Encuentro Internacional de Doctorandos en Ingeniería Civil - EIDEIC 2022

Feasibility of steel slag as binder and aggregate in alkali-activated materials

PhD candidate: VITOR ALENCAR NUNES

Supervisors: Prof. PhD. Carlos Thomas (UC)
Prof. PhD. Paulo Borges (CEFET-MG)

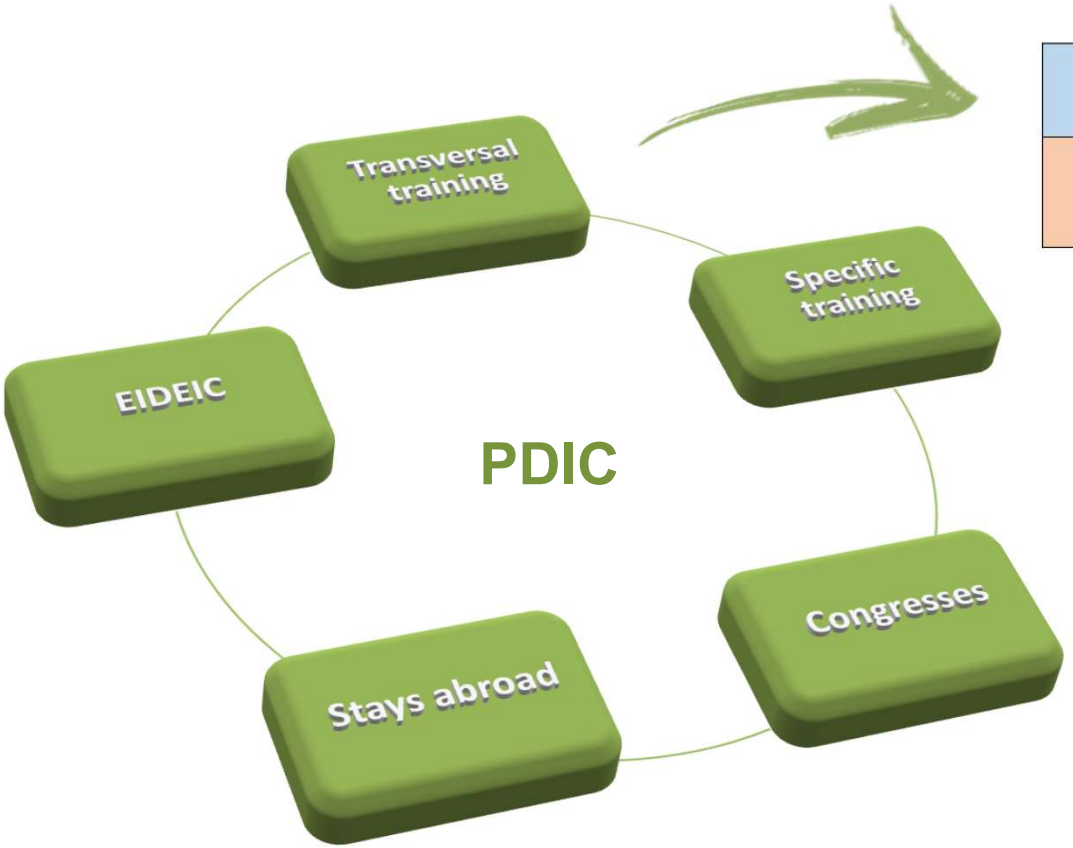
Agenda

1. Training and competences
2. Research development
3. Timetable


Training and
competences

Training and competences

- The PDIC classifies the learning activities in the next categories:



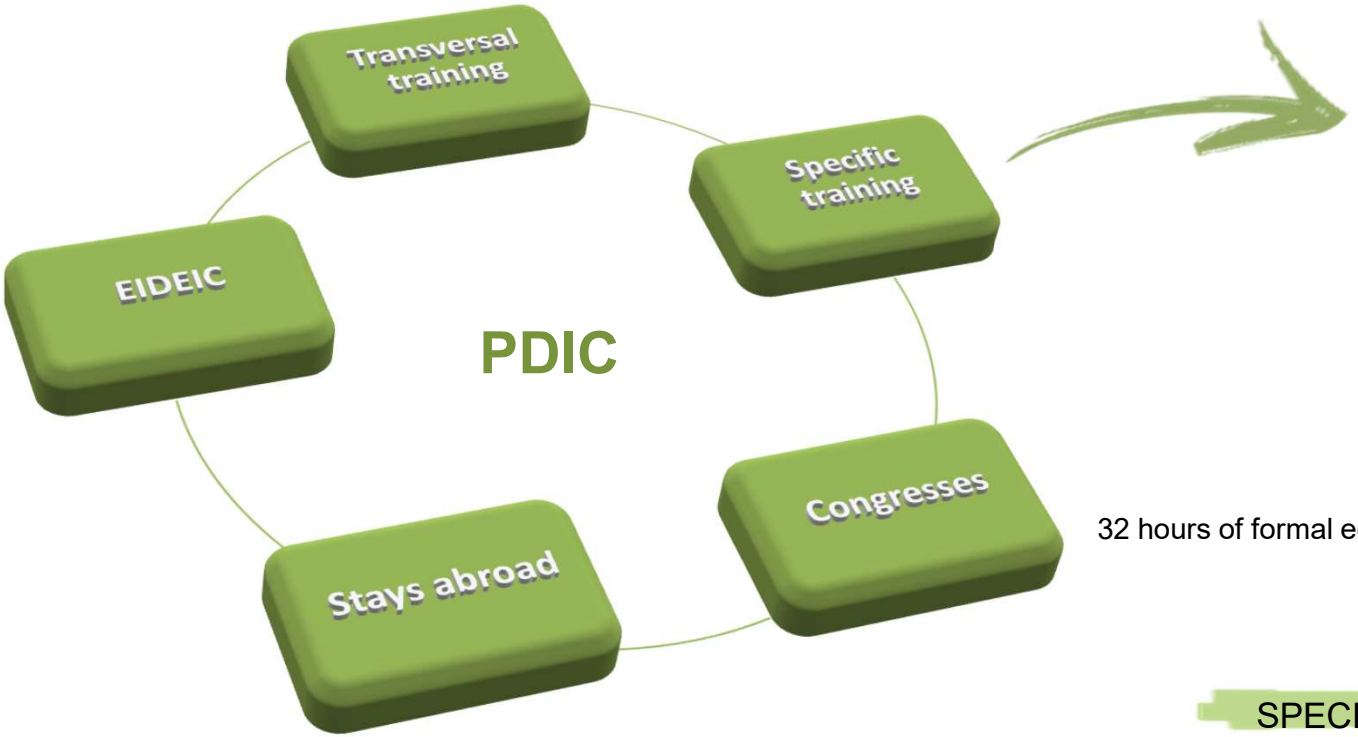
Formación Transversal Básica	Bloque I. Obligatorio y común	6 horas	6 hours
	Bloque II. Libre elección*	34 horas	34 hours
Formación Transversal Avanzada	Bloque I. Obligatorio y común.	3 horas	3 hours
	Bloque II. Libre elección*	37 horas	44 hours
			87 hours

