

INTERNATIONAL PROJECTS BRIDGE SCIENCE AND THE TEACHING PROCESS

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Abstract: In recent decades, the Republic of Serbia and the Republic of Srpska have focused their efforts on expanding industrial ventures to produce new, more sustainable, building products and boosting the research capacities of universities and other scientific organizations. Simultaneously, they encourage the entrepreneurial efforts of young and energetic entrants into the field of building materials, who are increasingly populating the two countries' research institutions. This paper describes the bilateral project 'New technologies in the production of environmentally friendly mortar and concrete', carried out by team members from the Faculty of Technical Sciences at the University of Novi Sad (Serbia) and the Faculty of Architecture, Civil Engineering, and Geodesy at the University of Banja Luka (Republic of Srpska), and funded by the Provincial Secretariat for Higher Education and Scientific Research of the Autonomous Province of Vojvodina. The impact of project research on the educational process is underlined since undergraduate Civil Engineering students are members of the project and are directly involved in its implementation.

Key Words: industrial ventures, building materials, project research, educational process

1. INTRODUCTION

In recent years, The Autonomous Province of Vojvodina's Provincial Secretariat for Higher Education and Scientific Research began financing collaborative research projects of scientific research institutions formed by AP Vojvodina in collaboration with scientific research organizations of the Republic of Srpska. Projects are implemented as part of the research program with the goal of improving regional cooperation in terms of scientific research and education, which is an essential factor in comprehensive development, institutional connection, development of mutual relations, traditional ties, and mutual understanding.

The Provincial Secretariat chose to provide funding for a project titled "New technologies in the production of environmentally friendly mortar and concrete" in 2023. The project is led by the Faculty of Technical Sciences at the University of Novi Sad, with support from the Faculty of Architecture, Civil Engineering, and Geodesy at the University of Banja Luka [1]. Two civil engineering undergraduate and master's students were appointed to the project team, while the experimental study is being undertaken as part of the teaching process at Novi Sad's Faculty of Technical Sciences.

Members of both research institutions have actively participated in numerous national and international research projects relating to the circular economy in civil engineering practice and the incorporation of various alternative materials in the construction sector throughout the years. As both countries face similar issues in this area, such as low competitiveness, poor enterprise networking, and insufficient disposal of agricultural harvest residue-biomass, the project's approach is to improve networking by establishing a cross-border cooperation network to introduce a new approach to dealing with agricultural waste. This will be accomplished through the collaboration of skills, equipment, and research to solve challenges. The collaboration of educational and scientific institutions, industry, and construction enterprises will open up the prospect of using agricultural biomass ash as an integrated part of civil engineering constructions. Hence, the overall purpose of the research is to tackle the problem of dumping waste materials originating from agriculture, as well as to reduce CO₂ emissions and consumption of non-renewable natural mineral resources. Furthermore, the research findings will serve as preparation for participation in European programs.

This article briefly presents the project's key facts, including: study objectives, predicted outcome, description of so far conducted activities, and incorporation of project research into the educational process.

2. RESEARCH OBJECTIVES AND EXPECTED OUTCOME

Cement production generates roughly 8% of total yearly CO₂ emissions; hence the researchers all around the globe are putting their efforts trying to limit the use of non-renewable natural resources and introduce the use of alternative raw materials. Vojvodina's territory is dominated by extensive agricultural production, with corn dominating the sowing area (nearly a million hectares). The ash created by burning agricultural residues after harvesting (straw, cob corn...) could be used to make cement-based mineral binders. Substituting cement with ash

produced by biomass combustion as a CO₂ neutral fuel will minimize local CO₂ emission while also providing a new use value and the potential of evaluating ash as a raw material economically.

The ash that will be studied is a byproduct of the combustion of corn cob: corn cob ash (CCA). Data on available ash, combustion locations, methods, devices, and combustion temperatures will be collected in the first period of the project. The following tests will be performed on ash samples: physical properties (sieve composition, standard consistency, setting time, soundness, specific surface area, and bulk density), chemical composition (main inorganic elements, loss on ignition, chloride and sulfate content, heavy metal content), and pozzolanic properties. This stage of the research is critical because it allows for a comparison of this material with commonly utilized cementitious materials such as fly ash, slag, and silica fume.

