Proceedings
PRO 128

Proceedings of the International Conference on Sustainable Materials, Systems and Structures (SMSS2019)

PhD Symposium

Edited by
Ivana Carević
Stjepan Lakušić
Dirk Schlicke

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- prepare state-of-the-art reports to identify further research needs,
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Preface

RILEM International Conference on Sustainable Materials, Systems and Structures (SMSS 2019) is a conference organised by Faculty of Civil Engineering University of Zagreb as a supporting event of RILEM Spring Convention from in Rovinj, Croatia. Both are organised in the year Faculty of Civil Engineering in Zagreb is celebrating 100 years from its establishment, making 2019 a perfect year for hosting such an important international event. The scope of the conference was to gather scientists, practitioners, members of technical committees and users of technical recommendations, to jointly at the same place discuss and envision the future sustainable development of materials, systems and structures in a holistic, global way.

SMSS 2019 conference has gathered participants from 50 countries, from Argentina to United States of America, who will exhibit a total of 290 papers. The conference was sponsored by 10 international industrial partners, supported by 6 international organisations of scientists and practitioners and organised under the patronage of 4 governmental bodies. A total of 450 contributions which arrived was reviewed by more than 150 prominent reviewers from different fields. Event was organised by 16 members of the local organising committee and 6 invited international members of organising committee.

As part of the ***RILEM SMSS 2019 conference***, the *PhD SYMPOSIUM* segment is organized as a separate international segment with the aim of presenting doctoral students and their scientific research. The *PhD SYMPOSIUM* segment created a professional platform for excellent PhD students to discuss their scientific developments with established experts and to found a network of young scientists of various countries in order to exchange knowledge and promote scientific goals. Contributions from any field of sustainability and construction science and engineering in this segment are exclusively offered to PhD students whereby the inherent high standards of the scientific contributions were ensured by a review of international experts. The *PhD SYMPOSIUM* segment provided a great opportunity to present and showcase ongoing research in front of an audience of peers, key representatives and main experts in the field of materials, structures, energy efficiency and methods for characterization at material and structural scale.

The *PhD SYMPOSIUM* segment of the ***RILEM SMSS 2019 conference*** has consisted of 28 extended abstract where young researches presented their research and its contribution in 3 minutes. Since the preparation and publication of scientific research is crucial for the advancement of science and for the recognisability of scientists and scientific institutions, workshop „*Publishing Scientific Research*“ was organized as a part of this segment.

Editors wish to thank the authors for their efforts at producing and delivering papers of high standard. We are sure that this Proceedings will be a valued reference of research topics in this important field and that it will together with the other volumes from SMSS conference form a suitable base for discussion and suggestions for future development and research.

Ivana Carević (University of Zagreb, Croatia)
Stjepan Lakušić (University of Zagreb, Croatia)
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International Conference on Sustainable Materials, Systems and Structures (SMSS 2019)
PhD Symposium
20-22 March 2019 – Rovinj, Croatia

CARBONATION OF CEMENT PASTE WITH SUPPLEMENTARY CEMENTITIOUS MATERIALS INCLUDING THE EFFECT ON CHLORIDE INGRESS AND FROST SALT SCALING

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Abstract

The production of ordinary Portland cement (OPC) has a significant impact on the global CO_2 emissions. From a sustainability point-of-view, the use of supplementary cementitious materials (SCMs) such as granulated blast-furnace slag (GBFS) or fly ash (FA) as a partial replacement of OPC is desirable. Despite the growing gain of the production and consumption of cement with SCMs over pure OPC, more research is needed to completely understand the evolution of the microstructure of young cement pastes exposed to environmental attack. This will lead to a more accurate estimation of the impact of the early removal of formwork or short curing periods on the durability of concrete structures. Moreover, the reciprocal effect of combined degradation mechanisms on concrete is not well understood and investigated. For this, combined durability tests will be performed on concrete specimens with the intent to optimize the existing service life design models. The research primary focuses on carbonation of cement pastes and concrete. In a next phase, the impact of carbonation on chloride ingress and frost salt scaling will be investigated.

Keywords: SCM, carbonation, cement paste, combined degradation mechanisms

1. INTRODUCTION

In West European climates, carbonation is one of the two major deterioration mechanisms occurring in reinforced concrete. It induces serious consequences on the physical and chemical properties of concrete and when the carbonation front reaches the reinforcement bars, a depassivation of the reinforcing steel occurs what may ultimately lead to corrosion of the embedded rebar. The binder type largely affects concrete's vulnerability to carbonation as it determines the CO_2 buffer capacity. Furthermore, the pore structure, which changes due to

hydration and carbonation, is a major factor influencing the resistance against CO_2 ingress. Moreover, not only carbonation affects a concrete structure, but as a result of the changed pore structure and alkalinity, chloride ingress and frost salt scaling of carbonated concrete with SCMs is accelerated causing an overestimation of the concrete performance deduced from test methods for single deterioration mechanisms [1][2].

2. EXPECTED CONTRIBUTION

Partial replacement of OPC by SCMs leads to a binder composition with less reactive CaO. As a consequence, less CH but more C-S-H with a lower Ca/Si ratio is formed during hydration [3]. The buffer capacity is thus reduced and decalcification of C-S-H leads to a coarsening of the pore structure and therefore lower resistance against CO_2 ingress [4]. This process is accelerated if short curing periods are applied so the impact of the latter is important when calculating the carbonation resistance of concrete with SCMs. *The current task in the PhD project is to identify the reaction mechanisms and reaction products formed during natural and accelerated carbonation of cement paste with GBFS and FA and to identify the changes in pore structure. This information provides a fundamental basis to study in a second phase the combined degradation mechanisms in concrete*. This research focusses on the evolution of C-S-H and $CaCO_3$ by using the ATR-FTIR method at specific hydration and carbonation stages of OPC pastes and pastes containing GBFS and FA at different replacement levels and sealed cured for 3, 7 or 28 days. The changes in reaction products and the formation of different carbonate polymorphs during carbonation have an impact on the pore structure and the interaction with other chemicals and conditions such as chlorides and frost salt scaling. A comparison between the reaction products, reaction degrees defined by selective dissolution and the pore size distribution defined by MIP measurements will be made.

The PhD project will focus in the near future on a more accurate service life estimation model for concrete degradation including the effect of carbonation on chloride ingress and frost salt scaling. *Different concrete mixtures will be subjected to sequential and simultaneous degradation mechanisms with the intent to optimize the existing service life design models such as described in FIB Bulletin 34.*

ACKNOWLEDGEMENTS

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PERFORMANCE OF CLT WALL SYSTEMS AND TYPICAL CLT CONNECTIONS UNDER MONOTONIC LOADING

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Abstract

Cross laminated timber (CLT) buildings up to 10 storeys have been constructed in areas of low seismicity, however few CLT buildings have been constructed in areas of moderate to high seismicity as there is limited understanding regarding the seismic performance of CLT buildings and no structural codes for design guidance. Consequently, further research is required to provide the experimental basis necessary to develop such knowledge. This will enable CLT to become a competitive construction material for use in mid-rise and high-rise buildings in seismically active regions. This project examines the behaviour of wall systems within multi-storey CLT buildings by experimentally testing wall systems representative of those found within a 10 storey CLT building under monotonic lateral loading. It also aims to determine the behaviour of typical connections found within multi-storey CLT buildings by testing these connections under monotonic loading in the shear and tension direction.

Keywords: Cross-Laminated Timber, Lateral Loads, Multi-Storey, Tall Buildings

1. INTRODUCTION

Cross laminated timber (CLT) buildings up to 10 storeys have been constructed in areas of low seismicity, however few CLT buildings have been constructed in areas of moderate to high seismicity due to the limited understanding of the seismic behaviour of CLT buildings [1]. Previous studies have investigated the performance of CLT wall systems under lateral loading [2][3][4][5], however there is limited literature regarding the behaviour of above ground floor CLT wall systems in which the CLT wall panel is anchored to a CLT floor panel rather than a concrete or steel foundation. Previous studies are also limited to investigating wall systems in which vertical loads applied to the wall system are representative of gravity loads within buildings no taller than 3 storeys. Therefore, the aim of this study is to further the understanding of the seismic behaviour of multi-storey CLT buildings by experimentally investigating the behaviour of CLT wall systems, representative of above ground floor wall systems in a 10 storey building, under lateral loading as well as experimental investigating the mechanical behaviour of typical connections within multi-storey CLT buildings.

2. EXPERIMENTAL TESTING

2.1 Testing of CLT wall systems under monotonic lateral loading

A series of eight tests were undertaken on a CLT wall system. During each test a vertical load was applied and maintained, with each vertical load representative of the gravity load experienced by the walls at various storeys within a 10 storey CLT building. As this study focuses on CLT wall panel to CLT floor panel connections, the ground storey wall system in which the wall panel is fixed to a concrete foundation was not investigated, nor was the top storey in which vertical load is relatively small; thus, the vertical loads were representative of the gravity loads in floors 2-9 of a 10 storey CLT building. While the vertical load was maintained, the wall was loaded laterally in increments of 5kN to a maximum load of 50kN Displacement was measured at various locations within the wall system to allow the global behaviour of the wall system under lateral loading to be observed.

2.2 Testing of typical CLT wall panel to CLT floor panel connections under monotonic shear and tension loading

Three types of typical CLT connections have been tested under monotonic loading in both the shear and tension direction. The connections tested were a commercially available shear-resisting bracket, Simpson Strong-Tie ABR105-R, and uplift-resisting brackets of two different lengths, Rothoblaas WHT340 and WHT620. All three connections were tested with three different fixing arrangements compromising of anker annular ring nails and screws.

3. FINDINGS

Results of the experimental investigations suggest that each storey within a multi-storey building would behave differently with different connection system design being required at each storey to ensure optimal seismic performance. The behaviour of connections within the wall system was observed to be complex with shear connections yielding under lower load than the yield strength found during the connection testing. It appears the shear connection is also resisting the uplift of the wall and therefore this may be due to the reduced shear capacity of the connection due to bi-directional loading.

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CONSEQUENCES ON PHYSICAL FLOWS OF MEETING CSI CLINKER-TO-CEMENT RATIO MILESTONES AND THE ROLE OF ALTERNATIVE MINERAL ADDITIONS

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Abstract
To investigate the potential consequences on physical flows of the clinker-to-cement ratio progressive decrease, as prescribed by the Cement Sustainability Initiative (CSI), we developed a circular multi-industry and multiregional material-product chain model. This paper presents the modeling mathematical framework and its application to assess the disruptive effects of the CSI strategy in Canada on domestic production and international trades, and the potential benefits of developing glass powder as an alternative mineral addition.

Keywords: Cement industry, Glass powder, Material-Product chain, Multi-industry and multiregional model

1. INTRODUCTION

To address the challenges of climate change of the cement sector, the Cement Sustainability Initiative (CSI) recommends replacing up to 40% by 2050 the mass of clinker in cementitious products with mineral additions [1]. However, conventional mineral additions, such as ground granulated blast-furnace slag and fly ash are becoming increasingly scarce [2]. Thus, the achievement of the clinker-to-cement milestone implies a disruptive effect on the current material-product chain of interconnected industries. Until now, these market interactions have not been extensively studied [3]. To investigate the potential direct and indirect consequences on physical flows of the decrease of the clinker-to-cement ratio, we developed a circular multi-industry and multi-regional material-product chain model. Next, we applied the model to a Canadian case study in which a shortage of domestic fly ash is expected to occur by 2030 and glass powder from post-consumed mixed-colored glass waste is attracting more and more attention in the cement industry as a promising alternative pozzolanic mineral additions.

2. METHOD

We developed a circular multi-industry and multiregional material-product chain model. A Material-Product chain is a an optimization model that has at its core an equilibrium model (demand = supply) coupled with material balance equations [4]. The objective function seeks

to minimize the sum of the operating costs of all industries in set $\hat{U}$ in all regions in set J, by optimizing material and product flows to satisfy the domestic and foreign demands for all products in all regions at a given period. Equation 1 presents the mathematical framework used to develop the objective function.

$$\text{MIN } P_{T,\hat{u},j,t} = \sum P_{d,\hat{u},j,t} + \sum P_{i,\hat{u},\grave{j},j,t} + \sum P_{e,\hat{u},j,t} + \sum P_{\ddot{e},\hat{u},j,t} \; \forall \hat{u} \in \hat{U} \text{ and } \forall j \in J, \grave{j} \neq j, \text{ at period } t \qquad (1)$$

Where $P_{T,\hat{u},j,t}$ is the total operating cost to satisfy demand for product $\hat{u}$ in region j at period t, $P_{d,\hat{u},j,t}$ is the domestic cost to supply products $\hat{u}$ in region j, $P_{i,\hat{u},\grave{j},j,t}$ is the import cost of product $\hat{u}$ from region $\grave{j}$ to region j, $P_{e,\hat{u},j,t}$ is the cost to dispose product $\hat{u}$ at end-of-life in region j, and $P_{\ddot{e},\hat{u},j,t}$ is the cost to dispose material production losses in region j. Product costs are built endogenously according to the exogenous material and non-material costs (labor, energy and transport) of input materials (virgin material, closed-loop and open-loop recycled materials). This creates competition between materials upstream and downstream of the demand in the process of minimizing costs. Industries and regions are modeled to reflect the current and future Canadian cement reality. A set $\hat{U}$ of four products, namely $\hat{u}_1$ = blended Portland cement, $\hat{u}_2$ = glass packaging, $\hat{u}_3$ = hard coal, $\hat{u}_4$ = crude steel and a set J of four regions*:* j_1 = province of Quebec, j_2 = Province of Ontario, j_3 = Northeastern U.S., and j_4 =Rest of the World, are modeled. Blended cement can be produced using a set of intermediary materials such as clinker, gypsum, limestone filler, metakaolin and open-loop recycled materials such as glass powder, fly ash and ground granulated blast furnace. Then, each intermediary material is connected to a set of virgin or recycled materials. For all products in set $\hat{U}$ in region set J, we projected the demand, material availability, technology capacity and regional economic contexts up to 2050 using macroeconomic indicators, national statistics, industry-specific data and expert judgements. Finally, we solved equation 1, a nonlinear optimization problem, using a Generalized Reduced Gradient (GRG) Nonlinear solver.

3. PRMILARY RESULTS AND EXPECTED OUTCOMES

The approach detailed in this paper allows to investigate how interregional and interindustry physical flows may alter in response to the implementation of industrial strategies, such as the clinker-to-cement ratio milestones of the CSI roadmap. Preliminary results reveal that in a business-as-usual scenario, the growing Canadian demand up to 2050 for mineral additions will have to be met by imports of fly ash, mainly from the Northeastern U.S., due to the shortage of fly ash in Canada. However, in a scenario where the glass powder market is fully developed in the province of Quebec, modelling results shows a reduction in imports of 11%, due to combined costs and savings from both cement and glass industry.