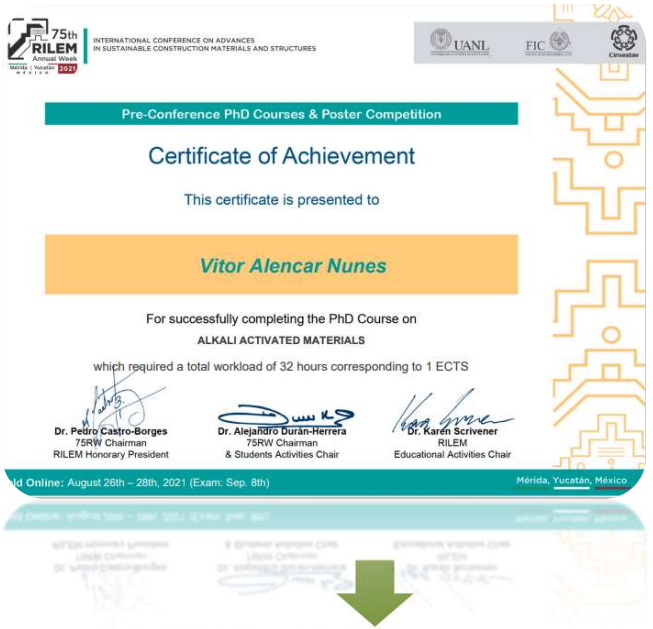
COMPETENCIAS BÁSICAS	I. La ciencia y la ética en la investigación científica
	II. Los instrumentos de ayuda en la preparación de tesis y artículos científicos
	III. La preparación, redacción y presentación de publicaciones científicas
	IV. La comunicación, la divulgación y la docencia de la ciencia
	V. La transferencia del conocimiento: propiedad intelectual y propiedad industrial
COMPETENCIAS AVANZADAS	I. La financiación de la investigación y los proyectos de investigación
	II. La colaboración Universidad/ empresa/administraciones
	III. El pensamiento creativo

TRANSVERSAL TRAINING COMPLETE !!

Training and competences

- The PDIC classifies the learning activities in the next categories:



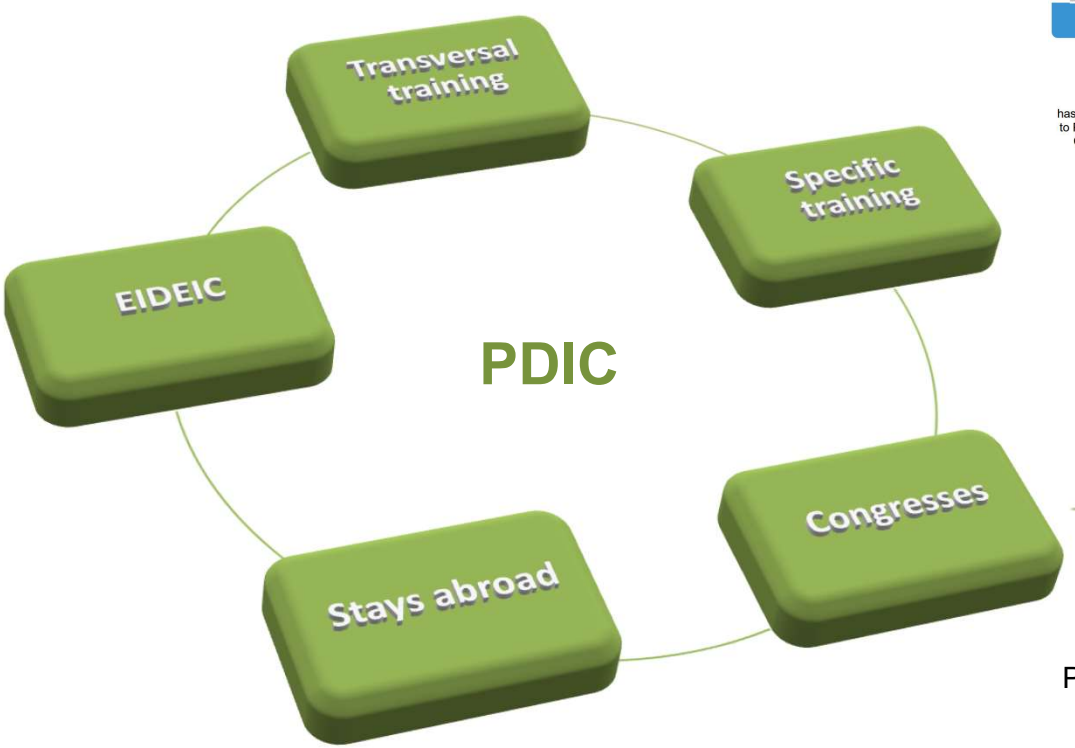


32 hours of formal education (PhD course) on the topic of the thesis

SPECIFIC TRAINING COMPLETE !!

