SEISMICITY AND SEISMIC HAZARD MODELING FOR BULGARIA

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Seismicity in Bulgaria and surroundings

Space and magnitude distribution on the territory of Bulgaria
- Strong earthquakes around large cities Sofia, Plovdiv, Blagoevgrad, Varna, Veliko Tarnovo

Some of the Europe’s strongest earthquakes in 20-th century occurred on the territory of Bulgaria
- 1901, Mw=7.1, (Ms=7.2) near the city of Varna
- 1904, two earthquakes Mw=6.8 and 7.2-7.6 (Ms=7.0, 7.8) near the city of Blagoevgrad
- 1913, Mw=6.7 (Ms=7.0) near the city of Veliko Tarnovo
- 1928, two earthquakes near the city of Plovdiv Mw=6.5 and 7.0 (Ms=6.8,7.0)

Strong earthquakes close to the city of Sofia
1450, Mw=6.0; 1818, Mw=6.0; 1958, Mw=6.5; 1917, Mw=5.7, 2012, Mw=5.6
Earthquakes with significant impact on the territory of Bulgaria previous century

Vrancea intermediate earthquakes – 1940, Mw=7.7; 1977, Mw=7.4-7.5; 1986, Mw=7.2; 1990, Mw=6.9

Shallow earthquakes
1931, Mw=7.1 - FYROM
Bulgarian seismological network-NOTSSI
(National Operative Telemetric System for Seismological Information)

The real time network NOTSSI was put in operation at the end of 1980. In 2005, overall modernization of the NOTSSI was performed. Digital data from all stations are transmitted in real time to the National Data Center installed in the National Institute of Geophysics Geodesy and Geography (NIGGG). Real-time data transfer was realized via Virtual Private Network (VPN) of the Bulgarian Telecommunication Company (BTC).

Real time data are received from stations in neighbor countries – Romania, Serbia, FYROM, Greece and Turkey.
NOTSSI is the only organization in Bulgaria in charge of acquisition of seismological information and is the national information centre of **rapid earthquake information** and seismic hazard mitigation. In the case of a felt earthquake on the territory of Bulgaria, the information is transmitted to the Council of Ministers, the Governmental Commission of Disasters, National Fire Safety and Protection of Population Service (Ministry of interior) and other interested organizations, including mass media and general public. In close relationship with the National Fire Safety and Protection of Population Service and other governmental institutions, NOTSSI and the National Institute of Geophysics Geodesy and Geography is responsible for earthquake disaster mitigation.

The major tasks of the Bulgarian Seismological Network are:

- To provide reliable recording and transfer of seismological data;
- **To ensure rapid notification of the governmental authorities, media and broad public in case of felt or damaging earthquakes on the territory of Bulgaria;**
- To provide a modern basis for seismological studies, including hazard assessment in Bulgaria.
As a key element of NPP seismic safety, a local network (LSN) of sensitive seismographs having a recording capability for micro-earthquakes have been installed around Kozloduy NPP and operated since 1997. Safety and security measures have in common the aim of protecting human life and health and the environment. LSN jointly with NOTSSI provide reliable registration of weak seismicity in the near (30 km) region of NPP site.

The results of about 20 years of operation of LSN “Kozloduy” are presented in the figure – earthquakes occurred in 150 km region surrounding Kozloduy NPP from 1997 through 2017.
The main strategy for risk reduction is based on the concepts that:
- seismic risk is expressed by expected losses (causalities, injures, destructions, etc) for a given time period due to seismic hazard;
- there is no risk, even in territories with high seismic hazard, without population, infrastructure, installations et.;
- the seismic risk could be reduced

The strategy for risk reduction includes the following activities:
- Seismic hazard maps generation;
- State regulations for all aspects connected with seismic hazard – seismic monitoring, seismic hazard evaluation, seismic risk evaluation, building codes, etc;
- Building in accordance with seismic hazard and building codes;
- Development of risk scenarios for large cities, recognition of hot points on the territory of the urban areas and additional activities if necessary;
- High preparedness for earthquake risk mitigation – prevention, training of population, planning of the emergency activities etc;
- Early warning system;
- Generation of near real-time shaking maps;
- Operative urban area planning;
- Effective insurance;
- Coordination among science, insurance, governmental and other administrative units.
Seismic hazard map generation (475 years return period)

The basic approach used for the creation of ground motion maps incorporate in GIS the source-geometry, earthquake occurrence model, the strength of the earthquake sources, and the appropriate attenuation relations.

The assessment of seismic hazard is the first link in the prevention chain and the first step in the evaluation of the seismic risk. The implementation of the seismic hazard into the policies for seismic risk reduction will allow focusing on the prevention of earthquakes.
Seismic hazard map implemented in the New National Building Code of Bulgaria
Estimated contribution of Vrancea intermediate earthquakes to the total hazard

- 80%
- 50%
The uncontrolled growth of mega cities in highly seismic areas around the world is often associated with the construction of seismically unsafe buildings and infrastructures, and undertaken with an insufficient knowledge of the regional seismicity peculiarities and seismic hazard. The generation of earthquake scenarios is the important stage in the prevention. Seismic scenarios are a basic input for developing detailed earthquake damage scenarios for the cities and can be used in earthquake-safe town and infrastructure planning. The generated intensity scenario maps can be used for developing risk scenario, for risk and engineering decisions, in infrastructure planning and insurance.

Seismic scenarios in terms of macroseismic intensities
Estimated damages in central part of Northern Bulgaria from shallow earthquake Mw=6.8 near the town of G. Orjahovitsa
An early warning system was developed in the frame of the DACEA (2010-2013) project (leading partner INFP Bucharest, Romania). The project was implemented in the framework of the Cross Border Cooperation Programme (2007-2013), co-financed by the European Union through the European Regional Development, the Bulgarian and Romanian Governments and the 5 project partners. The general objective of the cross-border system for Earthquake alerts is to prevent the natural disasters caused by events with significant impact on the cross-border area. The output of the system are: earthquake alarm and shake maps produced in INFP. The output shake maps are to be used by the emergency intervention units, local public authorities and for general public awareness.

On the territory of Bulgaria the seismic detection network involves 8 seismic stations (red) and 9 earthquake alert systems (black) spanned all over the North Bulgaria.
Time for reaction at different places on the territory of Romania and Bulgaria

Kozloduj NPP – about 40 seconds
What have to be done

- Organizing of a secondary seismological data center far from Sofia;
- Risk assessment and mapping of the seismic risk;
- Development of earthquake and risk scenarios for large cities (towns), recognition of hot points on the territory of the urban areas and additional activities if necessary;
- Improving preparedness for earthquake risk mitigation – prevention, training of population, planning of the emergency activities etc;
- Improvement of communication after an earthquake between the Monitoring Institutions, Authorities (governmental and local), Media, Emergency Units;
- Improving coordination among science, insurance, governmental and other administrative units.