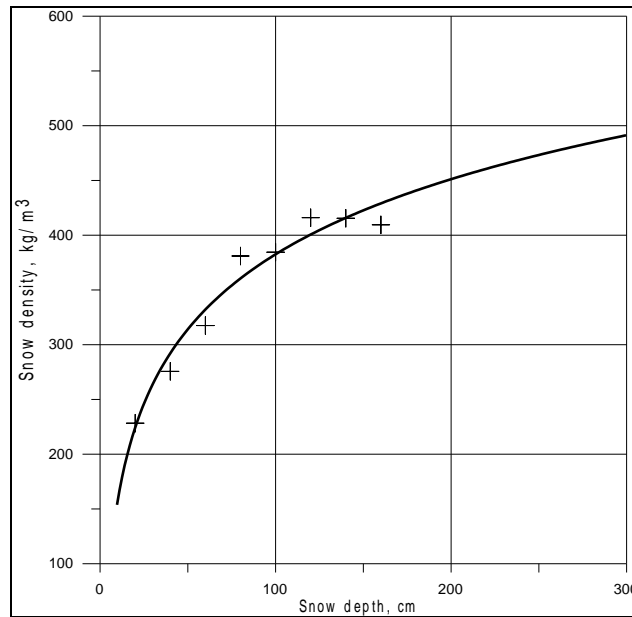


Figure 6.9 Averaged results from all expeditions in the mountain Pirin

6.3.4.4 The final snow load – altitude dependence

Summarizing all investigations carried out it was possible to estimate the final altitude dependency of the snow density and snow depth. The altitude dependence of the snow density is given on Figure 6.10. This relation is very similar to those given in Table C.1 of Annex C in EN 1991-1-3.

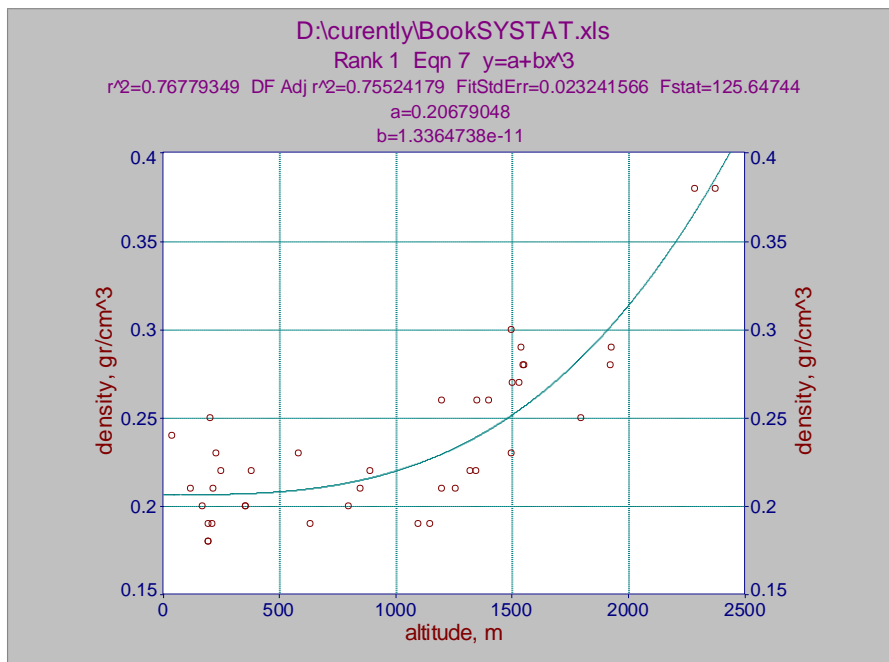


Figure 6.10 Averaged snow densities as function of the altitude

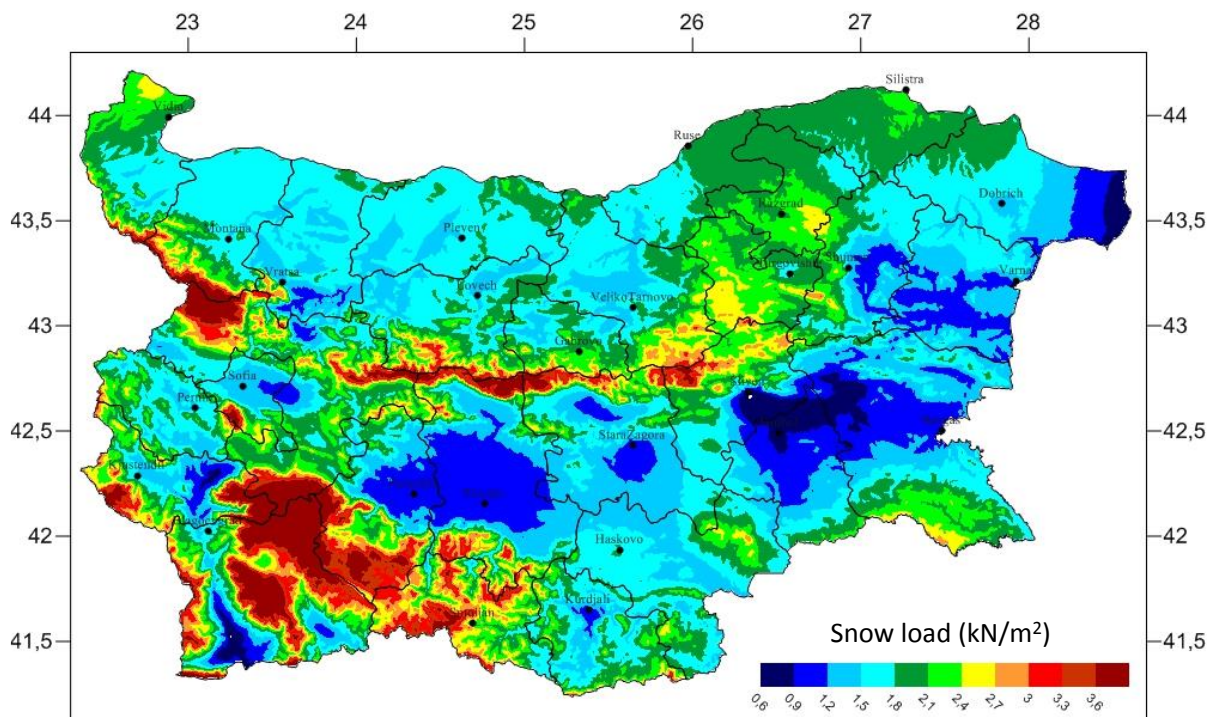
6.3.5 Consistency at the national borders

The next step before the last was to check for consistency at the national borders. Comparing the estimated characteristic values in border zones with neighbour countries no significant differences were found, except at the frontiers with Greece. It seems that the accepted fixed value of the snow density of 140 kg/m^3 in Greece is too low for our frontier mountainous regions. We used this low value in our estimations just for a try and then we received comparable values within the border zone with Greece.

6.3.6 The elaborated map for snow load in Bulgaria

The first maps for snow load in Bulgaria were elaborated in 1979 and 1989 with 2 years MRI (Moraliiski and Ivanov, 1978). In 2004 a new interim standard was accepted with MRI 25 years.

All previous described investigations and measurements gave us the capability to elaborate the final version of the new national map for snow load according to the requirements of the Eurocode EN 1991-1-3. The map contains 12 different snow zones including the mountain regions (Figure 6.11). However, all particular requests concerning the regions above 1500 m should be directed to the National Institute of Meteorology and Hydrology for a more detailed accomplishment. This map was officially published in 2011 and is now freely available on the site of the Bulgarian Institute for Standardization.



**Figure 6.11 The snow load map of Bulgaria according to EN 1991-1-3
[© Alexandrov²]**

² All official maps for climatic actions were drawn by Professor Alexandrov.

6.4 Elaboration of the wind load map of Bulgaria

The first wind load map in Bulgaria was elaborated in 1978 (Ivanov, 1978) with 2 minutes interval of averaging and MRI of 2 years, i.e. mean values of the yearly maxima as for the first two snow maps. Actually these maps were made in accordance with the valid at that time standard of the former Soviet Union.

An interim wind load map was produced in 2004 with 10 minutes mean velocity and 50 years MRI. However, the used methodology did not correspond to the requirements of the Eurocodes.

The main goals of the elaboration of the map for wind load according to EN 1991-1-4 were to determine the characteristic values of the wind velocity $v_{b,0}$ and the velocity pressure q_0 for Bulgaria, to find relations for estimation of other representative values (values with different MRI), to check for consistency at the national borders as well as to determine and to map the Black Sea strip, which belongs to the category "0".

The EN 1991-1-4 consists of 8 Sections (General; Design situations; Modelling of wind actions; Wind velocity and velocity pressure; Wind actions; Structural factor c_{sCd} ; Pressure and force coefficients and Wind actions on bridges) and 5 Annexes (A - Terrain effects; B - Procedure 1 for determining the structural factor c_{sCd} ; C - Procedure 2 for determining the structural factor c_{sCd} ; D - c_{sCd} values for different types of structures and E - Vortex shedding and aeroelastic instabilities), all of them being informative.

The definition of characteristic values is the same as for the snow and the same applies to the statistical methodology for estimation of these values. These means the characteristic values are defined on the basis of a MRI of 50 years and the same PDFs and LSM are used. The accepted terrain category is II from the Table 4.1 from Section 4 of the EN 1991-1-4.

Data from 150 meteorological stations for the wind speed at 10 m above ground and averaged for 10 minutes for the period 1956 – 2006 is used for the purpose of this project. Many of these stations are climatic stations, where only three observations per day are made. This may hamper the estimation of the characteristic values because the yearly maxima determined on the basis of these observations are lower than those determined on synoptic observations (8 in 24 hours). This is depicted on Figure 6.12.

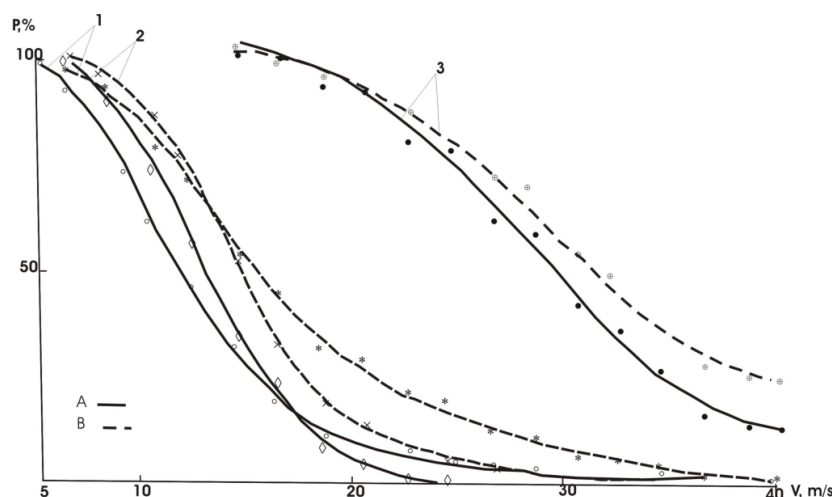


Figure 6.12 Cumulative distribution curves of the yearly maxima of the wind speed for three stations: 1 – Vratza; 2 – Sofia and 3 – peak Murgash; A – climatic data; B – synoptic data

However, by means of appropriate statistical methods this potential difficulty was overcome.

Another arising difficulty, concerning the original data again, was the need to transform the wind data with 2 minutes interval of averaging into 10 minutes means. This problem was solved by using the graph on the next Figure 6.13 and the coefficients for transformation given in Table 6.4.

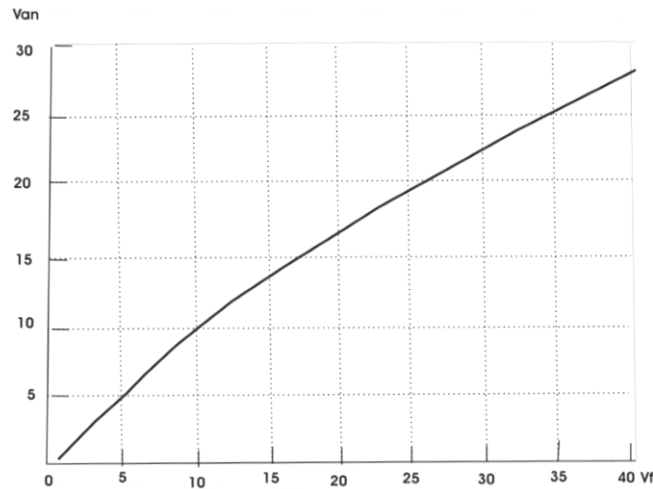


Figure 6.13 Relation between the 2 minutes mean wind speed (V_t) and the 10 minutes mean wind speed (V_{an})

Table 6.4 Coefficients for transformation of wind data with 2 minutes interval of averaging into 10 minutes mean.

Relief type	Coefficient
Flat country	0.83-0.85
Coastal regions	0.85-0.90
Mountain summits	0.90-0.92

The check for consistency at the borders did not reveal any significant differences.

6.4.1 The elaborated map for wind load in Bulgaria

On Figure 6.14 is presented the final version of the wind load in Bulgaria according to the requirements of the Eurocode EN 1991-1-4.

There are 7 different wind zones estimated.

It should be pointed out that the map concerns the regions with altitude up to 800 m. For altitudes between 800 and 1100 m the increasing of the wind speed can be given by the formula $y = 88.759 \cdot x^{-0.185}$ and the velocity pressure q_0 with the formula $y = 0.037 \cdot h^{0.3457}$ kN/m^2 .

The regions above 1000 m require special consideration.

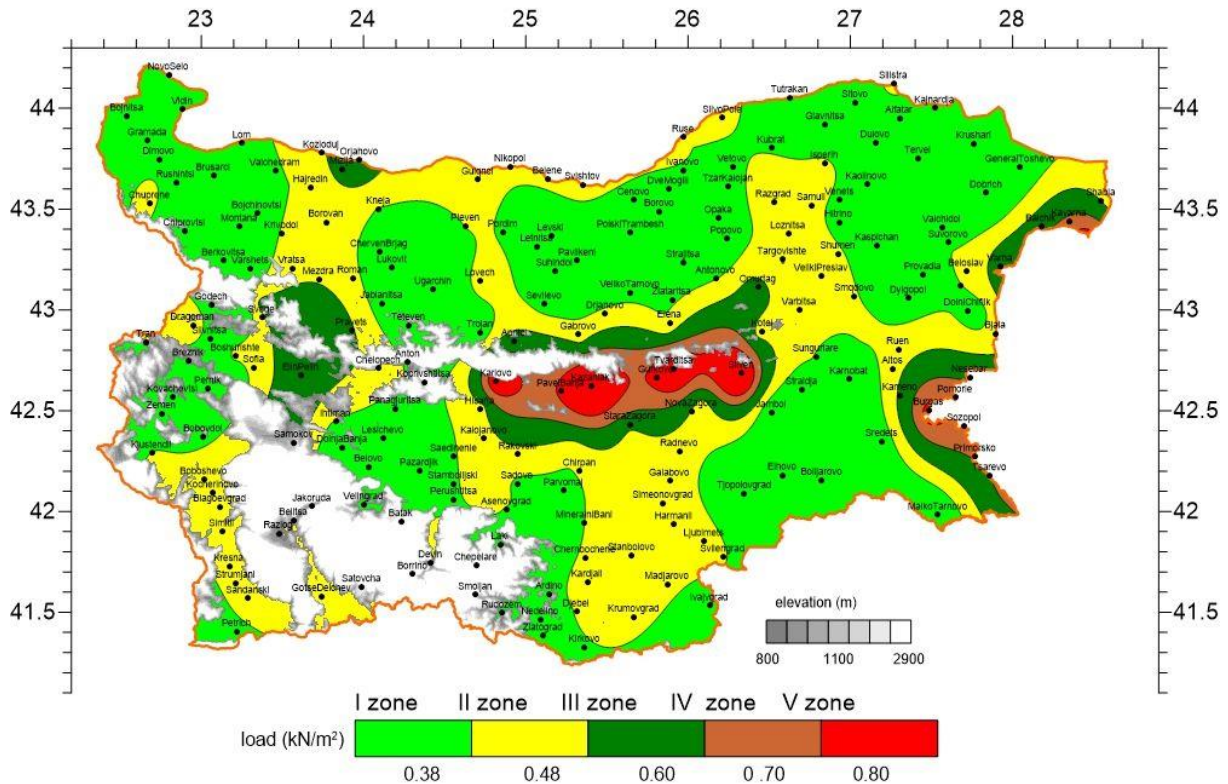


Figure 6.14 Map of the characteristic wind load of Bulgaria [© Alexandrov]

6.5 Elaboration of the maps for thermal actions of Bulgaria

The main tasks connected with the adoption and implementation of the Eurocode EN 1991-1-5 Thermal actions were as follow:

- to determine the characteristic values of the extreme temperatures (maximum and minimum shade air temperature – Tmax and Tmin) for Bulgaria;
- to elaborate maps for these values for both temperatures;
- to recognize the regions with very low/high air temperatures;
- to conduct an experimental investigations for assessment of temperature changes in buildings.

The definition of characteristic values here were the same as for the snow and wind loads. The statistical methodology is also based on the same recommendations.

The investigated period is 1950–2006 and number of the used stations is 125.

One averaged gradient for the change of the maximum shade air temperature with the altitude was determined and used: $t_{max}^{50} = -0.0096 \cdot H + 47.442$.

The averaged gradient for the change of the minimum shade air temperature with the altitude above 1000 m was estimated as: $t_{min}^{50} = -0.0053 \cdot H - 18.77$.

These both gradients are presented on the next two figures. The coefficients of correlations are 0.99 and 0.93 correspondingly.

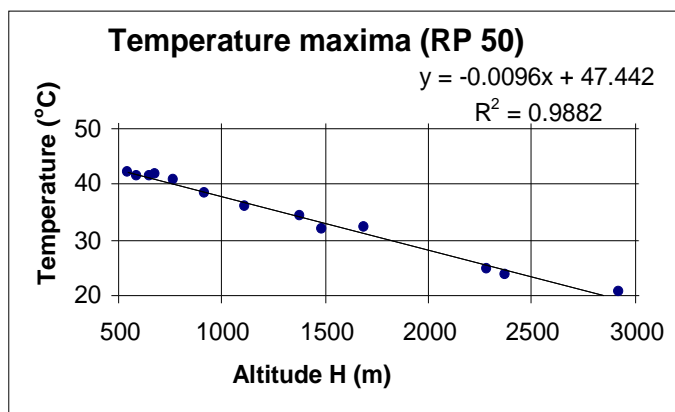


Figure 6.15 Change of t_{\max}^{50} with the altitude for selected representative stations

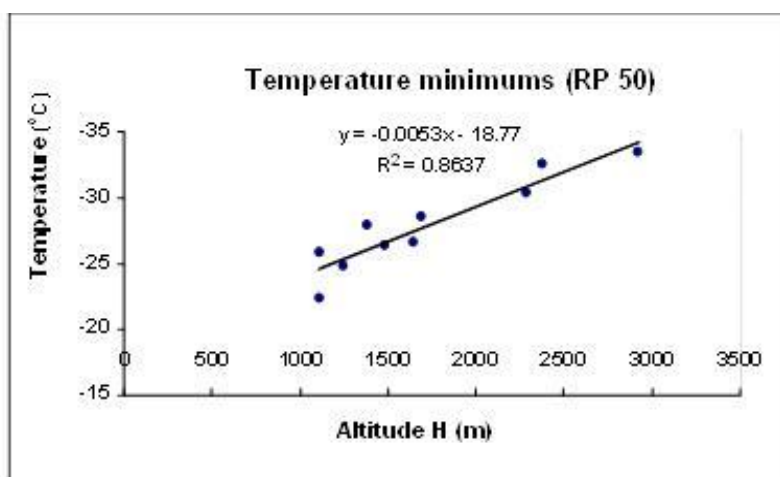


Figure 6.16 Change of t_{\min}^{50} with the altitude for selected representative stations

For the mapping of the characteristic values of the air temperatures a mixed approach was used. It is based on the Kriging method for interpolation in the flat regions of the country and on a regression model for the mountain regions. The regression equations for the relation between the air temperature and the altitude are given below:

$$T_{\max_elev} = -0.006 \cdot elev + 44.7 \quad 100 < elev < 1000 \text{ m} \quad (66.1)$$

$$T_{\max_elev} = -0.010 \cdot elev + 47.9 \quad elev > 1000 \text{ m} \quad (66.2)$$

$$T_{\min_elev} = -0.005 \cdot elev + 20.1 \quad elev > 800 \text{ m} \quad (6.3)$$

6.5.1 The elaborated maps for thermal action in Bulgaria

The elaborated maps for the characteristic values of the shaded air temperatures are presented of the next two figures (Figure 6.17 and Figure 6.18) as they were published by the Bulgarian Institute for Standardization.

No significant differences with the neighbour countries were found.

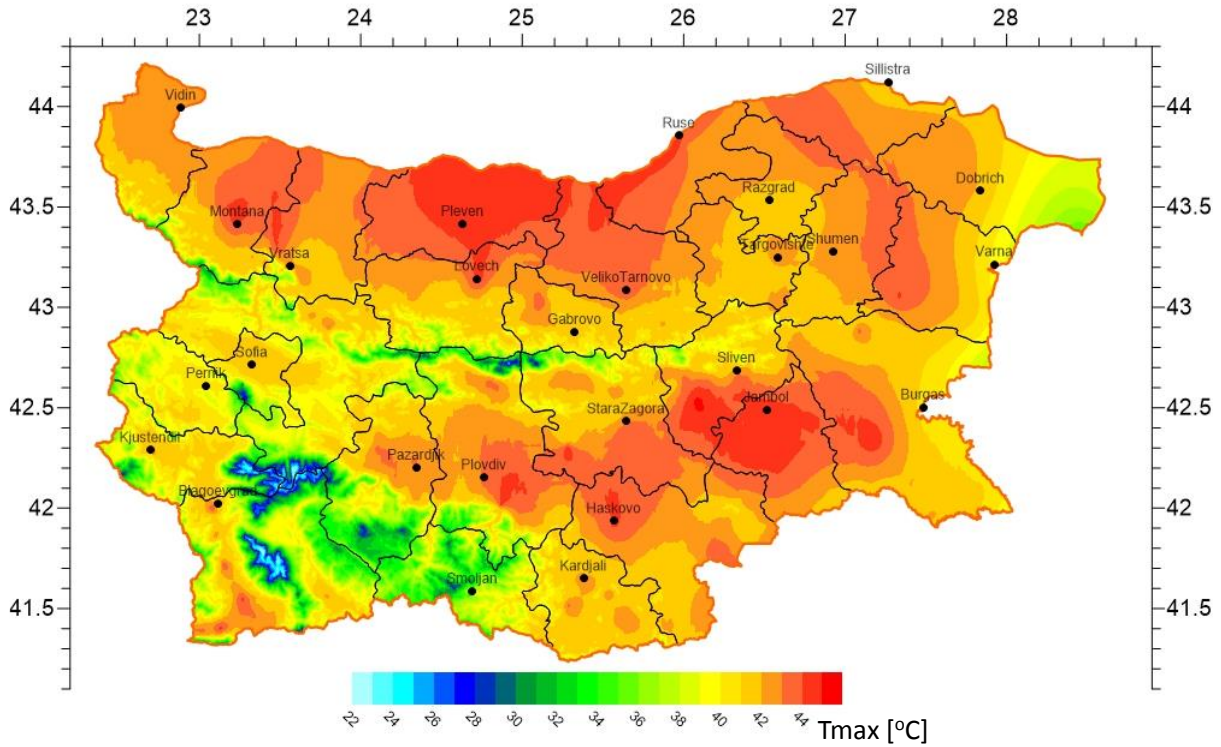


Figure 6.17 Map of the characteristic values of the maximum shade air temperatures [© Alexandrov]

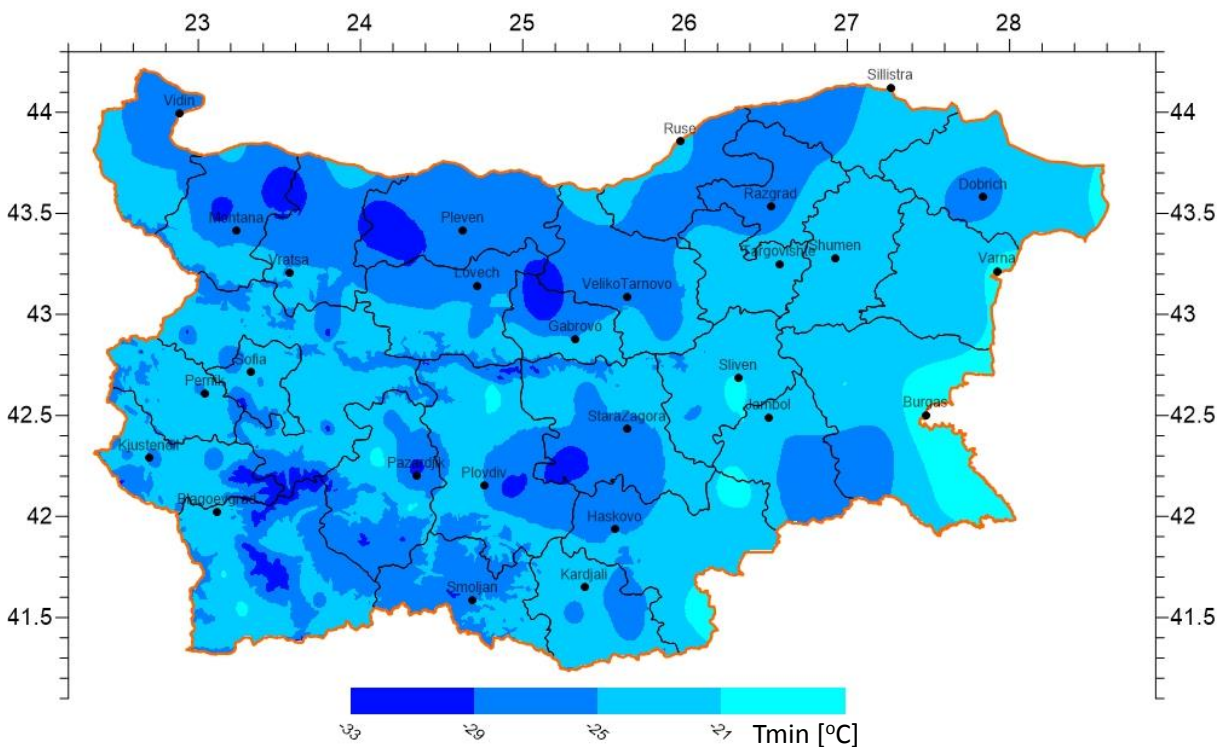


Figure 6.18 Map of the characteristic values of the minimum shade air temperatures [© Alexandrov]

It can be summarized that the characteristic values of the maxima of the air temperature vary between 35 °C for the coastal regions and 45 °C for the south regions. The characteristic values of the minima of the air temperature are between – 20 and – 30 °C for the regions with altitudes between 400 and 1000 m.

6.6 Conclusions

This report summarizes the efforts, which has been made and the gained experience in the elaboration of the maps for climatic actions according to the Eurocode 1991-1 Parts 1-3, 1-4 and 1-5 – for snow and wind loads and thermal actions correspondingly.

The report also briefly describes the encountered difficulties in execution of the project for adoption and implementation of this European Standard. These difficulties were: the estimation of the appropriate altitude dependency of the snow load in the task for elaboration of the snow load map; the transformation of the wind data with 2 minutes interval of averaging into 10 minutes means for the wind load map and the conducting of the experiment for assessment of temperature changes in buildings. All of these difficulties have been finally overcome and the needed maps have been elaborated.

We also do hope that this report and the corresponding presentation at the workshop "Elaboration of maps for climatic and seismic actions for structural design in the Balkan region", which was held on 27-28 October 2015 in Zagreb, will also contribute to the enhancement of the cooperation with neighbour countries in the Balkan region in the field of elaboration and cross-border harmonization of NDPs and NAs.

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CHAPTER 7

ASSESSMENT AND RETROFITTING OF EXISTING STRUCTURES – HIGHLIGHTS FROM THE SECOND GENERATION OF THE EUROCODES

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Structures*

7 Assessment and retrofitting of existing structures – highlights from the second generation of the Eurocodes

7.1 Policy Framework

7.1.1 Strategic importance of construction sector

The construction industry is hugely significant to the European economy. The construction sector is of strategic importance as it delivers the buildings and infrastructure needed by the rest of the economy and society. It is generally accepted that it represents more than 10% of EU GDP (Gross Domestic Product) and more than 50% of fixed capital formation. It is the largest single economic activity and it is the biggest industrial employer in Europe. The sector employs directly almost 20 million people.

Construction is a key element not only for the implementation of the Single Market, but also for other construction relevant EU Policies, such as sustainability, environment and energy.

The analysis of the present situation in the construction sector and the identification of the design concepts provided by the current structural design codes and trends in the construction market are the bases for the perspective of the future generation of codes for the design as well as for the assessment of existing structures.

The improvement of the competition in EU markets through the adoption of the Eurocodes is recognized in the strategy for the sustainable competitiveness of the construction sector and its enterprises and they are distinguished as a tool for accelerating the process of convergence of different national and regional regulatory approaches.

