Journal of the Georgian Geophysical Society, ISSN: 1512-1127
Physics of Solid Earth, Atmosphere, Ocean and Space Plasma, v.21(2), 2018, pp. 5 - 11

Evaluation of Seismic Hazard for Georgia and Seismic Risk for City Mtskheta with Modern Aproaches

Nino S. Tsereteli, Otar Sh . Varazanashvili, Zurab R. Gogoladze, Vakhtang G. Arabidze, Davit T. Svanadze, Manana P. Kupradze, Irine B. Khvedelidze

M. Nodia Institute of Geophysics of Iv. Javakhishvili Tbilisi State University

ABSTRACT

In this paper we are presented brief overview of the project "Evaluation of seismic hazard for Georgia and seismic risk for city Mtskheta with modern aproaches". Seismic hazard and risk assessment is very importance in Southern Caucasus (SC) and particularly in Georgia. The goal of society is to create urban environment that is protected from destructive earthquakes and minimize the expected losses. However, complete elimination of expected losses is unreal. One of the reasons for it is deficiency of knowledge about real seismic hazard and vulnerability of urban areas and infrastructure. In this regard, the general purpose of this project was to provide a reliable seismic hazard assessment at the national level and risk assessment for strategically important objects (cities, critical facility, lifelines, cultural heritage and others) of Georgia. In our case Historic city Mtskheta was chosen as strategic objects. Historic city Mtskheta is located in eastern Georgia, and is the administrative centre of the region of Mtskheta-Tianeti and Mtskheta Municipality. Mtskheta is a city museum and in 1994 was listed as a UNESCO World Heritage Site. Mtskheta is characterized by increasing urbanization, population density and infrastructure. Also taking into account the current reality of high vulnerability, the results of this project allowed us to evaluate recommendations for a new strategy of urban planning of the city, by proposing specific mitigation actions in district with high seismic risk, as well as adequate protection of infrastructures in case of earthquake.

Key words: seismic hazard, seismic risk, earthquake

Research goals

The one of main goal of the project includes a new assessment of the seismic hazard at the national level; evaluation of local seismic hazard for the city of Mtskheta; assessment of its seismic risk and analysis of mitigation action of the risk.

Seismic hazard analysis involves the quantitative estimation of ground shaking hazards at a particular area that are expressed in term of peak ground acceleration (PGA), spectral acceleration (SA) and macroseismic Intensity I. Seismic hazard analysis consists of four main steps: i. Definition of a reliable seismic earthquake catalogue extended back in time as much as possible; ii. development seismic sources model at national level; iii. selection of ground motion prediction attenuation models for the relevant ground shacking parameters; iv. Integrate (1)-(3) into probabilistic calculation of seismic hazard curves with uncertainties.

Seismic sources (SS) and methodology of probabilistic seismic hazard assessment of the region were developed in EMME project [1,2]. Catalogue were developed up to 2006 year for the region of Middle East [3]. Unification of catalogues towards of Mw and Ms were done according correlation equations proposed by Zare el al [3]. Following these work Catalogue of earthquakes were updated up to 2017 for Georgia and surrounding regions. In modern methods of seismic hazard assessment the use of active faoults as one of SS is recomended, which in turn requires accurate knowledge of the 3-dimensional geometry of the active faults and slip rates along them. Another type of SS is area seismic sources (ASS). In this work we have taken active foults sources from work [1] and developed new areas sources.

Each zone was defined with the parameters: the geometry, the magnitude-frequency relation parameters as slop of curve b_{GR} and seismic activity - a_{GR}, maximum magnitude Mmax, depth distribution and tectonic characteristics.

Due to the lack of records for strong earthquakes at short epicentral distances, four (global and regional) models of prediction equation were used [4,5,6,7]. On the basis of obtained seismic sources probabilistic seismic hazard maps were calculated in terms of peak ground acceleration (PGA) and spectral accelerations (SA) at 0.2, 1, 2, 4 sec for 10% probability and 2% probability in 50 years using attenuation relationships [4,5,6,7] correspondingly for Rock Vs_{30}=801m/sc using EZ-FRISK. Results are presented in Fig. 1,2.

