UNIVERSITY OF EAST SARAJEVO

FACULTY OF MECHANICAL ENGINEERING

7th INTERNATIONAL SCIENTIFIC CONFERENCE

COMETa 2024

„Conference on Mechanical Engineering Technologies and Applications“

PROCEEDINGS

14th-16th November East Sarajevo, RS, B&H

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Jahorina, B&H, Republic of Srpska

University of East Sarajevo
Faculty of Mechanical Engineering
Conference on Mechanical Engineering Technologies and Applications

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East Sarajevo, B&H, RS
14th – 16th November, 2024

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PREFACE

Mechanical engineering, as one of the basic engineering disciplines, represents the key to understanding and improving many aspects of modern society. From the development of energy-efficient systems, through advanced materials and production technologies, to robotics and automation, mechanical engineering is at the very heart of innovation, which drives the global economy and contributes to a better quality of life. Contemporary trends in mechanical engineering, such as the application of artificial intelligence, additive technology, digital transformation, minimizing the impact of industrial processes on the environment, etc. widely open new horizons and opportunities for our profession. Through mutual cooperation, interdisciplinary approaches and the integration of new technologies, we can find solutions that will shape the future of industry and society. Today, our profession faces numerous challenges, which are the result of accelerated technological development. They are at the same time extremely complex, but also very inspiring and require not only technical expertise, but also creativity, cooperation and a constant desire for new scientific achievements. Therefore, we must be able to recognize and implement new approaches, methodologies and technologies. Moreover, only a holistic approach in the application of knowledge in various engineering fields, and especially in the field of mechanical engineering, is a safe way into the future. Finally, in today's world, which is rapidly changing under the influence of global economic, environmental and social factors, it is important that all of us, who deal with the field of mechanical engineering from various aspects, do not forget our responsibility. In this context, engineering ethics, quality of work and continuous education play a crucial role.

Although the scientific research process is crucial for economic progress, we must not forget the importance of educating new generations of mechanical engineers. The conference COMETa 2024 is precisely an extraordinary opportunity to further encourage young researchers and students to actively engage in scientific activities through the development of their ideas. In this sense, academic institutions have a great responsibility to provide quality education and research programs to future generations.

Recognizing the importance of the broad field of mechanical engineering for the overall industrial development of society, the work of the conference will take place through 5 sections. The program is focused on the following thematic areas:

Manufacturing technologies and advanced materials,
Applied mechanics and mechatronics,
Machine design, simulation and modeling,
Product development and mechanical systems,
Energy and thermotechnic,
Renewable energy and environmental,
Maintenance and technical diagnostics,
Quality, management and organization.

Also, as part of the conference program, one round table and two workshops will be held, whose topics relate to the generation of ideas and proposals for future project activities that must inevitably be based on innovation, quality, and upcoming machine technologies, which is actually in accordance with the Development strategy of science and technology of the Republic of Srpska for the period 2023-2029, in which education, science, technology, research, innovation, and digitization are recognized as key prerequisites for achieving a sustainable economy.

Many experts, researchers, university professors, businessmen and students from various fields of mechanical engineering have registered to participate in this edition of conference COMETa 2024. The topics that will be discussed by the scientific and professional public will certainly contribute to the acquisition of new knowledge and open up a lot of space for future innovations. 77 papers will be published in the Conference proceedings, including 3 plenary lectures. The fact that numerous participants from abroad have been registered for the conference COMETa 2024 this year is especially pleasing.

Namely, 262 authors come from 16 countries. The review team is composed of 53 colleagues from the country and abroad. This is certainly the result of strenuous activities that were aimed at raising the international reputation and visibility of the conference in the regional, but also in the wider academic and scientific research area, which will be one of our primary goals in the future.