7.1.2 Environmental impact of construction works

After adopting the Kyoto protocol in 1997 and in all the subsequent climate summits – the most recent event will take place 2015 in Paris - sustainable development is a long term goal of the global policy.

The building and construction sector plays an important role in sustainable development. The environmental impact of construction sector is considerable:

- Total energy consumption: ~ 40%
- Consume of raw materials: ~ 50%
- Waste streams: 40 – 50%

An additional amount of 5-10% of the total energy consumption is being used in processing and transport of construction products and components.

Thus, the construction sector is one of the largest industrial sectors with all aspects of economic importance and environmental impact. The future of construction works will be closely governed by the sustainable development of urban and industrial areas and

infrastructures, which results in modifications or substitutions or extensions of existing buildings and engineering works.

This new strategy taking account of continued use of existing structures is of great significance due to environmental, economic and socio-political assets. Growing larger every year it will be a new challenge for architects and engineers and a new focus for the construction industry with a new technical basis and a change of market and of the main activities.

The future of construction works will be closely governed by the sustainable development of urban and industrial areas and infrastructures, which results in modifications or substitutions or extensions of existing buildings and engineering works.

In addition, societal needs influenced recently the views on the role of the construction industry: the maintenance of the heritage and the sustainable use of natural resources. In fact, these needs are not new, but they have become of vital importance. The consideration of all aspects of sustainability leads to integrated design procedures of structures that do not meet only the traditional requirements with regard to mechanical characteristics of structures.



Figure 7.1 Reintegration of an existing industrial building into a new residential development area

7.1.3 Basic requirements

During the past 25 years an alignment of the generally used design procedures can be observed worldwide. Most design procedures at present refer to the fundamental requirements to be met. According to the fundamental requirements a structure should be designed, executed and maintained in such a way that it will, during its intended life, with appropriate degrees of reliability sustain all actions likely to occur during execution and use and remain fit for the use for which it is required.

The complexity of design practice requires an integrated and concerted planning process. The consideration of all aspects of sustainability leads to integrated design procedures of structures that do not meet only the traditional requirements with regard to mechanical characteristics. More general requirements have to be respected. In this sense the Construction Products Regulation (Regulation EU No 305/2011) identifies in its Annex I the following basic requirements for construction works:

1. Mechanical resistance and stability
2. Safety in case of fire
3. Hygiene, health and environment
4. Safety and accessibility in use
5. Protection against noise
6. Energy economy and heat retention
7. Sustainable use of natural resources

As various requirements may lead to conflicting directions for design of structures, concerted actions are necessary to develop consistent code and standard families in future.

7.2 Assessment of existing structures

7.2.1 Existing structures and sustainability

A sustainable development for construction will not simply respond to new needs by adding new buildings to the existing building stock or demolish old buildings and simply substitute them by new ones. It will analyse existing structures to identify their possibilities for meeting sustainability goals.

An assessment of existing structures may be necessary in case of:

- Adequacy checking in order to establish whether the existing structure can resist loads associated with the anticipated change in use of the facility, operational changes or extension of its design working life
- Repair of an existing structure, which has deteriorated due to time dependent environmental effects or which has suffered damage from accidental actions for example due to impact, explosion, fire or earthquake
- Doubts concerning the actual reliability of the structure
- Rehabilitation of an existing building structure in connection with retrofitting the building technical systems
- Requirements from authorities, insurance companies or owners or from a maintenance plan

Owners of existing buildings, real estate agents and other partners interested in the technical performance of the structure are interested to profit from a successful assessment or retrofitting in achieving a higher value on the real estate or rent market.

With respect to bridges the situation is slightly different from that for buildings. Especially the reasons for assessing bridges and the impulse for maintenance intervention are different; however the principles are the same and the methodologies are comparable.

Due to the demand for freight volume on rail and road, traffic has increased significantly leading to increasing number of heavy vehicles in the traffic flows. Because of environmental considerations there is also a tendency to further enhance the admissible loads in the design of new heavy vehicles. In addition to the change of the traffic flows the exposure to climate actions and extreme emissions may impair the long term behaviour of a structure. This all may affect the safety, serviceability and durability of existing bridges. Bridge authorities are therefore interested in agreed methods to assess the safety, and durability of existing bridges and to make appropriate provisions for more refined methods for the evaluation and maintenance.



Figure 7.2 Assessment and retrofitting of a series of existing prestressed concrete road bridges of an alpine transit highway [images a) and b) © European Union, 2015]

7.2.2 Potential for future development

General principles of sustainable development lead to the need for extension of the life of the structure, in most cases in conjunction with severe economic constraints. The application of design-orientated methods to the assessment of existing structures leads to a high degree of conservatism. This is why the assessment of existing structures often requires the application of sophisticated methods, as a rule beyond the scope of design codes for new structures.

The approach to the assessment of an existing structure is in many respects different from that in designing new structures. The effects of the construction process and subsequent life of the structure, during which it may have undergone alteration, deterioration, misuse and other changes to its as-built (as-designed) state, need to be taken into account.

It is thus possible to obtain and gain more or less detailed information on a specific structure. This is one of the fundamental differences with respect to the methodology used for the design of new structures where uncertainties are dealt with by relying on information gained from experience.

New technical guidelines for the assessment and retrofitting of existing structures will provide the basis and give tools to master this new challenge.

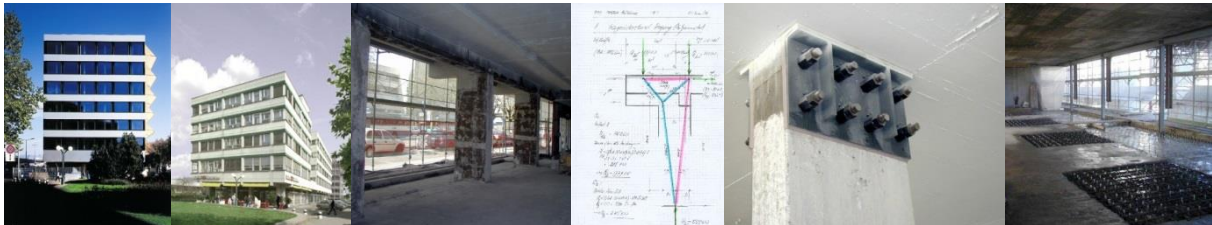


Figure 7.3 Assessment, rehabilitation, and additionally increasing by two storeys of an existing office building with a reinforced loadbearing structure

7.3 CEN/TC250 initiative / Mandate 515

7.3.1 Background and justification

The CEN/TC250 initiative is motivated by the lack of an applicable set of European-wide technical rules to deal with the enormously expanding construction activities in assessing and retrofitting buildings and engineering works.

The new strategy of continuing to use existing structures is of great significance due to environmental, economic and socio-political assets. It will be a new challenge, growing larger every year, for architects and engineers and a new focus for the construction industry with a new technical basis and a change of market and of the main activities.

This is the reason that over the last 20 years, methodologies inherent to existing structures have evolved in many countries and applied on a national level. However they have not yet been generally adopted in broad practice. Therefore it is an urgent need for bringing together the different national approaches to a broadly accepted, coherent and harmonised set of rules for existing structures complementing those for the design of new structures.

The proposed new European technical rules for existing structures are related to the principles and fundamental requirements of the EN Eurocodes. Thus, the technical rules for existing structures are not self-standing rules but they complement rules of the relevant

EN Eurocodes by identifying and distinguishing the differences between the design of new structures and the assessment and retrofitting of existing structures.

7.3.2 Approach to execution of the Mandate

7.3.2.1 Work packages

The purpose of the Mandate M/515 (European Commission Mandate M/515, 2012) was to initiate the process of further development of the Eurocode system, incorporating both new and revised Eurocodes. The Mandate M/515 identifies two work packages. Package I is concerned with standards of general relevance and the production of a technical report on requirements for climate change. Package II is concerned with material specific standards, including new Eurocodes.



Figure 7.4 Assessment and rehabilitation of large scale prestressed concrete basins and tanks in an urban sewage-treatment plant

With regard to the new European technical rules for assessment and retrofitting of existing structures package I will include the general rules complementing EN 1990 *Basis of structural design* and those for actions complementing EN 1991 *Actions on structures*.

The new European technical rules for the different type of structures such as concrete, steel, composite steel and concrete, timber, masonry and aluminium structures will be a subject of package II.

7.3.2.2 Stepwise procedure

The works of the future generation of Eurocodes will be performed in several steps:

- Step 1: Preparation and publication of a "Scientific and Policy Report", subject to agreement of CEN/TC250
- Step 2: After agreement of CEN/TC250, preparation and publication of CEN Technical Specifications (previously known as ENV)
- Step 3: After a period for trial use and commenting, CEN/TC250 will decide whether the CEN Technical Specifications should be converted into Eurocode Parts

As a conclusion, the procedure in several steps does not predetermine to draft immediately new Eurocodes or new Eurocode Parts. In fact the procedure allows for a progressive development, agreed by CEN/TC250, in order to take into account observations from national experts and users.

The production of Scientific and Policy Reports is declared as pre-normative work and as such will not be funded under Mandate M/515.

7.3.2.3 Organisation of work

The new European technical rules for the assessment and retrofitting of existing structures will be developed using the existing organization of CEN/TC250.

The works are initiated and carried out by the Working Group WG2 “Assessment and retrofitting for existing structures” and supervised by CEN/TC250. The Working Group WG 2 will develop general rules for the assessment and retrofitting of existing structures on the one hand and it will provide guidelines for the different types of construction on the other hand.

7.3.3 JRC Science and policy report

The JRC Science and policy report “New European Technical Rules for the Assessment and Retrofitting of Existing Structures” (Luechinger et al., 2015) is published in the JRC Report Series “Support to the implementation, harmonization and further development of the Eurocodes”.

The report encompasses three parts:

- Part I introduces the policy framework and the CEN/TC250 initiative
- Part II is a collation of the different existing National regulations and standards in Europe with regard to existing structures
- Part III gives a prospect for CEN guidance for the assessment and retrofitting of existing structures

Having in mind the stepwise procedure, the content is broader, covers more aspects, and includes more information than normative CEN Technical Specifications. Part III presents scientific and technical proposals intended to serve as a starting point for further work to achieve a harmonized European view on the assessment and retrofitting existing structures. In particular, key issues are identified that require resolution and a summary of different national perspectives is provided rather than seeking to resolve all difficult technical issues during the first work step.



Figure 7.5 Assessment and rehabilitation of an existing masonry high-rise residential building (left) and of an existing office building with a reinforced concrete loadbearing structure (right)
[images e) and f) © European Union, 2015]

7.4 Prospect for CEN Guidance

7.4.1 Scope

The prospect for CEN Guidance provides proposals for general requirements and procedures for the assessment and retrofitting (repair and upgrade) for all types of existing structures such as buildings, bridges, construction, and works as well as for all construction materials. The new rules are based on the principles of structural reliability and consequences of failure in agreement with the principles of EN 1990.

The new rules are applicable to the assessment and retrofitting of any type of existing structure that was originally designed, analysed and specified based on accepted engineering principles and/or design rules, as well as structures constructed on the basis of good workmanship, historic experience and accepted professional practice.

The new rules may also be applied to historical structures, provided additional considerations are taken into account concerning the conservation of the construction identity and authenticity, through the preservation of its appearance and materials.

However the assessment and retrofitting of existing structures under seismic actions are to be performed according to the rules of EN 1998-3.

7.4.2 Contents

It is recommended that the general rules for the assessment and retrofitting existing structures, complementary to the current EN 1990 for design, should address to the following items:

1. General (scope, normative references, assumptions, terms and definitions)
2. Basic requirements
3. Framework for assessment, structure management and retrofitting upon existing structures introduction, generic procedures (preliminary assessment, detailed assessment, assessment based on knowledge levels)
4. Investigation and updating information (general, actions, material properties, geometrical properties, structural models, resistances and deformations)
5. Structural analysis and verifications (verification by partial factors, verification by probabilistic methods, risk analysis)
6. Interventions (retrofitting and modification, survey and monitoring, maintenance, immediate safety interventions)

7.4.3 Basic requirements

The objective of the assessment and retrofitting of an existing structure in terms of its required future structural performance shall be specified in consultation with the client and the relevant authority based on the following performance levels:

- Safety performance level, which provides appropriate safety for the users of the construction and third parties, in accordance with the principles of the Eurocodes
- Continued function performance level, which provides continued function for special structures such as hospitals, communication buildings or key bridges, in the event of an earthquake, impact, or other foreseen hazard
- Serviceability performance levels if required by the client, based on criteria that can affect the appearance of the structure, the comfort of users, or the functioning of the structure

Performance requirements for existing structures are to be based on an acceptable level of risks to persons (individual and societal) and, simultaneously, on economic criteria including environmental aspects. In some cases, cultural and social aspects should also be taken into account.

The level of special performance requirements related to property protection (economic loss) or serviceability is generally based on life cycle cost and special functional requirements.

The assessment should be carried out taking into account the actual and/or future condition for the remaining life time. Management of the structure by techniques such as monitoring may be taken into account to warrant the performance requirements over the lifetime.

7.4.4 Procedure for assessment and retrofitting

The process of assessment and structure management is a decision process which aims to remove any doubts regarding its current condition and future structural performance and/or to identify the most effective interventions required to fulfil the basic requirements. It is important that this process is optimised considering the total service life costs of the structure.

In general, the assessment of an existing structure is carried out in progressive stages, in increasing depth, depending on the quality and the importance of information available. The procedure depends on the assessment objectives and on specific circumstances (e.g. the availability of the design documents, the observation of damage, the use of the structure) and consists of:

1. Specification of the assessment objectives
2. Identification of scenarios, with respect to changes in structural system and actions
3. Preliminary assessment, level of detail to be agreed
4. Detailed assessment, level adequate to conclude on structural performance
5. Evaluation of results

Each step of the assessment should include an evaluation of the plausibility of the results prior to the decision being made to implement the required interventions.



Figure 7.6 Preliminary assessment of existing road bridges

7.4.5 Investigation and updating information

The investigation and updating of information with regard to the actions as well as with regard to the mechanical resistance is one of the key issues when assessing existing structures in order to reduce uncertainty.

Data for assessment and retrofitting are related to the material properties, structural properties, dimensions, soil conditions, deformation capacity and other conditions as actually established for the existing structure, and to previous, actual and/or future actions to the structure.

In general, updating of information consists of:

- Document search (design information and information on interventions, alterations during use etc.)
- Inspection of the structure

- Establishment of prior information based on the results from document search and inspection, taking into account information from literature
- Testing
- Evaluation of site data from measurements, tests, etc.
- Combination of site data and prior information in order to obtain updated information

The document search and check of original design, if available, should focus on assumptions, static systems (joints, support conditions, etc.) and construction detailing.

Inspections may help to detect deterioration, which in turn may be the consequence of particular exposure conditions and hazard scenarios. In general, updated information on an existing structure should take into account:

- Occurrences during construction and use affecting structural performance
- Findings from observations, inspections, and measurements
- Previous interventions
- Experience gained from the behaviour of comparable structures under comparable use
- Results of investigations
- Specified scenarios and assessment situations for the remaining working life

The assessment approach on the basis of the partial factor format in accordance to the current generation of standards requires the knowledge of actual characteristic values of action-, action effects- and resistance variables. If the uncertainties associated with the relevant parameters are small, or if updating is impossible for some reason, characteristic values may be deduced from the previously available information (e.g. construction documents, etc.). Otherwise, characteristic values of the variables should be obtained by updating.

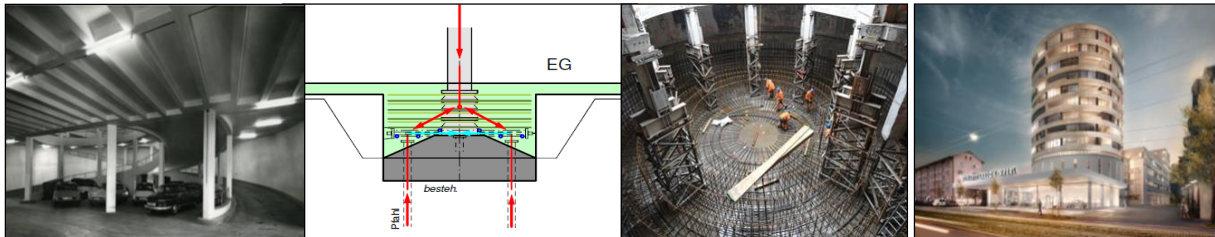


Figure 7.7 Assessment, upgrading, and reintegration of a listed industry building into a new residential complex

7.4.6 Structural analysis and verifications

The evaluation and assessment of an existing structure should be based on the principles of limit states. The relevant assessment situations (equivalent to design situations for new structures) should be selected taking into account the updated information and the actual conditions and circumstances under which the structure is required to fulfill its function during the remaining working life.

Structural assessment aims to determine the reliability of a structure as a whole or in terms of individual members, with respect to prescribed limit states and for a given time period.

The assessment of an existing structure should focus on the verification of structural safety, serviceability, and durability. To this scope the existing structure should be adequately modeled and the limit state function clearly formulated.

The actual reliability of the structure should be compared to the corresponding target values by means of:

- the partial factor format or the global resistance format
- the probabilistic format
- risk analysis

In the present document, information is given concerning analysis and verifications based on the partial factor format or global factor format, respectively.

7.4.7 Interventions

7.4.7.1 Recommended measures

If the structural safety or serviceability is shown to be inadequate, remedial interventions should be planned and implemented. The recommended measures taking into account the results of the assessment form the basis for fundamental decision with respect to required interventions.

The concept of interventions may include the following different options for construction measures:

- Immediate correction of the existing condition by means of urgent safety measures
- Retrofitting, repair and/or upgrading
- Replacement of the entire structure or of individual parts thereof
- Decommissioning
- Dismantling

As an alternative to construction measures risk control may include the following operation measures:

- Acceptance of the existing condition
- Restrictions in use
- Supplementary safety measures
- Performance of a further detailed assessment
- Initiate or change in monitoring and maintenance procedures

In case of a transformation of a part of the structure, the concept of interventions remains pertinent.

7.4.7.2 Retrofitting

Assessment of existing structures may result in several possible construction interventions. Retrofitting as a structural intervention to reach compliance with required structural performance includes:

- Repair
- Upgrading

The purpose of repair is to improve the condition of a structure either by repairing or replacing existing structural members that have been damaged, or by adding new structural members in order to reach its originally intended structural performance.

Upgrading modifications are applied to improve the structural performance of an existing structure compared to its originally intended structural performance.

These construction interventions should consider previous applied interventions and may be necessary in combination with operational interventions such as survey and monitoring maintenance.



Figure 7.8 Assessment, reintegration, and upgrading of an existing airport building respecting severe restrictions for logistics and construction works due to the tarmac traffic [Left image © European Union, 2015]

7.4.7.3 Survey and monitoring

Monitoring and maintenance are carried out according to the updated monitoring and maintenance plan.

If serious deterioration cannot be eliminated, more intensive monitoring should be introduced as a supplementary safety measure.

The measured (monitored) values should be compared to threshold values which, in turn, should be established on the basis of the admissible probability of failure. Actions to be taken when exceeding the thresholds should be determined in advance and registered in the monitoring and maintenance plan.

7.4.7.4 Remedial interventions

Remedial interventions shall be defined object-specifically according to the following criteria:

- Importance of the structure and damage potential
- Nature of the structural failure (with/without prior warning)
- Possibility of monitoring the structural behavior
- Possibility of controlling use
- Costs-risk considerations
- Various possibilities of damage limitation

The nature of remedial interventions may be operational or constructional. Often, different measures may successfully be combined.

7.5 Conclusions

The new generation of structural codes will highlight new and advanced concepts for the design of new structures as well as for the assessment of existing structures.

They will perform an efficient platform to contribute to the sustainable development of urban areas and infrastructures.

However, sustainable development will not respond to new needs only by adding new structures or substituting existing structures.

The new technical rules for the assessment of existing structures are a tool to identify their potential for meeting sustainable goals.

Owners - public and private – as well as users will profit from higher value and from extending the working life of existing structures.

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CHAPTER 8

EN 1998-3: SEISMIC ASSESSMENT AND RETROFITTING OF EXISTING BUILDINGS

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8 EN 1998-3: Seismic assessment and retrofitting of existing buildings

8.1 Introduction

8.1.1 General

Often structural assessment and retrofitting of a building is triggered by a major refurbishment for change of use, improved energy efficiency, etc. Old building structures may have to be assessed and possibly retrofitted to address:

1. more demanding actions due to change of use/operation, an extension of the design working life, or an increase in loads (e.g., from traffic, changes in the seismic zonation, etc.)
2. deterioration due to environmental effects or due to damage inflicted by accidental actions, such as impact, explosion, fire or an earthquake beyond the design level.
3. requirements set out by authorities, insurance companies, owners, or maintenance plans, especially if the structure has been built according to codes considered in the light of our present knowledge as obsolete and inadequate.

At first sight, any one of these reasons may suffice to question the adequacy of an older building vis-à-vis the current requirements for new structures (e.g., those in the first EN-Eurocode generation). The upside is that the simple design models and verifications of the past (and even of the present day) were quite safe-sided. So, their application has normally endowed old structures with considerable safety margins, which help them meet new demands of type 1 to 3 above. To quantify and use these margins, refined analysis methods and models, which are beyond the scope of design codes for new ones, need to be employed for existing structures. This indeed holds in the European Standard EN 1998-3:2005 "Seismic assessment and retrofitting of buildings". Refined models or methods may be adopted also in the upcoming extension of EN 1990 "Basis of structural design" and EN 1992 "Design of concrete structures" to cover assessment and retrofitting under all sorts of actions, and not just the seismic one.

8.1.2 Overview of the Chapter

In the few years since the publication of EN 1998-3:2005 ("Seismic assessment and retrofitting of buildings") and its adoption at national levels (alongside the National Annexes), this European Standard had limited application to real cases. From the experience gained so far, critical comments have focused on three aspects:

- a) The criteria for the assessment of performance concern individual members and have to be met by each and every one of them, at least after the retrofitting; it would be more logical to use, instead, global criteria for the building as a whole, at least at the performance level of Near Collapse.
- b) Uncertainties considered concern only the materials and the geometry (including the reinforcement) and depend on the amount of information available or collected; the magnitude of the uncertainty impacts the assessment through universal "confidence factors" applied on material strengths; uncertainties should be addressed, instead, individually, not collectively, and impact individually any property or aspect affected.

- c) Mechanical models and assessment criteria for nonstructural elements (especially masonry infill walls) are lacking and should be included.

The apparently first pilot application of EN 1998-3:2005 for the seismic assessment and retrofitting of a real building is highlighted. Less than seven years after its rehabilitation works were completed, the building was subjected to an earthquake which was almost as strong as the one for which it had been assessed and retrofitted. The ground motion records obtained nearby was used as input to back-analyses, in order to compare the observed performance to the outcome of the assessment per EN 1998-3:2005. This exercise confirmed the general approach of this European Standard, as well as its specific rules and criteria, but illustrated also the impact of the complete lack of attention to nonstructural infill walls.

Finally, this Chapter sets the forthcoming revision of EN 1998-3 against the backdrop of the enriched scope of the upcoming second generation of EN-Eurocodes (to be published by 2020), which will include assessment and retrofitting for actions other than the seismic.

8.2 Overview of EN 1998-3:2005 - feedback from its application

8.2.1 Introduction

Eurocode 8 "Design of structures for earthquake resistance" stands out as the only one among the first generation of EN-Eurocodes that addresses existing structures – notably buildings. This goes back to the early days when Eurocodes were pre-standards (ENVs), well before sustainable use of construction materials was seen as a reason for retrofitting old structures. This special feature of Eurocode 8 is due to the large size of Europe's building stock which is seismically deficient even in the most seismic parts of Europe, and the threat it poses to public safety.

8.2.2 Performance objectives - compliance criteria - analysis models

EN 1998-3 follows fully a performance-based and displacement-based approach. Three performance levels (termed "Limit States") are defined:

- "Near Collapse" (NC): the structure is heavily damaged, may have large permanent drifts, retains little residual lateral strength or stiffness, but its vertical elements can still carry the gravity loads. Primary members may reach a safe-sided (e.g., mean-minus-standard-deviation) estimate of their chord-rotation capacity and shear force ULS resistance (the former based on mean material strengths, the latter on design values); secondary members may reach their mean chord-rotation capacity and shear force resistance, computed from mean material strengths.
- "Significant Damage" (SD), which corresponds to "Life safety" and to the local-collapse prevention level for which new buildings are designed per EN 1998-1:2004. The structure is seriously damaged, may have moderate permanent drifts, but retains some residual lateral strength and stiffness and its full vertical load-bearing capacity. Repair may be uneconomic. A safety margin should be provided against the chord-rotation limits that apply to the NC Limit State, but the limit value of shear resistance is the same as in that Limit State.
- "Damage Limitation" (DL), which essentially means "Immediate Occupancy". The structure does not have residual drifts, its elements do not have permanent

deformations, retain their full strength and stiffness; and do not need repair. Members are verified to remain elastic in flexure and to meet the ULS shear checks specified for the NC Limit State (see above).

The "Seismic Hazard" levels for which the three Limit States are to be checked are set by National Authorities; otherwise, by the owner. EN 1998-3 itself does not make a recommendation, but mentions that the performance objective recommended for ordinary new buildings is a 225 year earthquake (20% in 50 years), a 475 year event (10% in 50 years), or a 2475 year one (2% in 50 years), for the DL, the SD or the NC "Limit States", respectively. National authorities may decide how many and which of the three Limit States will be checked.

Members are checked in flexure in terms of chord-rotations at their ends. The main aim of the analysis is to estimate the chord rotation demands. Nonlinear analysis – static (pushover) or dynamic (response-history) – is the reference method. It may be applied to all cases, as it can capture certain common idiosyncrasies of existing buildings which are adverse to earthquake resistance and, as such, can be avoided in the design of new buildings. Linear analysis with the elastic spectrum and application of the equal displacement rule at the level of chord rotations is also allowed, if the ratio of the elastic moment to the moment resistance does not vary too much (the recommended range is from 2.5 to 1) among all possible plastic hinge locations.

Secondary members are distinguished from primary ones solely on the basis of their importance for lateral force resistance, without an upper limit to their total contribution to lateral stiffness. They are not exempted from the verifications, but the limits they have to meet are laxer.

Regarding modeling of members, EN 1998-3 is specific and emphatic only about the use of the secant-to-yield-point stiffness as elastic stiffness; for concrete members it also gives information for its calculation, per Biskinis and Fardis (2004, 2010a). Guidance on nonlinear modeling is minimal: essentially, EN 1998-3 only says that the hardening ratio in monotonic loading should realistically reflect the post-yield behavior till the maximum deformation demand, and that hysteresis models – if used – should account for the energy dissipation in cyclic loading.

8.2.3 Treatment of uncertainties due to limited knowledge of the as-built structure

Depending on the data available for the as-built structure, three levels of knowledge are defined:

- "limited knowledge"
- "normal knowledge"
- "full knowledge".

"Normal knowledge" of the structure's geometry, material properties and amount and detailing of reinforcement comprises all information needed to build a detailed structural model for nonlinear analysis. It is obtained either from original specifications and construction drawings (confirmed for each type of structural member with one material sample per floor and check of dimensions and reinforcement in about 20% of their number) or in-situ measurements (two samples per floor for each type of member and exposure of reinforcement in about 50% of all members). For this level of knowledge, the estimated mean material strengths are modified by a "confidence factor" with a recommended value of 1.2.

"Limited knowledge" can support only a linear analysis model. Default assumptions for the materials may be made based on the codes and the practice prevailing at the time of construction, verified with one sample per floor for each type of member. Simulation of the

original design and spot checks in about 20% of the structural members per member type suffice for the amount and detailing of reinforcement. The recommended value of the "confidence factor" modifying the estimated mean material strengths is 1.35.

For "full knowledge", the confirmation of original construction drawings extends to 20% of the members of each type, and the in-depth survey, when original drawings are not available, to 80% of their number. Material properties are inferred either from test reports at the time of construction, verified with one sample per floor and type of member, or by taking three samples per floor and member type. The recommended value of the "confidence factor" is then 1.0.

8.2.4 Critical comments from the application of EN1998-3

In the few years since the publication of EN 1998-3:2005 and its adoption at national level together with the National Annexes, this European Standard per se has found limited application to real cases. Significant experience has been gained, though, from the application of regulations with strong similarities to EN 1998-3:2005 in Italy (Presidente del Consiglio dei Ministri, 2003) or Greece (EPPO, 2012). Certain critical comments have been expressed from the application of the Italian regulation (Pinto and Franchin 2014), which are in tune with the Greek experience:

1. The three "Limit States" are defined for the structure as a whole, but compliance criteria refer to individual members and have to be met by each and every one of them, at least after the retrofitting. It would be more logical to use global criteria instead, at least at the Near Collapse Limit State, and leave some room for judgment, depending on the number, location and importance of non-complying members.
2. The uncertainties considered only concern the materials, the geometry of the structure and the amount and detailing of the reinforcement, depending on the amount of information available. The magnitude of uncertainty impacts the assessment via a universal "confidence factor" applied on material strengths. If materials are less known than the geometry or the reinforcement, or vice versa, it is difficult to assign the entire building to a single knowledge level. Uncertainties should be addressed individually, not collectively, and impact individually any property or aspect affected. Model uncertainties and sensitivity studies reflecting the magnitude of uncertainty should also be introduced.
3. The freedom given concerning nonlinear member models is felt more as lack of guidance and direction. The problem is particularly acute regarding nonstructural elements (especially masonry infill walls), for which even compliance criteria for assessment are lacking.

