SEISMIC HAZARDS IN UKRAINE, INVESTIGATION EXPERIENCE AND EARTHQUAKE ENGINEERING DEVELOPMENT TASKS

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SUMMARY:
The seismic hazard in Ukraine are considered. The reasons for the low seismic structures are measures to enhance seismic safety, given the concept of the National Program "Seismic safety of the territory of Ukraine", examined ways of Earthquake Engineering.

Keywords: seismic hazard, earthquake engineering, National Program

1. NATURAL HAZARDS AND SEISMICITY OF UKRAINE

The natural hazards, danger to people and economic resources in Ukraine, are natural phenomena including earthquakes, hurricane winds, storms, tornadoes, tsunamis, landslides, mud flows, extreme temperatures and other hazardous processes. According to UNESCO data there are 15 – 30 thousand earthquake victims in the world every year. The analysis of disasters for 100 years shows that their geography tends to increase [1].

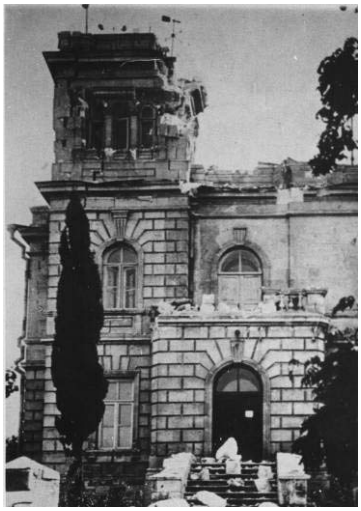
Economic loss because of catastrophic earthquakes (intensity is 8 points and more) are the hundreds of billions of U.S. dollars. The loss of human lives is a serious danger to society. They are distributed non-uniformly in time depending on the level of earthquake load, geographic location of the earthquake and level of economic development of the state. Thus, the main strategy to protect people and economic resources against natural disasters should be based on warning the earthquakes but not on overcoming the consequences of disasters.

The last earthquakes observed in China (Sichuan province, in May 12, 2008, Mw =7,9), in Italy (Abruzzo region and the city of L`Aquila, in April 06, 2009, Mw = 6,3), on the island of Sumatra in Indonesia (in September 30, 2009, M=7,6), in Haiti (Port-au-Prince, in January 12, 2010, Mw = 7,0), in Japan (Fukushima NPP area, in March 11, 2011) showed an insidious force of underground elements which brought destruction and suffering to these regions.

More than 120 thousand square kilometers in Ukraine (about 20 %) are seismically hazardous areas. The earthquakes, intensity of which is 6 - 9 points on the MSK-64 scale, can be observed there. 10,9 million of people (22 % of the total population) live in seismically hazardous areas including the areas of 6 point scale earthquake activity – 7,98 million people (15,5 %), 7 point scale earthquake activity – 2,16 million people (4,2 %), 8-9 point scale earthquake activity – 0,79 million people (1,5 %). Conditions for modern construction in seismic areas are also difficult because there are dangerous geological processes (flooding, landslides, tornados, karsts and etc.). On the territory of Rus' and Ukraine for 900 years there were more than 30 major earthquakes. Strong earthquakes in the Crimea

(1927) brought damages to about 70 % of all buildings in Yalta. Five towns of the Crimea have areas of 8 point scale earthquake activity [2, 3]. Fig. 1 shows some consequences of the given earthquake in Yalta and Sevastopol.

a)



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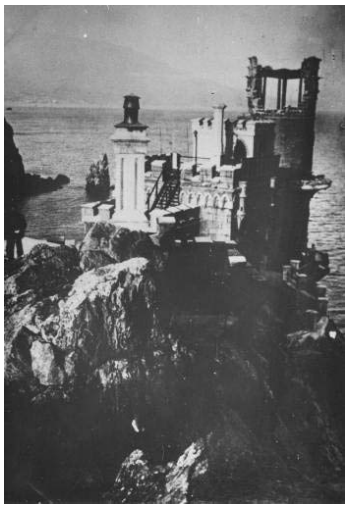

c)

