ULUSAL YÖNETMELIKLERDE TEMEL KURALLAR: UKRAYNA’DA DEPREM BÖLGELEERINDE İNŞAAT – 2006

BASIC REGULATIONS OF NATIONAL NORMS: «CONSTRUCTION IN SEISMIC REGIONS OF UKRAINE» -2006

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ÖZET


Anahtar Kelimeler: Ulusal yönetmelikler, Ukrayna da deprem bölgeleri

ABSTRACT

This report presents Basic Regulations of National Norms of Ukraine DBN B.1.1-12:2006 “Construction in seismic regions of Ukraine”, approved by The Ministry of Construction of Ukraine and recommended for application since 01.02.2007. The Document has been prepared taking into account the basic provisions of SNiP II-7-81* and the project of interstate CIS SNIP “Construction in seismic regions”, as well as requirements of Eurocodes and CIS Norms for earthquake-proof construction. [Eurocode 8 (2002), SNiP II-7-81* (1991), SNiP KR B.1.2-4-98 (1998), SNiP II-7-81* (2002)].

Keywords: National Norms, seismic regions of Ukraine

SEISMIC ZONING OF THE TERRITORY OF UKRAINE

For the territory of Ukraine the most dangerous are earthquakes in Vrancea Mountains (Rumania), in Crimea and seismic hypocenter areas of Carpathians. Characteristic intensity of seismic impacts in points for a construction area should be assigned on the basis of set of the general seismic zoning maps (GSZ-2004) of the territory of Ukraine (Fig. 1). The set includes following types of maps:

1. GSZ Maps of types: A; B; C for the whole territory of Ukraine on a scale of 1:2 500 000.
2. Detailed GSZ maps: A0; A; B; C for territories of Crimea autonomy and Odessa region on a scale of 1:1000 000 (insets to the GSZ-2004 maps of the territory of Ukraine). The

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seismic intensity that is indicated on the maps is related to the areas of medium soils according to their seismic properties (the II\textsuperscript{nd} category according to the Table 1.1 of DBN).

The GSZ-2004 map “A” corresponds to 10% exceedance probability of design intensity during 50 years and average return period of such intensities once per 500 years. The map shall be applied for design and construction of mass civil and industrial building and structures, different residential buildings in urban and rural areas.

The GSZ-2004 map “B” corresponds to 5% exceedance probability of design intensity during 50 years and average return of such intensities once per 1000 years. The map shall be applied for design and construction of the building and structures, the failure of which at severe earthquakes can cause a considerable loss of human lives and which are of a serious ecological threat for population.

The GSZ-2004 map “C” corresponds to 1% exceedance probability of design intensity during 50 years and average return period of such intensities once per 5000 years. The map shall be applied for design and construction of the structures of especially important category (e.g. large-scale waterworks, large-scale chemicals plants, different ecologically dangerous works and others).

The detailed GSZ-2004 map “A0” corresponds to 39% exceedance probability of earthquake design intensity during 50 years and average return period of such intensities once per 100 years. The map shall be applied for design and construction only on territory of Crimea autonomy and Odessa region for buildings and structures of low importance.

BASIC PARTICULARITIES OF THE NORMATIVE DOCUMENT

1. Except the GSZ-2004 maps, a list of inhabited localities in seismic hazardous regions of Ukraine is included to the Norms. Seismic intensity (soil acceleration) corresponds to design earthquake on maps A and B.
2. For design of important, especially significant and ecologically dangerous works as well as waterworks it is necessary additionally apply the map “C”. At that the seismic impact intensity corresponds to maximum design earthquake (MDE).
3. The characteristic and design seismicity of construction site from 6 up to 9 points depending on soil category according to their seismic properties.
4. Permissible rations between periods of structure natural oscillations and predominant periods of soil base natural oscillations (more then 1,5) is recommended to keep for prevention of resonant regimes of buildings oscillation during earthquake.
5. The Norms foresees application of seismic protection and other systems of seismic load dynamic control for reduction of seismic loads on buildings and structures.
6. DBN B.1.1-12:2006 foresees installation of engineering seismometer services stations. At that, installation of the stations is mandatory for important structures and high buildings (higher than 70 m) and for pilot projects.
7. The Norms also recommends fulfilling a dynamic certification for erected important building and structures more than 16 storeys in height.