According to Pinto and Franchin (2014), owing to 1 and 3 above, equally competent designers may reach different assessment outcomes; i.e., unlike design of new buildings, performance assessment of old ones is seen as an analysis problem with a single possible outcome. However, this interpretation may be too narrow: modeling always has a strong subjective component, and engineering judgment is essential. As a matter of fact, in the pilot application of the NEHRP guidelines FEMA 273 for the seismic assessment and retrofit design of 43 real buildings (BSSC, 1999), several buildings were studied independently by two US design firms. Retrofitting cost estimates for the same building differed between the two by up to 300%. This confirms the importance of judgment and shows that lack of an unequivocal outcome is natural.

As we will see in Section 4.2.1, the issues raised by the critical comments above are high on the list of items addressed in the upcoming revision of EN 1998-3. Noteworthy in this respect is the (CNR, 2013) approach, described and advocated by (Pinto and Franchin 2014). This approach is fully probabilistic, accounts for all possible uncertainties arising

from the seismic action and demand, the properties and capacities of components, as well as from the model, and addresses the building as a system. It is computationally very demanding, though, because it relies heavily on Monte Carlo simulation. To the extent that it can be simplified without losing its fundamental features, this approach provides very valuable input to the revision of EN 1998-3.

8.3 First building retrofitted to EN 1998-3 tested by earthquake

8.3.1 The backdrop

The building housing the municipal theater of Kefalonia is the largest in the island's main town. It was designed in 1979 with the 1959 seismic code, for an Effective Peak Acceleration (EPA) of 0.125g (in today's terms). The structural frame of the building was left exposed to the salt-laden environment of the site for over 10 years, without rendering or finishings. The building was completed in the early 1990s. About ten years later, reinforcement corrosion was evident in the perimeter vertical elements. The serious deficiencies of the building raised concerns about its structural safety; the owner was faced with the dilemma of demolition or retrofitting. The conclusion of the seismic assessment per EN 1998-3 was that the building violated the Limit State criteria of Eurocode 8 for an EPA around 0.05g, which is much less than the design EPA specified nowadays in the national code (i.e., of 0.36g). The owner was convinced not to demolish the building, but to retrofit it using EN 1998-3:2005.

8.3.2 Seismic retrofitting of the building with EN 1998-3:2005

The design of the retrofitting took place in the first half of 2005. Besides cost considerations, there were certain constraints:

- to limit interventions to the exterior and minimise disruption of use during the retrofitting;
- to avoid visible change of the façade;
- to allow only minor changes of the appearance of the two sides of the building.

The main thrusts of the retrofitting were to tackle corrosion of the reinforcement of the exterior vertical elements, especially in the lateral sides, where it was more serious, and to counteract the torsional imbalance due to two large RC walls at the façade. The retrofit design:

- applied one-sided RC overlays on the exterior face of the perimeter vertical elements,
- connected the two structurally independent and torsionally imbalanced units of the building, shown in Figure 8.1 and Figure 8.2, into an integral system as in Figure 8.3, and
- added two large walls to the back side, counterbalancing the two large walls at the façade.

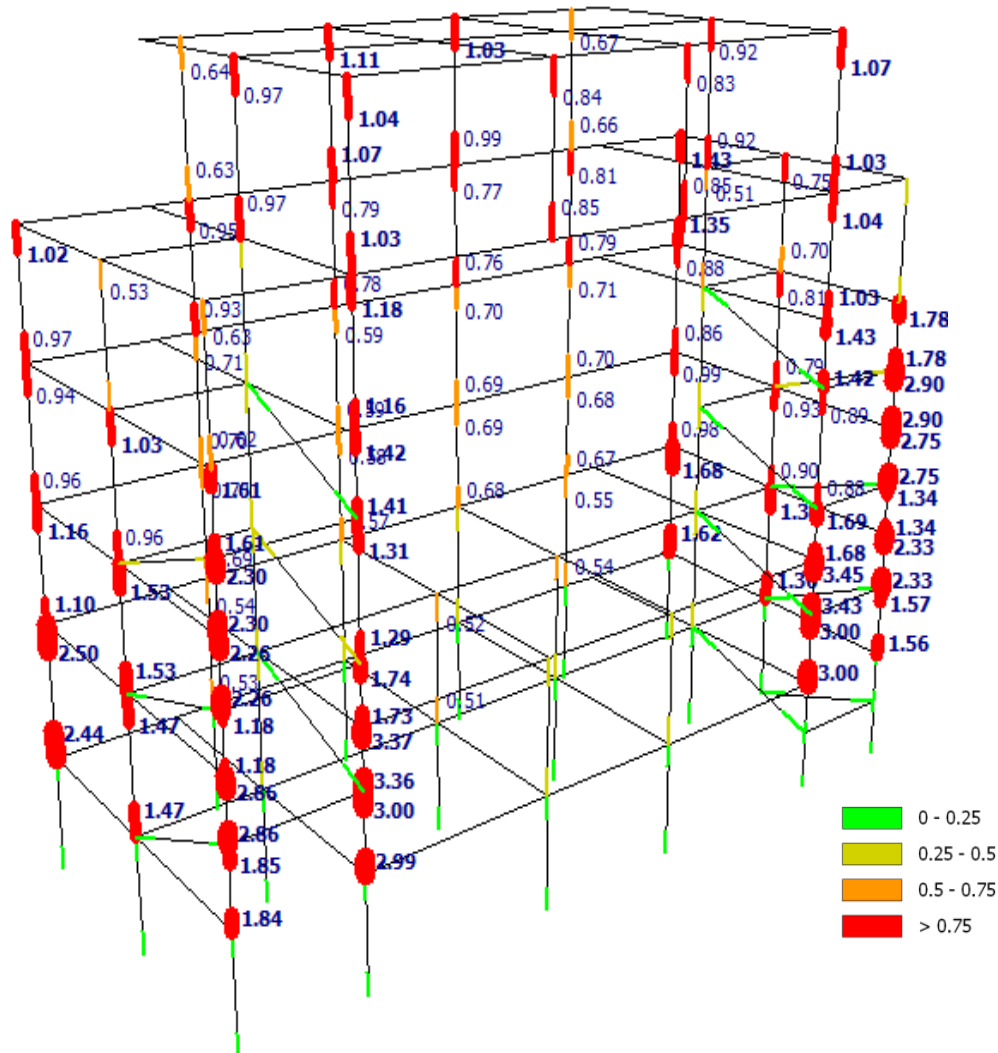


Figure 8.1 Ratio of shear force in the vertical elements of the unretrofitted structure of the "Stage" part of the building due to earthquake of 26-01-2014, to the shear resistance per EN 1998-3:2005

The nonlinear-response history analyses under bi-directional ground motions scaled to the current design EPA of 0.36g have shown persisting shortfalls in shear in vertical elements which are vital for the stability of the whole; these deficiencies were impossible to correct through RC jackets or overlays, because of limited access to the foundation so as to connect the RC jacket and restrictions in the use of RC overlays at the façade. So, the shear deficiencies were corrected with horizontal Fiber Reinforced Polymer (FRP) sheets, applied on the exterior face of the two large walls at the façade and on the surface of the accessible long sides of two pairs of interior walls (Kosmopoulos et al, 2007). Some deficiencies in shear persisted in the vertical elements of the penthouse and in beams and columns of the façade, especially at the top storey. It was decided not to take further action, profiting from the infills of the frame bays made of thick clay-brick masonry, whose contribution to lateral stiffness and resistance was neglected in the analysis.

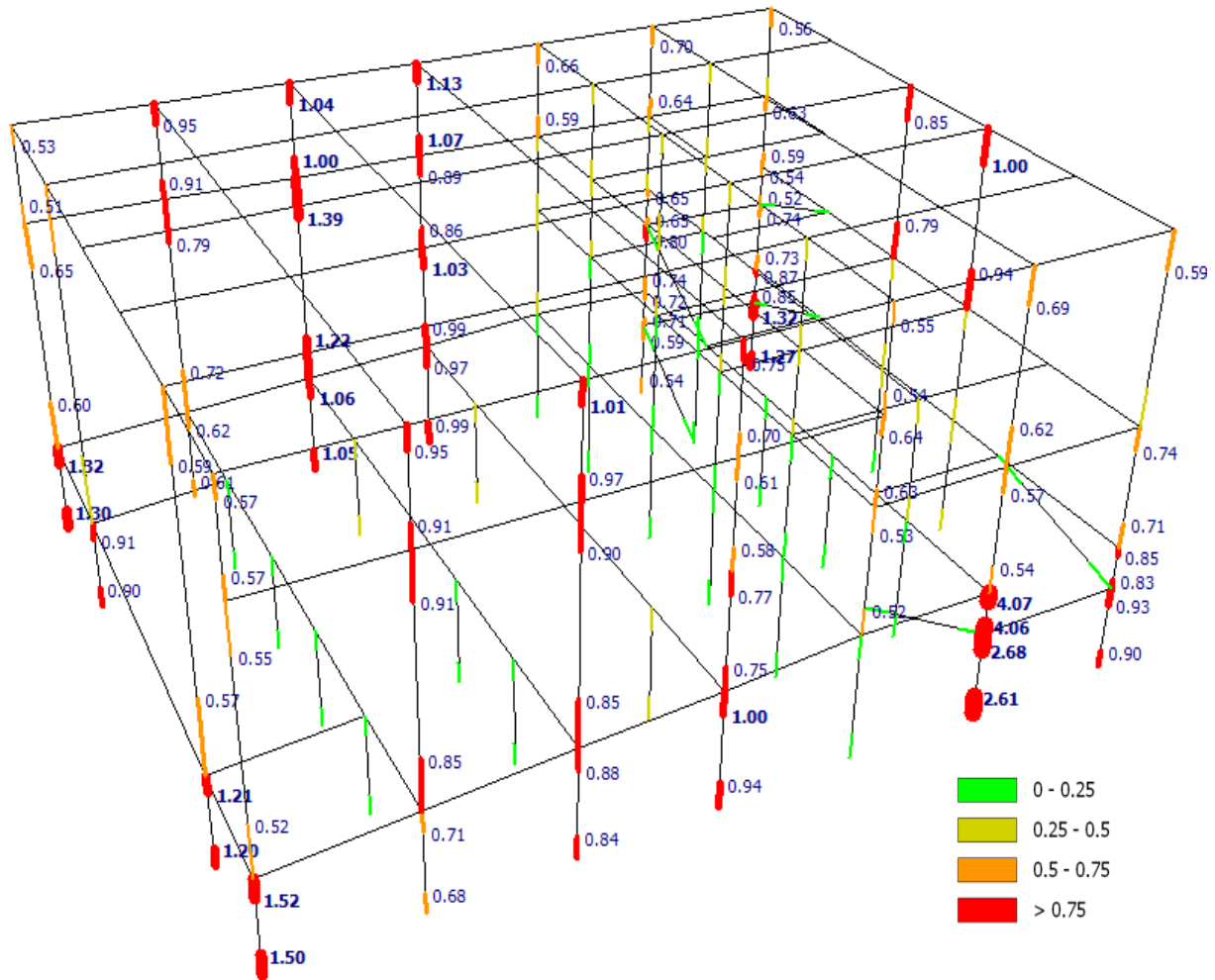


Figure 8.2 Ratio of shear force in the vertical elements of the unretrofitted structure of the "House" part of the building due to earthquake of 26-01-2014, to the shear resistance per EN 1998-3:2005.

The total cost of the intervention, including whatever removal and replacement of wall and floor finishings was needed and 19% VAT, was budgeted to €20 per cubic meter of the building's volume. So, in apparently its first application for seismic assessment and retrofitting of a RC building, EN 1998-3 succeeded to upgrade the building's resistance to ground motions from an EPA around 0.05g to the code-specified EPA level of 0.36g, at a very low cost. Minor deficiencies which could not be corrected without altering the façade or jeopardizing more important elements were tolerated as non-critical for the building as a whole, relying, instead, on the lateral resistance of masonry infills near the deficient elements.

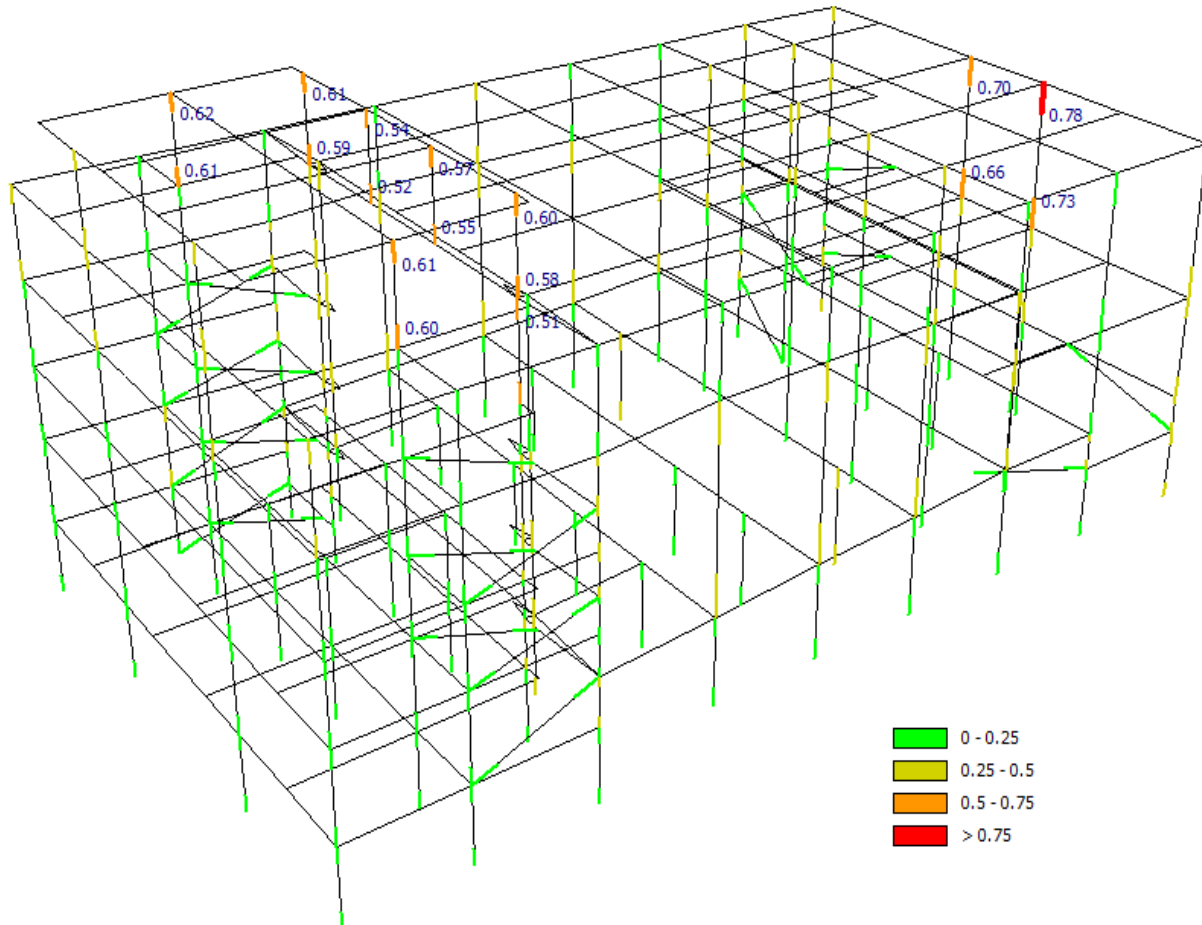


Figure 8.3 Ratio of shear force in the vertical elements of the retrofitted structure due to earthquake of 26-01-2014, to the shear resistance per EN 1998-3:2005

8.3.3 Computed response vs actual performance in the M6.1 earthquake of 26-01-2014

On January 26, 2014, six-and-a-half years after strengthening works were completed in July 2007, a Magnitude 6.1 earthquake struck Kefalonia. The ground motion was recorded 100 m from the building. The peak ground acceleration was 0.39g in the EW direction, 0.355g in NS and 0.32g in the vertical. Elastic spectral accelerations were well below the design ones in the vicinity of the fundamental periods of the retrofitted building, but well above in the range of the upper natural periods. A nonlinear dynamic analysis was carried out for each one of the two individual as-built parts of the original building under the recorded horizontal ground motions. A large exceedance of the cyclic shear resistance in key load bearing elements (Figures 8.1 and 8.2) suggests that collapse would have been a real possibility, had the building not been retrofitted (Fardis et al, 2015).

Consistent with the analysis of the retrofitted building (Figure 8.3), there was no damage to the retrofitted elements or the walls added at the back side. Cracks with residual width of few tenths of a mm were observed in slabs of the roof – suggesting that the corresponding parts of the top slab worked with the roof beams as effective flange in tension – and at the connection of two stair flights with the floor slab or the landing – confirming that stairs take part in the seismic response. The columns around the penthouse, and the top storey beams and columns of the façade were essentially free of damage, confirming that masonry infills adjacent to these elements, but neglected in the

analyses, played a beneficial role for the structural frame. The most serious damage was observed at two pairs of masonry infill panels on the sides of the penthouse. These infills were indeed meant to be sacrificed so as to protect the penthouse columns, which were found to be vulnerable and could not be retrofitted without increasing the seismic demands on precarious roof beams supporting the penthouse. Damage to these infills was concentrated around points where systems essential for the operation of the stage were supported. There was also clear evidence of out-of-plane distress of the infills due to their role in supporting these systems. The damaged infill panels were not confined by columns at both ends: they either had a door opening at one end or terminated at a short cross-wall (Fardis et al, 2015).

So, EN 1998-3:2005 achieved in this case its prime goal: to protect life. More attention should be paid, though, to nonstructural damage, in order to reduce repair costs and disruption of use.

8.4 The conclusion: assessment and retrofitting in the next generation of EN-Eurocodes

8.4.1 The context

In December 2012 the European Commission (EC) sent Mandate M/515 to CEN, inviting it to develop a detailed standardization work program for the second generation of EN-Eurocodes, which will include revised versions of the current ones, alongside new Eurocodes. The response of CEN Committee TC250: "Structural Eurocodes" (Denton and Angelino 2013) delineated the scope and the direction of the evolution item-by-item. The work will be carried out in four phases. The first and most important one starts in mid-2015. The last one is planned to finish by 2020, which is the target date for completion of the whole package of new and revised Eurocodes. Phase 1 will include a full revamp of EN 1998-3 under the new title "Seismic Retrofitting of Structures", reflecting the extension of its scope to bridges. New Eurocodes (or a new Section or Annex in the existing ones) will be added, at least to EN 1990 ("Basis of structural design") and to EN 1992 ("Design of concrete structures"), to cover assessment and retrofitting of existing structures against actions other than the seismic.

8.4.2 The forthcoming new version of EN 1998-3 "Seismic Retrofitting of Structures"

8.4.2.1 Buildings

Research on seismic assessment and retrofitting has a short history, so scientific technical developments are still fast. Hence, EN 1998-3 needs a thorough update for buildings:

- To rationalize "knowledge levels" and the associated "confidence factors".
- To supplement the current local compliance criteria for member performance with global ones addressing the building as a whole.
- To enhance/update the provisions for nonlinear analysis.
- To enrich/strengthen the part of EN1998-3 specific to masonry buildings, which is much less developed than the one for concrete buildings.
- To revisit/improve areas of weakness, such as the assessment of the cyclic shear resistance of concrete and masonry elements, the seismic behavior of walls and floor diaphragms, etc.

- To cover the facility as a whole, including its nonstructural components and equipment.
- To update the technical information on retrofitting techniques, in the light of recent developments (e.g., Biskinis and Fardis 2004, 2010a, 2010b, 2013a, 2013b, Fardis and Negro, 2005, Fardis et al 2013, Biskinis et al 2016).

8.4.2.2 Bridges

Most transportation networks in Europe predate seismic design codes for bridges. Bridges not designed for earthquake resistance pose a serious threat to the operation of a network after a strong earthquake. Some national authorities have launched seismic evaluation campaigns of old bridges and have even undertaken their retrofitting. To support such national efforts, EN 1998-3 will be extended to cover seismic assessment and retrofitting of bridges.

Strengthening the foundation of a bridge is a serious technical challenge, which often sets a limit to the upgrading of the lateral force resistance of the piers. So, seismic isolation of the superstructure and/or supplementary energy dissipation devices at the interface between the superstructure and the top of the piers and/or the abutments hold great promise as a means of seismic retrofitting and will be prominent in the extension of EN 1998-3 to cover bridges.

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CHAPTER 9

SEISMIC PERFORMANCE ASSESSMENT AND REHABILITATION OF EXISTING RC BUILDINGS IN TURKEY

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9 Seismic performance assessment and rehabilitation of existing RC buildings in Turkey

9.1 Seismic performance assessment procedures

The objective of seismic performance assessment is to evaluate a building or group of buildings under a considered earthquake effect and determine the expected performance of the building/buildings.

The seismic performance assessment procedures can generally be classified into three categories. The simplest and quickest way, called walk-down survey or street survey, requires only superficial data collected from a brief inspection of the building. The number of stories, vertical and plan irregularities, location of the building, age of the building, its structural system and apparent material and workmanship quality are typical parameters that are used. FEMA 154 (1988), FEMA 310 Tier 1 (1998) evaluation and Japanese system of assessment (Ohkubo, 1991) fall into this category. The purpose of rapid evaluation techniques is to identify or rank highly vulnerable buildings that deserve further investigation. A procedure has been developed for Turkish RC buildings by Sucuoğlu et al. (2007) that considers seismic zone, number of stories, material quality and some important architectural features including soft story and heavy overhangs. A performance score that indicates the vulnerability is assigned to each building. The application of this procedure is limited to low to mid rise ordinary reinforced concrete buildings in Turkey. This procedure was applied to several districts in Istanbul, Turkey (Sucuoğlu et al., 2007).

Preliminary assessment techniques are employed when a more detailed and reliable assessment is needed. In addition to what is collected from the street survey, data on the size and orientation of the structural components, material properties and layout are needed. This requires entrance to the building and review of structural drawings. This procedure does not rely on sophisticated and time-consuming analysis of the building but some quick calculations are performed. The building capacity is determined approximately and checked against an anticipated demand. By this comparison the expected performance of the building is predicted. The success of these techniques depends on the availability and quality of data. FEMA 310 Tier 2 (1998) evaluation is a widely used preliminary assessment technique. Several methods were developed in Turkey for RC Buildings (Yakut 2004, Yakut et al. 2006, Hassan and Sozen 1997, Tezcan et. al. 2011). Efficiency and adequacy of these procedures depend strongly on the quality of data, features of the buildings studied and applicability of the procedures (Yakut, 2014).

The detailed evaluation of existing buildings where comprehensive field survey and sophisticated structural analyses are required falls into the third category of vulnerability assessment. The comprehensive information on the geometrical properties of the components, mechanical properties of the materials, and detailing of the components are obtained from the structural drawings and as-built features of the building. Linear or nonlinear analyses techniques are used to determine the response quantities for an anticipated seismic action. These response quantities are then compared with certain accepted values to arrive at a decision regarding the expected performance of the building. FEMA 356 (ASCE, 2000), ASCE41 (ASCE, 2007), ATC-40 (1996), FEMA 310 Tier 3 (1998), Eurocode 8 (CEN, 2005) and Japanese level three (Ohkubo, 1991) evaluation procedures are among the most widely used techniques at this level. This level of assessment is generally used in site-specific applications, and is able to capture architectural features, material quality as well as detailing of the components to a certain extent. Detailed seismic assessment procedures in Turkey are discussed in the next section.

9.1.1 Detailed assessment procedures in Turkey

The general procedure for detailed assessment of an existing building starts with a decision on the performance level to be met. Then, a thorough survey in the field is conducted to obtain the as-built building properties using available information and carrying out measurements and tests needed. Following this, a representative building model is developed and the building is analyzed under the desired earthquake effect. Member deformations and internal forces obtained from the analysis are compared with the performance level based limit values to check whether they satisfy the required performance or not. If the building is found adequate it is assumed that it satisfies the desired performance criteria, however if the building is found inadequate, the building requires strengthening in order to meet the desired performance criteria.

There are two codes in Turkey that deal with performance assessment of existing buildings. A specific chapter of 2007 seismic code is devoted to assessment and rehabilitation of existing buildings. A new technical guideline was promulgated in 2013 under the urban renewal law to determine whether a building has high risk or not. These codes are summarized next.

9.1.1.1 Seismic design code 2007: Chapter 7- Assessment and rehabilitation of existing buildings

The Turkish seismic design code was revised in 2007 and a new section on assessment and strengthening of existing buildings was added (MPWS, 2007). The code requires data collected from the buildings based on three knowledge levels; namely limited knowledge, moderate knowledge and comprehensive knowledge. The data collected includes soil properties, foundation system and building structural properties. In addition to member dimensions and the reinforcement detailing, existing damage, repair, alterations and corrosion should be noted if any. The amount of data and the level of detail depend on the knowledge level selected. If the structural drawings are unavailable then Limited or Moderate knowledge levels can be selected. If structural drawings are available, Moderate or Comprehensive knowledge can be preferred. The detail of work for building geometry, member details and material properties are specified for each knowledge level. To determine material strengths, core samples are required to be taken and tested. For reinforcement detailing, both destructive and non-destructive methods are required. The number of core samples to be taken and the number of members to be examined for detailing depend on the knowledge level. The selected knowledge level affects the material capacities such that member capacities are multiplied with knowledge level factors which are 0.75, 0.90 and 1.0 for limited, moderate and comprehensive knowledge levels, respectively.

In the Turkish code, members are classified either as ductile or brittle. In brittle members, the internal forces are compared and these members are expected to be strengthened. Three damage limits and regions are defined for ductile members, that are minimum damage limit (MN), safety limit (GV) and collapse limit (GC). Member force and deformation demands are compared with the damage limits to determine which damage region the member falls (Figure 9.1).

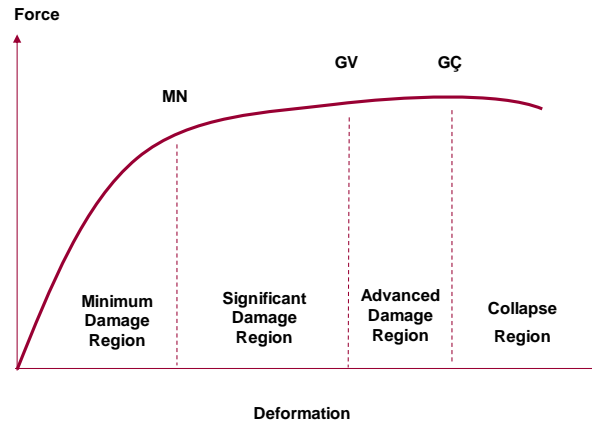


Figure 9.1 Member damage limits and regions

In the current Turkish code, the performance levels and the earthquake effect are specified for the building type and occupancy as shown in Table 9.1. Three earthquake and three performance levels are used. Immediate occupancy (IO), Life safety (LS) and Collapse prevention (CP) performance levels are specified. The earthquake effect is represented in terms of the response spectra given for three return periods corresponding to 50 percent, 10 percent and 2 percent probabilities of exceedances in 50 years.

Table 9.1 Earthquake effects and performance levels for building type and occupancy

<i>Building Type and Occupancy</i>	<i>Exceedance Probability of Earthquake Ground Motion</i>		
	50 % in 50 years	10 % in 50 years	2 % in 50 years
<i>Important Buildings to be Operational After Earthquakes:</i> Hospitals, health facilities, fire stations, communication and energy facilities, transportation stations, disaster management centers, important governmental buildings.	-	IO	LS
<i>Buildings with Dense and Long Term Occupation:</i> Schools, Dormitories, hostels, military posts, prisons, museums.	-	IO	LS
<i>Buildings with Dense and Short Term Occupation:</i> Theatre halls, Concert halls, Cultural centers, Sports facilities	IO	LS	-
<i>Hazardous Buildings:</i> Buildings housing toxic, explosives and explosive substances	-	LS	CP
<i>Other Buildings:</i> Buildings not classified above (residential, offices, hotels, industrial facilities etc.)	-	LS	-

Methods of analysis

Once the analysis model for the building is obtained based on the data collected, two options are available for the performance assessment. The first alternative is linear elastic analysis based approach requiring the demand capacity ratios (r values) be calculated for each member. In ductile members, the moment due to earthquake loading alone is divided by the residual moment capacity which is obtained by subtracting the vertical load moment demand from the section moment capacity. For brittle members, shear force is divided by the shear capacity to get r value. These values are then compared with the limit r values for each member to determine member damage region. Linear analysis using either

equivalent static load or mode superposition method are employed to determine member internal forces. The limit r values depend on the section properties such as confinement, the level of axial load, lateral reinforcement amount and shear force ratio. Table 9.2 shows the limit r values for columns. Similar tables are given for beams and shear walls in the code.