Phase II involves exploring the possibility of using CCA as a partial cement substitute in cement-based mortars. These effects will be studied by replacing 10-50% of the cement and monitoring the change in mechanical properties and capillary water absorption of the mortar.

In phase III, it is proposed to examine the application of CCA in cement-based concrete. The effect of utilizing CCA as a bio-based binder will be tested by substituting a portion of cement in the range of 10-50%. The influence of CCA on the properties of fresh concrete: consistency (slump) and hardened concrete: compressive strength, water-impermeability, and wear resistance will be analyzed.

The findings of the laboratory studies should indicate if CCA can be used to manufacture cement composites: mortar and concrete, and in what proportion of cement substitution. Based on the findings, recommendations for the use of this waste material will be developed. The most significant research findings will be published in peer-reviewed journals and presented at scientific conferences.

The outcomes of this study will allow the use of CCA in cement composites, which are historically employed in a variety of construction fields (masonry and plastering mortars, cement screeds, masonry blocks, and so on). In this way, additional new use value will be created for this waste material, and conditions for sustainable development in this sector of the economy will be developed.

The members of both research institutions are listed in the Table 1. Two students (one from each university) participate in the project's experimental program and implementation as active members of research teams.

Table 1 – Project team members

Team members of FTN, Novi Sad	Team members of AGGFBL, Banja Luka
Slobodan Šupić, Assistant professor, project leader	Gordana Broćeta, Associate professor, project leader
Ivan Lukić, Associate professor, member	Andelko Cumbo, Assistant professor, member
Vladan Pantić, Teaching assistant, member	Marina Latinović-Krndija, assistant, member
Slavoljub Drinjak, student, member	Jovan Volaš, student, member

3. CONDUCTED RESEARCH ACTIVITIES

In the first period of project implementation, following activities were conducted:

- Kick off project meeting in Novi Sad (Figure 1);
- Joint participation of team members at the international conference MASE 2023 in North Macedonia (Figure

2).

Kick off meeting of team members, which officially got the project off the ground, was organized in Novi Sad, Serbia, in September 2023. In the scope of the meeting, project activities in the first period of realization have been defined and timeline of activities for the first year of the project has been created. Furthermore, Banja Luka team members have been introduced to the Laboratories for testing materials in Novi Sad.

Afterwards, team members from both countries participated at the International conference organized by Macedonian Association of Structural Engineers – MASE 2023, which took place in Skopje, North Macedonia. The initial results of conducted experimental research were presented at the conference to the broader community involved in the topic of the project. As such, the conference was an effective occasion to communicate key project information to the relevant public audience. The obtained results were published as an original scientific article, titled: "Development of environmentally friendly corn cob ash blended cement mortar".



Figure 1. Kick-off project meeting and the visit to the Laboratory of FTN



Figure 2. Participation of project members at the International civil engineering conference in Skopje

4. INVOLMENT OF THE PROJECT RESEARCH IN THE EDUCATIONAL PROCESS

In the summer semester of 2023, a portion of the experimental study (phases 1 and 2) was undertaken as part of the teaching process at the Faculty of technical sciences through an elective teaching course titled "Contemporary composites based on agriculture, industry, and construction waste." Undergraduate students investigated the feasibility of using CCA as an alternative binder material in sustainable cement-based composites (Figures 3 and 4). They aimed to conduct the necessary characterization studies and create an optimal mortar mix to build sustainable composites.



Figure 3. Laboratory exercises at the Department of civil engineering and geodesy



Figure 4. Modern eco-friendly composites produced by students within educational process

The results of testing selected mechanical and physical properties of cement-based mortars blended with CCA, up to the 50% cement substitution level are illustrated in the Figures 5-7.

In general, the substitution of cement had negligible effect on the mechanical performance of mortar. There was no noticeable loss of strength as the cement replacement amount was increased. Figure 5 shows that the mortar mix containing 10% biomass ash has the highest flexural strength at 28 days of age among the mortars blended with biomass ash. Overcoming this replacement barrier results in a minor loss of strength, which may be as low as 90% of the strength of the reference mortar. When ash levels up to 30% were utilized, there was clearly a modest decrease in the compressive strength of the mortar - Figure 6. Nonetheless, as the curing age approached, this gap was reduced.