Training and competences

- The PDIC classifies the learning activities in the next categories:




BCCM4
4th Brazilian Conference on Composite Materials

Rio de Janeiro
PUC-Rio 2018
July 22th to 25th

CERTIFICATE OF PRESENTATION

The Organizing Comittee certifies that

Vitor Alencar Nunes

has presented the paper Compatibility and adhesion of MK/BFS alkali-activated repair mortars to Portland cement concrete substrates; Authors: Vitor A. Nunes (a) , Paulo H. R. Borges (a) , Cristina Zanotti (b) , Raquel P. Batista (a); at the 4th Brazilian Conference on Composite Materials, BCCM4, held in Rio de Janeiro, Brazil, from July 22th to 25th, 2018.

Prof. Dr. Flávio de Andrade Silva
Chairman of BCCM4 – PUC-Rio


The Chair of the

1st International Santander
Eco-Concrete Conference - ISECC21

certify that

Vitor Alencar Nunes

Has attended as a plenary speaker with the speech entitled

Recent advances in the reuse of steel slags and the future perspectives applications in alkali-activated materials

Conference placed in the
Civil Engineering School of the University of Cantabria, Spain
On December 16 & 17, 2021

Carlos Thomas Garcia
Conference Chair

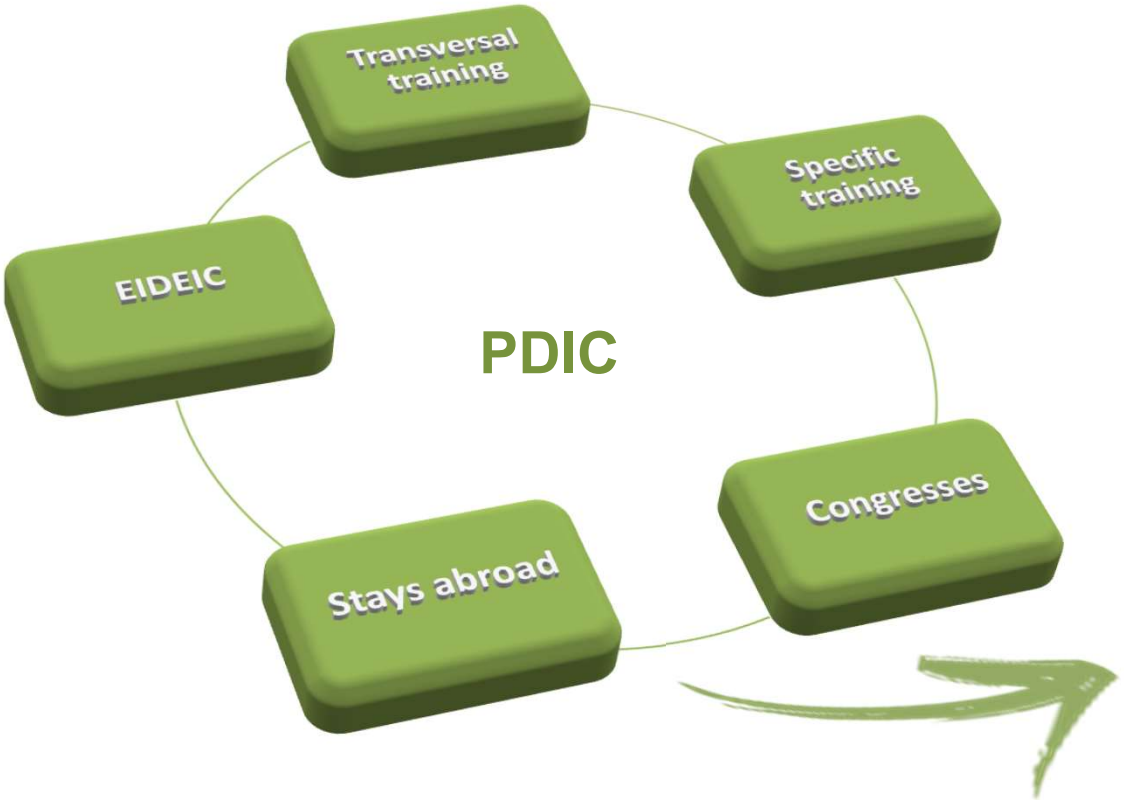
Ali Aghajanian
Scientific Committee Chair

Presentation and plenary speaker

INTERNATIONAL CONGRESSES COMPLETE !!

Training and competences

- The PDIC classifies the learning activities in the next categories:

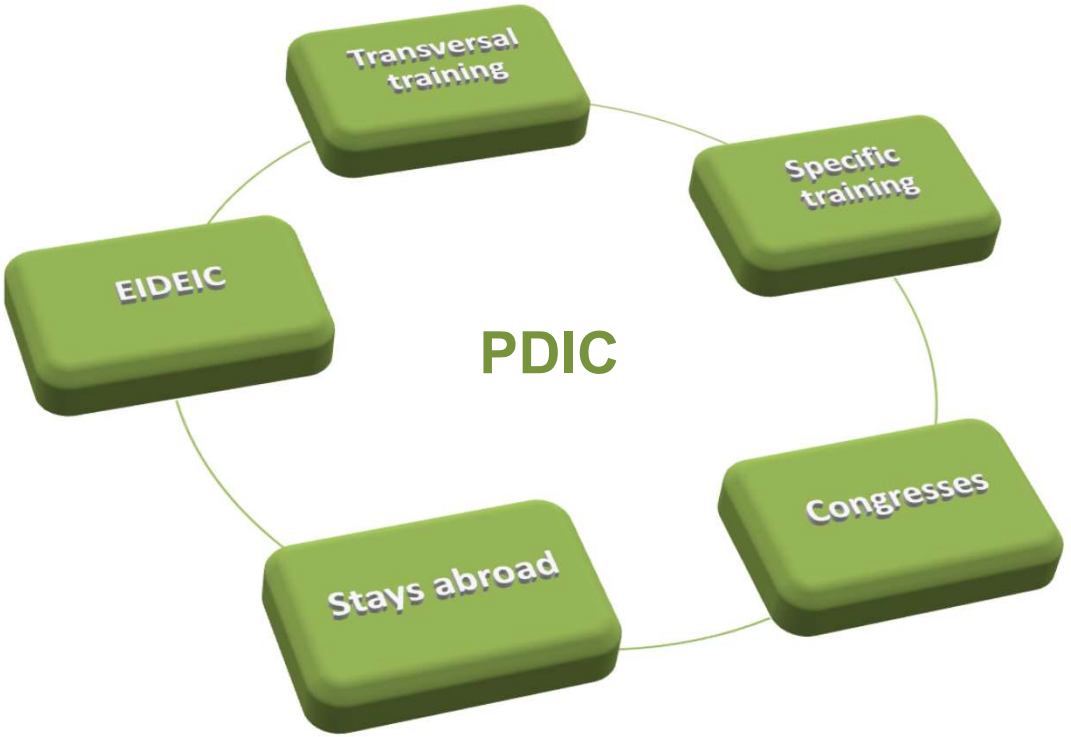


STAY ABROAD COMPLETE !!

Convention for thesis co-tutelage

Training and competences

- The PDIC classifies the learning activities in the next categories:



EIDEIC VII EDICIÓN
21 DE MAYO DE 2021

Programa

SESIÓN 1: ENCUENTRO DE DOCTORANDOS DE PRIMER AÑO
FIRST-YEAR PhD STUDENTS

Hora / *Time*	Ponente / *Speaker*	Título / *Title*
09:15	Jorge Rodríguez Hernández, PDIC Coordinator	Introduction by the Doctoral Program Coordinator
09:25	Maira Delgado Lindeman	Políticas de estacionamiento: una mirada al espacio público considerando competencia entre vehículos de pasajeros y de carga.
09:35	Elías Daniel Valadez González	Desarrollo de una metodología innovadora para la caracterización en fractura mediante ensayos Small Punch (FRACTOPUNCH).
09:45	Miklos Radics	Applications of Data Science in Transport Policy Analysis.
09:55	Ebenezer Yiwo	Flood resilience
10:05	Manuel Zornoza Aguado	Climate Change Adaptation: Early Warning System of Coastal Flooding (Beach4Cast).
10:15	Javier Sedano Cibrián	Fotogrametría con drones y minería.
10:25	Marcos Sánchez García	Evaluation of fracture toughness by means of sub-size specimens.
10:35	César A. Carrasco Payero	Investigación relacionada con la Integración de Geographic Information Systems(GIS) y Building Information Modelling (BIM) & HeritageBIM.
10:45	Vitor Alencar Nunes	Feasibility of steel slag as binder and aggregate in alkali-activated concrete.
10:55	Conclussions	

EIDEIC 2021 AND 2022

TWO PARTICIPATIONS COMPLETE!!

Training and competences

Compulsory multidisciplinary training: every doctoral student must have more than 80 hours of multidisciplinary training organized by the EDUC in two courses to be taken at the beginning (Basic Course) and the end (Advanced Course). All the related information is available in http://www.doctoradouniversidadcantabria.com/content/actividades-transversales

Favourable assessment of his yearly PI along the doctoral studies: the importance of the PI and its assessment is critical since on it the acquisition of competences CB11 and CB14 and the personal skills and capacities CA01, CA03 and CA06 directly depend, directly related to their sections 2, 3, 4, 6, 7 and 9.

International scientific publications: the publication of the results obtained in papers in international scientific journals helps the doctoral student to ensure the acquisition of competences CB12, CB13, CB15 and CB16 and the personal capacity and ability CA02.

International mobility: this condition is essential to achieve the personal capacity and ability CA04, completing the doctoral student training.

INFORME DE (márquese lo que proceda): TUTOR ☐ DIRECTOR ☐ COMISION ACADÉMICA ☒

Previamente a esta evaluación, el doctorando ha tenido que presentar su DAD y Plan de Investigación en la secretaría de la Escuela de Doctorado (EDUC).

DAD, VALORACIÓN: Positiva ☒ Negativa ☐	NINGUNO	DEFICIENTE	BUENO	MUY BUENO
Aprovechamiento de las actividades formativas realizadas				X
Grado de cumplimiento, en su caso, de las actividades programadas en el Plan de Investigación				X
Grado de consecución de las competencias formativas y de investigación, en su caso, previstas en el programa de doctorado				X
INFORME JUSTIFICATIVO DE LA VALORACIÓN OTORGADA: Vistos el DAD y los informes de tutor y directores, la Comisión acuerda una valoración positiva de la primera anualidad, destacando el reconocimiento de varios cursos de formación.				

(pueden incluirse folios anexos si es necesario)

PLAN DE INVESTIGACIÓN, VALORACIÓN: Positiva ☒ Negativa ☐	NO ESTÁ DEFINIDO	DEBE MEJORARLO	ES CORRECTO
El tema de investigación está presentado de forma adecuada			X
Revisa el estado de conocimiento a partir de fuentes de información relevantes y plantea una hipótesis plausible y contrastable sobre la materia.			X
Los objetivos están bien definidos y son relevantes			X
La metodología es adecuada			X
El plan de trabajo está estructurado y es viable			X
INFORME JUSTIFICATIVO DE LA VALORACIÓN OTORGADA: Visto el PI y los informes de tutor y directores, la Comisión acuerda una valoración positiva, destacando la realización de la investigación en el marco de un acuerdo de cotutela.			

