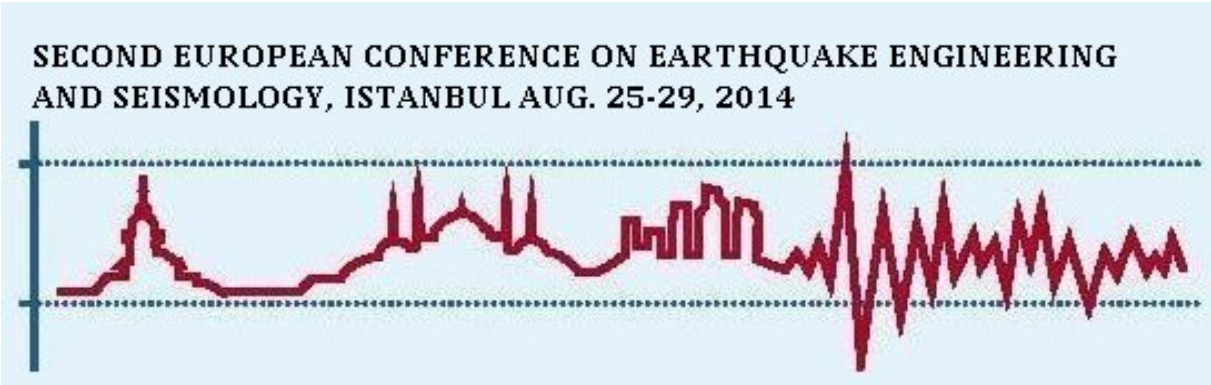

SEISMIC MICROZONATION: CASE STUDY ULPIJANA SETTLEMENT IN PRISHTINA - KOSOVO

Dragi DOJCINOVSKI[1], Tatjana OLUMCEVA[2] and Shemsi MUSTAFA[3]

1. INTRODUCTION

In the last decades, strong earthquakes have caused massive loss of lives and extensive physical destruction throughout the world (Mexico City 1985, Armenia, 1988; Iran, 1990; US, 1994; Japan, 1995; Turkey, 1999; Taiwan, 1999, India 2001, Sumatra 2004, Pakistan, 2005).

The earthquake damage basically depends on three groups of factors: earthquake source and path characteristics, local geological and geotechnical site conditions, structural design and construction features.

Microzonation has generally been recognized as the most effective tool in seismic hazard assessment and risk evaluation and it is defined as the zonation with respect to ground motion characteristics taking into account source and site conditions. Improving the conventional macrozonation maps and regional hazard maps, microzonation of a region generates detailed maps that predict the seismic hazard at much smaller scales.

Seismic microzonation can be considered as a methodology for estimating the response of soil layers under earthquake excitations and the relative variation of earthquake ground motion characteristics on the ground surface for a specific area. The purpose of microzonation is to provide input for urban planning and assessment of the vulnerability of the building stock for different hazard (performance) levels.

Seismic microzonation is addressed in four parts: In the first part, estimation of seismic hazard is made using seismotectonic and geological information. The second part deals with site characterization using geotechnical and shallow geophysical techniques. In the third part, local site effects are assessed by carrying out one-dimensional (1-D) ground response analysis (using the SHAKE 2000 software) using borehole data and shear wave velocity profiles within the area of Ulpijana settlement. Further, field experiments using microtremor studies were also carried out for evaluation of predominant frequency of the soil profiles. The same was assessed by 1-D ground response analysis and compared with microtremor results. The final part is integration of all the hazard parameters and developing final hazard map for the area as well as recommendation for appropriate land use and urban planning of the Ulpijana settlement.

Site specific earthquake characteristics on the ground surface are the essential components for microzonation with respect to ground shaking intensity, used for the assessment of the seismic vulnerability of the urban environment like Ulpijana settlement.

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Earthquake damage basically depends on three groups of factors: earthquake source and path characteristics, local geological and geotechnical site conditions, structural design and construction features. Seismic microzonation should address the assessment of the first two groups of factors. In general terms, seismic microzonation is the process of estimating the response of soil layers to earthquake excitations and thus the variation of earthquake characteristics is represented on the ground surface. Seismic microzonation is the initial phase of earthquake risk mitigation and requires multidisciplinary approach with major contributions from geology, seismology and geotechnical engineering.