Table 9.2. Limit Demand capacity ratios (r) for columns

Ductile Columns			Damage Limit		
	Confinement		MN	GV	GÇ
≤ 0.1	Yes	≤ 0.65	3	6	8
≤ 0.1	Yes	≥ 1.30	2.5	5	6
≥ 0.4 ve ≤ 0.7	Yes	≤ 0.65	2	4	6
≥ 0.4 ve ≤ 0.7	Yes	≥ 1.30	1.5	2.5	3.5
≤ 0.1	No	≤ 0.65	2	3.5	5
≤ 0.1	No	≥ 1.30	1.5	2.5	3.5
≥ 0.4 ve ≤ 0.7	No	≤ 0.65	1.5	2	3
≥ 0.4 ve ≤ 0.7	No	≥ 1.30	1	1.5	2
≤ 0.7	-	-	1	1	1
Brittle Columns			1		

The second alternative is to use linear inelastic analysis. Either pushover or nonlinear time history analysis can be preferred. The pushover analysis can be used under certain limitations. In the analysis, strains at the most outer concrete and steel layers are calculated at each member end. These strains are then compared with the limit values given below to determine member damage regions.

Minimum Damage Limit:

$$\epsilon_c = 0.0035 ; \epsilon_s = 0.010$$

Safety Limit:

$$\epsilon_c = 0.0035 + 0.01 (\rho_s / \rho_{sm}) < 0.0135 ; \epsilon_s = 0.040$$

Collapse Limit:

$$\epsilon_c = 0.004 + 0.014 (\rho_s / \rho_{sm}) < 0.018 ; \epsilon_s = 0.060$$

Performance assessment and acceptance criteria

From the type of analysis chosen, damage region for each member is determined. The next step is to check whether the building satisfies the target performance level. For this, a story based evaluation is followed: the acceptance criteria is given for the percentage of shear force carried and the damage region of the members. For example, for immediate occupancy to be satisfied, for every floor, all columns are required to be in the minimum damage region whereas 10 percent of the beams are allowed to be in the significant damage region. In the case of life safety, 30 percent of the beams and some of the columns are allowed to be in the advanced damage region, all other members need to be in lower damage regions. The columns in the advanced damage region can contribute to the total story shear by not more than 20 percent. In collapse prevention performance, at most 20 percent of the beams and some of the columns can be in the collapse damage region, other

members should be in lower damage regions. The columns in the collapse region can contribute to the story shear by not more than 20 percent.

Therefore, if the above performance criteria are not met in any story then the building is considered to not satisfy the desired performance level.

9.1.1.2 Specifications for Classification of High Risk Buildings-SCHRB

A new urban renewal law was passed on May 16, 2012 (MEU, 2012) to mainly address the vulnerable residential building stock. According to the law, local municipality authorities, Ministry of Environment and Urbanization (MEU) or any of the apartment owners may request the seismic assessment of a building. If a building is found to be seismically vulnerable, occupants are given 60 days to either demolish the building or present an approved strengthening design. The applicants are provided either 18 months of rent support as a grant or offered reduced interest rates for mortgage by the government for the process of refinancing of the building as an encouragement.

According to the law a building is classified as high risk or critical if the building is expected to experience collapse or very heavy damage under the design earthquake. The Ministry of Environment and Urbanization set up a committee to draft a relatively fast and acceptable procedure for assessment of residential buildings (named as Specifications for Classification of High Risk Buildings-SCHRB). The procedure is based on linear elastic analysis of the building model that may be generated from the information collected for the ground floor.

The building data (concrete strength, member dimensions, detailing etc.) to be collected from the ground floor only unless vertical element discontinuity is found. A three dimensional model of the building is generated based on a detailed survey performed for the critical floor (generally the ground floor) only. If preferred, a complete survey can be carried out. Since the assessment is done for only columns and shear walls at the critical floor, material properties and reinforcement detailing are determined for these members. At least five concrete core samples are required from the columns and walls to determine the concrete strength. Removing the cover concrete for several members is required to determine the reinforcement details. The complete building model may be obtained by the replication of the ground floor layout over the building height for regular buildings. However, one must consider irregularities in height and in plan as defined in the TEC (MPWS, 2007).

Based on the results of linear elastic analysis (equivalent lateral load or response spectrum) under the design response spectrum (given in TEC (MPWS, 2007)) and using no response modification factor, the bending moment demand capacity ratios (DCR) at member ends and interstory drift deformations are determined.

For each column and wall at the critical floor, DCR and interstory drift deformations are compared with the corresponding limit values. If the interstory drift ratios in any floor are higher than the ones obtained in the ground floor then assessment of the members for the interstory drift ratio at that floor is also carried out. If the column/wall does not satisfy either one of the limits, it is classified as unacceptable. Depending on the number of unacceptable members, buildings are classified as "critical" or "not critical." Critical building represents a building that is expected to suffer heavy damage or collapse under the design earthquake effect. Because of the inability of the linear elastic analysis to allow for redistribution, some flexibility is provided on how many columns are allowed to exceed their performance limits. When the average axial stress resulting from gravity loads in the considered floor exceeds 0.65, none of the members are allowed to exceed their performance limit to classify the building as "not critical, (NC)." When the average axial load ratio is less than or equal to 0.1, columns/walls that carry up to 35 percent of the story shear are allowed to exceed their performance limits in order to classify the building

as NC. Linear interpolation is used to determine the acceptable story shear ratio for intermediate average axial load ratios.

Columns are classified into three and walls are classified into two groups according to their expected failure mode; flexural failure, shear-flexure and shear failure. Limiting values for demand capacity ratios and interstory drift ratios are determined based on analysis of data obtained from experimental and analytical studies (Binici et al., 2015). These values are given for Class A and B columns in Table 9.3.

Table 9.3. Performance limits for DCR and Interstory drift ratios

a) Class A			b) Class B			
$N_k/(f_{cm} \times A_g)$	DCR_{limit}	$(\delta/h)_{limit}$	$N_k/(f_{cm} \times A_g)$	$A_{sh}/(s \times b_k)$	DCR_{limit}	$(\delta/h)_{limit}$
≤ 0.1	5.0	0.03	≤ 0.1	≤ 0.0005	2.0	0.01
≥ 0.6	2.5	0.0125		≥ 0.006	5.0	0.03
			≥ 0.6	≤ 0.0005	1.0	0.005
				≥ 0.006	2.5	0.0075

9.2 Seismic rehabilitation of existing RC buildings in Turkey

Rehabilitation of existing RC buildings has found great attention in last decades in Turkey due to their observed poor performance after recent earthquakes. In the current practice, rehabilitation of a building is required to be checked according to TEC (MPWS, 2007). There are two objectives in rehabilitation of an existing building: 1. member rehabilitation, 2. system rehabilitation. In the member rehabilitation, the aim is to enhance member capacities in terms of both strength and deformation. This will generally have no significant change in the building capacity but improves ductility. The system level strengthening, on the other hand, aims to significantly improve the building capacity thorough major interventions.

9.2.1 Member strengthening

The most common techniques for strengthening RC members is to jacket members using RC, Steel or fiber polymers. It is expected to increase the shear and compressive strength as well as flexural deformation capacity. In RC jacketing, existing member section is generally enlarged by adding longitudinal and transverse reinforcement. The minimum jacket thickness is around 10 cm. An example application is shown in Figure 9.2.



Figure 9.2 Application of RC Jacketing to a column

Although not very common in Turkey, steel jacking is also an efficient method used to strengthen RC members. Typically, steel plates and angles are used to jacket column faces (Figure 9.3).

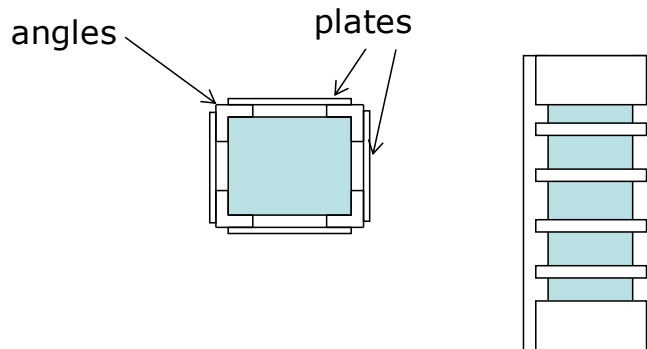


Figure 9.3 Steel Jacketing of RC columns

One of the most common method for column strengthening in Turkey is to wrap the columns with carbon fiber reinforced polymers (CFRP). This method is also applied to beams in which case anchors need to be used for connection to the slab. Although the application and style of CFRP depends on the objective, full or stripe forms can be used.

9.2.2 System strengthening

The most common technique for strengthening of RC buildings is addition of shear walls and strengthening of weak members. Addition of external framing, diagonal steel braces and strengthening of existing masonry infill walls are other methods employed. Since the buildings needing rehabilitation generally have inadequate strength and stiffness, addition of shear walls has been found to be the most efficient method. However, care must be given to especially connection of the added walls to the existing frame. Added walls must be continuous over the height. The location of shear walls is determined considering symmetry in plan to reduce torsion. For added walls, a new foundation is also needed. The design is carried out according to Turkish codes (MPWS, 2007) where minimum anchorage diameter (16 mm), anchorage length ($>10 \varnothing$) and ancrohe spacing are specified.

Special attention is required when a low strength concrete building is strengthened, especially for anchorage problems and foundation connections. Figure 9.4 shows example application showing addition of shear walls to a span where surrounding columns are also jacketed.



Figure 9.4 Addition of shear walls and frame column jacketing

An alternative and less destructive method is to apply CFRP to existing masonry infill walls to provide strength and stiffness to the building. A significant amount of research conducted at METU showed that diagonal stripes anchored to the columns and infill wall qualifies as an efficient method (Binici and Ozcebe, 2006). A comparison of CFRP and addition of shear wall on a typical frame is shown in Figures 9.5 and 9.6. It is shown that CFRP can provide the same strength as RC wall.

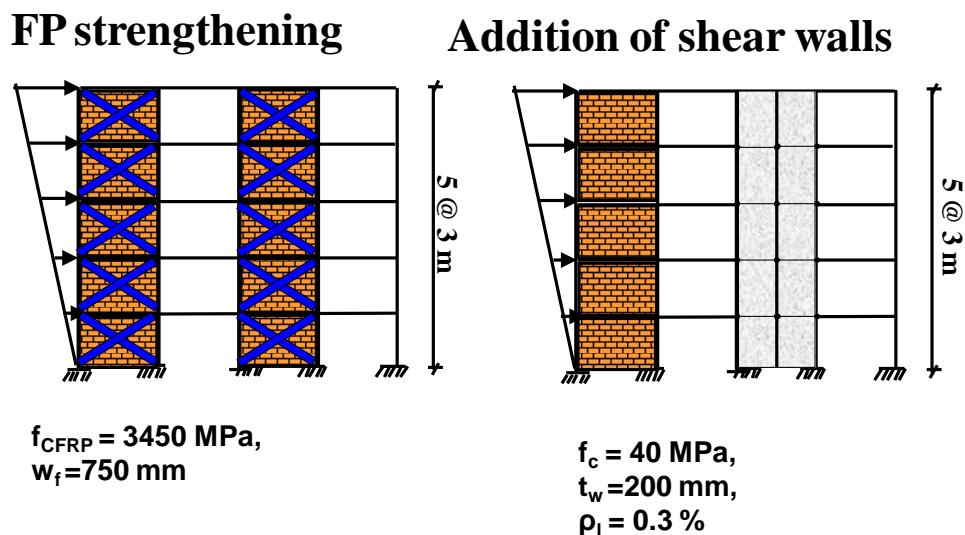


Figure 9.5 Alternative strengthening methods on an example frame (Binici and Ozcebe, 2006)

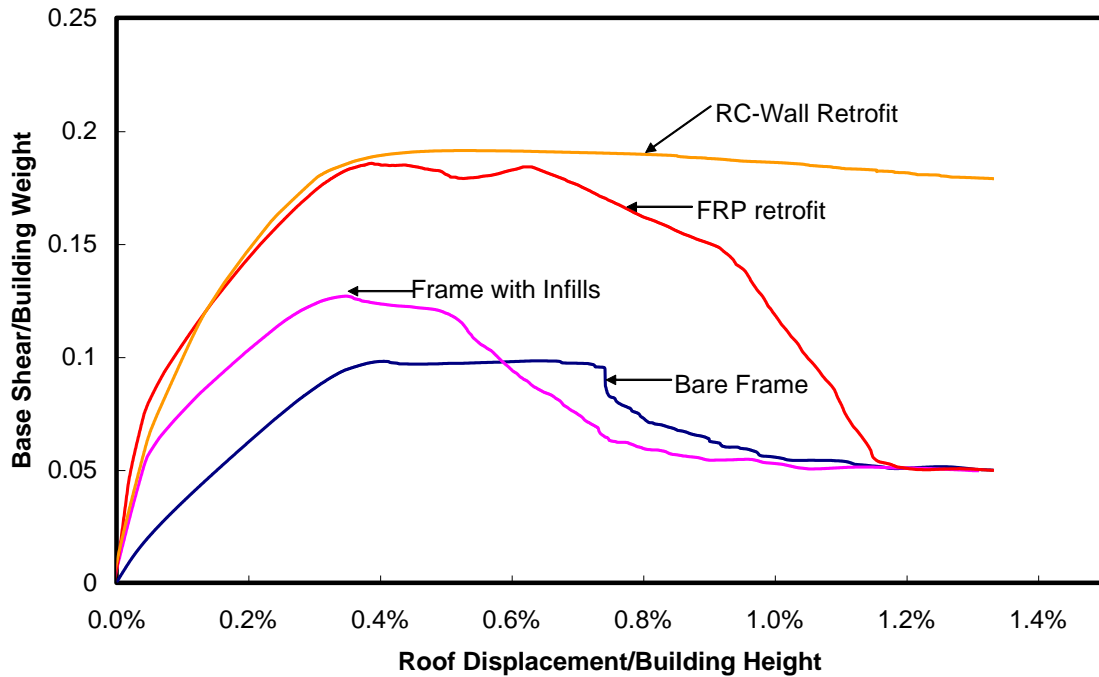


Figure 9.6 Comparison of force deformation response for various cases (Binici and Ozcebe, 2006)

Strengthening of RC buildings using diagonal steel braces is preferred especially for prefabricated buildings. An application of such technique to a prefabricated building damaged after an earthquake is shown in Figure 9.7. In this case, all connections were made rigid.



Figure 9.7 Retrofit using steel bracing

Another example showing addition of walls only externally in order not to stop the operation inside the building is shown in Figures 9.8 and 9.9. In this case, anchorage of the external

members to existing frames and floors is extremely important. Special attention should be given to foundations of external frames and their connections.

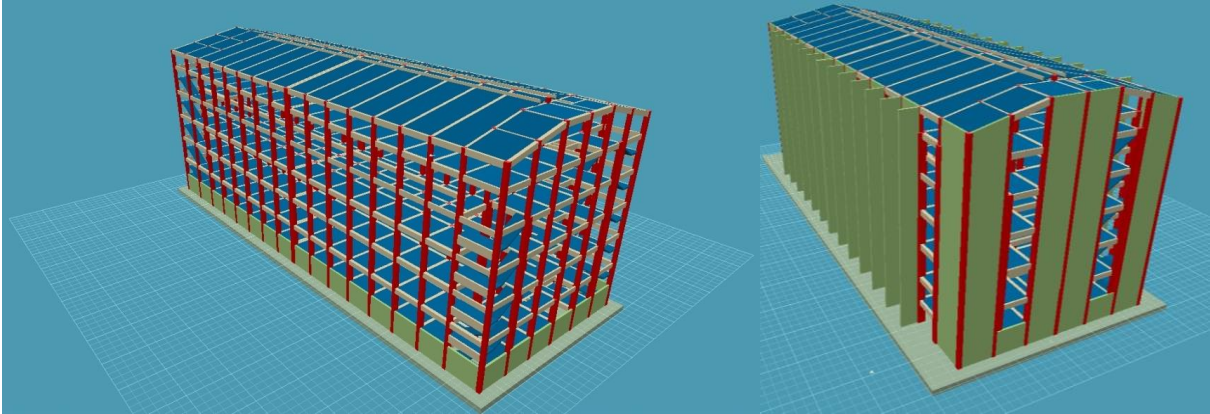


Figure 9.8 Externally added walls



Figure 9.9 Various stages of construction

9.2.3 Performance of rehabilitated buildings

There is not much information on the seismic performance of rehabilitated buildings in Turkey. However, observations from recent earthquakes showed that properly strengthened buildings performed satisfactorily. Performance of a school building rehabilitated using shear walls (Figure 9.10) is shown in Figure 9.11. For this building, the rehabilitation seemed to have worked and saved the building from significant damage.

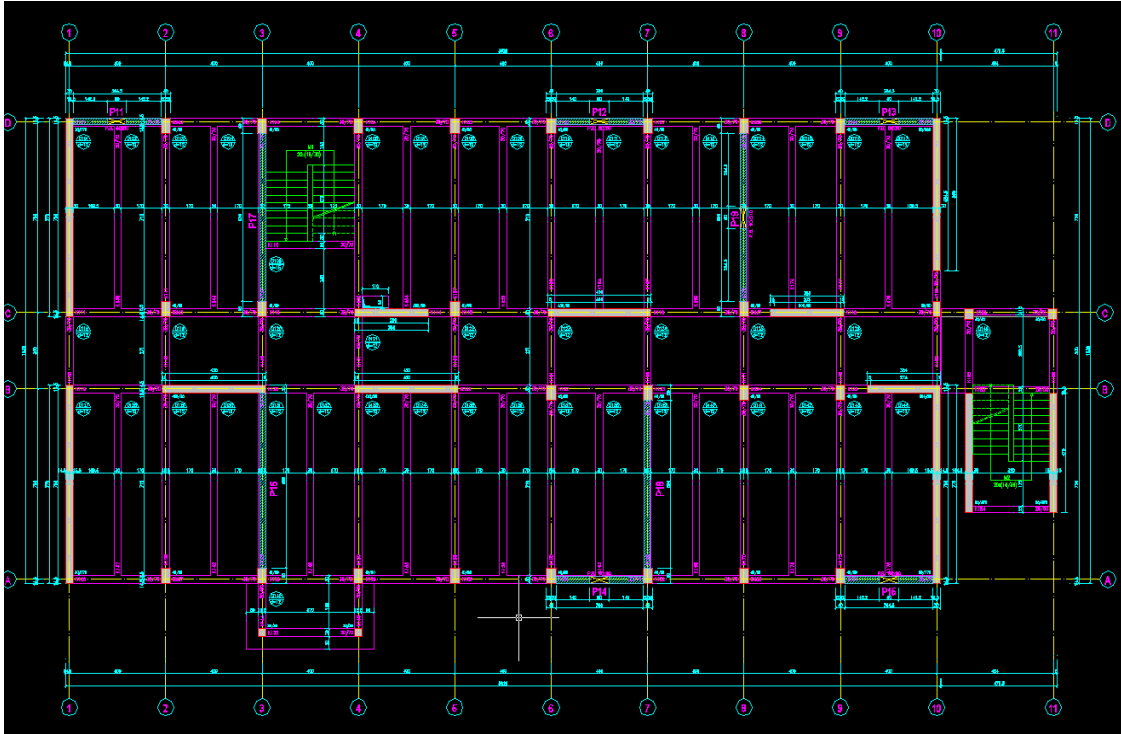


Figure 9.10 RC School building rehabilitated using shear walls (yellow walls were added)



Figure 9.11 Performance after 2011 Van Earthquake

9.3 Conclusions

Assessment and rehabilitation of existing buildings in Turkey are carried out according to TEC (MPWS, 2007). Besides, buildings are evaluated for determining their risk under urban renewal law per a separate code that only classifies the buildings either having high risk or not (Binici et al. 2015). A significant number of public and private buildings have been rehabilitated in Turkey. Majority of these buildings are RC and were rehabilitated using addition of shear walls. The largest public building stock rehabilitated is school buildings in different parts of the country. Seismic performance of properly rehabilitated buildings were observed to be satisfactory.

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CHAPTER 10

ADOPTION AND IMPLEMENTATION OF THE EUROCODES IN THE NON- EU COUNTRIES IN THE BALKAN REGION

**Activities supported by enlargement and integration action of
the Joint Research of the European Commission -**

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10 Adoption and implementation of the Eurocodes in the non- EU Countries in the Balkan Region

10.1 Introduction

Standardization is playing an important part in supporting the European Union's strategy for smart, sustainable and inclusive growth (European Commission, 2010). The EN Eurocodes are a set of European standards that provide common rules for the design of construction works, to check their mechanical resistance and stability against live and extreme loads such as earthquakes and fire.

Within the national framework for implementation of the Eurocodes each country must define Nationally Determined Parameters (NDPs) to be applied in their territory. These parameters are left open for national choice and should cover country differences in geographical, geological and climatic conditions, different design and construction practices, as well as, different safety level requirements. NDPs are required for the national implementation of the Eurocodes.

The considerable interest in the implementation and adoption of the Eurocodes in the EU Member States, as well as in non-EU countries in the Balkan region is based on the opportunity to have an advanced common standardization environment, which is adaptable to the particular requirements of each country with regard to geographical, geological and climatic conditions, allowing to select specific levels of safety. The other important benefit is the fact that the Eurocodes are comprehensive design tool, which over a mid- to long-term period intends to cover additional fields of design, such as protection of the environment, resources, energy efficiency, safety-and health conditions and security.

Moreover, adoption and implementation of Eurocodes will help the Candidate Countries to fully implement EU *acquis* at the time of accession and support Potential Candidate Countries to progressively align themselves with the EU *acquis*.

This chapter addresses the activities carried out for the adoption and implementation of the Eurocodes in the non-EU countries in the Balkan region within the context of the Enlargement and Integration Action of the JRC.

The main objective of the activities presented herein was to focus on:

- Progress and specific needs for adoption and implementation of the Eurocodes and related EN standards in the Balkan region
- Progress, difficulties and needs for the definition of the Nationally Determined Parameters (NDPs) and National Annexes (NAs)
- Progress, difficulties and needs for elaboration of maps for climatic and seismic actions for structural design in the Balkan region

10.2 Building capacities for adoption of the Eurocodes in the non-EU countries from the Balkan region

Three workshops with representatives of the Balkan countries were organized in order to provide scientific and technical contribution in the context of the JRC support work to DG GROW for the implementation, harmonization and further development of the Eurocodes, and to support acceding and candidate countries within the framework of the JRC Enlargement and Integration Action.

10.3 Identification of target countries and relevant national stakeholders

In line with the EU enlargement and neighbourhood policy the following non-EU countries in the Balkan region were identified: Albania, Bosnia and Herzegovina, Kosovo³, the former Yugoslav Republic of Macedonia, Montenegro, Serbia and Turkey, as well as Moldova, which belongs to the European neighbouring countries of Eastern Europe.

In each of the non-EU countries in the Balkan region several different groups of national stakeholders were identified:

- National authorities and policy decision makers (Ministries of Construction, Ministries of infrastructure, etc.)
- National Standardization Bodies (NSBs)
- Professional users of standards (Design and construction companies, Industry organizations, National Economic Chambers, Chambers of professionals involved in design and engineering, etc.)
- Institutions that will stream the determination of NDPs, NAs, elaboration of maps for climatic and seismic actions and the application and training on the Eurocodes (Universities, research institutions, Academies of Sciences, etc.)
- Chairmen of TC250 Mirroring Committees and members of the working groups for all Eurocodes, except EN 1994 and EN 1999.

10.4 Workshop on the adoption of the Eurocodes in the Balkan region

The first Workshop on the *Adoption of the Eurocodes in the Balkan region* was held on 5-6 December 2013 in Milan and at the Joint Research Centre of the European Commission (JRC), Ispra, Italy⁴, (Apostolska et al., 2013). The Workshop was organized by DG JRC, included a visit to the European Laboratory for Structural Assessment (ELSA) (Figure 10.1) and was supported by the JRC Enlargement and Integration Action.

³ This designation is without prejudice to positions on status, and is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo Declaration of Independence

⁴http://eurocodes.jrc.ec.europa.eu/showpage.php?id=2013_12_WS_Balkan

The workshop focused on the progress and on specific needs for the adoption and implementation of the Eurocodes and related EN standards in the Balkan region. In particular, the workshop and the round table discussions served the following objectives:

- Assess the level of commitment and the progress of adopting the Eurocodes
- Assess the level of harmonization of national policy/legislation with EU regulatory frameworks
- Assess the progress of definition of Nationally Determined Parameters (NDP)
- Define the strategies for training and elaboration of guidelines and training materials
- Facilitate exchange of views, knowledge and information between EU experts and representatives of non-EU countries in the Balkan region
- Facilitate regional cooperation in preparing National Annexes (NAs) and harmonization of NDPs



Figure 10.1 Visit to ELSA

The programme of the workshop was composed of three parts:

- Lectures delivered by invited experts from JRC and DG ENTR of European Commission, CEN/CENELEC and EU Member States
- National presentations of non-EU countries about adoption of the Eurocodes (standards and legislation); specific problems and needs, training, guidelines and training material
- Round table discussions regarding adoption of the Eurocodes in the Balkan region – conclusions and recommendations

Thirty seven representatives of the National Authorities, National Standardization Bodies, Academia and Chambers of Engineers from non-EU countries in the Balkan region participated as well as seven invited experts from CEN/TC250, CEN&CENELEC Management Centre, DG ELARG and EU Member States and seven representatives of the JRC (ELSA Unit). The total number of participants was 51. The nominated participants from non-EU countries in the Balkan region came from each of the following groups: high-level officials from relevant governmental institutions (TG_1); members from national standardization bodies (TG_2); chambers of engineers and/or construction industry (TG_3) and universities and research institutions (TG_4) (Figure 10.2). There were also few cases where participants were nominated by National Standardization Bodies.

The current situation in the adoption and implementation of the Eurocodes in the Balkan region was characterised by means of a questionnaire sent to relevant national stakeholders. Generalized data requirements of the questionnaire were organized in four groups: (1) National regulatory framework; (2) NDPs, National Annexes and harmonization; (3) Education and training and (4) Additional comments. Selected outcomes gathered from the questionnaires are presented below.

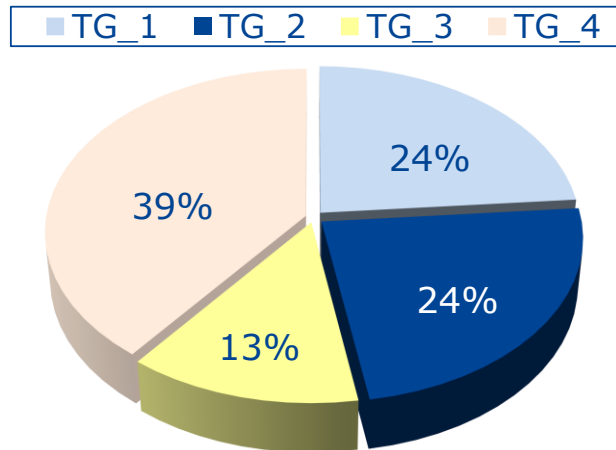


Figure 10.2 Groups of participants [%]

The Eurocodes are going to be used as primary standards in most of the non-EU countries in the Balkan region (Figure 10.3). Turkey expressed its willingness for using as primary standards those parts of the Eurocodes for which there are no existing contemporary national standards. The process of adoption of the Eurocodes related harmonized standards have been completed in Bosnia and Herzegovina, Croatia⁵, Montenegro and Serbia (Figure 10.3). The process is in an advanced phase in Albania and Moldova, and at the beginning in the former Yugoslav Republic of Macedonia. No data was received from Turkey.

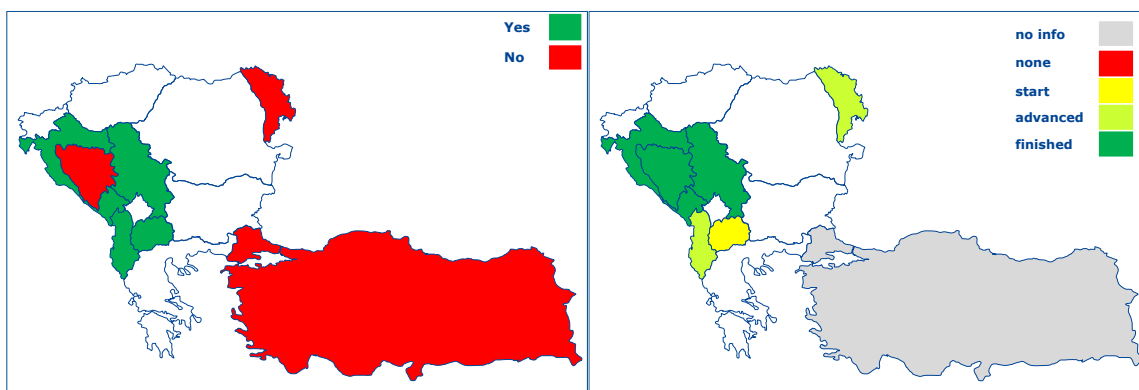


Figure 10.3 Countries in which Eurocodes will be used as primary standards (left) and progress of adoption of the Eurocodes related harmonized EN standards (right)

Concerning education and training, the data provided in the questionnaires show that the Eurocodes are comprehensively included in the first study cycle (Bachelor level) of

⁵ Croatia became a Member State since July 1, 2013.