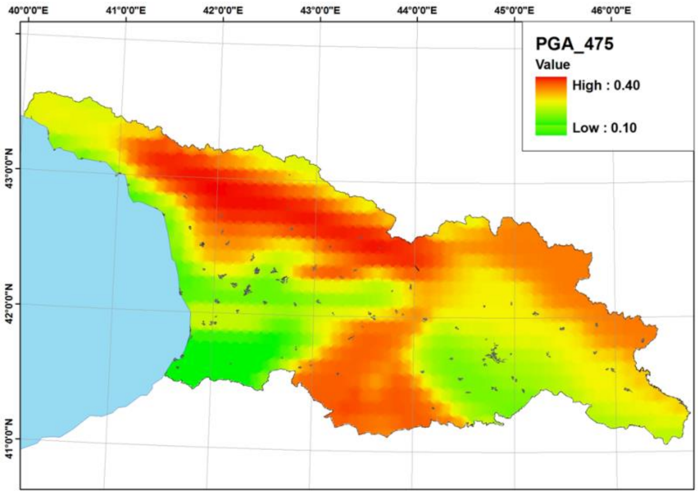

Fig. 1. Probabilistic seismic hazard maps for 10% probability in 50 years.

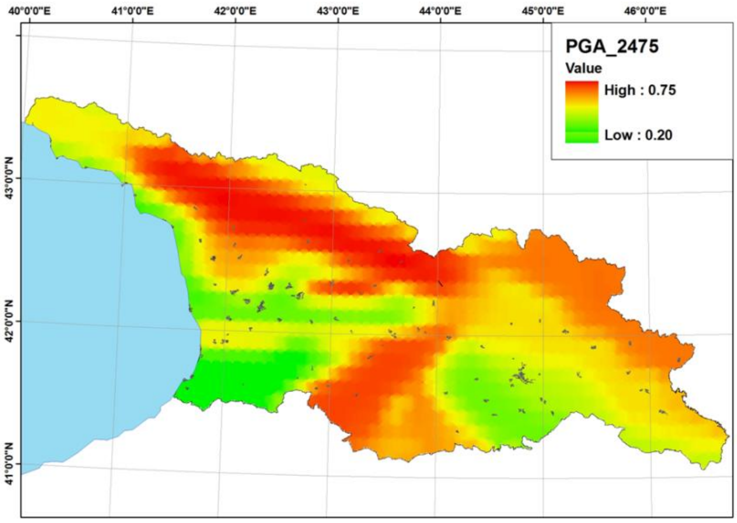

Fig. 2. Probabilistic seismic hazard maps for 2 % probability in 50 years

Estimated seismic hazard were used as input motion for local seismic hazard assessment for Mtskheta region.

Local seismic hazard assessment

In Mtskheta areas, for the local seismic hazard assessment first all information of previously available geological, geotechnical, geophysical data were collected. These information were provided by City Hall of Mtskheta.

New on-sight fieldworks investigations were done to define the subsoil model, based on local lithological-geotechnical units, their stratigraphic and geometric relationships, and their typical physical-mechanical parameters. The site investigation of Mtskheta was carried by geophysical measurements that performed MASW and noise measurements processed with HVSR technique. HVSR method is widely used for the site investigation studies in the last two decades [8,9]. However the horizontal and vertical (H/V) spectral ratio of natural seismic noise first proposed by Nogoshi and Igarashi [10,11]) and this technique revised by Nakamura [12]. The analysis of H/V allows us to estimate S-wave resonance frequency f_0 *(Hz)* of the sedimentary cover and it's thickness of overlying bedrock. As a relation between the thickness h and average S-wave velocity (Vs) of the sedimentary layer [13,14] by the equation :

$$f = \frac{Vs}{4h} \quad (1)$$

In order to evaluate S-wave velocity profile with depth we use Joint inversion of Raylegh wave dispersion curve and H/V curve. The inversion procedure was carried out by Montecarlo algorithm (MC), a multimodal Monte Carlo inversion based on a modified misfit function [15] that was proposed by Maraschini and Foti [16].

Figure 3 is presented investigating area. Red dots are were single station investigations were done and blue lines indicated place were MASW measurement were done.

