ICBBM 2021

PROGRAMME AND PRACTICAL INFORMATION

16-18 June 2021, Barcelona, Spain

4th International Conference on Bio-based Building Materials

50 ANYS UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH sense Limits

UNIVERSITÉ Clermont Auvergne

INSTITUT PASCAL

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GdR MBS MATÉRIAUX de CONSTRUCTION BIOSOURCÉS

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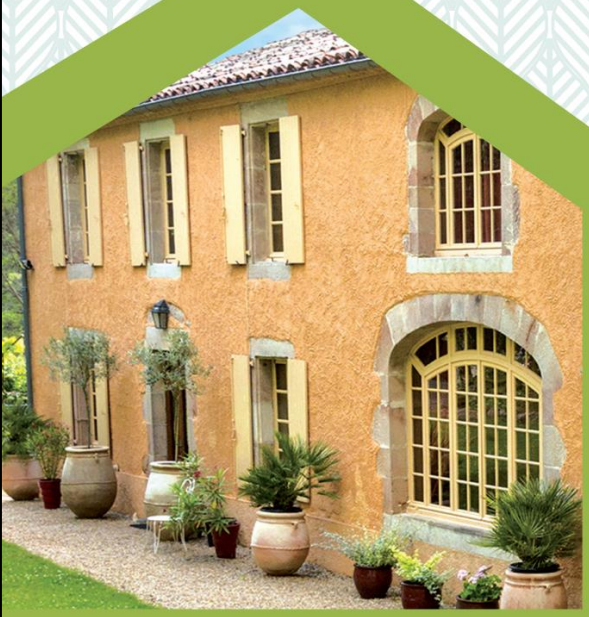
Solutions biosourcées par PAREXLANKO

PARNATUR CORPS D'ENDUIT CHANVRE

THE BIO-BASED MORTAR TO REDUCE CO_2 EMISSIONS BY PAREXLANKO

PARNATUR CORPS D'ENDUIT CHANVRE is the first **"easy-to-spray" thermal and phonic insulation hemp-based mortar for old masonry**. **PARNATUR** could be applied in 2 to 8 cm depth for an internal or external insulation and has to be covered with a protective and decorative layer to ensure his good performances.



PARNATUR CORPS D'ENDUIT CHANVRE BENEFITS

- Provides thermal and phonic insulation benefits thanks to the continuous envelope that prevents thermal leakage (thermal conductivity 0,066 W/m.K)
- Comfort: inertia building improvement thanks to his low diffusivity (0.179 mm^2/s) and high effusivity (156 $J/K.m^2.s1/2$)
- Perfect for renovation and leveling of uneven surfaces since thickness of the coat can be adapted
- Respects the breathability of old walls providing optimum air interior comfort
- Low carbon footprint material : high hemp content and innovative mineral binder
- Easy to apply with a standard spraying machine

CSTB le futur en construction

FABRIQUÉ EN FRANCE

Produit biosourcé 25%

construire en CHANVRE

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Welcome to ICBBM 2021

Dear colleagues,

Despite the exceptional COVID-pandemic situation we have been experiencing for over a year around the world, we have maintained our ICBBM face-to-face event in Barcelona as planned in Belfast in June 2019. This decision is made necessary by the fact that we believe that presentation of progress in knowledge and intense exchanges cannot wait several more months.

Yes, the climate change is much more dramatic for humanity and it is urgent for us to change our ways of building. Yes, we have the immense responsibility to continue our march forward with taking the maximum sanitary precautions.

This march we started in 2015 while the first International Conference on Bio-based Building Materials (3BM) ICBBM2015 was organised in Clermont-Ferrand. More than 150 participants from 32 countries attended the conference. Approximately 120 papers were selected for publications in the proceedings. In 2017 a significant progress has been made in the research, development and implementation of 3BM. In 2017, the second International Conference on Bio-Based Building Materials ICBBM-EcoGrafi 2017 was held in the same city. More than 260 participants from a wide range of academics, researchers, students, designers and policy makers and end-users from 40 countries and 130 papers were presented at the conference. The third series ICBBM2019 was held on 26-28 June 2019 in Belfast (UK) with more than 150 people (https://www.qub.ac.uk/sites/ICBBM2019/).