Universities in Bosnia and Herzegovina (BiH). In Albania and Moldova, the Eurocodes are not included at all. Montenegro, Serbia and Turkey show some progress (in average four out of ten Eurocodes are included) and in the former Yugoslav Republic of Macedonia only EN1990 is included. At the second cycle studies (Master level) the situation is more promising. Since most of the countries are in seismic prone areas, it is interesting to observe the inclusion of EN 1998 in the education of young engineers (see Figure 10.4). Training material (booklets, leaflets, guidelines, etc.) in national languages is available in Croatia, the former Yugoslav Republic of Macedonia, Montenegro (except EN 1994 and EN 1999) and Serbia. Implementation of the EN Eurocodes meets difficulties due to the lack of material available in each national language. It is also important to emphasise the lack of a common strategic approach at a national level.

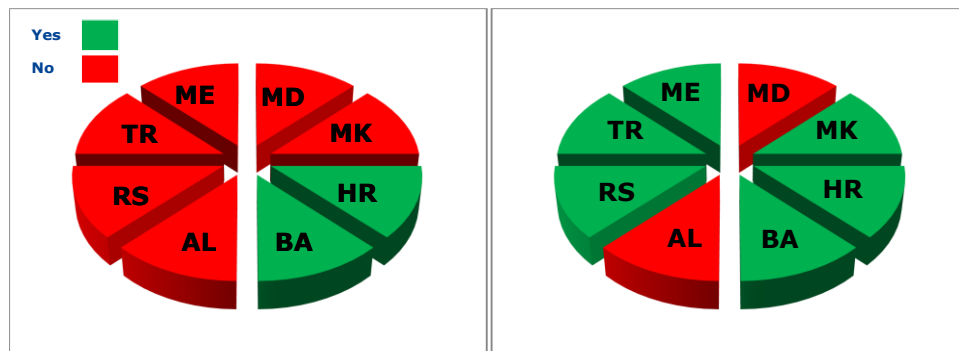


Figure 10.4 Presence of the EN 1998 in the education (left –first level and right – second level)

It should be pointed out that the above presented results refer to 2013. Since the assessment of the progress, difficulties and needs for the definition of the National Determined Parameters (NDPs) and National Annexes was one of the main objectives of the second workshop, the relevant data regarding this topic are presented in section 10.5.

10.5 Workshop on building capacities for elaboration of NDPs and NAs of the Eurocodes in the Balkan region

The workshop “Building capacities for elaboration of NDPs and NAs of the Eurocodes in the Balkan region” was focused on further adoption and implementation of the Eurocodes in non-EU countries in the Balkan region⁶. The main goal was to assess recent progress, difficulties and needs for the definition of the NDPs and NAs since the first workshop held in 2013, and to boost regional collaboration for cross-border harmonization of NDPs (Apostolska et al., 2014).

In particular, the workshop and the round table discussions served the following objectives:

- Assess recent progress, difficulties and needs for the definition of the NDPs and NAs since the first workshop held in Milan & Ispra on 5-6 December 2013

⁶http://eurocodes.jrc.ec.europa.eu/showpage.php?id=2014_11_WS_Balkan

- Boost regional collaboration for cross-border convergence of NDPs, in particular for the harmonization of seismic hazard maps based on the experience of the SHARE and NATO projects
- Facilitate transfer of knowledge from EU MS experts (Croatia, Greece, Bulgaria, Slovenia) to representatives of non-EU countries in the Balkan region in the field of elaboration of NDPs and NAs
- Increase awareness of existing enlargement funds and instruments which might support further progress in adoption and implementation of the Eurocodes
- Give an overview of state-of-the-art training material, background information and worked examples and raise awareness of the existing Eurocodes web site and benefits emanating from its use
- Improve information flow between National Standardization Bodies and European Commission

The Workshop was held on November 4 and 5, 2014 in Skopje and it included a technical visit to the Institute of Earthquake Engineering and Engineering Seismology, UKIM-IZIIS (Figure 10.5).

Thirty-seven representatives of the National Standardization Bodies, Academia and Chambers of Engineers from non-EU countries in the Balkan region and one observer from Kosovo participated, as well as seven invited experts from CEN/TC250, EU Member States, SHARE and NATO SfP projects and four representatives of the JRC (ELSA Unit). The total number of the participants was 49.

The assessment of the recent progress, difficulties and needs for the definition of the NDPs and NAs since the first workshop was carried out by means of a questionnaire, which was compiled and sent to the members of each country delegation. The questions in the questionnaire were organized in four groups:

1. The EN part translation in National language
2. Definition of NDPs for this EN part
3. The EN part published as National standard and
4. Additional comments that are not covered in the questionnaire.

Selected results are presented further in the paper.



Figure 10.5 Visit of the UKIM-IZIIS

Monitoring the progress of translation since the last workshop revealed that the process is in a very advanced phase in Albania (more than 60% translated), with an envisaged date for translation of EN1994, EN1997 and EN1999 in 2016. Turkey made good progress with more than 20% of EN parts translated; this process was just initiated in Bosnia and Herzegovina (Figure 10.6).

Progress of translation of the Eurocodes										
	EN1990	EN1991	EN1992	EN1993	EN1994	EN1995	EN1996	EN1997	EN1998	EN1999
AL	✓	✓	✓	✓	none	none	none	none	✓	none
BA	none	none	none	none	none	none	none	none	start	none
MK ¹	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ME	✓	advance	none	none	none	none	none	none	advance	none
RS	✓	✓	advance	✓	✓	✓	✓	advance	advance	✓
TR	advance	advance	advance	advance	advance	none	none	none	advance	none

¹('MK' is a provisional code which does not prejudice in any way the definitive nomenclature for this country, which will be agreed following the conclusion of negotiations currently taking place on this subject at the United Nations).

Figure 10.6 Translation of the Eurocodes (data refers to December, 2013)

However, it is important to point out that according to the recent information from the last workshop held in Zagreb in 2015 (details are presented in section 10.4) Bosnia and Herzegovina is actively working on the translation of the standards with 36% of them already translated. The former Yugoslav Republic of Macedonia and Moldova completed the translation and the process is almost finished in Albania (95% parts translated).

Another conclusion drawn from the previous workshop (Apostolska et al., 2013) showed that the process of elaboration of NDPs and NAs was in an initial phase in the majority of non-EU countries in the Balkan region. In Bosnia and Herzegovina, Moldova, Turkey and Albania (except EN 1998), the process had not yet started (Figure 10.7).

Progress of definition of NDPs										
	EN1990	EN1991	EN1992	EN1993	EN1994	EN1995	EN1996	EN1997	EN1998	EN1999
AL	none	none	none	none	none	none	none	none	start	none
BA	none	none	none	none	none	none	none	none	none	none
MK ¹	✓	start	start	start	start	start	advance	start	start	start
MD	none	none	none	none	none	none	none	none	none	none
ME	✓	advance	none	none	none	none	none	none	advance	none
RS	✓	advance	start	✓	✓	start	start	start	advance	advance
TR	none	none	none	none	none	none	none	none	none	none

Figure 10.7 Progress of definition of the NDPs (data refers to the first workshop, December, 2013)

Significant progress on the national choices of NDP values could be observed based on the questionnaires and on country report presentations that were delivered at the second workshop in Skopje. Most of the non-EU countries in the Balkan region (except Bosnia and Herzegovina and Turkey) have initiated the process of establishing NDP values for their NAs. Albania and Serbia are the most advanced countries with around 60% of NDPs already determined. The former Yugoslav Republic of Macedonia reported that 71% of their NAs are in the phase of public enquiry and that the mean percentage of acceptance of the recommended values is 80% (Figure 10.8). The average percentages of acceptance shown in Figure 10.8 for the Balkan countries are all above the mean value of 73.2% (see section 11.3.2) obtained for the NDPs uploaded in the European Commission NDPs database, by early January 2016, by the EU and EFTA Member States.

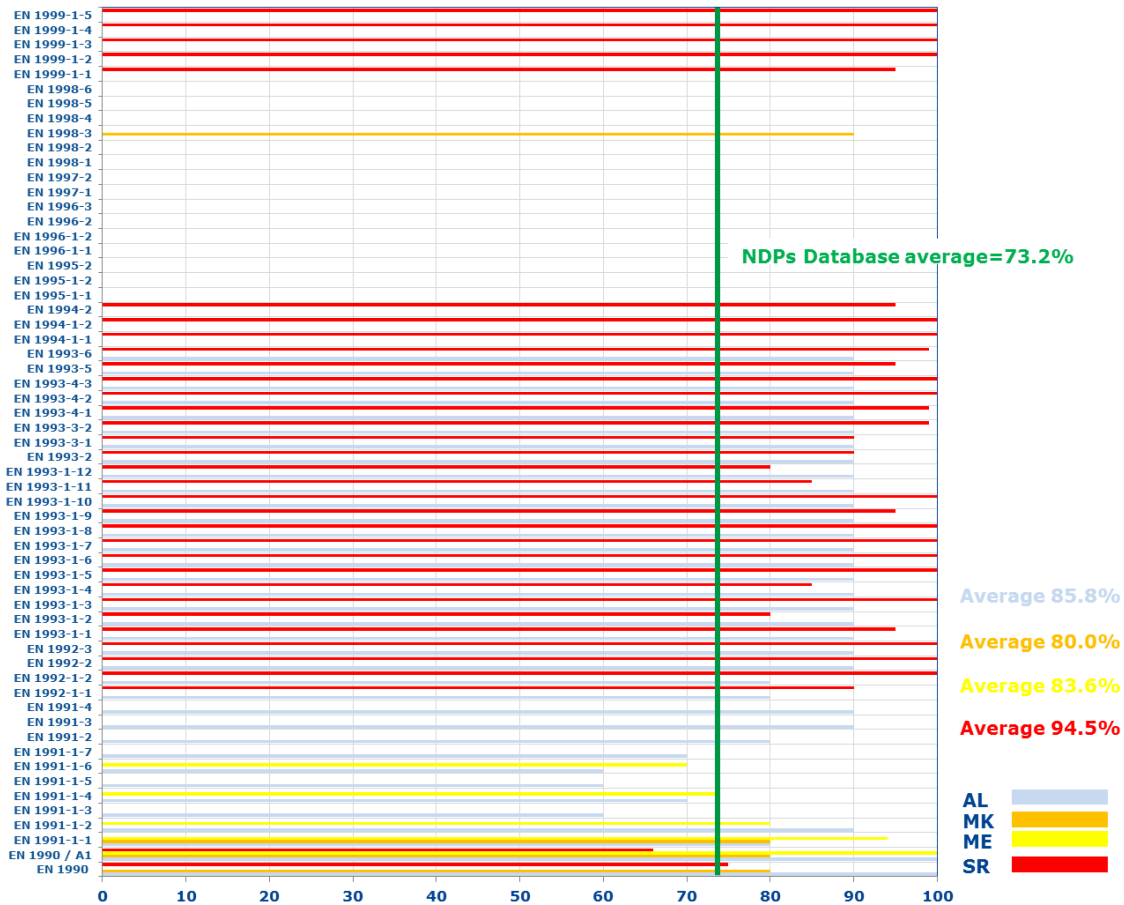


Figure 10.8 Acceptance of recommended values [%]

10.6 Workshop on elaboration of maps for climatic and seismic actions for structural design in the Balkan region

The Workshop on *Elaboration of maps for climatic and seismic actions for structural design in the Balkan region* was held on 27-28 October in Zagreb, Croatia⁷. It was organised by Directorate General Joint Research Centre (DG JRC) of the European Commission with the support of the JRC Enlargement and Integration Action and the European Committee for Standardization, Technical Committee 250 (CEN/TC250). The workshop was hosted by the University of Zagreb and by the Croatian Standards Institute.

It builds upon the activities carried out at the two previous workshops:

- 1) *Adoption of the Eurocodes in the Balkan region*, held on 5-6 December 2013 in Milan and the JRC, Ispra, Italy
- 2) *Building capacities for elaboration of NDPs and NAs of the Eurocodes in the Balkan region* held on 4-5 November 2014 in Skopje, the former Yugoslav Republic of Macedonia

⁷http://eurocodes.jrc.ec.europa.eu/showpage.php?id=2015_10_WS_Balkan

The Workshop is aimed at further adoption and implementation of the Eurocodes in the non-EU countries in the Balkan region. In particular, it is envisaged to serve the following main objectives:

- To strengthen the capacities of the stakeholders from non-EU countries in the Balkan region for the elaboration of maps for climatic and seismic actions for structural design with the Eurocodes.
- To facilitate the regional cooperation and networking among non-EU countries in the Balkan region towards successful implementation of the Eurocodes.

The total number of NDPs which are related to the maps for climatic and seismic action is 142 and is presented in Figure 10.9.

Eurocodes Part	Nb NDPs
EN 1991: ACTIONS ON STRUCTURES; Part 1-3: General Actions - Snow loads	33
EN 1991: ACTIONS ON STRUCTURES; Part 1-4: General Actions - Wind actions	68
EN 1991: ACTIONS ON STRUCTURES; Part 1-5: General Actions - Thermal actions	29
EN 1998: DESIGN OF STRUCTURES FOR EARTHQUAKE RESISTANCE, Part 1: General rules, seismic actions and rules for buildings	11
EN 1998: DESIGN OF STRUCTURES FOR EARTHQUAKE RESISTANCE, Part 3: Assessment and retrofitting of buildings	1

Figure 10.9. Total number of NDPs related to climatic and seismic maps

The programme of the Workshop is composed of four parts:

- Lectures delivered by invited experts concerning the elaboration of maps for seismic and climatic (wind, snow and thermal) actions, and sharing mostly regional experience
- Lectures delivered by invited experts concerning the assessment and retrofitting of existing structures – prospect for European Guidance
- National presentations of non-EU Balkan countries about the progress of elaboration of maps for climatic and seismic actions for structural design
- Round table discussion regarding the progress of elaboration of maps for climatic and seismic actions for structural design in the Balkan region; drivers and barriers - conclusions and way ahead

Twenty-four representatives of the National Standardization Bodies, Academia and Chambers of Engineers from non-EU countries in the Balkan region and ten representatives from Croatia as local host participated the Workshop, as well as twelve invited experts from CEN/TC250, EU Member States, Seismic Hazard Harmonization in Europe (SHARE) and NATO Science for Peace (SfP) projects. The JRC participated with four representatives from the European Laboratory for Structural Assessment. The total number of participants was 50, (Figure 10.10).



Figure 10.10 Participants of the workshop

The assessment of the current situation in the elaboration of maps for climatic and seismic actions for structural design was carried out by means of a questionnaire sent to the relevant national stakeholders. Generalized data requirements of the questionnaire were organized as given in Figure 10.11.



Figure 10.11 General scheme of the questionnaire

A brief summary of selected outcomes gathered from the received questionnaires is presented in Figure 10.12 (concerning elaboration of maps for climatic and seismic actions) and Figure 10.13 (concerning elaboration of NAs relevant to the objectives of the workshop).

Country	Snow map	Wind map	Thermal map	Seismic hazard map
Albania	YES	YES	YES	YES
BiH	NO	NO	NO	NO
FYROM	NO (end of 2015)	NO (end of 2015)	NO (end of 2015)	NO (end of 2015)
Kosovo	NO	NO	NO	YES
Moldova	NO (ongoing)	NO (ongoing)	NO (ongoing)	YES
Montenegro	NO	NO	NO	YES
Serbia	YES (should be modified)	YES	YES (finished but not confirmed)	YES
Turkey	YES	NO	NO	YES (revision done-to be approved)

Figure 10.12 Elaboration of maps for climatic and seismic action – summary

Country	EN1991-1-3	EN1991-1-4	EN1991-1-5	EN1998-1	EN1998-3
Albania	NO (end of 2016)	NO (end of 2016)	NO (end of 2016)	NO (end of 2016)	NO (end of 2016)
BiH	NO (stage 10.99)	NO (stage 10.99)	NO (stage 10.99)	no info	no info
FYROM	YES	YES	YES	YES	YES
Kosovo	NO	NO	NO	NO	NO
Moldova	NO	NO	NO	no info	no info
Montenegro	NO (end of 2015)	NO (end of 2015)	NO (end of 2015)	YES	no info
Serbia	NO (end of 2015)	NO (end of 2015)	NO	no info	no info
Turkey	NO	NO	NO	NO	NO

Figure 10.13 Elaboration of NAs related to the workshop' objectives – summary

10.7 State of the progress and views on the way ahead

10.7.1 State of the progress

After two-days of presentations and discussions, as well as knowledge gathered experience from the two previous workshops the main results can be summarised as follows:

- National Standardisation Institutions from most of the non - EU countries in the Balkan region have adopted the Eurocodes as standards, in parallel with existing national codes that are part of National regulation. Eurocodes can be used as long as National regulations are respected.

- There is a good progress on Eurocodes translations since the first workshop held in Milan 2013. The former Yugoslav Republic of Macedonia and Moldova completed the translation and the process is almost finished in Albania (95% translated).
- Most of the non-EU countries in the Balkan region (except Turkey) have started the determination of the NDPs. The former Yugoslav Republic of Macedonia is the most advanced, with all NDPs already established (excluding the maps for climatic and seismic actions), followed by Albania and Serbia with around 60% of NDPs already settled. The percentage of acceptance of the recommended values is greater than 80%. However, in most of the countries there is a lack of relevant institutional support for this process.
- A very good example, which summarises the effect of the JRC support in the process of adoption of the Eurocodes in non-EU countries in the Balkan region, is the case of Bosnia and Herzegovina. While having almost no progress before the first JRC workshop, Bosnia and Herzegovina is currently actively working on the translation of the standards (36% already translated) and on the publication of National Annexes in cooperation with the Czech Standardization Institute.
- Concerning the elaboration of maps for climatic and seismic actions, Albania and Serbia are the most advanced countries with all the maps prepared. It was also observed that in most of the countries the seismic hazard maps are ready, except for Bosnia and Herzegovina and for the former Yugoslav Republic of Macedonia. In the latter, the maps are expected to be published by end of 2015. Compared with the seismic hazard maps, the elaboration of maps for climatic actions is lagging behind mainly due to insufficient data.
- The process of publication of NAs to the EN parts that are relevant to the objectives of the Workshop is in its initial phase for all countries, except for the former Yugoslav Republic of Macedonia where all NAs are already published (the maps will be included by the end of 2015). Montenegro is in an advanced stage also, with the NA elaborated to EN1998-1 and the NAs to EN1991-1-3, EN1991-1-4 and EN1991-1-5 foreseen for the end of 2015.
- In 2016, the JRC will publish a report on basic principles and national experience in the elaboration of maps for climatic and seismic actions consisting of written material prepared by the experts invited to the Workshop.

10.7.2 Views on the way ahead

In following are highlighted the essential points to further facilitate the process of adoption and implementation of the Eurocodes in the non- EU countries in the Balkan region and, in particular, the elaboration of maps for climatic and seismic actions for structural design:

- There is a need for creating a regional platform to boost regional collaboration for cross-border convergence of NDPs, in particular for harmonisation of seismic hazard, snow, wind and thermal actions maps.
- It is proposed to launch bilateral (twinning) projects for building national capacities and for the transfer of knowledge for the elaboration on maps for climatic and seismic actions (positive example – collaboration between Bosnia and Herzegovina and Czech Standardization Institute).
- It is recommended to bring in the experience, methodologies and tools developed in different projects (e.g. Global Seismic Hazard Assessment Program (GSHAP), Harmonization of Seismic Hazard Maps for the Western Balkan Countries (BSHAP), Seismic Hazard Harmonization in Europe (SHARE)) and to work in synergy with Balkan's experts, to facilitate the process of elaboration of climatic and seismic hazard maps in the region.

- It is recommended to intensify communication between experts on the elaboration of maps for climatic and seismic actions, the National Authorities responsible for enforcement of standards and regulations, and the engineering community, in order to make all involved stakeholders aware of the implications of these actions on design issues.
- Most countries suggested that regional cooperation should be promoted for elaboration of maps for climatic and seismic actions and to further facilitate the implementation of the Eurocodes, by setting up itinerant regional conferences, meetings, seminars, workshops and training events hosted by each of the countries in the Balkan region. The National Standardisation Body of Moldova kindly offered to be the next host of such event(s).
- As a result of the brainstorming sessions, different issues were addressed as possible topics for the next event, namely: (1) the importance of the implementation of the Eurocodes for the extension of the EU economic area; (2) the levels of reliability achieved with the national choices of NDPs and (3) the implications of climate change on the elaboration of maps for climatic actions. There was a joint understanding that the topic of the next event should have a much broader prospective.
- It is recommended to intensify the communication between National Standardisation Bodies and national stakeholders in the CEN Member countries in the Balkan region, to ensure the nomination of relevant experts to the CEN/TC250 working groups, in order to obtain timely information and to participate on the decisions regarding the second generation of the Eurocodes.

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CHAPTER 11

STATE OF HARMONIZED USE OF THE EUROCODES NATIONALLY DETERMINED PARAMETERS RELEVANT TO THE DEFINITION OF CLIMATIC AND SEISMIC ACTIONS

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11 State of harmonized use of the Eurocodes Nationally Determined Parameters relevant to the definition of climatic and seismic actions

11.1 Introduction

The European Committee of Standardization (CEN) produced the EN Eurocodes that are a set of 10 European Standards, EN 1990 – EN 1999, providing common technical rules for the design of buildings and other civil engineering works and construction products.

The on-going implementation of Eurocodes in the Member States of the European Union (EU) and of the European Free Trade Association (EFTA) does enhance the functioning of the Internal Market for construction products and services by removing the obstacles arising from different national practices. Further, the Eurocodes are meant to lead to more uniform levels of safety in construction in Europe. The Eurocodes are the product of a long procedure of bringing together and harmonizing the different design traditions in EU and EFTA Member States, but at the same time, they safeguard the right of the regulatory authorities in each Member State to determine values related to regulatory safety matters at a national level. In fact, they include the Nationally Determined Parameters (NDPs), which are those parameters that were left open in the Eurocodes to take into account different requirements for safety levels, different design cultures and procedures for structural analysis, as well as differences in geographical, geological or climatic conditions.

The set of the NDPs comprises: (i) values and/or classes where alternatives are given in the Eurocodes, (ii) values to be used where a symbol only is given in the Eurocodes, (iii) country specific data, e.g., seismic zone maps, snow maps, wind maps, etc., and (iv) the procedure chosen to be used when alternative procedures are given in the Eurocodes.

Since March 2005, the Joint Research Centre provides scientific and technical support to DG GROW of the European Commission in the frame of Administrative Arrangements on the Eurocodes. The mission initially devoted to the JRC included support to the national implementation and harmonization of the Eurocodes, support to the training, international promotion and further development of the Eurocodes. Since 2015, the scope of the JRC contribution has been extended to support to policies and standards for sustainable construction (Dimova et al., 2015).

In this framework, and in view of achieving the concerned Parts of the European Commission Recommendation of 11 of December, 2003 (2003/887/EC) on the implementation and use of Eurocodes for construction works and structural construction products, the JRC presently provides the development and maintenance of a Nationally Determined Parameters (NDPs Database) adopted in the countries of EU and EFTA applying the EN Eurocodes. The NDPs Database has restricted access, acts as a platform of notification to the European Commission by the Member States on the adopted values of the NDPs and constitutes the basis for the analysis of the NDPs, contributing to the definition of strategies tending to achieve further harmonization of the Eurocodes.

The next goal of the European Union is to keep the Eurocodes as the most advanced state-of-the-art codes for structural design in the world. The Directorate General Internal Market, Industry, Entrepreneurship, and Small and Medium Enterprises (DG GROW) mandated CEN (M/466, 2010; M/515, 2012) to develop the second generation of the Eurocodes, whose publication is expected by 2020 (Dimova et al, 2015). Among the guiding principles of the projects to be developed, further harmonization of the Eurocodes is aimed at through minimizing the number of the NDPs. The assessment of the potential

to significantly reduce their number, shall be done in collaboration with the JRC using the NDPs uploaded in the NDPs Database.

The objective of the present chapter is to analyse the state of harmonized use of the Eurocodes NDPs relevant to the definition of climatic and seismic actions, based on the NDPs uploaded in JRC Database. The analysis will focus on:

- the availability of data in the NDPs Database, allocated to Member State and Eurocode;
- the harmonized use of NDPs in the Database;
- the uploading of NDPs in the Database that are related to the definition of climatic and seismic actions, per Eurocode Part;
- the acceptance of the NDP values related to the definition of climatic and seismic actions;
- the examination of the acceptance rate per NDP type, with a view to analysing harmonized patterns and divergences in the NDPs related to the definition of climatic and seismic actions;
- examples of maps uploaded in the Database, or referred to, by the Member States.

11.2 Brief outline of Eurocodes and NDPs

The EN Eurocodes apply to structural design of buildings and other civil engineering works including geotechnical aspects, structural fire design, situations including earthquakes, execution and temporary structures. For design of special construction works (e.g. nuclear installations, dams, etc.) other provisions than those in the EN Eurocodes might be necessary. The EN Eurocodes cover the basis of structural design (EN 1990), actions on structures (EN 1991), the design of concrete (EN 1992), steel (EN 1993), composite steel and concrete (EN 1994), timber (EN 1995), masonry (EN 1996) and aluminium (EN 1999) structures, together with geotechnical design (EN 1997) and design, assessment and retrofitting of structures for earthquake resistance (EN 1998) (see Figure 11.1).

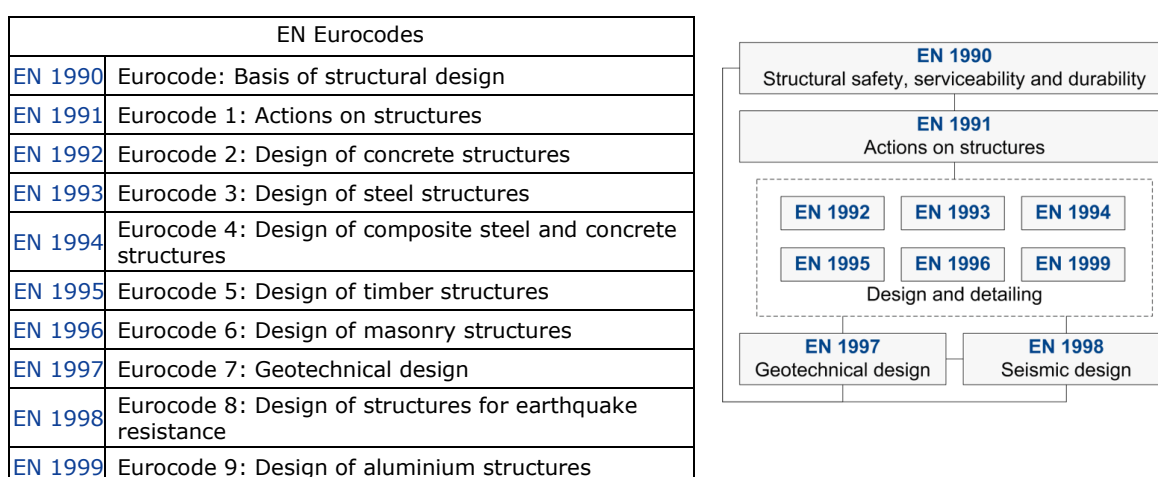


Figure 11.1 EN Eurocodes and links between the Eurocodes

Each of the Eurocodes (except EN 1990) is divided into a number of Parts covering specific aspects of the subject. In total there are 58 EN Eurocode Parts distributed in the ten

Eurocodes (EN 1990 – 1999). All of the EN Eurocodes relating to materials (EN 1991 to EN 1996 and EN 1999) have a Part 1-1 which covers the design of buildings and other civil engineering structures and a Part 1-2 for fire design. The Eurocodes for concrete, steel, composite steel and concrete, and timber structures and earthquake resistance have a Part 2 covering the design of bridges. Parts 2 should be used in combination with the appropriate general Parts (Parts 1).

In all 58 Parts of the Eurocodes there are 1,506 Nationally Determined Parameters (NDPs). In a number of cases, a NDP cannot be represented by a single numerical value. In fact, many NDPs take the form of tables, graphs, acceptance of the recommended procedure, choice of calculation approach among given alternatives, introduction of a new procedure, etc. The description of the different types of NDPs may be found in Table 11.1.

