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SEISMIC HAZARD ASSESSMENT OF HIGH SEISMIC RISK LOCATED SETLEMENTS

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Abstract: *The most seismic hazardous setlements in Bulgaria are under investigation in the area of Kresna-Krupnik seismic source. The expected Peak Ground Accelerations (PGA)are modeled as a measure for the seismic risk. The methodology is applied to the towns of Simitli and Kresna and the village Krupnik. It is proved that the main factors for the seismic risk are the distance to the fault and the soil ground conditions, mainly influenced by the geology layers and underground waters. The quantitative parameters are under investigation and comparative analysis.*

ОПРЕДЕЛЯНЕ НА СЕИЗМИЧНАТА ОПАСНОСТ ЗА СЕЛИЩА РАЗПОЛОЖЕНИ ВЪВ ВИСОКО РИСКОВИ ЗОНИ

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Ключови думи: *Сеизмична опасност, високорискови зони, количествени модели*

Резюме: *Разгледани са най-застрашените от сеизмична опасност селища в района на сеизмично огнище Кресна-Крупник. Моделирани са очакваните максимални ускорения, като мярка за сеизмичния риск. Методологията е приложена за селищата Симитли, Крупник и Кресна. Показано е че най-съществено влияние оказват разстоянията до сеизмичния източник и грунтовите условия доминирани от геоложкия строеж и състава на горележащите скали и подпочвените води. Анализирани са количествените показатели за различните селища.*

Introduction

The mapping of the natural hazards and environmental threats, vulnerability of structures and risk assessment and management are important issues to the prevention of population and the infrastructure [1, 2]. The assessment of the damages and losses is the most important task in case of huge catastrophes and frequently influenced the GDP of any country [3]. The most advanced techniques and technologies are extensively used for the research and assessment of the consequences of the natural and technological disasters such as space remote sensing, high effective communication systems, etc. [4, 5].

The seismic hazard and risk assessment in the recent times are exploited and implemented using different technologies, the most popular of which are models for simulation risk calculations and risk management [6]. The present study is focused to the seismic hazard assessment of the high seismic risk located settlements. The observations of the highest intensities, registration of PGA and PGV, and predictive models are so complicated and do not coincide with the observations so that the recent seismology is looking for more universal approach, especially to the near field areas of the activated faults. Several cases show surprising facts – for example Izmit (17th Aug. 1999, M7.6), Loma Prieta (17th Oct. 1989, M7), Kobe (17th Jan. 1995, M7), Tohoku (11th March, 2011, M9) and many other strong earthquakes show significant differences to the near field PGA and predicted model values.

Special attention is focused to the near field settlements to the active faults, because the nonlinear behavior of the attenuation is frequently observed [7]. In many cases the observed strong ground motions are far from the predicted values. Not only the ground conditions are influencing the strong motions, but also the direction of the energy emission, the activation of the fault segment especially in case of very strong seismic events during the event time history development, the activated depth fault plane, the soil conditions, the fault's parameters etc.

Considering the well-known history and available documentation our target cities and settlements for the seismic hazard modeling are the cities Simitli, Kresna and the village of Krupnik, all of them located at the near field of the Krupnik seismogenic fault. Krupnik itself lie on the fault segment generated the famous Kresna-Krupnik earthquake of 4th April 1904. In fact there were two very strong seismic events separated by a time interval of 20 minutes - M7.8 and M7.2 considered as a foreshock of the main event.