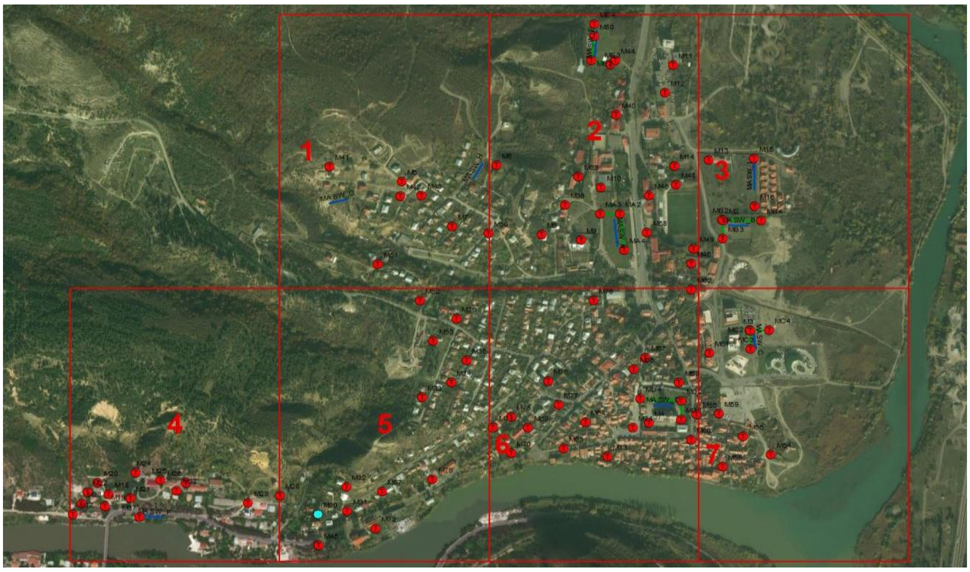

Fig. 3. Investigated areas of city Mtskheta for seisic microzonation

Finally investigated area were characterised by dominant frequency and V_{S30}.

Seismic Risk Assessment

For seismic risk assessment first inventory of residential building were created for city Mtskheta.

The inventories of the built environment (building and lifeline system) was studied and converted into a GIS system with the following categories:

- Base map: Buildings, streets (street name and building number), parks, green areas, rivers, lakes, sports stadia etc (Fig. 1);
- Buildings: Building material, number of storeys, number of entrances, condition of building, building period of Tbilisi buildings, photos of old Tbilisi buildings, populatin numbe;
- Initial cost of bulding;
- Electricity system: Electric power transmission lines, operating stations and centrals;
- Water aqueducts and supply system: water transmission system, sanitary sewer system, pumping stations, and reservoirs;
- Relief of Mtskheta: Digital Elevation Model (DEM);
- Aerial photos of Mtskheta.

Based on inventory map, vulnaranilty of building were estimated according to [17].

Finally seismic risk in terms of damage, economic losses in GEL were estimated for scenario earthquakes with intensity I=7,8,9 at MSK 64 scale.

