BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iași
Volumul 66 (70), Numărul 4, 2020
Secţia
CONSTRUCŢII. ARHITECTURĂ

COMPARATIVE ANALYSIS BETWEEN EUROCODE 8 AND SNiP II-7-81*

BY

EVGHENI CUTIA* and VADIM ȚURCAN

“Gheorghe Asachi” Technical University of Iași,
Faculty of Civil Engineering and Building Services, Iași, Romania

Received: November 5, 2020
Accepted for publication: November 20, 2020

Abstract. This paper presents a comparison of the seismic design code used in Republic of Moldova (SNiP-7-81*) and European and non-European countries (Eurocode 8). The main scope of this article is to provide a detailed comparison between the above mentioned two standards. The key aspects of structural design in seismic regions for each document ware reviewed and detailed conclusion were drawn for each aspect.

Keywords: SNiP; Eurocode 8; comparison; earthquake design.

1. Introduction

One of the most powerful and dangerous natural phenomena that human kind endured, and is still affecting continents, countries and cities are earthquakes. This natural disaster can veil entire city in flames and dust, can change landscape of affected region or even submerge under the water a part of continent. However, above-described events are classified as devastating or catastrophic earthquakes with intensity I >10 degree, and have less probability of occurrence then moderate or strong earthquakes (5 < I < 9). However, statistics

*Corresponding author; *e-mail*: evgheni.cutia@student.tuiasi.ro

show that for moderate and strong seismic action with magnitude M > 5 the total number of events each year can vary from 1500-2500 events (Duffin, 2020). Most of this seismic event have influences different structures from cities and villages, that are part of a social and economic network of country. Therefore, the seismic design codes are used to reduce seismic effects on buildings or other vital important structure.

In the early 20th and middle of 20th century, every country that is affected with earthquake started to develop its own design code for seismic resistance of buildings. The resulted codes vary, and usually depends on the developed and applied region, soil type, tradition in construction and other peculiar factor for each country.

The Eurasian continent consist more than 100 countries, almost half of them are affected, partially or completely by earthquake. Every country has its own national design code, but it is necessary to emphasize 2 particular codes due to territory cover:

- Eurocode 8 – Seismic code used in European Union (EU) and some countries affiliated to European Union
- SNiP II-7-81* - seismic code used in former Soviet Union. After collapse of Soviet Union, codes are used by Commonwealth of Independent States (CSI) countries.

In Republic of Moldova the SNiP II-7-81* code was adopted as national standard on 1 January 1982 and replaces previous version – SNiP II-A-12-69*. During its existing, since implementation, the normative suffered few changes (MEI, 2020):

- Change Nr.1, published in BOC (Bulletin of construction) Nr. 9 from 1987
- Change Nr.2, published in BOC (Bulletin of construction) Nr. 11 from 1989

The main scope of this paper is to provide a detailed comparison between the above mentioned two standards.

2. Brief History

2.1. Brief History of EUROCODE 8

The Eurocodes are European standards for the design of buildings and other civil engineering works and constructions products. These were developed by the European Committee for Standardization (CEN) upon the request of the European Commission (JRC, 2020).

The main purpose of Eurocodes is to harmonize technical specifications in European Union (EU) by creating a set of codes for structural design and remove obstacles that emerge from different national practices. There are ten structural Eurocodes that cover design principles. Eurocode 8 (EN 1998) applies to the design and construction of buildings and other civil engineering works in seismic regions. Its purpose it to ensure that in the event of earthquake, human lives are protected, the damage is a limited one; important structures for civil protection remain operational.

