28 May 2010, 2:00 pm - 3:30 pm

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Fifth International Conference on
Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics
and Symposium in Honor of Professor I.M. Idriss
May 24-29, 2010 • San Diego, California

GEOTECHNICAL PRECONDITIONS FOR SKYSCRAPERS CONSTRUCTION IN BULGARIA AND SEISMIC RISK ASPECT

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ABSTRACT

Parallel to the economic development of Bulgaria in the last nine – ten years there is a rapid raise in construction as well. This increase has been a good precondition for invest in some very high buildings with application of the newest technological achievements. These buildings are situated in the centrums of the largest Bulgarian cities: Sofia, Plovdiv, Varna and Bourgas.

The Paper describes the geotechnical preconditions for construction of this type of buildings from seismic risk aspect. These preconditions are divided in four groups: geological, urban, technological and economical. The paper renders an account of the preconditions which are very different in the four cities. Varna and Bourgas have more or less similar conditions because they are situated on the Black Sea coast. The seismic risk for these two cities is relatively smaller. However, the wind pressure from the sea is strong. The geologist profiles of the quaternary period under Sofia are very variegated and the rock basement is to 400m of the depth. Plovdiv is a typical example for the risk of sand liquefaction combined with hay degree of seismic risk. Specific soils around Bourgas are peat and silt clay.

Analyzed are the possibilities for application of combined raft – pile foundation, and are chosen and presented different technologies for deep excavation's protection with respect to the geological conditions and the seismic risk.

Urban and economical peculiarities of these ancient Bulgarian cities present difficult problems contradictions the aspiration for skyscraper construction.

A GENERAL VIEW OF THE SEISMOLOGICAL SITUATION ON BULGARIAN TERRITORY

The whole territory of Bulgaria and Balkans is periodically impacted by earthquakes from local or neighboring seismic zones**.** This territory is a part of the Aegean, a well-known high degree seismically region. The earthquakes here have a shallow, crust's genesis with the exclusion of the earthquakes of Vrancea's seismic zone (Romania), where the hypocenters of the seismical events are deeper.

The oldest written information about earthquakes in Bulgaria dated from XV century. However, Roman chronicles describe an earthquake during the I century a.c. on the northern Black Sea coast, near Kaliacra Cape. It is the place where an earthquake occurred with magnitude M=7,2 in 1901.

The information about earthquakes before 1892 is not reliable enough because it is based on memories, newspapers, and chronicles. The precision of epicenter determination increased after the installment of the first seismograph in Sofia (1905). The precision increased to 0,10 ÷ 0,20. A new National seismological network was completed after 1977. Now the newest high technology National seismologic network is online from 2006. The precision of epicenter determination has increasing additional. The magnitude of the registered events fall down to M=1.0 [Solakov D., S. Simeonova, 2007].

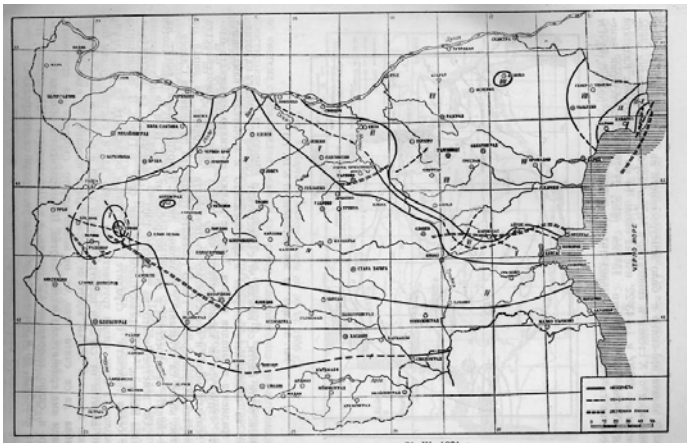

Fig. 1 Isoseismic map of the earthquake from 31.03.1901 г. with magnitude M= 7.2 (Grigorova, Grigorov, 1964) [Shanov S., 2006]

The most considerable earthquakes in Bulgaria (with magnitude more them 7,0) are registered during the first half of the last century. These occurred in four different and most dangerous seismic zones (Fig. 1).

The strongest registered shallow earthquake in Europe during the XX-th century occured in South-West Bulgaria near the villages of Kroupnik and Kresna with magnitude M= 7,8 in 1904 (Fig.2). This earthquake was felt all the way to Budapest [Solakov D., S. Simeonova, 2007], [Dobrev N., 2005].

During the 1913 an earthquake with magnitude M=7,0 had an epicenter in the third important seismic zone, the one near Gorna Oryahovitza (a town in North Bulgaria) (Fig.3, Fig. 4).