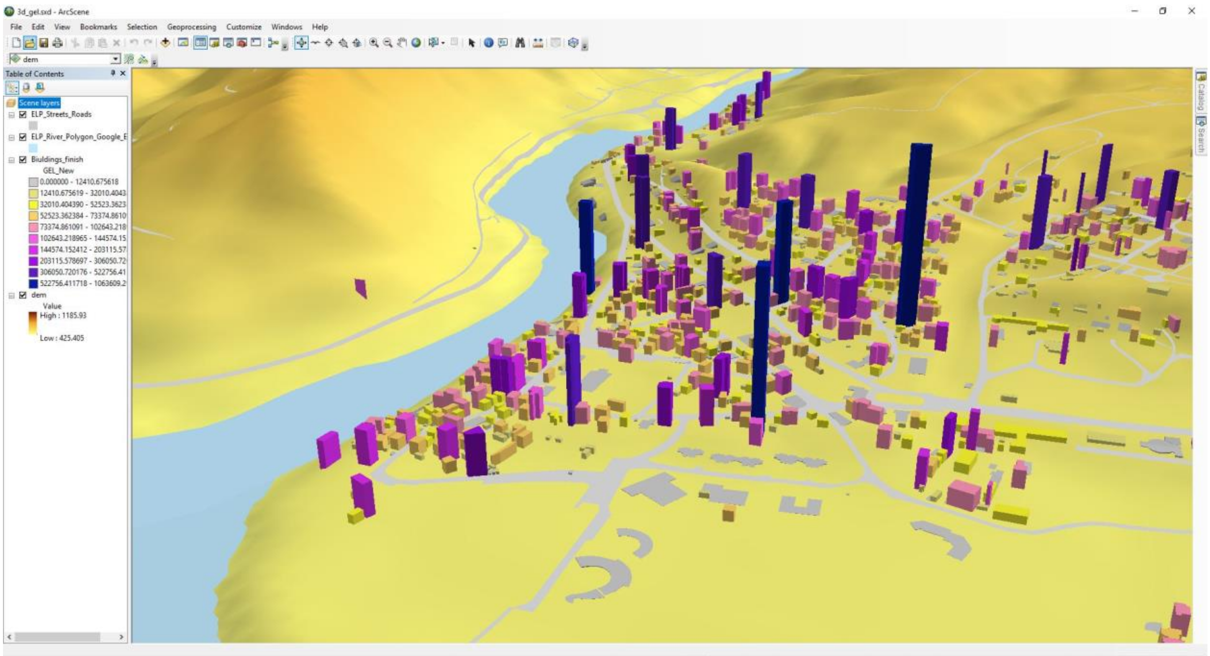

Fig. 4. Economic losses in GEL for Intensity I = 9 at MSK 64 scale

On bases of obtained investigation Map of the emergency limit condition was produced for the study area, underlining critical elements and priority order of intervention.

Acknowledgements: This work was supported by Shota Rustaveli National Science Foundation (SRNF) (Project 216758).

References:

[1] Danciu, L., Sesetyan, K., Demircioglu, M. B., Giardini, D., Erdik, M., Akkar, S., Gulen, L., Zare, M., Adamia, Sh., Ansari, A., Arakelyan, A., Askan, A., Avanesyan, M., Babayan, H., Chelidze, T., Durgaryan, R., Elias, A., Hamzehloo, H., Hessami, Kh., Kalafat, D., Kale, O., Karakhanyan, A., Khan, M. A., Mamadli, T., Al-Qaryouti, M., Sayab, M., Tsereteli, N.,Utkucu, M., Varazanashvili, O., Waseem, M., Yalcin, H., Yilmaz, M.T.The 2014 Earthquake Model of the Middle East: Seismogenic Sources. Bulletin of Earthquake Engineering. Volume 16, Issue 8, 1 August 2018, Pages 3465-3496.DOI: 10.1007/s10518-017-0096-8