DESIGN MODELS AND CALCULATION METHODS

1. The Norms is oriented to applying the up-to-date software complexes and application of two-dimensional and tree-dimensional dynamical multimass models of buildings and structures.
2. In case of applying the spectral method it is recommended to fulfill buildings and structures analysis as taking into consideration of translational and torsion oscillations.
3. The direct dynamic analysis method should be applied for buildings and structures of principal new structural solutions and also for buildings more than 50 m in height, large-span structures with spans more than 30 m, as well as at applying of seismic protection systems and systems of seismic response regulation.
Figure 1. The GSZ-2004 maps of types “A”, “B” and “C” for the whole territory of Ukraine
4. The vertical seismic load shall be considered under seismicity 9, 8 and 7 points for frames, arches, trusses and spatial covering systems of buildings and structures with spans equal to 12 m, 18 m, 24 m and more correspondently.

5. For determining of the design values of horizontal seismic loads to buildings and structures with height $H$ that exceeds its width $B$ and length $L$ twice or more times it is allowable to apply the design model (see Fig. 2, a) as the multi-mass elastic-deformed cantilever rod that is rigid fixed in the base, and which bears the concentrated masses of weight $Q_k$, at the level of floors and being in oscillatory motion along one of the directions (X or Y). Design diagram in view of multi-mass cross system with concentrated mass in floor levels may be accepted if a width $B$ of structure is smaller then other dimensions ($H$ and $L$) at three and more times.

![Figure 2: Design models of buildings and structures: a) as multi-mass cantilever rod; b) as multi-mass transversal system; c) as 3-D dynamic model](image)

6. The design value of horizontal seismic load $S_{ki}$, applied to the point $k$, and corresponding to $i$ mode of the natural oscillations of building or structure shall be determined by formula:

$$S_{ki} = k_1 \cdot k_2 \cdot k_3 \cdot S_{0ki}$$

where $k_1$ is a factor that considers the inelastic deformations and local damages of building members; it is taken according to the Table 2.3 DBN;

$k_2$ is a factor of structures importance: it is taken according to the Table 2.4 DBN; it can varied for different building and structures from 0.5 to 1.5;

$k_3$ is a factor that considers the number of building storeys of more than 5, and it is determined by formula:

$$k_3 = 1 + 0.06 \cdot (n - 5)$$

where $n$ is the number of storeys in building. Maximum value of $k_3$ is accepted no more than 2.0 (including frame, frame-bonded and bounded systems) and it is no more then 1.8 for wall and frame-wall structural systems; $S_{0ki}$ is horizontal seismic load under $i$ mode of building’s natural oscillations that is determined by formula:

$$S_{0ki} = Q_k \cdot a_0 \cdot k_{rp} \cdot \beta_i \cdot \eta_{ki}$$

where $Q_k$ is a load that corresponds to concentrated mass in point $k$ and that is determined with taking into account the factors according to clause 2.1.1 DBN;

$a_0$ is the relative soil acceleration that is accepted equal to 0.05; 0.1; 0.2 and 0.4; correspondingly for regions of seismicity of 6, 7, 8 and 9 points; at applying of maps “A” and “B” depending on design values $a_0$ according to the Table 2.5 DBN;
\( k_{ps} \) is a factor considering the soil nonlinear deforming. It should be accepted according to the Table 2.6 DBN;

\( \beta_i \) is the spectral dynamic factor that corresponds to \( i \) mode of natural oscillations of building or structure according to clause 2.3.2;

\( \eta_{ki} \) is a factor that depends on the mode of natural oscillation of building or structure and it is determined by formula:

a) for cantilever and transversal design models:

\[
\eta_{ki} = \frac{\sum_{j=1}^{n} Q_j U_i(z_j)}{\sum_{j=1}^{n} Q_j U_i^2(z_j)}
\]  

(4)

where \( U_i(z_k) \) and \( U_i(z_j) \) are the displacements of buildings or structures for natural oscillations under \( i \) mode; \( n \) is the number of concentrated loads.

b) for crossed and 3-D design models:

\[
\eta_{ki} = \frac{\sum_{j=1}^{n} Q_j U_i(z_j) \cos(U_{ki}, U_0)}{\sum_{j=1}^{n} Q_j U_i^2(z_j)}
\]

(5)

where \( \cos(U_{ki}, U_0) \) are the cosines of the angles between the direction of displacements \( U_{ki} \) and vector of seismic impact \( U_0 \).