ICBBM2021 is an international forum for information dissemination and exchange, discussions and debates on research and practice related to innovative bio-construction materials and technologies with objectives for sustainable development. The purpose of this international conference is to present the latest available scientific and technical information in the field of bio-based building materials. To dynamically address these, and to capitalise real opportunities which they present for the future, University Clermont Auvergne, Queen's University Belfast and Universitat Politècnica de Catalunya bring together leading building and civil engineering sector players and international experts, and other key stakeholders for what promises to be a landmark event in 2021's professional and business calendar. Working together in an international context is nowadays a basic condition for progress.

The conference attracted 180 people a wide range of academics, scientists, researchers, students, designers, policy makers and other industrialists from a wide variety of backgrounds, including fields of engineering, materials, sustainable, architecture, and ecological technologies, biomaterials, materials sciences, environmental engineering and government agencies, end-users, etc. Participants have the opportunity to share ideas on the state-of-the-art innovations, state-of- the-practice and future trends of bio-based building materials and sustainable materials used in construction.

The ICBBM2021 proceedings include the keynote lectures and papers presented at ICBBM2021 conference. It consists of a book of full texts of papers and extended abstracts: 8 plenary papers and 160 papers from over 28 countries. The plenary keynotes and papers cover the wide spectrum of the topics related to Natural fibres and materials, Mechanical performances of bio-based building materials and design properties, Hygroscopic and hygrothermal properties of biomaterials, Acoustic and durability performance of bio-materials, sustainability of bio-based materials, Agro-by products, treatment of fibres, Eco-friendly binders with low CO2-emission and Low embodied carbon energy, Advances in research methodologies and Bio-materials testing, modeling building materials Rammed earth, Life-cycle assessment of materials, recycling materials, and others.

On behalf of the Local Organizing Committee of ICBBM2021, we would like to take this opportunity to express our sincere thanks to all our contributors and participants for their carefully prepared, stimulating and thought provoking manuscripts; to the organisers of conference for their dedicated task.

Thanks are extended to the members of the International scientific committee to review the papers. Without their dedicated efforts, the proceedings could not have been published for distribution at the conference. The cooperation of the authors in accepting reviewers' suggestions and revising their manuscripts accordingly is greatly appreciated.

The organisation of a conference of this scale could not have been possible without the support and contributions of many organisations and individuals. This conference would not have been possible without the financial support given by two gold sponsors (Parexlanko and Vicat). We also value the financial support of Association Universitaire de Génie Civil AUGC and GdR MBS Matériaux de construction biosourcés (CNRS). We also thanks RILEM organization (The International Union of Laboratories and Experts in Construction Materials, Systems and Structures) for the promotion of our conference.

Thanks go to all those who have devoted their time and effort to the organization of the conference, specially Prof Evelyne Toussaint from University of Clermont Auvergne (France), and publication of the proceedings, specially Associate Professor Jonathan Page from University d'Artois (France) including secretarial staffs and research students of Universitat Politècnica de Catalunya (Spain) for their diligent work in bringing this ICBBM2021 to success!

Barcelona, 15th June 2021

Chairs of the conference
Sofiane Amziane – University of Clermont Auvergne (France)
Mohammed Sonebi – Queens University Belfast (UK)

Local organisers of the conference
Mònica Ardanuy - Universitat Politècnica de Catalunya (Spain)
Laia Haurie Ibarra- Universitat Politècnica de Catalunya (Spain)

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Committees

Conference Chair

Prof. Sofiane Amziane

Université Clermont Auvergne, Institut Pascal - CNRS, Clermont-Ferrand, France

Dr. Mohammed Sonebi

Queen's University Belfast, School of Natural and Built Environment, Belfast, UK

Co-chair

Dr. Laia Haurie

Universitat Politècnica de Catalunya, Department of Architecture Technology, Barcelona, Spain