Fig. 2. Picture of the fault where the main shearing of the earth crust during the earthquake at 4-th April 1904 near Kroupnik village [Shanov S., 2006]

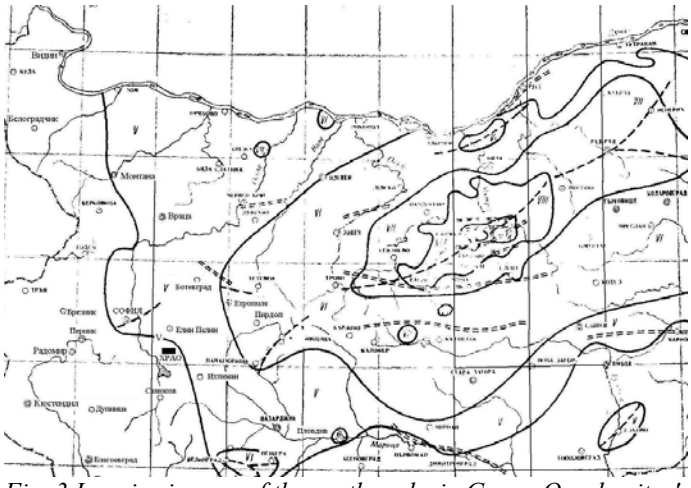

Fig. 3 Isoseismic map of the earthquake in Gorna Oryahovitza's zone at 14.07.1913 г. (Grigorova, Grigorov, 1964) [Shanov S., 2006].

There was a consecution of three disruptive earthquakes along the Maritza river valley (South Bulgaria) in the city of Plovdiv, the town of Chirpan and the town of Parvomay with magnitude up to M=7 in the year 1928.

Fig. 4. Destructed church tower in Mirovo village (Gorna Oryahovitza's zone) during the earthquake with magnitude M=5.1 (February 1986) [Shanov S., 2006]

Bulgarian territory was strongly influenced by the big earthquake in Vrancea mountain (Romania) in 1977.This earthquake had a magnitude M=7, 2 and a depth of the focus more than 60km [Solakov D., S. Simeonova, 2007].

MAIN FEATURES OF THE GEOTECHNICAL AND SEISMIC CONDITIONS UNDER THE BIGGEST BULGARIAN CITIES

In the biggest Bulgarian cities: Sofia, Plovdiv, Varna, and Bourgas were undertaken several prestigious projects for very high buildings during the last three, four years. These buildings are planned to be 140 m high or more. Therefore it was necessary to estimate thoroughly the geotechnical and seismic conditions of the project sites.

Fig.5. Scheme of the faults after the earthquake near Plovdiv City, Chirpan Town and Popovitza village (1928) (Radulov et al., 2004) [1].

The main special features which are connected with the general geological and seismic characteristics of the respective regions are as following:

Sofia

The Sofia's kettle is formed after a vertical sinking of the earth crust later filled up by sediments during the Neogene's period. During the first stage of the sedimentation the rivers have banked up layers of clay and sand. The thickness of these is up to 400m.

7 millions years ago new movements of the earth crust started. New shearing of the earth crust occurred accompanied by rising of the mountains around. A lot of marshlands formed on the field. The longest second stage of sedimentation began. Horizontal layers of marsh clay precipitated on the sediments of gravel, sand and sandy clay. At the end of this period in the North/West part of the kettle conditions were favorable for lignite formation from the marsh peat. The total thickness of the second stage sediments is 48-132 m.

The continuous sinking of the earth crust led to the formation of a large and deep freshwater lake. The lake was filled by river sand and sandy clays. The total thickness of the sediments reached to 100-400 m.

During the third stage of the sedimentation 5 millions years ago there appeared intensive movements of the earth crust. In this way step by step the present-day kettle of Sofia was formed. Deposits from rivers and slopes settled down. Some of these faults are active today too and the high seismicity of the region is another evidence for this. [www.sofia.bg/history].

The shallow underground water is also a problem. It causes difficulty to construction and it amplifies oscillation of the earth layer above during seismic activity.

The maximum prognosticate magnitude (M) for earthquake in the zone of Sofia is up to 7. From seismic point of view Sofia is among the most dangerous places in Bulgaria.

A historic survey shows that many earthquakes in the past had destructive effect on Sofia. There are historic documents of seismic activity in this zone from XV to XVII century. These dates are not precise enough and they can indicate the place and the intensity of an earthquake only approximately. The most intensive earthquakes in the zone of Sofia are estimated up to magnitude of 6,5 [Solakov D., S. Simeonova, 2007].

According to seismic investigations and studies considerable destructions and damage should be expected as a result of local focuses i.e. over situated in the area itself.

The urban planning of Sofia began at the end of the XIX century and its central zone is not large enough for modern communications, transport and new high buildings construction. New constructions have to take into consideration not only geology and seismic specifics but also preservation and restoration of the culture layers of the ground. The oldest of these date back to the time of the Roman Empire.

According to the remarks above the best possible modern method of foundation for very high buildings is Deep foundation – piles or Combined Pile – Raft foundation. In fact the projects envisage these methods. The excavations for this type of buildings have to have three or four underground levels and these supported by impermeable walls. When the walls are not temporary supporting structure, the anchors are not suitable support because they are flexible under stress. Steel frames are more recommended for supporting.