7. The factor \( k_1 \) considers the inelastic deformations and damages of building or structure members depending on construction site seismicity and building structural system for determination of seismic loads under spectral method.

8. The diagrams of spectral dynamic factors (see Fig. 3b) are drawn based on the instrumental records of soil accelerations by means of digital seismic stations of the Institute of Geophysics of National Academy of Sciences on different sites with different soil conditions. At that the long-period (from 0.9 up to 1.5 seconds during the earthquake in Carpathians in 1977) seismic impacts at earthquakes with epicenter in Vrancea Mountains (Rumania) were considered. The values of spectral dynamic factors that equal to 2.5 for buildings and structures with natural oscillation periods up to \( T = 1.2 \) s for soils of the IIIrd category are increased (in comparison with acting SNiP II-7-81*) the design loads for flexible and high-rise buildings and structures.

9. Except traditional approach, the recommendations for determination of oscillation mode factor \( \eta_{ki} \), as for plane (cantilever) and for 3-D design models of structure, as well as at angular direction of seismic moving vector relate to the building orientation in plan are given.

10. In regions with high seismicity (8 and 9 points) the height of buildings with steel framework is limited, correspondently, by 12 and 16 storeys (see Table 1). According to this Table the height of buildings from reinforced concrete structures is allowed to apply not more than 9 storeys at site design seismicity equals to 9 points.

11. Limitations for building height are assigned for most widespread structural building systems as reinforced concrete girder-less frame with reinforced concrete diaphragms or with rigidity cores.

12. The buildings of more storeys than above indicated at DBN (Table 3.1) are considered as works of experimental construction. The provisions for design and construction of such buildings are regulated by special directives of Ministry of Regional Development and Construction of Ukraine.
Basıc Regulations of National Norms

Figure 3. The diagrams of spectral dynamic factors:

a) SNiP II-7-81* with modification -1997:

b) DBN of Ukraine

c) Code of Romania П100-92:

Figure 3. The diagrams of spectral dynamic factors: a) – SNiP II-7-81*; b) – DBN of Ukraine B.1.-12:2006; c) – Code of Romania П100-92.
13. A new requirement for considering of additional moment from vertical loads (static and seismic ones) at design of buildings of 70 m and higher and also permissible values for floor tilts are implemented in DBN (Table 2.8).

14. There is a requirement concerning correlation considering of the high-frequency oscillation modes at determining of forces in structure members that is especially important at using 3-D design models of buildings and structures.

15. At design of buildings and structures in plane irregular shape and asymmetrical distribution of rigidities and masses along the height it is recommended to apply the 3-D design models and consider the seismic torsion oscillations and loads, and non-uniform field of soil oscillation under earthquake as well.

16. The recommendations for fulfilling of direct dynamical design method and set of design accelerograms, which can be used in case of absence of instrumental records of the soil accelerations on construction site are given.

Table 1. The storey quantity for residential, civil and industrial buildings depending on site seismicity