(pueden incluirse folios anexos si es necesario)

En Santander, 22 de noviembre de 2021.

Firmado digitalmente por RODRIGUEZ HERNANDEZ JORGE - DNI 72039149K
Fecha: 2021.11.22 15:08:42 +01'00'

Fdo. (Nombre y cargo): Jorge Rodríguez Hernández, Coordinador del PDIC

Training and competences

Compulsory multidisciplinary training: every doctoral student must have more than 80 hours of multidisciplinary training organized by the EDUC in two courses to be taken at the beginning (Basic Course) and the end (Advanced Course). All the related information is available in http://www.doctoradouniversidadcantabria.com/content/actividades-transversales

Favourable assessment of his yearly PI along the doctoral studies: the importance of the PI and its assessment is critical since on it the acquisition of competences CB11 and CB14 and the personal skills and capacities CA01, CA03 and CA06 directly depend, directly related to their sections 2, 3, 4, 6, 7 and 9.

International scientific publications: the publication of the results obtained in papers in international scientific journals helps the doctoral student to ensure the acquisition of competences CB12, CB13, CB15 and CB16 and the personal capacity and ability CA02.

International mobility: this condition is essential to achieve the personal capacity and ability CA04, completing the doctoral student training.

So far…

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Recent advances in the reuse of steel slags and future perspectives as binder and aggregate for alkali-activated materials

Vitor A. Nunes *, Paulo H.R. Borges

HIGHLIGHTS

- The recovery rate for steel slag varies from 20 to 98%, depending on the country.
- A state-of-the-art on the reuse of steel slag is presented.
- Emphasis was given to the potential and challenges in construction materials.
- Steel slag may be suitable as an alternative binder and aggregates for AAM.
- LCA is important to assess the environmental impact.
- The effect of SS on the durability properties of AAM needs to be addressed.

ARTICLE INFO

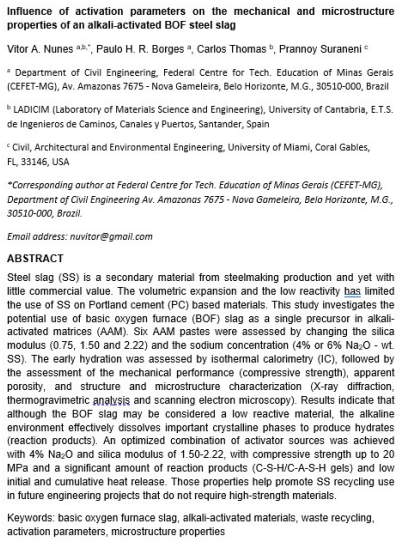
ABSTRACT

Steel slag (SS) is a secondary material from the production of steelmaking with little commercial value. It has several possible applications as raw material for different industrial process. However, small amounts are reused in some countries, where this material continues to be a burden to the steel industry. This paper presents the recent advances in the utilisation of SS in activities other than steelmaking. The main focus is the potential use of SS as binder and aggregates in cement-based materials, notably in alkali-activated materials (AAM). The latter are alternative construction materials to Portland cement (PC) and sometimes with lower environmental impact. The paper also discusses technical and commercial challenges of employing SS as raw material, e.g. legislation barriers and need for thorough treatment processing. The findings indicate that SS is a well-established material in some applications, such as agriculture and road construction. The potential use of SS as cementitious material and aggregates for concrete is highly promoted in the literature. However, the major obstacles are the variable chemical composition of SS, expansion issues, and worse fresh properties when employed as aggregates. Those issues are detrimental to mechanical strength and durability. The use of SS as binder or aggregate for AAM is still incipient albeit promising. Studies on SS-based AAM present an improved interfacial transition zone, but still, low SS reactivity as a binder. The lack of durability studies and life-cycle assessment clearly shows the demand for further investigation. Overall, a great research opportunity is the employment of SS both as binder and aggregates in AAM.

© 2021 Elsevier Ltd. All rights reserved.

2nd chapter

+



Influence of activation parameters on the mechanical and microstructure properties of an alkali-activated BOF steel slag

Vitor A. Nunes [a,b,*], Paulo H. R. Borges [a], Carlos Thomas [b], Prannoy Suraneni [c]

[a] Department of Civil Engineering, Federal Centre for Tech. Education of Minas Gerais (CEFET-MG), Av. Amazonas 7675 - Nova Gameleira, Belo Horizonte, M.G., 30510-000, Brazil

[b] LADICIM (Laboratory of Materials Science and Engineering), University of Cantabria, E.T.S. de Ingenieros de Caminos, Canales y Puertos, Santander, Spain

[c] Civil, Architectural and Environmental Engineering, University of Miami, Coral Gables, FL, 33146, USA

*Corresponding author at Federal Centre for Tech. Education of Minas Gerais (CEFET-MG), Department of Civil Engineering Av. Amazonas 7675 - Nova Gameleira, Belo Horizonte, M.G., 30510-000, Brazil.

Email address: nuvitor@gmail.com

ABSTRACT

Steel slag (SS) is a secondary material from steelmaking production and yet with little commercial value. The volumetric expansion and the low reactivity has limited the use of SS on Portland cement (PC) based materials. This study investigates the potential use of basic oxygen furnace (BOF) slag as a single precursor in alkali-activated matrices (AAM). Six AAM pastes were assessed by changing the silica modulus (0.75, 1.50 and 2.22) and the sodium concentration (4% or 6% Na_2O - wt. SS). The early hydration was assessed by isothermal calorimetry (IC), followed by the assessment of the mechanical performance (compressive strength), apparent porosity, and structure and microstructure characterization (X-ray diffraction, thermogravimetric analysis and scanning electron microscopy). Results indicate that although the BOF slag may be considered a low reactive material, the alkaline environment effectively dissolves important crystalline phases to produce hydrates (reaction products). An optimized combination of activator sources was achieved with 4% Na_2O and silica modulus of 1.50-2.22, with compressive strength up to 20 MPa and a significant amount of reaction products (C-S-H/C-A-S-H gels) and low initial and cumulative heat release. Those properties help promote SS recycling use in future engineering projects that do not require high-strength materials.