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EFFECT OF BINDER ON THERMAL CONDUCTIVITY OF ENVIRONMENTALLY FRIENDLY STRAW-BASED THERMAL INSULATION BOARDS

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Abstract
Nowadays huge amount of thermal insulation materials have to be produced. Materials with high performance have high price, and the most popular thermal insulations have large environmental footprint and these are not able to biodegradation and their production needs high energy investment [1, 2]. One alternative the use of natural based biodegradable materials. Straw bales, and rediscovered straw bale houses are widely documented in the literature (e.g. [3]). Previous researches dealt with raw and bonded straw, in case of the last one the effects of the binder was neglected, although it plays key role in mechanical, durability and thermal properties. The optimal balance of these functions must be found because this balance provides good usability [4]. To minimize the negative effect of binder to thermal conductivity is one of the most important topics in development.

Keywords: straw, thermal insulation, thermal conductivity, binder, natural fibre

1. EXPERIMENTAL PART AND RESULTS

In the research, thermal conductivity of straw specimens was measured in the range of 80-180 kg/m^3 density with and without binder (Fig. 1). In every case, the Guarded Hot Plate Method was used and the specimens were in completely dry state and framed by EPS stocks. The fibre-binder ratio by mass was constant for bonded specimens. The straw and binder were mixed manually, thus causing higher internal unevenness. Because of the unevenness (in density) in the results of bonded specimens outlier analysis was made, which can excluded values that cause error in the evaluation (Fig 1). The studies have shown that the difference of thermal conductivity between two adjacent investigated density categories may be at least double or more times bigger in case of bonded straw, than in case of straw without binder. Beyond 160 kg/m^3 this tendency is turn around. The effect of binder pushes lambda values of the curve of non-bonded straw into another range and push the thermal conductivity of adjacent densities apart (Fig 1). The denser binder frame which surrounds the fibres provides a more favourable medium for the heat flow and the connections between the fibres become direct. The characteristic of two types (with and without binder) of curves is similar in range of 120-180 kg/m^3 and the density which giving the minimum point are also the same, if this range is considered (Fig 1). The effect of binder can be reduced with foaming of binder and surface treatment of straw. The reaction to fire was investigated by a unique test. This test were

performed by using a gas-burner (flame: 950-1030 °C). Tests were stopped 200 °C where reached on the protected side of the specimen. Thermocouples were fixed to the centreline of the protected side of the specimen (one against a gas burner flame- sensor 1, one 4 cm laterally from other-sensor 2). This method is not standard, but it is more informative from the point of view of the protected side temperature than commonly used standards nowadays. Based on the experiences during testing the insulation's class of reaction to fire is B s1 d0 (MSZ EN 13501-1). EPS and mineral wools are a most common thermal insulations nowadays and the mineral wool has the same bulk density as straw insulation.

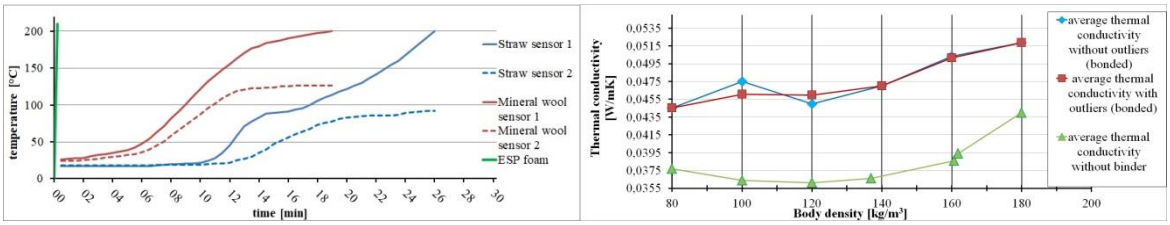

Figure 1: The average of the fire test of 100 kg/m^3 mineral wool and 100 kg/m^3 bonded straw specimens and EPS specimens (left), Average thermal conductivity vs. density of bonded and non-bonded samples (right)

Concerning fire tests, in case of raw straw lateral fire spread is discernible and it isn't self-extinguishing. The bonded straw only have lateral carbonization and it is self-extinguishing, furthermore the heat spread is surprisingly slow (100 kg/m^3: 7.7 °C/min). Comparing the fire behaviour of straw and mineral wool specimens which characterized by the same density, the straw thermal insulation was more resistant to the fire (Fig 1). Smoke production was relatively low; a clear, almost white and not irritating smoke was produced.

2. CONCLUSIONS

The binder increases the differences of thermal conductivity between two investigated adjacent density categories compared to a binderless case. The variation of thermal conductivity with increasing density for bonded straw and raw straw is characterized by the same evolution in range of 120-180 kg/m^3 and the minimum value obtained at 120 kg/m^3. It is also observable that the binder significantly improves the behaviour against fire.

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SENSITIVITY OF DYNAMIC PARAMETERS FOR CORROSION DETECTION ON RC ELEMENTS: A LITERATURE REVIEW

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Abstract

Visual inspection is the default inspection methodology for reinforced concrete (RC) structures. However, there are several limitations (timing, interpretability, accessibility, etc.) that might affect the efficiency of decision making. Due to that, vibration-based damage detection methods as NDT tool get more focus in the damage assessment of RC structures. Reinforcement corrosion is one of the major durability problems, which causes cracking or spalling of concrete cover, reducing strength and stiffness of RC structures. The aim of this work is to make literature review on the area of vibration based methods applied for reinforcement corrosion detection on RC elements. Dynamical parameters have a large potential in defining corrosion damage detection on reinforced concrete elements, however, this area is insufficiently explored, and there is an evident need of further research.

Keywords: corrosion, dynamic parameters, reinforced concrete elements, damage detection

1. INTRODUCTION

Vibration-based damage detection methods as NDT tool are getting more in focus for damage assessment of reinforced concrete structures [1]. One of the major problems related to durability of reinforced concrete structures is related to influence of reinforcement corrosion [2], which leads to reduce of strength and stiffness of reinforced concrete structures [3].

2. LITERATURE REVIEW

All articles, total five of them, had an aim to research the use of dynamic changes of natural frequencies and/or modal for damage estimation/detection assessment due to corrosion. J. Wu and S.X. Wu [3] presented modal analysis technique to locate damage due to corrosion in RC structures using frequency square ratio. On-site and lab experiments on four members in the RC balustrades of Lian Yun-harbor west dam were conducted [3]. R. Capozucca [4] experimentally investigated three prestressed reinforced concrete (PRC) beams through dynamic testing in order to verify damage degree due to reinforcement corrosion obtained by an artificial electrochemical process. One of the beams was subjected to a corrosion process through three artificial corrosion cycles for a period of 3 months [4]. S. Shahzad et al. [5] examined the possibility of corrosion damage detection, based on modal damping and natural frequencies' changes. There experiments were conducted on four RC beams, which were damaged artificially by inducing uniform and localized corrosions [5]. Corrosion levels (steel

mass losses) of uniformly corroded beams were 1,03% (no visible crack) and 6,18% (visible cracks along the length) [5]. L. Zuccarino at al. [6] studied sensitivity and identifiability problems of the modal parameters in the presence of corrosion damage. Their tests were made on three different groups of PRC beams and with corrosion levels (steel area loss) of 3, 5, 6, 10, 12, 15 and 30% [6]. H.A. Razak and F.C. Choi [7] examined three RC beams to establish a relationship between the degree of corrosion damage and changes in natural frequencies and modal damping. Two of the beams were subjected to different states of reinforcement corrosion while the other acted as a control [7]. Both beams suffered a loss of area less than 8% [7]. Results of studies in accordance with uniform corrosion [4-7], obtained from the first four natural frequencies, shows changes from 0,1 % to 5,6 % so they might be a relevant parameter in vibration based damage detection. The main result obtained from [5-7] is that changes in modal damping are quite significant. For example, Shahzad et al. [5] stated that the changes in the modal damping ratio can be found in the interval between 28% and 59%.

3. CONCLUSIONS

To conclude, although dynamical parameters have a large potential in defining corrosion damage detection on reinforced concrete elements, authors found out that this area is not sufficiently explored. As presented, there are possible opportunities in advancing today's methods for corrosion damage detection by the usage of dynamical parameters. According to only a few studies, there is an evident need of extensive further research in damage detection and localization by using dynamic properties (modal shapes and natural frequencies) introducing discrete and uniform corrosion with various loss of area, furthermore, with different reinforcement ratio and boundary conditions of beams.

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FUNDAMENTAL RESEARCH ON THE STATICAL ANALYSIS OF RC BUILDINGS WITH HOLISTIC 3D CALCULATION MODELS

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Abstract

Nowadays, holistic 3D calculation models can be seen as a substantial part of structural engineering, especially in case of irregular, more complex and/or unconventional structures. The herewith presented research aims at an optimal use of such holistic 3D calculation models for the structural analysis of buildings. In detail, a representative high-rise building with flat slabs and a core for structural stability was modelled with a holistic 3D model taking into account the overall compatibility of the structural elements in the structure when loaded.

This contribution concentrates on the comparison of the calculation results from the 3D models with and without construction stage analysis (CSA) with those from commonly used extracted 2D subsystems. Furthermore, the effect of stress distribution due to differential creep and shrinkage in the individual concrete columns and the concrete core will be discussed.

Keywords: holistic 3D calculation model, construction stage analysis, creep and shrinkage

1. INTRODUCTION

Holistic 3D calculation models are often an indispensable part of structural design, especially for complex and/or unconventional structures [1]. In addition, the importance of holistic 3D calculation models is growing in context of "Building Information Modelling" (BIM) in order to integrate essential information about the building structure into the BIM model. Moreover, the consideration of the interaction between horizontal and vertical elements can lead to a quality jump regarding the prediction of the realistic structural behaviour of buildings.

2. HOLISTIC 3D CALCULATION MODEL

A current research project of the Institute of Structural Concrete at Graz University of Technology and FCP Fritsch, Chiari & Partner ZT GmbH investigates the effects of different modelling approaches on the holistic 3D model systematically. Therefore, a representative high-rise building with flat slabs and a core for structural stability was defined (see figure 1). The geometry and basic information of this simplified building can be found in [2]. Core walls, slabs and foundation plate are modelled as 2D shell elements and columns as 1D beam elements with rigid connections. The effect of present reinforcement was neglected at this stage. By now, this model is also enhanced with the consideration of the construction process including deformation compensation through construction stages, the soil-structure-interaction using a linear-elastic half-space and the time-dependent behaviour of concrete (creep and shrinkage).

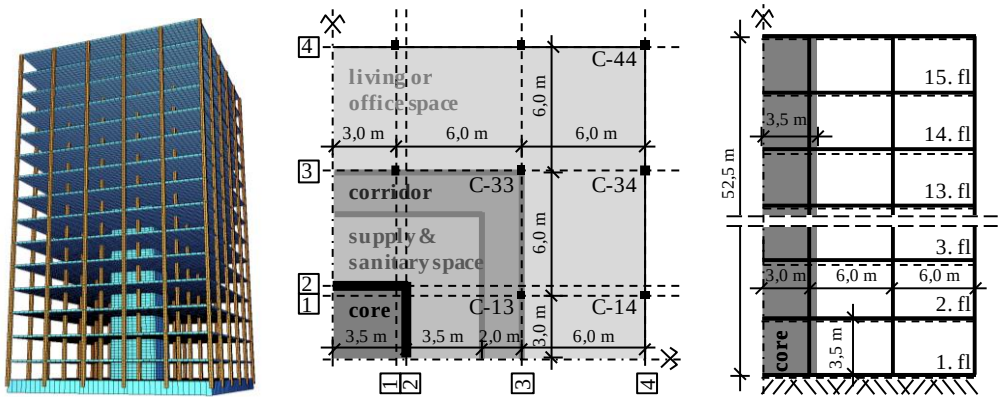

Figure 1: holistic 3D model (left); floor plan (center); vertical section (right)

Caused by a gradually increase of the frame stiffness, the CSA shows different column forces than the analysis with the final system (see figure 2, right). Moreover, it can be shown that time-dependent effects reduce the axial force of highly stressed columns at young age (figure 2, left).

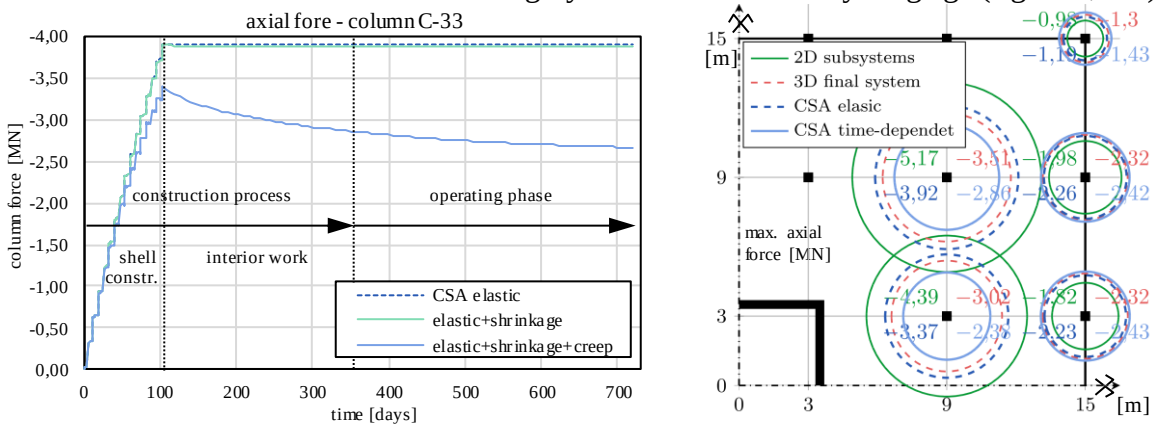

Figure 2: development of column force – C-33 (left); maximum column forces (right)

3. FINAL REMARKS

The analysis with holistic 3D models leads to a homogenization of maximum column forces. Furthermore, the consideration of the construction stages and time-dependent effects have a significant influence on the internal forces. In the next step, further effects like redistribution of stresses due to cracking as well as different reinforcement ratios will be investigated. It is expected that these effects will significantly reduce the homogenization of axial forces.

The presented research was conducted within the project "Holistic Building Models" funded by the Austrian Research Promotion Agency (FFG) (Project No. 861488).

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3D-FE MODEL FOR HOLISTIC ANALYSIS OF THE LONG-TERM DEFLECTION OF PRESTRESSED CANTILEVER BRIDGES

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Abstract

Unexpected deflections of cantilever bridges is a often reported phenomena worldwide. Different explanatory approaches exist, whereby the inaccuracy in the current models for creep and shrinkage of concrete is expected to have an important influence, e.g. [1]. But also the consequences of underestimated prestress losses are discussed in this context, e.g. [2].

Based on observation, that the real deflection of the majority of all concrete bridges (not only cantilever bridges) complies quite well with the predicted deformation from the design with current models for creep and shrinkage, it is assumed, that properties in geometry, slenderness, prestress as well as construction process may have a predominant influence of the deflection behaviour of cantilever bridges rather than only a possible inaccuracy of the models for creep and shrinkage. The interplay of these parameters is currently analysed with a comprehensive research programme based on the long-term deflection of the valley crossing Schottwien in Austria. This research programme consists of an on-site monitoring of the 250 m spanning main field of this bridge, numerical investigations with commonly used beam models and time-discrete simulations with 3D-volume models, as well as testing of the creep behaviour of samples taken from a comparable bridge with same age and level of stressing.