Figure 1. Damage to buildings in Yalta and Sevastopol at earthquake in September 11 – 12, 1927: a- 2 Botkin Street in Yalta; b - Naval observatory in Sevastopol; c - Swallow nest at Ai-Todor cape (photo from the archive of Gosstroy of the Ukrainian SSR)

According to new data the seismically hazardous areas (different intensity) are the following: the Crimea (6 – 9 point), Transcarpathian (7 points), Chernovtsy (6 – 7 points), Vinnitsa (6 points), Kirovograd (6 points), Lvov (6 points), Odessa (6 – 9 points), Ternopol (6 points), Khmelnitsky (6 points) regions of Ukraine. In the Crimea, Carpathian region, Donbas, Odessa, Khmelnitsky and Dnepropetrovsk regions more than 130 thousand of landslides covering the area of about 5 thousand square kilometers are registered. 60 % of sea shore has landslides and shifts. More than 60 % of territory in Ukraine is subject to karsts formation, 27 % of the territory in Ukraine has open karsts (the Crimea, Vinnitsa, Volyn, Donetsk, Lugansk, Lvov, Nikolayev, Rovno, Ternopol, Khmelnitsky regions). These factors influence the level of earthquake hazard in Ukraine negatively.

Buildings and structures vulnerability assessment is a predictive value and structures behavior quality characteristic at maximum earthquake which can occur in the given region in the area where there is a construction object during its existence. The methodology to determine the vulnerability is based on the main principles of the State construction norm DBN B. 1.1.-12:2006 "Construction in seismic regions of Ukraine" [4] and other data which characterize the load-bearing capacity and deformability of building structures.

The Carpathian earthquakes occurring in Vrancea Mountains are felt over a large area and distributed to hundreds or thousands of kilometers from the epicenter. They are observed at arc sharp bend of the Eastern Carpathian and determine the total seismic situation of the territories in Moldova and western regions of Ukraine. The strong influence of the Romanian earthquakes in Ukraine was registered in historical records, literature, various earthquake catalogs and by instrumental observations in 1091, 1170, 1230, 1443, 1446, 1471, 1701, 1790, 1802, 1838, 1893, 1908, 1912, 1940, 1977, 1986, 1990. The earthquakes of the given area caused great damage to buildings and structures in Moldova and Ukraine (see Table 1).

Table 1. The strongest earthquakes of Vrancea area were observed in Ukraine and Moldova

Date of earthquakes	Magnitude measured on Richter scale	Intensity in the epicenter, points	Earthquake intensity in cities, points				
			Kishinev	Lvov	Chernovtsy	Odessa	Kiev
26.10.1802	7,5	9-10	7	4	7	7	5
26.11.1829	6,5	8	7		6	6	4-5
23.01.1838	7,0	9	7	4-5	6	6	4-5
6.10.1908	6,75	8	6	5	6	6	5
10.11.1940	7,3	9	7-8	5	6	7	5
4.03.1977	7,2	9	6-7	4	5-6	5-6	4-5
30.08.1986	7,0	8-9	6	4	5	5	4
30.05.1990	6,7	8-9	6	4	5	5	4

The strongest earthquakes of Vrancea area were observed in Ukraine and their intensity was 5 - 6 points. The exception was the earthquake (intensity is 7 points on MSK-64 scale) observed in October 26, 1802 in Odessa and Chernovtsy.

Construction sites in Ukraine are characterized by a variety of soil, geological, hydrogeological and climatic conditions. There is a tendency to earthquake hazard increase in seismically hazardous areas and in areas which were non-seismic previously. More than 130 thousand landslides covering the area of about 5 thousand square kilometers are registered in the Crimea, Carpathian region, Donbas, Odessa, Khmelnitsky and Dnepropetrovsk regions. 60 % of sea shore has landslides and shifts. More than 60 % of territory in Ukraine is subject to karsts formation, 27 % of the territory in Ukraine has open karsts (Crimea, Vinnitsa, Volyn, Donetsk, Lugansk, Lvov, Nikolayev, Rovno, Ternopol, Khmelnitsky regions). The open karsts areas are particularly large in Volyn (594 km^2), Rovno (214 km^2), Khmelnitsky (4235 km^2) regions.