Table 11.1 NDPs type and descriptions; number of NDPs in the Eurocodes

NDP type & description	
1.1	Predetermined Parameters (with Recommended Values - RV)
1.2	Predetermined Parameters (without RV)
1.3	No Predetermined Parameters
2.1	Fixed Tables (only cell values can be changed)
2.2	Flexible Tables (rows and columns can be changed)
3.1	Acceptance of recommended procedures / approaches or introduction of new ones
3.2	Country procedures / approaches
3.3	Alternative choice from given options (with RV)
3.4	Alternative choice from given options (without RV)
3.5	Choice from given options (without RV)
3.6	Choice from given options (with and without Recommended Value) or introduction of new procedures / approaches
3.7	Acceptance of recommended procedures / approaches in fixed tabular form or introduction of new ones
3.8	Acceptance of recommended procedures / approaches in flexible tabular form or introduction of new ones
4	Country specific data
5	National charts or tables
6	Diagrams
7	References to non-contradictory complementary information
8	Decisions on the application of informative Annexes
9	Provision of further, more detailed information
10.1	Reference to information which is included in an informative annex
10.2	Reference to information which is included in other Parts of the EN text

Figure 11.2 shows the distribution of NDPs per Eurocode, according to their types.

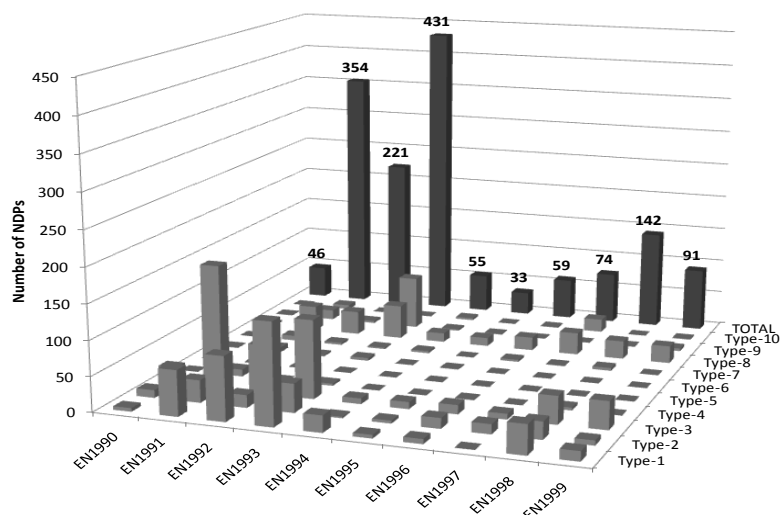


Figure 11.2 Distribution of NDPs in the Eurocodes according to their type (Pinto et al., 2011)

Among the Eurocodes related to materials, the EN 1992, *Design of concrete structures* and the EN 1993, *Design of steel structures* include the highest amount of NDPs. EN 1991, *Actions on structures* contains a big number of NDPs, most of them arising from different geographical, geological and climatic conditions. Only 563 NDPs in Eurocodes (37.5% of all NDPs) have numerical values and the most frequent type is 3 (see the description of this type in Table 11.1). The majority of the NDPs relates to choice of calculation approach, country specific data (geographical, climatic, etc.) diagrams, reference to non-contradictory complementary information, decisions on the application of informative annexes and provision of further more detailed information (Pinto et al., 2011). The NDPs with Recommended Value given are of the type 1.1, 2.1, 2.2, 3.1, 3.3, 3.6, 3.7, 3.8 and 6 and their number in the Eurocodes is 842, *i.e.*, 55.9% of the total number of NDPs.

11.3 Statistical analysis of the NDPs available in the Eurocodes Database

11.3.1 Statistical analysis on the availability of data

Before carrying out the analysis of the harmonized use of the Nationally Determined Parameters, information on the availability of data is processed and the status of uploading the NDPs for countries on the different Eurocodes is analysed.

The full set of expected data for the statistical analysis on all Eurocode Parts should contain 42,804 NDPs provided by a total of 29 countries. These countries are the 28 EU Member States (MS) and Norway, which is an EFTA Member State that made considerable progress in the uploading to the Database. It should be noted, that Switzerland is also registered in the Database, but is not yet actively uploading NDPs.

The set of expected data is currently calculated with reference to the National Annexes (NAs) published by the countries, taking into consideration the information on the implementation of the Eurocodes in the EU Member States and Norway (Dimova et al., 2015). If meanwhile the countries have uploaded their National Annexes in the Database, they were also taken into consideration. Based on that information, by early January 2016

the set of expected data corresponds to 37,308 NDPs and as there is a total of 23,488 **NDPs uploaded in the Database**, that represents **63%** out of all expected data.

Figure 11.3 illustrates the geographical distribution of the percentage of NDPs uploaded in the Database, by early March 2016. The Figure shows that 15 countries uploaded more than 75% of their NDPs and that one EU country, Malta, is not uploading yet.

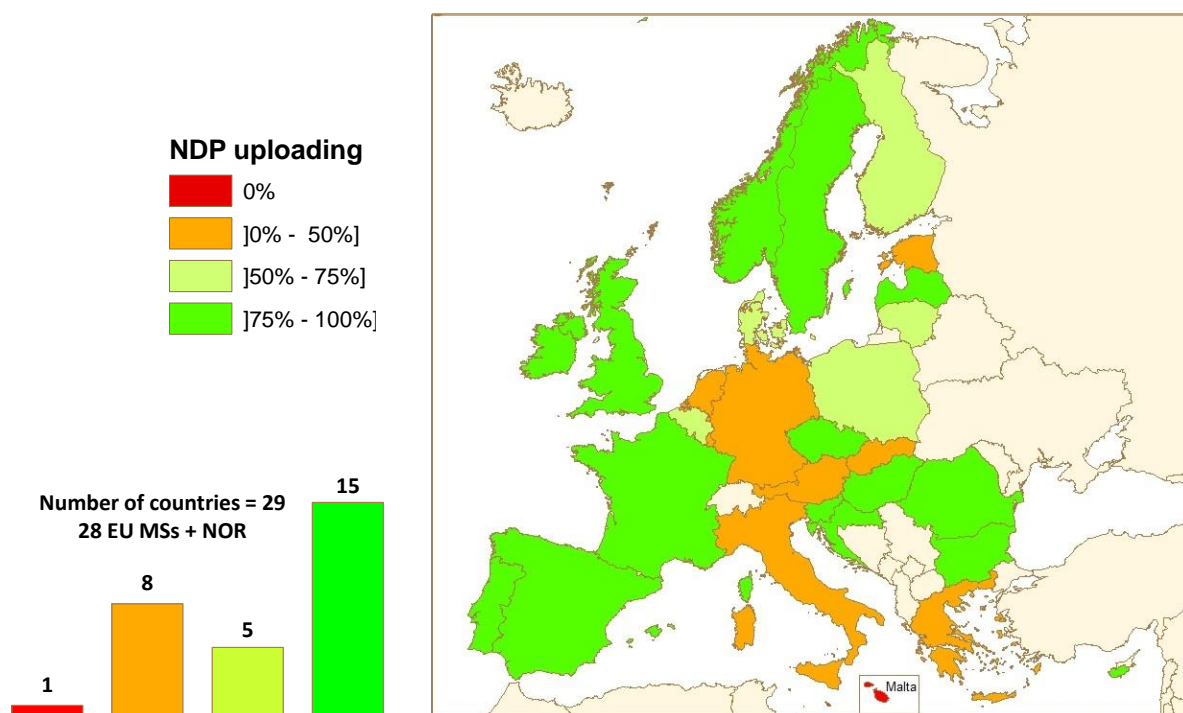


Figure 11.3 Geographical distribution of the percentage of uploaded NDPs in the Database

As by early 2016, the Database contained NDPs for all 58 Parts of the Eurocodes. Table 11.2 presents the number and percentage of NDPs uploaded in the Database, per Eurocode. The most populated Eurocodes are EN 1992 and EN 1994, respectively with a percentage of uploading of 74.8% and 71.3% of the expected NDPs. The least populated Eurocodes, having a percentage of uploading less than 55%, are EN 1990 and EN 1997 with a percentage of uploading of 54.8% and 53.4%, respectively, based on the number of NAs published by the countries.

Table 11.2 Number and percentage of NDPs uploaded in the Database, per Eurocode

EN 1990	EN 1991	EN 1992	EN 1993	EN 1994	EN 1995	EN 1996	EN 1997	EN 1998	EN 1999	All
668	5 585	4 600	6 641	1 026	580	832	729	1 587	1 240	23 488
54.8%	60.5%	74.8%	62.7%	71.3%	67.6%	56.9%	53.4%	56.5%	55.8%	63.0%

Figure 11.4 illustrates a query in the NDPs Database on the number of uploaded NDPs by Eurocode and by country. This report was extracted to show that the Database is prepared to receive NDPs uploaded by the non-EU Balkan countries. Values shown in italic and in brackets imply that the Eurocode Parts were not declared as completed by the uploading countries.

Report generated at: 15:00 Tue 09 February 2016

EN	Total CEN	ALB	AUT	BEL	BGR	BIH	CHE	CYP	CZE	DEU	DNK	ESP	EST	FIN	FRA	GBR	GRC	HRV	HUN	IRL	ISL	ITA	LTU	LUX	LVA	MDA	MKD	MLT	MNE	NLD	NOR	POL	PRT	ROU	SRB	SVK	SVN	SWE	TUR
Total	1476	-	76	1010	1136	-	5	1426	1476	25	831	376	207	695	1350	1317	131	1472	1074	1469	-	292	793	1	1144	-	-	-	494	1400	751	810	1362	-	465	1310	1091	-	
1990	46	(-)	(TBU)	46	(TBU)	(-)	(-)	(46)	(46)	(TBU)	(10)	(NE)	(TBU)	(46)	46	46	(TBU)	46	46	46	(-)	(2)	(6)	(1)	(46)	(-)	(-)	(TBU)	(-)	(10)	(11)	(6)	(46)	(4)	(-)	(26)	46	(36)	(NE)
1991	348	(-)	(11)	(114)	(245)	(-)	(1)	(332)	(348)	(TBU)	(228)	(NE)	(139)	(294)	348	345	(TBU)	348	348	(345)	(-)	(12)	(89)	(TBU)	(265)	(-)	(-)	(TBU)	(-)	(100)	347	(180)	(215)	(327)	(-)	(75)	(243)	(303)	(TBU)
1992	221	(-)	(TBU)	(143)	(214)	(-)	(-)	(210)	(221)	(TBU)	(165)	(187)	(33)	(208)	221	218	(TBU)	(221)	221	(220)	(-)	216	(144)	(TBU)	(218)	(-)	(-)	(NE)	(-)	(158)	221	(174)	(213)	(205)	(-)	(177)	(219)	(212)	(NE)
1993	431	(-)	(TBU)	(430)	(405)	(-)	(-)	(420)	(431)	(25)	(192)	(140)	(7)	(63)	395	(291)	(TBU)	(430)	(142)	(430)	(-)	(6)	(327)	(TBU)	(401)	(-)	(-)	(NE)	(-)	(89)	431	(256)	(78)	(427)	(-)	(91)	431	(304)	(NE)
1994	52	(-)	(TBU)	(50)	52	(-)	(-)	(49)	(52)	(TBU)	(36)	(49)	(22)	(50)	52	52	(TBU)	(52)	52	(52)	(-)	(11)	(29)	(TBU)	(47)	(-)	(-)	(NE)	(-)	(14)	52	(31)	(36)	(51)	(-)	(33)	52	(51)	(NE)
1995	33	(-)	(TBU)	(TBU)	33	(-)	(4)	(32)	(33)	(TBU)	(26)	(NE)	(6)	(30)	33	33	(TBU)	(33)	33	(32)	(-)	32	(11)	(TBU)	(33)	(-)	(-)	(NE)	(-)	(27)	(33)	(17)	(NE)	(29)	(-)	(11)	(33)	(32)	(NE)
1996	58	(-)	(TBU)	(TBU)	58	(-)	(-)	(55)	(58)	(TBU)	(45)	(NE)	(TBU)	(4)	58	58	(TBU)	(58)	58	(57)	(-)	(8)	(33)	(TBU)	(52)	(-)	(-)	(NE)	(-)	(41)	42	(37)	(41)	(55)	(-)	(TBU)	(NE)	(36)	(NE)
1997	55	(-)	(TBU)	(TBU)	(4)	(-)	(-)	(55)	(55)	(TBU)	51	(NE)	(TBU)	(TBU)	55	55	(TBU)	(55)	55	(55)	(-)	(TBU)	(TBU)	(TBU)	(47)	(-)	(-)	(NE)	(-)	(55)	55	(23)	(31)	(53)	(-)	(TBU)	55	(25)	(NE)
1998	142	(-)	(TBU)	141	(59)	(-)	(-)	(137)	(142)	(TBU)	(NE)	(NE)	(NE)	(NE)	142	(129)	(131)	(140)	(80)	142	(-)	(TBU)	(112)	(TBU)	(35)	(-)	(-)	(NE)	(-)	(NE)	(118)	(NE)	(75)	(122)	(-)	(12)	(141)	(NE)	(NE)
1999	90	(-)	(65)	(86)	(66)	(-)	(-)	(90)	(90)	(TBU)	(78)	(NE)	(TBU)	(TBU)	NE	90	(TBU)	(89)	(39)	(90)	(-)	(5)	(40)	(TBU)	(TBU)	(-)	(-)	(NE)	(-)	(TBU)	90	(27)	(75)	(89)	(-)	(40)	90	90	(NE)

TBU = NDPs are expected To Be Uploaded for at least one Part
NE = No NDP uploading is Expected for all Parts
- = No NDP was uploaded

Figure 11.4 Number of uploaded NDPs by Eurocode and country

Table 11.3 lists the status of registration and use of the NDPs Database by the Balkan countries, which are not EU Member States. It shows that 5 out of 8 countries are not registered yet. Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia and Montenegro are the three countries registered.

Table 11.3 Registration and use of the NDPs Database by non-EU Balkan countries

Country	N° user nominated / registered
Albania	Not registered
Bosnia and Herzegovina	1/1
former Yugoslav Republic of Macedonia	11/6
Kosovo	Not registered
Moldova	Not registered
Montenegro	3/3
Serbia	Not registered
Turkey	6/2

11.3.2 Statistical analysis of the acceptance of Recommended Values

A total of 10,167 Recommended Values (RVs) has been accepted among the 13,895 NDPs with Recommended Value that have so far been uploaded in the Database by the aforementioned 29 EU and EFTA Member States.

As illustrated in Figure 11.5, by early January, 2016, the post-processing of NDPs with Recommended Value shows that:

- the mean percentage of acceptance of the Recommended Values for all NDPs is 73.2%. This preliminary result is based on 66% of all expected data available, i.e., expected NDPs with Recommended Values, and cannot be treated as a final one;
- the Eurocodes with higher than the mean percentage of acceptance of the Recommended Values are EN 1994 with 83.4% of acceptance, EN 1993 with 82.8%, EN 1992 with 77.1% and EN 1999 with 74.8%. These results indicate that a good harmonization can be expected in the national adoption of the most widely-used "material Eurocodes" that are EN 1992 and EN 1993;
- the Eurocode with the lowest percentage of acceptance of the Recommended Values is EN 1997 with 47.4% of acceptance, closely followed by EN 1990 with 50.1% of acceptance. This result for EN 1997 can be explained by the fact that it introduces "a common language" in the field of geotechnical design, in which the national practices are very different and should be further harmonised. As regards EN 1990, this Eurocode specifies the basic elements of structural safety (partial safety factors for actions, combination factors, choice of procedure for fundamental combination of actions, choice of the main variable action for accidental design situations, etc.), which are under national responsibility.

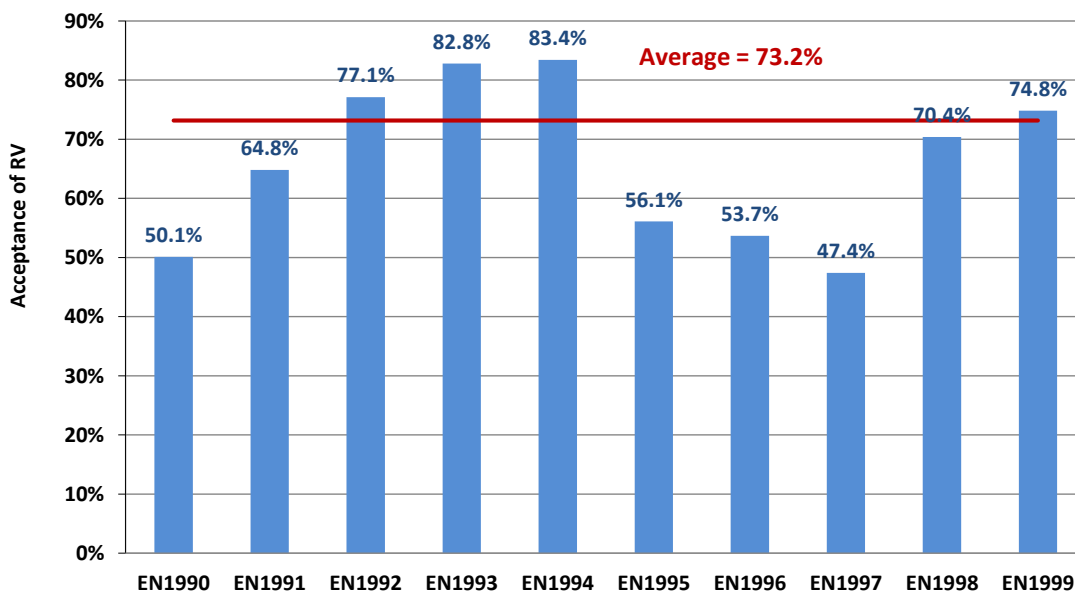


Figure 11.5 Percentage of acceptance of Recommended Values for each Eurocode

The percentage of acceptance of uploaded NDPs with RV, for the 16 countries that have uploaded more than 75% of their NDPs, is shown in Figure 11.6. Among them there are eight countries with an acceptance rate higher than the average (Bulgaria, Cyprus, the Czech Republic, Latvia, Poland, Portugal, Romania and Slovenia). The country with the highest rate of acceptance of the RVs is Slovenia, with 91%, closely followed by Latvia with 90%. The country with the lowest rate of acceptance is the United Kingdom, with 47%, followed by France, with 53%. The low rate of acceptance of the RVs by the UK and France is most probably caused by their preference to keep as much as possible to existing traditions in the design, which are not reproduced in the Recommended Values or procedures of the standards.

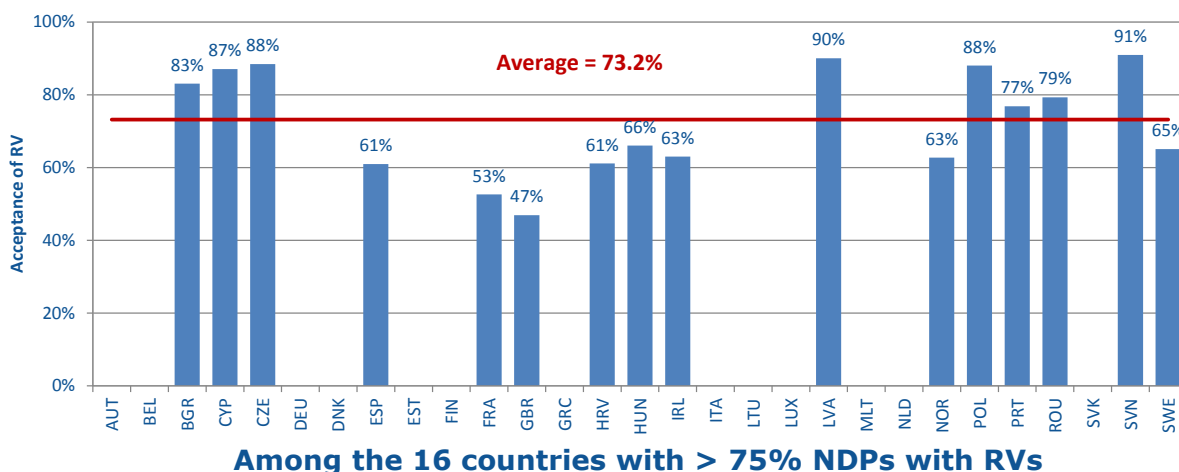


Figure 11.6 Percentage of acceptance of RVs by countries that uploaded more than 75% of their NDPs with RVs

Figure 11.7 presents the percentage of NDPs, per Eurocode, that reached 100% of acceptance among the uploading countries, by November 2015. The number of NDPs being accepted by 100% of the countries is also presented above the bars of the Figure reaching a total of 96 NDPs, i.e. 6% of the 1 506 NDPs existing in the all 58 Parts of the Eurocodes

and 11% of the total number of NDPs with RVs (842). In Figure 11.7 it is shown that 14% of the RVs in EN 1993 reached consensus among the countries uploading their NDPs for this Eurocode. On the other hand, none of the RVs of EN 1995, EN 1996 and EN 1997 was accepted by all the uploading countries.

The identification of the consensus achieved among the countries in the choice of the NDPs is important for definition of a potential set of NDPs that may eventually be removed in the next generation of Eurocodes, when those NDPs are not related to safety and durability issues, or to geographical, geological or climatic aspects.

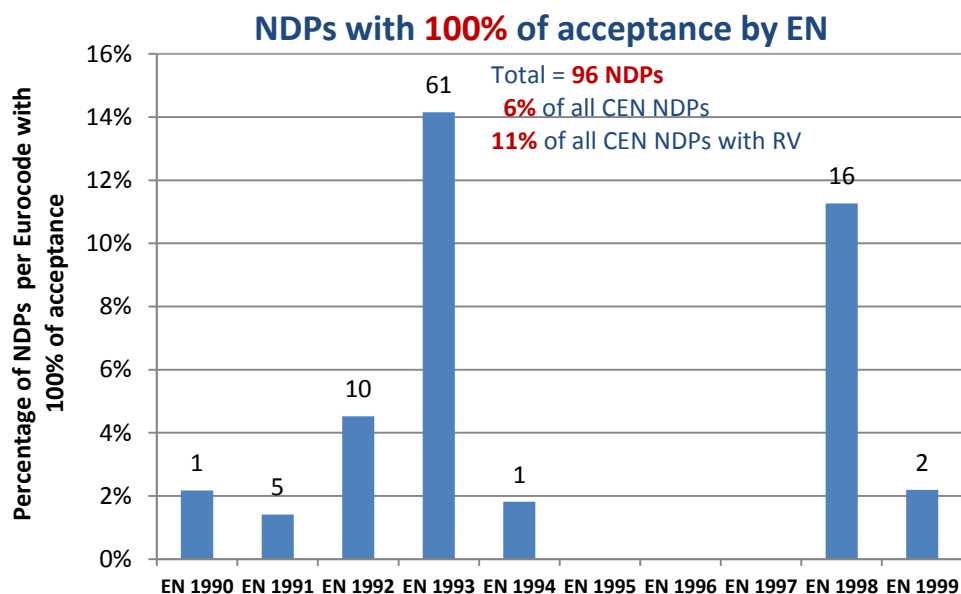


Figure 11.7 Percentage of NDPs, per Eurocode, that reached 100% of acceptance among the uploading countries (NDPs with RV)

11.4 Statistical analysis of the NDPs relevant to the definition of climatic and seismic actions

11.4.1 Data related to the definition of climatic and seismic actions

In order to assess the current status of elaboration of maps for climatic and seismic actions for structural design in the Balkan region, the JRC, together with an external expert on the Eurocodes, prepared a Questionnaire to examine the NDPs relevant for that purpose, which have so far been adopted by the Balkan countries (see Chapter 10 in this report).

In this context, the JRC identified 142 NDPs relevant to the definition of climatic and seismic actions for structural design with the Eurocodes, which are distributed in 3 Parts of EN 1991 and in 2 Parts of EN 1998, as shown in Table 11.4. Annex A lists the NDPs used in the analysis performed in the current section.

Data used in the statistical analysis of the acceptance of NDPs related to the definition of climatic and seismic actions were extracted from the Database by October 2015.

By that date, the EU Member States and Norway have uploaded in the Database a total of 2,383 NDPs related to the definition of climatic and seismic actions. According to the published National Annexes, the number of countries expected to upload data for EN 1991 is 27, whereas for EN 1998-1 and EN 1998-3 the number is 20 and 17, respectively. The

maximum number of countries that uploaded data on Parts 1-3, 1-4 and 1-5 of EN 1991 was 20, 17 and 20, respectively, whereas data on Parts 1 and 3 of EN 1998 were uploaded by a maximum of 13 and 9 countries, respectively. The average percentage of uploading, by EN Part, is also presented in Table 11.4.

Table 11.4 Number of NDPs, per Eurocode and Part, related to the definition of climatic and seismic actions

Eurocode and Part	NDPs Number	Percentage of uploading
EN 1991: Actions on structures Part 1-3: General Actions - Snow loads	33	74%
EN 1991: Actions on structures Part 1-4: General Actions - Wind actions	68	63%
EN 1991: Actions on structures Part 1-5: General Actions - Thermal actions	29	74%
EN 1998: Design of structures for earthquake resistance Part 1: General rules, seismic actions and rules for buildings	11	65%
EN 1998: Design of structures for earthquake resistance Part 3: Assessment and retrofitting of buildings	1	52%
Total	142	67%

11.4.2 Statistical analysis of the acceptance of NDPs

In the following, a statistical analysis of the NDPs related to the definition of climatic and seismic actions is performed per Eurocode Part and NDP type. Four different sets of NDPs are considered in the analysis:

- i. a group of NDPs where the EN text can be accepted as proposed in the standards, *i.e.*, by accepting the recommended values or options, or without definition of further value or other content. Accepting the EN text as it is in the Eurocodes indicates that the country did not adopt his own "value". In the following Figures and Tables, this group of NDPs is identified by the short name "Accept as is". The NDPs belonging to this group are of type 1.1, 1.2, 1.3, 2.1, 2.2, 3.1, 3.2, 3.3, 3.7, 3.8, 4, 5, 7 and 9. Among the 142 NDPs relevant for the definition of climatic and seismic actions, there are 116 NDPs within this group. The average acceptance rate of the NDPs in this group is 55%. This group is thereafter identified as set "i" and called "Accept as is" in Table 11.5 and in Figure 11.8.
- ii. The NDPs with RVs given, *i.e.*, NDPs of type 1.1, 2.1, 2.2, 3.1, 3.3, 3.7, 3.8 and 6. There are 79 NDPs within this group that have an average acceptance rate of 67%, almost 7 percentage points lower than the average percentage of acceptance for all NDPs with RV (74%, see Figure 11.5). This result is not surprising, because this second group of NDPs accounts for specific geographical, geological or climatic conditions of the Member States. This group is thereafter identified as set "ii" and called "with RV" in Table 11.5 and in Figure 11.8.

- iii. A subset of the first group of NDPs, *i.e.*, of the NDPs without RV, but where the EN text can be accepted as proposed in the standards. The subset encompasses the NDPs of type 1.2, *Predetermined parameters without RV*, of type 1.3, *No predetermined parameters* and of type 3.2, *Country procedures / approaches*. These types of NDPs may be an important source for further harmonization, since they mostly concern further refinement/adjustment of methods and procedures. Among the 142 NDPs relevant for the definition of climatic and seismic actions there are 11 NDPs belonging to this group. They have an average acceptance rate of 37%. This group is thereafter identified as set "iii" and called "of type 1.2, 1.3 and 3.2" in Table 11.5 and in Figure 11.8.
- iv. The NDPs of type 1.1, *i.e.*, *Predetermined Parameters with RV*. A specific analysis of the statistics on the convergence of the national choices for the NDPs of this type is made. Among the 142 NDPs relevant for the definition of climatic and seismic actions there are 31 NDPs within this group, which have an average acceptance rate of 71%. This group is thereafter identified as set "iv" and called "of type 1.1" in Table 11.5 and in Figure 11.8.

Table 11.5 summarizes the statistics of uploading and acceptance for the four groups of NDPs aforementioned and Figure 11.8 presents, for all Parts concerned, the average percentage of acceptance of the NDPs per Eurocode Part.

Table 11.5 Number of NDPs for different sets of NDP and statistics of acceptance

Set	NDPs	No. CEN NDPs	No. uploaded NDPs	No. accepted NDPs	Percentage of acceptance
i	Accept as is	116	1 983	1 084	55%
ii	with RV	79	1 348	900	67%
iii	of type 1.2, 1.3 and 3.2	11	186	69	37%
iv	of type 1.1	31	539	381	71%

Table 11.5 and Figure 11.8 show that, in average, the NDPs with RV (shown in red and in green in the Figure) have an average acceptance rate higher than the average acceptance rate of the others NDPs relevant for the definition of climatic and seismic actions, although it is lower than the average acceptance rate of 73% for the NDPs with RV in all Eurocodes Parts (see Figure 11.5). In fact, Figure 11.8 reveals that a good consensus was achieved for NDPs of type 1.1 for all Eurocodes Parts analysed, except for EN 1991-1-3. Also a good consensus among the countries was achieved for the NDPs with RV belonging to Parts 1-4 and 1-5 of EN 1991. The NDPs showing the lowest percentage of acceptance (21%) belong to EN 1991-1-4 and to the set of NDPs of type 1.2, 1.3 and 3.2 (set (iii)). Note that in EN 1998-3 only one NDP was considered, so its own percentage of acceptance is presented in the Figure.

