РЕЗЮМЕТА

на научните публикации за участие в конкурса;
доц. д-р инж. Радан Иванов Иванов

В. Хабилитационен труд – научни публикации

104. Pshenichnov, S., **Ivanov, R**., Datcheva, M.. TRANSIENT WAVE PROPAGATION IN FUNCTIONALLY-GRADED VISCOELASTIC STRUCTURES. Mathematics, 10, 23, Multidisciplinary Digital Publishing Institute (MDPI), 2022, ISSN:2227-7390, SJR (Scopus):0.538, JCR-IF (Web of Science):2.592 Q1 - оглавява ранглистата (Web of Science)

Transient wave processes in viscoelastic structures built from functionally graded material (FGM) still remain almost unexplored. In this article, the problem of the propagation of nonstationary longitudinal waves in an infinite viscoelastic layer of a FGM with plane–parallel boundaries is considered. The physical and mechanical parameters of the FGM depend continuously on the transverse coordinate, while the wave process propagates along the same coordinate. The viscoelastic properties of the material are taken into account employing the linear integral Boltzmann–Volterra relations. The viscoelastic layer of the FGM is replaced by a piecewise-homogeneous layer consisting of a large number of sub-layers (a package of homogeneous layers), thus approximating the continuous inhomogeneity of the FGM. A solution of a non-stationary dynamic problem for a piecewise-homogeneous layer is constructed and, using a specific example, the convergence of the results with an increase in the number of sub-layers in the approximating piecewise-homogeneous layer is shown. Furthermore, the problem of the propagation of nonstationary longitudinal waves in the cross section of an infinitely long viscoelastic hollow FGM cylinder, whose material properties continuously change along the radius, is also considered. The cylinder composed of the FGM is replaced by a piecewise-homogeneous one, consisting of a large number of coaxial layers, for which the solution of the non-stationary dynamic problem is constructed. For both the layer and the cylinder composed of a viscoelastic FGM, the results of calculating the characteristic parameters of the wave processes for the various initial data are presented. The influence of the viscosity and inhomogeneity of the material on the dynamic processes is demonstrated.

116. Pashova, L., Oynakov, E., Paskaleva, I., **Ivanov, R.** Seismic Response Analysis of a Six-Story Building in Sofia Using Accelerograms from the 2012 Mw5.6 Pernik Earthquake. Applied Sciences, 15, 15, 8385, 2025, DOI: 10.3390/app15158385, Q2 (Scopus)

On 22 May 2012, a magnitude Mw 5.6 earthquake struck the Pernik region of western Bulgaria, causing structural damage in nearby cities, including Sofia. This study assesses the seismic response of a six-story reinforced concrete building in central Sofia, utilizing real accelerogram data recorded at the basement (SGL1) and sixth floor (SGL2) levels during the earthquake. Using the Kanai–Yoshizawa(KY)model, thestudyestimatesinter-story motion and assesses amplification effects across the structure. Analysis of peak ground acceleration (PGA), velocity (PGV), displacement (PGD), and spectral ratios reveals significant dynamic amplification of peak ground acceleration and displacement on the sixth floor, indicating flexible and dynamic behavior, as well as potential resonance effects. The analysis combines three spectral techniques—Horizontal-to-Vertical Spectral Ratio (H/V), Floor Spectral Ratio (FSR), and the Random Decrement Method (RDM)—to determine the building's dynamic characteristics, including natural frequency and damping ratio. The results indicate a dominant vibration frequency of approximately 2.2 Hz and damping ratios ranging from 3.6% to 6.5%, which is consistent with the typical damping ratios of mid-rise concrete buildings. The findings underscore the significance of soil–structure interaction (SSI), particularly in sedimentary basins like the Sofia Graben, where localized geological effects influence seismic amplification. By integrating accelerometric data with advanced spectral techniques, this research can enhance ongoing site-specific monitoring and seismic design practices, contributing to the refinement of earthquake engineering methodologies for mitigating seismic risk in earthquake-prone urban areas.

105. Pshenichnov, S., Ryazantseva, M., **Ivanov, R**., Datcheva, M.. Dynamic Problem for a Viscoelastic Hollow Cylinder with Coaxial Elastic Inclusion. Comptes Rendus de L'Academie Bulgare des Sciences, 75, 8, „Prof. Marin Drinov“ Publishing House of Bulgarian Academy of Sciences, 2022, ISSN:1310–1331 (Print), 2367–5535 (Online), DOI:https://doi.org/10.7546/CRABS.2022.08.11, 1184-1194. SJR (Scopus):0.19, JCR-IF (Web of Science):0.326 Q3 (Scopus)

A problem of non-stationary longitudinal wave propagation in the cross section of an infinite hollow linear-viscoelastic cylinder with coaxial elastic inclusion is considered. On the contact surfaces between the layers, continuity of displacements and stresses is assumed. The solution of the problem is constructed using the integral Laplace transform in time with subsequent reversal. For the case when each of the relaxation kernels is a finite sum of exponentials, the original is presented as a series of residues. Thus, the process of constructing a non-stationary solution is reduced to the search for the roots of the characteristic transcendental equation. The derived solution allowed to investigate the transient wave propagation in a viscoelastic cylinder with coaxial elastic inclusion with specified initial data.

109. Oynakov, E., **Ivanov, R.**, Aleksandrova, I., Milkov, J., Popova, M.. Evaluation of the Nakamura vulnerability index of a cast-in-situ reinforced-concrete building from ambient noise records. Lecture Notes in Networks and Systems, 638, Springer Nature, 2023, ISSN:ISSN 2367-3370, DOI:https://doi.org/10.1007/978-3-031-26754-3, 66-76. SJR (Scopus):0.11 Q4 (Scopus)

Abstract. The deformation characteristics and the dynamic amplification of the response of a building subjected to an earthquake can be estimated from the dynamic characteristics of the structure. In the present study, the fundamental natural frequency of a structure, a key factor influencing the damage after earthquakes, is examined. The investigated structure is the building of the National Institute of Geophysics, Geodesy and Geography (NIGGG), to the Bulgarian Academy of Sciences, which is a five-floor, cast-in-situ reinforced concrete (RC) building. The campus area adjacent to the building was also studied. Two indexes, related to the performance during earthquake were calculated using ambient vibration data; (i) the vulnerability index of the studied structure (K_b), and (ii) the coefficient of vulnerability of ground of the adjacent free field (K_g). The vulnerability index was calculated at ten locations on each floor. The maximum value computed in the present study was 81, indicating the location where the structure experiences the highest dynamic amplification and is hence the weakest and most likely to fail first during earthquake. The maximum possible interstorey drift ratio due to a design earthquake peak ground acceleration (PGA) was also determined. All measurements were performed using four ETNA 2 mobile accelerometers with a recording frequency of 100 samples/second, and recording time at each point 20 min.

111. Emil Oynakov, **Radan Ivanov**, Liliya Dimitrova, Alexander Radulov. EVALUATION AND ANALYSIS OF MICROSEISMIC RECORDS ON THE TERRITORY OF THE SOFIA BASIN. Journal of Theoretical and Applied Mechanics, 54, 4, BULGARIAN ACADEMY OF SCIENCES, NATIONAL COMMITTEE OF THEORETICAL AND APPLIED MECHANICS, 2024, ISSN:1314-8710, SJR (Scopus):0.158 Q4 (Scopus)

The content of the microseismic wave field continuously recorded at any measurement point is closely related to the structure and geology of the Earth’s crust. All registered oscillations have individual amplitude-frequency characteristics, temporal mode of existence and variations (permanent, periodic, spontaneous) and, what is particularly important, characteristic spatial distribution in the geological environment. Seismic noise records were analyzed to study the structure of the microseismic wavefield and the spatial variability of soil dynamic characteristics for the SE part Sofia Basin area. The natural frequencies of the soil were determined by two methods: the standard spectral ratio (SSR) method and the horizontal to vertical spectral ratio (HVSR) method. On the basis of the recorded extensive experimental material, the possibility of using the natural oscillations of the soil (microseisms) for differentiating the ground in a seismic sense has been proven.

