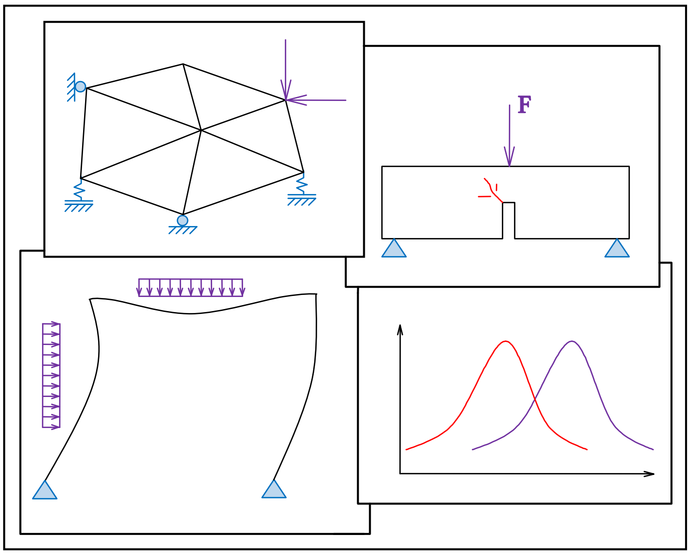
VSB TECHNICAL UNIVERSITY OF OSTRAVA | FACULTY OF CIVIL ENGINEERING

21. ročník mezinárodní konference

Modelování v mechanice 2023

25. - 26. 5. 2023

Sborník rozšířených abstraktů



21st International Conference

Modelling in Mechanics 2023

25th and 26th May 2023

Proceedings of extended abstracts

ISBN 978-80-248-4673-6 (Print)
ISBN 978-80-248-4674-3 (Online)

TABLE OF CONTENTS / OBSAH

Parametric Study of a Straw Bale Load-Bearing Wall

Hana BRÁZDILOVÁ, Petr LEHNER

Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 33 Ostrava-Poruba, Czech Republic

hana.brazdilova.st@vsb.cz, petr.lehner@vsb.cz

For many years, straw was in the background, but more recently its use in construction is making a comeback. In the case of the straw bale, the so-called American method is used and it's most commonly used in the United States. It is a method of construction that works with self-supporting straw bales, stacked into a wall, which are stacked between the foundation and the wreath. They are designed to transfer loads from the ceiling to the foundation. They also have the advantage of acting as a single layer of thermal insulation. Numerical models of straw bale structures are only a marginal topic. Most often, numerical models are used to investigate heat or moisture transfer. Only a few numerical models can be found in the literature, most of them combining wood and straw. Thus, the load-bearing bale industry is still dependent on empirical observation and previous experience and does not use modern numerical approaches.

Tab.1: Material properties.

Number of material model	Parameters	
	Modulus of elasticity [MPa]	Poisson's constant [-]
1.	0.211	0.1
2.	0.193	0.1
3.	0.211	0.2
4.	0.193	0.2

This paper aimed to present eight wall models made of straw bales of different properties. The walls were loaded in two ways. The first set was loaded by deformation from the top (Fig. 1a) and the second from the side (Fig. 1b). A total of four types of bales with different material properties were used to form these walls (Tab. 1.). The result of the work was a comparison of the stress, relative strain and deformation of the walls.

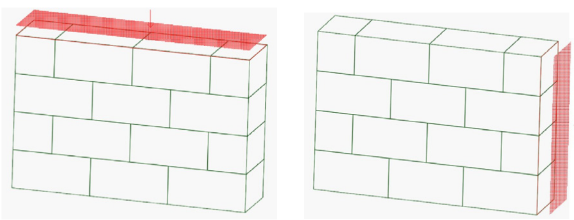


Fig. 1: (a) Model of the wall loaded from the top
(b) Model of the wall loaded from the side.

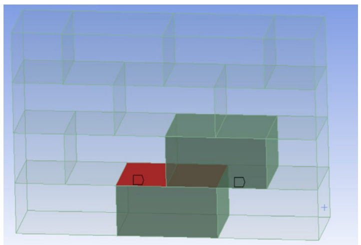


Fig. 2: Demonstration of fixed contacts set in wall joints.

In the wall contact joints the contacts were considered with friction. The friction coefficient was set to 0.2. For the integrity of the model, the contacts in the loading joints were set as fixed, so they can simulate realistic connections of straw bales with wooden pins (Fig. 2).

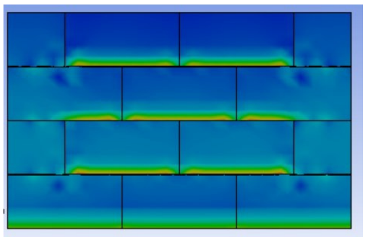


Fig. 3: Example of the resulting relative transformation under top load.

Tab.2: Results of numerical analysis.

Number of material	Top load		Side load	
	Equivalent stress [MPa]	Equivalent strain [-]	Equivalent stress [MPa]	Equivalent strain [-]
1.	23.37	0.126	43.37	2.055
2.	20.10	0.104	39.41	2.040
3.	24.27	0.115	38.85	1.840
4.	22.25	0.115	35.55	1.820

Acknowledgements

Financial support from VSB-Technical University of Ostrava by means of the Czech Ministry of Education, Youth and Sports through the Institutional support for conceptual development of science, research and innovations for the year 2023 is gratefully acknowledged.

Remodelling of corroded steel surfaces based on microscope image outputs

Jiri BROZOVSKY[1], *Martin KREJSA*[1], *Miroslav VACEK*[2], *Vit KRIVY*[2]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, VSB – Technical University of Ostrava, Ludvika Podeste 1875, Ostrava, Czech Republic
[2]Department of Structures, Faculty of Civil Engineering, VSB – Technical University of Ostrava, Ludvika Podeste 1875, Ostrava, Czech Republic

jiri.brozovsky@vsb.cz, martin.krejsa@vsb.cz, miroslav.vacek@vsb.cz, vit.krivy@vsb.cz

1. Introduction

Steel structures have been often used for engineering and industrial structures. Being subjected to aggressive environments they naturally corrode. Modern equipment (eg microscopes [1]) can provide interesting view on steel surfaced damaged by corrosion. However, even more important results for understanding of corrosion effects on micro–mechanical material behaviour can be obtained from numerical simulations which will use these microscope images as basis for model geometry definition.

Conversion from 2D image (often represented by not so suitable data file as is the JPEG/JFIF image) to a 3D surface model is obviously not a straightforward task. There are many possible approaches. The one adopted by paper authors is described here.

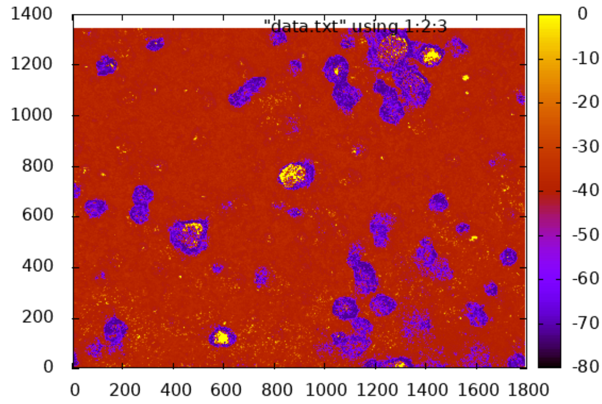


Fig. 1: Computer plot of converted data (corrosion depth map on studied part of steel sample).

2. Approach

The results obtained by an external contractor are available in a form of bitmap picture (in the JPEG/JFIF compressed data format). This is not ideal from several points of view. The JPEG is **not** the lossless format thus some information can be damaged. The image itself is fixed to size about 900x600 pixels (up to 1600x1200 is availably by cost of losing the depths scale). Textual data are represented as human-readable (but not machine-readable) bitmaps. The corrosion depth data thus were analyses on per-pixel basis and a finite element model was created from these data.

3. Conclusions

The paper discussed an engineer-level approach for conversion of modern microscope output to a finite element model. The procedure is going to be further improved and used for preparation of models for theoretical fatigue studies.

Acknowledgment

This contribution has been developed as a part of the research project of the Czech Science Foundation 21-14886S "Influence of material properties of high strength steels on durability of engineering structures and bridges."

References

[1] Keyence VHX-7000 microscope presentation: VHX-7000, Computer Hardware.

RESULT OF RAPID CHLORIDE PERMEABILITY TEST IN THE CASE OF METALLURGICAL SLUDGE WASTE CONCRETE

Kateřina BUGNEROVÁ, Petr LEHNER, Marie HORŇÁKOVÁ

Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 33 Ostrava-Poruba, Czech Republic

katerina.bugnerova.st@vsb.cz, petr.lehner@vsb.cz, marie.hornakova@vsb.cz

The use of metallurgical sludge waste (MSW) in concrete can be an ideal solution to reduce the environmental burden of this waste material, which disposal is a current problem not only in Central Europe. Using of MSW as a good substitute for fine aggregate has been demonstrated in several studies [1, 2]. Thus, the mechanical properties are known, but the properties related to the resistance to aggressive substances in the context of the amount of MSW in such concrete are missing. This paper presents results from the rapid chloride permeability test (RCPT) [3] (see Fig. 1.), which is used to determine the permeability of chloride ions in concrete and subsequently even the diffusion coefficient in concrete. The standard clearly states that charge above 4000 coulombs means high chloride permeability, above 2000 coulombs moderate, above 1000 coulombs low, above 100 coulombs very low and below 100 coulombs negligible.

Fig. 1: RCPT measuring set.

Four concrete mixes were prepared: a reference one, one with a 30% substitution, one with a 60% substitution, and one with a 90% substitution of fine aggregate. Cylindrical samples with a height of 200 mm and a diameter of 100 mm were formed during the concreting process. These samples were left to mature in a water bath for 28 days. Subsequently, the samples were cut into flat specimens of 100 mm diameter and 50 mm height. The top sample (designated TOP) and the bottom sample (designated BOTTOM) were used for RPCT testing. Results are shown in Fig. 2. It is noticeable that there is a difference (about 20 %) between the top and bottom results. This may be due to settlement of the fine MSW aggregate during the concreting of the small-size specimens. In terms of the passed charge results, the samples with 30% MSW are in the high permeability category, and the other samples are in the moderate or borderline category. The best results show the concrete with 90% of MSW.

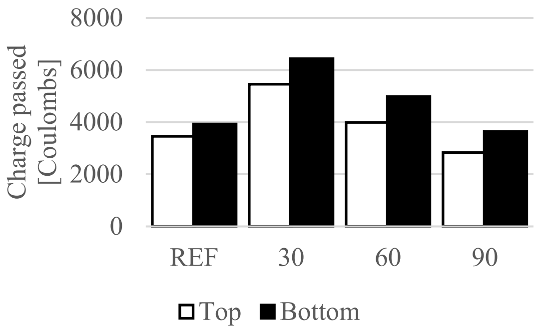


Fig. 2: Results of RCPT test.

Acknowledgements

The research was funded by the Ministry of Education, Youth and Sports of the Czech Republic through VSB - TU Ostrava (SGS SP2023/056).

References

[1] PIZOŃ, Jan, Jacek GOŁASZEWSKI, Mohamed ALWAELI a Patryk SZWAN. Properties of concrete with recycled concrete aggregate containing metallurgical sludge waste. Materials. 2020, 13(6). ISSN 19961944.

[2] ALWAELI, Mohamed, Jacek GOŁASZEWSKI, Marian NIESLER, Jan PIZOŃ a Małgorzata GOŁASZEWSKA. Recycle option for metallurgical sludge waste as a partial replacement for natural sand in mortars containing CSA cement to save the environment and natural resources. Journal of Hazardous Materials. 2020, 398, 123101. ISSN 03043894.

[3] ASTM C1202, "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration"

Combining vectorized and parallelized Matlab code for elasticity problems

Martin ČERMÁK[1]

[1]Department of Mathematics, Faculty of Civil Enginnering, VSB – Technical University of Ostrava, Ludvika Podeste 1875/17, Ostrava, Czech Republic

martin.cermak@vsb.cz

Elastic problems still represent an essential topic in the continuum mechanics of steel and solids. This contribution is focused on the Matlab implementation of elastic problems formulated in terms of displacements.

This approach is based on two previously published papers [1, 2] that addressed the problem of elastoplasticity in combination with TFETI domain decomposition and a second paper where we discussed an efficient approach to vectorization, which is a powerful tool in speeding up code in Matlab and other programming languages.

In the case of the parallel approach, we use one variant of the non-overlapping domain decompositions method TFETI (Total Finite Element Tearing and Interconnecting) introduced in 2006 by Z. Dostál, D. Horák, and R. Kučera, where the domain is divided into individual subdomains, and for each domain, a stiffness matrix and a right-hand side vector are constructed separately. Of course, the question is how to solve these domains as a whole. For this, we use "gluing" conditions to ensure the continuity of the problem, and these conditions are stored in the matrix for equality constraints. The advantage of this method is that all the stiffness matrices for the individual subdomains are singular because the Dirichlet conditions are also not considered in the individual stiffness matrices but just in the equality constraint matrix. An example of partitioning a domain into subdomains can be seen in Figure 1, where the problem has been partitioned into subdomains by Metis.

In the second case related to vectorization in Matlab, we use the matrix inter-multiplication approach, which is considerably more efficient than the classic for loops for constructing a stiffness matrix, wherein a loop, you construct a local stiffness matrix for each finite element, which you then store in a global stiffness matrix for a specific subdomain.

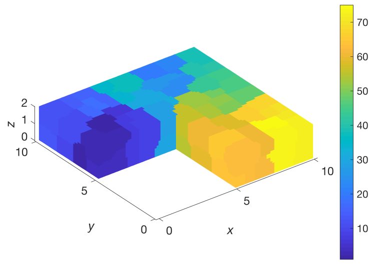


Fig. 1: Decomposition of L-shape body into 75 subomains by Metis.

Acknowledgments

This contribution has been prepared thanks to the Czech Foundation (GAČR) through project no. 22-13220S “Development of iterative algorithms for solving contact problems emerging in the analysis of steel structures bolt connections.”

References

[1] M. Čermák, T. Kozubek, S. Sysala, and J. Valdman, “A TFETI domain decomposition solver for elastoplastic problems,” *Applied Math. and Comp*, vol. 231, pp. 634–653, 2014.

[2] M. Čermák, S. Sysala, and J. Valdman, “Efficient and flexible matlab implementation of 2d and 3d elastoplastic problems,” *Applied Mathematics and Computation*, vol. 355, pp. 595–614, 2019.

Ratio of Volumetric and Surface Electrical Resistivity of Recycled MSW Concrete

Petr LEHNER[1], *Jan DEDEK*[2], *Marie HORŇÁKOVÁ*[1]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic

[2] Department of Building Construction, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic

petr.lehner@vsb.cz, jan.dedek1@vsb.cz, marie.hornakova@vsb.cz,

A typical example of a waste material with potential for application in concrete is a metallurgical sludge waste (MSW) [1]. In this study, concretes made of fine MSW aggregate and then crushed or grinded and used as coarse aggregate were analysed. Previous studies have described the production processes of these concretes as well as their mechanical properties [2]. The present article aims to analyse the ratio between bulk and surface resistivity [3] and to evaluate the differences compared to conventional concrete. Seven types of concrete were prepared: one reference standard OPC, three concretes with coarse aggregate replacement (CR) obtained by grinding of the original concretes (25%, 50% and 75% replacement) and three concretes with coarse aggregate replacement (RO) obtained by crushing of the original concretes (25%, 50% and 75% replacement). Cylinders with a diameter of 100 mm and a length of 200 mm and prismatic samples with a cross section of 100 x 100 mm and a height of 200 mm were analysed.

Surface resistivity was measured with a Wenner probe on each side of the specimen. An RCON instrument was used to determine the volumetric resistivity. The ratio of surface and volumetric resistivity for standard concrete is expected to be 2.35. The results of the analysis and the calculated ratios for both tests are shown in Fig. 1. All results are within 10 % of the reference value. There is also no connection between the shape of the sample and the amount of aggregate replacement. This aspect will be further investigated by analyzing correlation and regression.

Acknowledgements

The research was funded by the Ministry of Education, Youth and Sports of the Czech Republic through VSB - TU Ostrava (SGS SP2023/056).

References

[1] ASSI, Lateef, Kealy CARTER, Edward (Eddie) DEAVER, Rafal ANAY and Paul ZIEHL. Sustainable concrete: Building a greener future. Journal of Cleaner Production [online]. 2018, 198. ISSN 09596526.

[2] LEHNER, Petr; HORŇÁKOVÁ, Marie; PIZOŃ, Jan, Jacek GOŁASZEWSKI. Effect of Chemical Admixtures on Mechanical and Degradation Properties of Metallurgical Sludge Waste Concrete. Materials 2022, 15, no. 23: 8287.

[3] MORRIS, W., E. I. MORENO and A. A. SAGÜÉS. Practical evaluation of resistivity of concrete in test cylinders using a Wenner array probe. Cement and Concrete Research [online]. 1996, 26(12), 1779–1787. ISSN 00088846.

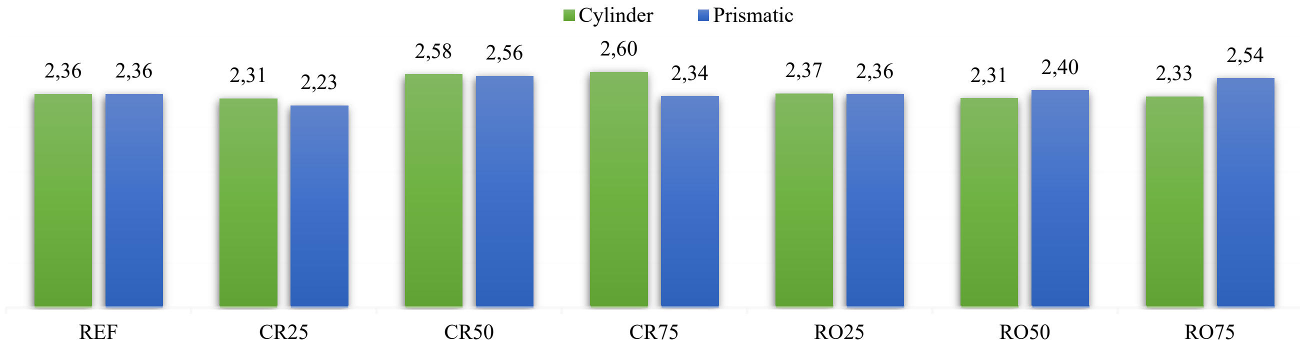


Fig. 1: Results of the ratio between volumetric and surface electrical resistivity on MSW concretes.

DIFFERENT APPROACHES FOR NUMERICAL MODELLING OF THREE-LAYER CLT PANELS

Pavel DOBEŠ[1], *Antonín LOKAJ*[2]

[1] Centre for Building Experiments and Diagnostics, Faculty of Civil Engineering, VSB – Technical University of Ostrava

[2] Department of Structures, Faculty of Civil Engineering, VSB – Technical University of Ostrava

pavel.dobes1@vsb.cz, antonin.lokaj@vsb.cz

The paper deals with the deformation analysis of cross laminated timber (CLT) panels. The panel CLT 140-3 was composed of three solid timber layers (C24 strength class) with a total thickness of 140 *mm*: the outer layers (40 *mm*) were laid in the longitudinal direction, and the middle layer (60 *mm*) was laid in the transverse direction.

The aim was to show methods of numerical modelling of the CLT panel using two completely different approaches in commercial software, ANSYS Workbench and SCIA Engineer. ANSYS Workbench uses 3D finite elements and is not commonly available to the general public in the construction practice, while SCIA Engineer is a software commonly used by engineers who design structures in the construction practice.

The numerical model in SCIA Engineer consisted of beam and shell finite elements with orthotropy, which has proven to be a fast, effective and accurate alternative to numerical analysis in ANSYS Workbench. The orthotropic material was defined by several physical constants based on Kirchhoff plate theory. The individual orthotropic plates were connected by rigid arms. The translational rigidity in the longitudinal direction was defined at the end of each rigid arm and it represented the shear compliance between the layers (shear compliance coefficient $K = 253000$ *N/mm*).

The numerical model in ANSYS Workbench used rectangular orthotropy (without considering the curvature of annular rings) which was defined by three mutually perpendicular directions: longitudinal L, tangential T, and radial R. The material model was given by nine elastic constants in the system of these directions (three moduli of elasticity, three shear moduli, and three Poisson's ratios). The outer load-carrying layers were modelled as individual planks, and the middle non-load-carrying layer was simplistically modelled as continuous. A thin layer of epoxy resin was added between the elements and this contact was set as "bonded". The contact between the support and the panel was set as "frictional". The size of the finite element mesh was from 30 to 40 *mm*.