Prof. Mònica Ardanuy

Universitat Politècnica de Catalunya, Department of Materials Science and Engineering, Barcelona, Spain

Committees

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Construction & Building Technology

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Construction & Building Technology

Dr. Mariana Palumbo
Construction & Building Technology

Alina Avellaneda
Construction & Building Technology

Dr. Mònica Ardanuy
PhD
Materials Engineering & Textile Engineering

Dr. Josep Claramunt
PhD
Construction & Building Technology

Dr. Heura Ventura
Textile Engineering & Industrial Design

Dr. Pilar Giraldo
Construction & Building Technology

Other Organizing Committee

Dr. Jonathan Page

Université d'Artois, LGCgE, Béthune, France

Prof. Evelyne Toussaint

Université Clermont Auvergne, Institut Pascal - CNRS, Clermont-Ferrand, France

Committees

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J. Khatib, Beirut Arab University, Lebanon
A. Olonade Kolawole, University of Lagos, Nigeria
R. N. Krishna, Contech, Chaennai, India
G. Senthil Kumaran, UR-CST, Rwanda
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C. Magniont, Toulouse Paul Sabatier University, France
S. Marceau, Gustave Eiffel University, France
S. Mertens, BBRI, Belgium
I. Merta, Institute of Material Technology, Austria
P. Nadrah, SNBI, Slovenia
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L. Nunes, LNEC, Lisbon, Portugal
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R.D. Toledo Filho, University Fed. Rio de Janeiro, Brazil
Y. Xiao, ZJjui, Zhejiang University, China

Keynote Speakers

Rafat SIDDIQUE

Use of Industrial Byproducts in Design and Development of Sustainable Greener Concrete for Circular Economy
DAY 1 (Wednesday 16th June), 9:00 - 9:30

Prof. Rafat Siddique is Dean, Research & Sponsored and Senior Professor of Civil Engineering at Thapar Institute of Engineering & Technology, Patiala. He is amongst the top 15 academicians/researchers in the area of Sustainable Construction Materials" with Google Citations of 12000+ having H-Index of 61. He is Editor of Construction and Building Materials (Elsevier); Associate Editor, Journal of Materials in Civil Engineering (ASCE); Editorial Board members of various journals of Elsevier. He has been Visiting/Invited Professor to number of universities in Bangkok, France, Germany, U.K., Australia and USA. He is prolific speaker, and delivered keynote/Invited lectures in number of Universities in USA, UK, Australia, China, and other parts of the world by visiting Australia, Bangkok, Belgium, Botswana, Burkina Faso, Canada, China, Czech Republic, etc.

Mariana PALUMBO

Bio-based decarbonisation
DAY 1 (Wednesday 16th June), 9:30 - 10:00

Mariana Palumbo is lecturer and scientist at the Vallès School of Architecture (ETSAV) of the Universitat Politècnica de Catalunya and member of the Interdisciplinary Group on Building Science and Technology (GICITED). Her research has focused on the development, characterisation and optimisation of construction elements and systems based on bio-based materials. She is currently investigator in the Interreg Poctefa SAVASCO project, which aims to transfer technology through a pilot project for the production of construction materials based on agricultural by-products. It brings together all the actors in the value chain evaluating its social and environmental impact. She also works on the analysis, diagnosis and intervention in energy and material flows associated with urban metabolism. Her work aims to contribute to closing the material cycles associated with the built environment and reducing its environmental impact. In addition to her work in the academic field, she has been carrying out technology transfer and architectural experimentation activities under the umbrella of the Map13 Barcelona studio, as a founding partner.