<table>
<thead>
<tr>
<th>No</th>
<th>Bearing structures of building</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steel framework</td>
<td>ns</td>
<td>ns</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Reinforced concrete framework:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- hinged or frame-hinged with vertical reinforced concrete diaphragms or stiffening cores;</td>
<td>ns</td>
<td>16</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>- framed with walling of piece brickwork;</td>
<td>ns</td>
<td>9</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>- framed without walling;</td>
<td>12</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>- girderless with reinforced concrete diaphragms and stiffening cores;</td>
<td>ns</td>
<td>16</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>- girderless without walling</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>In situ reinforced concrete walls</td>
<td>ns</td>
<td>24</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Large-panel reinforced concrete walls</td>
<td>ns</td>
<td>20</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>Framed-wallng</td>
<td>ns</td>
<td>10</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Walls of cyclopean concrete masonry or vibrated brickwork one</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>- of two-row bond, connected by embedded parts and extension bars;</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>- of two-row bond, strengthened by continuous vertical reinforcing</td>
<td>ns</td>
<td>9</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>Walls of combined structure of the brick, stone and small building blocks</td>
<td>12</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Walls of bricks, concrete stones and small blocks</td>
<td>9</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Walls of small cell-concrete blocks of combined structure</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Walls of hollow-wood, timber, whole timber</td>
<td>ns</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes:
The requirements for construction in 6 points seismic areas see items 3.12.1…3.12.5 of DBN.
The storey height is accepted not more than 4 m for residential and civil buildings and 6 m for industrial ones.
Letters “ns” in the table indicate that buildings are designed according to requirements for non-seismic regions.
The storey, which height is above ground level more than it’s a half should be related to aboveground storeys.
In regions with seismicity 7 and 8 points the quantity of storeys can be increased for one storey in the buildings of stone walls (items 8 and 9) under ensuring normal cohesion in stonework $R_{nt} \geq 180$ kPa (1.8 kg/cm²).
The design of buildings with storey quantity more than indicated in the table is allowed as experimental construction based on a proper substantiation, approved by regulating authorities of Ukraine.
Bricks with density more then a grade D600 and on compression strength class more then B2.5 should be used for bearing structures according to item 9.

INITIAL DATA AND COMPARATIVE ANALYSIS

Conditions for construction in Ukraine

Construction in Ukraine is characterized by variety of soil, geological, hydro-geological and climate conditions. About 90% of urban and rural areas are affected to dangerous processes of natural origin. There are big floods, landslides, tornado, karsts and earthquakes. The karts processes
are appeared on more then 60% of Ukraine territory, including opened karst on 27% of territory. More then 130 thousands landslides on square about 5 thousands km$^2$ were recorded in Crimea, Prikarpattia, Donbas, Odessa, Khmelnitsky and Dnepropetrovsk regions.

More then 120 thousands km$^2$ (20% of Ukraine territory) are seismic dangerous zones with intensity from 6 to 9 points on MSK-64 scale. About 20% of population lives in these zones.

Natural conditions for construction in many regions are complicated by catastrophic floods.

**Seismic regions of Ukraine**

A general seismic activity in Ukraine is characterized by following seismic regions:

- **Carpathian region** - Vrancea zone in Romania and zones of local earthquakes on Ukraine territory. The data on powerful earthquakes were recorded in 1091, 1230, 1445, 1802, 1838, 1940, 1977, 1990 years with magnitude in epicenter 8-9 points. Earthquakes occur in Odessa region with intensity 6-7 points, Chernivtsi region – 7 points, Khmelnitsky region – 6 points, Kyiv region – 5-6 points, Carpathian region – 4-5 points with average return period $T = 17 \div 28$ years.

- **Crimea-Black Sea region**. There is known some powerful earthquakes with intensity 7-8 points during last 2000 years. The earthquakes in June, 26 and in September, 11 of 1927 with magnitude $M=6.8$ are referred to powerful earthquakes in Crimea. They have been a reason for damage about 70% of all structures in Yalta city. Cities Alupka, Alushta, Gurzuf, Miskhor, Yalta were affected by 8 point earthquake. Intensity of shaking has been 9 points in Yalta region.

- **Seismic active zones on south-west of East European platform**. Areas of Kirovograd region (1873 year – 7 points on boarder with Cherkassy region), Donetsk region (1937 year – 6 points near Konstantinovka city), Kharkov region (1858 and 1913 year – 5-6 points) and Chernigov region (1905 year – 5-6 points) related to that zone.

**Spectral design method (SDM)**

Figure 3 presents diagrams for spectral dynamic factors adopted in different Norms: SNiP II-7-81*, Ukraine DBN and Romanian Code Р100-92. Their comparison is testifying about offsetting of maximal values for dynamic factor in Romanian and Ukrainian Norms toward range of large period values of system oscillation.