We are sure that the work at the conference COMETa 2024 will be fruitful and that each of you, after its end, will leave with new ideas, knowledge and contacts that will contribute to your further professional development. This is an opportunity not only to learn from each other, but also to build the foundations for future research projects and industrial innovations together. In addition, we believe that in the coming days we will have the chance to get to know each other better, discuss common challenges and establish new forms of cooperation. In this sense, we would like to point out that all your proposals and suggestions are more than welcome and will be carefully considered by the Organizing and Scientific Committee in order to improve the organization of the next conferences.

Finally, on behalf of the Organizing and Scientific Committee of the conference COMETa 2024, we express our great gratitude to all authors, reviewers, universities and faculties, business entities, and national and international institutions and organizations that supported the organization of the conference. Special thanks go to the Ministry of Scientific and Technological Development and Higher Education of the Repubilc of Srpska, the City of East Sarajevo, the Municipalities of East New Sarajevo, East Ilidža and Pale, without whose help the organization and work of the conference certainly could not be at the level that its status deserves.

East Sarajevo, November 13th, 2024.

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USER INTERFACE DEVELOPMENT FOR IDENTIFYING CDP CONSTITUTIVE MODEL PARAMETERS

Dragan Rakić[1], Vukašin Slavković[2], Aleksandar Bodić[3], Milan Bojović[4], Miroslav Živković[5]

Abstract: This paper presents the development of a user interface for the automatic identification of concrete damage plasticity (CDP) constitutive model parameters, based on the results of experimental results. The application uses the results of uniaxial compressive and tensile tests. CDP constitutive model is often used in the simulation of the mechanical behaviour of concrete, and with appropriate modifications it can also be used to simulate the behaviour of the rock mass. The theoretical basis of the concrete damage plasticity constitutive model is given in the paper and the theoretical meaning of certain parameters is explained. In order to unambiguously identify the material parameters, it is necessary to obtain the experimental stress-strain dependence, as well as the stress-degradation dependence. In order to determine these dependencies, it is necessary to carry out load-unload tests, until the complete failure of the specimen. Verification of the material parameters obtained by the identification process using the developed user interface was carried out through numerical simulations of uniaxial compression and tension tests using PAK software.

Key words: concrete damage plasticity, finite element method, material parameters identification, PAK, user interface

1 INTRODUCTION

Concrete is a highly heterogeneous material that exhibits complex, nonlinear mechanical behavior. Therefore, precise description of concrete behavior within numerical simulations of concrete structures is very difficult. In addition, accurate definition and assessment of damage within concrete structures represents a great

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challenge for engineers and researchers. To address these complexities in finite element analysis (FEA) of concrete structures, material models are employed [1]. One widely utilized example is the Concrete Damaged Plasticity (CDP) model which integrates the principles of plasticity and damage mechanics, enabling a more comprehensive and effective analysis of concrete behaviour under various loading conditions [2, 3]. Nowadays, is there many papers where CDP is used for the numerical analysis of structures such as: reinforced concrete structures with glass fiber-reinforced polymers [4] or carbon-fiber reinforced polymers [5], corners of reinforced concrete frames [6], reinforced concrete shear walls [7], reinforced concrete buildings subjected to blast loading [8], missile impact on reinforced concrete structures [9, 10], etc. Therefore, it can be concluded that the application of this material model is very widespread and significant in the numerical analysis of concrete structures.

A great challenge in using this material model is the correct determination of its parameters. Accordingly, procedures developed for the identification of the parameters of this material model can be found in literature [11, 12, 13]. This paper is a continuation of the previous research [14] in which a methodology was developed for determining CDP parameters. In this paper, an application developed for the automatic determination of parameters based on experimental data from uniaxial compression and tension tests is presented. Verification is performed by comparing results of numerical analysis with experimental data from literature [15, 16].