According to data of the Ministry of emergency situations in Ukraine there are dozens of earthquakes in Carpathian and Crimean-Black Sea regions every year. A significant seismic event was in 2008 on the shelf of the Black Sea, 120 km south of Odessa near Snake Island.

2. TECHNICAL STATE OF HOUSING STOCK AND "EARTHQUAKE HAZARD PROGRAM"

According to experts data Ukraine has main housing stocks at the cost of more than trillion hrivnias including more than 10 million of residential buildings, the total area of which is more than 1, 03 billion square meters. 20 % of them are built in earthquake hazard areas. The technical state of most main housing stocks is inadequate. Some historical architectural monuments of Kiev, Lvov, Chernovtsy and other cities which are included in UNESCO lists of world heritage have critical state.

The housing stock of Ukraine includes the following: historical buildings; buildings of 50 - 60 years which are subjected to demolition or reconstruction; 9 – 16 storied large-panel buildings of better design built in the 70 – 80 years; modern residential buildings including multi-storied ones. The given problem is exacerbated by the fact that most of the buildings built in the 80 - 90 years of the last century are significantly old and deteriorated. Many buildings cannot be reconstructed.

The main principles of the National target-oriented program "Seismic safety in Ukraine" are developed. The general purpose is to increase the seismic safety of the population by strengthening and reconstruction of the existing buildings and construction of earthquake-resistant buildings, to reduce damage of earthquakes, reduce social, economic and ecological risk in seismically hazardous regions of Ukraine and to prepare the cities, towns, villages, industrial, energy, transport and other objects for strong earthquakes. The concept is based on necessity:

- to realize the researches and certification of buildings and facilities in seismically hazardous areas of Ukraine and to realize the measures on their strengthening;
- to prepare the experimental base to assess the earthquake hazard and to realize researches on earthquake resistance;
- to develop the general seismic zoning of cities, towns and villages of Ukraine and micro seismic zoning of sites at construction of new buildings and facilities and reconstruction of the existing ones;
- to harmonize the Concept requirements with the European standards requirements;
- to improve the national and local preparedness for earthquakes and to eliminate the earthquake consequences.

3. THE PROBLEMS OF EARTHQUAKE ENGINEERING DEVELOPMENT IN UKRAINE

At construction of important and experimental multi-storied buildings at the stage of pre-studies it is necessary to study the earthquake hazard, assess the level of earthquake load and realize the control to follow the design norms requirements at the stage of facility construction and operation.

SNiP II- 7-81* "Construction in seismic regions" edited in 1991 with additions of Russian version edited in 1996 which were realized since 15.08.1997 in Ukraine (the Order No. 134 of the Sate committee for urban planning in Ukraine dated on 06.08.1997) was valid up to February 01, 2007 in Ukraine. But SNiP II - 7-81* did not consider the specificity of complex engineering-geological conditions in Ukraine. Actually it was not reviewed since 1981.

The new state construction norms DBN B. 1.1-12:2006 "Construction in seismic regions of Ukraine" approved for use since 01.02.2007 by the Order No. 282 of the Ministry of regional development, construction and housing of Ukraine dated on 23.08.2006 were developed to improve the normative requirements to insure the objects earthquake resistance. The document was developed by leading scientific organizations of Ukraine and the CIS countries (Russia, Azerbaijan, Armenia, Georgia, Kazakhstan, Moldova and Uzbekistan). In DBN the new maps of general seismic zoning in Ukraine (OCP-2004) developed by the Institute of Geophysics of NASU were adopted.

Fig. 2 shows one of such maps (map "A") developed for design and construction of residential, industrial buildings, various residential objects in urban and rural areas. It corresponds to a 10% probability of calculated seismic intensity exceeding for 50 years and average intensity repetition periods of once in 500 years [4].

Different structural scheme are used depending on the type of the main buildings load-bearing structures at construction in seismic regions.