**Buildings analysis under earthquake accelerograms**

The application of synthesized design accelerograms, plotted with taking into consideration condition and location of site relatively to dangerous seismic-genous zones is allowed in direct dynamic analysis at design of important buildings and structures.

Set of synthesized accelerograms (Tabl. 2.10 DBN) presented in DBN for the first time in practice of designing. The accelerograms whose predominant periods are close to periods of building natural oscillations under first mode are recommended as design accelerograms at carrying out of specific analysis for buildings and structures.

The seismic load values, structure displacements and deformations should be determined taking into consideration the features of non-linear structures deformation.

**TRANSPORT STRUCTURES DESIGN**

The provisions for transport structures design are presented in section 4 DBN. They cover design of following:

- specific and increased responsibility structures, including requirements for railways, motorways, metro, highway and trunk roads;
- industrial, auxiliary, warehouses and other structures of logistic purposes;
• especially important transport structures (bridges, floodgates, viaducts, overpasses, tunnels, landslide protective structures, transport flyovers etc.) and also other objects of length from 100 to 500 m.

HYDRO-TECHNICAL STRUCTURES

The specific requirements for hydro-technical structures (HTS) installed or located in regions with characteristic seismic intensity of 6 and more points on MSK-64 scale are presented in Norms.

The principal new approach to hydro-technical structures design is presented in section 5 DBN that stipulate application of two-level seismic actions: design earthquake (DE) and maximum calculation earthquake (MCE).

The earthquake with return period $T$ equalled to once per 500 years is assigned as DE (GSZ Map «A») and one earthquake per 5000 years - as MDE (GSZ Map «C»).

The HTS should withstand to DE without of disturbance of its normal operation. At that the residual displacements, cracks and other damages those do not prevent from structure repair during its normal functioning are allowed. MDE should be withstood without of a danger of structure failure or break of pressure front. At that some damages of HTS and its base are admissible.

The fields of application of the direct dynamic method (DDM) or linear spectral method (LSM), depending on seismic impact level, are related to specific class of designed structure and presented in Table 2.

<table>
<thead>
<tr>
<th>Design earthquake</th>
<th>Structure class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I – II</td>
</tr>
<tr>
<td>Water supporting, underground and sea oil and gas industrial structures</td>
<td>DDM</td>
</tr>
<tr>
<td>Water supporting and underground structures</td>
<td></td>
</tr>
<tr>
<td>The rest HTS</td>
<td></td>
</tr>
<tr>
<td>DE</td>
<td>DDM</td>
</tr>
<tr>
<td>MCE</td>
<td>DDM</td>
</tr>
</tbody>
</table>

Note: The list of structures in I and II class concerning to water supporting structures may be extended by design organization accounting pressure-pipelines of big diameter and other object whose failure effect is identical to break of pressure front.

RENEWAL, STRENGTHENING AND RECONSTRUCTION OF BUILDINGS AND STRUCTURES

Such section is introduced in some normative documents of CIS counties [CNAR II-2.02-94 (1998), CNAR I-4.02-99 (2000), International construction norms of CIS (2003), International construction norms ICN 2.03 (2004), KMK 2.01.03-95 (1996)]. The requirements of the section should be applied to following building and structures:

a) being damaged during earthquake;

b) being built without proper seismic protective measures or its insufficiency, and also at change of design seismic intensity for a territory;

c) for reconstructing objects.

A range of renewal, strengthening and reconstruction is prescribed by customer depending on impotency of building and its functional purpose, and also based on inspection results and should be specified in project statement. It is recommended to elaborate the project on improvement of buildings and structures seismic durability based on design documentation and detailed field inspection results of soil basement and building structural members.

The maximum preservation of existing undamaged structures or members, which bearing capacity, determined by analysis for seismic loads, will be higher then existing internal forces should be foreseen in design for renewal, reconstruction, strengthening or seismic resistance improving.

Determining of bearing capacity of structures should be fulfilled based on results of inspections and evaluation its technical conditions by means of building analysis under design
seismic impact taking into consideration the data of strength non-destructive measures of the structure materials. At that the design values of material strengths should be determined based on statistic analysis for “dispersion” of measured values within a storey or a building as minimal value in normal distribution confidence interval with norm of 0.95.

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