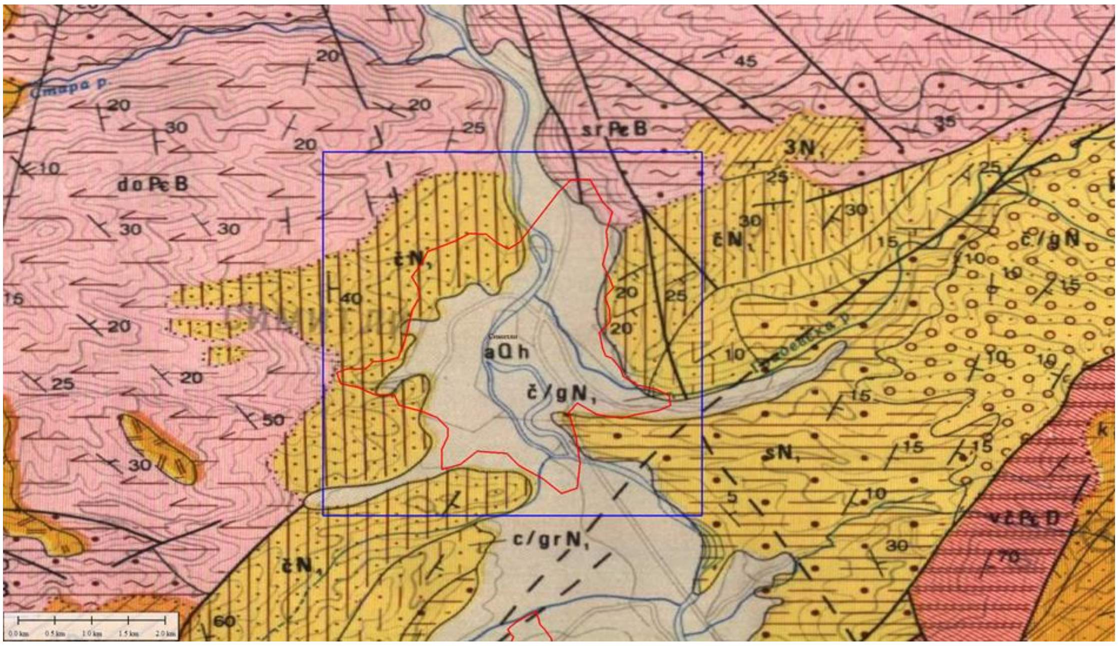
Methodology and modeling

The main focus of the presented investigations is on the area of SW Bulgaria – the most seismic hazardous region of Bulgaria due to this M7.8 earthquake occurred on 4th April 1904 [8].

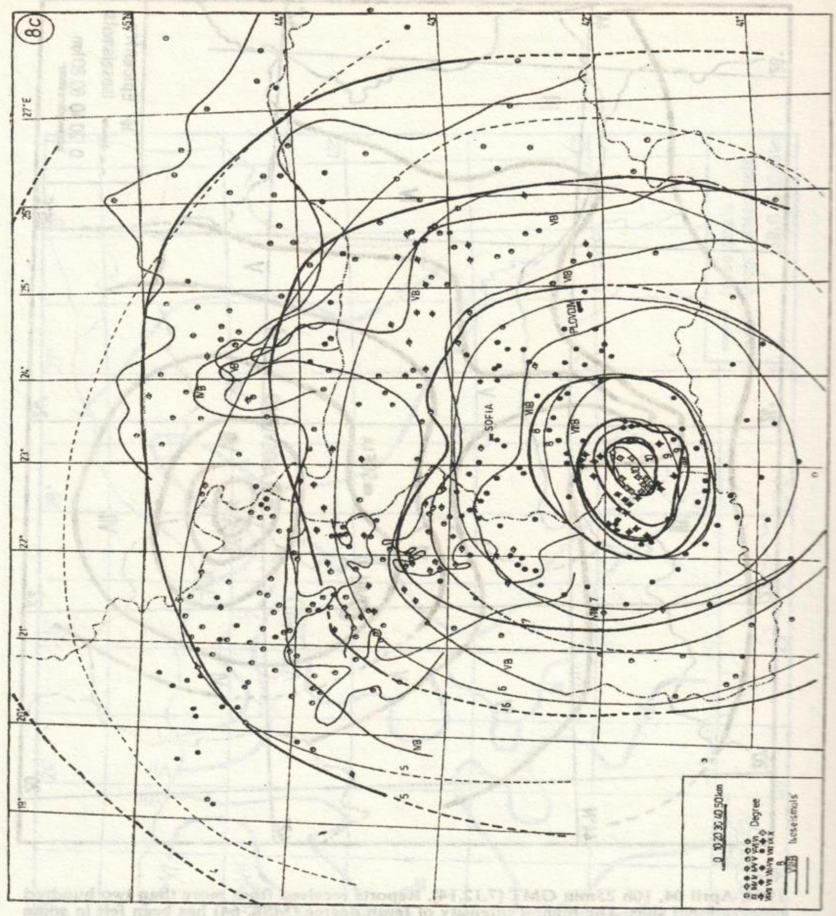
For the calculations of the PGA (Peak Ground Acceleration), Sa (Spectral acceleration for the respective frequencies (0.3 and 10 – the first value representing low frequency content of the seismic waves, and the second one of the high frequency content) and "sigma" as a measure of the accuracy of calculations. All these values are calculated and mapped considering wide spectrum of primary data and specialized newly developed software [12, 13, 15].

