# ADVANCED LOW $CO_2$ CEMENTITIOUS MATERIALS
# ACT

Joint Research Project (JRP) accepted for funding on the call "Croatian-Swiss Research Programme CSRP 2017 – 2023", under the project ID IZHRZO_180590/1. Executing Agencies for CPRS projects are the Swiss National Science Foundation (SNSF) and the Croatian Science Foundation (CSF) for Swiss and Croatian partner respectively.

**Swiss Principle Investigator**: Karen Scrivener, PhD, Professor, EPFL, Lausanne, Switzerland
https://people.epfl.ch/karen.scrivener

**Croatian Principle Investigator**: Marijana Serdar, PhD, Assistant Professor, University of Zagreb, Faculty of Civil Engineering, Department of Materials, Zagreb, Croatia
http://www.grad.unizg.hr/en/marijana.serdar

## SUMMARY OF THE RESEARCH PLAN

We propose a collaboration between Professor Karen Scrivener of the Laboratory of Construction Materials at EPFL and Professor Marijana Serdar from Department of Materials, Faculty of Civil Engineering, University of Zagreb. The proposed work aims to optimise the formulation of cements and concretes based on partial replacement of CO2 intensive clinker by locally available waste streams and by-products as supplementary cementitious materials (SCMs). This will have the dual benefit of reducing CO2 emissions and utilising materials which would otherwise be landfilled.

In 2015, the total mass of cement produced was equivalent to about 626 kg of cement/per capita, a value higher than the amount of human food consumption. Currently the production of ordinary Portland cement accounts to 5-8% of world-wide CO2 emissions. Taking into account rising demand for construction materials, it is projected that by 2050 cement production alone could account for 16–24% share of all global CO2 emissions. At the same time there are numerous industries producing by-products and landfilling them as waste, that could actually be used as a replacement of ordinary Portland cement. To find solutions for both of these environmental problems, there is a need to activate the knowledge available in countries such as Switzerland to enable development of advanced low CO2 cementitious materials, based on local materials having low environmental impact relative to performance.

Professor Scrivener is a world leading expert on the chemistry and microstructure of cementitious materials, with extensive expertise on the mechanisms governing the behaviour of more sustainably cements containing SCMs. Professor Serdar is a talented young researcher, with expertise on the durability of Concrete. The main activity of the project will be carried out by 2 PhD students, based in Croatia and with Professor Serdar as the main supervisor. These PhD students will spend about one third of the project at EPFL, learning about microstructural analysis of cementitious materials and applying the methods of Professor Scrivener's group to their materials. In this way there will be a high level of knowledge transfer from the Swiss group to Croatia.

The PhD students will work on two, quite different aspects of advanced sustainable concrete. One will look at how to achieve the minimum environmental footprint for standard concrete: strength in range 20-40 MPa and no particular durability requirement, for example for housing. The second will look at high performance concrete for infrastructure subject to aggressive environment, such as chloride ingress. In both cases the objective will be to develop generic approaches to the incorporation of waste or by-product materials and apply these to the Croatian situation. To do this the focus will be on linking the microstructural development to macroscopic performance. This will build on the synergy between the two partners and establish a good basis for future microstructural analysis in Croatia, which will become a leader in the field in Southeast Europe.

Lowering CO2 emission and utilising valuable properties of waste materials are European and national priorities, as can be seen from the support letter to project ACT from Croatian Ministry of Environment and Energy, Croatian Agency for Environment and Nature and Environmental Protection and Energy Efficiency Fund. Different industries and stakeholders, such as raw materials producers, cement producers, producers of concrete precast elements, investors in infrastructure, realise that only by introducing solutions with enhanced sustainability performance they can continue to grow at current market, which is also evident from their letter of support to project ACT. Therefore, in Croatia the project has support from all sectors of the construction industry and government, which will enable a broader impact of the project and the application of the research in the field. Background of ACT project