115. Radan Ivanov, Sergey Pshenichnov, Gergana Chalakova, Maria Datcheva. Wave propagation through a viscoelastic layer with uniformly-distributed elastic inclusions. Advanced Computing in Industrial Mathematics - 18th Annual Meeting of the Bulgarian Section of SIAM December 11-13, 2023, Sofia, Bulgaria. Revised Selected Papers, Studies in Computational Intelligence, Springer, 2025, 122-130, ISSN:1860-949X, https://doi.org/10.1007/978-3-031-96311-7_11, Q4 (Scopus)

We examine how square elastic inclusions, arranged in a uniform grid, influence P-wave transmission through a viscoelastic layer under a smoothed-step normal stress pulse at its surface. We track longitudinal stress at two locations: directly beneath an inclusion column at the layer's base, and midway between columns. Results show that rigid inclusions amplify bottom stresses compared to the homogeneous case, whereas compliant inclusions reduce them with the latter effect being more pronounced. Wave speed decreases markedly with softer inclusions but remains nearly unchanged for stiff inclusions. Stress differences are even greater at the layer midpoint, where soft inclusions generate concentration factors approaching two (similar to voids), while stiff inclusions produce clear stress relief.

107. Emil Oynakov, **Radan Ivanov**, Irena Aleksandrova, Yordan Milkov, Maria Popova. ASSESSMENT OF THE NAKAMURA'S VULNERABILITY INDEX OF AN EARTHEN DAM, FROM AMBIENT NOISE RECORDINGS. Proceedings of 23rd International Multidisciplinary Scientific GeoConference SGEM, 23, 1, 2023, ISBN:ISBN 978-619-7603-56-9, ISSN:ISSN 1314-2704, DOI:DOI 10.5593/sgem2023/1.1/s02.23, SJR (Scopus):0.123 SJR, непопадащ в Q категория (Scopus)

Among the important parameters determining the likelihood of occurrence of significant damage to engineering structures during an earthquake are the dynamic and seismic characteristics of the structures such as natural frequency, damping coefficient, and vulnerability index of the structure.

In this article, the Nakamura method is applied to investigate the seismic stability of an earth-filled dam wall and the surface layer using microtremors. Measurements were taken at seven points on the dam crest and three points at its base. All measurements were taken using two mobile accelerometers (ETNA 2), with a recording frequency of 100 samples/second. The recording time at each point was 20 minutes. The accelerometer's *y* axis was aligned with the dam crest's normal, and the *x* axis was parallel to the wall. The data was processed using the GEOPSY v.3.4.1 program, by which a geotechnical test was performed for the site – computation of the horizontal to vertical spectral ratio (HVSR). Graphs of the spectral H/V ratios for each observation point were made. The vulnerability indices for each point were calculated.

Using the obtained vulnerability indices, it was shown that neither the dam nor its base layer are likely to suffer damage due to an earthquake with peak ground acceleration of 0.37g., which is the design event for the region where the dam is located. The study is the first of its kind in Bulgaria, and was carried out in full by the authors.

99. Ivanov, R., Pshenichnov, S., Datcheva, M.. Non-stationary wave propagation in a viscoelastic layer due to step loading. iNDiS 2021, 15th International Scientific Conference; Planning, Design, Construction and Building Renewal, University of Novi Sad, 2021, pp. 611-616

In this work, an analytical solution of the P-wave propagation through a viscoelastic layer subjected to a smoothed-step pressure applied on the surface, is compared to the solution of the same problem obtained by FE simulation using explicit dynamic analysis. Viscoelasticity is introduced by either a regular or singular relaxation kernel. Time-histories of the normal stress in the direction of wave propagation at specific locations were obtained by both methods for a number of values of the Poisson's ratio and compared. An excellent match is demonstrated for the wave propagation velocities, the shapes and sizes of the peak regions of the time histories, and the apparent damping of wave motion, except for the singular kernel, where the shape of the peak region is reproduced only

approximately. In terms of finite element modelling, a 3-D solid model was used with only one element along the transverse directions, which has been verified as most suitable by a previous study.

101. Pshenichnov, S., **Ivanov, R.**, Datcheva, M.. Comparison between analytical and numerical solutions of one-dimensional, non-stationary wave propagation in a viscoelastic layer. XXI Anniversary International Scientific Conference "Construction and Architecture" VSU'2021, Висше строително училище "Любен Каравелов", 2021, pp. 406-414

Materials exhibiting hereditary properties are widely used in modern technology. In this work, an analytical solution of the P-wave propagation through a viscoelastic layer subjected to a triangular stress pulse applied on the boundary, is compared to the solution of the same problem obtained by a FE simulation using explicit dynamic analysis. It is shown that for the regular exponential hereditary kernels used in the study, the time-dependent elastic properties of the material can be represented by a Prony expansion of only one term and the Prony parameters can be directly related to the parameters of the kernels. For a singular kernel the Prony parameters are obtained by curve fitting. Time-histories of normal stress in the direction of wave propagation at specific locations were obtained by both methods for a number of values of the Poisson's ratio and compared. An excellent match is demonstrated for the wave propagation velocities and the shape of the stress spikes. A good match is demonstrated for the magnitude of the spikes and the apparent damping of the wave motion. In terms of FE modelling, a beam model, 3D-solid model and a plane-strain model were tried and the results obtained were practically identical.

108. Ivanov R., Oynakov E., Aleksandrova I., Popova M., Milkov J.. Evaluation of the fundamental frequency and damping of a cast-in-situ reinforced-concrete building by ambient noise analysis. Проблеми на географията, Книга 1-2, Книга 1-2, НАЦИОНАЛЕН ИНСТИТУТ ПО ГЕОФИЗИКА, ГЕОДЕЗИЯ И ГЕОГРАФИЯ – БАН, 2023, ISSN:ISSN 0204-7209; ISSN 2367-6671, DOI:DOI: 10.35101/prg-2023.1-2.1, 3-14

Earthquakes are among the most significant natural phenomena with highly negative social and economic consequences. The behavior of building structures during earthquake, the ensuing damage and other side effects are extremely important for all large cities. The dynamic characteristics of structures - predominant frequency and damping ratio used to assess the vulnerability of buildings, are most conveniently determined by analyzing ambient vibration data, as opposed to the more expensive and time-consuming traditional methods of Experimental Dynamics. In the present work, the damping ratio and the fundamental frequency are calculated by the RDM (Random Decrement Method). A bandpass filter with filter parameters chosen according to the predominant frequency obtained by the FSR (Floor Spectral Ratio) method is applied to the signal before the actual RDM processing. The results obtained by the RDM method are compared with those obtained by the FSR method. The investigated structure is the building of the National Institute of Geophysics, Geodesy and Geography (NIGGG), to the Bulgarian Academy of Sciences, which is a five-floor, cast-in-situ RC building. Ambient noise measurements of 100 samples/second were made at ten locations on each floor using ETNA 2 mobile accelerometers.