The CLT panel was supported and loaded in a similar way as for the four-point bending test. The load force value was $F = 2 \times 20$ *kN* $= 40$ *kN*, which corresponded to approximately 40% of the estimated maximum load-carrying capacity of the panel, where the linear elastic behaviour of timber could still be considered. The maximum deflection at the mid-span was used for the comparison. The results showed a good agreement in the bending behaviour between the analytical calculation according to the standard Eurocode 5 ($w_{MAX} = 25.7$ *mm*) and both approaches in numerical analysis (see Fig. 1 and Fig. 2).

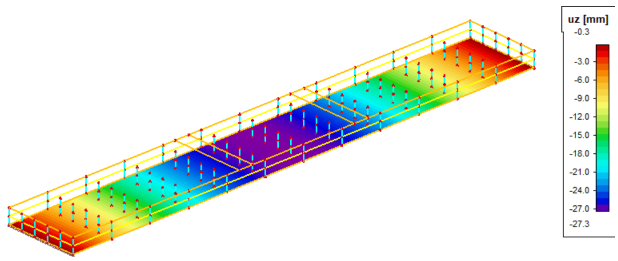


Fig. 1: Deflection area of the numerical model in SCIA Engineer (values in [mm]).

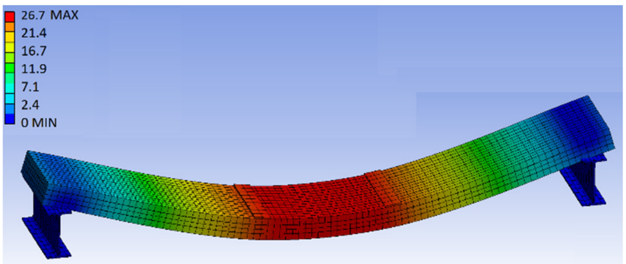


Fig. 2: Deflection area of the numerical model in ANSYS Workbench (values in [mm]).

Acknowledgements

Financial support from VSB-Technical University of Ostrava, The Faculty of Civil Engineering, by means of the operating costs of The Department of Structures is gratefully acknowledged.

ON USE OF WIM DATA IN RELIABILITY ANALYSIS OF EXISTING ROAD BRIDGES

Michal DRAHORÁD[1], *Roman LENNER*[1,2], *Miroslav SÝKORA*[3]

[1]Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, Prague, Czech Republic
[2]Valbek, spol. s r.o. V Olšinách 2300/75, Prague, Czech Republic
[3]Klokner Institute, Czech Technical University in Prague, Šolínova 7, Prague, Czech Republic

michal.drahorad@fsv.cvut.cz, roman.lenner.jr@valbek.cz, miroslav.sykora@cvut.cz

1. Introduction

Long-term trends of traffic intensity on the road and motorway network in Czechia exhibit steady increase in road transport. As the traffic intensity and composition are key factors affecting the loads for designing new and assessing existing bridges, a more detailed analysis of the actual traffic flow and the effect of its changes on loads on bridges is needed and should be adequately reflected in codes of practice. Data that are being compiled from recently introduced systems for weighing of vehicles at operating speed (WIM – Weigh in Motion) provide a unique opportunity in this regard.

To indicate opportunities of WIM data in updating of traffic load models, it is essential to understand the basic assumptions that have been made when the Eurocode traffic load models have been developed. These are discussed in detail in this contribution.

2. WIM Data

Currently, six locations in the Czech Republic are instrumented with high-speed WIM. Even a single day of traffic data does exhibit values in the tail that correspond to the legal limit of 48t (Fig. 1). This limit is in fact higher when compared to other countries; typical gross weight of vehicles operating the region of EU is 40t according to the International Transport Forum.

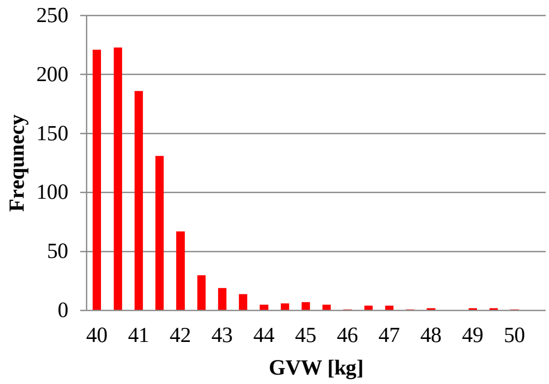


Fig. 1: Daily frequency of GVW (> 40t, highway)

3. Preliminary Conclusions

The submitted study discusses the background of the road traffic load models in EC1-2 and challenges and opportunities that are related analysis of newly available traffic records. It appears that:

- Records providing the basis of the EC12 road traffic load models were of limited length and might be considered to provide sufficient information about common traffic conditions only.
- As the records supporting the EC12 load models originate from the 1970-1980s and the traffic composition was shown to be different between European countries, the most recent WIM data taken in the Czech road network may help to significantly improve the load effects to be considered in reliability verifications of Czech bridges.

The probabilistic approach should be applied to adequately describe uncertainties in a number of factors affecting the traffic load effects on bridges. Particularly for the assessment of existing bridges and calculation of their load-bearing capacity, it is expected that the analysis of new traffic data will make it possible to propose new (or updated) load models in CSN 73 6222.

Acknowledgements

Part of this study has been supported by the Technology Agency of the Czech Republic under Grant CK03000125.

DEVELOPMENT OF SUSTAINABLE MIXTURE DESIGN OF 3D PRINTED CONCRETE (3DPC) CONTAINING FINE RECYCLED 3DPC AGGREGATE

Karol FEDEROWICZ[1], Szymon SKIBICKI[1], Marcin HOFFMANN[2], Daniel SIBERA[1], Krzysztof CENDROWSKI[1], Mateusz TECHMAN[1], Pawel SIKORA[1]

[1]Faculty of Civil and Environmental Engineering, West Pomeranian University of Technology in Szczecin, Al. Piastów 50a, 70-311 Szczecin, Poland

[2]Faculty of Mechanical Engineering and Mechatronics, West Pomeranian University of Technology in Szczecin, Al. Piastów 19, 70-310 Szczecin, Poland

kfederowicz@zut.edu.pl, szymon.skibicki@zut.edu.pl, marcin.hoffmann@zut.edu.pl, daniel.sibera@zut.edu.pl, krzysztof.cendrowski@zut.edu.pl, mtechman@zut.edu.pl, psikora@zut.edu.pl

The use of 3D printing technology in the construction industry has gained significant attention in recent years due to its potential for increased efficiency and waste reduction. 3D concrete printing has strong potential for inclusion of recycled materials, specifically recycled aggregate. In this research optimization of the mixture design of 3D printed concrete (3DPC) by inclusion of recycled fine 3DPC aggregate into mixture is presented.

The properties of recycled aggregate are different from those of traditional aggregate, and this presents unique challenges in the 3D printing process. However, studies have shown that by optimizing the mixture proportions, 3D printed concrete with recycled aggregate can achieve satisfactory fresh and hardened properties. Therefore, strong potential for reducing the environmental impact of concrete production can be achieved.

In addition to the potential environmental benefits, 3D printed concrete with recycled aggregate also presents economic benefits. By using recycled materials, the cost of concrete production can be significantly reduced. Furthermore, 3D printing technology enables the production of complex geometries that would be difficult or impossible to achieve using traditional construction methods.

In the presented research recycled aggregate made of crushed 3D concrete were used as partial replacement of cement. Replacement of cement by 10-50 vol.% with fine recycled aggregate was evaluated. The process of production of recycled 3D concrete aggregate is shown in Figure 1. To evaluate the influence of recycled aggregate on the rheological properties static yield stress development over time was evaluated based on the methodology presented in Figure 2. Additionally flow table and mechanical properties were tested for each designed mixture. In the final stage, an extrusion tests of material were performed along with quality inspection of printed elements.

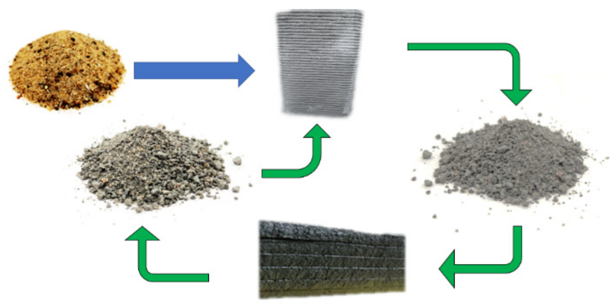


Fig. 1: Concept of production of recycling aggregate made out of 3DCP.

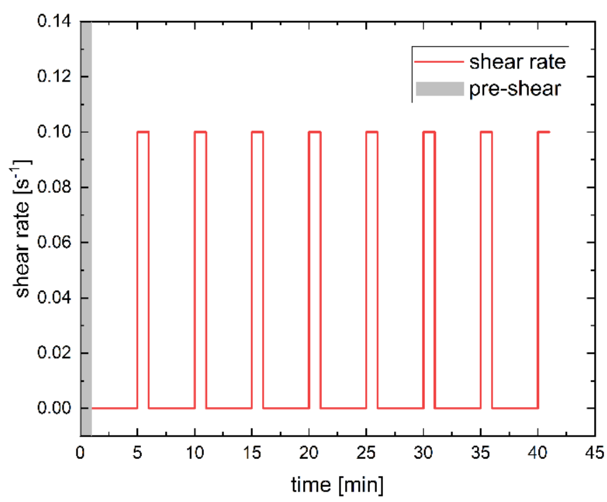


Fig. 2: Methodology of static yield stress determination test.

Acknowledgements

This research was funded in whole by the National Centre for Research and Development (NCBR), Poland within Project no. ERA-MIN3/140/Recycl3D/2022 (ERA-NET Cofund ERA-MIN3 (Joint Call 2021)).

THREE-DIMENSIONAL NUMERICAL MODEL OF CHLORIDE PENETRATION IN CONCRETE

Dominik GŘEŠICA, Petr LEHNER

Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 33 Ostrava-Poruba, Czech Republic

dominik.gresica.st@vsb.cz, petr.lehner@vsb.cz

The aim of the work was to create 3D models to simulate chloride penetration into the concrete. The model was prepared in the commercial software Ansys Workbench. Two types of concrete are considered in this work - OPC (ordinary concrete) and HPC (high strength concrete). The results of chloride concentration values in the model were compared with previously published results from a numerical model prepared in Ansys software. Tab. 1 shows the input parameters for the model that simulates the concrete disc sample used for the chloride test.

Tab.1: Model input information.

Parameters	Value
Height *H* [m]	0.025
Diameter *B* [m]	0.150
Diffusion coefficient D_c [m^2/s]	8.79 x 10^{-12}
Surface chloride concentration C_0 [%]	1.40 %

Fig. 1 shows a model of a concrete sample. The finite element mesh is shown, the average dimension was chosen as one tenth of the total thickness of the sample.

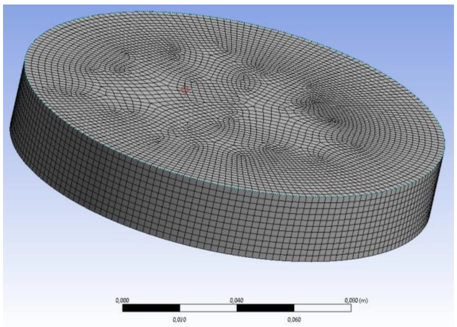


Fig. 1: The geometry of a concrete specimen with a 2.5 mm finite element mesh marked.

Two models of concrete discs made of HPC and OPC concrete were created and exposed to chloride over the entire surface of the specimen. Fig. 2 shows the chloride penetration results for OPC concrete at 7, 14, 28, 56, and 91 days after concreting. These times are chosen because electrical resistivity testing of the samples is normally performed at the same time. The results were also compared with a model prepared in Matlab software, previously published (see Tab. 2). For the first two results (7 and 14 days) the chloride concentration in both models is so small that the difference at 208 % and 88 % cannot be taken realistically. The other results show high agreement.

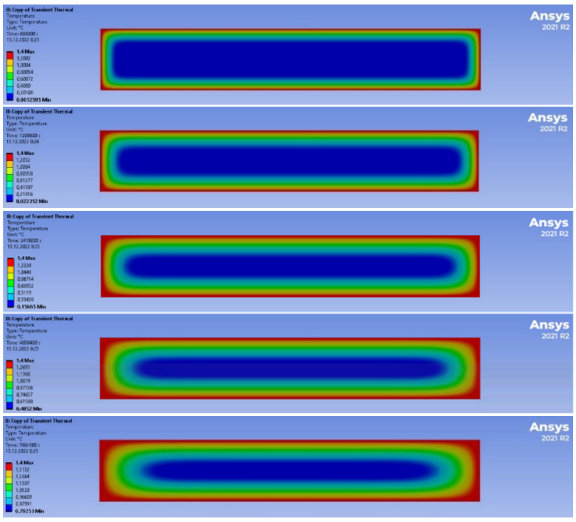


Fig. 2: Graphical output from Ansys Workbench for OPC concrete (7, 14, 28, 56, and 91 days after concreting).

Tab.2: Results of numerical analysis - chloride concentration [%].

Day	MATLAB	ANSYS 3D	MATLAB / ANSYS 3D
7	0.004	0.0013	-208 %
14	0.0027	0.022	88 %
28	0.1593	0.157	-1 %
56	0.4901	0.485	-1 %
91	0.8065	0.793	-2 %

Acknowledgements

The research and paper were funded by the Ministry of Education, Youth and Sports of the Czech Republic through VSB – Technical University of Ostrava (SGS SP2023/056).

AN OVERVIEW OF 3D PRINTING TECHNIQUES USING CONCRETE FOR CONSTRUCTION APPLICATIONS

Marcin HOFFMANN[2], Karol FEDEROWICZ[1], Szymon SKIBICKI[1], Mateusz TECHMAN[1], Daniel SIBERA[1], Krzysztof CENDROWSKI[1], Pawel SIKORA[1]

[1]Faculty of Civil and Environmental Engineering, West Pomeranian University of Technology in Szczecin, Al. Piastów 50a, 70-311 Szczecin, Poland

[2]Faculty of Mechanical Engineering and Mechatronics, West Pomeranian University of Technology in Szczecin, Al. Piastów 19, 70-310 Szczecin, Poland

marcin.hoffmann@zut.edu.pl, kfederowicz@zut.edu.pl, szymon.skibicki@zut.edu.pl, mtechman@zut.edu.pl, daniel.sibera@zut.edu.pl, krzysztof.cendrowski@zut.edu.pl, psikora@zut.edu.pl

The development of 3D printing technology has revolutionized various industries, including the construction industry. One of the most exciting areas of application for 3D printing in construction is the use of concrete as a printing material. Concrete is a widely used construction material and offers many benefits, including durability, strength, and resistance to fire and weathering. Using 3D printing technology to print concrete structures offers many advantages over traditional construction methods, including increased speed, reduced waste, and increased flexibility in design.

This article provides an overview of various 3D printing techniques using concrete, along with their characteristics, advantages, and potential applications in the construction industry. The methods covered include direct printing with piston extruders, auger nozzles, and various shaped nozzles with multiple outlets (Fig.1). Each method has its own advantages and disadvantages depending on the specific application.

In addition to discussing the various printing techniques, this article also evaluates the use of additive manufacturing in the construction industry, particularly in the building of houses (Fig.2).

Overall, this article aims to increase awareness of the potential applications of 3D printing using concrete in the construction industry. The development of this technology has the potential to revolutionize the construction industry, allowing for faster, more efficient, and more sustainable construction processes.

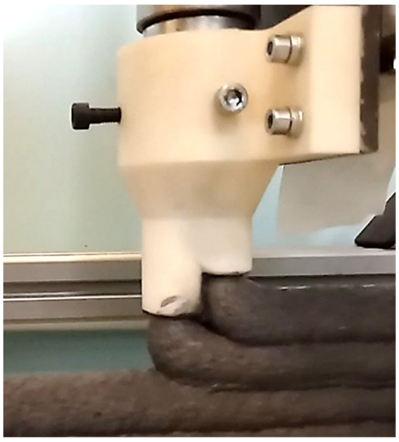


Fig. 1: Concept of printing with using dual-exit nozzle.

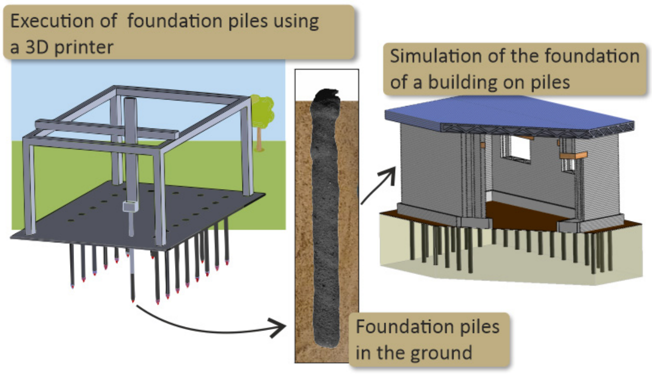


Fig. 2: Concept of 3D printing of foundation piles.

Acknowledgements

This research was funded in whole by the National Centre for Research and Development (NCBR), Poland within Project no. ERA-MIN3/140/Recycl3D/2022 (ERA-NET Cofund ERA-MIN3 (Joint Call 2021)).

EFFECT OF CHEMICAL ADMIXTURES ON WASTE METALLURGICAL SLUDGE CONCRETE AT THE LATE AGE

Marie HORŇÁKOVÁ[1], Jan PIZOŃ[2], Jacek GOLASZEWSKI[2] and Petr LEHNER[1],

[1] Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 33 Ostrava-Poruba, Czech Republic

[2] Department of Building Processes and Building Physics, Faculty of Civil Engineering, Silesian University of Technology, Akademicka Street 5, 44-100 Gliwice, Poland

marie.hornakova@vsb.cz

This study follows the development of concrete with metallurgical sludge waste (MSW) used as a replacement of aggregate in concrete [1, 2] and presents the results after the concrete samples have matured. The applicability of MSW concrete has been presented previously but the results of long-term characteristics are still lacking in the literature. In this article, the effect of superplasticizer (SP) and air-entraining admixture (AEA) on compressive strength and electrical resistance in time are evaluated. The resistivity measurement leads to the diffusion coefficient of concrete, which can be assumed as an indicator of durability. Measurements were taken approximately one year after concrete was casted, and the results are compared with the results measured earlier and published in [3]. In this case, four concrete mixes were analysed. First one was a reference mixture without MSW and any other chemical additives, second one was prepared without MSW but with AEA (REF+AEA). Two of them was prepared with MSW as a 30 % replacement of fine aggregate – with AEA (MSW+AEA) and without AEA (MSW). However, in the case of using MSW in the concrete, it is necessary to enrich the mixture with SP because of higher water consumption of MSW.

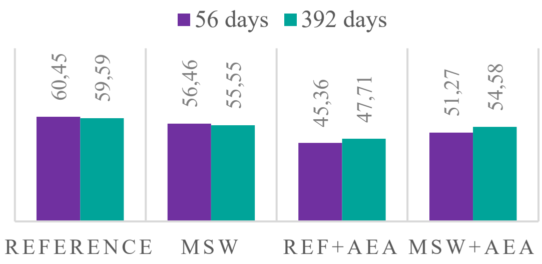


Fig. 1: Compressive strength results [MPa]

Based on the results, the compressive strength slightly benefits in time from using of AEA (5 % increase), see Figure 1. In terms of diffusion coefficient, all of the mixtures show improvement over time, which is a generally known phenomenon, AEA does not affect the diffusion coefficient and by using MSW the diffusion coefficient increases by 40 % and 60 % with AEA, which means worse diffusion characteristics, see Figure 2.

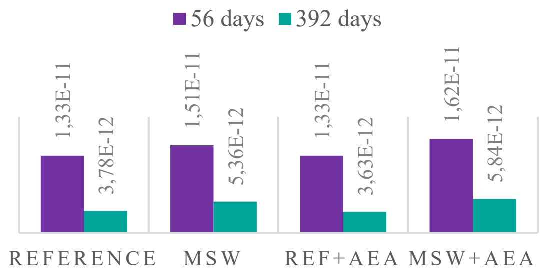


Fig. 2: Diffusion coefficient results [m^2/s]

Acknowledgements

The research was funded by the Ministry of Education, Youth and Sports of the Czech Republic through VSB - TU Ostrava (SGS SP2023/056).

References

[1] PIZOŃ, Jan, Jacek GOŁASZEWSKI, Mohamed ALWAELI a Patryk SZWAN. Properties of concrete with recycled concrete aggregate containing metallurgical sludge waste. Materials. 2020, 13(6). ISSN 19961944.

[2] ALWAELI, Mohamed, Jacek GOŁASZEWSKI, Marian NIESLER, Jan PIZOŃ a Małgorzata GOŁASZEWSKA. Recycle option for metallurgical sludge waste as a partial replacement for natural sand in mortars containing CSA cement to save the environment and natural resources. Journal of Hazardous Materials. 2020, 398, 123101. ISSN 03043894.