Table 1
Short History of Eurocodes (Calgaro, 2006)

Years	Description
1971-1976	Public procurement Directive (1971) Appointment of a steering committee steering committee to examine the feasibility the feasibility of developing a common European common European set of technical documents covering the design of a design of a wide range of range of construction works.
1976-1990	Drafting the first set of technical documents under the Commission's authority: the Eurocodes – International inquiry (1980) – Unique Act and Act and New Approach (12/07/1986) (12/07/1986) – Construction product directive (CPD directive (CPD- 1989) – Transfer to CEN
1990-1998	Conversion, by CEN, of the first Eurocodes into provisional European standards (standards (ENVs)
1998-2006	Conversion of the provisional European standards ENV European standards EN
2007-present	Maintenance and evolution and evolution of the Eurocodes

In December 2012, through Mandate M/515, the European Commission asked CEN to develop new standards, or new parts of the existing standards. This was to include the incorporation of new performance requirements and design methods, the introduction of a more user-friendly approach in several existing standards, and a technical report on how to adapt the existing Eurocodes and the new Eurocode for structural glass such as to take into account the relevant impacts of future climate change.

2.2. Brief History of SNiP II-7-81*

SNiP is the abbreviation that can be translated as "Construction norms and regulations". The first sets of SNiP standards were developed in 1929 in USSR and was called "Temporary norms and regulations for the design and erection of buildings and structures".

For the first time, the documents called “Construction norms and regulations” (SNiP) ware published in 1954. All design and construction requirements were combined in 4 set of documents (Blinder, 2013):

- SNiP I – Construction materials, details and design
- SNiP II – Structural design
- SNiP III – Rules for production and reception
- SNiP IV – Price estimates indicators

Each part of SNiP is divided in separate sections, and each section in separated in chapters and paragraphs. While the academic institutions were in process of conducting scientific research in the field of construction, state organizations were increasing their experience in the design, construction and building management, separated chapters of SNiP were reviewed and new paragraphs were added.

Law of the USSR from 19991 “The Protection of Consumer Rights” classified building norms and rules as state standards (USSR, 1991). At the time of the collapse of the USSR in the construction industry, there were 140 building codes and 700 standards.

The SNiPs adopted in the USSR were not purely technical norms and rules, but also contained legal norms. So, SNiP 1.06.04-85 “Regulations on the chief engineer (chief architect) of the project”, approved by the resolution of the USSR Gosstroy of 06.06.1985 No. 103 and applied from July 15, 1985, determine the rights, duties and responsibilities of the chief engineer and chief architect of the project.

The design norms applied on the territory of the Republic of Moldova are presented in the “Catalogul Documentelor Normative” (Catalogue of Normative Documents). The maintenance of the respective document is ensured annually by the Ministry of Economy and Infrastructure.

Currently, the system of normative documents in constructions (SNDC) of the Republic of Moldova consists of 2615 normative documents. Most normative documents in construction are adopted from the former U.R.S.S. and R.S.S.M., the application of which on the territory of the Republic of Moldova was allowed by letter of the former Ministry of Architecture and Constructions of the Republic of Moldova no. 03-05 / 340 of 01.04.1993 “Regarding the functioning of the construction norms on the territory of the Republic of Moldova”. This letter authorized the application of the normative documents of the former U.R.S.S. and R.S.S.M., until their cancellation or other specification.

3. Seismic Hazard

In this chapter by “seismic hazard” will be considered how each code defines ground motion due to an earthquake.

3.1. Seismic Hazard in EUROCODE 8

In most of application given in EN 1998 seismic hazard is described in terms of a parameter, *i.e.* the value of the reference peak ground acceleration (PGA), a_{gR}, on type A ground (Solomos *et al*., 2008).

The PGA is strongly related with other two factors that should be described *i.e.* probability of exceedance in a certain period (annual rate of exceedance) and return period.

3.2. Seismic Hazard in SNiP II-7-81*

In contrast with EN 1998, the SNiP normative is describing earthquake strength by using intensity MSK-64 scale (Medvedev and Sponheuer, 1969). A differentiation of intensity zones according to the recurrence periods of earthquake for the general seismic zoning map of the territory of USSR was made, which had indexes 1,2,3 in list of settlements and on maps provided in SNiP II-7-81* annex. In addition to this, for index 1 corresponds the average of earthquakes 0.01, index 2 – 0.001 and index 3 – 0.0001.