Patience TUNJI-OLAYENI

Adoption and Diffusion of Bio-Based Building Materials (3BM) through Active Stakeholder Engagement: A case of Bio-Based Supplementary Cementitious Materials (2BSCMs)

DAY 1 (Wednesday 16th June), 13:45 - 14:15

Dr. Patience Tunji-Olayeni is a Senior Lecturer in the Department of Building Technology, Covenant University, Nigeria. Her vision is to raise a new breed of construction professionals with environmental and social consciousness who will transform the construction landscape through active research and exemplar projects for the sustainable existence of the planet. Patience has keen interests in construction management, construction education, gender issues in construction and sustainable/green construction. By the grace of God, she has over 80 peer reviewed articles in journals and conference proceedings indexed in the Scopus data base, a Scopus H-index of 10, and over 600 citations on the google scholar platform. Patience is a reviewer of several journals including the International Journal of Construction Management, Journal of Cleaner Production and Case Studies in Construction Materials. Patience enjoys volunteering and mentoring young people.

Jamal KHATIB

The potential use of Bio-Fibers in the Eastern Mediterranean Construction Industry

DAY 1 (Wednesday 16th June), 14:15 - 14:45

Jamal Khatib is presently Professor of Civil Engineering at the Faculty Engineering at Beirut Arab University (Lebanon) and Emeritus Professor of the University of Wolverhampton (UK). Prof Khatib was one of the early UK researchers who conducted research on metakaolin as partial substitution of cement and his publications in this area have been extensively cited. The products of his extensive research activities have been comprehensively disseminated through: over 400 refereed academic journal & conference papers, text books, abstracts, research seminars and workshops; articles and features. According to WoS, Scopus and Google Scholar, Prof Khatib has an H-index of 23, 25 and 33 respectively. According to a study conducted by Stanford University in October 2020, Prof Khatib was classified as one of the top 2% researchers in the world in the building and construction field.the building and construction field.

Keynote Speakers

Raul FANGUERO

Natural Fibers: from nano to macro scale
DAY 2 (Thursday 17th June), 9:00 - 9:30

Raul Fangueiro is currently professor and senior researcher in the School of Engineering at the University of Minho, Portugal. He is the Head of the Fibrous Materials Research Group of the same university with expertise in advanced materials (nano, smart, composites) and structures (3D, auxetic, multiscale) with 25 researchers. He is the mentor and the coordinator of the FIBRENAMICS International Platform (www.fibrenamics.com) including 200 partners developing promotion, dissemination, technology transfer and research activities on fiber-based advanced materials. He has more than 115 published papers in international reputed scientific journals, 350 conference publications, 36 books and 14 patents. He is the scientific coordinator of several national and international research projects on advanced fibrous and composite materials, manly for building, architectural and health-care applications. He supervised various PhD and Pos-Doc scientific works and is an expert of the European Technological Textile Platform and member of the editorial board of several leading international scientific journals on composite and fibrous materials.

Ildiko MERTA

Advanced natural fibre reinforced composites : Potentials and challenges
DAY 2 (Thursday 17th June), 9:30 - 10:00

Ildiko Merta is a senior scientist at the Institute of Material Technology, Building Physics, and Building Ecology of the Faculty of Civil Engineering at the TU Wien, Austria. Her research is focusing on the development, characterisation and optimisation of bio-based high-performance composite building materials with enhanced environmental sustainability, circular-based design approach and improved durability toward their application in civil engineering structures. She was a Hertha Firnberg Fellow of the Austrian Science Fund (FWF) for outstanding female scientists at the TU Wien. As a recognition of her outstanding research achievements in area of bio-based sustainable cementitious building materials, she was awarded by the Sustainability Award (2016), the Award for Excellent Female Scientist (BAWAG PSK, 2013), the Energy Globe Award (2019) and the i²c START Academy Award (2020) in Austria. Ildiko Merta is strongly involved in the activities of the international scientific community, she authored/co-authored more than 100 high-impact scientific publications and gave more than 40 presentations at international conferences. She serves continuously as a reviewer for more than 20 scientific journals in area of building materials science, for science foundations and as an expert evaluator for the EU Commission.

Bruce PLAYLE

Bioregional Design : Toward Zero Carbon Future, Naturally !