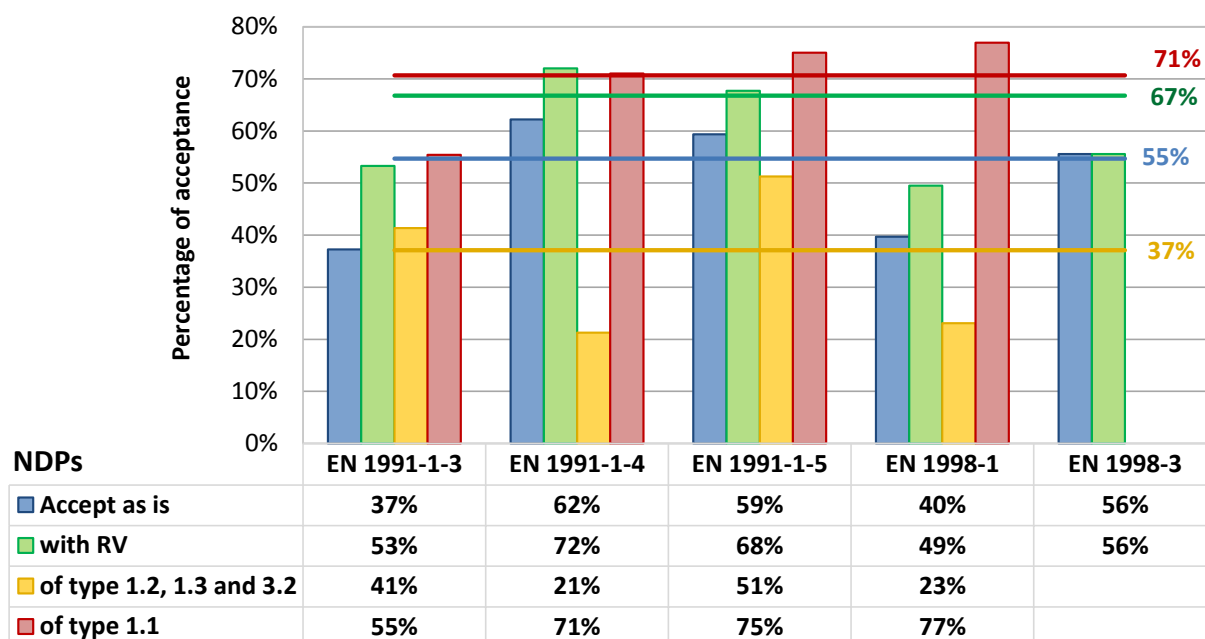


Figure 11.8 Percentage of acceptance of NDPs relevant to the definition of climatic and seismic actions, per Eurocode Part

Figure 11.9 presents the number of NDPs, with and without RVs, where the EN text can be accepted as proposed in the standards (set i), distributed by 7 different classes of percentage of acceptance. The Figure shows that, among the 116 NDPs in these conditions, there are 34 (30%) that have been accepted by more than 70% of the countries uploading and 8 (7%) that reached a consensus by more than 90% of the countries. Among them there are 2 NDPs (1.7%) that have been accepted by all (100%) uploading countries, as it will be seen below in more detail.

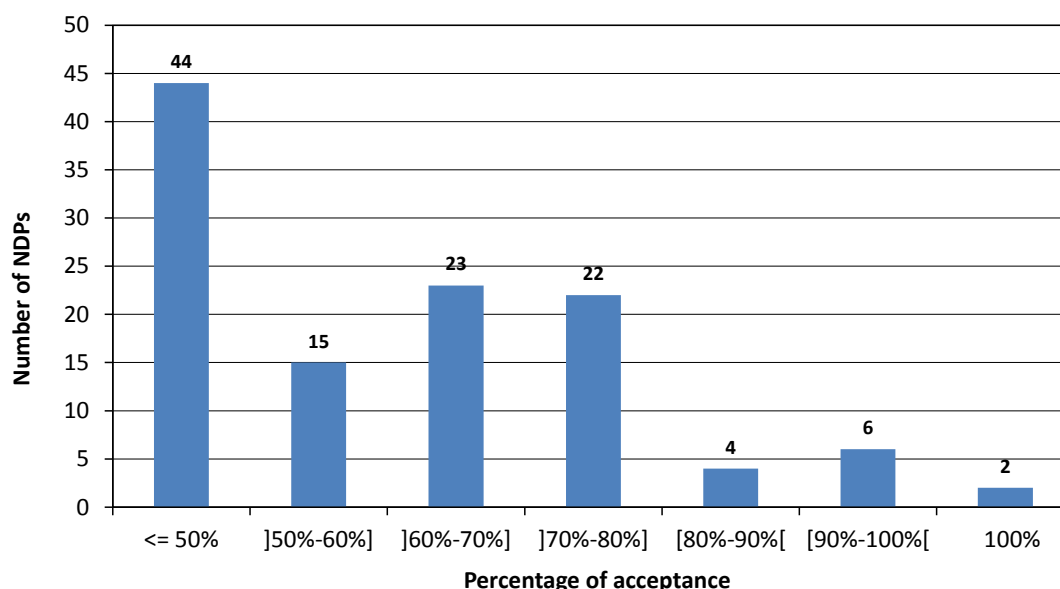


Figure 11.9 Number of NDPs relevant to the definition of climatic and seismic actions per percentage acceptance

Table 11.6 identifies the NDPs that have the lowest and the highest percentage of acceptance, for the set of NDPs where the EN text can be accepted as is (set i). For each NDP identified its type (see Table 11.1) is also presented. Table 11.6 shows that there are two NDPs of type 6, *i.e.*, *Diagrams*, belonging to EN 1991-1-4, that have been accepted

by 100% of the uploading countries. The lowest acceptance rate Table 11.6 is 17% and belongs to a NDP of type 3.8 in EN 1998-1.

Table 11.6 NDPs related to the definition of climatic and seismic actions with the highest and lowest rate of acceptance (NDPs of the group "Accept as is")

EN	Part	Accept. (%)	NDP	NDP type	Min % acceptance	Max % acceptance
1991	1-3	37	4.3 (1) The coefficient for exceptional snow loads C_{est}	1.1	27.8	
			Annex A (1) Table A.1 Definition of exceptional conditions and definition of design situations which apply for the particular local effects described in Section 6 for cases B1 and B3	3.8	27.8	
			5.2 (7) The values of the exposure coefficient C_e for different topographies	2.1		70.0
	1-4	62	4.3.2 (1) The procedure for determining the roughness factor, $c_r(z)$	3.1	47.1	
			7.6 (1) NOTE 1 The values of the reduction factor for square sections with rounded corners, ψ_r	6		100
			7.10 (1) NOTE 1 The values of the alongwind force coefficient of spheres $c_{f,x}$	6		100
1-5	59	6.1.4.2 (1) Values of vertical temperature differences for bridge decks	3.1	47.4		
		6.1.6 (1) Values for the differences in the uniform temperature component	1.1		84.2	
1998	1	40	3.2.1 (4) Governing parameter (identification and value) for threshold of low seismicity	3.8	16.7	
			3.2.2.5 (4) Lower bound factor β on design spectral values	1.1		92.3
	3	56	2.1 (3) Return period of seismic actions under which the Limit States should not be exceeded	3.8	55.6	55.6

Table 11.7 lists and numbers sequentially the parameters of type 1.1 related to the definition of climatic actions that belong to Parts 1-3, 1-4 and 1-5 of EN 1991. The NDPs that have more than one parameter are shown in a common shaded box in that table. The description of the parameters can be found in the Annex B of this chapter.

Figure 11.10 presents the mean value of the parameters of type 1.1 in EN 1991, normalized with respect to their Recommended Values, i.e., $\overline{NDP/RV} = \overline{NDP}/RV$. The standard deviation of the variable NDP/RV , is summed, with positive or negative signs, to its mean value, being illustrated by the red points in Figure 11.10, i.e., $\overline{NDP/RV} \pm \sigma_{NDP/RV}$. For the analysed sample, that represents 66% out of all the concerned NDPs with RV in EN 1991, the possible range of deviation within minus or plus one standard deviation from the mean value of NDP/RV is also illustrated.

Table 11.7 Parameters of type 1.1 related to the definition of climatic actions in EN 1991

EN 1991			
#	Part	Section	Clause
1	1-3	4.3	1
2	1-3	5.3.5	1 NOTE 1
3	1-3	5.3.6	1 NOTE 1
4	1-3	5.3.6	1 NOTE 1
5	1-3	5.3.6	1 NOTE 2
6	1-3	5.3.6	1 NOTE 2

#	EN 1991 Part	Section	Clause
7	1-4	4.2	2 NOTE 2
8	1-4	4.2	2 NOTE 3
9	1-4	4.2	2 NOTE 5
10	1-4	4.2	2 NOTE 5
11	1-4	4.3.1	1 NOTE 1
12	1-4	4.4	1 NOTE 2
13	1-4	4.5	1 NOTE 2
14	1-4	7.4.3	2
15	1-4	7.7	1 NOTE 1
16	1-4	8.1	4
17	1-4	8.1	5
18	1-4	8.3.4	1
19	1-4	8.3.4	1
20	1-4	Annex E.1.3.3	1
21	1-4	E.1.5.2. 6	1 NOTE 1
22	1-4	Annex E.1.5.3	2 NOTE 1

#	EN 1991 Part	Section	Clause
23	1-5	6.1.4.3	1
24	1-5	6.1.4.4	1
25	1-5	6.1.5	1
26	1-5	6.1.5	1
27	1-5	6.1.6	1
28	1-5	6.1.6	1
29	1-5	6.1.6	1
30	1-5	6.2.2	1
31	1-5	6.2.2	2
32	1-5	7.5	3
33	1-5	7.5	4
34	1-5	Annex A.1	3
35	1-5	Annex A.2	2
36	1-5	Annex A.2	2
37	1-5	Annex A.2	2
38	1-5	Annex A.2	2

NDPs with more than 1 parameter are shown in common shaded areas

In EN 1991, the parameter of type 1.1 with the highest ratio between the NDP value and the Recommended Value (NDP/RV) is number 25 and corresponds to a NDP of the Section 6.1.5, Clause 1, of Part 1-5 (see Table 11.8). This parameter is described as a *reduction factor of uniform temperature component for combination with temperature difference component* (ω_N). It was found that among 19 uploading countries only one country was responsible for the uploading a very different value from the RV, causing the largest divergence identified.

Figure 11.11 presents the statistical analysis of parameters of type 1.1 in EN 1998-1 uploaded in the Database. The parameters are described in Table 11.9.

Table 11.8 NDP of type 1.1 with the highest maximum value of NDP/RV in EN 1991, among the NDPs related to the definition of climatic actions in EN 1991

Part	Section & clause	NDP Description	#	Parameter Description
1-5	6.1.5 (1)	Values of ω_N and ω_M ω_N - reduction factor of uniform temperature component for combination with temperature difference component ω_M - reduction factor of temperature difference component for combination with uniform temperature component	25	Values of ω_N

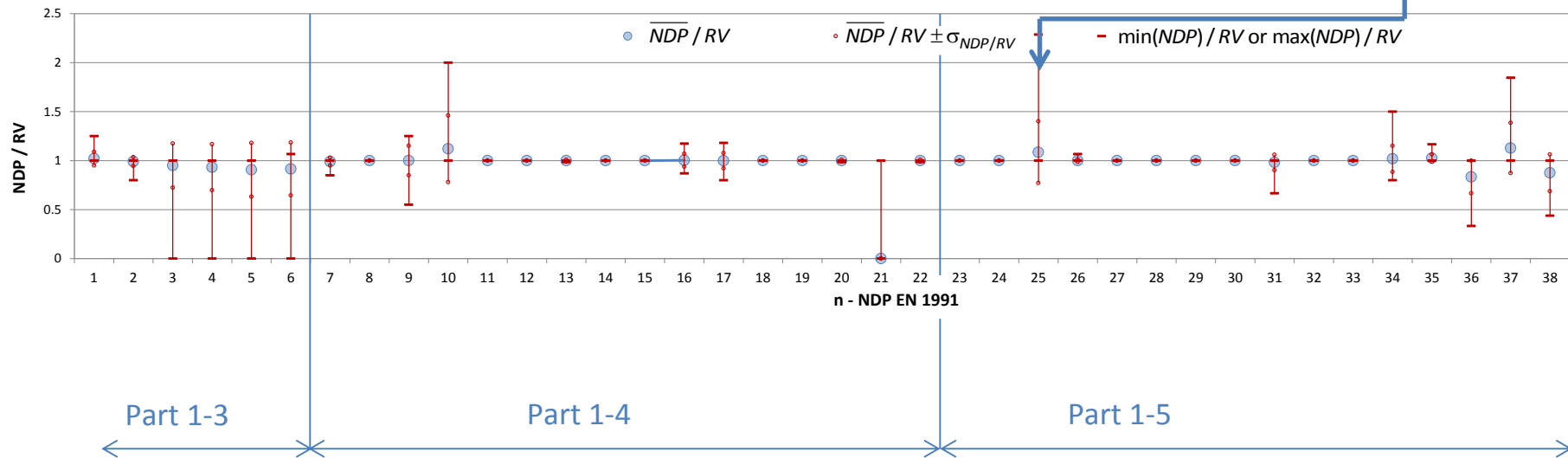


Figure 11.10 Mean value, standard deviation, maximum and minimum value of NDP/RV ; NDPs of type 1.1 related to the definition of climatic actions in EN 1991

Table 11.9 NDPs of type 1.1 related to the definition of seismic actions in EN 1998, Part 1

#	Section	Clause	NDP Description	NDP Parameter
1	2.1	(1) NOTE 1	Reference return period T_{NCR} of seismic action for no-collapse requirement or, equivalently, reference probability of exceedance in 50 years, P_{NCR}	The value of P_{NCR} (%)
2	2.1	(1) NOTE 1	Reference return period T_{NCR} of seismic action for no-collapse requirement or, equivalently, reference probability of exceedance in 50 years, P_{NCR}	The value of T_{NCR} (years)
3	2.1	(1) NOTE 3	Reference return period T_{DLR} of seismic action for the damage limitation requirement or, equivalently, reference probability of exceedance in 10 years, P_{DLR}	The value of P_{DLR} (%)
4	2.1	(1) NOTE 3	Reference return period T_{DLR} of seismic action for the damage limitation requirement or, equivalently, reference probability of exceedance in 10 years, P_{DLR}	The value of T_{DLR} (years)
5	3.2.2.5	4	Lower bound factor, β on design spectral values	The value of lower bound factor, β

NDPs with more than 1 parameter are shown in common shaded cells

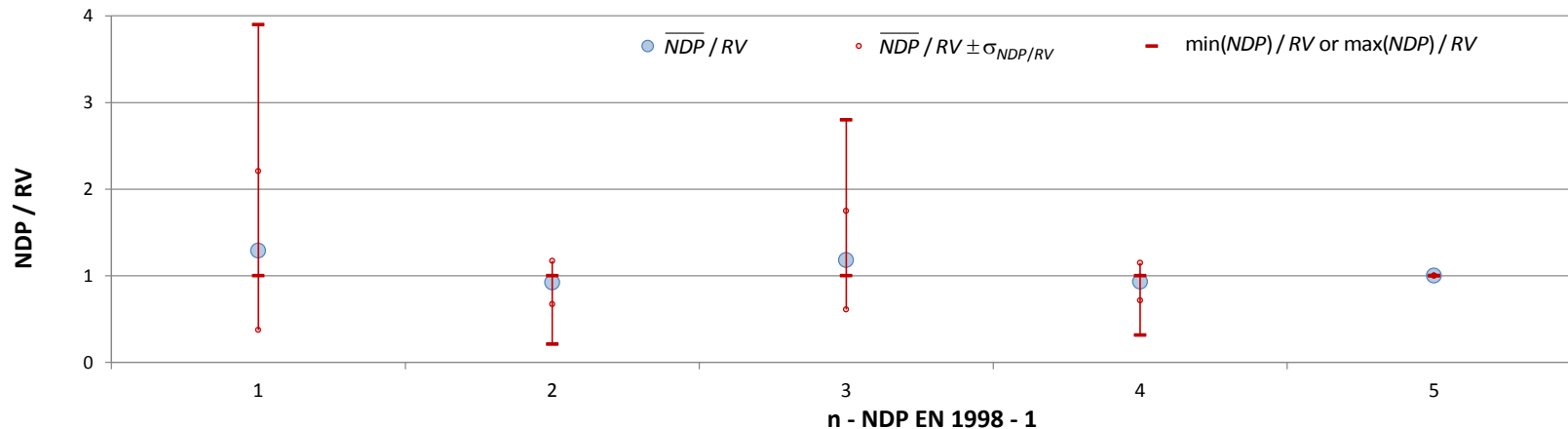


Figure 11.11 Mean value, standard deviation, maximum and minimum value of NDP/RV; NDPs of type 1.1 related to the definition of seismic actions in EN 1998-1

Figure 11.11 shows that the type 1.1 parameter with the highest ratio between the NDP value and the Recommended Value (NDP/RV) corresponds to a NDP of the Section 2.1, Clause 1, NOTE 1 of EN 1998-1. This NDP is described as the Reference return period T_{NCR} of seismic action for no-collapse requirement or, equivalently, reference probability of exceedance in 50 years, P_{NCR} , and has two parameters, the value of P_{NCR} (%), numbered 1 in Table 11.9, and the value of T_{NCR} (years), numbered 2 in Table 11.9. The parameter with the highest ratio between the NDP value and the Recommended Value (NDP/RV) was found to be the number 1 of the list.

The causes of the largest divergences found in the NDP parameter of the EN 1998-1 were investigated, showing that they were due to the non-acceptance of the Recommended Values by one Member State, among 10 uploading countries.

11.4.3 Seismic zone maps adopted by EU Member States

Seismic zone maps were chosen as example to illustrate the state of harmonization of the maps adopted by Member States in their National Annexes.

Thus, this section presents the NDP 3.2.1 (2), described as *Seismic zone maps and reference ground accelerations therein*, currently uploaded, or referred to, in the NDP Database, then it addresses the state of harmonization of the countries border acceleration values, and it compares the layout of the maps.

By early March 2016, Belgium, Bulgaria, Cyprus, the Czech Republic, Croatia, Greece, Hungary, Portugal and Romania have uploaded the *Seismic zone map and reference ground accelerations* in the Database or the National Annex for EN 1998-1. France and Slovenia have uploaded a reference to where to find the seismic zone map. In addition, Latvia and Luxembourg have adopted a constant reference ground acceleration for their entire territories, with values of 0.02 g and 0.04g, respectively.

All the considered EU Member States, except Romania, have adopted the Recommended Value of 475 years for the *Reference return period, T_{NCR} , of seismic action for the no-collapse requirement* (NDP 2.1(1) Note 1 of EN 1998-1). Romania has uploaded a T_{NCR} equal to 100 years, being the EU Member State that has adopted the NDP value with the greatest divergence from the RV (see Figure 11.11). On the other hand, the seismic zone map uploaded by Hungary is mentioned to have an informative status. Although that seismic map corresponds to a reference return period of 475 years, Hungary uploaded a text in the NDP 2.1(1) Note 1 referring that no national decision has been made yet on the value of T_{NCR} .

Finally, for the NDP 3.2.1 (2)), *Seismic zone maps and reference ground accelerations therein*:

- Ireland has decided to accept the EN text as is in the Eurocode;
- Lithuania did not give the “distribution of Seismic zones by the hazards” and has mentioned that “The reference peak ground acceleration on type A ground is derived by the relevant Parts of EN 1998”;
- Sweden has decided to not use the EN 1998-1 Part in its territory;
- the United Kingdom has uploaded the National Annex to EN 1998-1, in which is referred a restricted document (PD 6698) containing the seismic map.

Figure 11.12 and Figure 11.13 present the seismic zone maps for two groups of neighbouring countries and Figure 11.14 shows the seismic zone maps for the remaining countries. Information on the copyright of the maps is also shown, pertaining, in most of the cases, to the National Standardization Body of the EU Member State.

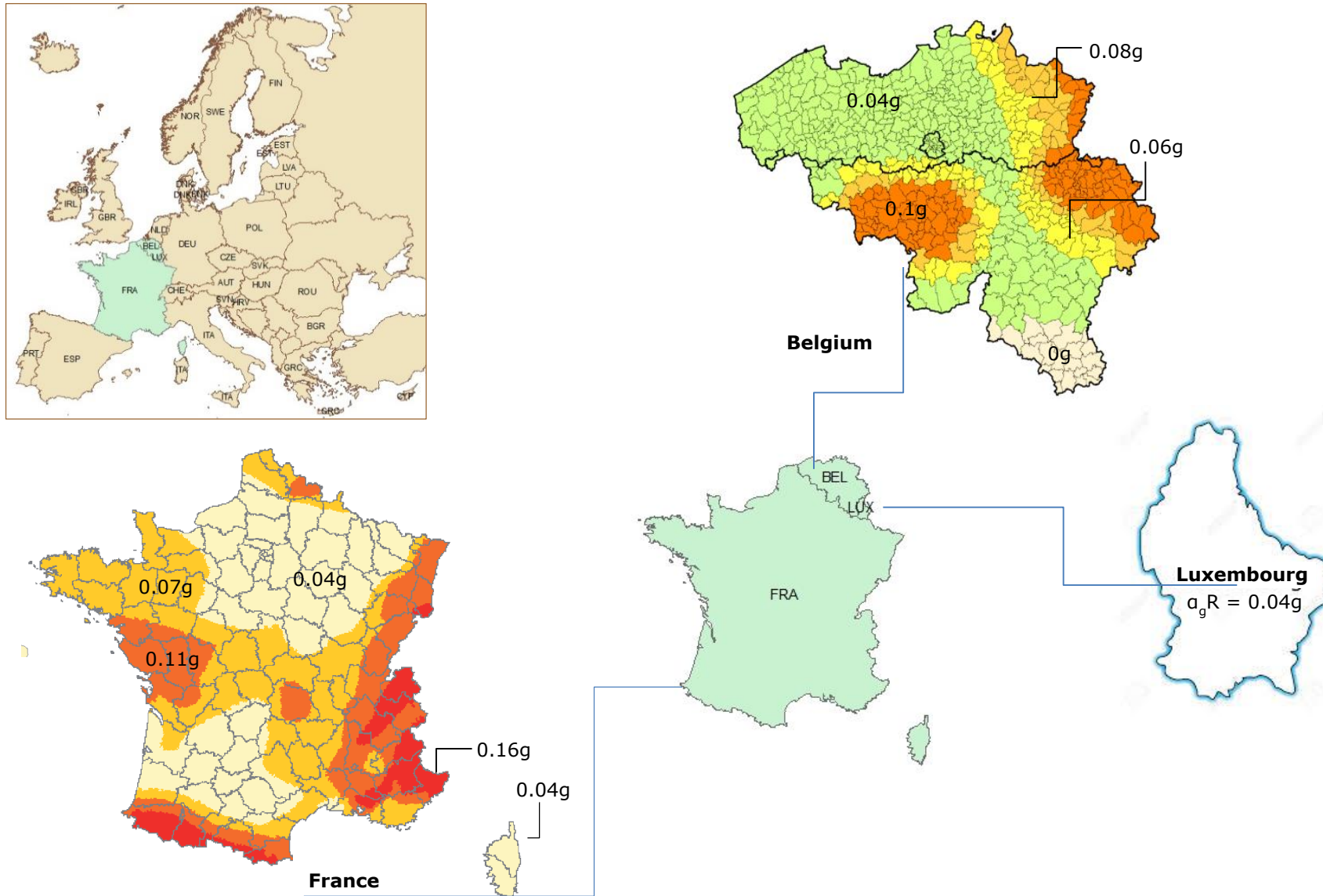


Figure 11.12 Seismic zone maps for neighbouring countries: Belgium [© NBN], France⁸ [© République Française] and Luxembourg

⁸ France seismic zonation: article D. 563 - Code de l'environnement.

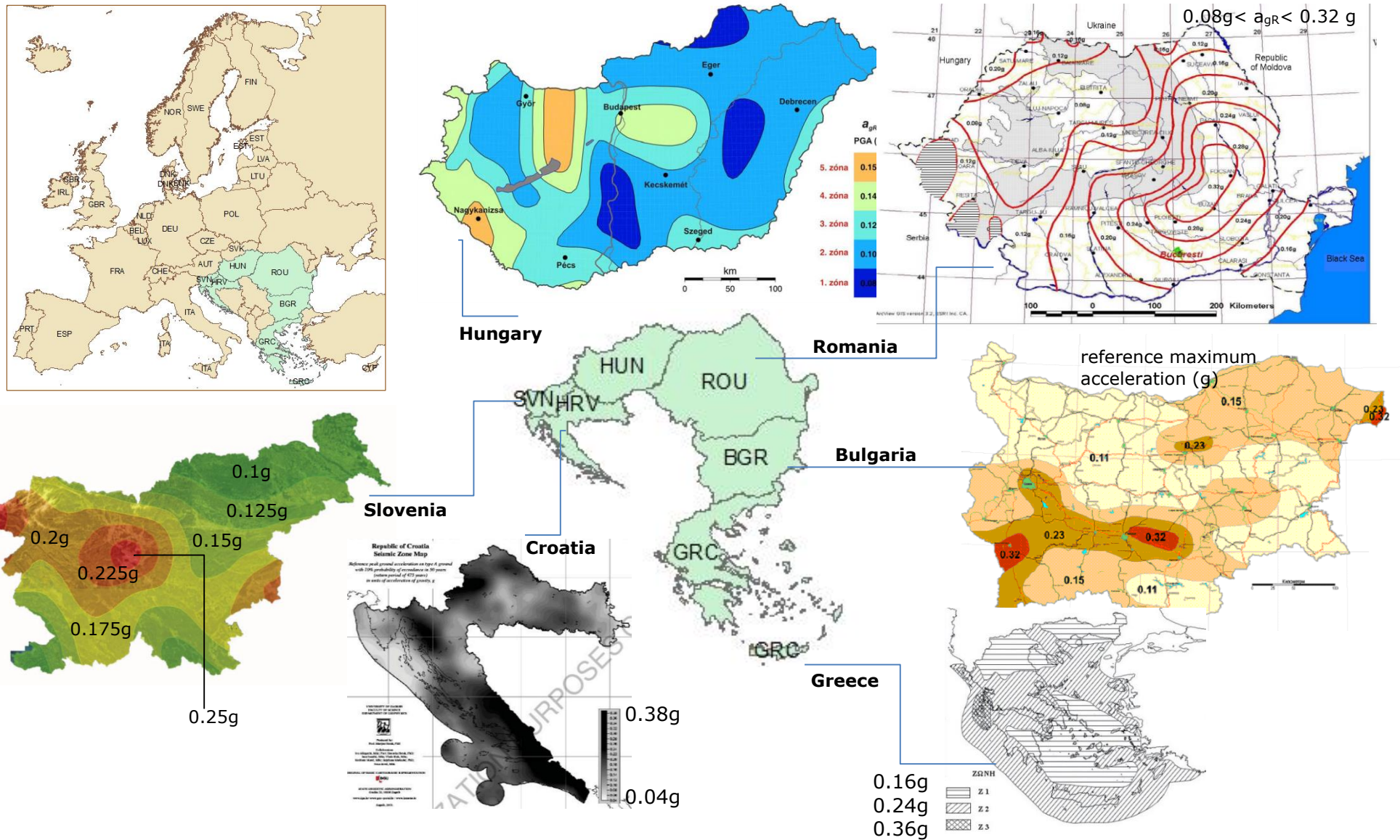


Figure 11.13 Seismic zone maps for neighbouring countries: Bulgaria [© BDS; БДС, 2015], Croatia [© HZN], Greece [© NQIS/ELOT], Hungary [© MSZT], Romania [© ASRO] and Slovenia [© SIST, 2015]

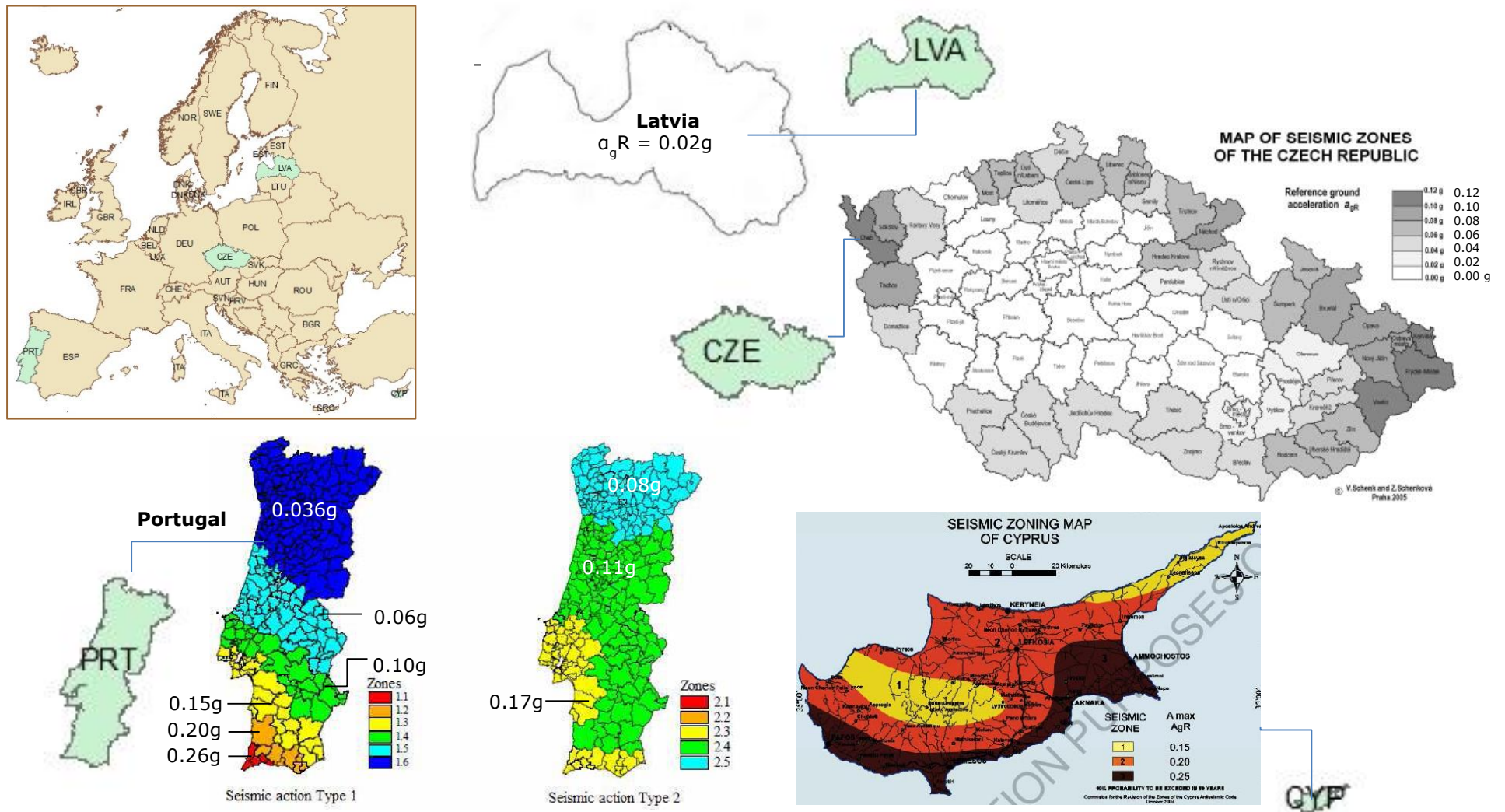


Figure 11.14 Seismic zone maps for the Check Republic [© UNMZ], Cyprus [© CYS], Latvia and Portugal [© IPQ]

The overseas territories of the EU Member States, like, for instance, the islands of Guadeloupe (France), or of Azores (Portugal) are not shown in the Figures. For this reason, two seismic zones shown in the scale of the Portuguese map for seismic action type 2 have no correspondence in the map. Those are seismic zones 2.1 and 2.2 that are related to regions located in the Azores islands.