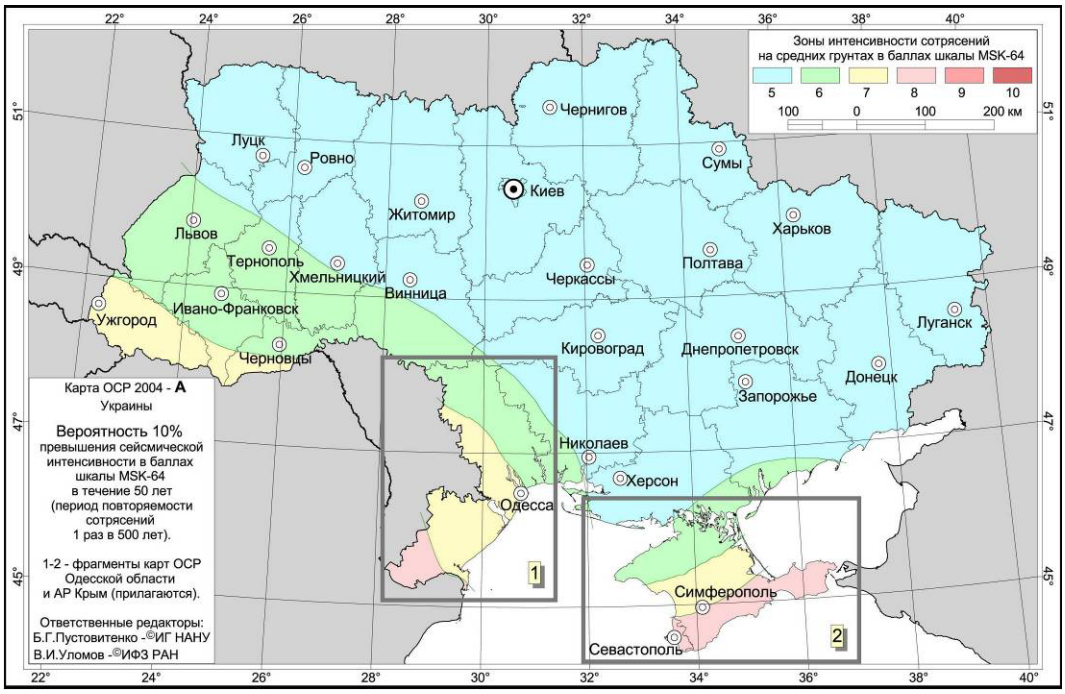

Figure 2. A map of seismic zoning in Ukraine (OCP-2004-A)

The buildings of different structural systems behave differently at earthquakes. Trends in the development of construction in seismic regions greatly depend on the state of the construction industry base and production of structures and materials [4, 5]. The priority directions should be based on solutions of actual issues on production of materials in Ukraine including the construction of new production facilities and modernization of the existing enterprises.

Most of the local industrial enterprises of building structures produce the hollow small sized wall elements which are not developed for construction in seismic regions. The multi-slit stones are widely used. They have 20 % of voids which influence the load-bearing capacity of structures at earthquake loads. The multi-slit stones are manufactured by the equipment using the vibrocompression technology. The fine sandy concrete B5 – B7,5 with stone volumetric weight of 1000 kg/m^3 is used.

The problem of "affordable housing" is very actual now, especially when considering its cost. The last fact determined the necessity to make an attempt to restore the construction of large-panel buildings taking into account the previous domestic experience. The management of the construction company "Consol LTD" decided to use a large-panel company building "Mittatyö" (Finland) as a basis. In order to manufacture the residential building components the Sevastopol concrete products plant was reequipped and new equipment was bought in Finland (Fig. 3). At development of building design the current requirements of Ukrainian national norms were taken into account. The following structures were determined [7]:

- external three-layer wall panels with bearing inner layer;
- internal single-layer panels;
- precast monolithic flooring of hollowcore extrusion-type slabs.

Figure 3. Automated line for production of reinforced concrete extrusion-type slabs by Finish technology at Sevastopol "CONSOL LTD"

In the process of adaptation of Finish residential building design to Ukrainian national normative base it was necessary to solve a lot of problems on inadequacy of Finish norms to current norms. They belonged to space-planning and design solutions. In Fig. 4 there are facade of the 9-storied residential buildings in Simferopol and process of building fragment full-scale testing for horizontal loads realized at NIISK.