110. E. Oynakov, **R. Ivanov**, A. Radulov, L. Pashova, M. Popova, Y. Donkova. EQUIVALENT LINEAR SITE RESPONSE ANALYSIS FOR THE SOFIA BASIN. Proceedings: 18th World Conference on Earthquake Engineering, International Association for Earthquake Engineering, 2024, ISSN:3006-5933

New results for the seismic microzonation of Sofia city were obtained through equivalent linear site response analysis. We present seismic microzonation that is based on free-field peak acceleration (PGA)values. The computation of free-field peak acceleration values was performed using the freeware STRATA program developed with financial support by the Pacific Earthquake Engineering Research Center (USA). A 95-year return period event and 475-year return period event at bedrock level were derived from the horizontal components of two ground motion records scaled to PGA of 0.10g and 0.36g, respectively. The records were obtained from an instrument installed on bedrock in the Vitosha (VTS) station of the Bulgarian Strong Ground Motion Network, located 12 km south the city centre. The input data concerning geological sections - soil densities, shear wave velocities, and ground water levels were extracted from 107 drilling core logs of the basin deposits. The boreholes were spread over an area of 360 sq. km, i.e. an average density of 3 sq. km per borehole. The drilling core logs were modelled to compute the variations in the peak accelerations, peak velocities (PGV) and peak displacements (PGD) with

increasing depth, as well as to attain the corresponding response spectra. Seismic microzonation maps of the city territory are presented for earthquakes of 95-year and 475-year return periods

Г. Научни публикации

4. Johnson R., **Ivanov R.**, Local effects of concentrated longitudinal shear in composite bridge beams, The Structural Engineer, Vol. 79, No 5, 2001, pp.19-23

The situations where the shear connection in a composite beam of steel and concrete can be subjected to concentrations of shear flow are listed and discussed. An account is given of relevant finite element (FE) analyses. The design rules given in the draft Eurocode for composite bridges, ENV 1994: 2, for shear connection near anchorages of prestressing tendons, or at nodes in composite trusses, are shown to be radical simplifications of the results of these analyses. Reference is made also to similar situations, such as sudden changes of section, and shear connection in bowstring arches.

38. Partov D., Bankov B., **Ivanov R.**, Structural rehabilitation of the small Asparuhov bridge, Proceedings: 21st Chech and Slovak International Conference on Steel structures and bridges, Slovakia, 2006

The paper presents the rehabilitation project for the small Asparuhov bridge, following its failure in 1975. The reconstructon included installing new superstructure in two bays, while the original structure in the trird bay was kept in place. Details are given on the design conceps, the technological, procurement and installation aspects of the project.

47. Partov D., **Ivanov R.**, The rehabilitation of the small Asparuhov Bridge in Varna, 2008, Proceedings of the 7th International Conference on Steel Bridges, Guimaraes, Portugal, 2008, CD

The paper presents the rehabilitation project for the small Asparuhov bridge, following its failure in 1975. The reconstructon included installing new superstructure in two bays, while the original structure in the trird bay was kept in place. Details are given on the design conceps, the technological, procurement and installation aspects of the project.

49. Ivanov R., Variations in the seismic response of large panel RC buildings due to different modeling approaches, Proceedings of the 7th International Conference on "New Trends in Statics and Dynamics of Buildings, October, 22-23, Bratislava, Slovakia, 2009. (CD)

In this paper, the seismic forces in a typical Bulgarian large panel (LP) RC building are investigated. Two models of the building are used – one where the walls are modelled by shell elements, and another where the walls are modelled by frame elements. The frame model has three variations, reflecting the possible types of interaction between the floor slabs and the shear walls. The models are solved for the worst possible input earthquake according to the Bulgarian seismic code, and the response in terms of internal forces, stress in the shear walls and modal shapes are compared.

50. Partov D., **Ivanov R.**, Static analysis, design and assembling of the back anchor of the tunnel boring machine (TBM) at station 7 of Sofia city metro, 2009, Proceedings of the 7th International Conference on "New Trends in Statics and Dynamics of Buildings, October,22-23, Bratislava, Slovakia, 2009, (CD).

The paper provides a review of the design issues that were encountered during this unusual for Bulgarian practice design project. The paper starts with the choice of structural configuration and elaborates on the structural analysis

and design decisions made. Finally, the construction process, the materials used, and the monitoring of the structure during the TBM start are described.

51. Ivanov R., Influence of soil-structure interaction on the seismic response of precast large panel RC buildings, International conference VSU 2010, Sofia, Bulgaria, Vol. II, 2010, pp. VIII-33 – VIII-37

Abstract: One of the problems encountered in the structural analysis of buildings, is the influence of soil-structure interaction on the seismic response. The degree of soil structure interaction may significantly modify the behaviour of some structures, while being virtually negligible for others. The same argument holds for large panel buildings as the methods used for calculation of their seismic response do no account for dynamic soil-structure interaction (SSI). In this paper a building with a mat foundation and typical layout is considered. The height of the building is varied between 5 and 8 stories, which is the height range of all such buildings. The difference in the seismic response in terms of maximum normal stress in the shear walls has been computed, and the influence of SSI quantified for all building heights. The stiffness of soil has also been considered to range between the practicable lower and upper bounds of soils suitable for supporting buildings.

52. Ivanov R., Seismic response of large panel reinforced concrete buildings, Conference Savremena gradevinska praksa 2011, Novi Sad, Serbia, 2011, pp. 71-81

In this paper, the seismic forces in a typical Bulgarian large panel (LP) RC building are investigated. Two models of the building are used – one where the walls are modelled by shell elements, and another where the walls are modelled by frame elements. The frame model has three variations, reflecting the possible types of interaction between the floor slabs and the shear walls. The models are solved for the worst possible input earthquake according to the Bulgarian seismic code, and the response in terms of internal forces, stress in the shear walls and modal shapes are compared. In order to assess the influence of soil-structure interaction (SSI), the same building with a mat foundation is considered. The difference in the seismic response in terms of maximum normal stress in the shear walls has been computed, and the influence of SSI quantified. The stiffness of soil has been considered to range between the practicable lower and upper bounds of soils suitable for supporting buildings.

53. Ivanov R., The 2011 Tohoku earthquake in Japan, International conference VSU 2011, Sofia, Bulgaria, Vol. II, 2011, pp. I-169 – I-174

This earthquake which occurred on March 11, 2011, had a magnitude of 9.0, which places it as the fourth largest in the world since 1900, and the largest in Japan since modern instrumental recordings began 130 years ago. It will surely become a landmark earthquake, and one which will shape seismology and earthquake engineering research for many years to come, just as the 1995 Kobe earthquake did. This paper attempts to give an early account of the source mechanisms that caused the earthquake, the distribution of seismic intensity and damage, as well as the characteristics of the ground motion at selected strong motion recording stations. A summary and analysis of the damage attributable to strong ground motion and tsunami is also included

54. Partov D., Ivanov R., Petkov M., Survey of the design of back anchors for tunnel boring machines (TBM), used in the excavation of metro tunnels in Sofia, 2012, Procedia Engineering, 40, pp. 351-356.

In the year 1974 the Minicipality of Sofia approved the city plan containing the intention to build a metro system in Sofia. The construction works commenced in the year 1982. The route for Sofia metro Line- 1 Extension Project from Sveta Nedelya Square to Vassil Levski Stadium was financed with a loan from Japan International Cooperation Agency(JICA) and was carried out by the Japanese Contractor Taisei Corporation, under contract with the Sofia Minicipality.For this route, with length of 2,4 km, two metro stations, two ventilations shafts and one start shaft, for strengthening of this deep excavations was design and used more than 610 tons temporary steel structures to keep the R.C. wall and pilot in vertically position. Contemporary machine methods of the tunnel excavation in the soft ground in Sofia was used for this route. The machine excavation is executed as a full-face excavation, employing tunnel-boring machines (TBM), with diameter 5820 mm.

55. Stoynova I., **Ivanov R.**, Kazakov K., Review of computational and mechanical models for failure analysis of RC column-flat slab connection, Conference DCB 2012, Varna, Bulgaria, pp. 395-399

This paper presents a critical review of computational and mechanical models applicable to the investigation of punching shear arising at column-flat slab connections. A detailed account is made of models available in the 1988 Bulgarian "Design Code for Concrete and Reinforced Concrete Structures", EUROCODE 2, as well as several other models of punching shear failure.