A higher replacement level resulted in a lower concentration of cement clinker and hydration products, which increased the mortar's capillary porosity and permeability (the dilution effect), resulting in a higher rate of water absorption, as shown in Figure 7. This was especially noticeable early in the hydration process, when the pozzolanic reaction had not yet fully developed and the amount of free water accessible to react with the cement particles had grown. These negative consequences could be mitigated by lowering the water-to-binder ratio in the mortar, which is being studied further.

According to the foregoing research, positive findings were obtained during the initial stage of project implementation, indicating that a considerable amount of cement may be substituted with locally accessible waste material. Obtaining these objectives may be a viable strategy and method of boosting the greenness and sustainability

of cement-based materials. On the other hand, joint research between two universities is further developing and contributing to the enhancement of researchers' positions in the global and European research areas.

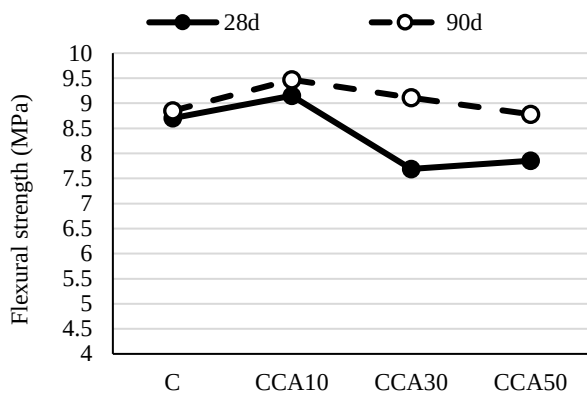


Figure 5. Flexural strength of mortars blended with CCA

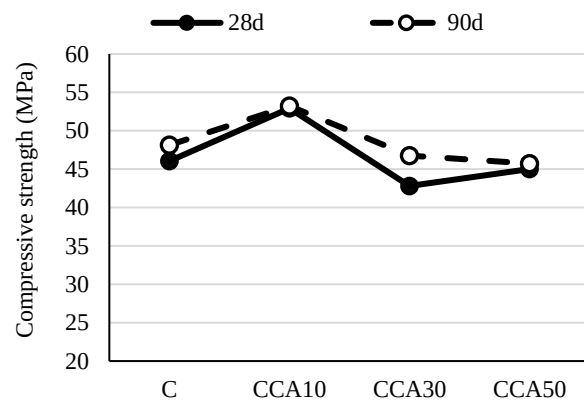


Figure 6. Compressive strength of mortars blended with CCA

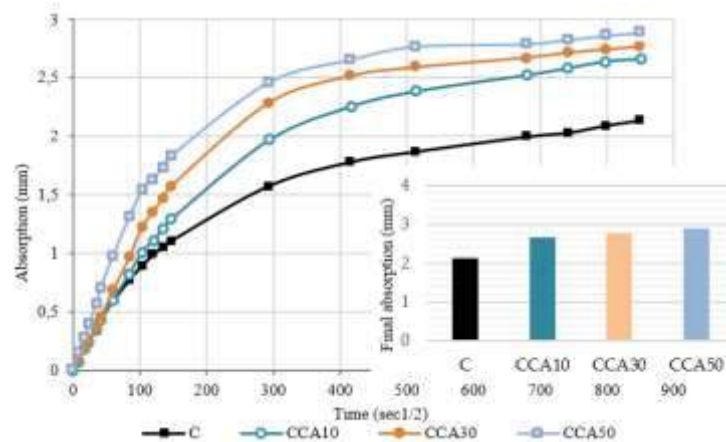


Figure 7. Capillary water absorption: the kinetics and the final values

5. CONCLUSIONS

This paper briefly described an innovative bilateral project: 'New technologies in the production of environmentally friendly mortar and concrete', conducted by team members from the Faculty of Technical Sciences at the University of Novi Sad (Serbia) and the Faculty of Architecture, Civil Engineering, and Geodesy at the University of Banja Luka (Republic of Srpska). The objective of the project is to develop novel eco-friendly cement-based composites by utilizing locally available waste materials: agricultural biomass ash.

The most valuable profit and advantage of the two research teams is the establishment of solid foundations for future collaboration. The competence, experience, and mutual trust developed throughout this collaboration-project will provide the researchers with a solid foundation for future collaboration in European research initiatives.

Moreover, undergraduate Civil Engineering students are members of the project and are directly involved in its implementation. This means that the additional education they receive as a result of the scientific endeavor will play a significant role in their growth as young engineers.

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6. REFERENCES

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