[3] LEHNER, Petr, Marie HORŇÁKOVÁ, Jan PIZOŃ a Jacek GOŁASZEWSKI. Effect of Chemical Admixtures on Mechanical and Degradation Properties of Metallurgical Sludge Waste Concrete. Materials. 2022, 15(23), 8287. ISSN 1996-1944.

Effect of Degradation Processes on the Compressive Strength of High Performance Concrete

Kristýna HRABOVÁ[1], *Petr LEHNER*[2],

[1]Institute of Building Testing, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, 602 00 Brno

[2]Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvíka Podéště 1875/17, 708 33 Ostrava-Poruba, Czech Republic

kristyna.hrabova@vutbr.cz, petr.lehner@vsb.cz

High performance concrete (HPC) has been used for many years, for example in the construction of bridge structures [1]. It is clear that these structures are exposed to weathering and aggressive substances such as chloride ions or carbon dioxide [1]and it is therefore appropriate to investigate the effect of these substances on the material properties. The cubic compressive strength of high-value concrete ranges from 55 MPa to 120 MPa. In this study, a concrete with an expected cubic strength of just around 55 MPa was prepared, i.e. on the borderline between standard and HPC concrete. The composition of this concrete is shown in Table 1.

Tab.1: Concrete mixture properties.

Material	kg/m³
CEM II/A-S 42.5R	400
Aggreagate 0/4	752
Aggreagate 4/8	204
Aggreagate 8/16	755
Water	165

The concrete was prepared according to EN 206 [2] and strength testing was carried out according to EN 12390-3 [3]. In addition to several tests during the ageing of the concrete at 28, 90 and 181 days, strength tests were carried out on specimens subjected to degradation processes. The specimens were tested for frost resistance and their strength was determined after removal from the apparatus at 118 days. In addition, separate samples were immersed in chloride solution and other samples in a carbonation chamber at 90 days. At 181 days their compressive strengths were then obtained again.

Fig. 1 shows the average values of the cubic compressive strengths determined from the three samples. The standard deviation is also show. Light columns are without the inclusion of degradation tests. The blue column shows samples after freeze hardiness testing, the orange column is after exposure to chloride bath and the grey column is after exposure to carbon dioxide.

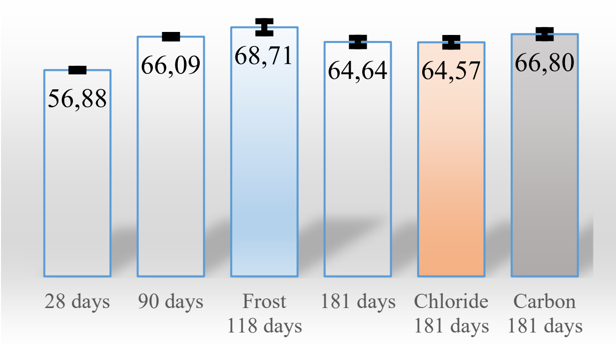


Fig. 1: Results from compressive strength tests [MPa].

Acknowledgements

The investigations has been conducted within the framework of Project GACR 22-19812S: "Effect of gaseous and traffic induced pollutants on the durability of reinforced concrete structures".

References

[1] VOŘECHOVSKÁ, Dita, Petr KONEČNÝ, Martina ŠOMODÍKOVÁ a Pavla ROVNANÍKOVÁ. Preliminary analysis of durability related field inspection of highway bridge No. 57-039. In: IASTEM 2018. 2018, s. 55–58.

[2] EUROPEAN COMMITTEE FOR STANDARIZATION. EN 206-1. Concrete - Part 1: Specification, performance, production and conformity. 2000

[3] EN 12390-13. EN 12390-13. In: Testing hardened concrete - Part 13: Determination of secant modulus of elasticity in compression. 2013.

ASPECTS OF TESTING AND MODELLING OF RECYCLED CONCRETE FROM PAVING BLOCKS

Marie HORŇÁKOVÁ[1], *Petr LEHNER*[1], *David BUJDOŠ*[2], *Lucie CHOVANCOVÁ*[1], *Dominik GŘEŠICA*[1], *Jan DEDEK*[3], *Petr KONEČNÝ*[1]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic

[2] Department of Building Materials and Diagnostics of Structures, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic

[3] Department of Building Construction, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic

marie.hornakova@vsb.cz, petr.lehner@vsb.cz, david.bujdos@vsb.cz, lucie.chovancova.st@vsb.cz, dominik.gresica@vsb.cz, jan.dedek1@vsb.cz, petr.konecny@vsb.cz,

It is still of high interest of many research groups around the world to design and study possibilities of using waste as replacement of traditional ingredient for certain construction materials. In the case of concrete industry, the most common trend is to use construction and demolition waste as a replacement of natural aggregate. Despite the differences in the mixture compositions, the general conclusions are that recycled aggregate should be considered as a valuable material in concrete industry [1]. The waste materials can be paving blocks (PB) too (see example in Fig. 1 [2]). The paving block is a vibro-pressed element with a low water-cement ratio, which allows for obtaining appropriate mechanical properties. However, if the strict requirements for dimensions or shape are not met during pavement installation or if the pavement is dismantled, these elements must be somehow disposed of. One of the following uses of these elements might be crushing and using as a replacement for natural coarse aggregate in a new concrete mixture with the intention to increase the compression strength [3]. This paper summarizes the assumptions of the project and research conducted at the Department of Structural Mechanics, Faculty of Civil Engineering, VŠB-TUO.

Fig. 1: Example of concrete paving blocks [1].

Due to the properties of PB, it is believed to be an ideal material for replacing coarse aggregate in concrete. Milling to a fine powder and replacement as fine aggregate is practically and economically inefficient [2]. As a basis, the percentage of crushed or ground PB in the whole range of replacement should be from 0 to 100%, ideally in 20% increments. The raw material will be obtained from the University of Gliwice, where it will be crushed and aggregate analysis (specific gravity, grading, water content and water absorption) will be carried out, after which the mixes will be designed and concreted and tests for mechanical resistance and durability of the materials will also be carried out. The research will include the study of the microstructure of concrete materials. Based on the data obtained, a material model will be developed and used for numerical modelling in ATENA/ANSYS software to evaluate and optimize the long-term degradation tests.

Acknowledgements

The research was funded by the Ministry of Education, Youth and Sports of the Czech Republic through VSB - TU Ostrava (SGS SP2023/056).

References

[1] El-Reedy, M. A. (2009). Advanced Materials and Tech-niques for Reinforced Concrete Structures. Taylor and Francis Group, LLC.

[2] CS-Beton: CSB - KOSTKA [online]. [cit. 2023-04-26]. https://www.csbeton.cz/cs/csb-kostka-4

[3] Muwafaq, Wadhah & Alshareedah, Othman & Hossain, Taimoor. (2016). Properties of Concrete Mix with Crushed Pavement Blocks as Coarse Aggregate. International Journal of Scientific and Engineering Research. 7.

EXPERIMENTAL DETERMINATION OF THE ROTATIONAL STIFFNESS OF A TIMBER SEMI-RIGID CONNECTION

Marek JOHANIDES, Antonín LOKAJ

Department of Structures, Faculty of Civil Engineering, VŠB – Technical University of Ostrava, 708 00 Ostrava - Poruba, Czech Republic

marek.johanides@vsb.cz, antonin.lokaj@vsb.cz

Abstract. *The paper describes with the determination of the rotational stiffness of a timber semi-rigid connection. The rotational stiffness was calculated on the basis of the currently valid standard and experimental test. In the first case, the connection was made from the standard combination of bolts and dowels. In the second case, the connection was made of fully threaded screws.*

1. Introduction

Despite today's knowledge, the joints of timber structures are still not fully researched. Especially stiffness, which can significantly influence the redistribution of internal forces between individual elements of the structure. The article describes the experimental determination of the rotational stiffness of the timber semi-rigid connection between the post and the transom. The results of the experimental testing were compared with the values that can be calculated according to the standard for designing wooden structures EC5.

The table shows the values where, $k_{r,u,EC5}$ is the rotational stiffness value achieved by substituting the standard values of the wood density and the outer diameter of the connecting means. The value $k_{r,u,EC5,1}$ contains the actual measured density of the wood and the diameter of the shank of the connecting means. The $k_{r,test}$ values were obtained by experimental testing at a load level of 60, 80 and 100% of the value of the limit state of the bearing capacity calculated according to the EC5 standard.

Fig. 1 shows a scheme of a solved connection, fig. 2 shows the dependence of the rotational stiffness on the load and in tab.1 individual results are shown and compared.

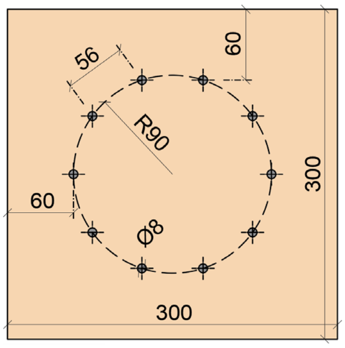


Fig. 1 Connection detail.

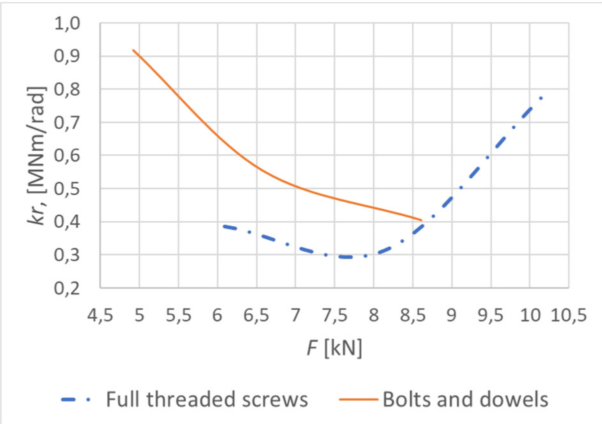


Fig. 2 Dependence of rotational stiffness on load.

Tab. 1 Results of rotational stiffness.

Type of connecting agent		Value [MNm/rad]	Comparison [%]
Bolts and dowels	$k_{r,u,EC5}$	0,323	-
	$k_{r,u,EC5,1}$	0,299	-8
	$k_{r,test,60}$	2,198	+85
	$k_{r,test,80}$	1,055	+31
	$k_{r,test,100}$	0,404	+20
Full thread screws	$k_{r,u,EC5}$	0,323	-
	$k_{r,u,EC5,1}$	0,206	-57
	$k_{r,test,60}$	0,386	+16
	$k_{r,test,80}$	0,313	-3
	$k_{r,test,100}$	0,896	+64

2. Conclusion

The paper presents and compares the results obtained by experimental testing and the results calculated according to the EC5 standard. In the results, it is possible to observe a non-negligible difference between the calculated and the actual measured value of the rotational stiffness, especially in the case of a joint made of fully threaded screws.

Size Effect of 3D Printed Samples

David JURACKA[1], *Marek KAWULOK*[1], *David BUJDOS*[2], *Martin KREJSA*[1]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic
[2]Department of Building Materials and Diagnostics of Structures, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic

david.juracka@vsb.cz, marek.kawulok@vsb.cz, david.bujdos@vsb.cz, martin.krejsa@vsb.cz

One of the most well-known additive manufacturing processes is 3D printing technology. There are types for very detailed objects, and others are ideal for large-scale or fast printing. It is also possible to work with various materials - thermoplastic, concrete, metal, and others.

The quality and strength of printed materials depends on many factors. The most widespread 3D printing technology, FFF / FDM (fused filament fabrication / fused deposition modelling) was chosen for this research. Printed objects are assembled from fibres and layers. The arrangement of the fibers and their size in the object strongly influence their final overall strength according to the applied load [1].

The purpose of this research is to determine the effect of the sample size on the maximum normal stress during the three-point bending test performed according to the ČSN EN ISO 178 standard. Three sets of PC Blend samples A, B, and C are produced and tested, in three sizes (A - 80x20x15 mm; B - 120x30x22.5 mm; C - 160x40x30 mm). These sizes are a proportional multiple of the smallest sample A (see Fig. 1). One direction (longitudinal) and size (0.4x0.2 mm) of printed fiber are used for all samples.

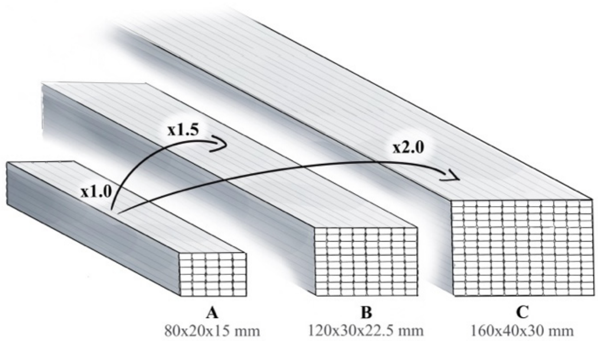


Fig. 1: Schematic of three sets of samples showing fiber orientations.

The purpose of the test is to determine the maximum possible force F (N) to bend the sample, and then the value of the maximum normal bending stress σ_{fM} (MPa) can be calculated:

$$\sigma_{fM} = \frac{3FL}{2bh^2}, \qquad (1)$$

where L is seating of the abutment surfaces [mm], b is the width of the test piece of rectangular cross-section [mm] and h is its thickness [mm].

The resulting average values of the maximum normal stress achieved are compared (see Fig. 2). As can be seen, the differences in values are quite minimal, and thus the total size of the specimen has no effect, or only a small one, on its maximum normal stress.

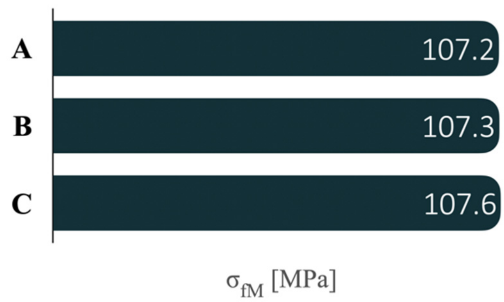


Fig. 2: Results of the average values of the maximum stress achieved during the three-point bending test for sets of samples with different sizes.

Acknowledgements

The research was funded by the Ministry of Education, Youth and Sports of the Czech Republic through VSB - TU Ostrava (SGS SP2023/098).

References

[1] JURACKA, David, Marek KAWULOK, David BUJDOS a Martin KREJSA, 2020. Influence of Size and Orientation of 3D Printed Fiber on Mechanical Properties under Bending Stress. Periodica Polytechnica Civil Engineering. ISSN 1587-3773. doi:10.3311/PPci.19806

NUMERICAL PROCEDURE FOR SOLVING THE NONLINEAR BEHAVIOUR OF A SPHERICAL ABSORBER

Marek KAWULOK[1,2], *Martin ČERMÁK*[3], *Stanislav POSPÍŠIL*[1,2]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, VSB – Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic

[2]Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences, Prosecka 809/76, 190 00 Prague 9, Czech Republic

[3]Department of Mathematics, Faculty of Civil Engineering, VSB – Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic

marek.kawulok@vsb.cz, martin.cermak@vsb.cz, stanislav.pospisil@vsb.cz

Abstract. *This article is aimed at providing one of possible approaches to carry out numerical computations of a nonlinear system of equations of motion. The approach is demonstrated using an example of a ball absorber placed on a support bowl. The motion of the ball is constrained to a planar problem. The numerical solution of the derived system of equations is carried out using the continuation method and the modified secant method. By these techniques, the response of the absorber to different amplitudes of harmonic excitation force is simulated. The results are presented as a graphical representation of the dependence of the response amplitude on the excitation angular frequency. These results also include the identification of stable and unstable solution regions using the values of the determinant of relevant Jacobian matrix.*

Introduction

Vibrations are an unwanted phenomenon to which the load-bearing systems of buildings can be subjected. They may be caused by human activity or natural processes, u.e. earthquake. To minimise the effects of vibration and reduce potential damage, damping devices are incorporated into the structures. The robust ones and thus most widely used are so called passive absorbers. One representative of this group of dampers is the ball vibration damper, which, despite all its advantages, can suffer from motion instability, splitting and complications associated with auto-parametric oscillation [1]. It is therefore desirable to investigate the behaviour of this absorber with this respect.

The aim of this contribution is to present a procedure for the numerical calculation of a system of nonlinear equations describing the response of a spherical absorber placed in a support bowl, considering only planar behaviour. The derivation of the system of equations is based on the principles used in the [1]. The equations are solved by applying Modified Secant Method and Continuation Method. The main reason for choosing these methods is the ability to solve equations that describe not only functions but also resulting trajectories. This is useful for creating curves showing the dependence between the absorber response and the angular excitation frequency. Due to the nonlinear behaviour of the absorber, a softening effect occurs in these curves, resulting in multiple response solutions for a single excitation angular frequency. If this phenomenon occurs, it is necessary to analyse whether the solution is a stable or unstable. Simulations are carried out for three values of the excitation force amplitude. For each of these cases, dependence curves between the response and the angular frequency of the excitation are plotted. The results also include graphical outputs of the relationship between the value of the determinants of the Jacobian matrix and the excitation angular frequency.

Acknowledgements

The financial supports of the grant program financed by Ministry of Education, Youth and Sports of the Czech Republic through VSB–TUO SGS SP2023/059 and from the budget for conceptual development of science, research and innovations are highly acknowledged.

References

[1] NÁPRSTEK, J., C. FISCHER, M. PIRNER and O. FISCHER, Non-linear Model of a Ball Vibration Absorber. In: PAPADRAKAKIS, Manolis, Michalis FRAGIADAKIS a Vagelis PLEVRIS, ed. Computational Methods in Earthquake Engineering. Dordrecht: Springer Netherlands, 2013, s. 381-396. Computational Methods in Applied Sciences. ISBN 978-94-007-6572-6. DOI:10.1007/978-94-007-6573-3_18

NUMERICAL ANALYSIS OF HEAT TRANSFER ABOVE A WIND LOADED HEATED PLATE

Ivan KOLOŠ[1], *Vladimíra MICHALCOVÁ*[1], *Lenka LAUSOVÁ*[1]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, VSB – Technical University of Ostrava, Ostrava, Czech Republic

ivan.kolos@vsb.cz, vladimira.michalcova@vsb.cz, lenka.lausova@vsb.cz

This article deals with the behaviour of building materials during heat transfer. It is a numerical analysis of the flow over a heated plate of material used in historic buildings under wind load. The main goal of the study is to describe the heat transfer in the mixed velocity-thermal boundary layer near the heated plate.

The numerical study was performed on two cases of plate temperature. The flow around the unheated plate was modelled as isothermal flow, whereas in the case of the heated plate by $\Delta T = 20$ °K, it was modelled as incompressible non-isothermal flow. The calculations were performed for 3 velocities: $v_1 = 1$ m/s, $v_2 = 3$ m/s, $v_3 = 5$ m/s. The tasks were solved in Ansys Fluent software using the Large Eddy Simulation (LES) method. The parameters entered in the numerical solution in the case of heated cylinder are: air temperature T [K], thermal conductivity λ [W/(m·K)] and sensible enthalpy h_s [J/m^3], which is dependent on the specific heat capacity of the air c_p [J/(kg·K)]. The present work was solved using the SL subgrid model, where the so-called subgrid turbulent viscosity is dependent on the length scale of small vortices.

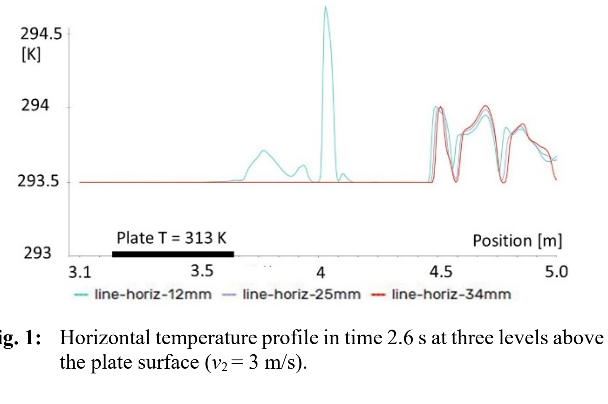


Fig. 1: Horizontal temperature profile in time 2.6 s at three levels above the plate surface ($v_2 = 3$ m/s).

The dimensions of the computational area are $8.6 \times 0.05 \times 0.917$ m (length × width × height), the position of the heated plate can be seen from Fig. 1. Although the monitored quantities change significantly only in the direction of the x and z axes, the domain in the third direction was modeled with a non-zero thickness so that the LES model could be used. The mesh was constructed to meet the requirements of y+ ≤ 1 for all three velocities.

Fig. 1 describes horizontal temperature profile in time 2.6 s at three levels above the plate surface for the velocity v_2. From a height of 12 mm above the level of the plate, a temperature change was recorded behind the plate. For that reason, the instantaneous temperature was also recorded at points above the plate (position 3.4 m) and almost at its end (position 3.6 m), in both cases 3 mm and 12 m above the plate (Fig. 2).