This contribution gives insights on the previous investigations with the 3D-volume model.

Keywords: cantilever bridges, holistic analysis, time-discrete analysis

1. OPPORTUNITIES AND LIMITATIONS OF TIME-DISCRETE SIMULATION OF BRIDGE DEFLECTION WITH 3D-VOLUME MODELS

In contrast to beam models, which are usually used for the practical design of cantilever bridges, a 3D-volume model enables a detailed consideration of local interactions within the cross section. On one hand, these local interactions result from differential thermal and hygric deformations within the cross section due to different massiveness of the different parts of the cross-section which changes also along the span; and on the other hand they result from non-uniform creep deformations over the width due to non-uniform distribution of stresses.

However, complexity of modelling as well as computational costs of a 3D-volume model are disproportionately high compared to beam models, so that they are usually only used for scientific investigations on representative cutouts of the bridge, e.g. a quarter of a span.

2. CALCULATION MODEL SCHOTTWIEN AND PRE-STUDY

Figure 1 features the numerical model of a representative cutout of the main field of the valley crossing Schottwien. It regards construction stages, pre-stressing, time-dependent

concrete behaviour due to shrinkage and creep with independent implementation in each element, as well as the influence of seasonal variation of ambient temperatures.

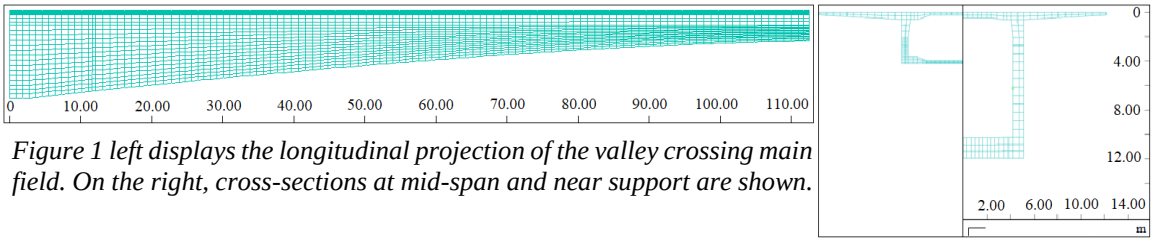
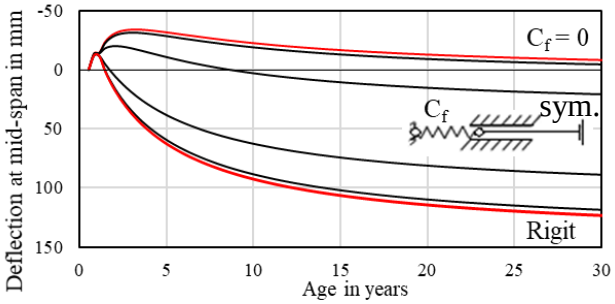


Figure 1 left displays the longitudinal projection of the valley crossing main field. On the right, cross-sections at mid-span and near support are shown.

Figure 1: Numerical model – lateral projection and Cross-Section

Functionality of the model with special attention on set boundary conditions are analysed in a pre-study. Realistic assumption of axial constraint is of major importance whereas the rotation over the column can be assumed as completely restrained due to the very stiff construction needed during erection. Figure 2 features calculated deflections at mid-span occurring due to shrinkage and for different axial constraint after the construction process is finished. Pre-stressing and viscoelasticity are neglected in this particular study. Variation between limits of "full axial constraint" and "joint support" show, deflections at mid span are highly influenced by chosen boundary-stiffness. Differential shrinkage of flanges, respectively shrinkage strain, lead to nonlinear time-deflection relations, as the cross-sections tend to rotate.



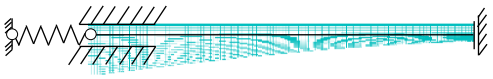


Illustration of chosen boundary conditions. Supporting at the right side implicates longitudinal symmetry. In this study, impact due to preventation of longitudinal strain is carried out.

Figure 2: Variation on spring stiffness

3. CONCLUDING REMARKS

It is necessary to determine realistic boundary conditions. Discrete modelling of surrounding beams and supportings seem to deliver good results as drawback in intensive calculation time. The presented research was conducted within the project "Holistic consideration of the deflection-behaviour on prestressed cantilever bridges" funded by the Austrian Research Promotion Agency (FFG) (Project No. 860550).

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MODELLING OF VISCOELASTIC CONCRETE BEHAVIOR WITH RESPECT TO RECENT OBSERVATIONS IN MACROSCOPIC TESTS

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Abstract

This contribution presents a comparative study of different modelling assumptions for the effect of viscoelasticity on the stress development in hardening and restrained concrete. The goal was to analyze the performance of an alternate model developed by [1] and [2], which was developed with regard to the insights gained with measurements in several on-site monitorings in mass concrete as well as with restraining frame experiments.

The results of the presented comparative study indicate, that the experimentally observed effects of viscoelastic behaviour in hardening concrete cannot be consistently reproduced with the application of basic assumptions in today's creep modelling, namely similarity of creep in tension and creep in compression as well as consequent application of superposition.

Keywords: viscoelasticity, numerical modelling, early-age concrete

1. MOTIVATION

The computational simulation of the stress development in hardening and restrained concrete is increasingly gaining importance in order to optimize the required minimum reinforcement for crack width control but also to enable innovative construction methods, e.g. jointless structures. A key factor of these simulations is the consideration of the viscoelastic behaviour of concrete, which can have a significant influence of the occurring stresses in reality. Recent on-site monitorings in mass concrete as well as restraining frame experiments of the Institute of Structural Concrete at Graz University of Technology (iBB) have however shown certain discrepancies regarding today's understanding of viscoelastic behaviour of early-age concrete and its respective modelling. In detail, these insights indicate the necessity to distinguish between creep in tension and compression as well as to overrule the superposition principle in phases of unloading by reducing the remaining viscoelastic potential according to the rate of unloading. Based on these insights an alternate creep model was developed by [1] and [2], which performance will be analysed by the following comparative study.

2. COMPARATIVE STUDY

The comparative study was conducted on basis of one restraining frame experiment of iBB. In particular, the same restraining frame experiment was used, which was recently profoundly analysed and discussed in the international numerical benchmark of COST Action TU1404, whereby all relevant material parameters and conditions of the experiment are given in [1] and

[3]. For the creep modelling, the basic creep according to EC2 [4] was used in general, whereby three different cases were simulated:

1. common approach with strict application of superposition and no distinction between creep in compression and tension,
2. as case 1., but with distinction between creep in compression and tension acc. to [1]
3. as case 2., but with overruling the superposition principle in phases of unloading acc. to [1] and [2]

The results of the simulations are presented in the diagrams shown in Figure 1. As expected, at the beginning (loading under compression) the three models show the same behaviour and are in agreement with the measurements from the experiment. At the beginning of unloading (Figure 1 right), however, the simulated stress evolution shows certain discrepancies when the superposition principle is applied (cases 1 and 2). Besides, the case 1 with no distinction between creep in compression and creep in tension shows additional deviations with ongoing time since the creep rate in tension is not similar to the one in compression.

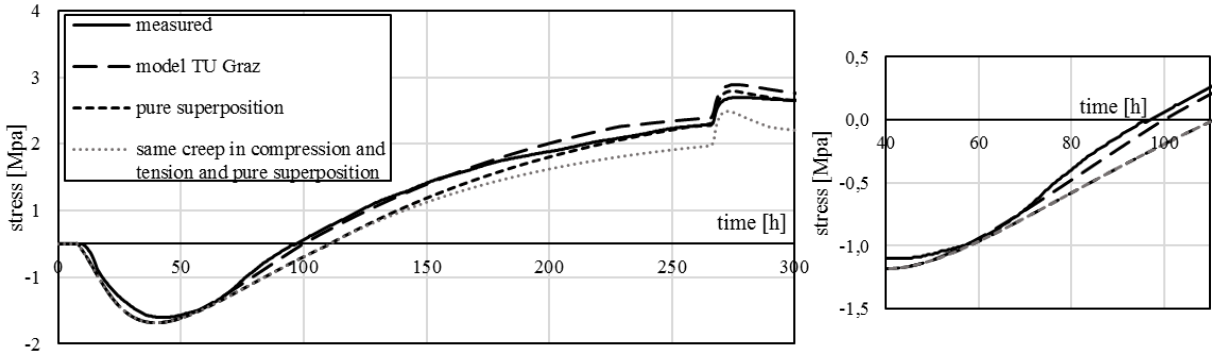

Figure 1: Simulation of viscoelastic stress development

3. CONCLUSIONS

The results of the study permit the following two conclusions:

- tensile stresses are underestimated when creep in tension is assumed to be similar as creep in compression and
- the application of the superposition principal in the unloading phase must be seen critical since it delays the actual time for the beginning of tensile stress development.

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CHARACTERISATION OF MICROSTRUCTURE IN LIMESTONE CALCINED CLAY CEMENTITIOUS SYSTEMS

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Abstract

Recent studies on the binder and concrete properties of limestone calcined clay cement (LC3) have shown good potential for producing high-performance, low clinker cement with a combination of limestone and calcined clay [2]. The greater resistance to ionic ingress, more specifically chloride ingress and sulphates, was found to be strongly influenced by the reduced pore sizes due to higher reactivity of calcined clay present in LC3 systems [2]. Even lower grade calcined clay results in an early refinement of pore structure due to highly pozzolanic nature of the amorphous phase [3] and dense microstructure formed in such systems [4]. This alteration in the physical structure is related to the nature and chemistry of hydration products and the variation in the composition of C(A)SH formed in these systems discussed in this paper.

Keywords: LC3; calcined clay; microstructure; nano-indentation.

1. EXPERIMENTAL PART AND RESULTS

In this paper, a detailed investigation on the micromechanical and chemical characteristics of OPC (Ordinary Portland Cement), FA30 (fly ash-based binder; 30% Class F fly ash) and LC3 was performed using energy dispersive X-ray spectroscopy (20 KV) and nanoindentation technique on a matured cement paste made with water-binder ratio of 0.4 and sealed cured for 150 days. Figure 1 shows the shift in the Ca/Si ratio in FA30 and LC3 systems compared to OPC. The mean Ca/(Si+Al) values for OPC, FA30 and LC3 were 1.94 (±0.13), 1.61 (±0.12) and 1.12 (±0.14) respectively. The statistical variation in C(A)SH composition is shown in Figure 1 (a). The difference in the composition of the C(A)SH indicates that there is an uptake of a greater amount of alumina and silica in C(A)SH, more specifically in the LC3 binder system due to the higher reactivity of the amorphous phase, despite lower kaolinite content of clay used for LC3 (<60%). Also, Figure 1 (b) shows higher alkali uptake in C(A)SH (represented as Na+K normalised by Ca/(Si+Al)) which leads to changes in the measured pH of pore solution for OPC, FA30 and LC3 as 12.88, 12.72 and 12.32 respectively. This characteristic alteration in the phase chemistry and microstructure alters the development of properties in the cementitious systems. In a previous study, the macroscopic effect of this intervention was shown on the formation factor and other transport properties of LC3 systems, which showed a major rise from an early curing period compared to OPC and fly ash-based systems [3]. The variation in micromechanical characteristics was studied using Hysitron Triboindenter to probe the stiffness parameter of the hydrates in the microstructure. The deconvolution of the probability densities

from indentation modulus evaluated over a matrix of 225 data points (15x15matrix; 15 microns distance) showed three major regions of hydrate moduli (10-70 GPa). The study of indentation modulus of the C(A)SH indicated that a reduction in dominant modulus region was significant for calcined clay systems compared to fly ash systems (Figure 1 c).

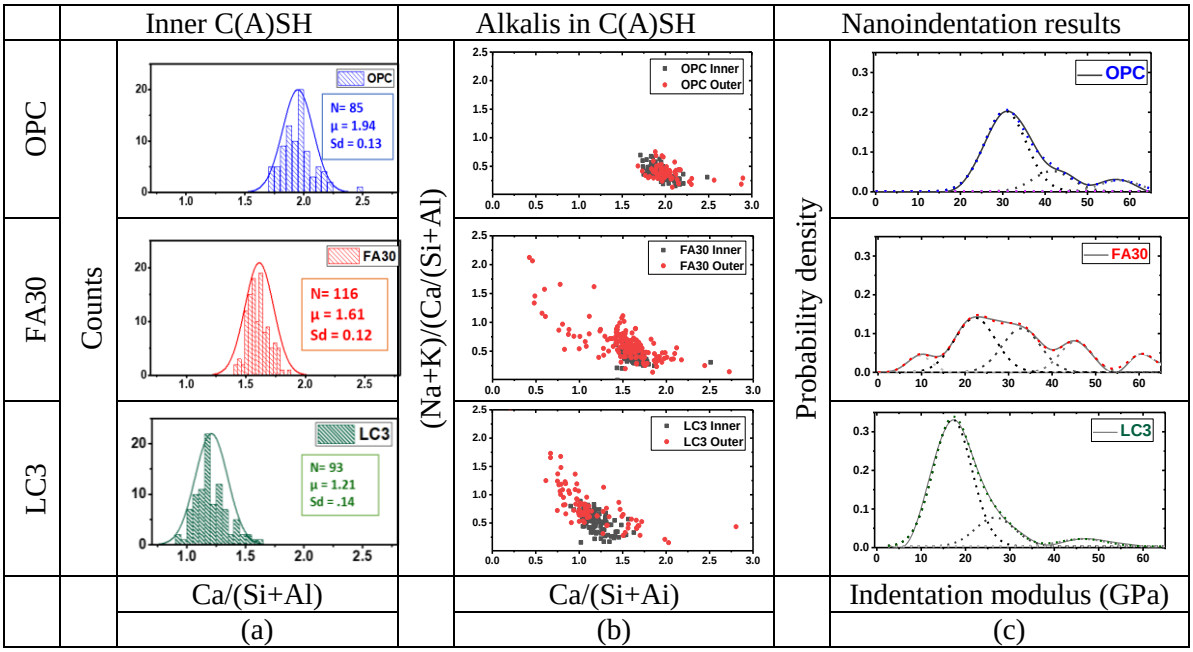

Figure 1: Microstructural characteristics of OPC, FA30 and LC3 binder

2. CONCLUSION

The result suggests a shift in the dominant modulus region of the microstructure for FA30 and LC3 systems. In fly ash-based systems, only the outer C(A)SH region showed a major shift due to the low Ca/Si ratio from the slower dissolution of fly ash. However, in the case of calcined clay systems, the early reactivity of calcined clay shifts the region of the dominant modulus (less than 20 GPa) in contrast to plain Portland cement (greater than 20 GPa) in line with low Ca/Si ratio in inner and outer hydration products observed in EDX. This study also draws a connection between the early reactivity of calcined clay, its effect on microstructural development and the corresponding early impact on the microstructure, which governs the concrete properties such as ionic resistance.