[2] Sesetyan, K., Demircioglu, M., Gulen, L., Zare, M., Basili, R., Elias, A.,Adamia, Sh., Tsereteli, N., Yalcin, H., Utkucu, M., Asif Khan, M., Sayab, M., Hessami, Kh., Rovida, A. N., Stucchi, M., Burg, J. P., Karakhanian, A., Babayan, H. Avanesyan, M., Mammadli, T., Al-Qaryouti, M., Kalafat, D., Varazanashvili, O., Erdik, M., Giardini, D.The 2014 seismic hazard model of the Middle East: overview and results**.** Bulletin of Earthquake Engineering. Volume 16, Issue 8, 1 August 2018, Pages 3535-3566. DOI: 10.1007/s10518-018-0346-4
[3] Mehdi Zare , HamidehAmini, PouyeYazdi, Karin Sesetyan, Mine BetulDemircioglu, DoganKalafat, Mustafa Erdik, Domenico Giardini , M. Asif Khan , Nino Tsereteli. 2014. Recent developments of the Middle East catalog. Journal of Seismology. Volume 18, N4 , pp.749-772, July. DOI 10.1007/s10950-014-9444-1
[4] Cauzzi, C., Faccioli, E., Vanini, M., Bianchini, *A.* 2015a. Updated predictive equations for broadband (0.01–10 s) horizontal response spectra and peak ground motions, based on a global dataset of digital acceleration records. Bulletin of Earthquake Engineering 13 (6), 1587-1612.
[5] Campbell, K. W., and Bozorgnia, Y. 2014. NGA-West2 ground motion model for the average horizontal components of PGA, PGV, and 5%-damped linear acceleration response spectra. Earthquake Spectra, 30(3): 1087–1115, Aug 2014. doi: 10.1193/062913EQS
[6] Chiou, B. and Youngs *R. R.* 2014. Update of the Chiou and Youngs NGA Model for the Average Horizontal Component of Peak Ground Motion and Response Spectra. Earthquake Spectra: August 2014, Vol. 30, No. 3, pp. 1117-1153.
[7] Kotha, S.R., Bindi, D. and Cotton, F. 2016a. Magnitude and Region Dependent Correlation of Response Spectral Values for Site-specific Conditional Mean Spectra. Submitted to Bulletin of Earthquake Engineering 12.
[8] Bard, P.-Y.: Microtremor measurements: a tool for site effect estimation, in: The effects of surface geology on seismic motion, edite by: Irikura, K., Kudo, K., Okada, H., and Sasatani, T., Balkema, Rotterdam, 1251–1279, 1999.
[9] Bonnefoy-Claudet, S., Cotton, F., Bard, P.-Y., Cornou, C., Ohrnberger, M., and Wathelet, M.: Robustness of the H/V ratio peak frequency to estimate 1D resonance frequency, in: Proceedings of the 3rd International Symposium on the Effects of Surface Geology on Seismic Motion, 2006.
[10] Nogoshi, M. and Igarashi, T. (1970). On the propagation characteristics of microtremors. J. Seism. Soc. Japan 23, 264-280(in Japanese with English abstract).
[11] Nogoshi, M. and Igarashi, T. (1971). On the amplitude characteristics of microtremors. J. Seism. Soc. Japan. 24, 24-40(in Japanese with English abstract).
[12] Nakamura, Y. （1989）. A method for dynamic characteristics estimation of subsurface using microtremor on the ground surface. Quarterly Report Railway Tech. Res. Inst., 30:1, 25-30.
[13] Lachet C., Bard P.-Y. (1994). Numerical and Theoretical Investigations on the Possibilities and Limitations of Nakamura's Technique. J. Phys. Earth, 42, 377-397.
[14] Fäh, D., Rüttener, E., Noack, T. and P. Kruspan (1997). Microzonation of the City of Basel. Journal of Seismology, 1, 87-102.
[15] Maraschini M. Ernst F.E. Foti S. Socco L.V., 2010. A new misfit function for multimodal inversion of surface waves, *Geophysics*, 75 (4), G31–G43, doi:10.1190/1.3436539.
[16] Maraschini M. Foti S., 2010. A Monte Carlo multimodal inversion of surface waves, *Geophys. J. Int.*, 182(3) 1557–1556, oi: 10.1111/j.1365-246X.2010.04703.x.
[17] Nino Tsereteli, VakhtangArabidze, OtarVarazanashvili, TengizGugeshashvili, TeimurazMukhadze and Alexander Gvencadze. 2014. Vulnerability Analysis and GIS Based Seismic Risk Assessment Georgia Case. Improving Disaster Resilience and Mitigation - IT Means and Tools. ISBN:NATO Science for Peace and Security Series C: Environmental Security 143, pp.307-321. http://link.springer.com/chapter/10.1007/978-94-017-9136-6_20#page-1

სეისმური საშიშროების შეფასება საქართველოსთვის და სეისმური რისკის ქალაქ მცხეთისთვის თანამედროვე მიდგომებით

ნ. წერეთელი, ო. ვარაზანაშვილი, ზ. გოგოლაძე, ვ. არაბიძე, დ. სვანაძე, მ. კუპრაძე, ი. ხვედელიძე