2 THEORETICAL BASICS

2.1 Concrete damaged plasticity material model

The yield function of CDP material model [3] is defined by equation:

$$F(\bar{\boldsymbol{\sigma}},\boldsymbol{\kappa}) = \frac{1}{1-\alpha}\left(\alpha \bar{I}_1 + \sqrt{\frac{3}{2}}\left\|\bar{\mathbf{S}}\right\| + \beta\left(\boldsymbol{\kappa}\right)\left\langle \bar{\sigma}_{\max}\right\rangle\right) - c_c\left(\boldsymbol{\kappa}\right) \le 0 \quad (1)$$

where $c_c\left(\boldsymbol{\kappa}\right)$ is material cohesion, $\bar{I}_1$ is first stress invariant, $\bar{\mathbf{S}}$ is deviator of effective stress, $\bar{\sigma}_m$ is mean effective stress, $\bar{\sigma}_{\max}$ is algebraic maximum of eigenvalues of effective stress tensor.

The effective stress – total strain dependence for tension and compression is shown in Figure *1*, where the terms in the figure are: $f_c^{'}$ is compressive strength, $f_t^{'}$ is tensile strength, f_{c0} is compression yield stress, E_0 is initial value of Elasticity modulus, d_c *is* damage parameter for compression, d_t is damage parameter for tension, e^E is elastic strain, e^P is plastic strain.

2.2 Identification of CDP material parameters

Identification of concrete damaged plasticity material model parameters can be performed by using experimental results of the cyclic loading-unloading uniaxial compression and tension tests. The following is an overview and identification procedure of material model parameters [14].

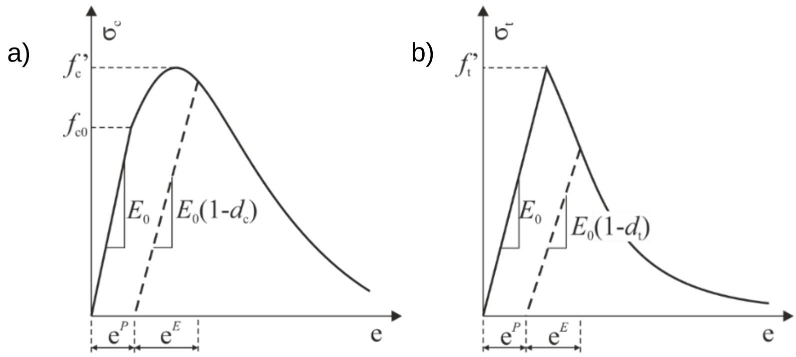

Figure 1. *Dependence of stress on total strain for: a) compression and b) tension*

Based on the stress-strain dependence, using basic relations from the theory of plasticity and damage theory, stress-plastic strain and stress-degradation dependences can be determined. Young's modulus represents the dependence between stress and strain in the elastic behavior region of a material and it can be determined as the initial slope of the curve on the stress-total strain chart. Value of degradation can be determined at each unloading cycle based on the current and initial elasticity modulus of material using equation:

$$E = (1-\mathrm{d})E_0 \tag{2}$$

Based on that it is possible to create stress-plastic strain and stress-degradation chart for uniaxial compression and tension, which are essential for determining other parameters. Compressive and tensile strength represent maximum stress values on stress-total strain chart and can be read directly from those charts. Compression curve parameter a_c can be determined from relation between compressive strength and yield stress which is given by equation:

$$f_c^{'} = f_{cm} = f_{c0}\frac{\left(1+a_c\right)^2}{4a_c} \tag{3}$$

Parameter D_c represents the degradation which corresponds to the compressive strength. Parameter D_t represents degradation which corresponds to the stress value $f_t^{'}/2$. Both parameter scan be determined from the stress-degradation charts (Figure *2*) for compression and tension tests, respectively.