DAY 2 (Thursday 17th June), 14:00 - 14:30

A founding principal of Davis, California based Indigo Hammond + Playle Architects, Mr. Playle has over 40 years of experience serving civic, educational, and corporate clients. He has been an innovator in the areas of bioregional design and straw bale construction for many years. After hurricane Katrina devastated New Orleans in 2005, he realized that bioregional design methods could help make buildings more survivable and serviceable. He has been practicing resilient building design ever since, completing numerous public safety buildings with this in mind. He is a recognized subject matter leader in the field and is a frequent speaker to national audiences, including national conferences of the American Institute of Architects. Presently, he serves as principal-in-charge of several public safety buildings and serves as a zero-net-energy consultant to the State of California. His work has been recognized by the U.S. Green Building Council Northern California and the International Living Building Future Institute.

Alessandro FANTILLI

Sheep wool as fiber-reinforcement of gypsum composites

DAY 3 (Friday 18th June), 12:30 - 13:00

Alessandro P. Fantilli is an Associate Professor in the Department of Structural, Building, and Geotechnical Engineering of Politecnico di Torino, Turin, Italy. He received his MS and PhD from Politecnico di Torino. His research interests include nonlinear analysis of concrete structures and structural applications and sustainability of high-performance fiber-reinforced cementitious concrete.

Wi-Fi informations

Connecting to UPC Wi-Fi

- Eduroam: in order to connect to Wi-Fi you can use eduroam from your institution.
- UPCGuest connection. It provides an Internet connection for any visitor who is not a member of the UPC community or comes from an institution that is not adhered to eduroam.

1- Select UPCguest from the list of available Wi-Fi connections on your mobile device.

2- Open a browser and the UPCguest main page will be shown (https://upcguest-portal.upc.edu/)

3- Complete the registration process providing an email address and a mobile phone number with the format **00 + country code + mobile phone number. Example: 0033654789555**

4- An SMS will be sent to the mobile phone number providing you with an activation code.

5- Enter the code in the activation form to start the connection.

How long can I be connected to UPCGuest?

The code for UPCguest you received via SMS will be valid for 30 days.

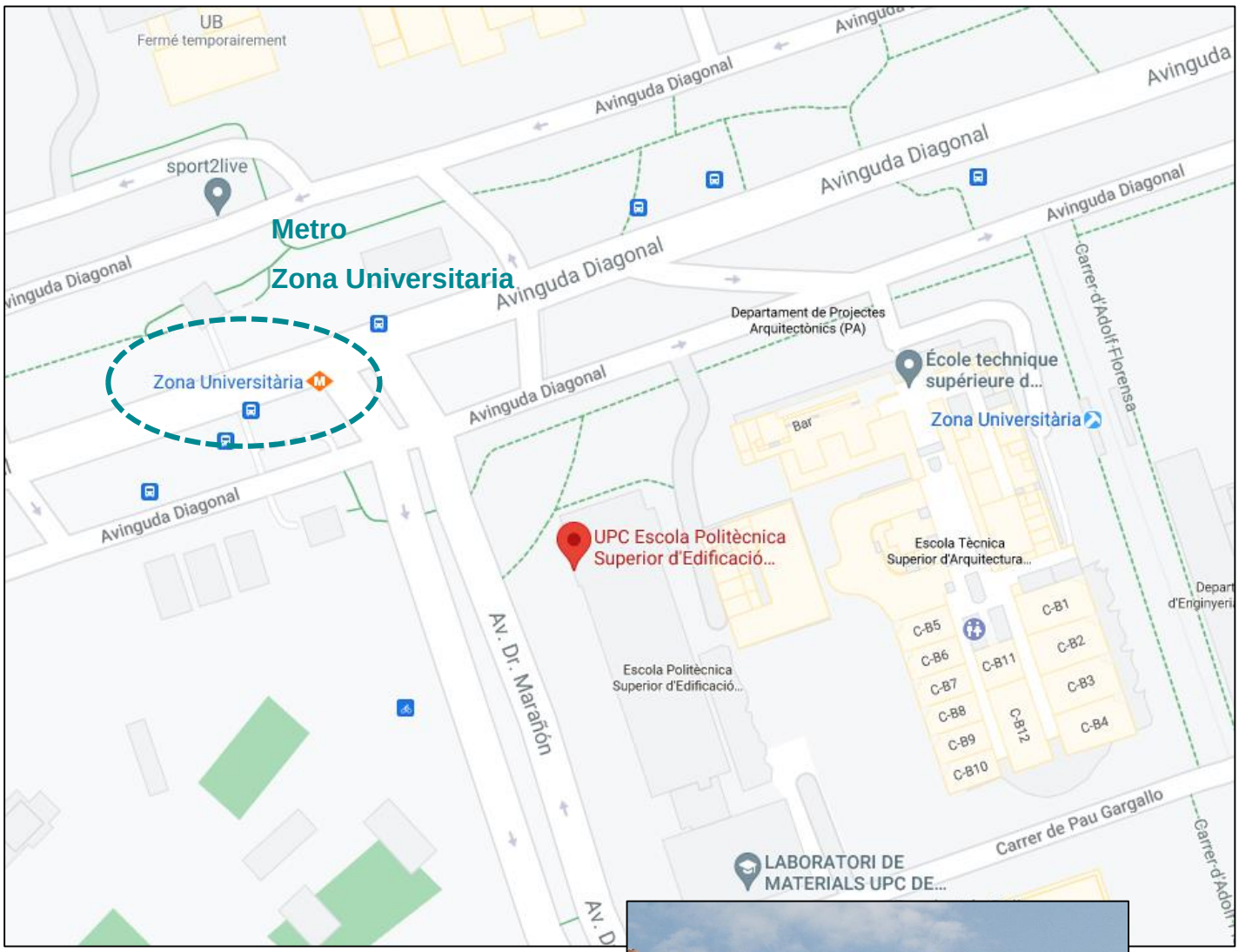
The maximum lenth of the connection is of 8 hours, at that point the connection will be interrupted and you will have to activate it again on the UPCguest main page using the same original code you received via SMS.