The MSK-64 scale is based on earthquake results analysis and allows to predict intensity of seismic event using historical data. The table below (Table 2), is generated from compiling the historical data with measurable results which provide an attempt of physical interpretation of MSK-64 scale.

Table 2
Seismic Intensity Based on Recorded Data (Gordeev *et al*., 2007)

Description	Design intensity according to MSK-64 scale			
	6	7	8	9
Maximum acceleration, $[\mathrm{m/s^2}]$	0.5	1	2	4
Maximum soil speed frequency, $[\mathrm{m/s}]$ for:				
Soft soils	0.06	0.12	0.24	0.48
Hard soils	0.045	0.09	0.016	0.36
Maximum soil displacement, $[\mathrm{m}]$ for:				
Soft soils	0.045	0.09	0.17	0.35
Hard soils	0.025	0.05	0.1	0.19

In current code of Republic of Moldova, the only seismological parameter that describes construction site in design process is seismicity, measured in grades. For every grade of intensity in code is prescribed the maximum value of acceleration Ag, which is used for determination of inertial seismic loads that are introduced in seismic design of buildings as static loads.

Maximum design value of acceleration in terms of SNiP II-7-81* noted as Ag ($g = 9.81\ \mathrm{m/s^2}$) is related to the factor A with design intensity I_p and computed in accordance with the following expression:

$$A = 0.1 \cdot 2^{I_p - 7} \tag{1}$$

Factor A, can take values 0.1, 0.2, 0.4 for site intensities 7,8,9.

4. Ground Condition and Soil Classification

4.1. Ground Condition and Soil Classification in EUROCODE 8

Seismic ground response proprieties depend on site soil conditions. In EN 1998 soil profile at site is classified according to the value of the average shear wave velocity, $v_{s,30}$, if this is available. Otherwise, the value of N_{SPT} (Standard Penetration Test) should be used (Eurocode, 2004).

The average shear ware velocity $v_{s,30}$ is computed in accordance with the following expression:

$$v_{s,30} = \frac{30}{\sum_{i=1,N} \frac{h_i}{v_i}} \tag{2}$$

$$N_{SPT} = \frac{30}{\sum_{i=1,N} \frac{h_i}{N_{SPT}}} \tag{3}$$

where h_i and v_i denote the thickness (in meters) and shear-wave velocity (at a shear strain level of 10^{-5} or less) of the i-th formation level in a total of N, existing in the top 30 meters; N_{SPT} is standard penetration test blow number of the i-th formation level in a total of N.

The classification of soil conditions according to EN 1998 is described by following stratigraphic profiles:

Category of soil A

- Rock or other geological formation characterized by a shear wave velocity v_s of at least $800\ \mathrm{m/s}$, including at most $5\ \mathrm{m}$ of weaker material at the surface.

Category of soil B

- Stiff deposits of sand, gravel or over consolidated clay, at least several tens of meters thick characterized by gradual increase of the mechanical proprieties with depth and by v_s values at least $360 - 800\ \mathrm{m/s}$ at the depth 10 meters.

Category of soil C

- Deep deposits of medium dense sand gravel or medium stiff clays with thickness from several tens to many hundreds of meters, characterized by v_s of at least $200\ \mathrm{m/s}$ at depth of 10 meters, increasing to at least $350\ \mathrm{m/s}$ at a depth of 50 meters.

Category of soil D

- Loose cohesionless soil deposits with or without some soft cohesive layers, characterized by v_s values below $200\ \mathrm{m/s}$ in the uppermost 20 meters.
- Deposits with predominant soft – to – medium stiff cohesive soils, characterized by v_s values below $200\ \mathrm{m/s}$ in the uppermost 20 meters.