Keywords: basic oxygen furnace slag, alkali-activated materials, waste recycling, activation parameters, microstructure properties

3th chapter - paper in peer-review process

Training and competences

BASIC SKILLS
CB11 – Systematic understanding of a field of study and command of the skills and research methods related to the field.
CB12 – Skill to conceive, design or create, implement and adopt a substantial process of research or creation.
CB13 – Skill to contribute to the enlargement of the knowledge limits through an original research.
CB14 -Skill to carry out a critical analysis and assessment and synthesis of new and complex ideas.
CB15 – Skill to communicate with the academic and scientific community and with society in general about the scope of knowledge in the ways and languages of common use in the international scientific community.
CB16 – Skill to encourage, in academic and professional contexts, the scientific, technological, social, artistic or cultural progress in a society based on knowledge.

CAPACITIES AND PERSONAL ABILITIES
CA01 – Cope in contexts in which there is little specific information.
CA02 – Find the key questions to be answered to solve a complex problem.
CA03 – Design, create, develop and undertake new and innovative projects in the knowledge scope.
CA04 – Work both in teams and individually in an international or multidisciplinary context.
CA05 – Integrate knowledges, face complexity and formulate judgements with limited information.
CA06 – Intellectual criticism and defence of solutions.

COMPLETE ACQUISITION OF

SKILLS, CAPACITIES, AND ABILITIES!!


Research
development

Research development

Chapter 2 presents the recent state-of-art studies from 2018 to 2021 on the advances in applications and re-utilization of the steel slag. It begins with a short overview about the steel slag production and characteristics and then presents several studies divided in sections for type of application: agriculture, soil stabilization, wastewater treatment, fuel development, CO2 capture, road and pavement, cement and concrete, construction materials and, last, alkali-activated materials. Potential, challenges, and research need are also discussed – specific objective (i). It led to the published paper: "**Recent advances in the reuse of steel slags and future perspectives as binder and aggregate for alkali-activated materials**".

Construction and Building Materials

Review

Recent advances in the reuse of steel slags and future perspectives as binder and aggregate for alkali-activated materials

Vitor A. Nunes *, Paulo H.R. Borges

HIGHLIGHTS

ARTICLE INFO

ABSTRACT

Chapter 3 presents the development of SS as binder in alkali-activated materials – specific objective (ii). It led to the following paper which is in the peer-review process: "**Influence of activation parameters on the mechanical and microstructure properties of an alkali-activated BOF steel slag**".

Influence of activation parameters on the mechanical and microstructure properties of an alkali-activated BOF steel slag

Vitor A. Nunes [a,b,*], Paulo H. R. Borges [a], Carlos Thomas [b], Prannoy Suraneni [c]

[a] Department of Civil Engineering, Federal Centre for Tech. Education of Minas Gerais (CEFET-MG), Av. Amazonas 7675 - Nova Gameleira, Belo Horizonte, M.G., 30510-000, Brazil

[b] LADICIM (Laboratory of Materials Science and Engineering), University of Cantabria, E.T.S. de Ingenieros de Caminos, Canales y Puertos, Santander, Spain

[c] Civil, Architectural and Environmental Engineering, University of Miami, Coral Gables, FL, 33146, USA

*Corresponding author at Federal Centre for Tech. Education of Minas Gerais (CEFET-MG), Department of Civil Engineering Av. Amazonas 7675 - Nova Gameleira, Belo Horizonte, M.G., 30510-000, Brazil.

Email address: nuvitor@gmail.com

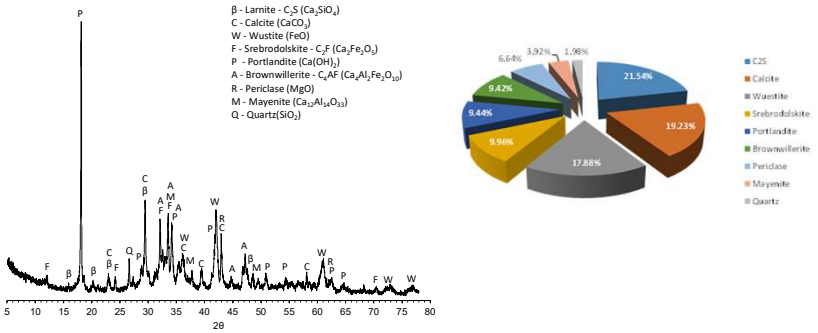
ABSTRACT

Steel slag (SS) is a secondary material from steelmaking production and yet with little commercial value. The volumetric expansion and the low reactivity has limited the use of SS on Portland cement (PC) based materials. This study investigates the potential use of basic oxygen furnace (BOF) slag as a single precursor in alkali-activated matrices (AAM). Six AAM pastes were assessed by changing the silica modulus (0.75, 1.50 and 2.22) and the sodium concentration (4% or 6% Na_2O - wt. SS). The early hydration was assessed by isothermal calorimetry (IC), followed by the assessment of the mechanical performance (compressive strength), apparent porosity, and structure and microstructure characterization (X-ray diffraction, thermogravimetric analysis and scanning electron microscopy). Results indicate that although the BOF slag may be considered a low reactive material, the alkaline environment effectively dissolves important crystalline phases to produce hydrates (reaction products). An optimized combination of activator sources was achieved with 4% Na_2O and silica modulus of 1.50-2.22, with compressive strength up to 20 MPa and a significant amount of reaction products (C-S-H/C-A-S-H gels) and low initial and cumulative heat release. Those properties help promote SS recycling use in future engineering projects that do not require high-strength materials.