56. Paskaleva I., D. Dojcinovski D. and **Ivanov R.**. A note on the attenuation for peak ground acceleration and response spectra for the 22, May, 2012 earthquake (western Bulgaria), SE-50EEE Conference, Skopje, Macedonia, 2013, CD

An earthquake of magnitude 5.6 Mw hit Western Bulgaria, on May 22-th/ 3:00 am local time (00:00 UTC)/, 2012, 25km South West of the Bulgarian capital, Sofia. The depth is 9.4 km, epicenter coordinates 42 ° 41'10 "N 23 ° 00'32" E; maximum intensity MM VII and aftershock series in this day - 4.6 Mw and 4.3Mw. This shallow earthquake was largely felt in the region and up to Greece, Macedonia, Turkey and Romania. No severe injuries have been reported so far, though a state of emergency was declared in Pernik (the closest city to the epicenter) and superficial damages were observed. Those statements provoked the aim of this work. The analyses of attenuation of the peak ground acceleration (PGA) with the distance from the source as well the attenuation in 5% damped pseudo-absolute acceleration response spectra (PSA) is carried out. The empirical attenuation relationships are proposed using accelerograms recorded on the territory of the nearer countries Macedonia, Romania and Turkey. In spite the insufficient data we consider the derived attenuation relationships to be appropriate for predicting accelerations amplitudes of earthquakes of moment magnitude Mw = 4 - 6 at sites with epicentral distances R > 40 km around that tectonic region.

57. Paskaleva I., D. Dojcinovski D. and **Ivanov R.**. A note on the main characteristics of the May 22, 2012 earthquake in the vicinity of town of Pernik, International conference VSU 2013, Sofia, Bulgaria, Vol. III, 2013, pp.VIII-1 – VIII-6

An earthquake of magnitude 5.6(Mw) hit Western Bulgaria, on May 22-nd. This shallow earthquake was largely felt in the region as well as in Greece, Macedonia, Turkey and Romania. No severe injuries have been reported so far. 7 superficial damages were observed. Those statements provoked the aim of this work. The analyses of the earthquake parameters which characterized the damage potential and the predominant frequency content is presented. The attenuation of the peak ground acceleration (PGA) with the distance from the source to the recording station as well as the attenuation in 5% damped acceleration response spectra (SA) is discussed. The empirical attenuation relationships are proposed using accelerograms recorded on the territory of the nearer countries Macedonia, Romania and Turkey. In spite the insufficient data we consider the derived attenuation relationship to be appropriate for predicting accelerations amplitudes of earthquakes of moment magnitude 4-6(Mw) and sites with epicentral distances R > 40 km around that tectonic region.

58. Stoynova I., **Ivanov R.**., Kazakov K., On the modelling of the failure of column-flat slab RC connection (in Bulgarian), 13 International conference VSU'2013, Sofia, Bulgaria, 2013, Vol. I, pp. I-1 – I-6

This paper presents a critical review of mechanical models applicable to the investigation of punching shear arising at column - flat slab connections. Examined the characteristics of some finite elements, applied for modeling of punching shear arising at column-flat slab. An overview of the spatial continuum 3- D finite elements, and shell – elements, using for punching shear modeling and simulation with FEM.

59. Partov D., **Ivanov R.**, Dinev D., The History of the first Orthotropic Bridge in Bulgaria, Proceedings of the 3rd Orthotropic Bridge Conference, June, 26-28, Sacramento, California, USA, 2013, pp. 80-89

The paper presents the rehabilitation project for the movable bridge in Varna, following its failure in 1975. The existing old bridge was designed and built by the "MAN" company in 1939. In 1975 the movable part and one of

the stationary parts of the bridge was completely destroyed by a ship accident. The reconstruction included installing new superstructure in two bays, while the original structure in the third bay was kept in place. The movable and the one stationary part were designed as simply supported bridge structure with an orthotropic deck. The movable bridge consists of two identical Warren trusses with spans of 31.62 m. The members of the upper, the lower chords and compression diagonals have box cross-sections; the tension diagonals have "I"- shaped cross-sections. The truss deck is an orthotropic plate structure and consists of a 12 mm thick steel plate, stiffened by longitudinal ribs with dimensions of 10x160 mm at 300 mm centers. The stationary parts were designed as a simply supported bridge with an orthotropic deck. The superstructure consists of two main girders which are 2.80 m deep with a distance between them of 8.00 m. The steel deck is 12 mm thick and 13. 86 m wide. The bridge is a 3-span steel structure with a total length of 80.34 m. The lateral bracing of the deck is a "K"-truss placed at the lower flanges of the main girders.

60. Paskaleva I., **Ivanov R.** and Dojcinovski D., Analysis of the 22nd May 2012 earthquake (Western Bulgaria) to evaluate regional attenuation, Third international conference ESI'2013, Pernik, pp. 123-133

Abstract: An earthquake of magnitude 5.6 Mw hit Western Bulgaria, on May 22-th/ 3:00 am local time (00:00 UTC)/, 2012, 25km South West of the Bulgarian capital, Sofia. The depth is 9.4 km, epicenter coordinates 42 ° 41'10 "N 23 ° 00'32" E; maximum intensity MM VII and aftershock series in this day - 4.6 Mw and 4.3Mw. This shallow earthquake was largely felt in the region and up to Greece, Macedonia, Turkey and Romania. No severe injuries have been reported so far, though a state of emergency was declared in Pernik (the closest city to the epicenter) and superficial damages were observed.

Those statements provoked the aim of this work. The analyses of attenuation of the peak ground acceleration (PGA) with the distance from the source as well the attenuation in 5% damped pseudo-absolute acceleration response spectra (PSA) is carried out. The empirical attenuation relationships are proposed using accelerograms recorded on the territory of the nearer countries Macedonia, Romania and Turkey. In spite the insufficient data we consider the derived attenuation relationships to be appropriate for predicting accelerations amplitudes of earthquakes of moment magnitude Mw = 4 - 6 at sites with epicentral distances R > 40 km around that tectonic region.

61. Ivanov R., Applications of the discrete element method in earthquake engineering, 4th Specialist Conference "Seismic Engineering and Engineering Seismology", 19÷21 May 2014, Bor, Serbia, pp. 35 - 46

The current needs of earthquake engineering require effective tools for assessing the behaviour of structures until a state of complete failure is reached. The discrete element method (DEM) is outlined, and its ability to simulate the real time earthquake response of large scale RC structures is demonstrated by case studies on a single column bridge pier. The performance of the method is also demonstrated by failure analysis of a pipeline, and the analysis of the movement of unrestrained bodies (furniture) during earthquake. In all examples the power of the method in capturing the behaviour of the structures from the initial elastic stage well into the post-failure stage is demonstrated.

62. Paskaleva, I., **Ivanov R.**, An application of generating artificial earthquake accelerograms matched to the 22, May, 2012 Earthquake (Western Bulgaria), 14 International conference VSU'2014, 5 - 6 June 2014 , Sofia, Bulgaria . Vol. II, pp. 297-303

An earthquake of magnitude 5.6 Mw hit Western Bulgaria, on May 22-th/3:00 am local time (00:00 UTC)/, 2012, 25km South West of the Bulgarian capital, Sofia. The depth is 9.4 km, epicenter coordinates 42 ° 41'10 "N 23 ° 00'32" E; maximum intensity MM VII and aftershock series in this day - 4.6 Mw and 4.3Mw. This shallow earthquake was largely felt in the region and up to Greece, Macedonia, Turkey and Romania. No severe injuries have been reported so far, though a state of emergency was declared in Pernik (the closest city to the epicenter) and superficial damages were observed. The absence of real time histories and limited access at to real accelerograms for the region of most affected town Pernik provoked this work. An application capable of generating artificial earthquake accelerograms matched to a specific target response spectrum using different calculation methods and

varied assumptions is discussed. It is noted that the use of real accelerograms and spectrum matching techniques can be recommended for the derivation of suits of records for use in nonlinear dynamic analysis of structures.