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WATER ABSORPTION OF CRUSHED CONCRETE AGGREGATES BY THE MODIFIED PYCNOMETER METHOD

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Abstract

Crushed Concrete Aggregates (CCA) as fine and coarse aggregates in new concrete demands the knowledge of the water absorbed by the CCA to ensure fulfilment of the workability requirements and mechanical performance of the concrete. Sedimentation and air entrapment are the practical challenges encountered while performing the water absorption of fine CCA using the EN 1097-6 standard method. Additionally, Saturated Surface Dry (SSD) state assessment seems operator specific and non-reproducible. Contrary to the standard 24 hour water absorption values, findings from this paper show results at 15 minutes are influential for concrete workability. The modified pycnometer method measures the water absorbed by the combined CCA fraction consisting of coarse and fine CCA as proportioned in the concrete recipe. Sedimentation and air entrapment is prevented by the use of a dispersant solution produced using superplasticizer. Ultimately, the combined CCA is drained to SSD condition by vacuum filtration, which is easy to handle by professional operators. Therefore the appropriate water amount to saturate the CCA is determined from the water absorption development of the combined fraction CCA from starting point to 24 hours.

Keywords: crushed concrete aggregate, water absorption, pycnometer, SSD, sustainability

1. INTRODUCTION

Crushed Concrete Aggregates (CCA) as fine and coarse aggregates in new structural concrete helps achieve closed-loop recycling. Satisfying the workability requirements of new structural concrete containing CCA demands knowledge of water absorption of the included CCA. Practical issues such as sedimentation and air entrapment are encountered when the WA of fine CCA is tested using the EN 1097-6 standard pycnometer method. The sedimentation of CCA is also problematic because of the difficulty in removing the CCA specimen from the pycnometer for SSD assessment. Also observed is the fine CCA do not meet the assessment requirements prescribed by the standard for saturated surface dry (SSD) condition, performed by the sand absorption cone. Researchers have attributed the issues with sedimentation and SSD assessment to the angular shape and presence of excessive fines in the crushed aggregates [1].

2. METHODOLOGY

This study employs the modified pycnometer method to investigate a combined fraction consisting of coarse and fine CCA to measure the WA just as it would happen during concrete

mixing. The modified method firstly eliminates CCA sedimentation by utilizing the dispersant properties of a superplasticizer achieved by pre-soaking CCA in a superplasticizer solution of concentration 6.35g/L. The solution is further used as a test medium instead of water. Secondly, the method consists of a robust SSD assessment procedure using vacuum filtration that drains the wet crushed aggregates to SSD condition.

A surface dry appearance of the coarse CCA in the combined fraction suggests the SSD condition for the combined fraction because the coarse fractions forms 45% of entire aggregate mass for the given concrete recipe. The appearance and procedure to bring the coarse crushed aggregate into SSD condition is considerably similar to the EN 1097-6 standard procedure, which prescribes the removal of water from the aggregate surface by wiping with a non-absorbent cloth.

3. RESULTS

The WA is measured for a total of 24 hours using the modified pycnometer method to understand the development of WA with time. Measurements have been taken at initial stages after the CCA is immersed in the pycnometer. Studies investigating the development of water absorption for CCA have found that most of the WA happens within the first 15 minutes [2]. In our investigations, it is seen that about 86% of the total water absorption happens within the first minute and is constant after 15 minutes. This could potentially be the optimum amount of water required to saturate the CCA before concrete mixing to improve the concrete workability.

The modified pycnometer method due to its robustness and easy execution is well suited for use in an industrial environment. The superplasticizer used in this investigation is the same that is recommended in the parent concrete recipe and is therefore readily available on site

ACKNOWLEDGEMENTS

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ASSESSMENT OF RC EXISTING BUILDINGS: CRITICAL ANALYSIS OF THE MODELS FOR THE EVALUATION OF THE RESIDUAL CAPACITY OF STRUCTURAL ELEMENTS

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Abstract

Aimed at estimating the residual life of existing buildings, in the present research, available models to evaluate residual strength of existing structural elements are compared and critically analysed, showing the effectiveness of the analytical models with respect to the empirical ones. The assessment of the preservation state of existing buildings is then herein further extended up to the global structural level, by proposing a new approach, which relates the behaviour of deteriorated elements over time with its effect on the whole structure.

Keywords: Existing RC buildings, residual life evaluation, reinforcement corrosion

1. INTRODUCTION

The poor preservation state of the building heritage highlights the urgency to develop a specific protocol to be addressed as a guideline in the selection of the most suitable strategy of intervention. Among the possible strategies, sustainable renovation should always be preferred as to reduce the environmental and social impacts of existing buildings; however, in some cases, demolition is mandatory. Scientific tools enabling rigorous assessment of the level of deterioration of existing buildings and their expected residual life need thus to be defined.

2. RESIDUAL LIFE PREDICTION

The first step to evaluate the residual life of existing structures is necessarily the identification of a simple model providing the residual strength of structural elements, such as beams or columns. Corrosion of the embedded steel is one of the most common and major causes of deterioration of RC structures because it leads to a reduction in strength, stiffness and ductility. Some models proposed in the literature to evaluate the residual strength of corroded structural elements are here critically analysed and compared. As a main result, empirical models obtained from regression of experimental data are often inadequate to describe natural corrosion processes mainly because of their sensitivity to even slight variation of the parameters (Figure 1). Besides, analytical models have been identified as the most suitable for providing a reliable estimation of the residual strength of beams as a function of their corrosion level. The prediction provided by these latter models have been compared with some experimental campaign results, in order to assess their effectiveness (Fig. 2). The next goal is to define an analytical model for columns, describing the reduction of moment-axial forces domain. Once reliable models providing residual strength of structural elements have been identified, a novel method is proposed to evaluate the building at the global level; such an approach is also inspired

by the work of Coronelli [4]. In detail, a set of equivalent parameters, which describe the deterioration level of the structural components over time, are defined and calculated. Such parameters describe the variation of stiffness, ductility or other mechanical properties based on the level of corrosion.

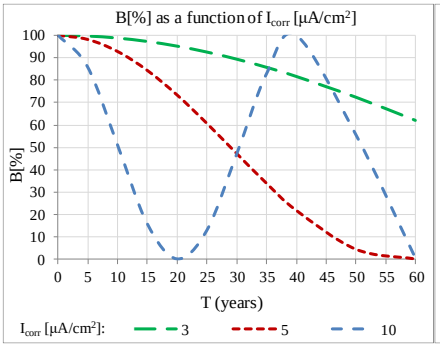

Figure 1: Example of results provided by an empirical model [1]: the strength reduction parameter B[%] do not provide significant results for some values of corrosion level, described by I_{corr} x T.

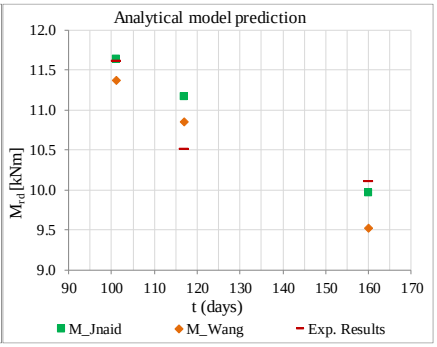

Figure 2: Analytical models of Wang [2] and Jnaid [3] can predict quite well experimental results, if implemented by considering the maximum reduction of rebar cross-section due to corrosion.

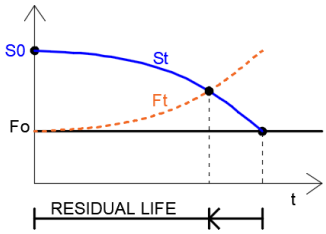

Figure 3: Example of contemporaneous strength reduction and internal force increase in a structural element. Its residual life results to be shorter than taking into account constant internal forces over time

In detail, the equivalent secant stiffness is defined for the beams as the ratio of the residual resisting moment and the curvature at yielding. The change of stiffness in some elements can lead to a redistribution of internal forces in the structure, and this can be a particularly critical result of the interaction between the elements. In fact, mechanical properties variation leads to a contemporaneous strength reduction and internal force increase in some structural elements, which in turn results in the further reduction of their residual life (Fig.3). Such a reduction couldn't be detected without considering the interaction of the elements inside the structure. The proposed approach aims at evaluating the effect of the deterioration of structural elements on the global capacity of the building. It can be applied to any kind of structure also with the help of numerical models in order to identify the most critical areas inside the structure as well as the residual life of the building and its structural behaviour and potential to the end of life.

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FORCE DENSITY METHOD – BEYOND SIMPLE ITERATIONS

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Abstract

The idea of the PhD thesis is to propose an extension of iterative application of force density method, originally used for design and internal force evaluation of tensile structures. Improvements are aimed to be made in two directions i.e. to accelerate computation in order to successfully implement this method into interactive structural design tool, as well as to enable the user to influence the appearance of final solution in a more efficient manner. Reduction of number of iteration steps, and consequently execution time, can be achieved by optimizing accuracy for solving system of linear equations in each step. Further time reduction will be explored by incorporating new solver into the extended algorithm. Performance of new versions of the algorithm will be evaluated and processing time will be compared against Newton-Raphson method. Focus of the thesis is also on the ability to assign undeformed lengths of elements, in addition to force and length constraints from initial set up of the algorithm. Proposed extension is aimed to be used for form finding of spatial truss structures in either tension or compression.

Keywords: form finding, cable-net, force density method, unstrained length, time reduction

1. METHOD

Freeform geometry of spatial truss structure has high aesthetic appearance, but irregular shapes introduce great difficulties in structural design. For structural engineer the challenge is to generate forms with high structural efficiency subject to the architectural space constraints during the conceptual structural design process. The procedure is called constrained form-finding and it demands extension to nonlinear force density method (FDM). In order to avoid nonlinear system of equation (NSEQ), linear FDM can be iteratively used, and prescribed force and length values in elements can be achieved by changing the distribution of force density (FD) values. FD coefficients are calculated in each step by using their values from the previous one, and conjugate gradients are used to solve the system of linear equations [1]. The goal of this research is to reduce the number of iteration steps, and consequently the time, by optimizing in each iteration step, accuracy for solving the system of linear equations [2]. In that way, inspired by Inexact Newton method, procedure provides the balance between the accuracy of the solutions of linear systems and the amount of computations done in single step of the iteration. Extension of the method also enables assignment of unstrained lengths without introducing Lagrange multipliers, in addition to force and length constraints (as in [2] and [3]).

2. RESULTS AND FUTURE WORK

Extensive numerical experiments show that the proposed method is almost always efficient and robust, although there are cases in which the efficiency strongly depends on constants in the proposed termination rule. The proposed rule for relaxation of accuracy is not the only one possible, so there still exist areas for further research and development. The oncoming step is measurement of execution time for the extended version of the algorithm and comparison against initial version as well as Newton-Raphson method (most often used solver for NSEQ). Described research is part of the project [4] that proposes a new solver for systems of linear equations which will also be implemented in algorithm for investigation of further potential time reduction.

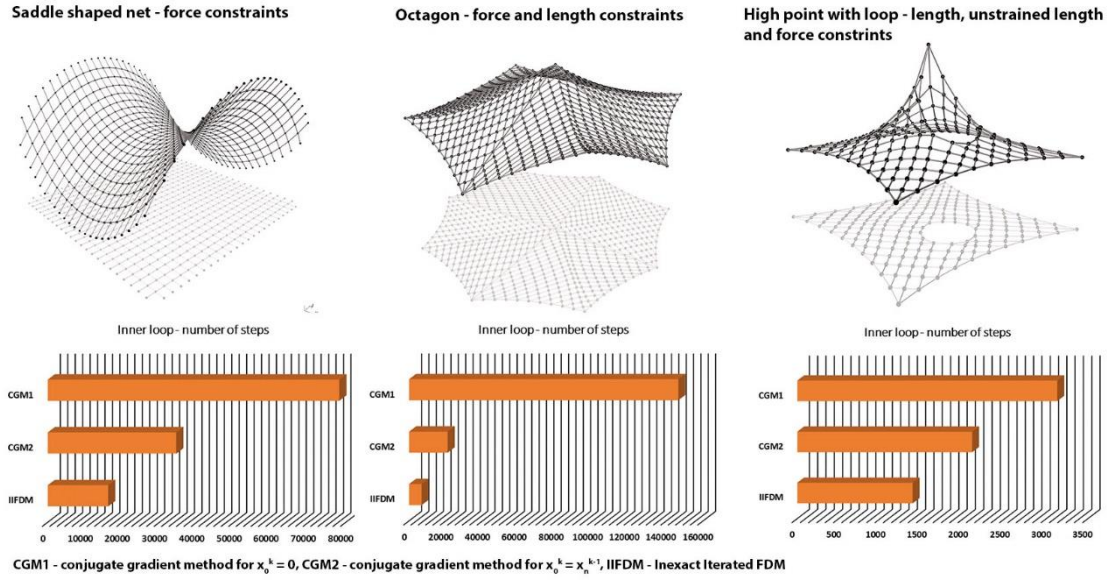

Figure 1: Reduction of steps in the inner loop for three types of examples with constraints

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WOOD BIOMASS FLY ASH IN THE CEMENT COMPOSITES

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Abstract

The growing trend of using biomass as a renewable energy source results also in a growth of the produced wood biomass ash (WBA), including fly wood biomass ash (WBA-F) and bottom wood biomass ash (WBA-B), as the waste in the energy production. Due to increase of WBA´ amounts, it is necessary to establish its sustainable management. The construction sector is one of the possible options for its sustainable management. This research focuses on the fly WBAs application as a new supplementary cementitious material (SCM) in the cement composites.

From the literature review, empirical experimental approaches of WBA-Fs in cement composites were mainly used, focusing on macroscopic performance. Even with satisfactory results, these approaches provide fragmented understanding of new potential materials in the construction industry without clear conclusions and recommendations for the practice. The main goal of this research is to perform a thorough testing of different types of WBA-Fs with assessing of their applicability in the cement composites.

Keywords: wood biomass, fly wood biomass ash, sustainable management, cement composites

1. INTRODUCTION – PROBLEM AND SUBJECT OF RESEARCH

During the wood biomass use, the waste is generated – wood biomass ash (WBA). Produced WBA can be divided into: WBA-B from combustion chamber and WBA-F collected from cyclones, electrostatic precipitator or filler bags [1]. Bottom ashes can usually be used as fertilizing agent on fields as it contains valuable elements for soils and plants and only minor concentrations of heavy metals. WBA-Fs are in most cases disposed as their heavy metal concentrations are too high for a usage as soil enhancer [2]. Therefore new approach for its reuse is needed. The literature review shows significant variability of the research's results where WBA is used in the cement´ mixtures leading to insufficient understanding of the influence this new material on the cement composites. In this research WBA-F is used in the cement composites as cement replacement.