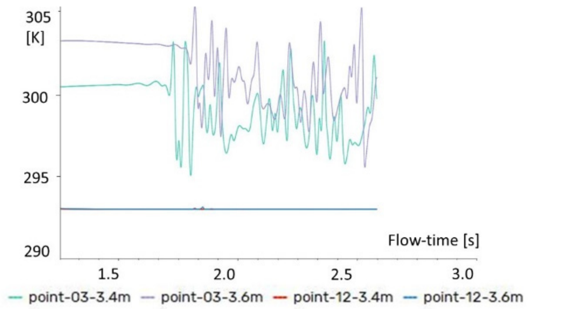


Fig. 2: Recording of instantaneous temperature at selected points.

The data obtained provide a description of the interrelationship between various parameters such as temperature, relative humidity, wind velocity and direction, as well as heat flows in the building part and surface roughness.

Acknowledgements

This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic through the e-INFRA CZ (ID:90140).

References

[1] KOLOS, IVAN, L. LAUSOVÁ and V. MICHALCOVÁ. Evaluation of turbulence models for flow over a thermally loaded hill. *Journal of Numerical Analysis, Industrial and Applied Mathematics*. 2019. 13(3-4). pp.10-19. ISSN 1790-8140.

PRELIMINARY STUDY ON EVALUATION CORROSION INITIATION OF REINFORCED CONCRETE WITH BINARY AND TERNARY CEMENTITIOUS MIXTURES BASED ON ZEOLITE

Petr KONEČNÝ[1], *Pratanu GHOSH*[2], *Anabelle RECINOS*[2]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, VŠB – Technical University of Ostrava, Czech Republic

[2]Department of Civil and Environmental Engineering, California State University Fullerton, California, USA

petr.konecny@vsb.cz, pghosh@fullerton.edu

Energy efficiency is a leading factor in case of competitive cementious material along with sustainability of the concrete industry. This study aims to evaluate the durability indicator of high-performance concretes (HPC) mixtures with various eco-friendly supplementary cementitious materials (SCM). The major supplementary cementitious materials (SCMs) namely volcanic pumice pozzolan (VPP), Zeolite (Z) Class C and F fly ash, ground granulated blast furnace slag of grade 120, silica fume, and metakaolin were included in the study. Thirteen concrete mixtures were analysed with respect to the corrosion initiation related to chloride ingress along with seven types of reinforcement protection (e.g. conventional steel, galvanized steel, carbon steel, MMFX steel etc.).

The chloride ions from deicing agents penetrate through concrete cover in the corrosion initiation period until chloride threshold is reached. When chloride threshold value is exceeded corrosion is initiated and propagation stage is reached. The diffusion of chlorides is considered as a major phenomenon governing chloride ion transport to the reinforcement level in case of bridge decks. Thus 2. Fick's Law is used to describe chloride ion transport and in-house Korozeenck tool is used for the analysis.

The concrete ability to resist chloride ion ingress is described by the diffusion coefficient that might be computed directly or indirectly. Direct computation is based on the analysis of chloride profile and indirect one is based on the evaluation of electrical resistivity of concrete. The electrical resistivity was evaluated as a surface or bulk resistivity and recomputed as the diffusion coefficient of chlorides. The diffusion coefficient, along with surface chloride concentration, depth of the reinforcement and chloride threshold to initiate corrosion are input parameters in order to compute corrosion initiation time.

The sample output of the analysis for selected depth of the cover and concrete mixtures is presented on as indicated on Fig. 1. The results present corrosion initiation time which is the time for the onset of corrosion for one of considered cases – epoxy coated reinforcement. It is possible to observe the difference between the reference ordinary Portland cement-based concrete, marked as 100TII-V and mixture with 20 percent of zeolite and 25 percent of pumice, marked as 22TII-V/20Z/25P. The nomenclature stands for the percentage of the cementitious material and its symbol.

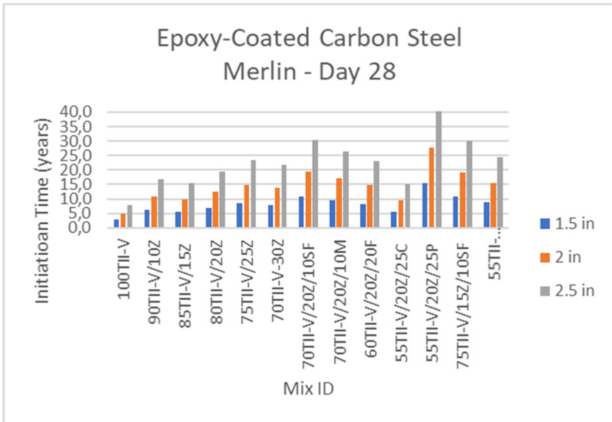


Fig. 1: Sample output of the analysis: Evaluation of corrosion initiation time (years) based on the concrete mixture and depth of the cover (1.5 in / 38.1 mm, 2 in / 50.8 mm, 2.5 in / 63.5 mm)

Acknowledgements

This contribution has been developed as a part of the research project GACR 22-19812S "Effect of gaseous and traffic induced pollutants on the durability of selected construction materials" supported by the Czech Science Foundation.

References

[1] P. Konečný, J. Brožovský, P. Ghosh, P. "Evaluation of Chloride Influence on the Cracking in Reinforced Concrete Using Korozeeneck Software". Transactions of the VŠB – Technical University of Ostrava, Civil Engineering Series, 11(1), 1–7, 2010.

STATIC ANALYSIS OF CYLINDRICAL WATER TANK USING FEM

Kamila KOTRASOVÁ[1], *Petr FRANTÍK*[2], *Eva KORMANÍKOVÁ*[1]

[1]Institute of Structural Engineering and Transportation Structures, Faculty, Faculty of Civil Engineering, Technical University of Košice, Vysokoškolská 4, 042 00 Košice, Slovakia

[2]Institute of Structural Mechanics, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, 602 00 Brno, Czech Republic

kamila.kotrasova@tuke.sk, frantik.p@fce.vutbr.cz, eva.kormanikova@tuke.sk

The demand for drinking and service water storage is rising with changing climate conditions and increasing life expectancy. Tanks are commonly used to store large volumes of liquids and materials in various fields of the economy. Still, their classification can be difficult due to varying shapes, purposes, and construction materials.

Cylindrical tanks offer advantages in terms of pressure and tension stresses on their outer shells and material consumption, but their construction requires complex formwork. The tank bottom design depends on the subsoil's bearing capacity. Specific requirements must be considered when designing cylindrical tanks for liquids, including the interaction between fluid and solid of the container with the subsoil.

Certain ordinary or partial differential equations systems can't be solved analytically in engineering mathematical problems. Numerical methods were developed to address this issue, particularly those suited for computers. The finite element method saw rapid progress starting in the early 1960s and is an ongoing area of development to this day.

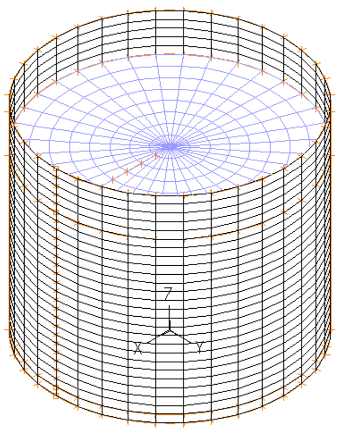


Fig. 1: Computational model of the cylindrical water tank

We consider a cylindrical water tank subjected to gravity loading with radii R = 15 m and wall height H = 25 m. The tank is made from steel, Young's modulus $E = 2.07 \cdot 10^{11}$ N/m^2, Poisson number $\nu = 0.3$, and density ρ_s = 7800 kg/m^3. The wall thickness is 50 mm, and the thickness of the bottom is 500 mm. The fluid filling has a height of 20 m with water, density ρ_w = 1000 kg/m^3, and bulk modulus κ = 2.1 N/m^2, see Fig. 1.

The effective stress of the tank solid domain by numerical simulation in software Adina, is documented in Fig. 2, and the pressure of the water filling on the tank solid domain is in Fig. 3.

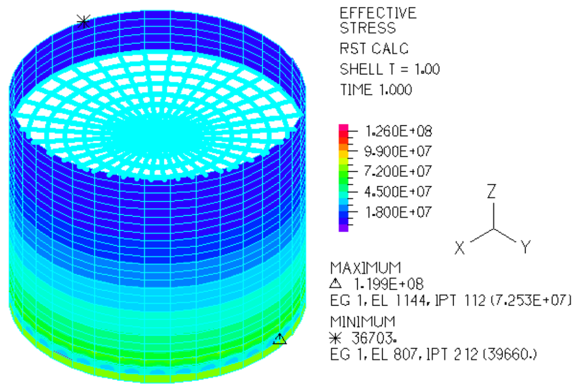


Fig. 2: The effective stress of the tank solid domain

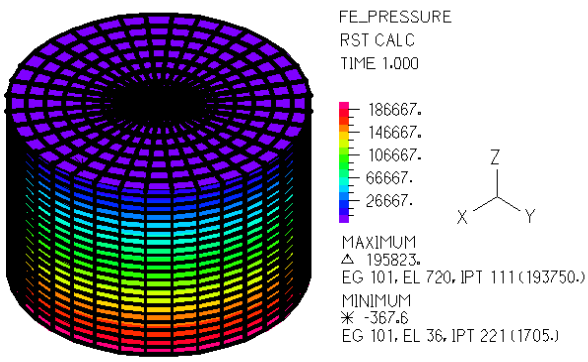


Fig. 3: The pressure of the fluid domain

Acknowledgements

This work was supported by Projects VEGA 1/0307/23, and MeMoV II CZ.02.2.69/0.0/0.0/18_053 /0016962.

NUMERICAL FEM MODEL OF CLOSED STEEL SUPPORTS OF UNDERGROUND STRUCTURES

Lenka KOUBOVÁ[1], *Petr LEHNER*[1]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic

lenka.koubova@vsb.cz , petr.lehner@vsb.cz

Closed Steel Supports (CSS) are a basic structural support element in mining and underground structures. In most cases, they are rolled, robust cross-sections assembled from a large number of parts to form a single closed structure. The bearing capacity of supports is influenced by shape, surrounding soil and conditions, among other factors. This paper presents a comparison of results from a finite element model (FEM) and results from a previously presented numerical solution [1]. This solution was based on the force method and numerical integration combined with the assumptions of the Winkler model [2]. The FEM model uses Scia Engineering software [3] to analyse the internal forces and the overall behaviour of the structure. Fig. 1 shows the analysed cross-section TH29. Fig. 2 shows the geometry of the entire support.

Fig. 1: TH29 profile – Liberty Ostrava, a.s. CZ.

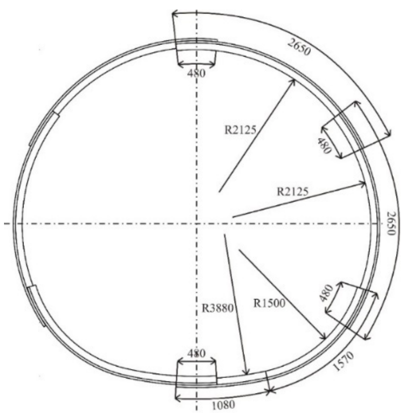
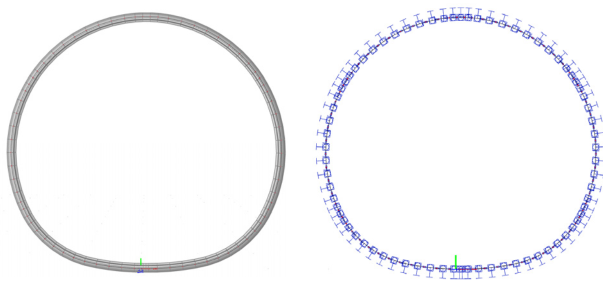


Fig. 2: Geometry of closed steel supports construction.

The FEM beam model contains the exact geometry of the structure and cross section of TH29 (see Fig 3 (a)). The supports are defined around the entire circumference of the CSS taking into account the stiffness characteristics of the soil calculated with consideration to the Winkler model. The procedure can be used to control more complex structures.



(a) (b)

Fig. 3: Precise numerical model in Scia Engineering (a) and display of supports in the model (b).

Acknowledgements

Financial support from VSB-Technical University of Ostrava by means of the Czech Ministry of Education, Youth and Sports through the Institutional support for conceptual development of science, research and innovations is gratefully acknowledged..

References

[1] KOUBOVA, L., P. JANAS, K. JANAS a M. KREJSA. Determination of the load carrying capacity of closed steel supports used in underground construction and mining. Steel and Composite Structures [online]. 2022, 35(5), 715–728. Online: doi:10.12989/scs.2022.45.5.715

[2] Kurian, N. P. A new continuous winkler model for soil-structure interaction. Journal of Structural Engineering (Madras), 2021, 27(4), 269-276.

[3] Scia Engineer [online]. [vid. 2023-03-28]. Online: https://www.scia.net/en

The influence of different notches on fatigue lifetime of round bar specimens made of HDPE

Kamila KOZÁKOVÁ[1,2], *Lukáš TRÁVNÍČEK*[1,3], *Jan KLUSÁK*[1], *Jan PODUŠKA*[1], *Jaroslav KUČERA*[4], *Pavel HUTAŘ*[1,3]

[1]Institute of Physics of Materials AS CR, Žižkova 22, 616 00 Brno, Czech Republic
[2]Faculty of Mechanical Engineering BUT, Technická 2896/2, 616 69 Brno, Czech Republic
[3]CEITEC BUT, Purkyňova 123, 621 00 Brno, Czech Republic
[4]Polymer Institute Brno, Tkalcovská 36/2, 602 00 Brno, Czech Republic

kozakova@ipm.cz, travnicek@ipm.cz

High-density polyethylene (HDPE) is one of the most demanded polymer materials due to its various properties. Thus, it has found practical applications in different industry sectors, such as automotive, buildings and constructions, chemical industry, electrotechnics, or food industry. These components often have complex shapes with different stress concentrators (notches) and are exposed to cyclical loading. To ensure its safe use, it is necessary to study the influence of notches on fatigue lifetime.

This research is focused on fatigue testing of notched round bar specimens made of HDPE and the evaluation of the experimental fatigue data by a modified approach of finite fracture mechanics [1]. This approach takes advantage of axial stress distribution around notches that was calculated by finite element analysis and experimental fatigue data to determine a length parameter. This parameter can then be used for fatigue lifetime predictions of notched specimens with various notch radii.

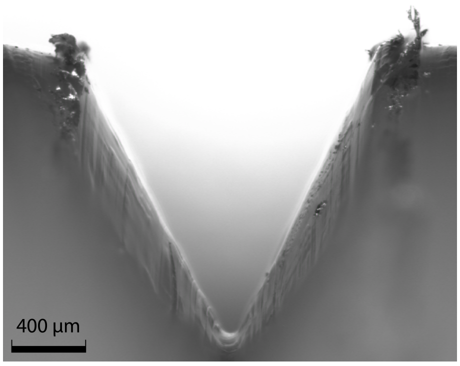


Fig. 1: Detail of notch $r = 0.1$ mm

Three types of notches in the round bar specimens were tested – "v" notch with radii r of 0.1 mm and 0.4 mm and extremely sharp notch representing a crack (see Fig. 1, 2). The notched specimens were exposed to cyclic loading with a frequency of 10 Hz at room temperature. The study includes the determination of length parameters from different types of notches, their analysis, and comparison.

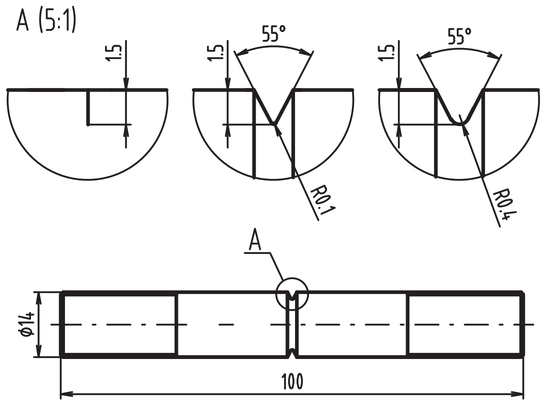


Fig. 2: Notched specimens: sharp notch representing a crack, $r = 0.1$ mm, $r = 0.4$ mm

Acknowledgments

This work was supported by University Specific Research, project CEITEC VUT/FSI-J-23-8289.

References

[1] Hu, Z., Berto, F., Hong, Y., Susmel, L.: Comparison of tcd and sed methods in fatigue lifetime assessment. International Journal of Fatigue 123, 105–134 (2019)

FRAGILITY ANALYSIS OF THE REACTOR STEEL SHAFT DOOR DUE TO ACCIDENTAL EXTREME OVERPRESSURE

Juraj KRÁLIK[1], *Jozef BOČKAJ*[1]

[1]Institute for Forensic Engineering, Faculty of Civil Engineering, Slovak University of Technology, Radlinského 11, 810 05 Bratislava, Slovakia

juraj.kralik@stuba.sk, jozef.bockaj@stuba.sk

This paper describes the fragility analysis of the steel doors of the reactor hall due to extreme pressure and temperature. The scenario of the hard accident in nuclear power plant (NPP) and the methodology of the calculation of the fragility curve of the failure overpressure using the probabilistic safety assessment PSA 2 level is presented. The nonlinear probabilistic analysis based on the response surface method (RSM) were considered.

The IAEA (International Atomic Energy Agency) in Vienna [1] adopted a large-scale project "Stress Tests of NPP", which defines new requirements for the verification of the safety and reliability of NPP due to the accident of NPP in Fukushima. Based on the recommendations of the IAEA in Vienna [1], the probabilistic methodology of the safety and reliability of the NPP structures was accepted for the problem of the safety of the critical structures.

The SE-ENEL proposes the maximum temperature in the reactor shaft is equal about to 1.800ºC and in the containment around the reactor shaft is equal about to 350ºC [4-6].

Tab.1 The assumed scenarios of the accidents

Type	Duration	Overpressure in HZ [kPa]	Internal temperature [ºC]
I.	1hour - 1day	150	127
II.	2hours - 7days	250	150
III.	1year	-	80 - 120

The possibility of the temperature increasing to the containment failure state is considered in the scenario too. In the case of the hard accident the overpressure can be increased linearly, and the internal and external temperature are constant.

Three types of the scenarios were considered (Tab.1). The critical was the accident during 7 days with the overpressure 250kPa, internal temperature 150ºC and external temperature -28ºC.

The hermetic steel doors type A262 (with dimension 1600/900/150 mm) are located at the reactor shaft. The steel doors fulfil both the sealing and shielding functions. The technology segments of the NPP hermetic zone are made from the steel (S235). The steel door is fitted in the frame cast in concrete and sealed to the frame with double rubber packing of 15 mm in width.

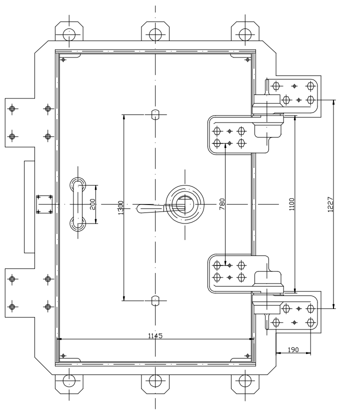


Fig.1: Hermetic door of the reactor shaft

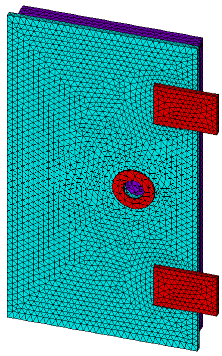


Fig.2: FEM model of hermetic door of the reactor shaft

The FEM model of the steel door is shown in Fig.2. The detailed FEM model has 65.194 SOLID185 and CONTA173 elements.

Acknowledgements
The project was performed with the financial support of the Grant Agency SR (VEGA 1/0453/20).

References

[1] IAEA (2010) *Safety Series No. SSG-4, Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants*, Vienna.

[2] Králik, J. (2009) *Safety and Reliability of Nuclear Power Buildings in Slovakia. Earthquake-Impact-Explosion.* Ed. STU Bratislava, 307pp.

PROBABILISTIC ASSESSMENT OF FATIGUE LIFE OF RAILWAY BRIDGES USING FEM AND MONTE CARLO LOAD ESTIMATION

Petr LEHNER[1], *Martin KREJSA*[1]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic

petr.lehner@vsb.cz, martin.krejsa@vsb.cz

There are 6,726 railway bridges in the Czech Republic [1], a large proportion of which are made up of riveted, welded, or bolted steel truss structures (e.g., Fig. 1.). Fatigue damage is considered to be the leading cause of premature failure of railway bridges worldwide [2].

Fig. 1: Riveted steel railway bridge over the Ostravice River.

One way to determine the service life of such a structure and or predict the need for inspection of the structure is to apply orthogonal resistance in conjunction with finite element method (FEM) modelling (see simplified beam model on Fig. 2). The result is then called fatigue curves or S-N curves, which are used to determine the repeated (dynamic) load capacity of the structure or part of it. Although the whole process is complex and involves several approaches and calculations, it can be described by the simple flow chart shown in Fig 3.