The analysis of Figure 11.12 to Figure 11.14 shows that all countries uploading the NDPs Database comply with the recommendation of EN 1998-1 to map the seismic zones in terms of the reference ground acceleration. However, several differences may be identified in the maps, not only in their layout, but particularly in terms of the ground acceleration levels on the two sides of a national border.

Most of the countries have drawn the seismic zones as acceleration contour maps, except Belgium, the Czech Republic and Portugal that have adopted constant levels of reference ground acceleration for the administrative units of the country.

Regarding the details of the cross border harmonization, Figure 11.12 shows that Belgium has adopted five different seismic zones in the neighbourhood of France, whereas France shows a less disaggregated zonation, comprising three seismic zones. Yet, the seismic acceleration reference level in the border area of both countries is consistently low, ranging from 0.04 g to 0.11 g in France and from 0 g to 0.1 g in Belgium. Similar observations apply to the border area of Belgium and Luxembourg, where the former shows a more disaggregated zonation, but a level of acceleration consistent with the latter. Finally, France and Luxembourg have exactly the same level of reference ground acceleration (0.04g) in the border area.

Figure 11.13 shows that the comparison of seismic zone maps in the border area of Croatia and Slovenia is not an easy task, because the representation adopted in the Croatian seismic zone map does not facilitate the differentiation of reference acceleration levels. In general, the acceleration level in the Croatian side seems higher than in the Slovenia side of the border. The same difficulties arise when comparing the border area of Croatia and Hungary, although herein the hazard levels seem more consistent. The reference ground acceleration on the border area between Hungary and Romania varies between 0.10g and 0.12g in the Hungarian side, and between 0.08 g and 0.20 g in the Romanian territory, meaning that the acceleration levels on the northwest border of Romania have reached double values of the ones adopted in the neighbouring Hungary. Notice that Romania has chosen a different return period from the other countries, so the seismic hazard underlying its seismic map is not directly comparable with the other countries hazards. In the Romanian side of the border area with Bulgaria, four different seismic zones are shown, with reference acceleration levels ranging between 0.12g and 0.20g. On the other hand, on the Bulgarian side of the border, two different seismic zones are drawn with acceleration levels of 0.11g and 0.15g. Finally, Figure 11.13 shows that in the border area between Greece and Bulgaria, the former has adopted two different seismic zones with reference acceleration levels of 0.16 g and 0.24g and the latter has implemented lower acceleration values varying between 0.11g and 0.23g. It is clear that there is no matching on the reference acceleration levels in these neighbouring regions, since zone Z2 in Greece (0.24g) is nearby a Bulgarian zone with a reference acceleration level of 0.15g, and zone Z1 in Greece (0.16g) is close to Bulgarian seismic zones with 0.15g and 0.11g.

As discussed previously, there are still a lot of differences in the seismic zone maps adopted in EN 1998-1 by the EU Member States. Note that the national seismic provisions were produced in different times and this may have contributed to the different layouts of the seismic maps. Additionally, as a result of different national practices, the seismic zone maps show discontinuities in the seismic levels at countries borderlines, making it difficult to harmonise the use of Eurocodes in neighbouring areas of different Member States.

Seismic zonation and the definition of the seismic action are key elements for all Parts of EN 1998 and advancements towards a more harmonized seismic zonation, still enabling the Member States to establish their own safety levels, are a matter of priority in the next generation of Eurocodes.

11.5 Concluding remarks

The statistical analysis of the uploading of Nationally Determined Parameters (NDPs) in the JRC Database by the various countries on the different Eurocodes showed that:

- by early January 2016, the set of expected data corresponded to 37,308 NDPs and 23,488 NDPs were uploaded in the Database, representing 63% out of all expected data;
- all EU Member States, except Malta, were uploading data in the NDPs Database, and there were 14 EU countries and one EFTA country (Norway) that uploaded more than 75% of the expected NDPs;
- The most populated Eurocodes were EN 1992 and EN 1994, respectively, with a percentage of uploading of 74.8% and 71.3% of the expected NDPs. The least populated Eurocodes were EN 1990 and EN 1997, having a percentage of uploading less than 55%.

The NDPs for which a Recommended Value is given in the Eurocodes were extracted from the Database and data post-processing gave the following results:

- the mean percentage of acceptance of the Recommended Values for all Eurocodes Parts was 73.2%. This preliminary result was based on 66% of all expected data for the NDPs with RV available;
- the Eurocodes with higher than the mean percentage of acceptance of the Recommended Values were EN 1994 with 83.4% of acceptance, EN 1993 with 82.8%, EN 1992 with 77.1% and EN 1999 with 74.8%. These results indicate a good harmonization in the national adoption of the most widely-used "material Eurocodes" EN 1992 and EN 1993;
- the Eurocode with the lowest percentage of acceptance of the Recommended Values was EN 1997, with 47.4% of acceptance, closely followed by EN 1990 with 50.1% of acceptance. This result for EN 1997 can be explained by the fact that it introduces "a common language" in the field of geotechnical design, in which the national practices are very different and should be further harmonised.
- The number of NDPs accepted by 100% of the countries reached a total of 96, i.e. 6% of the 1 506 NDPs existing in all 58 Parts of the Eurocodes and 11% of the total number of NDPs with RVs (842).

The statistical analysis of the uploading of 142 NDPs considered relevant to the definition of climatic and seismic actions for structural design with the Eurocodes, led to the following main results:

- by October 2015, the countries uploaded in the Database a total of 2,383 NDPs, which were distributed by 3 Parts of EN 1991 and by 2 Parts of EN 1998;
- the average percentage of uploading of this set of NDPs was 67%, where Parts 1-3 and 1-4 of EN 1991 showed the highest percentage of uploading (74%).

The statistical analysis on the acceptance of NDPs of different types, related to the definition of climatic and seismic actions, produced the following results:

- Among the NDPs where the EN text can be accepted as proposed in the standards there are 116 NDPs related to the definition of climatic and seismic action. In this total there were 34 NDPs (30%) accepted by more than 70% of the uploading countries, 8 NDPs (7%) that reached a consensus by more than 90% of the uploading countries and 2 NDPs (1.7%) globally accepted by all of the uploading countries. A subset of this group of NDPs, *i.e.*, the NDPs of type 1.2, 1.3 and 3.2 was further analysed, since it was considered as a potential source for further harmonization, as these NDPs mostly concern further refinement/adjustment of methods and procedures;
- the set of NDPs with RV given had an average acceptance rate higher than the rate of the others NDPs under analysis. A good consensus was achieved among the countries on the NDPs with RV that belong to Parts 1-4 and 1-5 of EN 1991, with an average acceptance percentage of 72% and 68%, respectively;
- a broad consensus (71%) emerged on the acceptance of NDPs of type 1.1 for all analysed Eurocodes Parts, except for EN 1991-1-3 (55%);
- A statistical analysis for each of parameters of type 1.1 uploaded in the Database was made for the concerned EN Parts. The causes of the largest divergences found in the NDPs were investigated, showing that they were due to the non-acceptance of the Recommended Values by only one EU Member State.

Finally, the seismic zone maps were chosen as example to illustrate the state of harmonization of the maps adopted by Member States in their National Annexes. The state of harmonization of the countries border acceleration values and the layout of the maps were addressed. The collected maps present dissimilar layouts and reveal discontinuities in the levels of the reference ground acceleration at countries borderlines.

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CHAPTER 11

STATE OF HARMONIZED USE OF THE EUROCODES NATIONALLY DETERMINED PARAMETERS RELEVANT TO THE DEFINITION OF CLIMATIC AND SEISMIC ACTIONS

ANNEX A

LIST OF NDPs RELATED TO THE DEFINITION OF CLIMATIC AND SEISMIC ACTIONS

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Table A.11.1 Description of NDPs related to maps for climatic and seismic actions

EN 1991-1: ACTIONS ON STRUCTURES; Part 1-3: General Actions - Snow loads
1.1 (2) Advice for the treatment of snow loads for altitudes above 1500 m
1.1 (3) Identification of different locations.
1.1 (4) Decision on the use of Annex B for shape coefficients to be used for the treatment of exceptional snow drifts
2 (3) The conditions of use (which may include geographical locations) of clause 2(3)
2 (4) The conditions of use (which may include geographical locations) of clause 2(4)
3.3 (1) Selection of the design situation for a particular local effect described in Section 6
3.3 (3) Selection of the design situation for a particular local effect described in Section 6
4.1 (1) The characteristic value of snow load on the ground (s_k)
4.1 (2) Further complementary guidance on the characteristic value of snow load on the ground (s_k)
4.2 (1) The values of ψ
4.3 (1) The coefficient for exceptional snow loads C_{esl}
5.2 (2) The use of Annex B for the roof shapes described in 5.3.4, 5.3.6 and 6.2 in specific locations
5.2 (5) Further guidance on suitable load arrangements when artificial removal or redistribution of snow on a roof is anticipated
5.2 (6) Further guidance on snow loads on roofs
5.2 (7) The values of the exposure coefficient C_e for different topographies
5.2 (8) The use of a reduced thermal coefficient, C_t
5.3.3 (4) Alternative drifting load arrangement based on local conditions
5.3.4 (3) Decision on the use of Annex B to determine the load case due to drifting for multi-span roofs
5.3.4 (4) Guidance on the snow load shape coefficients for the design of multi-span roofs, where one or both sides of the valley have a slope greater than 60 degrees
5.3.5 (1 NOTE 1) The upper value of μ_3
5.3.5 (1 NOTE 2) Rules for considering the effect of snow fences for snow loads on cylindrical roofs
5.3.5 (3) Alternative drifting load arrangement based on local conditions
5.3.6 (1 NOTE 1) The range for the snow load shape coefficient due to wind, μ_w
5.3.6 (1 NOTE 2) A restriction for the drift length, l_s
5.3.6 (3) Decision on the use of Annex B to determine the load case due to drifting for roofs abutting and close to taller construction works
6.2 (2) Decision on the use of Annex B to determine the load case due to drifting for quasi-horizontal roofs
6.3 (1) The conditions of use for Clause 6.3 (1)
6.3 (2) The values of a coefficient to take account of the irregular shape of the snow, k
Annex A (1 Table A.1) Definition of exceptional conditions and definition of design situations which apply for the particular local effects described in Section 6 for cases B1 and B3
Annex C ((1) to (7)) European ground snow load maps
Annex D ((1) to (4)) Adjustment of the ground snow load according to return period
Annex E ((1) to (2)) Bulk weight density of snow
NCCI Reference to other Non-Contradictory Complementary Information

EN 1991-1: ACTIONS ON STRUCTURES; Part 1-4: General Actions - Wind actions
1.1 (11 NOTE 1) Guidance on wind actions on lattice towers with non-parallel chords, wind actions on guyed masts and guyed chimneys, torsional vibrations, e.g. tall buildings with a central core, bridge deck vibrations from transverse wind turbulence, cable supported bridges, and vibrations where more than the fundamental mode needs to be considered
1.5 (2) Guidance on design assisted by testing and measurements
4.1 (1) National climatic information from which the mean wind velocity v_m , the peak velocity pressure q_p and additional values may be directly obtained for the terrain categories considered
4.2 (1 NOTE 2) The fundamental value of the basic wind velocity, $v_{b,0}$
4.2 (2 NOTE 1) Where the influence of altitude on the basic wind velocity v_b is not included in the specified fundamental value $v_{b,0}$, giving a procedure to take it into account
4.2 (2 NOTE 2) The value of the directional factor, C_{dir} , for various wind directions
4.2 (2 NOTE 3) The value of the season factor, C_{season}
4.2 (2 NOTE 5) The values for the shape parameter depending on the coefficient of variation of the extreme-value distribution, K and the exponent, n
4.3.1 (1 NOTE 1) The orography factor, c_0
4.3.1 (1 NOTE 2) Design charts or tables for $v_m(z)$
4.3.2 (1) The procedure for determining the roughness factor, $c_r(z)$
4.3.2 (2) Definitions of the angular sector and of the upstream distance
4.3.3 (1) The procedure to be used for determining the orography factor, c_0
4.3.4 (1) A procedure to take account of large and considerably higher neighbouring structures effect
4.3.5 (1) A procedure for the effect of closely spaced buildings and other obstacles
4.4 (1 NOTE 2) The value of the turbulence factor, k_t
4.5 (1 NOTE 1) Rules for the determination of the peak velocity pressure, $q_p(z)$
4.5 (1 NOTE 2) The values for the air density, ρ
5.3 (5) Determine whether lack of correlation may be applied generally or be restricted to walls as applied in 7.2.2 (3).
6.1 (1) Information on whether the structural factor $c_s c_d$ should be separated or not
6.3.1 (1 NOTE 3) The procedure to be used to determine k_p , B and R
6.3.2 (1) A method for determining the along-wind displacement and the standard deviation of the along-wind acceleration.
7.1.2 (2) Procedures for asymmetric and counteracting pressures and forces for other structures
7.1.3 (1) Further information on effects of ice and snow
7.2.1 (1 NOTE 2) A procedure for calculating external pressure coefficients for loaded areas above 1 m^2 based on external pressure coefficients $C_{pe,1}$ and $C_{pe,10}$.
7.2.2 (1) The rules for the velocity pressure distribution for leeward wall and sidewalls (zones A, B, C and E, see Figure 7.5)
7.2.2 (2 NOTE 1) The values of $C_{pe,10}$ and $C_{pe,1}$
7.2.8 (1) The values of $C_{pe,10}$ and $C_{pe,1}$ to be used for circular cylindrical roofs and domes
7.2.9 (2) Additional information on the size and distribution of the openings in the building envelope
7.2.10 (3 NOTE 1) Values for the wind effects on external walls and roofs with more than one skin

EN 1991-1: ACTIONS ON STRUCTURES; Part 1-4: General Actions - Wind actions
7.2.10 (3 NOTE 2) Rules for cases where the extremities of the layer between the skins are air tight (Figure 7.14(a)) and where the free distance between the skins is less than 100 mm (the thermal insulation material being included in one skin, when there is no airflow within the insulation).
7.4.1 (1) Values of the resulting pressure coefficients $c_{p,net}$ for free-standing walls and parapets
7.4.3 (2) The value of the horizontal eccentricity, e
7.6 (1 NOTE 1) The values of ψ_r
7.7 (1 NOTE 1) The value for $c_{f,0}$ for the structural elements with sharp edged section
7.8 (1) The value for $c_{f,0}$ for the structural elements with regular polygonal section
7.10 (1 NOTE 1) The values of $c_{f,x}$
7.11 (1 NOTE 2) A reduction factor for scaffolding without air tightness devices and affected by solid building obstruction
7.13 (1) Values for λ and Ω_{λ} , taking the effect of turbulence into account
7.13 (2) Values for λ and ω_{λ}
8.1 (1 NOTE 1) Wind actions for other types of bridges (e.g. arch bridges, bridges with suspension cables or cable stayed, roofed bridges, moving bridges and bridges with multiple or significantly curved decks),
8.1 (1 NOTE 2) The angle of the wind direction to the deck axis in the vertical and horizontal planes
8.1 (4) A value for $V_{b,0}^*$
8.1 (5) A value for $V_{b,0}^{**}$
8.2 (1 NOTE 1) Criteria and procedures on a dynamic response procedure for bridges
8.3 (1) Force coefficients for parapets and gantries on bridges
8.3.1 (2) Decision on application of reduction to F_w , defined in 8.3.2
8.3.2 (1) C-values
8.3.3 (1 NOTE 1) Values for $c_{f,z}$
8.3.4 (1) The longitudinal wind forces in y-direction
8.4.2 (1 NOTE 1) Simplified rules for wind effects on piers
AnnexA (A.1 to A.5) Terrain effects
AnnexA.2 (1) The procedure on the transition between different roughness categories
AnnexB (B.1 to B.4) Procedure 1 for determining the structural factor c_{sC_d}
AnnexC (C.1 to C.5) Procedure 2 for determining the structural factor c_{sC_d}
AnnexD (1) c_{sC_d} values for different types of structures
AnnexE (E.1 to E.5) Vortex shedding and aeroelastic instabilities
AnnexE.1.3.3 (1) The value of the air density ρ under vortex shedding conditions
AnnexE.1.5.1 (1 NOTE 1) The choice of calculation approach or alternative calculation procedures on for calculating the vortex excited cross-wind amplitudes
AnnexE.1.5.1 (1 NOTE 2) Definition of the range of application for the approaches proposed for calculating the vortex excited cross-wind amplitudes
AnnexE.1.5.1 (3) Providing information on the regions where very cold and stratified flow conditions
AnnexE.1.5.2.6 (1 NOTE 1) The minimum value for the number of load cycles N caused by vortex excited oscillation
AnnexE.1.5.3 (2 NOTE 1) The value of the air density ρ under vortex shedding conditions
AnnexE.1.5.3 (4) More detailed information on the influence of the turbulence intensity on K_a
AnnexE.1.5.3 (6) The peak factor k_p
AnnexE.3 (2) Additional guidance on the combined stability parameter, a_{IG}
AnnexF (F.1 to F.5) Dynamic characteristics of structures
NCCI Reference to other Non-Contradictory Complementary Information

EN 1991-1: ACTIONS ON STRUCTURES; Part 1-5: General Actions - Thermal actions
5.3 (2 Table 5.1) Values for T_1 and T_2
5.3 (2 Table 5.2) Values of the maximum shade air temperature T_{max} , minimum shade air shade temperature T_{min} , and solar radiation effects T_3 , T_4 , and T_5 ,
5.3 (2 Table 5.3) The values of T_6 , T_7 , T_8 , and T_9
6.1.1 (1 NOTE2) Values of the uniform temperature component and the temperature difference component for other types of bridges
6.1.2 (2) The selection of the approach on the vertical temperature difference component
6.1.3.1 (4) Values of $T_{e.min}$ and $T_{e.max}$
6.1.3.2 (1) Information (e.g. maps of isotherms) on minimum and maximum shade air temperatures
6.1.3.3 (3) The maximum expansion range of the uniform bridge temperature component, and the maximum contraction range of the uniform bridge temperature component for bearings and expansion joints
6.1.4 (3) Values of the initial temperature difference
6.1.4.1 (1) Values of $\Delta T_{M,heat}$ and $\Delta T_{M,cool}$
6.1.4.2 (1) Values of vertical temperature differences for bridge decks
6.1.4.3 (1) Numerical values for the temperature difference
6.1.4.4 (1) Temperature difference components within walls of concrete box girders
6.1.5 (1) Numerical values of ω_N and ω_M
6.1.6 (1) Values for the differences in the uniform temperature component
6.2.1 (1) The design procedure on consideration of temperature differences between the outer faces of bridge piers, hollow or solid
6.2.2 (1) For concrete piers (hollow or solid), the linear temperature differences between opposite outer faces
6.2.2 (2) For walls, the linear temperature differences between the inner and outer faces
7.2.1 (1) Information (e.g. maps of isotherms) on minimum and maximum shade air temperatures
7.5 (3) For concrete pipelines, the linear temperature difference component between the inner and outer faces of the wall
7.5 (4) The value of the difference of temperature
AnnexA.1 (1 NOTE1) Information (e.g. maps or tables of isotherms) on both annual minimum and annual maximum shade air temperature
AnnexA.1 (1 NOTE2) The adjustment procedure on the values of shade air temperature
AnnexA.1 (3) Value of the initial temperature, T_0
AnnexA.2 (2) The values of the coefficients k_1 , k_2 , k_3 and k_4 based on the values of parameters u and c
AnnexB (1 Tables B.1, B2 and B.3) Temperature differences for various other depths
AnnexC (1) Coefficients of linear expansion
AnnexD ((1) to (2)) Temperature profiles in buildings and other constructions works
NCCI Reference to other Non-Contradictory Complementary Information

EN 1998: Design of structures for earthquake resistance, Part 1: General rules, seismic actions and rules for buildings Chapters 2 & 3: Ground conditions and seismic action
2.1 (1 NOTE 1) Reference return period T_{NCR} of seismic action for no-collapse requirement (or, equivalently, reference probability of exceedance in 50 years, P_{NCR})
2.1 (1 NOTE 3) Reference return period T_{DLR} of seismic action for the damage limitation requirement. (or, equivalently, reference probability of exceedance in 10 years, P_{DLR})
3.1.1 (4) Conditions under which ground investigations additional to those necessary for design for non-seismic actions may be omitted and default ground classification may be used
3.1.2 (1) Ground classification scheme accounting for deep geology, including values of parameters S , T_B , T_C and T_D defining horizontal and vertical elastic response spectra in accordance with 3.2.2.2 and 3.2.2.3.
3.2.1 (2) Seismic zone maps and reference ground accelerations therein
3.2.1 (4) Governing parameter (identification and value) for threshold of low seismicity
3.2.1 (5) Governing parameter (identification and value) for threshold of very low seismicity
3.2.2.1 (4 NOTE 1) The selection of the shapes of the elastic response spectra
3.2.2.2 (2) Parameters S , T_B , T_C and T_D defining shape of horizontal elastic response spectra
3.2.2.3 (1) Parameters a_{vg} , T_B , T_C and T_D defining shape of vertical elastic response spectra
3.2.2.5 (4) Lower bound factor β on design spectral values

EN 1998: Design of structures for earthquake resistance, Part 3: Assessment and retrofitting of buildings
2.1 (3) Return period of seismic actions under which the Limit States should not be exceeded

CHAPTER 11

STATE OF HARMONIZED USE OF THE EUROCODES NATIONALLY DETERMINED PARAMETERS RELEVANT TO THE DEFINITION OF CLIMATIC AND SEISMIC ACTIONS

ANNEX B

DESCRIPTION OF NDPs OF TYPE 1.1 IN EN 1991

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Table A.11.2 Description of NDPs of type1.1 related to the definition of climatic actions in EN 1991, Part 3

#	Section	Clause	NDP Description	NDP Parameter
1	4.3	1	The coefficient for exceptional snow loads C_{esl}	The coefficient for exceptional snow loads C_{esl}
2	5.3.5	1 NOTE 1	The upper value of μ_3	The upper value for μ_3
3 4	5.3.6	1 NOTE 1	The range for the snow load shape coefficient due to wind, μ_w	The snow load shape coefficient due to wind, $\mu_w \leq$
5 6	5.3.6	1 NOTE 2	A restriction for the drift length, l_s	A restriction for the drift length, $l_s \geq$ (m) A restriction for the drift length, $l_s \leq$ (m)

Table A.11.3 Description of NDPs of type1.1 related to the definition of climatic actions in EN 1991, Part 4

#	Section	Clause	NDP Description	NDP Parameter
7	4.2	2 NOTE 2	The value of the directional factor, C_{dir} , for various wind directions	The value of the directional factor, C_{dir} , for various wind directions
8	4.2	2 NOTE 3	The value of the season factor, C_{season}	The value of the season factor, C_{season}
9 10	4.2	2 NOTE 5	The values for the shape parameter depending on the coefficient of variation of the extreme-value distribution, K and the exponent, n	The value for the shape parameter depending on the coefficient of variation of the extreme-value distribution, K The value for the exponent, n
11	4.3.1	1 NOTE 1	The orography factor, c_0	The value of the orography factor, c_0
12	4.4	1 NOTE 2	The value of the turbulence factor, k_t	The value of the turbulence factor, k_t
13	4.5	1 NOTE 2	The values for the air density, ρ	The value for the air density, ρ
14	7.4.3	2	The value of the horizontal eccentricity, e	The value of the horizontal eccentricity, $e = \pm \dots b$
15	7.7	1 NOTE 1	The value for $C_{r,0}$ for the structural elements with sharp edged section	The value for $C_{r,0}$
16	8.1	4	A value for $V_{b,0}^*$	The value for $V_{b,0}^*$ (m/s)
17	8.1	5	A value for $V_{b,0}^{**}$	The value of $V_{b,0}^{**}$ (m/s)
18 19	8.3.4	1	The longitudinal wind forces in y-direction	The longitudinal wind forces in y-direction in percentage of the wind forces in x-direction for plated bridges (%) The longitudinal wind forces in y-direction in percentage of the wind forces in x-direction for truss bridges (%)
20	Annex E.1.3.3	1	The value of the air density ρ ; under vortex shedding conditions	The value of the air density ρ under vortex shedding conditions (kg/m^3)
21	Annex E.1.5.2.6	1 NOTE 1	The minimum value for the number of load cycles N caused by vortex excited oscillation	The minimum value of the number of load cycles N caused by vortex excited oscillation \geq
22	Annex E.1.5.3	2 NOTE 1	The value of the air density ρ under vortex shedding conditions	The value of the air density ρ under vortex shedding conditions (kg/m^3)

Table A.11.4 Description of NDPs of type1.1 related to the definition of climatic actions in EN 1991, Part 5

#	Section	Clause	NDP Description	NDP Parameter
23	6.1.4.3	1	Numerical values for the temperature difference	Linear temperature difference between the outer edges of the bridge independent of the width of the bridge ($^{\circ}\text{C}$)
24	6.1.4.4	1	Temperature difference components within walls of concrete box girders	Value for a linear temperature difference ($^{\circ}\text{C}$)
25	6.1.5	1	Numerical values of ω_N and ω_M	Numerical values of ω_N
26				Numerical values of ω_M
27	6.1.6	1	Values for the differences in the uniform temperature component	Values for the differences in the uniform temperature between main structural elements (e.g. tie and arch) ($^{\circ}\text{C}$)
28				Values for the differences in the uniform temperature for light colour respectively between suspension/stay cables and deck (or tower) ($^{\circ}\text{C}$)
29				Values for the differences in the uniform temperature for dark colour respectively between suspension/stay cables and deck (or tower) ($^{\circ}\text{C}$)
30	6.2.2	1	For concrete piers (hollow or solid), the linear temperature differences between opposite outer faces	For concrete piers (hollow or solid), the linear temperature differences between opposite outer faces ($^{\circ}\text{C}$)
31	6.2.2	2	For walls, the linear temperature differences between the inner and outer faces	For walls, the linear temperature differences between the inner and outer faces (in $^{\circ}\text{C}$)
32	7.5	3	For concrete pipelines, the linear temperature difference component between the inner and outer faces of the wall	For concrete pipelines, the linear temperature difference component between the inner and outer faces of the wall (in $^{\circ}\text{C}$)
33	7.5	4	The value of the difference of temperature	The value of the difference of temperature ($^{\circ}\text{C}$)
34	Annex A.1	3	Value of the initial temperature, T_0	Value of the initial temperature, T_0
35	Annex A.2	2	The values of the coefficients k_1 , k_2 , k_3 and k_4 based on the values of parameters u and c	The values of the coefficients k_1
36				The values of the coefficients k_2
37				The values of the coefficients k_3
38				The values of the coefficients k_4

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