2. METHODOLOGY

Given that the chemical and physical properties of WBA are different from coal fly ash (FA) and do not meet the existing regulations for concrete application (standards HRN EN 450-1: 2013 [3] and ASTM C618 [4]), detailed characterization of WBA was carried out in order to determine the potential of its application in the cement composites. The physical and chemical

properties of WBA-Fs, collected from different locations in Croatia, were analysed. Experimental study included the laboratory testing of cement composites with the WBA-Fs in order to assess the influence of the different WBA-F and different technology used in the power plants on the mechanical and durability properties of the cement composites.

3. SCIENTIFIC GOALS AND EXPECTED CONTRIBUTION

The main goal of this research is to determine the impact of the WBA-Fs on the properties of cement composites, which includes: (a) characterization of the fly WBAs based on chemical and physical properties in the terms of its ability to be applied in the cement composites; and (b) understanding the impact of the WBA-F on the properties of cement composites, respectively correlation of microstructure of WBA-F on its macroscopic behavior in the cement composites. The main contribution of the study is to quantify the acceptable amount of WBA-Fs in the cement composites including the defining the influence of individual WBA-F on the cement composite´s behaviour through mechanical and durability properties.

4. CONCLUSIONS

Benefits of using FA have already been repeatedly demonstrated at commercial scale. For WBA, the same approach is not fully demonstrated yet. Also, well-known standards precludes the use of any material not derived from coal combustion from their use as cement components. As a new potential material in the concrete industry, there is a need for comprehensive understanding and research of the WBA-F use in the cement composites in order to determine suitable application and to insure an additional value of WBA-Fs.

ACKNOWLEDGEMENTS

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AN APPROACH TOWARDS THE MULTISCALE MODELLING OF HYDRATING CEMENT MATRIX

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Abstract

A modelling approach is proposed to develop a discrete lattice spring model to predict the mechanical property of the hydrating matrix at different stages of hydration, different constituent proportion and varying stiffness distribution between single grain-grain interfaces.

Keywords: Grain-grain interface, tricalcium silicate, dicalcium silicate, calcium silicate hydrate, multiscale modelling, microstructure, nanoindentation

1. INTRODUCTION

Modelling of cement and concrete has played a crucial role in the assessment and performance evaluation of cementitious systems. The hierarchical and heterogeneous nature of the matrix necessitates modelling at multiple length scales and the evolving microstructure and mechanical properties of the hydrating matrix demands the incorporation of hydration kinetics at varying time scales [1]. These models help to understand both strength and durability of cement based systems incorporating information from lower scales and they help reduce the trial-and-error cycles during material modifications and designing of new material. Among these different categories, multi-scale material models employing micromechanical modelling approaches have been used to predict the mechanical properties of cementitious systems under varying conditions such as the degree of hydration, water-cement ratio and presence of fillers, admixtures, supplementary cementitious materials (SCMs) etc. Such models can be divided into three general categories: analytical models using homogenization [2,3] schemes, continuum based numerical models [4,5] and lattice discrete particle models (LDSM) [6,7]. In this work the microstructure of hydrating cement grain (C_3S/C_2S) is obtained from SEM imaging and the mechanical properties of individual phases (inner product/outer product C-S-H) is determined using nanoindentation. Normal and shear stiffness distribution of individual grain-grain connection is then determined which is incorporated in a lattice spring system.

2. PROPOSED MODEL

The approach to evaluate of mechanical properties of the C_3S/C_2S matrix at different states of interface development has been divided into 4 major steps:

Step 1: Evaluation of microstructure of single grain-grain interface: Microstructure of the interface is captured using SEM imaging. The images consist of needle or fibrils that develop from the surface of a single C_3S/C_2S and then intertwine themselves with the needles from the adjacent grain. The grayscale image is converted to a binary form using a suitable threshold value.

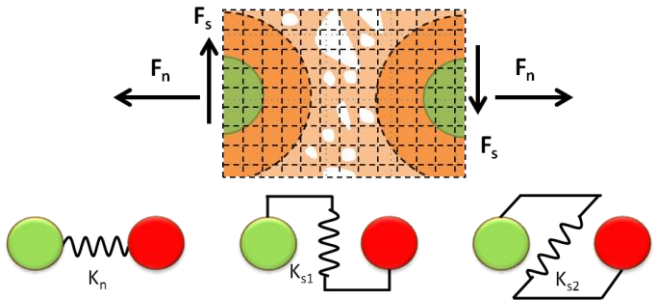

Figure 1: Schematic representation of grain-grain stiffness approximation. Both normal (K_n and shear (K_{s1} and K_{s2}) stiffnesses are determined

Step 2: Evaluation of mechanical properties of individual phases: Hydration is stopped using solvent exchange method at desired intervals time. Grid nanoindentation is performed on polished C_3S/C_2S specimens at these varying stages of hydration.
Step 3: Determine the interface stiffness: The input from microstructure and mechanical properties is incorporated into a finite element model assuming that the mechanical properties decrease from the inner core to the outer product in a single C_3S/C_2S grain. Both normal and shear stiffness distributions are determined.
Step 4: Distribution of interface stiffness to the lattice-spring model and evaluation of mechanical property: The stiffness is distributed to a lattice of interconnected springs (normal and shear). The overall lattice is evaluated to determine the mechanical properties at varying stages of interface development.

4. CONCLUSIONS

A model capable of predicting the contribution of interface microstructure and nanomechanical properties of individual phases towards the ultimate mechanical strength is developed.

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GEOPOLYMERS AS AN INNOVATIVE SOLUTION FOR THE DISPOSAL OF PROBLEMATIC NUCLEAR WASTES

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Keywords: Geopolymers, Nuclear Waste Immobilisation, Rheology.

1. INTRODUCTION

The nuclear industry within the UK has a responsibility and the duty to produce an appropriate disposal route for all types of nuclear waste. The disposal of certain wastes can be problematic due to compatibility with the cementation matrix [1]. Therefore, new grouts and disposal methods have been proposed for the disposal of these waste streams. Geopolymers, produced from the chemical reaction between an alkali silicate activator and a metakaolin precursor, have been proposed as one of these disposal routes. Preliminary studies have been performed on these materials and promising results have been seen, including respectable waste loadings and also resistance to irradiation damage, in the form of gamma irradiation [2, 3].

This project has been designed to analyse the physical and chemical properties of these metakaolin geopolymers from the fresh to the hardened state, including a study of the effects of gamma irradiation, leading to testing of leachability of encapsulated oils from the matrix. This will generate useful data for the UK nuclear industry to make recommendations with regards to including geopolymers in the current cementation model, and also to help develop a safety case for waste disposal.

2. PRELIMINARY RESULTS

To develop an effective grout for applications within the nuclear industry, rheology that is controllable is of upmost importance. Figure 1 shows a comparison between geopolymers produced from rotary (MetaMax) and flash calcined (Argicem) metakaolins, which has been activated using potassium silicate with variable water contents. These clay-based binders appear to follow a non-Newtonian rheological model. As is expected in a cementitious system, increasing the water content decreases the viscosity, however this also affects the shear-dependent rheological properties of the grout. The rotary calcined clay gives a consistently shear thickening paste independent of water content, which is different from the flash calcined product which moves from a shear thinning to a shear thickening paste with this same water addition. This effect is likely due to the particle size and shape, as well as the inclusion of secondary mineral phases, such as quartz, in the flash calcined product.

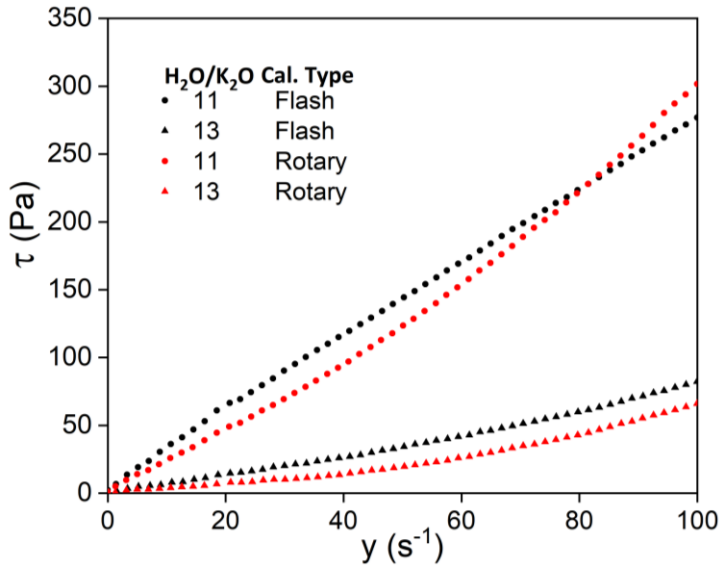

Figure 2: Decreasing shear vane-rheology plots for rotary (red) and flash (black) calcined metakaolin geopolymers, with H_2O/K_2O = 11 (circles) and 13 (triangles). The SiO_2/K_2O and Al_2O_3/K_2O were kept fixed at 1.

3. CONCLUSIONS

- Metakaolin based geopolymers have the potential to be used as an immobisation matrix for problematic nuclear wastes.
- The activating solution can be tailored to effect the viscosity. The clay type does not have a specific impact on the shear stress (τ).
- However, thixotropic effects vary between clays. The flash calcined product behaves with a shear thinning mentality and the rotary calcined product is more shear thinning.

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CHARACTERISTICS OF SELF-COMPACTING CONCRETE (SCC) WITH WASTE TIRE RUBBER AND ITS POSSIBLE APPLICATION IN STRUCTURAL ELEMENTS

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1. INTRODUCTION

Waste tire rubber, as a non-biodegradable material, have relative long lifetime, and because of this fact interest for replacing natural aggregate in concrete mixtures with waste tire rubber has attracted the attention of engineers, building industry and recycling industry to produce concrete with rubber, i.e. rubberized concrete (RC), providing eco-friendly concrete with recycled tire rubber. On the other hand, self-compacting rubberized concrete (SCRC) is a type of SCC with waste rubber which is partially replacing natural aggregate, on different replacement level, by weight or volume. The possibility to use recycled material, i.e. waste tire rubber, as a natural aggregate can not only preserve natural minerals but can also contribute to circular economy and sustainable waste management in accordance with currently valid European legislation.

2. LITERATURE OVERVIEW AND RESEARCH OBJECTIVES

Most of the researches replaced fine aggregate (size 0-4 mm) with rubber aggregate [1], [2] while some authors replaced coarse aggregate (size > 4 mm) with waste rubber aggregate [3], and on behalf of future experimental work it can be suggested that experimental investigations of SCRC properties should be investigated with fine aggregate replacement due to the better influence of smaller rubber particles on SCRC fresh and hardened properties, compared to coarse aggregate replacement. Different authors investigated fresh and hardened properties of SCRC at the material level. Most of the authors investigated mechanical properties of SCRC, concluding that replacing natural aggregate with rubber have negative impact on compressive strength, splitting tensile strength and modulus of elasticity [1], [3], [4]. However, positive impact of rubber aggregate on durability and dynamic properties of SCRC were also reported [5], [6].

There are two main research objectives: (i) to investigate fresh SCRC properties according to relevant European Standards and (ii) to investigated hardened, mechanical and durability, SCRC properties, i.e. compressive strength, splitting tensile strength, flexural strength, static modulus of elasticity, bond between reinforcement and concrete, fracture energy, interfacial transition zone (ITZ), water permeability, gas permeability, freeze-thaw resistance, resistance to high temperature, corrosion resistance and resistance to chloride – ion penetration, according to relevant European Standards, with different amount of natural fine aggregate being replaced with waste tire rubber.

3. METHODOLOGY

Methodology is divided in several important steps: (i) preliminary SCRC mixture design and preliminary testing of SCRC in fresh and hardened state should be done, all in purpose of better understating of SCRC behaviour with different amount of rubber aggregate and in purpose of determination of design of SCRC mixture, with later application of most appropriate SCRC mixture design in further experimental investigation of structural elements, (ii) analysis of test results and conclusions – based on literature overview and experimental part, test results should be analysed and conclusions about final usage of waste tire rubber on SCC should be made.

4. EXPECTED SCIENTIFIC CONTRIBUTION

There are several expected scientific contributions coming out from this research: (i) to define acceptable replacement level of natural aggregate with waste tire rubber in SCC, but also to maintain required mechanical and durability properties of SCC, (ii) to give recommendations for potential use of SCRC in structural elements, (iii) cooperation of educational institutions, concrete industry and recycling industry, i.e. Faculty of Civil Engineering and Architecture Osijek, local companies involved in concrete production and companies involved in recycle of waste rubber, (iv) to promote green buildings, circular economy and sustainable waste management through environmental friendly concrete (eco-concrete), (v) to potentially reduce concrete costs (natural aggregate price vs. waste rubber price), (vi) to obtain concrete with improved dynamic, thermal and durability properties.

ACKNOWLEDGMENTS

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MSWI FLY ASH FOR USE IN CEMENT BASED MATERIALS

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Abstract

Revisions in municipal solid waste management has resulted in increased waste incineration for heat and energy recovery, producing bottom and fly ash residue. The fly ash is regarded as hazardous and in theory remains an unexploited resource. It could potentially be utilized as a resource for making cement based materials, similarly to fly ash from coal incineration. To use the MSWI fly ash in cement based materials pre-treatment could be required, to reduce the hazardousness. Potential treatments could be electrodialytic remediation or solvent extraction. The goal of this project is to investigate if MSWI fly ash can be a resource for cement based materials, by partially replacing the cement, and analysing the resulting material properties.

Keywords: MSWI fly ash, Pre-treatment, Cement

1. INTRODUCTION

In the last couple of decades the EU's trends in municipal solid waste management has been steadfastly changing [1]. The volume of waste landfilled has decreased, while the amount of recycled, composted or incinerated waste has increased. Municipal solid waste incineration (MSWI) is the common practise of burning waste for heat and energy recovery. MSWI results in a waste volume reduction and bottom ash, fly ash and air pollution control residues [2]. The fly ash contains heavy metals, salts and organic toxins, and are therefore considered hazardous and disposed of in designated secure landfills [2]. Because of its harmful elements, MSWI fly ash remains an untapped prospective resource.

MSWI fly ash could potentially be used as a supplementary cementitious material (SCM) similarly to fly ash from coal incineration. Previous studies of MSWI fly ash as a SCM have shown varying degrees of success [3,4]. The hazardous nature of the fly ash poses a problem potentially requiring treatment before its use. Electrodialytic remediation and solvent extraction has been shown to recover the metals and reduce the harmfulness of the ash [5,6]. The feasibility of using the treated fly ash resulting from these two pre-treatment methods in cement based materials has yet to be properly researched. By implementing the MSWI ash as a SCM the ash could become part of circular construction, reducing waste and promoting sustainability. This

PhD project is therefore studying the effect of using treated and untreated MSWI ash in cement based materials.

2. OBJECTIVE

The objective of this project is to investigate the possibility of using MSWI fly ash as a SCM both in its raw state and after treatment with either electrodialytic remediation or solvent extraction. In order to accomplish this several scientific goals have been established.