For example:

- Geological maps of different scales, layers of petrology composition, age, time of origin, thickness, roughness of the layers overlapping boundaries, lateral inhomogeneity, etc. Usually almost all found maps and schemes are presented on paper as colored pictures and legend describing the meanings of colors and symbols (Fig. 1.) [11].
- Morphology and surface faults (Fig. 2.) [9, 10].
- Macroseismic maps (Fig. 3.) [8].
- Deep faults (Fig. 4.) [SHARE data base].
- Borehole diagrams.
- Pictures, sketches, schemes, photographs, etc.
- Seismic, electromagnetic, radioactivity profiles and measurement points, etc. [13].
- Hydrogeology and water bodies maps, sedimentation analysis, etc. [14].



Фиг. 1. Analogue geology map (scale 1:100 000) of Simitly
(red line – town boundary), interested area (blue quadrat) [2]



1904, April 04, 10h 25min GMT [14]. Reports received from more than two hundred observational sites. The highest intensity of tenth degree (MSK-64) has been felt in some villages (Krupnik, Simitly, Pehchevo etc.), near Bulgarian-Macedonian boundary. The Iskar riverbank has been cracked and water gushed to up to 15m in height. There are reports from some villages about a rise in the mineral bath temperature [1]. There have been formed many cracks along the Struma river, hundred meters in length and up to a meter in width. The villages Krupnik, Simitly and Pehchevo have been completely destroyed [12]. This quake has been recorded from more than sixty foreign seismic stations (the farthest more than thirteen thousand kilometers away from the epicenter [31])
A8c

Фиг. 2. A facsimile of the macroseismic map of the 1904 (M7.8) earthquake [8]

All analogue maps are digitized to transform the available information (mostly archive) and to make it available to the recent computing models for seismic hazards assessment [12, 15].

Results and discussion

The calculations include seismic hazard assessment expressed by PGA (Peak Ground Acceleration) and Sa (spectral acceleration at different frequencies – 0.3 and 10 Hz). The last two values of Sa are selected according the representative role of 0.3 Hz (as low frequency characterizing far field seismic sources) and 10 Hz representative of the very near field sources. Such approach gives alternatives to investigate the intensity of the seismic waves, their influence to the structures (sensitive to resonance effects of low and high frequency content) and the soil conditions as main modifying factor to the spectrum of the seismic waves.

All this information is synthesized with a main purpose – to assess the seismic hazard including the integral influence of the ground conditions [9, 16]. The results show the influence of the variety of ground conditions of the different settlements. All of the investigated settlements are located in near field or directly on the active segments of seismoactive faults. This change significantly the picture of PGA and Sa. The fault location is another investigated parameter and shows the great influence of the distance to the fault, clearly expressed to the modeled results. The fault trace on the surface and the fault plane are schematized and presented on Fig. 3.