63. Stoynova I., **Ivanov R.**, Kazakov K., On some finite elements used for modelling of cracking in concrete, 14 International conference VSU'2014, Sofia, Bulgaria, 2014, Vol. IV, pp. 93-99

This paper presents a critical review of approaches, applicable to the modeling of fractures and fractures process zones. The appearance and distribution of cracks is a process, related to the dissipation of energy, i.e. a softening of the structure and redistribution of internal forces. To avoid this brittle failure mechanism different models have been developed for its prediction. An overview of the finite elements, used for failure modeling and simulation by the FEM is presented

64. Partov D., **Ivanov R.** and Petkov M., Design Peculiarities on Some Details used in the Back Anchors for Tunnel Boring Machine(TBM), for Excavated of Metro Tunnels in Sofia, 14 International conference VSU'2014, Sofia, Bulgaria, 2014, Vol. II pp. 267-272.

The tunnels of Sofia metro in the city central area are excavated by tunnel boring machines (TBM). A TBM requires a temporary support called a back anchor to initiate the drilling and get inside the tunnel. The design brief submitted by warrants Taisei Co.(Japan) and "Doğuş Co"(Turkey) included two principle requirements to be met by the structure, namely, the design values of the forces acting on the back anchor and their application points, the type of hot rolled section to be used and an outline of the geometry of the structure commensurate with the dimensions of the TMB and the available space on site. It consists of two or one vertical frames parallel to the TMB axis which transfer the forces by mainly truss action. The overall 3-D stability of the structure is achieved by designing all memberto-member connections as rigid. Bracing is avoided as much as possible to facilitate construction of the back anchor and operation of the TBM

65. Stoynova I., **Ivanov R.**, Kazakov K., On the punching shear arising at column - flat slab connections, Proc.: DCB 2014, 11-13 Sept., Varna, (2014). (CD)

The flat slab reinforced concrete systems is widely used in modern construction. Application of concrete flat slab structures in modern construction is determined by their economical and functional advantages. However, there remains the problem of brittle fracture in punching, which is due to the transfer of shearing forces and unbalanced moments in flat slab-column connection. This paper provides an overview of the effect of various interrelated factors that manage punching resistance and behavior of column-flat slab connection, as well as their inclusion in current Codes.

66. Partov D., **Ivanov R.**, Petkov M., Survey of some types of back anchors for tunnel boring machine (TBM), used for excavation of metro tunnels in Sofia. International conference VSU 2012, Sofia, Bulgaria, Vol. I, 2012, pp. I-34 – I-40

The papers describes the choice of three various type of structural configuration of back anchors, using in the process of excavated of metro tunnels in Sofia. Finally, the construction process, the materials used, the static analysis and the monitoring of the structure during the TBM start are described.

67. Partov D. **Ivanov R.**, Petkov M., Design of some types of back anchors for Tunnel Boring Machine (TBM), used for excavation of Metro Tunels in Sofia" Proceedings of the International Conference, EUROSTEEL 2014, Naples, Italy, 2014, CD

The tunnels of Sofia metro in the city central area are excavated by tunnel boring machines (TBM). A TBM requires a temporary support called a back anchor to initiate the drilling and get inside the tunnel. The design brief submitted by warrants Taisei Co.(Japan) and "Doğuş Co"(Turkey) included two principle requirements to be met by the structure, namely, the design values of the forces acting on the back anchor and their application points, the type of hot rolled section to be used and an outline of the geometry of the structure commensurate with the dimensions of

the TMB and the available space on site. It consists of two or one vertical frames parallel to the TMB axis which transfer the forces by mainly truss action. The overall 3-D stability of the structure is achieved by designing all member-to-member connections as rigid. Bracing is avoided as much as possible to facilitate construction of the back anchor and operation of the TBM.

68. Stoynova I., **Ivanov R.**, Kazakov K., The FEM for modelling of RC elements and connections, VII International conference „Architecture, Construction – Modernity“, Varna, Bulgaria, 2015, pp. 323-329

Concrete is a complex composite material. Behavior of elements of quasi-brittle materials, such as concrete is characterized by a significant strain localization in fracture process zone. In this paper are presented charasteristics of finite elements, used for modelling of punching shear at column-flat slab connection. An overview of the finite elements, used for modeling of concrete members and connections and simulation by the FEM is presented, as well as their implementation in an actual model.

69. Ivanov R., Digital accelerometer RT130-SM – construction and operation (in Bulgarian), 15 International conference VSU' 2015, Sofia, Bulgaria, 2015, pp. 211-216

A modern digital multi-channel accelerograph was acquired at VSU "L. Karavelov" being one of the experimental equipment financed by project BG161PO003-1.2.04-0031-C0001 of Operational Programme „Development of the Competitiveness of the Bulgarian Economy“. The accelerograph is model RT130- SM, manufactured by the US company REF TEK. In this paper the principles of operation of the equipment are outlined, and the specifications of the main components of the equipment – the recorder and the sensors are given. Then a review of the set-up and communication software is presented, as well as the options for control of start and end of a recording, moving set-up data to and from the recorder, saving and extracting recorded data. A review of the visualization software is presented as well emphasizing on the options for conversion of the raw data to a readable text format for further processing. The paper concludes with a review of the possible practical uses of the equipment.

70. Stoynova I., **Ivanov R.**, Kazakov K., The FEM for modelling of the column - flat slab connection, 15 International conference VSU' 2015, Sofia, Bulgaria, 2015, pp. 234-241

The flat slab reinforced concrete systems are widely used in modern construction. The application of concrete flat slab structures in modern construction is determined by their economical and functional advantages. However, there remains the problem of brittle fracture in punching, which is due to the transfer of shearing forces and unbalanced moments in flat slab-column connections. This paper presents a review of Hallgren's modified model of punching shear. An overview of the finite elements, used for column – flat slab connection modeling and simulation by the FEM is presented, as well as their implementation in an actual model.

71. Partov D., Maślak M., **Ivanov R.**, Petkov M., Sergeev D., Dimitrova A., Timber bridge over the river Osam in Lovech in the light of the world historic heritage bridge structures (Part I), 15 International conference VSU' 2015, Sofia, Bulgaria, 2015, pp. 272-277

In this paper the authors describe the construction of the wooden bridge, built by the great Bulgarian builder Kolyu Ficheto in 1874. The bridge spans the river Osam at Lovech and has a total length of about 86 m. The importance of this bridge for our engineering society is viewed in the context of world historic-cultural heritage in the field of wooden bridges.

72. Partov D., Maślak M., **Ivanov R.**, Petkov M., Sergeev D., Dimitrova A., Timber bridge over the river Osam in Lovech in the light of the world historic heritage bridge structures (Part II), 15 International conference VSU' 2015, Sofia, Bulgaria, 2015, pp. 278-283

In this paper the authors describe the construction of the wooden bridge, built by the great Bulgarian builder Kolyu Ficheto in 1874. The bridge spans the river Osam at Lovech and has a total length of about 86 m. The importance

of this bridge for our engineering society is viewed in the context of world historic-cultural heritage in the field of wooden bridges.

73. Stoynova I., **Ivanov R.**, Kazakov K., MODELLING OF PUNCHING SHEAR ARISING AT COLUMN – FLAT SLAB CONNECTION, In Proc.: IX International Conference "Assessment, Maintenance and Rehabilitation of Structures and Settlements" 25-29 May, Zlatibor, Serbia, 2015, pp. 427-434

Flat slab reinforced concrete systems are widely used in modern construction. The application of concrete flat slab structures in modern construction is determined by their economical and functional advantages. However, there remains the problem of brittle fracture in punching, which is due to the transfer of shearing forces and unbalanced moments in flat slab-column connection. This paper presents a critical review of mechanical models applicable to the investigation of punching shear arising at column flat slab connections. The characteristics of some finite elements, applied for modeling of punching shear arising at column flat slab are examined. An overview of the spatial continuum 3-D finite elements used for punching shear modeling and simulation by the FEM is presented.