- Assessing the efficiency of pre-treating the ash with electrodialytic remediation and solvent extraction.
- Determining the mechanical and rheological properties of cement based materials containing raw and pre-treated ash.
- Evaluating the environmental impact of cement based materials containing MSWI fly ash by investigating the heavy metal leaching at different stages of hydration.
- Determine the effect of MSWI fly ash on cement hydration in terms of reactivity and phase development as well as its effect on durability.

3. EXPECTED CONTRIBUTION

The outcome of this project is expected to clarify whether MSWI fly ash has any intrinsic value as a partial cement replacement, as well as the effectiveness of pre-treating the ash before utilization. It is expected that this project will contribute to the general understanding of cement hydration and cement based materials in addition to validating MSWI fly ash.

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APPLICATION OF POST-CONSUMER GLASS-SCM IN CONCRETE FOR HIGH-RISE BUILDING CONSTRUCTION

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Abstract
The uncertain supply of Fly-ash and relatively high cost of Slag as Supplementary Cementitious Materials (SCMs) has become a concern to the concrete industry in the USA. Fly-ash is a byproduct from coal burning plants which are shutting down or converting to natural gas, and Slag is a residue from steel production mainly outside of the USA. This study focuses on the evaluation of self-consolidating concrete (SCC) for a high-rise building using recycled post-consumer glass, for 35% Glass-SCM cement replacement and 55 and 70 MPa strengths, to compare with a similar SCC mix with Slag. The field work involved evaluations of mix production, pump-ability, placement, finishing, curing, compressive and tensile strengths, and development of maturity curves from data loggers in concrete. This study offers great potential for benefitting the concrete and glass recycling industries.

Keywords: Sustainable concrete, Glass-SCM, Field application

1. INTRODUCTION

The two most used Supplementary Cementitious Materials (SCMs) in concrete are Fly-ash and Slag. The addition of SCMs to concrete is necessary to achieve better strength and durability properties. This paper describes the development and implementation of concrete mixes with Glass-SCM for the Hallets Point 1, a 23-story residential building located in Queens, New York. This was the first Glass-SCM application in high-rise building construction in the USA. This application was based on work performed by Krstic and Davalos (2018) on extensive experimental study and characterization of physical and chemical properties of concrete with Glass SCM for sidewalk construction, and its implementation in a field project in Queens, NY [1]. The main benefit of using Glass SCM concrete in sidewalks is durability, while for construction of high-rise buildings, the strength and workability are the main concerns.

2. METHODOLOGY

This project was used as a prototype to demonstrate the field implementation of Post-Consumer Recycled Glass SCM as a 35% replacement of cement, based on building specifications within the same range as for Slag SCM used in the project. Two different compressive strengths of concrete were used in this project. To achieve better workability and pump-ability, the mixes were designed as normal unit weight and non-air entrained self-consolidating concrete (SCC). The slabs and some columns were built with 55 MPa SCC. The walls and the rest of the columns were built with 70 MPa concrete. The majority of concrete mixes included Slag as SCM. Concrete mixes with Glass SCM were implemented in three phases. Concrete was pumped and placed into slabs, columns and wall of the fifth and eighth floors, while a bucket-and-crane was used to deliver concrete for the bulkhead roof slab at the top of the 23rd floor.

3. SELECTED RESULTS

In *Figure 3*.a, the 55 MPa mixes with Slag and Glass-SCM are compared. The graph with the highest value represents the concretes with Slag (green color). The three graphs below that are within a narrow band represent the mixes with Glass-SCM. It can be concluded that the testing results for the 55 MPa Glass-SCM concrete are consistent, and have about the same values for both proposed and actual mix designs. For Slag, the values for up to 28 days are higher than the average values for concretes with Glass-SCM, however the strengths of mixes with Glass SCM exceeded the values of concrete with slag at 56 days.

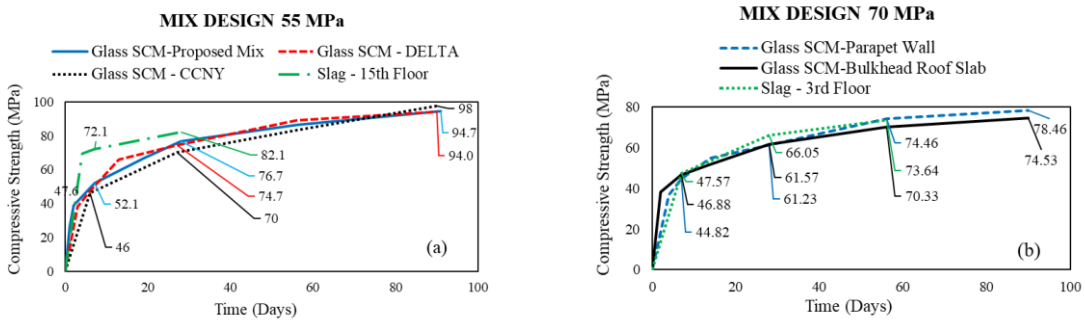

Figure 3: Compressive strength a) Mix design 55 MPa; b) Mix design 70 MPa

Figure 3.b shows the results of compressive strengths for all 70 MPa mixes with Slag and Glass-SCM. The green curve represents the concrete with Slag. The blue curve represents the concrete with Glass SCM for the parapet wall, and the black curve is for the concrete with Glass SCM for the bulkhead roof slab. The values for all mixes are within a close range, and there is not much difference in compressive strengths for Slag and Glass SCM mixes for up to 56 days.

4. CONCLUSION

The completion of this prototype building project has conclusively demonstrated the industrial application of Glass-SCM in construction, and has significantly contributed to: (1) the successful implementation of Glass-SCM in concrete mixes for selected building components, by limiting the cement replacement to 35% for target strengths of 55 MPa and 70 MPa concretes; (2) the development and testing of mix designs to achieve the target strengths; (3) the development of feasible processes at the concrete plant to include Glass-SCM in the mix; (4) the demonstrated application of conventional methods for pumping, placing, and finishing two mix designs of Glass-SCM concrete for selected building components; (5) the instrumentation of selected building components to obtain, for each mix, maturity of concrete in the field to predict the corresponding strength from maturity curves obtained from laboratory data.

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SEISMIC SHEAR BEHAVIOUR OF REINFORCED CONCRETE WALLS

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Abstract

A brief overview of shear demand and capacity of reinforced concrete (RC) walls is presented in this paper. Procedure given in EC8 [1] is analysed and compared to analytical and experimental results.

Shear capacity depends on the geometry of wall, amount of reinforcement, its layout and detailing. Besides that, ductility demand of a wall reduces its shear capacity.

Existing analytical procedure for shear capacity of RC columns is used to predict shear capacity of walls. It is shown in paper that the same procedure may be used for both walls and columns. Analytical calculations are in good accordance with experimental results.

Keywords: shear capacity, ductility demand, ductile walls, seismic behaviour, Eurocode 8

1. INTRODUCTION

During a strong earthquake, plastic deformations of a structure are inevitable. Structure should be designed in such a way that it does not collapse when large deformations occur. Ability of a structure to sustain large plastic deformations is called ductility. Elements that fail in bending have a higher ductility capacity than elements that fail in shear [2].

2. SHEAR DEMAND

2.1 Inelastic shear forces

Shear forces determined by elastic analysis should be amplified. Dynamic shear amplification is larger for structures with a longer fundamental period and for more ductile structures [3].

2.2 Dynamic shear amplification according to EC8

According to EC8 [1] shear forces are amplified by a factor of 1,5 for DCM walls. That amplification is unsafe for structures with high fundamental period or a large flexural overstrength. Amplification for DCH walls given in EC8 is appropriate when equivalent lateral force method is used, but unnecessary when modal response spectrum analysis is used.

3. SHEAR CAPACITY

Shear failure of a wall can be caused by sliding, diagonal tension or diagonal compression. Since the first two can be avoided by adding reinforcement and the last one cannot, diagonal compression will be analysed in greater detail in this paper.

3.1 Diagonal compression failure

According to EC8 shear capacity of DCM walls is the same as given by Eurocode 2 (EC2) [4], but shear capacity of DCH walls is only 40% of that value.

Walls are subjected to both normal and shear stresses. Increase in either normal or shear stress causes increase of principal stresses. When compressive principal stress reaches compressive strength of concrete failure occurs. For a given curvature at failure (i.e. ductility) normal stresses are known and remaining shear capacity may be obtained.

Procedure presented in this paper is a modified procedure by Park, Yu and Choi [5] used for columns. First, curvature of a section at failure is assumed. Second, normal stress distribution based on that curvature is calculated. Third, based on normal stress distribution and known strength of concrete, allowable shear stresses are calculated in several points. Fourth, shear capacity is calculated by integrating shear stresses over compression zone. Procedure is then repeated for different curvatures and each value of shear capacity is compared with values given in [4]. Curvature at failure depends on the behaviour factor and is known for DCM and DCH walls. Calculated shear capacity of DCM walls is 53% of the value given by EC2 and for DCH 40% of that value. Those values are in good accordance with experimental results given in [6] for both DCM and DCH walls. According to [2] shear capacity of DCM walls given by EC8 [1] should be reduced, but no specific value is given.

4. CONCLUSIONS

Current European code EC8 does not provide sufficient safety for DCM elements and should be revised. Procedure proposed in this paper can appropriately predict remaining shear capacity for a given ductility demand.

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EVALUATION OF WOOD BIOMASS FLY ASHES POZZOLANIC REACTIVITY

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Abstract

Presence of pozzolanic activity is generally evaluated from the sum of "pozzolanic oxides" SiO_2, Al_2O_3 and Fe_2O_3. Pozzolanic materials in the cement react with unbonded calcium hydroxide and form compounds with cementitious characteristics. According to European standard for coal fly ash EN 450-1:2013 sum of pozzolanic oxides greater than 70% of mass indicate pozzolanic activity. This study focuses on determination of reactivity of wood biomass fly ashes (WBA-F) which has potential to be used as cement replacement in the cement mixtures. In this paper three different methods were used in order to analyse pozzolanic reactivity of fly WBAs as a potential supplementary cementitious material (SCM).

Keywords: fly wood biomass ash, Frattini test, electrical conductivity, strength activity index test

1. INTRODUCTION

Using wood biomass as a renewable energy resource (RES) results in generating of wood biomass ash (WBA) as waste in the power plants. Many researches compare WBA with coal fly ash and expect positive pozzolanic reaction [1], [2]. However, studies of WBA usage in the cement mixtures have shown that different WBA exhibit both hydraulic and pozzolanic behaviour [1]. Vassilev et. al. [3] in the chemical analysis of 28 different wood and woody biomass found domination of CaO in the composition, with an average value of 43 % wt. Authors [4], [5], have shown that beside pozzolanic reaction, hydraulic behaviour is expected because of high CaO content among tested WBAs in comparison with reactivity of well-known mineral admixtures. Reactivity of WBA with high calcium content and its effect on properties of cementitious materials is still not systematically researched. The objective of this study is to assess the pozzolanic activity of WBA-Fs from different power plants with different tests methods.

2. MATERIALS AND METHODS OF INVESTIGATION

WBA-Fs were tested and compared to materials with known pozzolanic behaviour, silica fume (SF) and coal fly ash (FA). WBA-Fs were collected from different power plants in Croatia that uses different types of combustors (grate combustors, fluidized bed combustors and pulverized fuel combustors). The pozzolanic activity of the WBA-F´s samples were evaluated

using electrical conductivity tests, Frattini test according to EN 196-5:2011 [6] and strength activity index (SAI) [7]. Mortar mixes with maximum 15 % cement replacement by WBA-Fs were prepared.

3. RESULTS AND CONCLUSION

- All tested WBA-Fs fail according to criteria for pozzolanic oxides sum given in EN 450-1:2013 [8].
- Regardless sum of pozzolanic oxides fails standards requirement from EN 450-1:2013 [8], some WBAs show activity when evaluated after 35 days using Frattini test.
- Mortars mixes with 10% cement replacement by WBA-Fs met SAI requirements after 28 and 90 days. Mostly, SAI values are slightly decreasing over time.
- Negative results obtained for pozzolanic activity by standards and affirmative values for modified tests time and binding rates indicate that pozzolanic activity is insufficient but should be further tested for proper application as SCM.

ACKNOWLEDGEMENTS

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ANALYSIS OF ELECTRICAL POTENTIAL AND STRAY CURRENTS AT DC TRANSIT SYSTEM

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Abstract

Stray current corrosion is a consequence of current leaking from the rail. To stop this negative effect, operators among the world are using different type of measures that are described in standards. In the present work, a theoretical model was used to analyse the potential distribution at rail infrastructure. Based on the rail potential it is possible to detect sections of the railway infrastructure that are jeopardise by current leakage.

Keywords: stray currents, corrosion, rail potential, DC transit system

1. INTRODUCTION

Stray currents represent currents that leak from a negative electrical conductor as soon as they find less resistant returning path to the current source [1]. Stray currents are causing huge problems in DC transit systems, where rails are embedded in the road surface (so called embedded rail systems). Since rails are mostly used as returning conductor for the current from the vehicle to the source (electrical substation), to stop current leakage they need to be completely insulated from the ground [1]. If stray current leakage is not noticed on time, tram tracks stability and safety can be jeopardised due to the stray current corrosion. This type of corrosion can result with material loss at rail and at rail's fastening system [2].

2. ANALYSIS OF ELECTRICAL POTENTIAL AT DC TRANSIT SYSTEM

Part of the rails where current leaks is anodic part. It is characterised by positive electrical potential at the rail and by degradation (oxidation) of metal [2]. On the other hand, part of the rail near substation, where current is entering to the rail to get back to the source, is cathodic part [2]. It is characterised by negative electrical potential at the rail. In this part rail is under cathodic protection that is result of current entering to the rail (reduction of the metal).

For the analysis of rail to earth potential theoretical model described in [3] and [4] was used. A section 1000 m long was chosen, where electrical substation is at the beginning of the section. Following assumptions are made: electrical resistance of one rail is 20 mΩ/km, rail to earth resistance is uniform through entire section (typically it is from 2 to 100 Ω/km) and vehicle needs 1000 A current [4]. From the model, several observations can be made. For one vehicle placed at the end of this section (1000 m from the electrical substation) rail to earth voltage will

appear as 10 V near the train and -10 V near the substation. If there are more vehicles at different positions of section part, rail to earth voltage will become bigger, which would result with increasing anodic and cathodic zones (Figure 1).

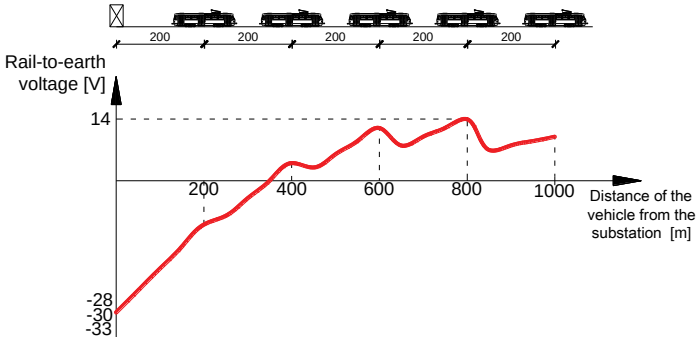

Figure 1: Rail-to-earth voltage

3. METHODS FOR REDUCING STRAY CURRENTS

Methods that are currently used for reducing stray currents can be separated in two groups: i) increasing rail to earth resistance and ii) decreasing electrical resistance of the rail (negative return conductor) [5]. Based on the standard EN 50122-2 [6] rails and return conductors need to be completely insulated from the ground, but level of rail to earth insulation has to satisfy balance between stray currents and dangerous electrical potential at the rails that can occur due the high rail to earth resistance [4].