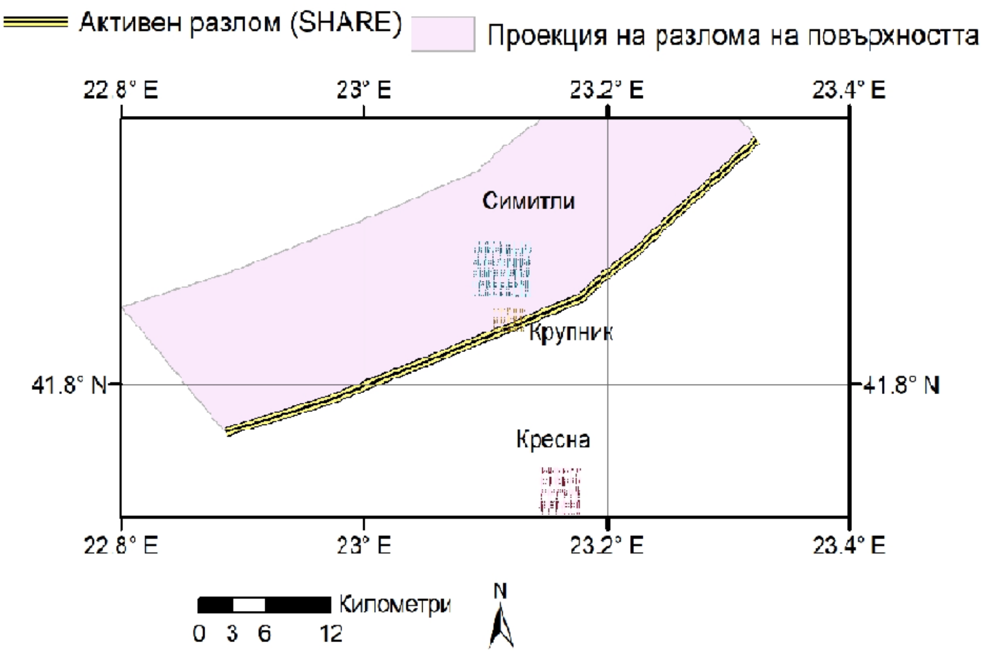


Fig. 3. Geography position of the selected settlements for seismic hazard assessment.
The line is accepted to model the active fault surface trace and the projection of the fault plane (in NW direction) is denoted by pink area (according SHARE).

The calculations are executed by specialized developed software by D.Solakov [12,15] and considered the general faults attributes – depth, plane, elongation, dip, strike, slip, etc.

The results of the modeling are presented to the next figures – Fig. 4, Fig. 5, and Fig. 6:

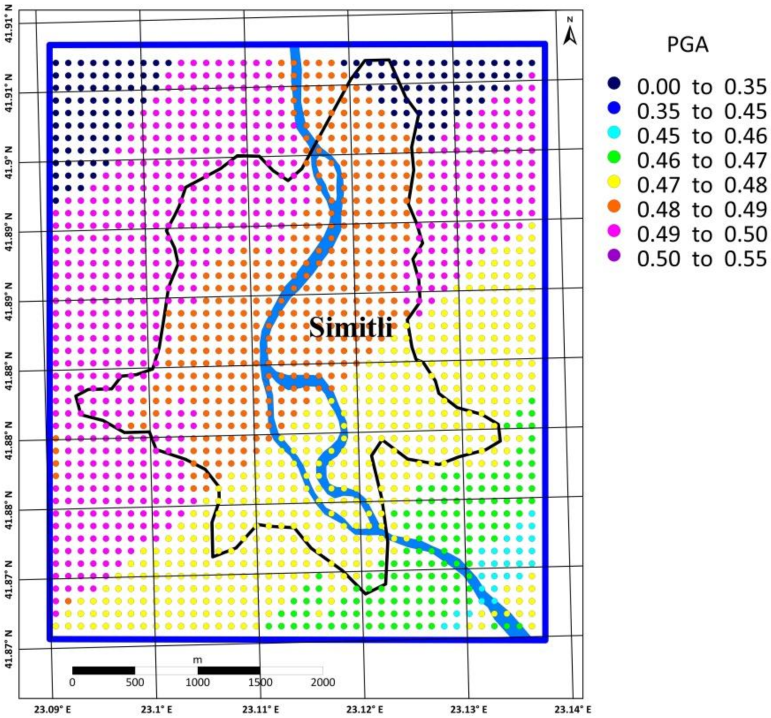


Fig. 4. PGA results for Simitly town

The picture of the seismic hazard for Simitly town is presented to Fig. 4. The diapason of PGA values are in a wide interval 0.3 to 0.5 cm/s^2 and spread across the town increasing to the NW. The dominant values are between 0.46 to 0.49 (more than 70% of the area). The influence of the river sediments is clearly expressed as well as the direction of the fault's plane. A little bit strange is cthe straight line crossing the town from SW to NE separating the values 0.47-0.48. The influence of the soil conditions is also significant and visible mainly to the North.