**Table 2 Schedule for the work to be carried out**

| PROJECT ACT | 1st year | | | | | | | | | | | | 2nd year | | | | | | | | | | | | 3rd year | | | | | | | | | | | |
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| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| **Project management** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Coordination of the project | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Project meetings | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data management plan | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **PhD student 1 - low CO2 "standard" concrete** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **1 Raw materials selection** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1 Survey and acquisition of materials in UNIZG | UNIZG | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.2 Characterization of materials in EPFL and UNIZG | | | | | EPFL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.3 Reactivity of materials in EPFL and UNIZG | | | | | EPFL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **2 Preliminary development of mixes** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.1 Formulation at UNIZG | | | | | | | | UNIZG | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.2 Strength development at UNIZG | | | | | | | | | | UNIZG | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.2 Volume stability at UNIZG | | | | | | | | | | UNIZG | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.3 Microstructural testing | | | | | | | | | | | | | | EPFL | | | | | | | | | | | | | | | | | | | | | | |
| 2.4 Durability testing | | | | | | | | | | | | | | | | | EPFL | | | UNIZG | | | | | | | | | | | | | | | | |
| **3 Mid term review evaluation** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.1 Analysis of results | | | | | | | | | | | | | | | | | | | | UNIZG | | | | | | | | | | | | | | | | |
| 3.2 Refinement of formulations | | | | | | | | | | | | | | | | | | | | | | | | | | EPFL | | | | | | | | | | |
| **PhD student 2 - low CO2 high performance concrete** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **1 Raw materials selection** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1 Survey and acquisition of materials in UNIZG | UNIZG | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.2 Characterization of materials in EPFL and UNIZG | | | | | EPFL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.3 Reactivity of materials in EPFL and UNIZG | | | | | EPFL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **2 Preliminary development of mixes** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.1 Formulation at UINZG | | | | | | | | UNIZG | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.2 Strength development at UNIZG | | | | | | | | | | UNIZG | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.2 Volume stability at UNIZG | | | | | | | | | | UNIZG | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.3 Microstructural testing | | | | | | | | | | | | | | EPFL | | | | | | | | | | | | | | | | | | | | | | |
| 2.4 Durability testing | | | | | | | | | | | | | | | | | EPFL | | | UNIZG | | | | | | | | | | | | | | | | |
| **3 Mid term review evaluation** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.1 Analysis of results | | | | | | | | | | | | | | | | | | | | UNIZG | | | | | | | | | | | | | | | | |
| 3.2 Refinement of formulations | | | | | | | | | | | | | | | | | | | | | | | | | | EPFL | | | | | | | | | | |
| **4 PhD thesis** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.1 Defence of PhD subject | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.2 Review | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.3 Writing | | | | | | | | | | | | | | | | | | | | | | | | | | | | | UNIZG | | | | | | | |
| **Dissemination** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Web page | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Scientific publications | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Technical committees participation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Workshops organisation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **MILESTONES** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M1 Needed raw materials obtained | | | | | M1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M2 Training in EPFL successfully finished | | | | | | | | M2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M3 Mixes defined | | | | | | | | | | M3 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M4 Testing in EPFL successfully finished | | | | | | | | | | | | | | | | | | | | M4 | | | | | | | | | | | | | | | | |
| M5 Mixes refined | | | | | | | | | | | | | | | | | | | | | | | | | | | | | M5 | | | | | | | |
| M6 Testing in EPFL successfully finished | | | | | | | | | | | | | | | | | | | | | | | | | | | | | M6 | | | | | | | |
| M7 Theses submitted | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | M7 | | |
| **DELIVERABLES** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| D1 Report on activity of raw materials | | | | | | | | D1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| D2 Report on properties of developed mixes | | | | | | | | | | | | | | | | | | | | | | D2 | | | | | | | | | | | | | | |
| D3 Report on mixes refined | | | | | | | | | | | | | | | | | | | | | | | | | | | | | D3 | | | | | | | |
| D4 Workshop proceeding | | | | | | | | | | | | | | | | | | | | D4 | | | | | | | | | | | | | | | | D4 |
| D5 Theses finished | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | D5 |
| D6 Report on scientific publications | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | D6 |