CONCLUSIONS

Since it is very hard to completely insulate the rail, it is important to detect sections of the railway infrastructure that are endangered by stray current. For this kind of analysis following parameters need to be consider: distance between vehicles and substations, traffic load and type of vehicles, rail to earth resistance, rail resistance. After detecting anodic zone at the rail infrastructure, adequate measures for stopping stray current leakage can be done.

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IDENTIFYING SOURCES OF VARIABILITY IN THE WATER FOOTPRINT OF CONCRETE PRODUCTION

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1. INTRODUCTION

Water is the most demanded substance in the world only followed by concrete [1]. Due to water scarcity crisis in different regions of the world and on the other hand increasing demand of concrete for housing and infrastructure, it is vital to assess water use in concrete production [2]. Data is still scarce and highly variable. Our goal is to identify sources of variability and estimate actual ranges of water footprint of concrete production, which is relevant for decision-making of the companies and policy makers.

2. METHODOLOGY

This paper includes direct water use for mixing the concrete, washing the trucks and washing the yard; indirect water use for cement production, slag treatment and aggregates production – activities that could be influenced by the concrete producer- and for energy production. Water use figures for direct and indirect water use where taken from [3, 4]. The functional unit is 1 m^3 of concrete of 25 MPa class with 120 mm slump, which is among the most commonly used formulations. Three water footprint methods are used: AWARE, Hoekstra and ReCiPe 2016.

3. RESULTS AND DISCUSSION

Direct water use ranges from 196-249 l/m^3. The mixing water compared to other water uses, represents a small fraction. Indirect water use varies from 302-2100 l/m^3. The activity that presents highest variability is the aggregates production, probably because the water withdrawal is not controlled. Also, the use of water in aggregates production depends on weather conditions but also on industry practices such as washing the aggregates. Finally, water for energy varies from 9400-10785 l/m^3 including water for fuel production and for electricity production.

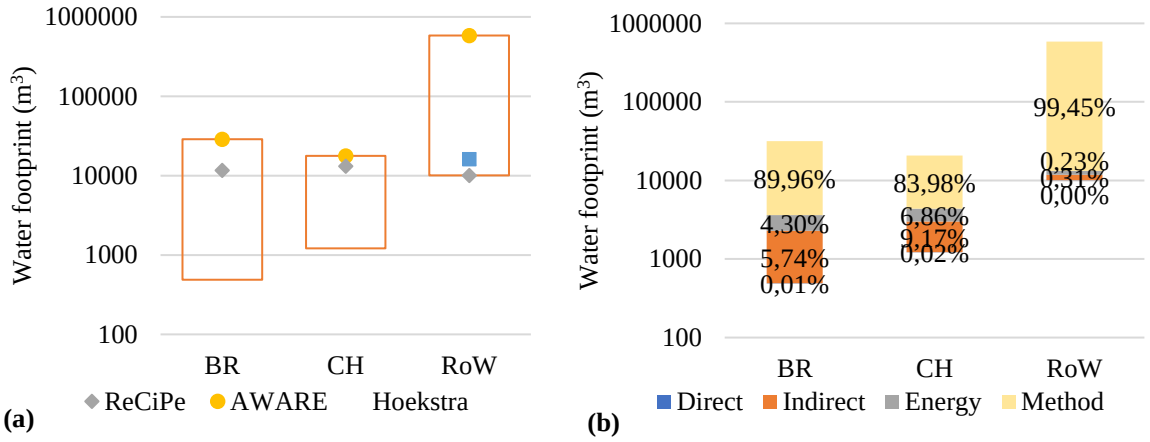

Figure 4: (a) Variability in concrete water footprint due to the choice of method for different regions for 1 m^3 of concrete, 25 MPa, 120 mm. (b) Contribution of each source of variability.

The highest results in Figure 4 correspond to the AWARE method that is based on a characterization factor 1/AMD, which is the inverse of the difference between availability per area and demand per area. Comparing the sources of variability, direct water use is low -this does not mean that the water use in the concrete plant should not be carefully assessed. Variability from indirect water use and energy production water use are in the range of 5-10 % for Brazil and for Switzerland. The indirect activities could be influenced by the concrete producer in addition to be more efficient in terms of materials use while for energy production the only possible strategy in terms of reducing water consumption would be to increase efficiency in energy use. The highest variability comes from the choice of method. These results demonstrate that the choice and understanding of the method as well as the location are crucial.

CONCLUSIONS

- The highest water consumption is due to energy production. Therefore, it is important to continue with efforts to reduce energy demand.
- The most important contributor in terms of water use after energy production is aggregates production. Measurements to improve aggregates water efficiency are needed.
- Most of the variability comes from the choice of method. Therefore, the use of water footprint methods and interpretation of water footprint results should be carefully done.
- Moreover, water footprint methods should converge to one universal method.

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RECONSTRUCTION OF BULIDINGS – RESEARCH TOPICS FROM ANALYSIS OF EXISTING STRUCTURES IN KOSOVO

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Abstract

This paper will try to construe the issue of post-war reconstructions in Kosovo and facing the lack of support for a thorough study of these constructions. We will elaborate legal aspects and researches concerning stability and justification of these overbuilt structures.

Keywords: buildings, reconstruction, overbuilding

1. INTRODUCTION

In the post war Kosovo, there has been a lack of laws on all fields including construction. In such a situation, illegal constructions have flourished, but in particular overbuilding on old apartment blocks which have been built over 30 years ago. The institutions have allowed the development of such upgrades on existing buildings due to the absence of laws and under the enormous investors pressure, to quickly build these residential structures to maximize the profit in short run. The upgrades on old buildings are far more dangerous than those on new buildings that exceeded building permits. Over the years, a legal basis has been issued, but still did not cover all the concerns or did not address the aspect of overbuilding, even though it posed a real danger for the lives of the residents and the investments as a whole. At the present, there is a more advanced legal basis but it still does not address this issue within the framework of demands or scientific studies to acquire a safe environment both for the people's lives and security of investment as well as buildings stability.

3. TREATMENT OF OVERBUILD BUILDINGS

The construction of tall buildings in Kosovo has been concentrated only in the capital, Pristine, and less in other residential areas. Therefore, this phenomenon has captured mostly this city. All constructions in Kosovo date back to the 70s and 80s and consist of walls and less on the skeletal system. To handle an upgraded building and to do a proper study, we must first have solved the legal framework and the technical-investment basis. Due to the limitations mentioned above, we also have flaws in the study. The technical-investment base in most cases is deficient owing to the lack of project documents. Therefore, a serious study requires more efforts and investments in basic building parameters, firstly by designing the project in accordance with the existing conditions, per old technical norms or EC ones.

4. THE SURVEY ON COMPILING DESIGN BASE LINE

Handling an overbuilding or refurbishment in Kosovo, first we should create the database for the architectural project and the structural project. The architectural project consists on two types of measurements: measurements on the surface and those under the ground. The former can be done by ordinary gadgets, like electronic, manual or laser meters, professionals staff and appropriate drawings and designs that are to be saved in the database. Measurements into the ground positions can be done by engaging workers and mechanism that will explore the dimensions of the footer and foundation wall. We can do this by digging on the outer side of the object and footer dimensions which is symmetrical with the inner side and from the thickness of the wall we can determine the width of the foundation. Excavations have to be carried on every single strip foundation, then we define the height of the foundation and thus we create the base of foundation and foundation wall and save it in the database. Then we create a database of the materials used and we take the samples to the lab to get the physical and mechanical properties of the materials so that we can create their database as well. We do the statics by taking the data from the redesigned architecture, by calculating well the hardness of the materials, the amount used in the constructive elements such as: foundation, foundation walls, slabs, beam and seismic wall. All of these are to be done by demolishing the element in the position where we have the lowest or zero moments. There we can read the amount of reinforcement, we take their samples to have their carrying capacity, measure the concrete strength, then the strength of clay bricks or the kind used. We do geodetic measurements to check degradations during the overbuild phase and we do the geo-mechanical drilling to take the data from the site. Based on these data we create the static model for the old building and then for the over build part, by comparing the decreases, evaluating bearing capacity of each single element and the object's response to the earthquake impact. By comparing the strains on land and the standards, we propose measures to ensure stability of the building, for the safety of both the people who use it and the investment. Finally, we make execution plans and apply for the building permits according to the law. As a result of previously described deficiencies, people's lives and investments are being jeopardized, there are evidences of cracking on walls and foundation, which urge deep analysis and immediate intervention.

5. CONCLUSION

We may conclude that it is necessary to conduct a sensitizing campaign to create a clearer and more rigorous legal basis, as well as the investors must allow engineers to work in compliance with technical building regulations, so as not to endanger human lives and investment, to create a safer environment, to have the least impact on the environment, to have an economic and social justification. A rigorous implementation of European norms and strict implementation of safety at work to save people's lives is absolutely required. The future scientific research shall focus on developing appropriate methodology to address the issue, considering technical and economic aspects. For verification of load-carrying capacity this will require testing to appropriately evaluate both the old concrete and smooth rebars.

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NUMERICAL MODELLING AND FINITE ELEMENT ANALYSIS OF FRICTION IN PREFABRICATED WOOD – BEARING GLASS COMPOSITE SYSTEMS

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Abstract

The bearing glass in combination with the wooden frame represents a new generation of supporting composite system that is predisposed to be earthquake resistant, while being energy-efficient and cost-effective, aesthetically acceptable and has good bearing characteristics. Furthermore, this composite system represents a design in which each material transmits the load and with the mutual interaction of the constituent elements simultaneously be earthquake-resistant. Research on friction between wood and glass is of crucial importance for understanding the behaviour and the performance of the composite system in which the glass panel can freely slide in a wooden frame. Numerical models of the composite system are developed and the output data (frictional stress) are compared with the experimental results.

Keywords: composites, wood, load-bearing glass, earthquake, friction, FEM analysis, Ansys

1. INTRODUCTION

In the last few decades, the development of structural glass has also contributed to the development of glass composite systems[1]. Better mechanical properties of modern structural glass give us the opportunity to create a new generation of structural composite systems of glass and wood with high aesthetic, economic and load-carrying value [2]. One of the key factors that affect the bearing capacity of the whole system is friction [3], [4]. Consequently, the experimental research was carried out and accompanied by FEM analyses. The goal of the numerical analysis was to enlarge the knowledge about the behaviour of the composite system. Likewise, numerical simulations were also used to confirm and amend experimental results.

2. FRICTION COEFFICIENT DETERMINATION

2.1 Experimental research and numerical model confirmation

In order to optimize the system, seven samples of different types and thickness of glass elements were used. The ultimate goal was to determine a friction coefficient μ which is obtained as a ratio of normal (F_n) force and friction force (F_t). A comparison of the experimental results of individual samples is given in figure 1 (right).

The analysis was carried out with commercial software ANSYS, where different model simulations were solved using the finite element method [5], [6]. FEM analysis procedure is given in figure 1 (left).

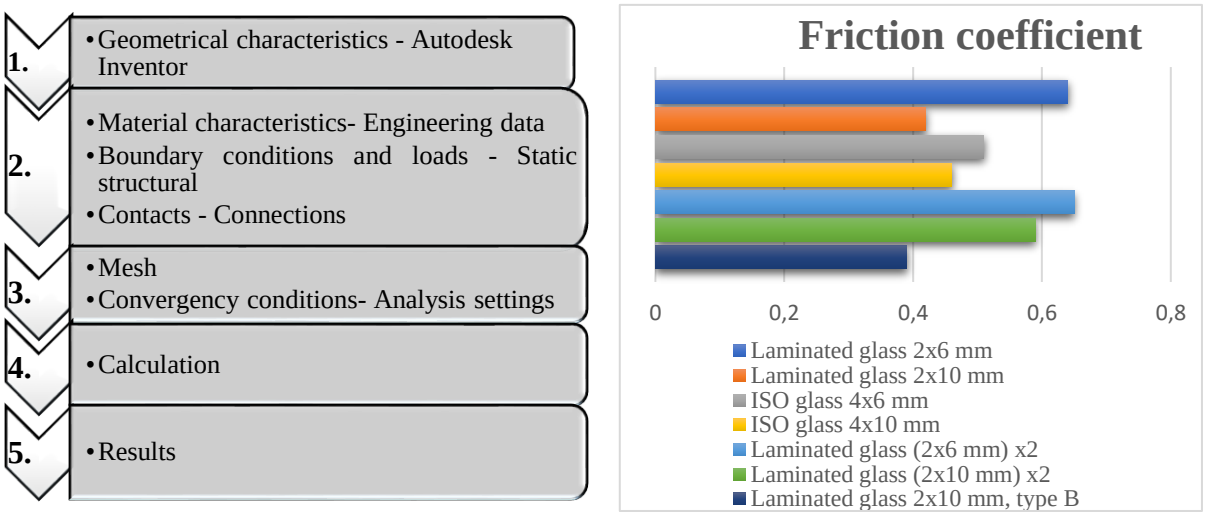

Figure 1: Numerical analysis procedure (left) and friction coefficient determination (right)

3. CONCLUSIONS

Considering that several samples were examined, the goal of the numerical analysis was to obtain the exact numerical model and a certain rule and a link that could foresee the behaviour of such a system in the future. The main parameter for the control of laboratory results and numerical simulations is the friction stress occurring on the contact surfaces. Numerical simulations can provide a more detailed insight into the behaviour and performance of composite systems and its constituent elements. Numerical simulations confirmed the behaviour of the composite system obtained in experimental work. Numerical modelling procedures are of great help for the design of such systems and can be a base for future research.

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PROBABILISTIC ASSESSMENT OF EXISTING ROAD BRIDGES USING BRIDGE WEIGH-IN-MOTION MEASUREMENTS

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Abstract

Assessment and analysis of existing road bridges is required for their continued use, due to increase in traffic volume and weight, along with deterioration and ageing of the bridge materials. Current codes for design of new bridges are not effectively applicable for this type of the assessment, due to theirs conservative assumptions regarding load and resistance modelling. Site-specific bridge assessment, based on measured Bridge Weigh-in-Motion (B-WIM) data can reveal hidden bridge reserves in terms of load carrying capacity, leading to reduction of maintenance costs and extension of remaining bridge service life. Two types of B-WIM measurements (short and long term) will be investigated, along with multi-level probabilistic assessment method where additional information is applied in every step to show benefits of measured data. Bridge performance indicators based on B-WIM measurements will be defined. Cost-benefit analysis will justify the contribution of this assessment approach in the optimization of the bridge management system.