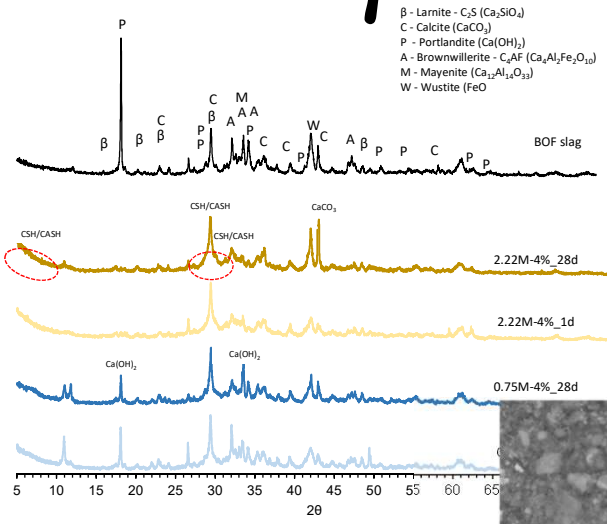
Keywords: basic oxygen furnace slag, alkali-activated materials, waste recycling, activation parameters, microstructure properties

Main results

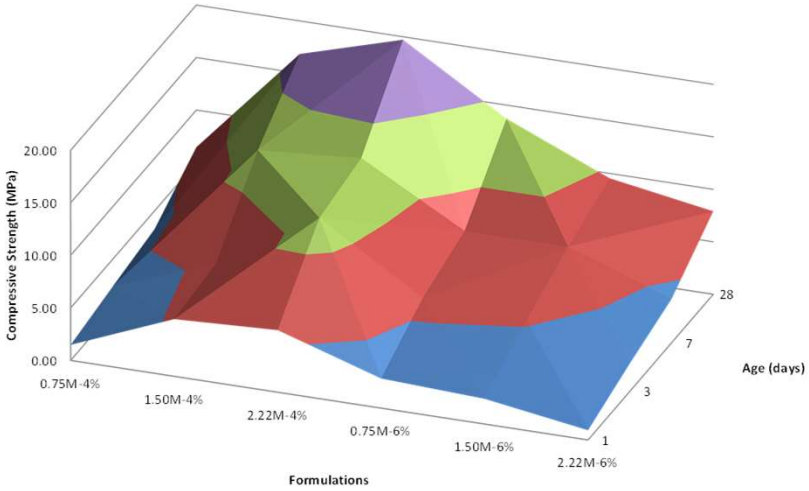
Research development



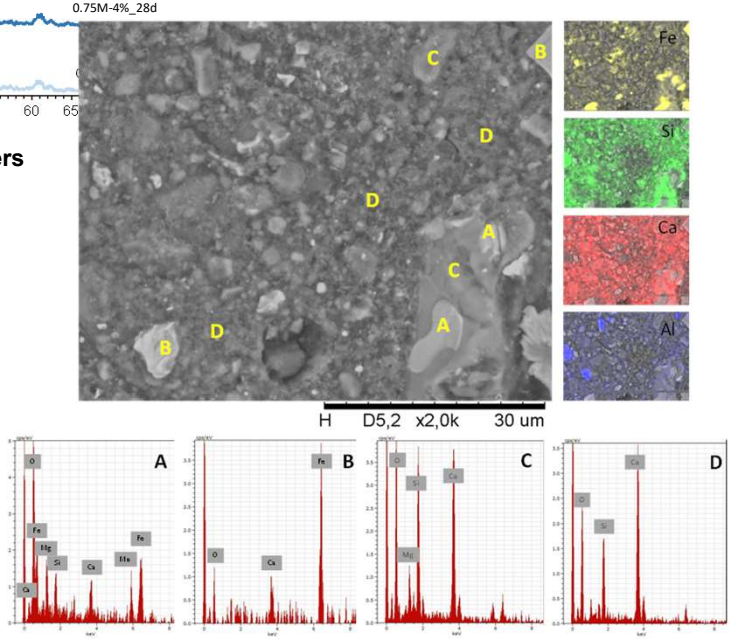
BOF slag XRD pattern and Rietveld refinement.



Comparison of XRD patters



Compressive strength distribution by variables.

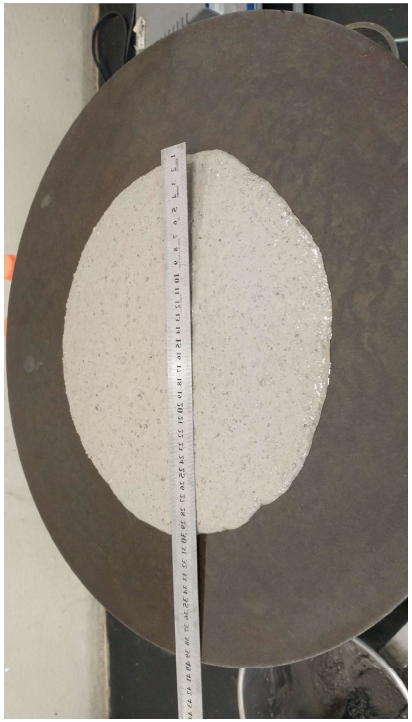


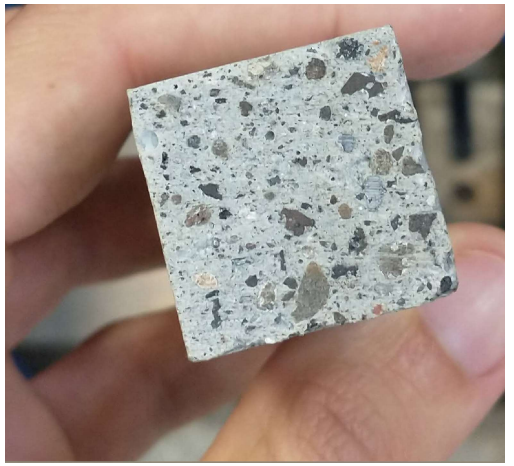
SEM image of 2.22M-4% (magnification of 2000x) with element mapping and EDX spectra

Research development

Chapter 4 presents the development of SS as aggregate in alkali-activated materials – specific objective (iii). It will lead to the following paper: "**BOF steel slag as aggregate in alkali-activated materials: optimum treatment to improve the mechanical and microstructural properties**".