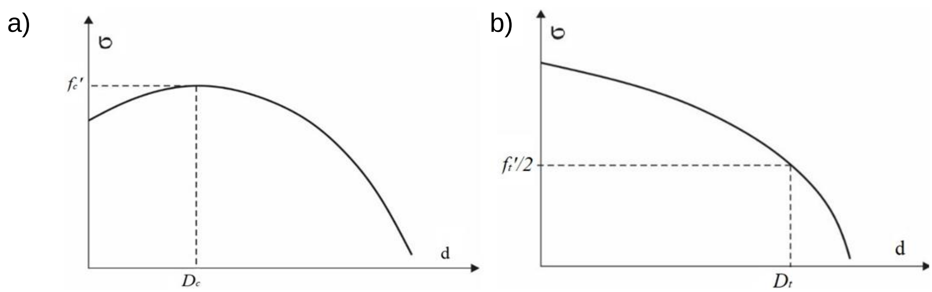

Figure 2. *Determination of a) D_c and b) D_t parameter*

The compressive fracture energy G_c and the tensile fracture energy G_t represent the areas below the stress-plastic strain curve for uniaxial compression and tension tests, respectively.

Parameter D_{cr} represents the maximum value of degradation that can be reached during uniaxial compression and tension tests. The parameter α defines the ration of the uniaxial and biaxial initial yield stresses and can be calculated using:

$$\alpha = \frac{\frac{f_{b0}}{f_{c0}} - 1}{2\frac{f_{b0}}{f_{c0}} - 1} \tag{4}$$

where f_{c0} and f_{b0} represent initial yield stresses for uniaxial and biaxial compression.

The parameter γ defines the ratio of the second invariant of deviatoric stress in the tension and compression meridians, which correspond to the same value of the first stress invariant. The dilatation parameter α_p represents the tangent of the dilatation angle ψ .

3 USER INTERFACE FOR AUTOMATIC IDENTIFICATION OF CDP PARAMETERS

In this part, we present the basic functionalities of the GeoGraphy toolbox, a tool intended for the automatic determination of CDP model parameters. This tool enables FEM engineers working with geomaterials to automatically determine the material parameters related to concrete material using the values of experimental results. GeoGraphy toolbox is written in Python language using libraries: PyQt5, matplotlib, numpy and scipy. shows the layout of the window with the available options: palette of basic options, space for plotting experimental results, options for manipulation of experimental results and determination of individual parameters.

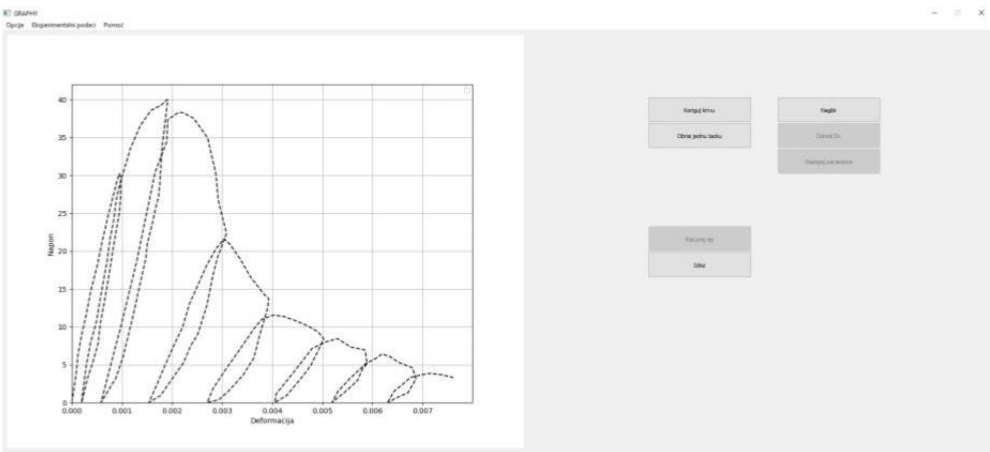

Figure 3. *Toolbox after loading the compression experimental results*

Experimental results obtained for concrete model often contain certain imperfections, inaccuracies or there is a lack of a certain part of the data. The developed GeoGraphy toolbox enables engineers to directly interact with experimental data, manipulate and correct obtained experimental curves and add missing parts of data. The stress-strain curves recreated and modified in this way can be used as a basis for determining certain parameters of the model graphically. Figure *3* shows the toolbox window after loading the compression experiment stress-strain curve (dashed black line). After loading the experimental results, it is possible to directly graphically correct the displayed curve and determine new slope values during relaxation. In order to make the work of engineers easier during manipulation, it is possible to recreate the entire curve, parts of the curve or delete individual points. After recreating the stress-strain curve, it is possible to export the parameter values to a file. Figure 4 shows the recreated stress-strain curve (blue solid line) and slopes (dashed green line).