4.2. Ground Condition and Soil Classification in SNiP II-7-81*

SNiP normative defines 3 soil categories according to seismic properties. SNiP II-7-81* does not classify soils according to v_s – shear wave velocity and N_{SPT} – standard penetration test, it classifies soils according to consistency index, porosity ratios and other mechanical proprieties.

Category of soil I

- Rocks of all type (including permanently frozen and thawed out), non-eroded and slightly eroded: large fragmental soils, compact less humid magmatic rocks containing up to 30% of sandy-argillaceous filling: eroded and strongly eroded rocks and earth, permanently frozen soils at temperature minus 2°C and below during construction and operation according to the Principle I (keeping the base soils frozen).

Category of soil II

- Eroded and strongly eroded rocks, including permanently frozen safe those related to the category I; large fragmental soils containing up to 30% of sandy-argillaceous filling with prevalent contacts between the fragments; semi-gravel sands, coarse and medium, dense and medium, humid and less humid; fine and pulverescent sands, dense and medium, less humid; clay soils with consistency indices $I_L \leq 0.5$; at porosity coefficient $e < 0.9$ for clays and loams and $e < 0.7$ – for clay sands; permanently frozen earth, plastic-frozen and granular-frozen as well as hard-frozen at the temperature above minus 2°C during construction and operation according to the Principle I.

Category of soil III

- Loose sands notwithstanding of humidity and coarsity; semi-gravel sands, coarse and medium, dense and medium, water-saturated; fine and pulverescent sands, dense and medium, humid and water-saturated; clay soils with consistency indices $I_L > 0.5$; clay soils with consistency indices $I_L \leq 0.5$ at porosity coefficient $e < 0.9$ for clays and loams and $e < 0.7$ – for clay sands; permanently frozen earth during construction and operation according to the Principle II (thawing of base soils is allowed).

Soil category is needed to define site seismicity which is chosen depending on region's seismicity.

Table 3
Site Seismicity for Region Seismicity (SNiP, 1981)

Soil category	Design intensity according to MSK-64 scale		
	6	7	8
I	6	7	8
II	7	8	9
III	8	9	> 9

From Table 3 can be denoted that seismic intensity of any given site is in strongly dependence of soil category. For softer soil, the seismic intensity will increase and vice versa.

For example, if the site is situated in region with seismicity of 8 grade MSK-64, and soils of investigated site belongs to category I; then site seismicity is decreasing with 1 grade *i.e.* 7 grade MSK-64.

5. Elastic Response Spectrum

Elastic spectrum graphs and soil amplifications coefficients defined in codes are the main parameters determining impacted seismic forces on structure. These factors are developed after a lot of research.

5.1. Elastic Response Spectrum in EUROCODE 8

The response elastic spectrum given in EN 1998, part 1-1 is defined by following relation:

$$\frac{S_e}{g} = S \cdot S_e(T) \tag{4}$$

where function $S_e(T)$ is given by (Eurocode 8):

$$
\begin{aligned}
&0 \le T \le T_B && S_e(T) = a_g \cdot S \cdot \left[1 + \frac{T}{T_B} \cdot (\eta \cdot 2.5 - 1)\right] \\
&T_B \le T \le T_C && S_e(T) = a_g \cdot S \cdot \eta \cdot 2.5 \\
&T_C \le T \le T_D && S_e(T) = a_g \cdot S \cdot \eta \cdot 2.5 \left[\frac{T_C}{T}\right] \\
&T_D \le T \le 4s && S_e(T) = a_g \cdot S \cdot \eta \cdot 2.5 \left[\frac{T_C T_D}{T^2}\right]
\end{aligned}
\qquad (5)
$$

where following notation is used: $S_e(T)$ – elastic response spectrum; a_g – design ground acceleration on type A ground; T_B, T_C, T_D – corner periods in the spectrum; S – soil factor; η – damping correction factor ($\eta = 1$ for 5% damping).