2. CASE STUDY ULPIJANA

Prishtina is a fast growing city with a population of over 350.000 and is the most important political, economic and cultural centre of Kosovo. The Ulpijana settlement was developed in the early 80's of the 20th century, in then outskirts of Prishtina. The mainly residential settlement is planned and developed on approximatelly 40ha area according to the practice of urban planning and development of bigger cities in ex-Yugoslavia. Settlement is characterized with buildings that have various structural types and different heights (4 to 13 stories), green belts and satisfying street network.

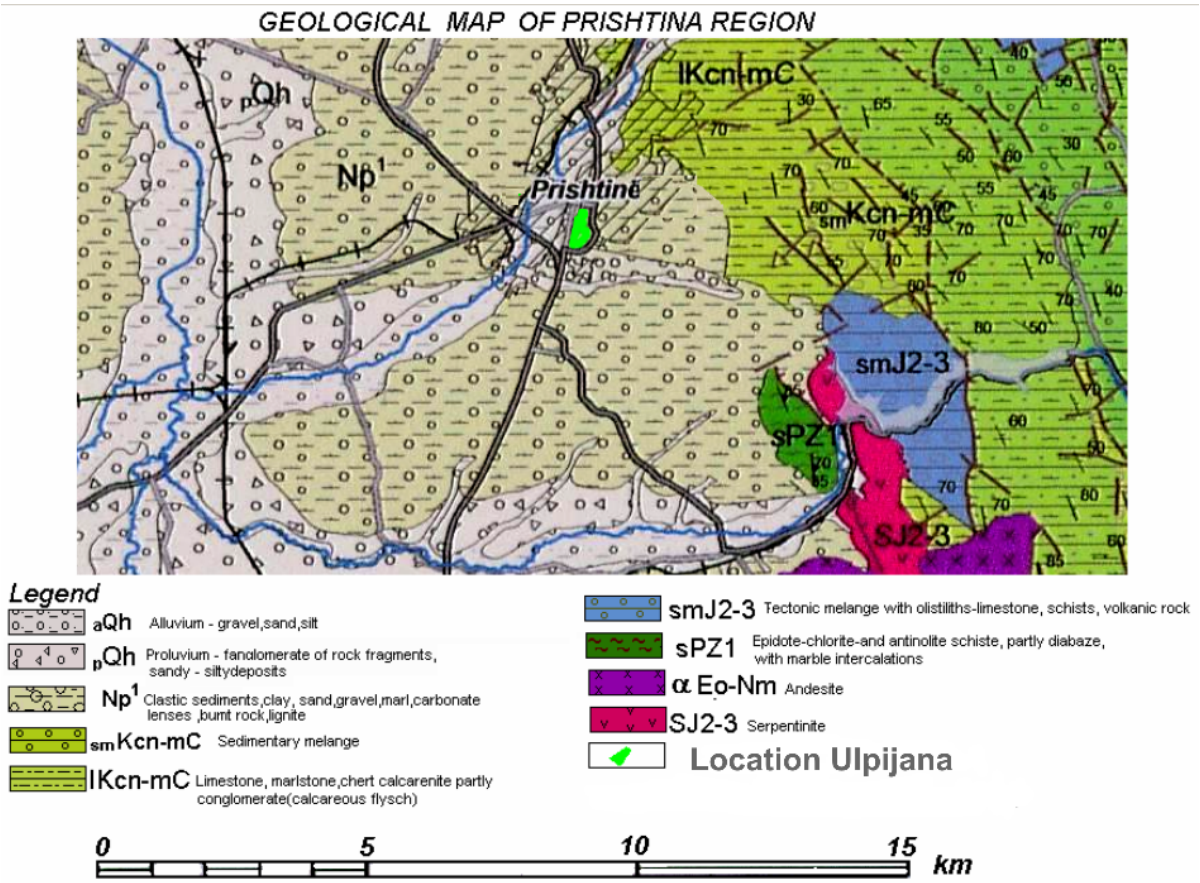

Figure 1 Location of the Settlement Ulpijana – Prishtina

The Ulpijana settlement is situated (Fig 1) on the border between Kosovo basin depression and the Vardar zone that is a part of the inner Dinarides. The block on which the settlement Ulpijana is located is characterized with small inclination of layers (5-10°) with NNW azimuth (towards the central part of the depresion). The surface is a slope with 4-6° inclination in Northwest and West direction and 3-5° inclination towards South. Slopes start from central and eastern part of the settlement, with the highest elevation of about 625m above see level. The underground water level at 2.5-7.0m depth is registered only in layers of sandy-gravel clays in all parts of the settlement.