რეზიუმე

სტატიაში მოკლედ არის წარმოდგენილი სამუშაოები, რომელიც ჩატარდა პროექტის - "სეისმური საშიშროების შეფასება საქართველოსთვის და სეისმური რისკის ქალაქ მცხეთისთვის თანამედროვე მიდგომებით" - ფარგლებში. სეისმური საშიშროებისა და რისკის შეფასება ძალიან მნიშვნელოვანია სამხრეთ კავკასიისთვის და განსაკუთრებით საქართველოსთვის. საზოგადოების მიზანია ისეთი ურბანული გარემოს შექმნა, რომელიც დაცული იქნება დამანგრეველი მიწისძვრებისაგან და შემცირებული იქნება მოსალოდნელი დანაკარგები. თუმცა, დანაკარგების სრული არიდება არარეალურია. ამის ერთ-ერთი მიზეზია ცოდნის დეფიციტი რეალური სეისმური საშიშროების, განაშენიანებისა და ინფრასტრუქტურის მოწყვლადობის შესახებ. ამასთან დაკავშირებით, მოცემული პროექტის ძირითადი მიზანი იყო სეისმური საშიშროების სანდო შეფასების უზრუნველყოფა ნაციონალურ დონეზე და რისკის შეფასება საქართველოს სტრატეგიულად მნიშვნელოვანი ობიექტებისათვის (ქალაქები, კრიტიკული ობიექტები, სასიცოცხლო მნიშვნელობის ხაზები, კულტურული მემკვიდრეობის ძეგლები და სხვა). ჩვენ შემთხვევაში მნიშვნელოვან ობიექტად არჩეული იქნა ქალაქი მცხეთა. ისტორიული ქალაქი მცხეთა მდებარეობს საქართველოს აღმოსავლეთ ნაწილში და წარმოადგენს მცხეთა-მთიანეთისა მცხეთის მუნიციპალიტეტის ადმინისტრაციულ ცენტრს. მცხეთა არის ქალაქი-მუზეუმი და 1994 წელს შეტანილ იქნა მსოფლიოს დანატოვარის UNESCO-ს სიაში. მცხეთისთვის დამახასიათებელია მზარდი ურბანიზაცია, მოსახლეობის სიმკვრივე და ინფრასტრუქტურა. გარდა ამისა თუ მხედველობაში მივიღებთ რეალურად არსებულ მაღალ მოწყვლადობას, ამ პროექტის შედეგებმა საშუალება მოგვცა შეგვემუშავებინა რეკომენდაციები ქალაქის ურბანული დაგეგმარების ახალ სტრატეგიასთან დაკავშირებით, შეგვეთავაზებინა კონკრეტული ზომები შედეგების შერბილებისათვის მაღალი სეისმური საშიშროების რაიონში, აგრეთვე ინფრასტრუქტურის დასაცავად მიწისძვრის შემთხვევაში.

Оценка сейсмической опасности для Грузии и сейсмического риска для города Мцхета с современными подходами

Н.С. Церетели, О.Ш. Варазанашвили, З.Р. Гоголадзе, В.Г. Арабидзе, Д.Т. Сванадзе, М.П. Купрадзе, И.Б. Хведелидзе

Резюме

В статье кратко представлены работы, проведенные в рамках проекта - «Оценка сейсмической опасности для Грузии и сейсмического риска для города Мцхета с современными подходами». Оценки сейсмической опасности и риска очень важны для Южного Кавказа и особенно для Грузии. Цель общества - создать такую городскую среду, которая будет защищена от разрушительных землетрясений и будут уменьшатся ожидаемые потери. Однако полное устранение потерь - нереально. Одна из причин этого является дефицит знаний о реальной сейсмической опасности, уязвимости застроики и инфраструктуры. В связи с этим основной целью этого проекта была обеспечить достоверную оценку сейсмической опасности на национальном уровне и оценку риска для стратегически важных объектов Грузии (города, критические объекты, жизненно важные линии, памятники культурного наследия и т.д.). В нашем случае в качестве важного объекта был выбран город Мцхета. Исторический город Мцхета расположен в восточной части Грузии и является административным центром Мцхета-Мтианети и Мцхета муниципалитета. Мцхета - город-музей, который в 1994 году был включен в список мирового наследия ЮНЕСКО. Мцхета характеризуется растущей урбанизацией, плотностью населения и инфраструктурой. Кроме того, если учесть реально существующую высокую уязвимость, результаты этого проекта позволили нам разработать рекомендации для новой стратегии городского планирования, предложить конкретные меры по смягчению последствии в районе высокой сейсмической опасности, также для защиты инфраструктуры в случае землетрясения.