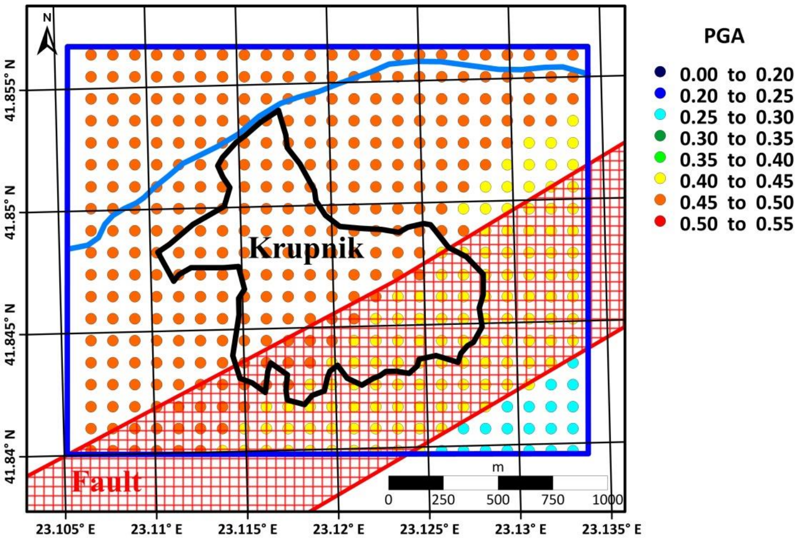


Fig. 5. PGA results for Krupnik village

The PGA distribution over Krupnik is presented to Fig. 5.The fault's plane is in red. As seen on the picture the highest values of PGA ate on the boundaries of the fault reaching 0.4 to 0.45. The village is entirely covered by these values which mean rather high seismic risk for the whole settlement. The soil conditions lateral changes are effective mainly to the SE.

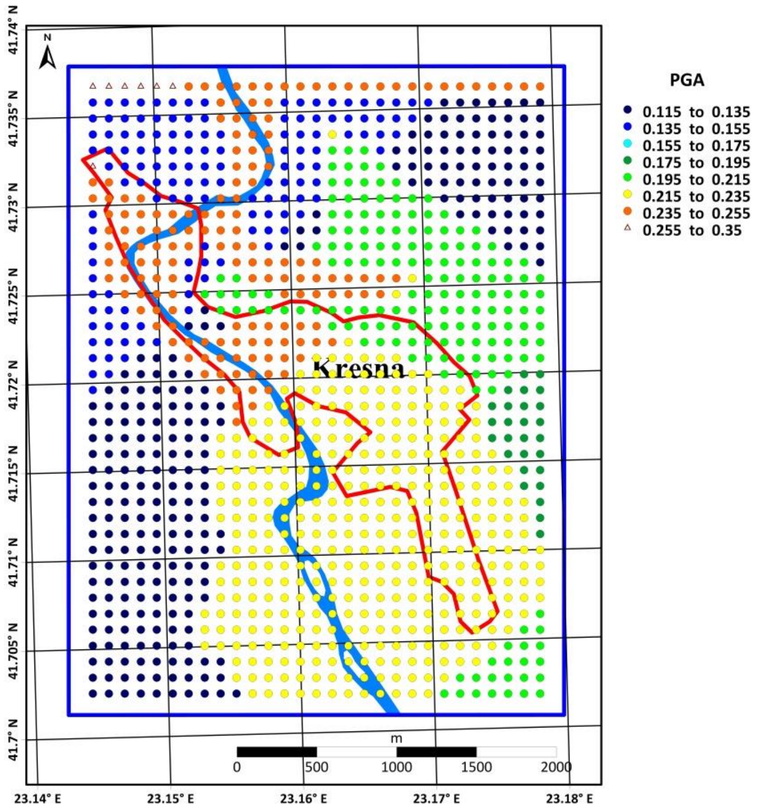


Fig. 6. PGA results for Kresna town

The Kresna town case (Fig. 6) is rather different than the others two settlements with very high seismic risk. The PGA has lowest values varied between 0.1 to 0.2 cm/s². The influence of soil conditions is significant and located around the river bed. The thick sediments modify the effect of seismic waves increasing the seismic effect to the S and NW. Larger portion of the town is covered by highest a value which is important for the construction and building works. The small spots with the lowest PGA are located in the North central part of the town.

The comparative analysis of the results obtained shows that the highest seismic risk is for the Krupnik village – PGA between 0.4 and 0.55 cm/s^2. This is due to two general considerations. First - the active seismogenic segment of the fault is crossing the area just under the village. And second – the influence of the soil conditions amplify the seismic effect. The Simitly is the second larger town with very high seismic hazard – 0.45-0.5 cm/s^2. Same considerations are valid, but the values are spreading and covered larger areas. This is due to the fault's plane domination the left-right lateral inhomogeneity's distribution. The Kresna case is completely different. The low values are due to the location of the town far from the seismogenic fault. The influence of the soil conditions are significant and show amplifying effect of the thick river sediments. In general the variation of the PGE is less than 20%.

Conclusions

The modeling and calculations about seismic hazard for nearly located settlements to the seismoatcive fault is done considering the position and the soil conditions – as main influencing factors to the seismic wave's propagation and their destructive effect.

It is quantitatively assessed the seismic hazard and risk for three near located towns and a village. The results obtained confirm in high percentage the observed effects of the 1904 strong seismic effects – M7.8 and M7.2 to the mentioned settlements. This shows the reliability of the used models and software.