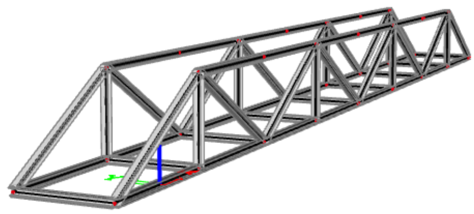


Fig. 2: Simplified beam model of railway steel bridge.

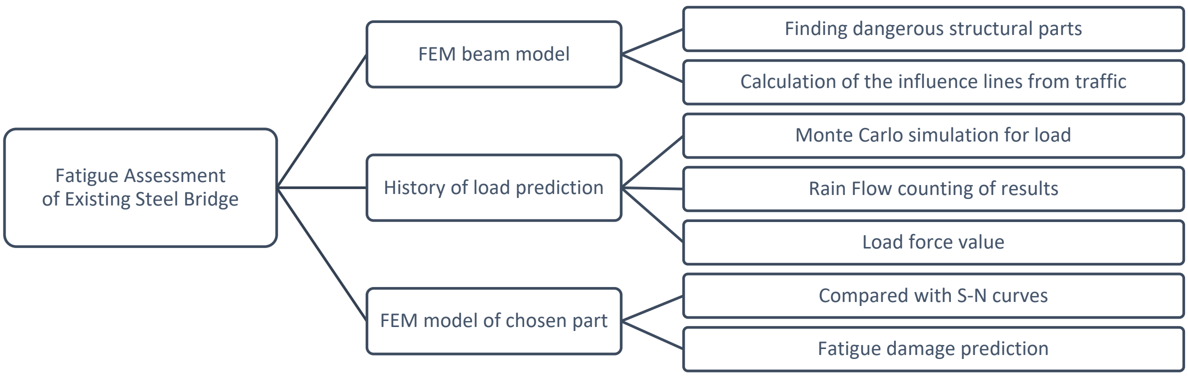


Fig. 3: Simplified diagram of the whole process of the fatigue assessment of existing steel bridge.

Acknowledgements

This contribution has been developed as a part of the research project GACR 21-14886S "Influence of material properties of high strength steels on durability of engineering structures and bridges" supported by the Czech Science Foundation.

References

[1] Mimořádné prověření mostů [online].[2023-03-25]. Dostupné z: https://www.mdcr.cz/Media/Media-a-tiskove-zpravy/Mimoradnym-proverenim-proslo-uspesne-34-zeleznicn

[2] X.W.Ye , Y.H.Su, and J.P.Han,(2014) A state of the art review on fatigue life assessment of steel bridges, Math Prob Eng, 2014 (2014),

ANALÝZA KOROZNÍHO POŠKOZENÍ VZORKŮ VYROBENÝCH Z VYSOKOPEVNOSTNÍCH OCELÍ

Vít KŘIVÝ[1], *Miroslav VACEK*[1], *Stanislav SEITL*[2], *Martin KREJSA*[1]

[1]Fakulta stavební, VŠB – Technická univerzita Ostrava, Ludvíka Podéště 1875/17, Ostrava - Poruba
[2]Ústav fyziky materiálů AV ČR, v.v.i., Žižkova 513/22, Brno

vit.krivy@vsb.cz, miroslav.vacek@vsb.cz, seitl@ipm.cz, martin.krejsa@vsb.cz

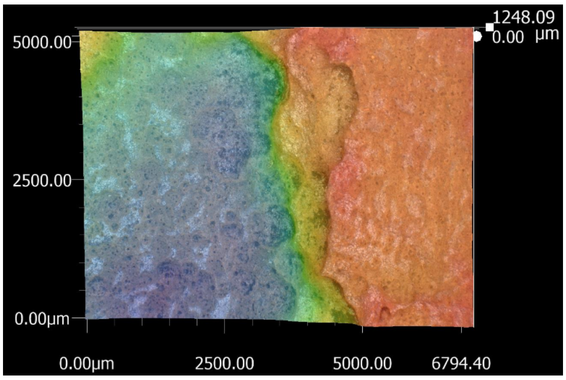
Oceli vyšších pevností se historicky uplatňují především ve strojírenském průmyslu. Tyto oceli se však stále častěji využívají i v mostním stavitelství. Ocel pevnostní třídy S460 byla například použita pro most Oresund spojující Dánsko a Švédsko nebo také pro Viadukt Millau ve Francii. Pro most Akahi - Kaikyó byly uplatněny třídy oceli S690 a S780. Ocelí vyšších pevností se však začínají používat i při výstavbě běžných mostů.

Jednou z hlavních předností pro uplatnění ocelí vyšších pevností ve stavebnictví je příznivý poměr pevnostních vlastností k hmotnosti konstrukce. Při navrhování konstrukcí z ocelí vyšších pevností uplatňují vyšší hodnoty pevnostních vlastností oceli. Díky této skutečnosti je možné provést efektivní návrh konstrukce s významnými ekonomickými úsporami oproti uplatnění tradičních konstrukčních ocelí.

Při použití ocelí vyšších pevností je potřeba věnovat zvýšenou pozornost zajištění dostatečné tuhosti konstrukce, vyhodnocení stabilitních jevů a také posouzení na únavu. Ze zkušeností z reálně provozovaných mostních konstrukcí vyplývá, že u některých prvků nosné ocelové konstrukce může docházet k rozvoji významných korozních poruch. Vlivem korozního poškození dochází k oslabení nosných konstrukčních prvků, k možnému snížení statické únosnosti a ke změnám geometrie povrchu konstrukce, které mohou mít významný vliv na únavovou odolnost korozí ovlivněného konstrukčního detailu. Ačkoliv jsou lokální poruchy spojené s významným korozním poškozením zasaženého povrchu častým jevem u ocelových nosných konstrukcí, stále není k dispozici dostatek experimentálně ověřených informací o vlivu tohoto fenoménu na únavovou odolnost konstrukcí navržených z ocelí vyšších pevností. K rozvoji poznání této problematiky má přispět i řešený grantový projekt GAČR 21-14886S. V předloženém článku jsou čtenáři seznámeni s úvodní experimentální částí projektu, v rámci které byla řešena příprava a provedení potřebných analýz korozních vzorků.

Obr. 1: Korozní produkty vzorku skupiny 4 se svary

Obr. 2: Odmořený povrch vzorku skupiny 4 se svary



Obr. 3: Povrch vzorku skupiny 4 pod mikroskopem (zvětšení 50x)

Poděkování

Tento příspěvek je součástí výzkumu GAČR 21-14886S "Vliv materiálových vlastností vysokopevnostních ocelí na trvanlivost inženýrských staveb a mostů" podporovaný Grantovou agenturou České republiky.

Uncertainty Quantification of Existing Bridge using Polynomial Chaos Expansion

Michael KŘÍŽEK[1], *Lukáš NOVÁK*[1]

[1]Institute of Structural Mechanics, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, Brno, Czech Republic

226874@vutbr.cz, novak.l@fce.vutbr.cz

The analysis of existing structures is of a great importance since it is often necessary to assess the reliability of structures reaching its designed life-time or adapt them to different conditions. However, existing structures are associated to many uncertainties regarding material properties possibly affected by deterioration, geometry or existing defects. Such uncertainties could play crucial role in reliability assessment of exisiting structures and thus it is necessary to extend deterministic analysis to stochastic analysis. The advanced stochastic analysis is especially valuable in case of existing concrete structures such as bridges, since there is a high variability of the basic variables assumed in the mathematical models.

This paper is focused on uncertainty quantification (UQ) in existing bridge structure represented by non-linear finite element model (NLFEM). The 3D model was created according to the original drawings and recent inspections of the bridge. In order to reflect the realistic mechanical behavior, the model reflects aspects of non-linear fracture mechanics and the calculation consists of the three construction stages depicted in Fig. 1. The single calculation of the NLFEM is very costly and thus even the elementary task of stochastic analysis – the propagation of uncertainties through a mathematical model – is not feasible by Monte Carlo type approach. UQ is thus performed via efficient technique for surrogate modeling – Polynomial Chaos Expansion (PCE). PCE is well-known technique for approximation of the costly mathematical models with random inputs, reflecting their distributions and offering fast and accurate post-processing including statistical and sensitivity analysis.

First of all, the experimental design was generated by Latin Hypercube Sampling containing 30 realizations of the input random vector consisting of 5 marginal variables: 4 material parameters describing a concrete and uncertainty in prestressing force. The original mathematical model was evaluated for all 30 realizations and three limit states were investigated: the decompression, the first occurrence of cracks and the ultimate limit state represented by the structural failure. PCE was constructed by advanced algorithms implemented in UQPy package, specifically deterministic coefficients of PCE were estimated by ordinary least squared in combination with least angle regression for an optimal reduction of basis functions. Once the PCE was constructed, it was possible to analyze all quantities of interest (QoIs) and analytically estimate Sobol indices as well as the first four statistical moments. Sobol indices directly measure the influence of the input variability to a variability of QoIs. Statistical moment were used for reconstruction of the probability distributions of QoIs, which will be further used for semi-probabilistic assessment. Moreover, once the PCE is available it could be possible to use it for further standard probabilistic or reliability analysis as a computationally efficient approximation of the original mathematical model.

Acknowledgments

The authors acknowledge the financial support provided by the Technology Agency of the Czech Republic under project number TM04000012.

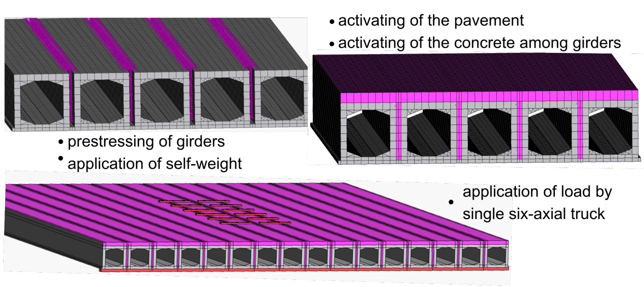


Fig. 1: The three construction phases of the analyzed bridge represented by a non-linear finite element model.

Interaction of FPZ with a random strength field in concrete specimens under excentric tension

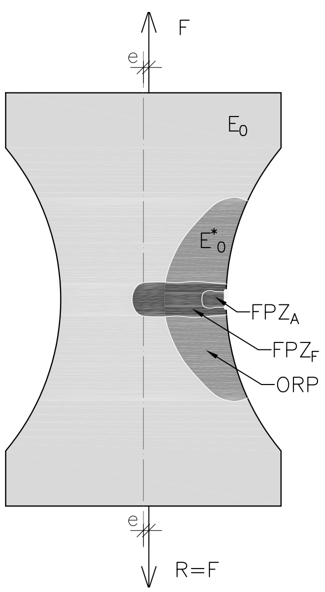
Michal KUČERA[1], *Miroslav VOŘECHOVSKÝ*[1]

[1]Institute of Structural Mechanics, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, 602 00 Brno, Czech Republic

kucera.m@fce.vutbr.cz, vorechovsky.m@vut.cz

The presented paper focuses on the use of a discrete meso-scale model, enhanced with the description of randomness in local material parameters, for the modeling of the size effect on structural strength. The random strength-size dependence is studied on dog bone shaped concrete specimens loaded in eccentric tension. These specimens were previously experimentally studied in van Vliet and van Mier [2].

The recent work of Eliáš and Vořechovský [1] shows how different parameters controlling the description of material randomness influence the loading capacity in fracture process zone (FPZ) and how they interact with the nonlinear processes in FPZ. The follow-up work of Vořechovský and Eliáš [3] presents an analytical model capable of simulating this interaction and applying it for statistical size effect prediction. However, this was done only for cases in which the FPZ is not dependent on size and when stress has the form of a linear plane. However, these assumptions do not hold in the case of dog bone specimens in which the stress field has a general shape.



Firstly, the discrete mesoscale model is applied to the modeling of a series of dogbone-shaped specimens with different sizes. In these models, the decisive strength material parameters are considered as a realization of a stationary Gaussian random field. Then, the size and shape of FPZ are measured via spatial profiles of energy dissipation. Then the interaction between its length l_{FPZ} and the autocorrelation length l_ρ of a random field is studied along with the proportions of energy dissipated in FPZ and in the rest of the specimen.

These results and the predictions from realizations obtained using the discrete model are compared to the experimental data.

Acknowledgments

This work was created with the financial support of the Specific University Research - FAST-S-23-8165 and the support of the Grant Agency of the Czech Republic within project no. 22-06684K.

References

[1] Jan Eliáš and Miroslav Vořechovský. "Fracture in random quasibrittle media: I. Discrete mesoscale simulations of load capacity and fracture process zone". In: *Engineering Fracture Mechanics* 235 (2020), p. 107160. ISSN: 0013-7944.

[2] Marcel R.A. van Vliet and Jan G.M. van Mier. "Experimental investigation of size effect in concrete and sandstone under uniaxial tension". In: *Elsevier Ltd* (2000), pp. 165–188.

[3] Miroslav Vořechovský and Jan Eliáš. "Fracture in random quasibrittle media: II. Analytical model based on extremes of the averaging process". In: *Engineering Fracture Mechanics* 235 (2020), p. 107155. ISSN: 0013-7944.

Improved Script for Calculating the Chloride Resistance of Concrete with Varying Time Step

Petr LEHNER[1], *Kristýna HRABOVÁ*[2]

[1] Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 33 Ostrava-Poruba, Czech Republic

[2]Institute of Building Testing, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, 602 00 Brno

petr.lehner@vsb.cz, kristyna.hrabova@vutbr.cz

The durability assessment of reinforced concrete structures exposed to chloride ions can be done by analytical and numerical models. Most analytical models are based on the application and development of Fick's diffusion law [1].

The original algorithm for estimating the service life of a reinforced concrete bridge deck exposed to aggressive chlorides was developed many years ago at VŠB-TUO [1]. The basic script allowed a deterministic calculation of the lifetime of the concrete structure considering the time-varying diffusion coefficient. The first improved version consisted of simulating an epoxy coating on the reinforcement and simulating waterproofing on the cut surface. Subsequent modifications included probabilistic calculations and allowed the very appropriate introduction of histograms of input data [2].

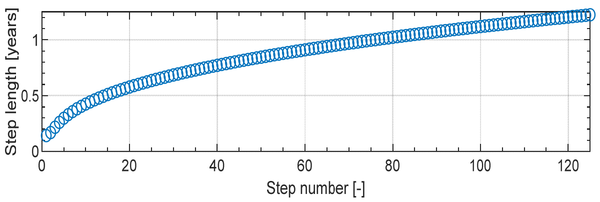


Fig. 1: Time step length in years based on "while" script.

In addition, a version of delayed exposure was created to allow for the variable value of the load - that is, chloride on the bridge deck surface [3]. The next evolutionary step was to use the adopted random field script, which was applied to the diffusion coefficient along the analysed section [4]. However, all the variants mentioned in the lifetime delay script were based on the same algorithm, which showed a high computational load on certain calculations. This was due to the use of a predefined "for" loop condition that does not reflect the fact that input parameters that are time-varying affect the computation speed. This is because the accuracy of the computation is dependent on both the size of the finite element and the size of the diffusion coefficient, which varies. The present paper shows a new and improved script that uses the "while" condition and circumvents the aforementioned limitation.

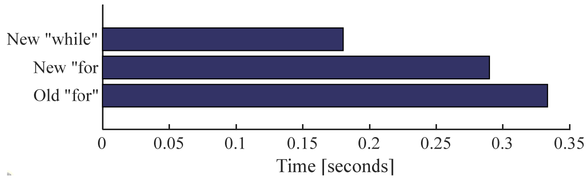


Fig. 2: Comparison of different scripts.

Acknowledgements

The investigations has been conducted within the framework of Project GACR 22-19812S: "Effect of gaseous and traffic induced pollutants on the durability of reinforced concrete structures".

References

[1] LEHNER, Petr, Petr KONEČNÝ, Pratanu GHOSH a Quang TRAN. Numerical analysis of chloride diffusion considering time-dependent diffusion coefficient. International Journal of Mathematics and Computers in Simulation. 2014, 8(1), 103–106. ISSN 19980159.

[2] LEHNER, Petr a Petr KONEČNÝ. Probabilistic durability evaluation of binary and ternary concrete mixtures considering aging effect. ARPN Journal of Engineering and Applied Sciences. 2016, 11(3), 1992–1997. ISSN 18196608.

[3] KONEČNÝ, Petr, Petr LEHNER a David PUSTKA. Reinforced Concrete Bridge Deck Model Considering Delayed Exposure to Chlorides. Periodica Polytechnica Civil Engineering . 2019, 63(3), 21–22. ISSN 1587-3773.

[4] LE, Tuan Duc T.D., Petr LEHNER, P. KONEČNÝ, Petr KONEČNÝ. Probabilistic Modeling of Chloride Penetration with Respect to Concrete Heterogeneity and Epoxy-Coating on the Reinforcement. Materials. 2019, 12(24). ISSN 19961944.

STRESS CONCENTRATION ON A CORROSION PIT

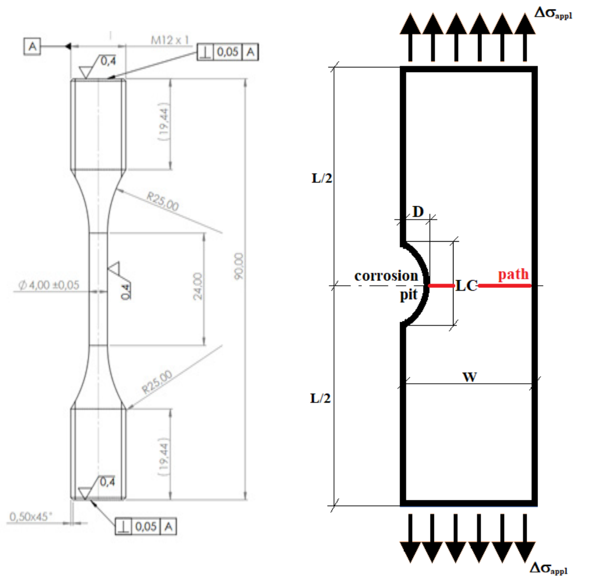
Lucie MALÍKOVÁ[1,2], *Anna BENEŠOVÁ*[2], *Mohammad AL KHAZALI*[2], *Vít KŘIVÝ*[3], *Stanislav SEITL*[1,2]

[1]Institute of Physics of Materials, Czech Academy of Sciences, v.v.i.. Žižkova 513/22, Brno, Czech Republic
[2]Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, Brno, Czech Republic
[3]Faculty of Civil Engineering, VŠB - TU Ostrava, Ludvíka Podéště 1875, 708 33 Ostrava, Czech Republic

malikova.l@fce.vutbr.cz, anna.benesova1@vutbr.cz, mohammad.al.khazali@vutbr.cz, vit.krivy@vsb.cz, seitl@ipm.cz

Steel constructions are very often besides the cyclic loading (fatigue) subjected to aggressive environment during their service life. Thus, when assessing their lifetime, this effect needs to be considered.

Corrosion pits are created based on the particular conditions of each structure, i.e. their size and shape depend on corrosive environment (its aggressivity, period of its impact etc.). Thus, effect of the pit length and depth on the stress distribution was investigated. A rectangular specimen which should simplify the real cylindrical specimen and represents the longitudinal cross-section in the middle of the specimen is suggested, see Fig. 1. The corrosion pit shape is a circular segment considering the relation between its depth and length as $LC = 4{\times}D$.



(a) (b)

Fig. 1: Scheme of the analysed specimen with a circular-segment-shaped corrosion pit subjected to remote tensile cyclic loading.

The values of the individual geometrical parameters were set as: $L = 24$ mm; $W = 4$ mm; $D = 0.1$ to 1 mm; $LC = 0.4$ to 4 mm and corrosion pit radius, $RC = (LC^2+4D^2)/8D$. Cyclic loading value and properties of the linear elastic material model representing the high-strength steels (HSS) were: $\Delta\sigma_{appl} = 100$ MPa; $E = 210$ GPa; $\nu = 0.3$.

Within the paper, various stress distributions have been investigated both on the corrosion pit surface and ahead of the corrosion pit along the specimen width. Nevertheless, one of the most important results of this paper is comparison of the stress concentration values for specimens with various corrosion pit sizes. The stress concentration factor K_t was defined as:

$$K_t = \frac{\sigma_{max}}{\sigma_{avg}}\,, \tag{1}$$

where σ_{max} represents the maximum stress value (occurring at the pit bottom) and σ_{avg} represents the average stress value (along the ligament of the cross-section ahead of the pit, as it is indicated by the red path in Fig. 1b). The von Mises stress values were assessed.

Tab.1: Values of σ_{max}, σ_{avg}, K_t and its percentual difference for selected increasing corrosion pit depth ($D = 0.1$ to 1.0 mm).