At scientific and technical support realized within the framework of consortium between NIISK, KrymNIIproekt and "Consol LTD" the technological line for production of panels was prepared, separate slabs were tested for strength, construction solutions were developed, the work of slab connection with load-bearing walls was modelled and separate components and full-scale building fragment load-bearing capacity was checked at earthquake load.

The results of the researches recommend the constructive solution on construction of buildings of up to 9 stories in seismic regions of 7 – 8 points.

The connection of the structural elements is the most important for construction of large-panel buildings in seismic regions. The connections between panels of the external walls are influenced by efforts appeared at co-operation of structures at static and dynamic loads and atmosphere (temperature, atmospheric precipitations, wind). At different stages on development of large-panel buildings construction the connection structures were improved very much.

The specific feature of this design is the use of large-hollow stressed slabs for flooring with further installation of reinforced concrete footing, thickness of which is 80 mm. Due to "concrete footing" the necessary shear stiffness is created in despite of slightly rippled lateral slab surface. Design of large-panel buildings using precast beam type flooring of prestressed slabs with circular voids were not used in mass construction in the USSR. The absence of dowels on their lateral surface is also a new solution which requires the new constructive solutions. That is why, it is not enough only to rely on theoretical studies and constructive activities. It is necessary to realize the experimental verification of new solutions which were approved at development of design.

a)

b)

c)

d)

Figure 4. Facade and section of the 9-storied large-panel building in Simferopol:
a – facade of the building; b, c - building fragment testing at NIISK; d - hinged joint

CONCLUSIONS AND PROPOSALS

1. Deterioration of the main housing stock results in an increase of seismic risk in seismically hazardous areas and in areas which were non-seismic previously.

2. Increase in number of the stories, non-usage of symmetrical forms of structures placement in plan, complexity of technology and increase of technogenic areas load are responsible for increasing the probability of seismic disasters. It is necessary to realize a set of measures to bring the objects earthquake resistance up to the level of normative requirements.

3. New Ukrainian norms DBN B.1.1-12:2006 “Construction in seismic regions of Ukraine” are in need of improvement and more careful study of issues on safety at design and construction of buildings in seismic regions.

4. Development of experimental base should include the preparation of new means for experimental verification of structures earthquake resistance (seismic platform, vibration machine for full-scale tests, stations to record the earthquakes, vibrodiagnostic equipment and etc.).

REFERENCES

1. Osipov V. I. – The natural disasters at the turn of the XI century. Bulletin of the Russian Academy of Sciences, volume 71, No. 4, p. 291 – 302. – The institute of geoecology of RAS. *http://vivovoco.rsl.ru/VV/JOURNAL/VRAN/CATA/CATA.HTM*
2. Pustovitenko B. G., Kulchitskiy V. E., Pustovitenko A. A. New data on earthquake hazard in Odessa and Odessa region / Department of seismology, the S. I. Subbotin institute of geophysics of NASU, Simferopol, Ukraine. - 11 p. *http://www.elisavet.kr.ua/seism/seism04-02_r.html*
3. Nemchinov Yu. I. Buildings and facilities earthquakes resistance. In two parts. - Kiev, 2008. – 480 p.
4. DBN B.1.1 – 12:2006. Construction in seismic regions of Ukraine. The official version. – The Ministry of regional development, construction and housing of Ukraine, 2006. – 82 p.
5. Korchinskiy I. L., Polyakov S. V., Bykhovskiy V. A., Duzinkevich S. Yu., Pavlyk V. S. The basis of buildings design in seismic regions. The guidebook for engineers. – M.: Gosstroyizdat, 1961. – 488 p.
6. Polyakov S. V. Seismic resistant buildings structures. (The basis of earthquake resistance theory). Edition 2, added and revised. – M.: High school, 1983. – 306 p.
7. Ilyashenko N. A., Biletnikov A. M., Mironchenko E. P., Kuzmenko, A. D., Kukunaev V. S. – Construction of modern large-panel buildings in the Crimea. – In “Building structures”, edition 69, Interdepartmental scientific-technical collection. “Construction in seismic regions of Ukraine”. – Kyiv, NDIBK, p. 529 – 537.