The future work is targeted to the assessment of the sensitivity and resolution of the methodology used and will include spectral acceleration at different frequency windows.

References:

1. Frantzova, A., 2016. Risk mapping methodology for environmental hazards, Proceedings, 6th Intl. Conf. On Cartography and GIS, 13-17 June 2016, Albena, Bulgaria
2. Frantzova, A., 2017. Risk mapping methodology and classification for environmental hazards (Lambert AcademicPublishing).
3. Frantzova, A., 2016. Classifications and typology of the natural and triggered technological risks according to the GDP and probability of occurrence Proceedings, 6th Intl. Conf. on Cartography and GIS,13-17 June 2016, Albena, Bulgaria.
4. Frantzova, A., 2012. Remote sensing data for snow cover monitoring and mapping South-Eastern European Journal of Earth Observation and Geomatics, Vol 1, No 1.
5. Frantzova, A., 2012. Detecting and monitoring of wildfires with remote sensing data South-Eastern European Journal of Earth Observation and Geomatics, Vol 1, No 2.
6. Frolova, N, Larionov V, Bonnin J, Suchshev S, Ugarov A and Malaeva N., 2019. Impact data bases application for natural and technological risk management Nat. Hazards Earth Syst. Sci. NHESS (2019)264
7. Ranguelov, B., 2011. Natural Hazards – Nonlinearities and assessment. (Sofia: Bulgarian Academy of Sciences Pres)
8. Ranguelov, B, Rizhikova S and Toteva T., 2001. The earthquake (M7.8) source zone (South-West Bulgaria) (Sofia: Bulgarian Academy of Sciences Pres).
9. Muco, B., Alexiev G., Aliaj S., Elezi Z., Grecu B., Mandrescu N., Milutinovic Z., Radulian M., Ranguelov B. and Shkupi D., 2012. Geohazards assessment and mapping of some Balkan Countries., Nat Hazards 64 2
10. Ranguelov, B., Alexiev G., Gospodinov D., Scheer S. 2010 Natural hazards and preventive measures in Bulgaria., In Bulgaria and Bulgarians in Europe., (Ed. P. Petkov), "Faber", V.Turnovo, pp 385–393
11. Ranguelov, B., D. Solakov, S. Dimovsky, and A. Kisyov., 2020. Digitalization of the ground conditions for big cities in North Bulgaria – Varna, Ruse, V.Tarnovo., Proc. XVI Intl. Conf. SES2020. http://www.space.bas.bg/SES/archive/SES%202020_DOKLADI/PROCEEDINGS%20SES%202020.pdf
12. Solakov, D., S.Simeonova, P. Raykova, B. Rangelov, C. Ionescu, 2020. Earthquake scenarios for the city of Ruse. Proceeding of 1st International conference on Environmental protection and disaster RISKs, https://doi.org/10.48365/envr-2020.1.34
13. Georgieva, B., B. Ranguelov, D. Solakov, S. Dimovsky, and A. Kisyov. 2020. Methodology of mapping and digitalization of V_{s_30} for the seismic hazard assessment in big cities., Journal of Mining and Geology., vol. 63. http://mgu.bg/new/docs/2020/Journal%20of%20MG%20Sciences%2063-2020.pdf
14. Kisyov, A., B. Ranguelov, D. Solakov, S. Dimovsky, Bozhurka Georgieva., 2020. Digitalization of V_{S_30} for large cities (Sofia city)., XXX Int. Symp. On modern technologies, education and professional practice in Geodesy., Sofia, 05 – 06 November 2020 http://symp2020.geodesy-union.org/wp-content/uploads/2020/11/EN-Paper-Sofia-16-9-2020-2.pdf
15. Solakov, D. , S. Simeonova, P. Raykova, and B. Ranguelov, 2020, Earthquake scenarios for the city of Blagoevgrad, Proc. 20th International Multidisciplinary Scientific Conference SGEM 2020, 272–280.
16. Ranguelov, B., D. Solakov, A. Kisyov, S. Dimovski, N. Stoyanov, M. Tomova, Ch. Tzankov, D. Gospodinov, E. Spassov, B. Georgieva, S. Christov and B. Milenkovich., 2021. Methodology of data extraction from archive information for the ground conditions**.** Proc. Days of Phisics, TU, SOFIA, 21-24 April 2021., http://phys.tu-sofia.bg/physdays_files/Sbornik/Sbornik_v13_2021.pdf