Since the seismic effects of the regional seismogeological characteristics of the terrain are characterized by the constant characteristics of the wider area of Prishtina, the seismic microzoning has been done based on the seismic parameters that depend on the local seismogeological characteristics of the terrain as are:

- Site-specific geological and geotechnical characteristics (litho-stratigraphy, Vp, Vs, γ, ...);
- Predominant period of surface soil deposits (Ti); and,
- Influence of the local, site-specific, soil conditions upon the amplitude and frequency content of regional seismic motions.

The geological characteristics of the terrain at the location have been defined based on existing, geological investigations as well as on the basis of geophysical investigations done for the needs of seismic microzoning. According to the results from these investigations, the terrain of the settlement site is composed of Pliocene sediments represented by sand, clay and gravel, disintegrated and loosened at the surface down to the depth of 8 – 20 m. The Pliocene sediments of thickness ranging from 130 to 160 m, are under layered by Cretaceous flysch sediments.

The geotechnical characteristics of the terrain have been investigated within the geophysical surveys (Fig.2) and hence, there have been defined the parameters that have a dominant effect upon the amplitude-frequency variations of the seismic motion and the seismic effect of the expected earthquakes as are the geological and lithological content, the thickness of the layers H, the values of the seismic velocities Vp and Vs, the densities γ and the damping of materials of the geological layers.

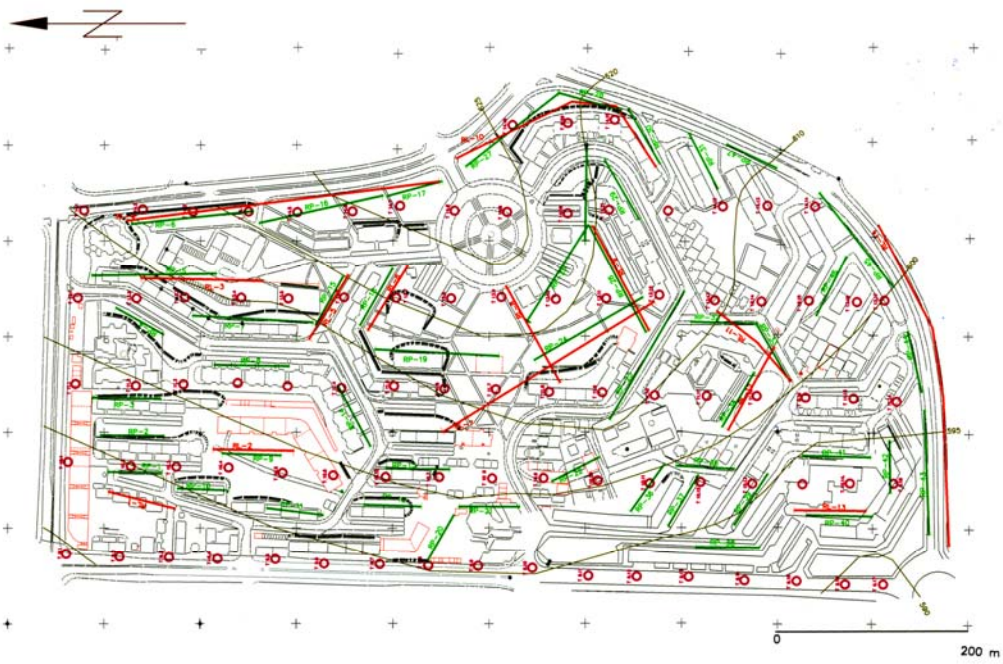

Figure2 Location of Geophysical investigations

These parameters have been used to define the surface layers with Vs < 750 m/s and pronounced amplification of seismic effect and the geological layers below them with Vs > 800 m/s that have been adopted as seismic bedrock on the terrain of the settlement location. For the needs of definition of the seismic parameters and seismic microzoning of the terrain, there have been defined corresponding geotechnical profiles and models, A sample of the defined geophysical profile for Ulpijana settlement is given in Fig 3.