74. Stoynova I., **Ivanov R.**, Kazakov K., FEM modeling of concrete and reinforced concrete members and connections, In Proc.: 16th International Symposium of MASE, 1-3 October 2015, Ohrid, FYROM, pp. 646-653

Slab-column connection in the flat slab system is frequently subjected to transverse shear forces, which can cause a punching shear failure. In this paper are presented characteristics of finite elements, used for modeling of punching shear at column-flat slab connection. An over view of the finite elements, used for modeling of concrete and reinforced concrete members and connections and simulation by the FEM is presented, as well as their implementation in an actual model. The models of concrete and reinforced concrete analyzed using the ANSYS program. The concrete is modeled using SOLID65 element, which is capable of simulating the cracking and crushing behavior of brittle materials. The reinforcement such as deformed bars, is modeled using BEAM188 element.

75. Stoynova I., Kazakov K., **Ivanov R.**, FEM modelling of concrete flat slab – column connection subjected to static loading, 13th Scientific conference ''Planning, design, construction and building renewal'' iNDiS 2015, 25-27 November 2015, Novi Sad, Serbia, 2015, pp. 116-123

Slab-column connection in the flat slab system is frequently subjected to transverse shear forces, which can cause a punching shear failure. An overview of the finite element, used for modeling of concrete members and connections and simulation by the FEM is presented, as well as their implementation in actual models. The models of concrete analyzed using the ANSYS program. Concrete model using for nonlinear elastic analysis is according to Eurocode 2, and plasticity of concrete is described by Willam и Warnke model. The concrete is modeled using SOLID65 finite element.

76. Partov D., **Ivanov R.**, Dinev D., Development of steel orthotropic bridges in Bulgaria, In Proc.: Symposium of the Association of Structural Engineers in Serbia, 15-17 Sept. 2016, Zlatibor, Serbia, pp. 677-686

In this paper the authors present the conceptual design and technology of construction of seven steel orthotropic bridge in Bulgaria. The particular structure proposed is described in detail, including structural action and detailed design of the orthotropic bridge deck, all principal and secondary members.

77. Partov D., **Ivanov R.**, Dinev D., 40 years from the structural rehabilitation of the small Asparuhov bridge in Varna, In Proc.: 16th International Symposium of MASE, Ohrid, FYROM, 2015, pp. 530-538, (CD)

The paper presents the rehabilitation project for the stationary and movable part of the existing old bridge in Varna, completely destroyed by a ship accident in 1975. The existing old bridge and the movable part of the bridge (Schercer type) is designed and built by the "MAN" company in 1939. The reconstruction after the ship accident in 1975 included installing new superstructure in two bays, while the original structure in the third bay was kept in place. Structural solution of stationary and movable part of the bridge, loading action types, static analysis and details of the design concepts are given.

78. Paskaleva I., **Ivanov R.**, A note on the bi-normalized response spectra for the 22, May, 2012 earthquake (western Bulgaria), XVI International Conference VSU'2016. Vol. I., Sofia, Bulgaria, 2016, pp. 287-292

The seismic design standards in seismic zones are based on universally accepted smooth response spectra. They are obtained from the use of the actual recordings by averaging a large number of elastic response spectra. Such spectra are constructed for each category of soil, essentially with plateau of the spectrum, usually equal to 2.5PGA, followed by descending branch of the acceleration. The range of periods on the plateau of constant acceleration is greater for soft soils. Analysis of the actual recordings shows that the flat shape of the spectra is different from the actual spectrum. By examining actual records, we demonstrate that the normalized spectral function SA/PGA(T), differs from the one of the bi-normalized spectrum SA/PGA(T/TP) which has a peak at T/TP = 1.0. The used records are from the earthquake of magnitude 5.6 Mw that hit Western Bulgaria, on May 22-th/ 3:00 am local time (00:00 UTC)/, 2012, 25km South West of the Bulgarian capital, Sofia. The depth is 9.4 km, epicenter coordinates 42 ° 41'10 "N 23 ° 00'32" E; maximum intensity MM VII and aftershock series in this day - 4.6 Mw and 4.3Mw. This shallow earthquake was largely felt in the region as well as in Greece, Macedonia, Turkey and Romania. No severe injuries have been reported so far, though a state of emergency was declared in Pernik (the closest city to the epicenter) and superficial damages were observed.

79. Stoynova I., Kazakov K., **Ivanov R.**, Nonlinear models of column-flat slab RC connection, XVI International Conference VSU'2016, Sofia, Bulgaria, 2016, Vol. II., pp.157-163

Slab-column connection in the flat slab system is frequently subjected to transverse shear forces, which can cause a punching shear failure. In this paper are presented characteristics of finite elements, used for modeling of nonlinear behavior at column-flat slab connection. An overview of the finite elements, used for modeling of concrete and reinforced concrete members and connections and simulation by the FEM is presented, as well as their implementation in an actual model. The models of concrete and reinforced concrete analysed using the ANSYS program. The concrete is modelled using SOLID65 element, which is capable of simulating the cracking and crushing behaviour of brittle materials. The reinforcement such as deformed bars, is modelled using BEAM188 element.

80. Stoynova I., Kazakov K., **Ivanov R.**, Modelling of reinforced concrete flat slab – column connection subjected to static load, Tuzla, BH, June 02-04, 2016

Slab-column connection in the flat slab system is frequently subjected to transverse shear forces, which can cause punching shear failure. Concrete is a complex composite material. Behavior of elements of quasi-brittle materials, such as concrete is characterized by significant strain localization in fracture process zone. An overview of the finite element, used for modeling of concrete members and connections and simulation by the FEM is presented, as well as their implementation in actual models. The models are analyzed using the ANSYS program. The concrete model used for nonlinear elastic analysis is according to Eurocode 2, and plasticity of concrete is described by the Willam и Warnk's model. The concrete is modeled using the SOLID65 finite element. The reinforcing bars are modeled using the BEAM188 finite element.

82. Paskaleva I., **Ivanov R.**, Comparison between records in Bulgaria and well-known international near-source records, XVII International Conference VSU'2017. Vol. I., Sofia, Bulgaria, 2017, pp. 77 -83

The work presents an analysis of strong-motion characteristics of Bulgarian records and some international near-source records from Greece and Italy. For a rational quantitative comparison, a selection of near-source records with intensity not greater than VII or VIII on the Modified Mercalli scale (MMI) are used. Several parameters of strong motion are evaluated and discussed. Emphasis is put on records from events with M < 6.0 which are found to satisfy several damage potential criteria, when recorded at small distances from the source. The predominant period of the velocity pulse, Tp, and the maximum ratio of spectral velocity to peak ground velocity, (SVmax / PGV) for a damping ratio ξ=0,05 attenuation are calculated and compared to the values of the selected near-source records. Since the records identified by the parametric study of the Bulgarian strong-motion databases are obtained in regions in which directivity phenomena have occurred, there is a strong indication that the damage criteria can be

successfully used to identify records with near-source characteristics. The ratio of spectral velocity (SV) to peak ground velocity (PGV) is a good indicator and criteria of the velocity pulse type. It can be stated also that for earthquakes of magnitude smaller than M = 6.0 its suitability to present near-source characteristics is enhanced.

83. Paskaleva I., **Ivanov R.**, Kaneva A., Ivanchev I., Seismic effects in the Pernik area after the 22, May 2012 earthquake, Sixth International Conference "Earthquake Engineering and Engineering Seismology, Kraljevo, Serbia, 2018, pp. 1-12

An earthquake of magnitude 5.6 Mw hit Western Bulgaria, on May 22, 2012. Its depth was 9.4 km, epicenter coordinates 42.66° N 23.01°E; maximum intensity MM VII. The source area of the earthquake is analysed, as well as observed damages to the building stock. The maximum ground velocity (PGV) distribution is presented. The strain distribution is computed on the basis of real records and analyses of attenuation of the PGV, the computation being deterministic only. An indicative plan distribution of ground strain and the resulting breaks in the water pipelines is also presented.