Conference venue

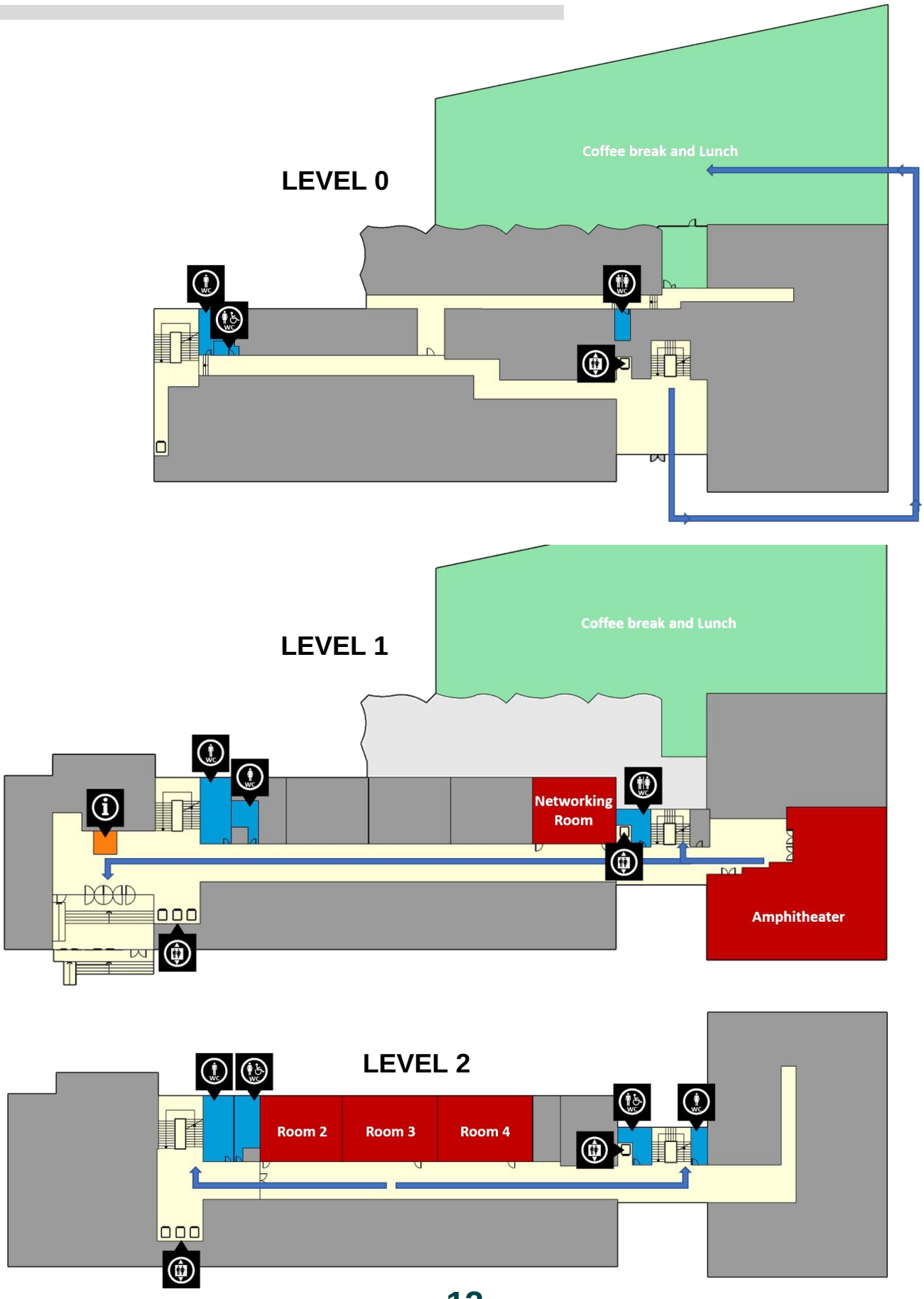
ICBBM21 will be held in the **Barcelona School of Building Construction (EPSEB)** of the Universitat Politècnica de Catalunya – Barcelona Tech