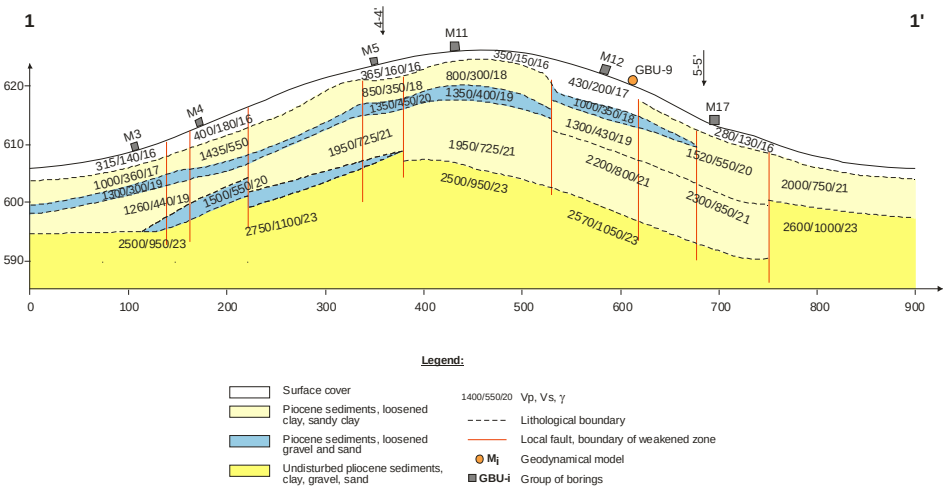

Figure 3 Ulpijana Geotechnical Profile 1-1

In the period 10 - 15 November 2009, microtremor (ground noise) measurements field studies were performed in the Ulpijana settlement, Prishtina, Kosovo. Measurements, using five TROMINO portable ultra mobile seismographs manufactured by MICROMED s.p.a. Italy, were performed in order to acquire reliable data for estimation of the influence of local soil conditions on the amplitude and frequency modification of theregional seismic motions and seismic microzonation of Ulpijana settlement site.

In total, 132 microtremor measurements were recorded. The 83 measurements with duration of 30 minutes were done at Ulpijana settlement site, whereas 50 measurements (control measurements), with duration of 10 minutes were done in front of the "NewBorn" Hotel, Prishtina. The control measurements were taken on a daily basis, at exactly the same location in front of the hotel, before the start and after the completion of the daily activities at the Ulpijana site in order to monitor the daily performances of the TROMINO seismometers.

The 83 measuring points were evenly distributed on five profiles in NS direction. The microtremor measurements at the Ulpijana site were performed in a regular grid with 50 x 50m cells. The cell dimensions were decided based on the expected variations of the local subsoil conditions at the Ulpijana site.

The microtremor measurements were aimed at defining the predominant periods of vibration of the surface deposits needed for modeling of the representative analytical geotechnical models for the site response analyses, microzonation in terms of predominant periods and cross-checking with results from geophysical investigations.

The predominant periods of microtremors on the terrain have been defined with the measurements of microtremors performed within the geophysical surveys. These investigations enabled definition of the geodynamic characteristics of the terrain that have an influence upon the amplitude frequency content of the earthquakes and their effect upon engineering structures. With these investigations, there have been defined two sets of predominant periods:

Predominant periods To = 0.50-0.52 s. that are conditioned by the total vibration of the Pliocene sediments down to the depth of 130 – 160 m. Due to the compactness of the Pliocene layers, these periods have little effect upon the amplification of earthquake ground motion, but they can cause amplification of seismic wave motion in higher engineering structures with similar natural periods. These periods are characteristic for the entire location of the settlement.

Predominant periods Tp = 0.08-0.20 s, which are conditioned by the vibration of the surface loose Pliocene layers down to the depth of 10 – 20 m below the terrain surface. These periods have greater effect upon the amplification of earthquake ground motion and the amplification of the seismic motion of the lower engineering structures with natural periods of 0.1 to 0.3 s. The values of these periods depend on the thickness and the level of disintegration of the surface Pliocene sediments and are different in individual parts of the location. Therefore, for these periods, a map of predominant periods of the terrain of the settlement site has been elaborated.