84. Kaneva A., Paskaleva I., **Ivanov R.**, Gorolomov A., Seismic risk of Pernik buried pipelines for potable water: preliminary study, Sixth International Conference "Earthquake Engineering and Engineering Seismology, Kraljevo, Serbia, 2018, pp. 371-379

The 22nd May 2012 earthquake caused damages to many buildings in Pernik and the vicinity. Damages to the underground pipelines were not investigated after the earthquake. The goal of the present paper is to outline the approaches for seismic risk analysis of the water system of Pernik and make preliminary analysis of the likelihood of occurrence of damages, breaks or leaks in the water system due to the earthquake of 2012, based on public data for the pipelines and assessment of the effects of the earthquake

85. Antoaneta Kaneva, Ivanka Paskaleva, **Radan Ivanov**, Ivan Ivanchev, Anton Gorolomov (2018) Behavior of the water pipelines in Pernik during the May, 2012 earthquake, *X Jubilee International Scientific Conference* „Civil Engineering Design and Construction" (Science and Pract1ice), Sept. 20-22, 2018, Varna, Bulgaria (ISBN 2603-4255) pp.595-604.

On 22 May 2012 an earthquake, 5km North-West from the centre of the town of Pernik, Bulgaria, caused damages to many buildings in the town and in the surrounding villages. Damages to the underground pipelines and structures were not reported, since they remain hidden from the eyes and usually are not recognized immediately after an earthquake. This paper investigates the seismic behaviour of the buried pipelines in Pernik based on previous research (analytical and field observations after earthquakes) analysing the seismic response using a complex investigation approach. In the present report different approaches are applied to assess the damages to the water system pipelines of Pernik due to the earthquake on 22 May, 2012. As the intensity measures of the earthquake in the vulnerability relations vary (MM intensity, PGV, strain), the earthquake of 2012 is adequately analysed in terms of those intensity measures. The results of the assessment are discussed in relation to the observed damages in the sewage system of Pernik.

86. Radan Ivanov, Antoaneta Kaneva, Ivanka Paskaleva, Ivan Ivanchev, Anton Gorolomov (2018) Earthquake-induced ground motion effects from the seismic sequence of 2012, May on the territory of Pernik, *XVIII Jubilee International Scientific Conference* „Civil Engineering Design and Architecture", October. 18-20, 2018, Sofia, Bulgaria, pp. 294-299

An overview of the source area of the destructive earthquake of 22, May 2012 (M5.6) in Pernik is provided. The depth structure and the geodynamics of the seismic source are discussed. The town is covered by a mesh of 100m x 100m, and a deterministic maximum ground velocity (PGV) distribution is obtained in the vicinity of Pernik, using a Ground Motion Prediction Equation. The expected duration of ground motions for all investigated locations is obtained by an empirical equation with parameters the magnitude, the distance to causative fault and the local soil conditions. Finally, the results for ground velocity and duration of shaking are used jointly with data for the shear modulus of soil and three levels of overburden pressure to obtain the SPT N-values below which liquefaction is

expected to occur for each of the two levels of earthquake analysed in the paper – the actual 22, May 2012 (M5.6) earthquake, and the largest plausible earthquake for the site (M7.0)

87. Ivanov R., Paskaleva I., Kaneva A., Ivanchev I., Gorolomov A. (2018) Initial results of the „SEAT“ project – seismic hazard and water pipelines damage estimates, Conference iNDiS 2018 Novy Sad, pp. 27-42

The “SEAT” project has a two-fold objective to quantify the seismic hazard for the town of Pernik on one hand, and to assess the damages to the existing water pipelines on the other. The ground motion effects most directly related to damage of underground infrastructure - the ground velocity, the ground strain and soil liquefaction are assessed by empirical methods. Three estimates are produced for the damages in the water and sewerage pipelines for two magnitude levels M5.6 of the 22 May 2102 earthquake and M7.0 of the maximum plausible earthquake; by the HAZUS methodology, by the ALA methodology, and by an empirical equation relating ground strain to pipeline damage

89. D. Partov, M. Maślak, **R. Ivanov**, M. Petkov, D. Sergeev, A. Dimitrova, The development of wooden bridges through the ages – a review of selected examples of heritage objects. Part 1 – the milestones, Technical Transactions; Civil Engineering, 2-B, Poland, 2016, pp. 93-105

In this article, selected examples of heritage wooden bridges, which were built over the centuries in various parts of the world, are presented and briefly discussed. The overview allows the observation of not only the continuous progress in the techniques used to construct bridges of this type but also the variety of the design solutions applied.

90. D. Partov, M. Maślak, **R. Ivanov**, M. Petkov, D. Sergeev, A. Dimitrova, The development of wooden bridges through the ages – a review of selected examples of heritage objects. Part 2 – the iconic structures from the western slavdom area and those that inspired them, Technical Transactions; Civil Engineering, 2-B, Poland, 2016, pp. 107-120

In the second part of this article, the development of the timber bridges is shown in detail in relation to the historical and cultural contexts specific to different regions subjectively selected from around the world. For such a purpose, some iconic timber bridges are presented and discussed on a country by country basis. Their mutual comparison allows us not only to appreciate the craftsmanship of both ancient and medieval builders but also to see the diversity of the proposed structural solutions.

91. D. Partov, M. Maślak, **R. Ivanov**, M. Petkov, D. Sergeev, A. Dimitrova, A covered wooden bridge over the Osam river in the Bulgarian town of Lovech – its history and the present day, Technical Transactions; Civil Engineering, 2-B, Poland, 2016, pp. 121-131

The history and structure of the historical covered wooden bridge built over the Osam River in the Bulgarian town of Lovech is described and discussed in detail. This bridge was completed in 1874 by Kolyu Ficheto and had a total length of approximately 86 m. The original bridge burned down in 1925. Its present structure is partially made from reinforced concrete and was opened to the traffic in 1931.

94. Iliev V, **Ivanov R**, Geshkova Z, Samichkov V, Yavorov N. Constitutive Model of Unplasticized Polyvinyl Chloride for Numerical Stress-Strain Analysis. Science, Engineering & Education, 5, 1, Химикотехнологичен и металургичен университет, 2020, ISSN:2534-8507, pp. 3-8

The mechanical properties of unplasticized polyvinyl chloride (UPVC) are modified during the manufacturing process of a product. Therefore, the data on the mechanical behavior of this material available in the scientific literature varies greatly. This requires that the type of mechanical behavior of the material and the corresponding constitutive model to be determined on a case-by-case basis. In the present work, an investigation of the mechanical behavior of UPVC is presented in order to select a model, best describing the material behavior at highly heterogeneous stress distributions within the structure. Twelve specimens from different parts of PVC window frames and sashes made by Weiss Profil, Bulgaria, have been tested under tension according to Bulgarian standard

12602-81. The mechanical behavior of the material and the corresponding material characteristics have been determined from the stress-strain curve obtained by the test. The research is directed at identifying the material model parameters, incorporated in FEM software used for the stress-strain analysis of load-bearing structures.

95. Geshkova, Z., Iliev, V., **Ivanov, R.**. Influence of the degree of stress triaxiality and the Lode angle on the fracture behavior of window frames. Science, Engineering & Education, 6, 1, Химикотехнологичен и металургичен университет, 2021, ISSN:2534-8507, pp. 18-26

The validity of the fracture models, based on plastic strain tensor invariants, is limited to predicting failure under specific stress states. The models can be made more general by including two additional characteristics of the stress state – the stress triaxiality and the Lode angle. In the present work, these characteristics are used in identifying the type of stress state and expected type of failure during the opening of a corner joint of a window frame, made of UPVC profiles. The characteristics are calculated from the principal and the equivalent (von Mises) stresses, obtained by numerical simulation with Ansys Mechanical. The obtained results for the type of stress state and expected type of failure can be used in the selection of a model for the analysis of crack formation processes and fracture of windowframe corner joints.