D [mm]	σ_{max} [MPa]	σ_{avg} [MPa]	K_t [-]	$(K_t - K_{t,D=0.1mm})/K_{t,D=0.1mm}$ [%]
0.1	202.47	88.84	2.28	-
0.2	204.71	89.18	2.30	0.72
0.4	217.67	91.11	2.39	4.83
0.7	251.55	96.68	2.60	14.17
1.0	304.92	105.14	2.90	27.25

The results show that depending on the level of the corrosion (corresponding to the corrosion pit size), the stress concentration increases. Particularly, when the corrosion pit is ten times larger ($D = 1.0$ mm in comparison to $D = 0.1$ mm), the stress concentration is higher about ca. 27 %. Experimental campaign on corroded specimens is running to be able to compare the results obtained. Then, the numerical simulations will probably enable to predict the lifetime of corroded specimens quickly and reliably.

Acknowledgements

Financial support from the project No. 21-14886S (Czech Science Foundation) and No. FAST-S-23-8216 (Faculty of Civil Engineering, BUT) is gratefully acknowledged.

EFFECT OF USING WASTE METALLURGICAL SLUDGE IN CONCRETE ON THE ENVIRONMENT

Kateřina MATÝSKOVÁ[1] *and Marie HORŇÁKOVÁ*[2]

[1] Department of Building Materials and Diagnostics of Structures, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvíka Podéště 1875/17, 708 33 Ostrava-Poruba, Czech Republic

[2] Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvíka Podéště 1875/17, 708 33 Ostrava-Poruba, Czech Republic

katerina.matyskova@vsb.cz, marie.hornakova@vsb.cz

The ingredients (aggregates and cement) used in concrete are not only expensive, but their extraction also represents a major environmental burden. With these facts in mind, the scientific effort is to replace the used natural materials with secondary raw materials. These materials are often waste products created during construction production, whether they are fragments of bricks, original concrete structures, glass, or any other materials. Products from metallurgical production may be also important secondary raw materials, for example sludge (MSW), slag, or various dust removals. These kinds of materials are often used as a substitute for filler or as a partial substitute for cement [1]. In this project, the concrete was made of MSW as a substitution of fine aggregate in various percentages [2], and the specimens were then crushed or grounded to use again as a substitution of a coarse aggregate in concrete. However, wastes from metallurgical production are often classified as hazardous, which would make it impossible to use them again. The chemical composition of MSW can vary depending on the specific manufacturing processes and the nature of the ores used. Therefore, it is necessary to prove that the waste intended to be used as a secondary raw material in another product, will not be harmful to the environment and to humans throughout its lifetime. As regards the production of concrete, it is necessary to guarantee that no chemical reactions occur during production that cause the formation of elements harmful to both human health and ecosystems. Therefore, the ecotoxicity of such concrete has to be determined before its use in construction [2].

According to the standard [3], the sample for the ecotoxicity test must consist of at least 95 % of grains smaller than 4 mm in size and the uncrushable parts need to be separated and recorded. Then, the basic characteristics are determined - pH value, dry matter content and water capacity for granular material, and pH value, dissolved oxygen concentration and conductivity for liquid waste. After determination, it is necessary to create an analytical sample. The particles are mixed with the leaching liquid and the solid and liquid phase mixture is then placed in a closed container in a shaker, where it is left for 24 hours ± 0.5 hours. Then, the solid particles are allowed to settle for 15 minutes ± 5 minutes and the sample is filtered. The leachate is analyzed to provide the concentrations of individual components [4]. The leaches can also serve us to investigate ecotoxicity by various biological methods. For example, the toxicity assessment in article [5] showed that leachates originating from metallurgical waste treatment can have toxic characteristics that inhibit germination rates and root development.

Acknowledgements

The research was funded by the Ministry of Education, Youth and Sports of the Czech Republic through VSB - TU Ostrava (SGS SP2023/056).

References

[1] Lehner, P., Horňáková, M., Pizoń, J., & Gołaszewski, J. (2022). Effect of Chemical Admixtures on Mechanical and Degradation Properties of Metallurgical Sludge Waste Concrete.Materials,15(23),8287.https://doi.org/10.3390/ma15238287

[2] Hybská, H., Hroncová, E., Ladomerský, J., Balco, K., & Mitterpach, J. (2017). Ecotoxicity of Concretes with Granulated Slag from Gray Iron Pilot Production as Filler. Materials,10(5),505. ttps://doi.org/10.3390/ma10050505.

[3] CSN EN 14735: Characterization of waste – Preparation of waste samples for ecotoxicity tests. 2007.

[4] CSN 12457: Characterization of waste - Leaching - Compliance test for leaching of granular waste materials and sludges - Part 4: One stage batch test at a liquid to solid ratio of 10 l/kg for materials with particle size below 10 mm (without or with size reduction). 2018.

[5] Potysz, A., Pędziwiatr, A., Hedwig, S., & Lenz, M. (2020). Bioleaching and toxicity of metallurgical wastes. Journal of Environmental Chemical Engineering, 8(6), 104450. https://doi.org/10.1016/j.jece.2020.104450

DUAL DISCRETE AND CONTINUOUS MESO-SCALE MODELLING OF CONCRETE

Jan MAŠEK[1], *Petr MIARKA*[1]

[1]Department of Structural Mechanics, Faculty Civil Engineering, Brno University of Technology, Veveří 331/95, Brno, Czech Republic

jan.masek1@vut.cz, petr.miarka@vut.cz

The present paper is devoted to the development of a software equipment that allows to model heterogeneous meso-structure by both discrete and continuous modelling approaches. The aim is to create a geometrical and topological representation of a discrete lattice particle model as well as its 1:1 twin counterpart as modelled by a continuum finite element (FE) method model, see Fig. 1. The presented results illustrate the ongoing initial phase of the efforts of the team in advanced modelling of damage propagation within concrete.

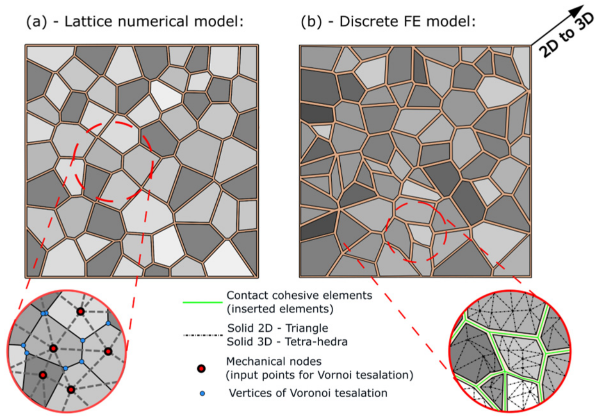


Fig. 1 Illustration of the meso-modelling approaches of a heterogeneous structure: (a) the discrete particle model, (b) the continuous model.

The overarching aim of the research and development efforts is to create a framework that allows to generate: (i) the geometry and topology of a meso-scale discrete particle model of concrete and (ii) a corresponding 1:1 twin continuous FE model of such a heterogeneous structure, see Fig. 1. For the solution of the discrete model, the OAS [1] project is used, given the experience of the team with its development. The continuous FE model is to be executed within the ANSYS framework [2].

The discrete particle model assumes the interparticle contact to be represented by a single 2D mechanical element, see Fig. 2a. The mechanical elements connect the Voronoi generator points that are considered as centres of individual aggregates. The continuous FE twin model is generated from the geometry and topology of the discrete particle model, see Fig 2b. The continuous FE model understands the regions of individual particles truly as volumes, therefore the structure follows the geometry of the generated Voronoi cells. Knowing the mutual connectivity, volumes of individual aggregates are created. To introduce the damage capability on the contact facets, cohesive elements are to be inserted.

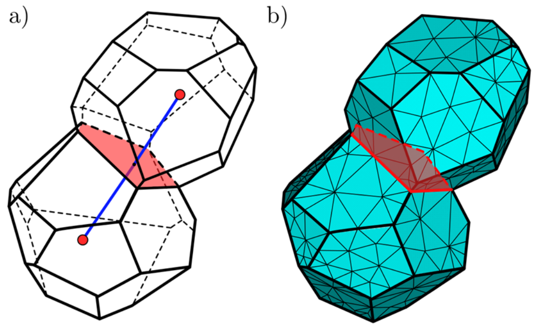


Fig. 2 Discrete and continuum modelling approaches: a) discrete particle representation by a mechanical element, b) full continuum FE modelling of volumes with cohesive elements inserted on contact surface of aggregates.

Acknowledgements

The financial support of the project FAST-S-23-8165 is gratefully acknowledged.

References

[1] ELIÁŠ, Jan; CUSATIS, Gianluca. Homogenization of discrete mesoscale model of concrete for coupled mass transport and mechanics by asymptotic expansion. Journal of the Mechanics and Physics of Solids, 2022, 167: 105010.

[2] THOMPSON, Mary Kathryn; THOMPSON, John M. ANSYS mechanical APDL for finite element analysis. Butterworth-Heinemann, 2017.

EFFECT OF CLIMATIC CONDITIONS ON MODELLING OF CARBONATION FOR RC STRUCTURES

Jan MLČOCH[1], *Miroslav SÝKORA*[1]

[1]Department of Structural Reliability, Klokner Institute, Czech Technical University, Šolínova 7, Prague, Czech Republic

jan.mlcoch@cvut.cz, miroslav.sykora@cvut.cz,

Carbonation-induced corrosion is the main degradation factor, which causes significant economic losses to the operators of an aging large, reinforced concrete (RC) structures such as cooling towers (CTs).

Due to large variability of basic variables, the carbonation ingress process needs to be described by probabilistic model. In this study, the carbonation model is developed for practical applications in service life assessments of these structures exposed to environmental effects.

Carbonation resistance of concrete as a main parameter affecting carbonation depth is difficult to obtain for existing structures. In most cases, it is thus only possible to describe carbonation ingress using carbonation depth data from in-situ surveys. Shape of the carbonation depth development curve with time is defined by the weather function which accounts for the effect of environmental exposure of the structure. The shape is essential for long-term predictions of carbonation ingress.

Modelling of carbonation depth

The relationship between depth of the carbonated concrete layer x_c (mm) and time t (year) can be expressed as:

$$x_c(t) = A(n)\, t^{0.5 - n} \qquad (1)$$

Through the exponent n, this simple relationship includes the effect of wetting events that will partly inhibit further ingress of CO_2. The exponent can be evaluated from the weather function $W(t)$ provided in the *fib* MC 2010, using local meteorological data. For practical assessments of existing RC structures, the use of the *fib* model appears to be complicated as the diffusion characteristics are affected by large uncertainties. Therefore, it is useful to derive the carbonation rate $A(n)$ from measurements of x_c for a specified value of n.

Various models for time variation of the mean carbonation depth, based on the measurements on several CTs located in the Czech Republic are displayed in Fig. 1. The figure also shows how the shape of the function affects long-term predictions of carbonation depths.

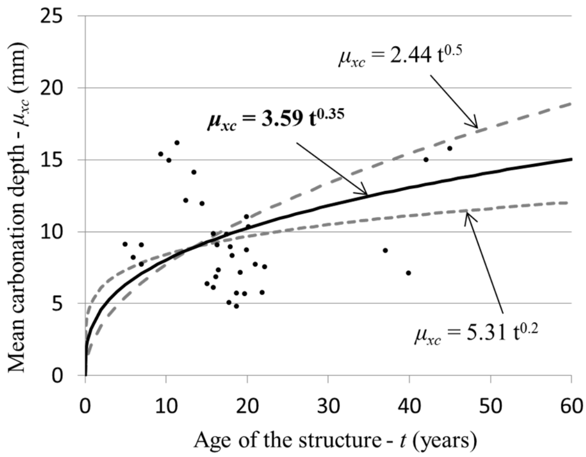


Fig. 1: Mean carbonation depths measured on CTs (dots) and derived carbonation model (solid) with its physical bounds (dashed).

Conclusions

- In common situations it is recommended to derive the carbonation rate $A(n)$ from measurements of the carbonation depth.
- If long-term observations of carbonation depth on reference areas are unavailable, the shape of the trend of carbonation depth development with time can be determined from the *fib* model through the parameters of climatic conditions from the nearest meteorologist station.
- It is expected that the proposed framework for the assessment of large reinforced concrete structures will support applications of the probabilistic approaches in practice.

Acknowledgements

This study has been supported by the Czech Science Foundation under Grant 23-06222S.

Recent Advances in Polynomial Chaos Expansion: Theory, Applications and Software

Lukáš NOVÁK[1], *Drahomír NOVÁK*[1]

[1]Institute of Structural Mechanics, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, Brno, Czech Republic

novak.l@fce.vutbr.cz, novak.d@fce.vutbr.cz

In modern structural analysis, uncertainties are represented by random variables described by specific probability distributions, the structural system can then be seen as a mathematical function of a set of random parameters. Evaluations of these functions existing in civil engineering are typically costly since their solutions are obtained numerically by finite element method and it is necessary to reflect also non-linear behavior of the physical systems. Moreover, due to existing uncertainties in physical systems and/or their mathematical models, the analysis of structures must be enriched by stochastic analysis. The elementary task of stochastic analysis is to propagate uncertainties through a mathematical model and analyse the quantity of interest (QoI), e.g. statistical or sensitivity analysis. Although uncertainty quantification has become one of the most growing research fields in the last two decades, it is still challenging to apply state-of-the-art techniques in practical applications. Therefore it is important to develop efficient but user-friendly software solutions allowing fast and accurate analysis of complex mathematical models.

The paper is focused on recent advances in uncertainty quantification using polynomial chaos expansion (PCE). PCE is well-known technique for approximation of the costly mathematical models with random inputs – surrogate model. Although PCE is widely used technique and it has several advantages over different surrogate models, it has still several limitations and research gaps. This paper will review some of the recent theoretical developments in PCE. Specifically a new *active learning* method optimizing the experimental design and an extension of analytical *statistical analysis* using PCE will be reviewed. These two topics represent crucial tools for efficient applications: active learning leads generally to significantly more efficient construction of PCE and improved statistical analysis allows for analytical estimation of higher statistical moments directly from PCE coefficients. Several applications of the theoretical methods are briefly presented in a context of civil engineering as well as some preliminary results of further research.

Finally, implementation of PCE into the new version of open-source UQPy (Uncertainty Quantification in Python) package are described together with architecture of the whole package. UQPy represents multipurpose complex software package for python containing recently developed techniques for uncertainty quantification including PCE, more details can be found on official website, see QR codes in Fig. 1. UQPy contains several modules associated to common techniques for uncertainty quantification including surrogate models. PCE module in UQPy contains state-of-the-art techniques developed for advanced statistical sampling, efficient construction of the approximation (e.g. truncation schemes, sparse solvers) and its post-processing (e.g. Sobol indicies and complex statistical information derived from PCE). UQPy can be easily used for practical applications as well as for research, since it is an open-source package and anyone can contribute to the UQPy code once their contributions pass the quality checks.

Acknowledgments

The authors acknowledge the financial support provided by the Czech Science Foundation under project number 22-00774S.

Fig. 1: UQPy software: left) QR code leading to Git-Hub repository containing the open-source code in python, middle) the graphical logo representing the package, right) QR code leading to documentation of the package.

NUMERICAL MODEL OF HSS S690 TENSILE TEST

Přemysl PAŘENICA[1], *Petr LEHNER*[1], *Martin KREJSA*[1], *Stanislav SEITL*[2]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, VSB-Technical University of Ostrava, Ludvika Podeste 1875/17, 708 00 Ostrava-Poruba, Czech Republic
[2]Institute of Physics of Materials, Czech Academy of Sciences, Zizkova 22, 616 00 Brno, Czech Republic

premysl.parenica@vsb.cz, petr.lehner@vsb.cz, martin.krejsa@vsb.cz, seitl@ipm.cz

This article presents an evaluation of the fracture test of grade S690 high-strength structural steel (HSS) using a numerical finite element model (FEM). Steels with better strength characteristics may exhibit different behaviours and therefore material models need to be thoroughly analysed and prepared for further numerical calculations. A numerical model that accurately simulates the experiments was prepared based on known information from tensile tests of high-strength steels [1,2]. The analysis is a combination of the experimental test results (tensile steel testing) and the numerical model used for the inverse analysis of the material properties of HSS. To account for statistical inaccuracies, five test specimens were prepared and Finite Element Analysis model was prepared in the commercial software ANSYS to simulate the test procedure. This model was used to estimate the material parameters of the analysed steel grade S690. The 1:1 scale numerical model was prepared in the FEM ANSYS Workbench software. It is a volumetric model consisting of SOLID186 elements (20-node quadratic). The finite element mesh has a size of 1.5 mm and multiple approaches were evaluated in the analysis.

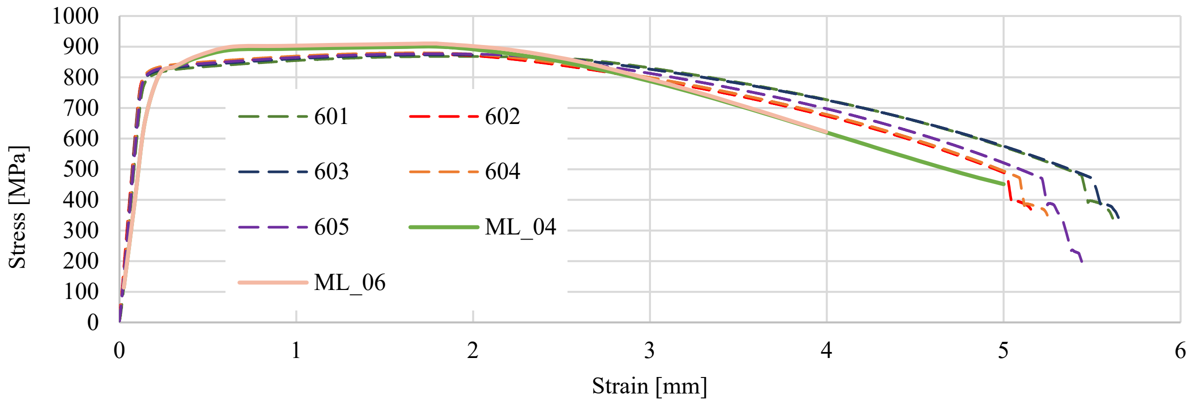


Fig. 1: Stress-strain diagram of steel S690 from experiments and best-fit material models.

Figure 1 shows the experimental results for specimens 1 to 5 (designations 601 to 605) compared to the derived plots from the numerical model. Two multilinear material models (ML_04 and ML_06) with manually adjusted stress-strain diagram parameters were found to be the most accurate.

Acknowledgements

This contribution has been developed as a part of the research project GACR 21-14886S "Influence of material properties of high strength steels on durability of engineering structures and bridges" supported by the Czech Science Foundation.

References

[1] CHEN, Huahui and Rui LIANG. Effect of controlled rolling and controlled cooling on microstructure and properties of high strength building steel. Jinshu Rechuli/Heat Treatment of Metals. 2019, 44(1) pp. 138-142. ISSN 0254-6051.

[2] DUBINA, Dan, Aurel STRATAN, Cristian VULCU and Adrian CIUTINA. High strength steel in seismic resistant building frames. Steel Construction [online]. 2014, 7(3) pp. 167-220. DOI: 10.1002/stco.201410028.

HYDRATION AND STRENGTH DEVELOPMENT OF BLENDED CEMENTITIOUS SYSTEMS MIXED WITH SEAWATER

Sundar RATHNARAJAN[1], Pawel SIKORA[1]

[1]Faculty of Civil and Environmental Engineering, West Pomeranian University of Technology in Szczecin, al Piastów 50a, 70-311 Szczecin, Poland

sundar.rathnarajan@zut.edu.pl, pawel.sikora@zut.edu.pl

Water and concrete are the first and second most consumed materials in the world. Water shortages are being reported across the world and an acute shortage of freshwater is expected in 17 countries by 2040. Alternative water sources for producing concrete to reduce freshwater consumption is being restricted by maximum limits on total solids and chlorides content by several international standards for concrete production such as EN 206, ACI 318, and IS456. However, in the recent years it is suggested that seawater-mixed concrete could be an alternative to the conventional concrete for niche applications in certain regions of the world with severe water shortage. Also, more research on long-term durability of these seawater-mixed concretes is necessary to adapt changes in codes and specifications for making concrete.

The present work focuses on understanding the acceleration effect of seawater mixing in concrete made with ternary blended cementitious systems containing ground granulated blast furnace slag, and metakaolin (PS20M10 & PS40M20). CEM I 42.5R (PC) cement was used to prepare cement paste specimens with water-to-cement ratio of 0.4. Among the six mixes in this study, three mixes were cast with freshwater (FW) and three mixes with artificial seawater (SW) prepared conforming to ASTM D1141. Paste specimens were cast and compressive strength at 2, 7, 14, and 28 days were measured. In addition, the cumulative heat of hydration for 7 days was determined in cement paste specimens using isothermal calorimeter.

Fig. 1 shows the evolution of % change in compressive strength (SW/FW) of cement paste specimens made with CEM I and CEM I blended with slag and metakaolin. The cementitious systems with slag and metakaolin showed a higher improvement in the strength even at 28 days contrasting to the performance of PC mixes that had better performance at an early age (< 7 days).