The effects of the local characteristics of the geotechnical media have been defined. by the values of the dynamic amplification factors (DAF) and amplitude-frequency variations obtained for selected accelerograms similar to expected earthquakes.

Based on the above described conditions and criteria for expected peak ground acceleration according to EC-8, regarding the seismic microzoning of the terrain – the geological and geotechnical characteristics, the predominant periods and effects of the local geotechnical media represented by the maximum mean accelerations and response spectra as well as on the basis of the morphological characteristics of the terrain, the following characteristic seismic zones have been defined in the urbanized area of the Ulpijana settlement.

According to the investigation results two seismic zones B1 and B2n were distinguished.

Zone B1, in which the terrain is composed of:

- Surface cover of Pliocene sediments composed of sand, clay, dust and gravel, degraded in the diluvial-alluvial cover of the terrain, with thickness of 2-6m, seismic velocities Vp=270-650m/s, Vs=120-180m/s and density γ=16-18 kN/m3,
- Surface loose Pliocene sediments composed of sand, clay, dust and gravel to the depth 8-12 m with Vp=800-1600m/s, Vs=300-650m/s and γ=18-21 kN/m3.

This zone is characterized by predominant periods of total vibration of Pliocene sediments of To=0.50-0.52 s and predominant periods of surface loose Pliocene layers of Tp=0.08-0.12 s. The local effects in this zone are characterized by values of (DAF)average=1.05-1.60 and (1.40) average and by increase of amplitudes of earthquake waves in the interval of periods of 0.08-0.12 s. No possibility of liquefaction. The maximum mean values of seismic accelerations of expected earthquakes in this zone amount to amax= 0.12 (g) for the design earthquake (10% probability of exceedance in 10 years = Ret. Per. 95 Years) and amax= 0.18(g) for the maximum earthquake (10% probability of exceedance in 50 years = Ret. Per. 475 Years).

Zone B2n, in which the terrain is composed of:

- Surface cover of Pliocene sediments composed of sand, clay, dust and gravel, degraded in the diluvial-alluvial cover of the terrain, with thickness of 2-7m, seismic velocity Vp=270-650m/s, Vs=120-180 m/s and density γ=16-18 kN/m3,
- Surface loose Pliocene sediments composed of sand, clay, dust and gravel to the depth 10-20 m with Vp=1000-1800m/s,Vs=350-700m/s and γ=19-21 kN/m3.

This zone is characterized by predominant periods of total vibration of Pliocene sediments of To=0.50-0.52 s and predominant periods of surface loosened Pliocene layers of Tp=0.10-0.20 s. The local effects of this zone are characterized by values of (DAF)average=1.35-2.00 and (1.60) average and by increase of seismic wave amplitudes in the period interval of 0.20-0.35 s. The maximum mean values of seismic accelerations of the expected earthquakes in this zone amount to amax= 0.14 (g) for the design earthquake (10% probability of exceedance in 10 years is equal to Ret. Per. 95 Years) and amax= 0.20(g) for the maximum earthquake (10% probability of exceedance in 50 years is equal to Ret. Per. 475 Years). Zone covers almost 70% of the Ulpijana settlement. According to the morphological and geotechnical characteristics of the terrain, there is a possibility of occurrence of dynamic instability (landslide) in the surface layers, down to the depth of about 7 m below the surface wherefore it can be defined as conditionally stable zone in which the stability of the structures should be defined by special investigations of their stability in dynamic conditions. The area is intersected with retainig walls in order to prevent soil instabilities.

Zone B2n should be regarded as conditionally stable since there is a possibility of occurrence of shallow landslides. All soil materials on the location of Ulpijana settlement are of type B according to EC 8 classification.

Seismic microzoning map based on the above obtained parameters on the geological, geophysical and microtremor characteristics as well as the effects of the local geotechnical media upon the earthquake effect, i.e., based on the seismic parameters, seismic microzoning map has been elaborated for the urbanized area of the settlement. Seismic microzonation of Ulpijana Settlement in Prishtina was performed on the basis obtained seismic design parameters for the investigated site.

The defined seismic design parameters can be used only in case of ordinary structures, but for design and construction of important structures (hospitals, schools, etc.) extensive investigations of the terrain are required.

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