Values T_B, T_C, T_D and S for each soil category and site proprieties could be found in national annex of Eurocode 8.

5.2. Elastic Response Spectrum in SNiP II-7-81*

The elastic response spectrum in SNiP II-7-81* is defined by following relation (SNiP II-7-81*):

$$\frac{S_e}{g} = \beta \cdot k_{soil} \qquad (6)$$

where β – is a dynamic coefficient with is equal to:

- For soil category I:

$$\beta = \frac{1}{T}\text{, but not greater than 3 and not less than 0.8.} \qquad (7)$$

- For soil category II and III:

$$
\begin{aligned}
&\beta = 17 \cdot T + 1 \text{ for } T < 0.1\ (s) \\
&\beta = 2.7 \text{ for } 0.1 \le T \le 0.5\ (s) \\
&\beta = \frac{1.35}{T} \text{ for } T > 0.59\ (s)\text{, but not less than 0.8}
\end{aligned}
\qquad (8)
$$

6. Building Behaviour Factor

During the seismic design, structural engineers are using the concept of the energy absorption, that leads to reducing the seismic forces in order to achieve economy. The behavior factor in design codes is taking important place in the design procedure by virtue of accounting implicitly for inelastic response, the presence of damping and other force reducing effects.

6.1. Building Behaviour Factor in EUROCODE 8

The European standards, EN 1998, specifies maximum allowable behavior factor q values for different structural configurations and forms of construction. For the design of the RC structures, three classes are defined: low (DCL), medium (DCM) and high (DCH).

Table 4
Behaviour Factor "q" for Ductility Medium and High Classes (Eurocode 8)

Structure type	DCM	DCH
Frame, dual and coupled wall systems	$3.0\alpha_u/\alpha_1$	$4.5\alpha_u/\alpha_1$
Uncoupled wall system	3.0	$4.0\alpha_u/\alpha_1$
Torsional flexible system	2.0	3.0
Inverted pendulum system	1.5	2.0

6.2. Building Behaviour Factor in SNiP II-7-81*

In SNiP II-7-81* the behavior factor is described with coefficient k_1, which is the inverse of building behavior factor defined in EN 1998. Three values of coefficient k_1 are defined as follows:

- $k_1 = 1$ – Buildings and structures where damages and irreversible deformations are not allowed. The building behavior is completely elastic under seismic load.
- $k_1 = 0.25$ – Buildings and structures where residual deformations and damages complicating their normal operation are allowed, under conditions of human safety and equipment preservation. The buildings behave plastically under seismic load.
- $k_1 = 0.12$ – Buildings and structures where significant residual deformations, cracks, damage of separate elements temporarily suspending their normal operations are allowed in presence of measures ensuring human safety.

7. Conclusions

The SNiP II-7-81* elaborated in 1981 till present day did not suffer any significant change since for over 40 years, the information and prescription presented in SNiP is briefly described with further explanation in guidance. On other hand, Eurocode 8 that consists of 6 parts offers for engineers a detailed explanation on every step of design. Regarding the seismic hazard, one can affirm that both normative have different approach of quantifying the seismic action *i.e.* ground motion. Nevertheless, the basis on which the hazard maps are made are the same – probabilistic seismic hazard analysis. The soil classification varies in both codes. The main difference consists that in Eurocode the soils are classified in categories by physical proprieties - the shear wave velocities, unlike SNiP II-7-81* that divides 3 categories of soil that are categorized using mechanical proprieties of soil.

What concerns the elastic response spectrum, in chapter Nr.5 in clear shown that the shapes of spectrum are the same, *i.e*. for structures with lower natural period of structure have higher acceleration values, while structures with high natural period that will have smaller acceleration values, but higher displacement. Along with shape similarity, one can notice that this shape is formed in EC by using design acceleration of site, different corner periods and soil factor provided in EN 1998 or National Annex of EN 1998 for each soil category, in contrast with SNiP that uses only natural period of structure to plot the response spectrum.