Fig 2. shows the reduction in final setting time in SW mixes calculated from the calorimetry results. Setting time is defined as the time taken for silicate peak/end of acceleration period from calorimetry results. A significant reduction in the setting time was observed in OPC and blended cementitious systems containing SW. Despite having very high replacement levels (60% in PS40M20 mix), the ternary blended cementitious systems also showed a significant reduction in setting time. These results demonstrate the feasibility of using seawater as mixing water for concretes produced with both Portland cement and blended cement systems. The presence of slag and metakaolin can enhance the chloride-binding and ensure an improved durability of cementitious systems.

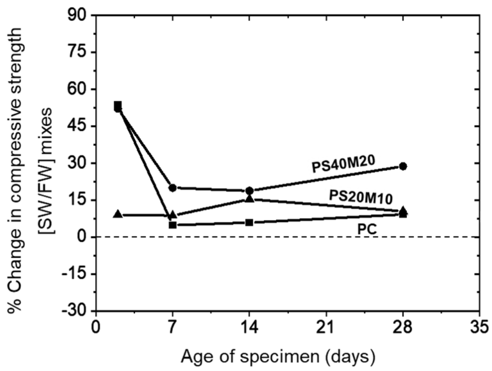


Fig. 1: Evolution of compressive strength in cement pastes between 1 and 28 days of moist-curing.

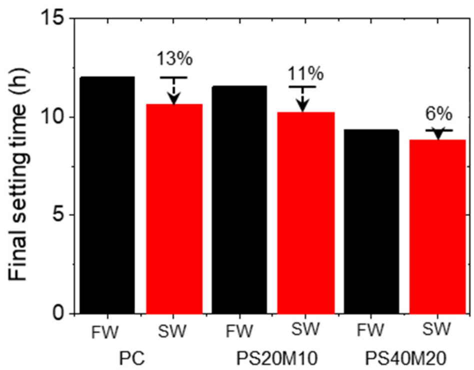


Fig. 2: Calculated setting time based on calorimetry results

Acknowledgements

This research is part of the project No. 2021/43/P/ST8/00945 co-funded by the National Science Centre and the European Union Framework Programme for Research and Innovation Horizon 2020 under the Marie Skłodowska-Curie grant agreement No. 945339.

DEVELOPMENT OF HEAVYWEIGHT CONCRETE FOR 3D PRINTING APPLICATIONS

Pawel SIKORA[1], *Karol FEDEROWICZ*[1], *Mateusz TECHMAN*[1], *Szymon SKIBICKI*[1]

[1]Faculty of Civil and Environmental Engineering, West Pomeranian University of Technology in Szczecin, Al. Piastów 50a, 70-311 Szczecin,

pawel.sikora@zut.edu.pl, karol.federowicz@zut.edu.pl, mateusz.techman@zut.edu.pl, szymon.skibicki@zut.edu.pl

Radiation shielding is becoming of consideration due to increased radionuclide releases from numerous sources and environmental protection issues. In recent years, concrete 3D printing has been introduced as a promising technology for intelligent construction, providing several benefits of free-formwork, flexible design, high safety, low labour demand, and material saving. Therefore, digital fabrication of concrete can offer new structural possibilities, design of sophisticated shielding barriers, structural optimization as well as reduce the amount of the labour exposure in case of potential radiation or extreme working conditions.

The main objective of this study is to develop heavyweight concrete (3DPHWC) mixture formulations suitable for digital fabrication. To reach this goal natural aggregate was gradually replaced by heavyweight magnetite aggregate up to 100 vol.%.

A series of experiments were conducted to assess the fresh and hardened properties of newly developed mixes. In the first stage a set of tests related to fresh properties were performed including flow table, setting time, penetration, and uniaxial unconfined compression tests. Afterwards, cast and printed specimens were prepared towards determination of mechanical and radiation shielding performance. Following the 3D printing of the hollow wall segments, several other parameters, such as shape stability employing the image-based correlation test, and porosity characteristics, were examined.

As an outcome set of heavyweight concrete mixes suitable for 3D printing were developed. All mixes were found to meet the printing requirements only with small modifications in superplasticizer dosage. Despite the higher self-weight of material, the layer's strength and stiffness were sufficient to sustain the dead load during printing. Slight improvement of mechanical performance in concrete was found as a result of magnetite aggregate inclusion. Replacement of the river sand with magnetite aggregate leads to considerable improvements in the shielding performance against radiation. In both cast and printed specimens, there are no noticeable differences between attenuation performance against gamma-rays.

Fig. 1: Printing of the HWC element (left) and quality of 3D printed column after hardening (right).

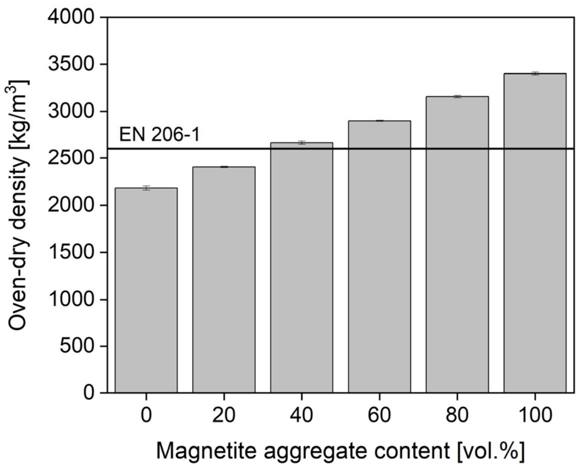


Fig. 2: Oven-dry density of the developed 3D printable mixture formulations with line indicator presenting the qualification of concrete as heavyweight.

Acknowledgements

This research was funded in whole by the National Science Centre, Poland within Project no. 2020/39/D/ST8/00975 (SONATA-16).

Artificial Neural Network-Aided Aimed Multilevel Sampling for structural damage detection

Bohumil ŠPLÍCHAL[1], *David LEHKÝ*[1]

[1]Institute of Structural Mechanics, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, 602 00 Brno, Czech Republic

splichal.b@fce.vutbr.cz, lehky.d@fce.vutbr.cz

Structural health monitoring is extremely important for sustaining and preserving the service life of civil structures. Research to identify the damage can detect, locate, quantify and, where appropriate, predict potential structural damage. This paper is about damage identified by non-destructive vibration-based experiments, which uses the difference between modal frequencies and deflection of an initial and damaged structure.

The optimization method used in this paper is the Aimed Multilevel Sampling (AMS), which due to its concept offers a significant reduction in computational complexity. Its basic idea is to divide the simulation run into several levels. Advanced sampling within a defined design space will be performed at each level. Subsequently, the sample with the best properties concerning the definition of the optimization problem will be selected. There are two methods to obtain the design vector. It can be obtained as the best realization generated at the ith level corresponding to the minimum of the objective function, or the best realization can be obtained, as an inverse analysis, using an artificial neural networks (ANN) trained from the data of the corresponding level. The third alternative is the hybrid method that combines above mentioned approaches.

The methods were applied to a single-span steel truss structure ten meters long. Numerical model was created using the finite element method in ANSYS. The structure was divided into ten sections. A different material model was created for each section. The damage was modeled by reducing the stiffness.

Evolution of the error E_r between experimental and estimated stiffness at each level during the optimization process for all three methods are presented in Figure 1. The first method (blue line) uses the minimum of the objective function as the best realization, the second (green line) uses ANN to identify the best realization. The third method (red line) is a hybrid method.

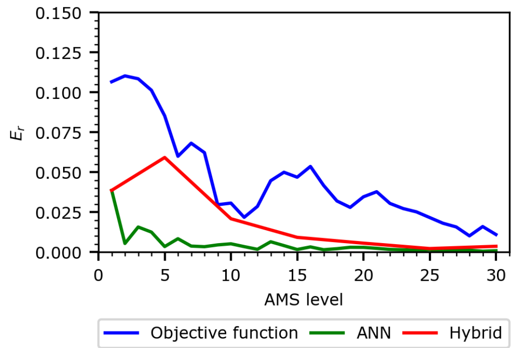


Fig. 1: Comparison of the methods – error progress during optimization

From the results, it can be concluded that all presented methods can correctly identify the given structural damage. When comparing the individual methods, it can be seen that the ANN method gives the best convergence and accuracy of the resulting damage identification. However, creating, training and simulating ANNs brings increased computational demands. The AMS method, on the other hand, due to the layering principle, progressively targets the correct solution using a limited number of simulations at each level. The proposed hybrid method, which combines the advantages of both approaches, appears from the results to be a suitable compromise between accuracy and speed of convergence on the one hand and time and computational complexity on the other.

Acknowledgments

This work was supported by specific university research project No. FAST-J-23-8267 granted by Brno University of Technology and the project No. TM04000012 supported by the Technology Agency of the Czech Republic.

Periodic boundary conditions allowing strain localization: literature review

Monika STŘEDULOVÁ[1], *Jan ELIÁŠ*[1]

[1]Department of Structural Mechanics, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, Brno, Czech Republic

stredulova.m@fce.vutbr.cz, jan.elias@vut.cz

Homogenization is a common way of incorporating material structure into a macroscale computational framework. The method allows to solve two separate problems during calculations: (i) at macroscale, at the level of the whole structure, and (ii) at microscale, at the level of individual material heterogeneities. A representative volume element (RVE), which is defined as statistically representative of the material, is used to solve the microscale problem. The transition between scales is provided through a scale parameter, defined in such way that scale separation is ensured.

In the computational framework, the RVE problem serves as a replacement of the constitutional relations. On the input, the RVE recieves strain tensor and stress tensor is the output. To solve the RVE as a separate boundary value problem, boundary conditions have to be defined to simulate the surrounding matter and load the RVE. Among different options (overview may be found in [1]), periodic boundary conditions (PBC) are the most popular, because they were shown to provide the most consistent results. The method is based on constraining degrees of freedom on opposite boundaries of the RVE to prescribe each of periodic node images the same displacements. The RVE is generated in such a way, that the nodes on opposite sides are mirrored.

This procedure may be easily applied to a material in elastic and pre-peak regime, however, during post-peak the constraints applied on opposite RVE sides mandate identical shear band or crack to occur simultaneously on the periodic side. As a result, the crack pattern is affected and the stress obtained from an RVE loaded in such a way is not realistic [2], hindering the application to materials experiencing strain softening. The phenomena is schematically showed in Fig. 1.

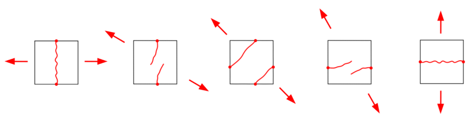


Fig. 1: Illustration of a crack pattern creation being influenced by boundary conditions, figure is inspired by [2].

During the last two decades, effort has been made by researchers to overcome the phenomena. The present contribution aims to review the methods which have been developed so far and compare them.

Modified PBC dubbed *percolation path aligned* BC have been inroduced by Coenen et al. [3]. The original framework has been extended by allowing for a rotation of the RVE coordinate system to align with the originating localization band. The inclination of the band and the amount of rotation is to be either known apriori or calculated after each iteration via additional method. Another method which aligns the coupling of points with the inclined band is called *tesselation* PBC [1], where the periodicity frame is shifted from one RVE to another to allow crack cross the boundary at non-symetrical points. Alternative approach of using spherical RVE has been devised by Glüge et al. in [4], showing promising alternative as a sphere is orientation independent which potentially simplifies the implementation. Each of the method brings its own advantages as well as challenges, which are discussed to a detail.

Acknowledgments

Support of the project FAST-J-23-8323 is gratefully acknowledged. The first author is Brno Ph.D. Talent Scholarship Holder – Funded by the Brno City Municipality, Czech Republic.

References

[1] J. Goldmann, J. Brommund, V. Ulbricht, *Int J Numer Methods Eng* **113**, 1-21 (2018).

[2] J. Stráský, M. Jirásek, *PARTICLES 2011*, 274-285 (2011).

[3] E. Coenen, V. Kouznetsova, M. Geers, *Int J Numer Methods Eng* **90**, 1-21 (2012).

[4] R. Glüge, M. Weber, A. Bertram, *Comput Mat Sci* **63**, 91-104 (2012).

Mortar method with segment-to-segment approach

Tadeáš SVĚTLÍK[1], *Radek VARGA*[1], *Lukáš POSPÍŠIL*[1,2], *Martin ČERMÁK*[1]

[1]Department of Mathematics, Faculty of Civil Engineering, VSB-TUO, Czech Republic
[2]Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany

tadeas.svetlik@vsb.cz

In this contribution, we focus on the mortar method with a segment-to-segment approach [2] used for connecting non-conforming and non-overlapping meshes and for the contact between two elastic bodies. We shortly review the theory, present our Matlab implementation and compare results on benchmarks. We compare our results with the analytical solution of Hertz stress [1] and popular commercial software Ansys.

The finite element (FE) algebraic formulation of the contact elastic problem between two bodies denoted as $\Omega^1,\ \Omega^2 \subset \mathbb{R}^2$ can be written as the following optimization problem

$$\text{Find} \quad \mathbf{u} \in \mathcal{K} : J(\mathbf{u}) \leq J(\mathbf{v}), \quad \forall \mathbf{v} \in \mathcal{K}, \tag{1}$$

where

$$J(\mathbf{v}) = \sum_{i=1}^{2} \frac{1}{2}\mathbf{v}_i^T \mathbf{K}^i \mathbf{v}_i - \mathbf{f}_i^T \mathbf{v}_i. \tag{2}$$

Here $\mathbf{v} \in \mathbb{R}^n$ and $\mathbf{f} \in \mathbb{R}^n$ denote the discretized domain displacements and the discretized domain vector of prescribed forces, and $\mathbf{K} \in \mathbb{R}^{n\times n}$ is a symmetric positive semidefinite block diagonal matrix consisting of the elastic stiffness matrices $\mathbf{K}^i$ defined for each domain $\Omega^i,\ i = 1, 2$. The set of feasible displacements

$$\mathcal{K} = \{\mathbf{v} \in \mathbb{R}^n \mid \mathbf{B}_E\mathbf{v} = \mathbf{c}_E,\ \mathbf{B}_I\mathbf{v} \leq \mathbf{c}_I\} \tag{3}$$

is restricted by equality constrain matrix $\mathbf{B}_E \in \mathbb{R}^{m_E\times n}$ representing Dirichlet boundary conditions such as supports and inequality constraint matrix $\mathbf{B}_I \in \mathbb{R}^{m_I\times n}$ representing the non-penetration condition on the contact zones. In our implementation, the inequality matrix $\mathbf{B}_I$ is evaluated using mortar method with segment-to-segment approach.

As a benchmark, we consider a contact between elastic semicircle and rigid halfspace, see Fig. 1 with analytical solution for contact pressure known as Hertz stress. Comparison between analytical, Ansys and ours solution is shown in Tab. 1.

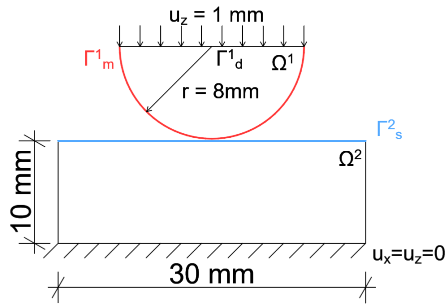


Fig. 1: Computational model of the structure.

Approach	p_c [Mpa]	Abs. Diff [Mpa]	Rel. Diff [%]
Hertz	14003	-	**-**
Ansys	13637	367	**2.62**
Our	13159	845	**6.03**

Tab. 1: Comparison of maximal normal contact pressure between Hertz stress, Ansys solution and our solution.

Acknowledgments

This contribution has been prepared thanks to the Czech Foundation (GAČR) through project no. 22-13220S “Development of iterative algorithms for solving contact problems emerging in the analysis of steel structures bolt connections.”.

References

[1] Valentin L. Popov. *Contact Mechanics and Friction*. Springer Berlin Heidelberg, 2010.

[2] Alexander Popp, Michael W. Gee, and Wolfgang A. Wall. A primal-dual active set strategy for finite deformation dual mortar contact. In *Recent Advances in Contact Mechanics*. Springer Berlin Heidelberg, 2013.

LABORATORY OF 3D PRINTING AND RECLAMATION OF WASTE

Mateusz TECHMAN[1]*, Anna GŁOWACKA*

[1]Department of Reinforced Concrete and Concrete Technology, Faculty of Civil and Environmental Engineering, West Pomeranian University of Technology in Szczecin,
Piastów 50a, Szczecin, Poland
[1]Department of Environmental Engineering, Faculty of Civil and Environmental Engineering, West Pomeranian University of Technology in Szczecin,
Piastów 50a, Szczecin, Poland

mtechman@zut.edu.pl, anna.glowacka@zut.edu.pl

The goal of the project is to establish a research laboratory for 3D printing of cementitious materials and laboratory for reclamation of resources from various wastes. There are two main ideas behind the project.

The first one is to expand already achieved successes in 3D printing and allow for further development. West Pomeranian University of Technology in Szczecin is the leading academic entity in Poland that works on the 3D printing of cementitious materials.

The university has been granted seven minor or major scientific projects, including the ERA-MIN 3 Cofund 2021 Recycled aggregates for 3D printed concrete structures developed in cooperation with universities from seven different countries across the globe.

The laboratory of 3D printing will allow the entrepreneurs and companies to find a place where their ideas concerning 3D printing can be developed and implemented on an industrial scale.

The idea behind the second part that regards the reclamation of wastes was developed due to strong environmental focus of European Union. West Pomeranian University in Szczecin has an extensive experience in cooperation with local governmental entities that oversee the utilization and recycling of wastes, including municipal.

In the whole chain waste producer – waste recycler, there is gap for a institution that would be able to evaluate as a whole the physio-chemical properties of waste, and their availability for processing and recycling. The laboratory fits well into the circular economy approach. Experience in Inter-Reg and Regional Operational Programmes will be herein expanded.

The faculty of Civil and Environmental Engineering has extensive knowledge and experience in working with all kinds of sewage sludges, grey water and other municipal and industrial wastes and reclamation of valuable resources from them.

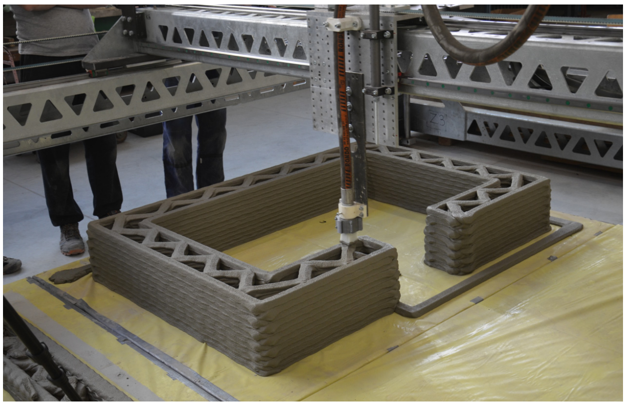


Fig. 1: Example of printed wall segment

Fig. 2: Experimental treatment plant for municipal and industrial wastewater

Acknowledgements

The authors are grateful for the financial support received from the project "Establishing of a research laboratory for 3D printing and research laboratory for reclamation of wastes" finances by Regional Programme of West Pomeranian Voivodeship and European Union.

Využití přímé optimalizované pravděpodobnostní metody pro predikci korozního úbytku ocelových konstrukcí

Miroslav VACEK[1], *Vít KŘIVÝ*[1], *Petr KONEČNÝ*[1], *Monika KUBZOVÁ*[1]

[1]Fakulta stavební, VŠB – Technická univerzita Ostrava, Ludvíka Podéště 1875/17, Ostrava - Poruba

miroslav.vacek@vsb.cz, vit.krivy@vsb.cz, petr.konecny@vsb.cz, monika.kubzova@vsb.cz

Při navrhování nosných konstrukcí je potřeba věnovat pozornost nejen vyhodnocení příslušných kritérií mezních stavů únosnosti a použitelnosti, ale také problematice související se zajištěním požadované životnosti konstrukce. Při návrhu systému protikorozní ochrany mostu je potřeba mít k dispozici výstižné údaje o korozní agresivitě prostředí. Při návrhu mostní konstrukce je potřeba zohlednit vliv chloridů jakožto korozních stimulantů [1] [2] [3].

Vstupní proměnné veličiny, jakými jsou například depoziční rychlost chloridů, teplota prostředí nebo koncentrace oxidu siřičitého nejsou konstantní hodnotou, ale jsou to náhodně proměnné veličiny. V současné době jsou dobře rozvinuté pravděpodobností metody, které umožňují inženýrům pracovat se vstupními i výstupními daty jako s náhodně proměnnými veličinami. V tomto článku je využito Přímé Optimalizované Pravděpodobnostní Metody (POPV), především programu HistAn [4] a ProbCalc [5]. Tímto příštupem je možné zohlednit náhodně proměnný charakter vstupních veličin a následně provést pravděpodobnostní predikci korozní rychlosti.