100. Geshkova, Z., Iliev, V., **Ivanov, R.**. Fracture analysis of corner joints of PVC window frames. XXI Anniversary International Scientific Conference "Construction and Architecture" VSU'2021, Висше строително училище "Любен Каравелов", 2021, pp. 54-62

Under normal operating conditions, structures made of welded profiles, such as PVC window frames, work together with the glazing and these two parts can be considered as a composite planar structure. However, before installation the two parts are transported separately, so it is necessary to secure them against static and dynamic transport loads. One of the most vulnerable locations of the window frames is the corner joints of its profiles. While for the thermal characteristics of these products a number of researches exist, research on their mechanical behavior is scarce. Detailed research of the total structure-load system and the fracture behavior is possible with the help of numerical modeling and computer simulation. The present article offers a methodology for the establishment of a model for numerical simulation of fracture behavior of UPVC window frames and identification of the parameters of the model related to the material characteristics. The methodology is based on the Cohesive Zone Model with maximum normal contact stress and contact gap at the completion of debonding as material characteristics of the model. Numerical experiments have been performed following the adopted methodology, varying the material characteristics, while the maximum stress at the tip of the crack and the crack status are monitored. The results obtained can be used in the identification of missing values of material characteristics and verification of models with similar features.

102. Цветкова, Т., Кутева-Генчева, М., **Иванов, Р.** Необходимостта и ползата от цифрови модели на сеизмичното натоварване от реално възникнали сеизмични събития. Сборни доклади; I младежка научна конференция с международно участие „Проектиране и строителство на сгради и съоръжения" DCB 2021, Научно-техническият съюз по строителство в България, 2021, ISSN 2738-7887, pp. 178-186

The age of most of the buildings and infrastructure facilities in Europe, including Bulgaria, compared to the evolution of standards for design and construction of earthquake-resistant buildings and facilities, poses a number of serious challenges to the engineers to assess the cumulative effect of past seismic events and the estimated assessment of potential damage. In this regard, basic engineering parameters that can be derived from the waveforms of seismic signals and used as a measure of earthquake impact are considered. Based on the analysis of publicly available international data, the seismic load parameters are dependent on the geological environment of the seismic wave propagation and the mechanism of occurrence of the seismic event. The necessity and the benefit of the availability of instrumental data – records of the movement of the earth base and the characteristic points in the analyzed structures during the earthquake, reflecting the specifics on the site, the region and the respective seismic sources are commented.

106. Emil Oynakov, **Radan Ivanov**, Irena Aleksandrova, Mariya Popova, Jordan Milkov. AQUIFER IDENTIFICATION BY PASSIVE SEISMIC METHODS IN SELECTED AREAS OF THE SOFIA BASIN. Proceedings: INTERNATIONAL SCIENTIFIC CONFERENCE GEOTECHNICAL ASPECTS OF CIVIL ENGINEERNIG AND EARTHQUAKE ENGINEERING, Association of Civil Engineers of Serbia, 2023, ISBN:978-86-88897-17-4, 17-34

Seismic noise methods are now widely used in geophysics as easy and non-invasive techniques to characterize the Earth's subsurface. In the present study, the F-K, H/V and the SPAC methods were applied, with the main objective to determine the thickness and physical properties of soil materials and the groundwater level in two areas of the Sofia Basin: "Manastirski Livadi“ and "Loven Park". For the H/V method we used a single Etna - 2 accelerometer to record seismic noise vibrations. On the other hand, for the F-K and SPAC methods we use an array of Etna - 2 accelerometers to obtain data. The processing and inversion of the seismic noise time-histories yielded the propagation velocity of the Rayleigh waves for each subsurface layer, and provided a good characterization of the material forming the layers. The velocity profiles obtained by all three methods in both studied areas are presented and compared with available borehole data. In practice, these profiles do not always correspond to geological data. Taking this into account, combined profiles were created from the results obtained by the three methods.

112. Pashova L., Radulov A., **Ivanov R.**, Dimitrova L. CARTOGRAPHIC REPRESENTATION ANALYSIS OF EARTHQUAKE HAZARD AND RISK MAPS FOR THE SOFIA REGION. Proceedings, 9th International Conference on Cartography and GIS, 16-21 June 2024, Nessebar, Bulgaria, Bulgarian Cartographic Association, 2024, ISSN:1314-0604, 1022-1033

The concentration of population and socio-economic and cultural activities in the capital city of Sofia leads to an increase in seismic risk with possible long-term consequences. This paper examines some aspects of seismotectonic model inputs, seismic source assumptions, and seismic activity modeling that are particularly important in seismic hazard and risk mapping. Several thematic maps published in the last two decades as a final product of the seismic hazard assessment (SHA) for Sofia are analyzed. The cartographic evaluation of these thematic maps is performed regarding hazard map content, depicted content, visualization methods, and cartographic layout. Comparisons are made with seismic hazard maps of other countries, and the advantages and disadvantages of specific criteria followed in the preparation of the map products are analyzed. Available national and European web-based GIS platforms providing access to up-to-date versions of seismic hazard and risk maps with different spatial resolutions for the Sofia region are discussed.

113. Radan Ivanov. ANALYSIS OF THE ROCKING BEHAVIOUR OF BUILDINGS DURING EARTHQUAKE BY THE DISCRETE ELEMENT METHOD. Proceedings: 13th ITERNATIONAL SCIENTIFIC FORUM CONDITION ASSESSMENT, MAINTENANCE AND REHABILITATION OF CIVIL ENGINEERING FACILITIES, Association of Civil Engineers of Serbia, 2024, ISBN:978-86-88897-20-4, DOI:10.46793/SGISXIII.09RI, 100-107

Incorporating the possibility for rocking motion into the design of structures can contribute to their seismic resilience and improve their ability to withstand earthquake-induced forces. A review of the history of rocking motion analysis is done, both in terms of methods and practical implications. This is followed by a framework for the implementation of the Discrete Element Method (DEM) for rocking analysis of a rigid body as it can be carried out by the open-code software Yade. The clump feature on which the simulation is based is explained in detail. A rigid-body model of a typical Bulgarian reinforced concrete residential building was created and analyzed by Yade for three levels of ground motion with PGV of up to 2.1 m/s. The rocking response of the building and its dependence on the intensity of ground motion are successfully demonstrated.

114. Пашова Л., **Иванов Р.**, Паскалева И. Анализ на силни земни движения от земетресението в гр. Перник, 22 май 2012 г., записани в района на гр. София. СУБ, Съюз на учените в България, 2024, ISBN:978-954-397-050-6, 128-135

На 22 май 2012 г. земетресение с магнитуд Ms=5.8 (Mw=5.6) удари Пернишка област и нанесе материални щети на много сгради в град Перник и близките села. Максималната наблюдавана интензивност в някои села е от VII-VIII степен по EMS64 скàла. Непосредствено след събитието са извършени комплексни полеви

проучвания, анализ и оценка на сеизмичния източник и сеизмичното въздействие върху строителни обекти за район обхващащ гр. Перник, околностите му и в гр. София. В настоящата работа са анализирани акселерометрични трикомпонентни записи в две станции от мрежата за силни земни движения на НИГГГ-БАН – VTS и SGFI. Първата е инсталирана в геофизичната обсерватория на Витоша планина, а втората - в сградата на института. Те отстоят от сеизмичното огнище съответно на епицентрално разстояние 19 km и 30 km. Разгледани са тези две представителни точки с цел да се определи влиянието на топографията и инженерно-геоложките условия. Оценени са основни параметри на силното земно движение следвайки хармонизирани процедури, които са от интерес за инженерната общност. Получените резултати може да са полезни за строителната практика и използвани за получаване на входни характеристики, свързани с антисеизмично проектиране на сгради и съоръжения.

Изготвил:……..

/доц. д-р инж. Р. Иванов/