Keywords: existing bridges, assessment, Bridge Weigh-in-Motion, probabilistic approach

1. INTRODUCTION

My PhD thesis is titled "Probabilistic assessment of existing road bridges using Bridge Weigh-in-Motion measurements". Main objective of my research is to prove that using Bridge Weigh-in-Motion (B-WIM) measurements can reveal hidden bridge reserves in terms of load carrying capacity, leading to optimization of whole bridge management system. Thesis is divided into two major parts, first part is focused on measurement system, data post processing, its implementation in load carrying capacity assessment and probabilistic modelling. Focus of the second part is on evaluation of economic aspects by quantifying the obtained data using Value of Information (VoI) analysis and detailed cost-benefit analysis in order to optimize bridge management system.

2. THESIS OVERVIEW

First part of the research included selection of Case Study Bridge based on the most common bridge types in EU [1], and its analysis including initial visual inspection, B-WIM measurements and development of numerical models based on original design plans [2]. Multi

– level assessment method [3] was defined where additional information from the measurements is applied in every step to show benefits of utilisation of bridge monitoring data. Assessment process is conducted using probabilistic approach, with results used to define bridge performance indicators based on traffic load monitoring and its benefits:

- Measured influence line (MIL) – increased reliability index for 35 %
- Girder Distribution factor (GDF) – definition of critical cross section on the bridge
- Dynamic amplification factor (DAF) – increased reliability index for additional 23 %

In addition to these indicators, its requirements in terms of measurement time and number of vehicles are also defined. Same procedure was later applied on second Case Study Bridge where similar results were obtained. Results of the Case Study Bridge analysis clearly showed benefits of B-WIM data application in bridge assessment process from the technical perspective, but in order to optimize bridge management system in general, socio-economical aspects from the perspective of both bridge owner and user must be taken into account.
Second part of the research is focused on Value of Information analysis [4] for quantifying the value of B-WIM application. Due to large number of possible outcomes and scenarios, the decision tree method is selected as a tool for VoI analysis.

3. CONCLUSION AND FUTURE REMARKS

As the benefits of B-WIM applications are clearly visible from the results, further research will include cost-benefit analysis to justify the socio-economical part of proposed method. It will include monetization of all associated consequences in terms of costs and benefits and implementation of assessment results in VoI analysis in order to show quantification of Bridge Weigh-in-Motion measurements in optimized bridge assessment.

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THE INFLUENCE OF CRACKS ON THE SALT SCALING RESISTANCE OF RECYCLED AGGREGATE CONCRETE

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Abstract

The use of recycled concrete aggregate (RCA) for the production of new concrete can be a promising solution for enormous use of raw materials, great energy consumption and large waste production. However, durability of recycle aggregate concrete (RAC) remains as an important issue regarding its sustainability. With relatively low tensile strength of concrete, the cracking of structural elements is almost inevitable due to the effect of load, so the influence of cracks on concrete durability also must be taken into consideration. Furthermore, the real environmental impact on concrete elements is not only one but a combination of different deterioration mechanisms. The influence of loading induced cracks (0.08 mm and 0.20 mm width) on natural or recycled aggregate concrete (NAC or RAC) resistance to salt scaling and the impact of previous carbonation on the salt scaling resistance of both concrete types was presented in this paper. Experimental results show that the presence of cracks on the concrete surface can increase the salt scaling resistance. Both the crack width and a number of cracks proved to be an important factor influencing concrete resistance to salt scaling. Also, it is shown that previous carbonation of RAC decreases the salt scaling resistance of concrete for more than 2.5 times.

Keywords: recycle aggregate concrete, cracks, salt scaling, carbonation

1. INTRODUCTION

Reuse of recycled concrete aggregate (RCA) for the production of new concrete can be a promising solution for the problem of enormous use of natural stone as aggregate. However, durability of recycle aggregate concrete (RAC) remains questionable. The existing models of deterioration mechanisms have been established on the basis of tests made on concrete with natural aggregate (Natural Aggregate Concrete – NAC).

Salt scaling is a result of freeze and thaw cycles with salt solution on the concrete surface. Numerous tests have been dealing with this phenomenon on concrete samples without cracks. However, cracks damage the structure of concrete cover and represent the channels for transport of harmful agents, leading to other types of concrete deterioration [1], [2].

2. EXPERIMENTAL PROCEDURES

The objective of the study presented in this paper was to determine the influence of cracks on the salt scaling resistance of RAC (100% coarse aggregate replacement), as well as the

impact of carbonation to their resistance to salt scaling. Salt scaling resistance was tested on reinforced concrete prisms with dimension 10x10x50 cm at the age of 28 days. Two types of samples were prepared: one with two different crack widths (0.08 and 0.2 mm) and the other without cracks - reference samples. Freeze/thaw tests with de-icing salt solution were performed during 25 cycles. Also, the influence of carbonation on the salt scaling resistance was examined using 2% of carbon-dioxide (CO_2) for 28 days, before they exposed to freeze/thaw test.

3. RESULTS AND DISCUSSION

3.1 The influence of cracks on concrete resistance to salt scaling

The crack width of both 0.08 mm and 0.2 mm reduced the amount of scaled material for 1.57 times compared with uncracked samples. Increasing the crack width did not result in the increase of the concrete resistance or further reduction of the amount of scaled material.

The samples showed the same amount of scaled material during all cycles, although concrete with RCA had 36% higher strength. The reason may be that these concretes have a greater amount of ITZ compared to concrete with natural aggregates, and therefore a greater porosity and water absorption. It can be concluded, in this case, that the strength of RAC is not a crucial factor when comparing the salt scaling resistance of these concretes with NAC. More important factor is the number of cracks formed on the exposed surface and their widths.

3.2 Influence of carbonation on concrete resistance to salt scaling

The results obtained in this study showed that carbonation reduced the amount of scaled material of NAC samples for 1.24 times but increased the amount of RAC scaled material for 2.76 times compared with non-carbonated samples. The cause may be the fact that the carbonation makes the old ITZ and hardened cement paste brittle, which affects their resistance to salt scaling [3]. This trend also appeared in cracked samples.

4. CONCLUSIONS

Presence of 0.08 mm crack width on the concrete surface can increase the salt scaling resistance of RAC, while larger cracks, 0.20 mm width, did not lead to increased resistance. Number of cracks is an important factor influencing concrete resistance to salt scaling. Increasing the number of cracks (from two to three) on concrete sample leads to the relaxation of tensile stress in ice, so the amount of scaled material will be lower. Carbonation of RAC decreases the salt scaling resistance of concrete.

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SHRINKAGE OF SELF-COMPACTING CONCRETE – EXPERIMENTAL AND ANALYTICAL ANALYSIS

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Abstract
Shrinkage deformation is the volume change that occurs in any concrete, including the self-compacting concrete (SSC). SSC has a greater predisposition to the emergence of shrinkage than regular concrete, because composition of concrete has a greater amount of powdered materials, and less maximum size of aggregate (16 mm). The paper give provides the new shrinkage prediction models predicting shrinkage of SSC. The aim of dissertation is to examine theoretically and experimentally association of optimal concrete mix design with the shrinkage of concrete and different concrete curing methods.

Keywords: self-compacting concrete, shrinkage, model, concrete composition, curing

1. INTRODUCTION

Self-compacting concrete (SCC) is concrete with superior flowability, which flows with its own weight, passing around reinforcement without blocking and without additional vibration. SCC consists of the same constituent material as the ordinary concrete (aggregate, cement, water, a superplasticizer) the only difference is that a higher content of fine particles (> 500 kg), the maximum particle size of the aggregate is 16 (20) mm and the required application admixtures superplasticizer. Due to the increased amount of fine particles, self-compacting concrete is more sensitive to increased shrinkage and cracks.

2. SHRINKAGE BEHAVIOR OF SCC

SCC as any other concrete has a volume deformations, which occur in the early stages of hydration and later at the stage of hardening, and can cause cracks in the concrete. Due to changes in humidity in the concrete, the concrete can lead to the shrinkage. The plastic shrinkage, caused by evaporation of water due to the start of the hydration, autogenous shrinkage occurs at day 1 (humidity changes in hardened concrete), due to hydration of cement is increased temperature of the concrete and eventually produced concrete shrinkage on drying (after the completion of hydration) which is less, but can last for years [1].

Mix design parameters of concrete act on the shrinkage of concrete, the type of cement, the amount of mineral additives, and the amount of filler type, and the proportion of aggregates, water and cement. The cracks due to shrinkage in SCC is common, because of the large

proportion of finesses and a greater amount of cement. In ordinary concrete shrinkage is often taken as a reason for the loss of moisture from the concrete due to drying, where it is known that high water / cement ratio (> 0.4) will have relatively small autogenous shrinkage [2]. As opposed to, SCC having a low water/cement ratio (0.3 - 0.4), in combination with high binder content will lead to greater autogenous shrinkage. Therefore, the self-compacting concrete shrinkage on drying and autogenous shrinkage must be taken into account [3].

3. THEORETICAL SHRINKAGE PREDICTION MODELS OF SCC

Theoretical shrinkage prediction models of SCC, which exhibit shrinkage of ordinary concrete are known and generally standardized. In the world has plenty of information on the collection of self-compacting concrete and a lot of tests performed [4]. The initial considerations to create a database of information, was collected tests results of SCC. Several authors made the comparison of results achieved with methods for predicting shrinkage ordinary concrete CEB-FIB; ACI; EUROCODE 2; JSCE; AASHTO and compared with the results obtained by experimental methods shrinkage of SCC from the other authors. [5] To new modified prediction method shrinkage of SCC occurred by comparing the ordinary and SCC [5] in a way that: (a) Establish an experimental database for shrinkage and creep; (b) Set up the base of the prediction models for shrinkage and creep; (c) Compared the results of database models with experimental results; (d) The propose SCC creep and shrinkage models based on the previous comparisons; (e) Verify the proposed models with experimental results tests.

4. CONCLUSION

Shrinkage is the concrete volume deformation, which occurs in SCC, and a result of the occurrence are cracks. Frequent occurrence of cracks on concrete elements, a major disadvantage and open the way for aggressive medium that penetrates into the concrete and reduces the durability of the structure. The shrinkage depends of the mix design of concrete, type and curing time of concrete. Based on literature studies research of self-compacting concrete, the test results of the experimental investigation and the choice of new modified shrinkage prediction models, it can be assumed SCC´ shrinkage. The doctoral thesis will be analyzed models predicting shrinkage and compared with experimental results. The result of this doctoral thesis will be guidelines for the design of SCC to reduce shrinkage, and guidelines for design the SCC in order.

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IMPACT OF WOOD BIOMASS FLY ASH ON THE SETTING TIME OF CEMENT PASTES

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Abstract

Majority of the European wood biomass ash is being deposited at landfills, causing financial and material wastage, as well as burdening the environment [1]. A large-scale utilisation of wood biomass welcomed in the future requires feasible applications of wood biomass ash. One of the possible applications could be the replacement of cement and/or sand in cement composites. This paper investigates the impact wood biomass fly ashes (WBA-F) as a partial cement replacement on the initial and final setting time and standard consistency of the cement pastes.

Keywords: wood biomass fly ash, supplementary cementitious material, setting time, standard consistency

1. INTRODUCTION

The fact that woody and agricultural biomass is considered to be a CO_2-neutral and renewable source of energy as it releases less CO_2 by burning than it absorbs while growing, places it among the top biomass-source potentials for energy production in the EU [2]. To ensure the fundamental transformation of Europe's energy system, ambitious goals have been set before all European Union Member states, which, among others, include the goal of using min. 32% renewable energy by 2030 [3]. Meeting only the goal of using 20% renewable energy by 2020 set by Directive 2009/28/CE, would result in producing approximately 15,5 million tonnes of biomass ash per year in the EU [4]. Therefore, the necessity to develop a coal exit strategy results in wood biomass increased usage as a sustainable fuel, generating large amounts of ash. The objective of this study is to quantify the acceptable amount of fly WBAs in the cement composites, taking into account the chemical composition of different fly WBAs. Due to highly variable chemical structure and properties of WBAs, depending on the type of biomass raw material (e.g. wood residues or agricultural biomass), combustion technology and geographic location where ashes are collected, further research on WBA as supplementary cementitious material is necessary [1].

2. MATERIALS AND EXPERIMENTAL PART

Six WBA-F utilized in this research were collected from different power plants located in Croatia, that use different types of combustors (grate combustors, fluidized bed combustors and pulverized fuel combustors). Cement pastes with 5, 10 and 15% of WBA-F as cement replacement were prepared using cement type CEM I 42.5 R. Standard consistency and the

setting time of cement pastes were determined according to Methods of testing cement -- Part 3: Determination of setting times and soundness (HRN EN 196-3:2016) standard [5].

3. RESULTS AND CONCLUSIONS

As a result of standard consistency testing, all cement mixtures had shown the same behavioural trend of increased water need, proportionally increasing with the quantity of WBA-F used. WBA-Fs characterization shows irregularly shaped and high porosity particles of higher specific surface, with high carbon and free CaO content, which can all be related to the increased water demand [6], [7].

Cement pastes with WBAs have shown a delay of the initial and final setting time in comparison with the reference mixture. High amounts of alkalis, sulphates and heavy metals in the WBA-F samples used in cement pastes have an impact on retarding effect of the setting time [8].

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- founding individual study programmes in the English language, and organising life-long learning and non-formal education in the English language
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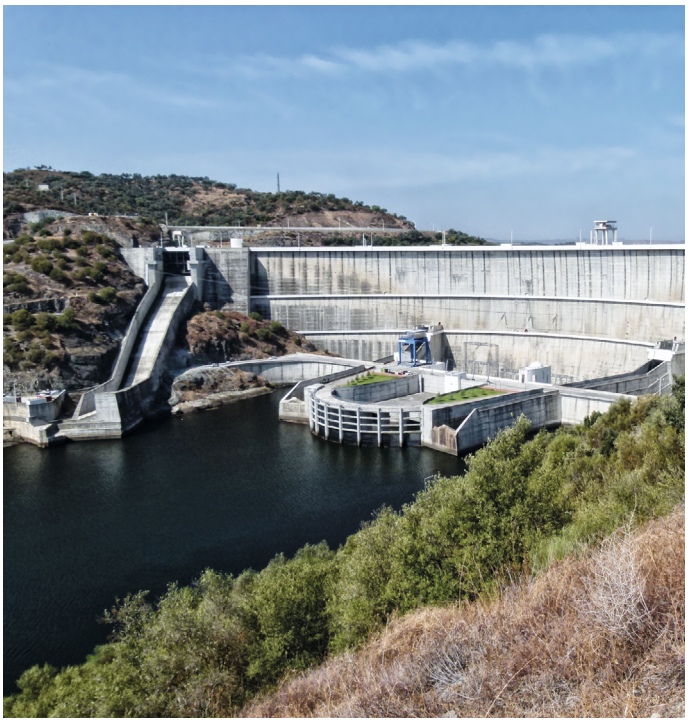

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*Figures provided are based on an actual case from the concrete producer BRONZO PERASSO in Marseille, France

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