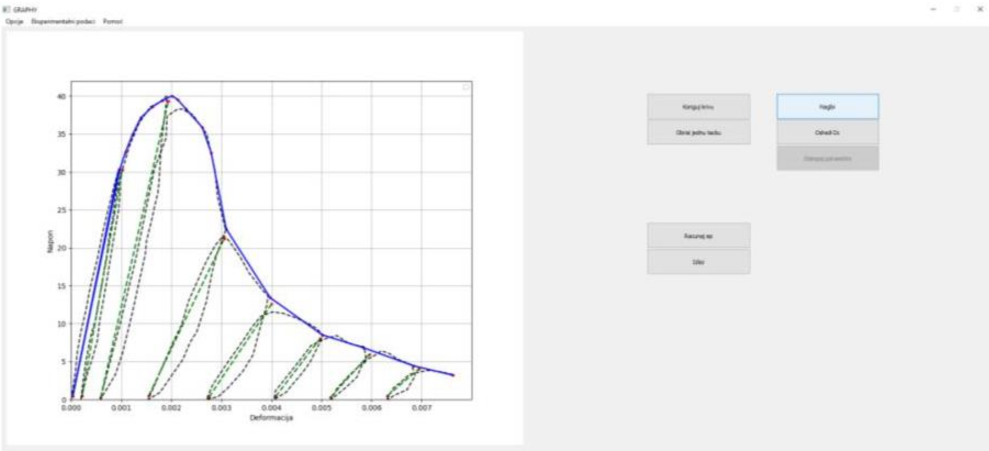

Figure *4. Toolbox window after defining the stress-strain curve and slopes by the user*

4 VERIFICATION

Numerical simulations of load-unload uniaxial compression and tension tests are performed using PAK software package [17]. For the purpose of numerical simulations, CDP model is used, and parameter values determined using developed application are used. The numerical simulations results are compared with the experimental data from the literature.

A schematic representation of the specimen model used in uniaxial tests simulations with defined boundary conditions and load is given in Figure 5. The FE model consists of one 3D hexahedral 8-noded finite element.

a)

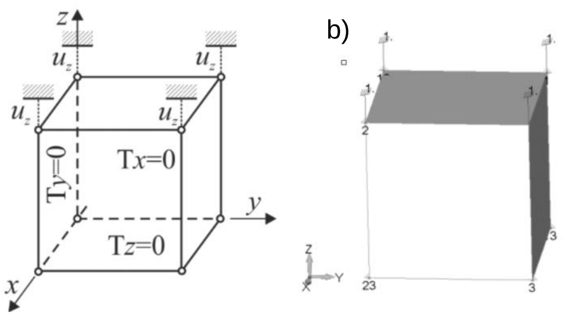

Figure 5. Specimen model for uniaxial tests a) schematic representation, b) FE model

Parameters of CDP material model determined using developed application are shown in Table *1*.

Table 1. *Parameters of CDP model determined using application*

Parameter	Value
E (kPa)	41/32 10^6
v	0.2
f_c *(kPa)*	$40{\cdot}10^3$
f_t *(kPa)*	$3.68{\cdot}10^3$
a_c	4.136
D_c	0.29
a_t	0.225
D_t	0.31
G_c *(kN/m³)*	122
G_t *(kN/m³)*	0.67
D_{cr}	0.95

Boundary conditions are set to correspond to the specimen experimental uniaxial test conditions. Symmetry boundary conditions are set on nodes located in symmetry planes. The load is applied using prescribed displacement in the direction of the z-axis at the nodes on the upper face of the model. In both, uniaxial compression and tension tests, the prescribed displacement is multiplied by the load function that corresponds to the experiment.