Plovdiv

The city of Plovdiv is situated on the two banks of the Maritza River on a large flat sandy terrace. Maritza is the longer Bulgarian river of the Aegean's basin and it follows a large fault on West-East direction [5 Kogouharov D. et al., 2005]. This is one of the most active seismic regions on Bulgarian territory. It is both activated by local focuses and the Aegeya's earthquake zone. During the earthquake in 1928, mentioned above, sandy soil liquefaction and "sandy fountains" had been seen on many places. These alluvial sands are fine, equal grainy and water saturated.

The geological profile is a typical for Plovdiv area: Quaternary alluvial settlements of average-size and fine sand, 6m to 10m thick, covered by young clay 4,00 ÷ 4,50m thickness. There are gravel and coarse sand at the bottom of the Quaternary layers. The cover clay layer does not have high density and is similar to slight soils ($M = 4 \div 5$ MPa; $\varphi = 18°$, $c = 15$ kPa).

The ground water level is dynamic, related to season and to Maritza River level. Variations of the level are between -3,50 and -4,50m. The sewage canals under the streets limit the ground water level.

The danger of sand liquefaction is the main danger for modern high buildings here. Piles foundation is successfully applied up to now. If a new building is situated fare from the river it may be founded on rock under the sands, and raft foundations will be possible guarded by deep enclosure wall (12m÷15m). So fare when a structure in Plovdiv has Pile Foundation, underground floors is eliminated because they are estimated like ineffective.

The urban plan of Plovdiv presents possibilities for considerable places for high buildings on the two boards of the river. The old Center has historic layers from Philip of Macedonian's epoch to the Bulgarian Renaissance. It is situated on four rock hills and around these.

Varna

Varna City is situated on the coast of large bay in the North part of Bulgarian Black Sea littoral. The soil is of thick layers of clay which filter and reduces the amplification of seismic waves from the nearest focus in front of Kaliacra Cape to the North-East, mentioned above [Kogouharov D. et al., 2005]. The main problems until now have been from slope stability and abrasion of the seacoast clay.

Load capacity of the soil clay under intensive vertical loads and significant seismic activity can be insured by Deep Foundations only (predominantly – piles).

Bourgas

Bourgas is the second largest City on the Bulgarian Black Sea coast, situated near the largest bay to the South of city of Varna.

The soil of the low places near the Sea and around the City is slight: peat, silt clay, fine sand. There are three large lakes to the North and to the South of Bourgas. The banks of the lakes are presented by settlements of peat and silt thickness up to 40m (Fig.6). These settlements possess very low values of the physical and mechanical characteristics: $\rho_d = 1 \div 1{,}1$ g/cm^3; M = 0,6 ÷ 3,0 MPa; $\varphi = 3° \div 8°$; c = 5 ÷ 10 kPa; e = 1,55 ÷ 1,65; S_r = 0,95 ÷ 1,0 [Brouchev I. et al. 1994].

The danger of liquefaction of sands is present on the costal zones of both Bourgas and Varna.
Founding by raft on the higher levels of the coast is possible. The soil there is strong enough for high buildings. The seismic effect is reduced in Bourgas region. Here is the most suitable place for construction of high buildings compared with the other three Cities. Very important special feature is the high speed of the wind near the Sea which is none the less a heavy temporary load.

www.sofia.bg/history

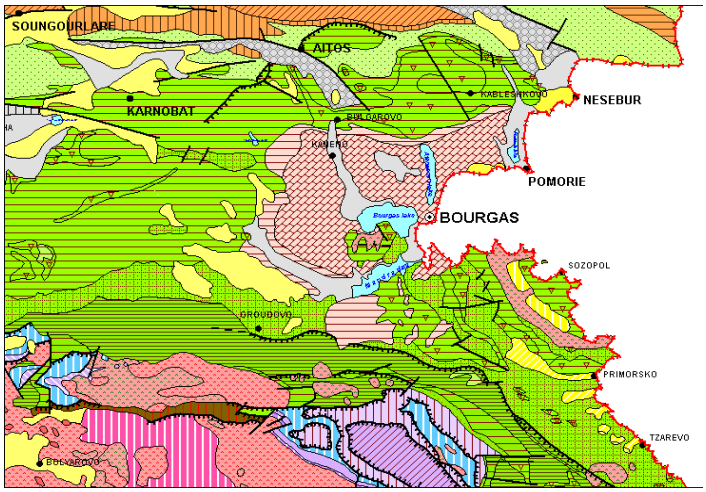

Fig.6 Fragment of 1:500000 map in real scale [Trendrafilov V., N. Markov, 1989]

CONCLUSIONS

- From seismic and geotechnical point of view Bourgas (excluding the low See coast) is a suitable place for construction of very high buildings compared with the other Bulgarian Cities mentioned above;
- The most difficult conditions from seismic and geotechnical point of view for skyscraper construction are in the town of Plovdiv;
- Sofia and Varna have soil for construction of skyscrapers of limited high with deep foundation;
- There are restriction in Sofia Centrum evolving from urbanity and deep cultural layers;
- The strong wind from the See is additional load factor in Bourgas and Varna which has to be taken into account in the analysis.

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