Čtenářům je v příspěvku představena samotná koncepce stochastického výpočtu a jeho výpočetní náročnost. Současně s tím je uvedeno, jakými způsoby lze redukovat výpočetní náročnost pomocí aplikace metody Přímého Optimalizovaného Pravděpodobnostního Výpočtu. V příspěvku jsou zmíněna použitá rozdělení pro jednotlivé vstupní náhodné proměnné a definovány parametry rozdělení. Dále je uvedena nutná kontrola vstupních parametrů dle požadavků jednotlivých přístupů predikce a jejich použití v rámci skriptů v Delphi 7 [6]. Výsledky použitých predikčních modelů jsou porovnány s výsledky měření korozního úbytku na vybrané lokalitě v Hrabyni-Josefovicích.

Poděkování

Práce byly podporovány z prostředků Studentské grantové soutěže VŠB-TUO. Registrační číslo projektu je SP2023/070.

Tento příspěvek je součástí výzkumu GAČR 22-198125 "Effect of gaseous and traffic induced pollutants on the durability of selected construction materials" podporovaný Grantovou agenturou České republiky.

Literatura

1. KRIVY, Vit; KUBZOVA, Monika; KREISLOVA, Katerina; URBAN, Viktor. Characterization of corrosion products on weathering steel bridges influenced by chloride deposition. *Metals*. 2017, vol. 7, no. 9, p. 336.
2. HARA, Shuichi; MIURA, Masazumi; UCHIUMI, Yasushi; FUJIWARA, Toshiaki; YAMAMOTO, Masataka. Suppression of deicing salt corrosion of weathering steel bridges by washing. *Corrosion science*. 2005, vol. 47, no. 10, pp. 2419–2430.
3. OU, Yu-Chen; FAN, Hong-Da; NGUYEN, Nguyen Dang. Long-term seismic performance of reinforced concrete bridges under steel reinforcement corrosion due to chloride attack. *Earthquake Engineering & Structural Dynamics*. 2013, vol. 42, no. 14, pp. 2113–2127.
4. JANAS P., KREJSA M., KREJSA V. *HistAn*. 2023-05-01.
5. JANAS P., KREJSA M., KREJSA V. *ProbCalc*. 2023-05-01.
6. SOFTWARE, GDK. *What is Delphi 7?* [online]. [visited on 2023-05-03]. Available from: `https://gdksoftware.com/nl/kennisbank/delphi-7`.

BLOCK CONCRETE FOUNDATION RESPONSE TO DYNAMIC LOAD

Jozef MELCER[1], *Gabriela LAJČÁKOVÁ*[1], *Veronika VALAŠKOVÁ*[1]

[1]Department of Structural Mechanics and Applied Mathematics, Faculty of Civil Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovak Republic

jozef.melcer@uniza.sk, gabriela.lajcakova@uniza.sk, veronika.valaskova@uniza.sk

Block reinforced concrete foundations are a common type of machine foundations. The foundation is placed directly on the subsoil, or an insulating layer is inserted between the foundation and the subsoil. This layer can be different. It can be, for example, a cork layer, a rubber layer, or a layer of spring insulators. The reason for its establishment can be different, for example, to increase the damping, to influence the natural frequency of the system, to reduce the transmission of vibrations to the surrounding environment, and the like. The task of the presented article is to assess the dynamic response of the block foundation of the machine, which acts on the foundation with a harmonically variable force, at different operating speeds. Numerical analysis was done in Matlab [1].

The foundation is placed on cork slab. The dimensions of the foundation are a = 2.0 m, b = 2.5 m, h = 1.6 m, the ground plane of the foundation $A = a \cdot b = 2.0 \cdot 2.5 = 5.0$ m^2, the volume of the foundation $V = A \cdot h = 5.0 \cdot 1.6 = 8.0$ m^3, bulk density ρ = 2 500 kg/m^3, the mass of foundation $m_z = V \cdot \rho = 8.0 \cdot 2\,500 = 20\,000$ kg. The subsoil compressibility module $K_z = 3.0 \cdot 10^8$ N/m^3. The elastic modulus of the cork slab $E_k = 1.0 \cdot 10^7$ N/m^2, the thickness of the cork slab h_k = 0.2 m. The mass of the machine m_s = 4 000 kg. The damping angular frequency ω_b = 12.566 371 rad/s. To solve the problem, the single degree of freedom calculation model is chosen, Fig. 1.

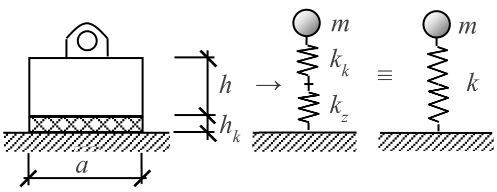


Fig. 1: SDF calculation model.

The amplitude and phase resonance curves will give us the best image about the influence of frequency ω of the excitation force $F(t)$ on the response of the system, Fig. 2.

The dynamic response is significantly affected by the damping. It can best be observed on the courses of the resonance curves in Fig. 3.

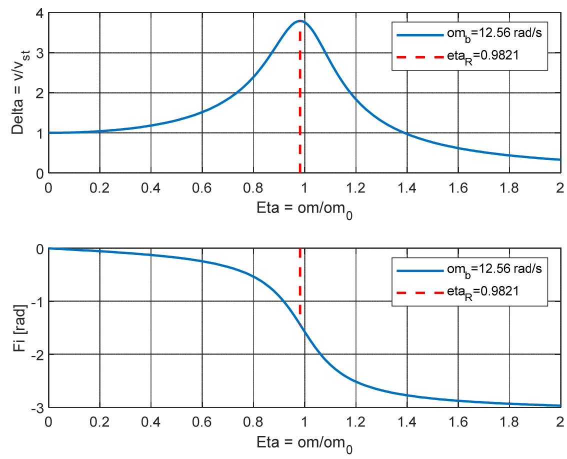


Fig. 2: Amplitude and phase resonance curves.

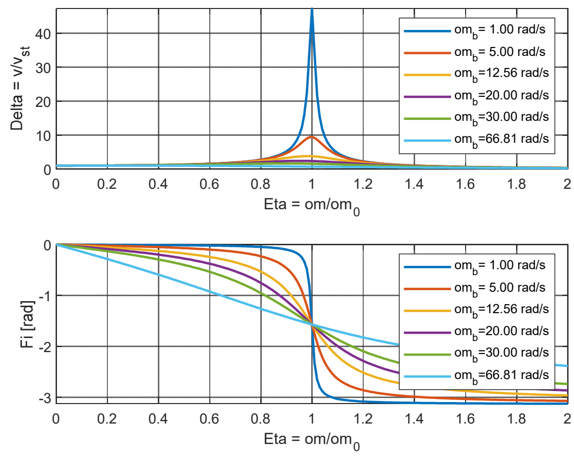


Fig. 3: Amplitude and phase resonance curves for various ω_b.

Acknowledgements

This work was supported by Grant National Agency VEGA of the Slovak Republic. Project number G1/0009/2023.

References

[1] MATLAB 7.0.4 *The Language of Technical Computing*. Version 7, June 2005.

Discrete element method in crack propagation analysis

Radek VARGA[1],

[1]Department of Mathematics, Faculty of Civil Engineering, VSB – Technical University of Ostrava, Ludvika Podeste 1875, Ostrava, Czech Republic

radek.varga@vsb.cz

The Discrete Element Method (DEM) is a numerical approach used to study the motion and interactions of individual elements. Although it is primarily utilized in particle mechanics, it can also be applied to problems of continuum mechanics. Unlike the more widely-used Finite Element Method (FEM), DEM is capable of handling combinated problems of continuum and particle mechanics with greater efficiency, making it a valuable tool in engineering analysis. One such application of DEM is in the analysis of crack propagation in reinforced concrete members.

This post discusses the possibility of using the DEM method with an extension of the beam-bound model (BBM) [1]. The BBM involves the insertion of a beam element between bounded discrete elements to transfer forces and moments. However, determining the beam members' appropriate cross-sectional and material characteristics can pose a significant challenge. This post is focused on the determination of those parameters and 2D modeling of fracture propagation in axially loaded concrete beam.

For example, an axially loaded member with a square cross-section of 1 m and a height of 2 m is shown. This element is compressed by a force of 5 MN. The element is made of a material with parameters E=30 GPa and v=0.3. The evaluated stresses according to DEM can be observed in Fig. 1. The contact stresses between the discrete elements that are used to subsequently break the fixed bonds are shown in Fig. 2.

A comparison of the results with the FEM Ansys model and the analytical solution can be found in Tab. 1.

Approach	σ_y max (MPa)	σ_y rel. dif (%)
DEM	5.020	-
FEM	4.999	-0.42
Analytic	5.000	-0.40

Tab. 1: stress comparison DEM/FEM/Analytic

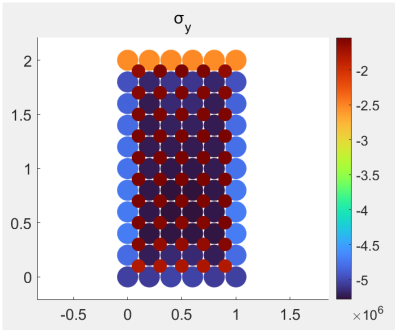


Fig. 1: Mean stress in elements

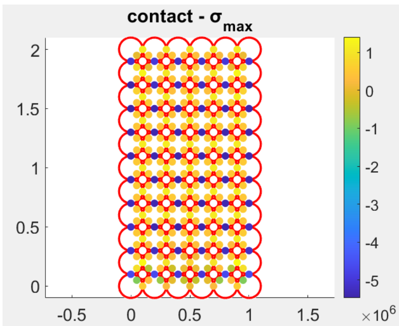


Fig. 2: Maximal stress in contacts

Acknowledgments

The work was supported by the Student Grant Contest of VŠB-TUO. The project registration number is SP2023/021.

References

[1] M. Obermay, K. Dressler, C. Vretoss and P. Eberhard "A bonded-particle model for cemented sand" *Computers and Geotechnics* 49 (2013): 299-313.

Modelling of Shear strength of concrete beams with steel and GFRP reinforcement

Jakub VEČEŘE[1], *Drahomír NOVÁK*[1]

[1]Institute of Structural Mechanics, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, 60200 Brno, Czech Republic

jakub.vecere@seznam.cz, novak.d@fce.vutbr.cz

Extensive experimental programme has been performed recently at Lodz University of Technology, Poland, focused on shear failure testing of concrete beams. One of the goals of the research was to develop an understanding of the differences between steel and composite reinforcement impact on shear strength of concrete beams. The aim of the paper is modelling performed by nonlinear fracture mechanics finite element (2D) software ATENA. Modelling is focused also on bond between concrete and reinforcement, the importance of correct bond modelling is extremally important for GFRP reinforcement.

1. Bond modelling

For bond modelling two pre-defined reinforcement bond models for concrete-steel (bond model by Bigaj and CEB-FIP 1990 model code) are used. However, there are no unique models for concrete-GFRP bond, and we did not have relevant measured data, estimation had to be done. Modulus of elasticity of GFRP is 4-5 times lower than of the steel, the bond-slip law should be lower too. Finally, the reduction to 20 % of bond was adopted.

2. Results

Simulation of shear strength of selected beams from experiment have been performed for many alternatives of material parameters and bond assumption. Here are the best results achieved so far. For comparison we used two monitoring points v25 and v26, which were measured in experimental programme.

2.1. Beam reinforced by steel

For beam reinforced by steel we assumed that bond-slip relationship would not play such a large role in beam reinforced by steel. However, the load-deflection curve of CEB-FIP 1990 model code was also slightly different from model, where the bond was not modelled.

2.2. Beam reinforced by GFRP

For beam reinforced by GFRP the bond-slip relationship played a significant role. Reduced bond model by Bigaj is not suitable for GFRP (crack patterns were not identical). Reduced CEB-FIP 1990 model code is quite similar. Although we estimated it, the results are quite good. Results are shown in Fig. 1, crack patterns in Fig. 2.

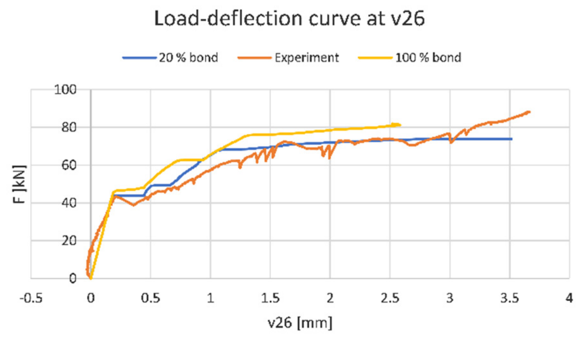


Fig. 1: Load-deflection curve – experiment vs. results of modelling, deflection at monitoring point v25.

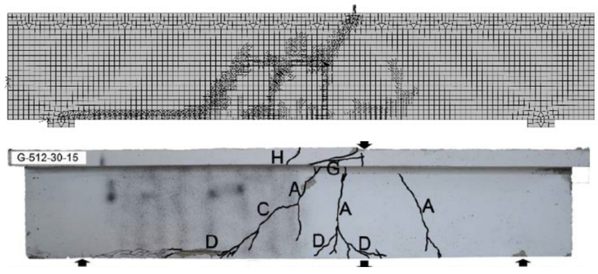


Fig. 2: Crack patterns from experiment and modelling (CEB-FIP).

Acknowledgements

The authors acknowledge the financial support from the Czech Science Foundation, project No. 22-00774S and Technology Agency of the Czech Republic, project DELTA No. TM04000012.

VSB-Technical University of Ostrava, Faculty of Civil Engineering
Vysoká škola báňská – Technická univerzita Ostrava, Fakulta stavební

21st International conference / 21. mezinárodní konference

MODELLING IN MECHANICS 2023 / MODELOVÁNÍ V MECHANICE 2023

25. - 26. 5. 2023

Proceedings of extended abstracts / Sborník rozšířených abstraktů

Topics / Tematické okruhy

The conference is focused on the following topics /
Konference je zaměřena na následující tematické okruhy:

- development and application of numerical methods in mechanics / rozvoj a aplikace numerických metod v mechanice,
- methods used in extensive tasks dealing with mechanics of continuum / metody řešení rozsáhlých úloh mechaniky kontinua,
- numerical modelling of static and dynamic behaviours of concrete, brick, steel, timber and composite building structures / numerické modelování statického a dynamického chování betonových, zděných, ocelových, dřevěných a kompozitních stavebních konstrukcí,
- interaction between subsoil and building structures / interakce stavebních konstrukcí s podložím,
- influence of undermining on building structures / vliv poddolování na stavební objekty,
- loads and responses of structures in extreme conditions / zatížení a odezva konstrukcí v extrémních podmínkách,
- rehabilitation, reconstruction and reinforcement of load-carrying structures in buildings / sanace, rekonstrukce a zesilování nosných konstrukcí staveb,
- statics and dynamics of building structures / statika a dynamika stavebních konstrukcí,
- automation of engineering tasks / automatizace inženýrských úloh,
- mechanics of materials / mechanika materiálů,
- non-linear mechanics / nelineární mechanika,
- fracture mechanics / lomová mechanika,
- experimental verification of structures / experimentální ověřování konstrukcí,
- modelling of structures subject to heat, including fire resistance / modelování teplotně namáhaných konstrukcí včetně požární odolnosti,
- reliability and probability tasks in mechanics / spolehlivostní a pravděpodobnostní úlohy v mechanice,
- analysis of durability and sustainability of building materials and structures / analýza trvanlivosti a udržitelnosti stavebních materiálů a konstrukcí,
- the environmental and human impact of traditional and new materials / vliv tradičních a nových materiálů na životní prostředí a člověka,
- nanomaterials and 3D printing in construction / nanomateriály a 3D tisk ve stavebnictví.

Scientific committee / Vědecký výbor konference

(in alphabetical order / v abecedním pořadí)

prof. Ing. Jiří Brožovský, Ph.D., VSB - Technical University of Ostrava, Czech Republic,

prof. Ing. Radim Čajka, CSc., VSB - Technical University of Ostrava, Czech Republic,

Ing. Michal Drahorád, Ph.D., Czech Technical University in Prague, Czech Republic,

doc. Ing. Jan Eliáš, Ph.D., Brno University of Technology, Czech Republic,

doc. Ing. Petr Frantík, Ph.D., Brno University of Technology, Czech Republic,

prof. Ing. Norbert Jendželovský, Ph.D., Slovak University of Technology in Bratislava, Slovak Republic,

prof. Ing. Jiří Kala, Ph.D., Brno University of Technology, Czech Republic,

prof. Ing. Zdeněk Kala, Ph.D., Brno University of Technology, Czech Republic,

Assoc. Prof. Eng. Jacek Katzer, Ph.D., University of Warmia and Mazury, Olsztyn, Poland,

prof. Ing. Zbyněk Keršner, CSc., Brno University of Technology, Czech Republic,

doc. Ing. Jan Klusák, Ph.D., Institute of Physics of Material Academy of Sciences of the Czech Republic,

doc. Ing. Petr Konečný, Ph.D., VSB - Technical University of Ostrava, Czech Republic,

prof. Ing. Eva Kormaníková, Ph.D., Technical University of Košice, Slovak Republic,

doc. Ing. Kamila Kotrasová, Ph.D., Technical University of Košice, Slovak Republic,

prof. Ing. Juraj Králik, Ph.D., Slovak University of Technology in Bratislava, Slovak Republic,

prof. Ing. Martin Krejsa, Ph.D., VSB - Technical University of Ostrava, Czech Republic,

doc. Ing. Vít Křivý, Ph.D., VSB - Technical University of Ostrava, Czech Republic,

prof. Ing. David Lehký, Ph.D., Brno University of Technology, Czech Republic,

prof. Ing. Antonín Lokaj, Ph.D., VSB - Technical University of Ostrava, Czech Republic,

Assoc. Prof. Eng. Izabela Major, PhD., Czestochowa University of Technology, Poland,

Assoc. Prof. Eng. Maciej Major, PhD., Czestochowa University of Technology, Poland,

prof. Ing. Alois Materna, CSc. MBA, VSB - Technical University of Ostrava, Czech Republic and Czech Chamber of Authorized Engineers and Technicians in Construction,

prof. Ing. Jozef Melcer, DrSc., University of Žilina, Slovak Republic,

prof. Ing. Milan Moravčík, CSc., University of Žilina, Slovak Republic,

doc. Ing. Jaroslav Navrátil, CSc., VSB - Technical University of Ostrava, Czech Republic,

doc. Ing. Ivan Němec, CSc., Brno University of Technology and FEM consulting, Czech Republic,

prof. Ing. Drahomír Novák, DrSc., Brno University of Technology, Czech Republic,

doc. Ing. Jaroslav Odrobiňák, PhD., University of Žilina, Slovak Republic,

Assoc. Prof. Eng. Tomasz Ponikiewski, PhD., Silesian University of Technology, Gliwice, Poland,

prof. Ing. Stanislav Pospíšil, Ph.D., Institute of Theoretical and Applied Mechanics Academy of Sciences of the Czech Republic and VSB - Technical University of Ostrava, Czech Republic,

doc. Ing. Stanislav Seitl, Ph.D., Brno University of Technology and Institute of Physics of Material Academy of Sciences of the Czech Republic,

dr hab. inż. Paweł Sikora, prof. ZUT, West Pomeranian University of Technology in Szczecin, Poland,

doc. Ing. Miroslav Sýkora, Ph.D., Czech Technical University in Prague, Czech Republic,

doc. Ing. Katarína Tvrdá, PhD., Slovak University of Technology in Bratislava, Slovak Republic,

prof. Ing. Miroslav Vořechovský, Ph.D., Brno University of Technology, Czech Republic.

Děkujeme společnosti Červenka Consulting
za finanční podporu této mezinárodní konference.

ČERVENKA CONSULTING
Concrete Engineering & Software Solutions

Thank you to Červenka Consulting
for the financial support of this international conference.

Děkujeme partnerům Fakulty stavební
VŠB-TU Ostrava.

ČKAIT

HSF SYSTEM

We thank the partners of the Faculty of Civil Engineering,
VSB-Technical University of Ostrava.

Title / Název:	Proceedings of extended abstracts **Modelling in Mechanics** 21st International Conference 25th and 26th May 2023 / Sborník rozšířených abstraktů **Modelování v mechanice** 21. ročník mezinárodní konference 25. - 26. 5. 2023
Author / Autor:	Team of authors / Kolektiv autorů
Place, year, edition / Místo, rok, vydání:	Ostrava, 2023, 1st edition / Ostrava, 2023, 1. vydání
Number of pages / Počet stran:	54
Published by / Vydala:	VSB-Technical University of Ostrava / Vysoká škola báňská – Technická univerzita Ostrava
Press / Tisk:	Editorial Center, VSB-Technical University of Ostrava / Ediční středisko, Vysoká škola báňská – Technická univerzita Ostrava
Number of copies / Náklad:	80

Not for sale / Neprodejné

ISBN 978-80-248-4673-6 (Print)

ISBN 978-80-248-4674-3 (Online)