4.1 Results of numerical simulations

The results of uniaxial tests numerical simulations are compared with experimental data. Figure *6* shows the comparison of stress-total strain dependence.

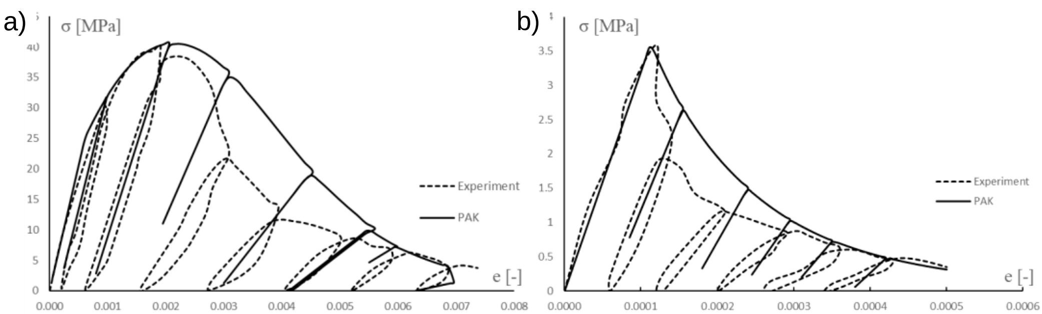

Figure 6*. Stress – total strain charts for a) compression, b) tension*

Figure *7* shows stress – degradation chart for uniaxial compression and tension. By comparing the previous charts, it can be concluded that the numerical simulation results by correspond to the experimental data. Therefore, it can be concluded that developed application can be used identification of material parameters for CDP effectively.

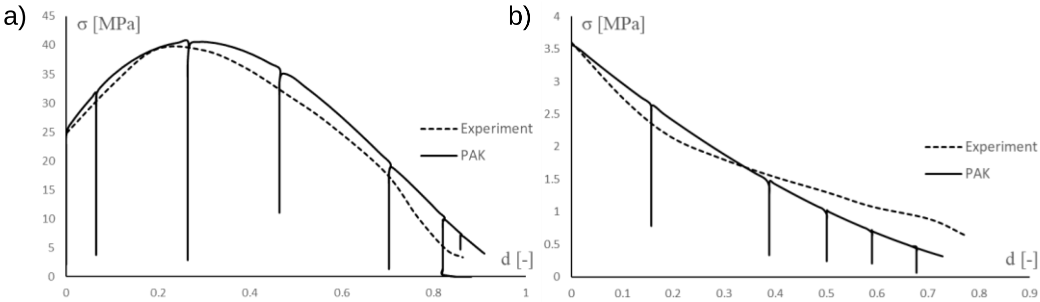

Figure 7. *Stress – degradation charts for a) compression, b) tension*

5 CONCLUSION

The application for automatic identification of CDP material model parameters is presented in this paper. This research is a continuation of the previous work in which a methodology was developed for determining CDP parameters is established. The previously developed procedure for the identification of CDP parameters is given in the paper.

Parameter identification is performed based on experimental data from the literature. The parameters of this material model can be determined based on experimental tests of uniaxial compression and tension with unloading. Using the developed application, the process of determining the parameters for this material model was automated. The verification was carried out by numerical simulations of uniaxial compression and tension tests and by comparing the results with the literature.

Based on the obtained results, it can be concluded that by using this user application, the process of identifying the parameters of the CDP material model can be effectively automated. Automating this process can significantly save engineering time and reduce human error.

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REFERENCES

[1] M. Kojić , R. Slavković, M. Živković and N. Grujović, Metod konačnih elemenata I, Kragujevac: Mašinski fakultet Univerziteta u Kragujevcu , 1998.

[2] J. Lubliner, J. Oliver and E. Onate, “A plastic-damage model for concrete,” *International Journal of Solids and Structures,* vol. Volume 25, no. 3, pp. 299-326, 1989.