Behavior factor is treated as important coefficient in both codes. Despite its importance; in SNiP II-7-81* one could find a double sense/interpretation for this coefficient (Gordeev *et al*., 2007). The first interpretation could be that design is made for a strong and rare earthquake; if we assume that during a strong earthquake in structure are allowed to be plastic deformation and local damage that does not cause harm to people then maximum efforts in structural elements could be raised. This explains multiplication with coefficient $k_1 \leq 1$, which is $k_1 = 0.25$ for most of structures. The second interpretation is that the design is made for weak and frequent earthquake; so, for a site intensity with 9 grade MSK-64 scale, it is diminished to 7 grade MSK-64 scale. This hypothesis suggests that during such events, the people safety is satisfied. Unlike SNiP, the behavior factor in EN 1998 is clearly described for every type of structure.

Acknowledgements. “This publication/material has been produced with the assistance of the European Union. The contents of this publication are the sole responsibility of < Evgheni Cutia and Turcan Vadim / “Gheorghe Asachi” Technical University of Iași > and can in no way be taken to reflect the views of the European Union or of the Joint Operational Programme Romania-Moldova 2014-2020 management structures”.

REFERENCES

Blinder A. *Studia Kompass. Elektronik publisher*, (2013), Retrieved May 2020, from: http://www.steps.ru/article/analiz_transformatsii_normativnyh_dokumentov_po_obschestvennym_zdaniyam/.

Calgaro J.-A., *The Eurocodes Eurocodes, History and Present*, Varese (2006, November 27-29), Retrieved from: https://law.resource.org/pub/eu/eurocode/guidance/Varese06_JAC.pdf.

Duffin E., *Development of the Number of Earthquakes (M5+) Worldwide from 2000 to 2019*, (Statista) (2020, March), Retrieved September 20, 2020, from https://www.statista.com/statistics/263105/development-of-the-number-of-earthquakes-worldwide-since-2000/.

Gordeev V.N., Lantuzh-Ljashhenko A.I., Pashinskij V.A., Perel'mutr A.V., Pichugin S.F., *Nagruzki i vozdejstvija na zdanija i sooruzhenija*, Moscova: Izdatel'stvo stroitel'nyh vuzov (2007).

Medvedev S.V., Sponheuer W., *Scale of Seismic Intensity, IV World Conference of the Earthquake Engineering*, Santiago, Chile (1969).

Solomos G., Pinto A., Dimova S., *A Review of the Seismic Hazard Zonation in National Building Codes in the Context of Eurocode 8*, Italy: JRC - European Commission (2008).

*** Eurocode, *Eurocode 8*, *Design of Structures for Earthquake Resistance*, Brussels: CEN (2004).

*** JRC, *About the EN Eurocodes* (2020, September 15), Retrieved from Joint Research Centre: https://eurocodes.jrc.ec.europa.eu/.

*** MEI, *Catalogul documentelor normative în construcții.* Chişinău: Ministerul Economiei și Infrastructurii (2020).

*** SNiP, II.-7.-81, *Construction in Seismic Regions*, Moscova (1981).

*** USSR, *USSR LAW "The consumer rights act" - 22.05.1991*, Moskow (1991).

ANALIZA COMPARATIVĂ ÎNTRE EUROCODE 8 ȘI SNiP II-7-81*

(Rezumat)

În această lucrare este prezentată o comparație a normativului de proiectare seismică utilizat în Republica Moldova (SNiP-7-81*) și țările europene și non-europene (Eurocod 8). Scopul principal al acestui articol este de a oferi o comparație detaliată între cele două standarde menționate mai sus. Au fost analizate principiile de proiectare structurală în regiuni seismice şi s-au formulat o serie de concluzii şi recomandări pentru fiecare document prezentat.