Ongoing lab work





Binder -> 100% GGBFS

Aggregate -> 100% BOF steel slag

Research development

To do…

Chapter 5 presents the development of SS-based mortar with SS aggregates – specific objective (iv). It will lead to the following paper: "**Novel eco-friendly alkali-activated BOF steel slag-based mortar: mechanical and microstructural evaluation"**.

CHAPTER 5. NOVEL ECO-FRIENDLY ALKALI-ACTIVATED BOF STEEL SLAGSTEEL SLAG AS BINDER AND AGGREGATE IN ALKALI-ACTIVATED MATERIALS: MECHANICAL PROPERTIES AND MICROSTRUCTURE

The previous chapters already evaluated the use of SS as binder and aggregate, separately. The objective of this chapter is to properly design a mix by using SS as binder and aggregate, considering the better processing parameters resulting from the previous chapter. The characterization will consist of: (i) fresh properties (flow table); (ii) mechanical properties (3, 7 and 28 days compressive and flexural strength); (iii) physical properties (water absorption, density, pore size distribution by MIP and X-ray CT) and (iv) microstructure analysis by SEM at ITZ to evaluate bond aggregate/matrix. Results will indicate the possibility to develop a high-performance AAM using only SS as raw material.

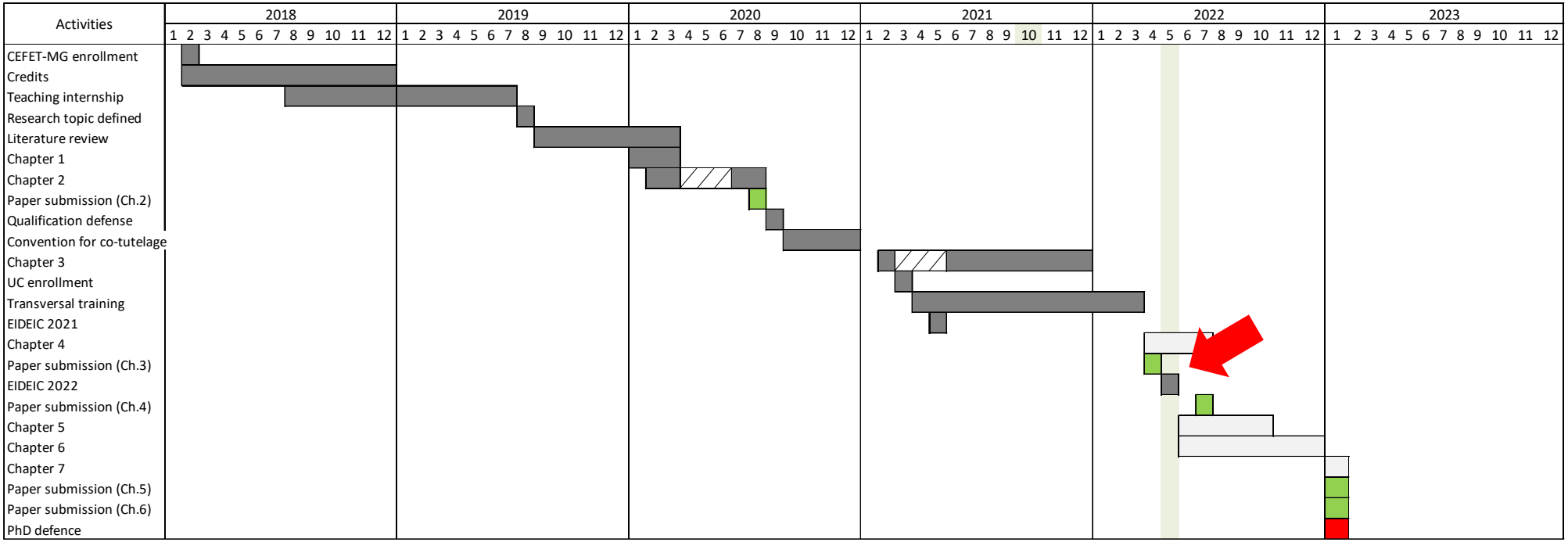
Chapter 6 presents the LCA studies of the SS-based AAM developed in Chapter 5 – specific objective (v). It will lead to the following paper: "**Life cycle assessment of BOF steel slag based AAM containing BOF steel slag as aggregate**".

CHAPTER 6. LIFE CYCLE ASSESSMENT OF BOF STEEL SLAG BASED AAM CONTAINING BOF STEEL SLAG AS AGGREGATE

The aim of this chapter is to present a life cycle assessment (LCA) of SS based AAM containing only SS as aggregate. A material´s environment impact is often equated with its effects on greenhouse gas emissions and climate change. The LCA approach compares the environment impact (not only the GHG) of a strength and service life related functional unit (FU) over the material´s entire life cycle (production, use and end-of-life). The scope (system boundaries and allocation rules), inventory database, analysis, and interpretation of the impact are still to be determined.


Timetable

Timetable



- Now -> EIDEIC 2022 (May, 20)
- Expected thesis submission date -> January 2023

Any questions?

Muchas gracias.

VITOR ALENCAR NUNES

vitor.alencar@alumnos.unican.es

+55 (31) 98816-9192

Acknowledgments