[3] J. Lee, *Theory and implementation of plastic-damage model for concrete structures under cyclic and dynamic loading,* Berkeley, California: University of California, 1996.

[4] A. Raza, Q. uz Zaman Khan and A. Ahmad, “Numerical Investigation of Load-Carrying Capacity of GFRP-Reinforced Rectangular Concrete Members Using CDP Model in ABAQUS,” *Advances in Civil Engineering,* vol. 2019, pp. 1-21, 2019.

[5] M. de Santana Santos and T. Denyse Pereira de Araujo, “NUMERICAL ANALYSIS OF THE BEHAVIOR OF CONCRETE COLUMNS CONFINED WITH CFRP USING THE CONSTITUTIVE MODEL CONCRETE DAMAGED PLASTICITY,” in *Proceedings of the XLI Ibero-Latin-American Congress on Computational Methods in Engineering*, Foz do Iguac¸u/PR, Brazil, 2020.

[6] M. Szczecina and A. Winnicki, “NUMERICAL SIMULATIONS OF CORNERS IN RC FRAMES USING STRUT-AND-TIE METHOD AND CDP MODEL,” in *XIII International Conference on Computational Plasticity. Fundamentals and Applications*, Barcelona, Spain, 2015.

[7] Q. Wang, K. Hou, J. Lu, Q. Dong, D. Yao and Z. Lu, “Study on concrete damaged plasticity model for simulating the hysteretic behavior of RC shear wall,” in *International Conference CIBv2019 Civil Engineering and Building Services*, Brasov, Romania, 2020.

[8] M. Talaat, E. Yehia, S. Mazek, M. Genidi and A. Sherif, “Finite element analysis of RC buildings subjected to blast loading,” *Ain Shams Engineering Journal,* vol. 13, no. 4, 2022.

[9] X.-X. Li, “Parametric Study on Numerical Simulation of Missile Punching Test Using Concrete Damaged Plasticity (CDP) Model,” *International Journal of Impact Engineering,* vol. 144, 2020.

[10] A. Fedoroff and K. Calonius, “Using the Abaqus CDP model in impact simulations,” *Journal of Structural Mechanics,* vol. 53, no. 3, pp. 180-207, 2020.

[11] M. Labibzadeh, M. Zakeri and A. Adel Shoaib, “A New Method for CDP Input Parameter Optimization of the ABAQUS Software Guaranteeing the Uniqueness and Precision,” *International Journal of Structural Integrity,* vol. 8, no. 2, pp. 264-284, 2017.

[12] Y. Sümer and M. Aktaş, “Defining parameters for concrete damage plasticity model,” *CHALLENGE JOURNAL OF STRUCTURAL MECHANICS,* vol. 1, no. 3, pp. 149-155, 2018.

[13] D. Rakić, A. Bodić, N. Milivojević, V. Dunić and M. Živković, “Material parameters identification of concrete damage plasticity material model,” in *8th International Congress of Serbian Society of Mechanics*, Kragujevac, 2021.

[14] D. Rakić, A. Bodić, N. Milivojević, V. Dunić and M. Živković, “CONCRETE DAMAGE PLASTICITY MATERIAL MODEL PARAMETERS IDENTIFICATION,” *Journal of the Serbian Society for Computational Mechanics ,* vol. 15, no. 2, pp. 111-122, 2021.

[15] D. Karsan and J. Jirsa, “Behavior of Concrete Under Compressive Loadings,,” *Journal of the Structural Division,* vol. 95, 1969.

[16] R. Taylor, FEAP: a finite element analysis program for engineering workstation. Rep. No. UCB/SEMM-92 (Draft version), University of California: Berkeley: Department of Civil Engineering, 1992.

[17] M. Kojić, R. Slavković, M. Živković and N. Grujović, PAK-S: Program for FE Structural Analysis, Kragujevac: University of Kragujevac, Faculty of Engineering, 2011.