UPC Escola Politècnica Superior d'Edificació de Barcelona (EPSEB)

Av. Dr. Marañón, 44-50, 08028 Barcelona, Espagne



Conference venue



Online informations

Zoom

Zoom will be used to join the online presentations.

The details and instructions for Zoom connection will be available one day before the conference starts (Tuesday 15th, June).

Each room in the conference venue will be equipped with a computer and a camera, so that participants can join a zoom meeting and connect with other panel members.

Online participants will be able to engage with onsite speakers via the Zoom chat interface, leaving questions and comments in the chat window, which the session moderator can navigate through.

Conference Agenda

DAY 0 : TUESDAY 15th June

Date: Tuesday, 15/June/2021	
4:00pm - 7:00pm	**Registration** Location: **Barcelona School of Building Construction (EPSEB) of the Universitat Politècnica de Catalunya**

DAY 1 : WEDNESDAY 16th June

Date: Wednesday, 16/June/2021				
8:00am - 8:30am	**Registration** Location: **Barcelona School of Building Construction (EPSEB) of the Universitat Politècnica de Catalunya**			
8:30am - 9:00am	**Opening Ceremony** Location: **Amphiteater (Plenary)** Chair: **Prof. S. Amziane**, Université Clermont Auvergne Chair: **Dr. M Sonebi**, Queen's University Belfast			
9:00am - 9:30am	**Key note 1 : Rafat Siddique, India** Location: **Amphiteater (Plenary)** Chair: **Prof. Monica Ardanuy**, Universitat Politècnica de Catalunya			
9:30am - 10:00am	**Key note 2 : Mariana Palumbo, Spain** Location: **Amphiteater (Plenary)** Chair: **Prof. Monica Ardanuy**, Universitat Politècnica de Catalunya			
10:00am - 10:30am	**Coffee Break** Location: **Barcelona School of Building Construction (EPSEB) of the Universitat Politècnica de Catalunya**			
10:30am - 12:30pm	**Natural reinforcements** Location: **Amphiteater** Chair: **Su Taylor**, QUB	**Cementitous composites** Location: **Room 2** Chair: **Laetitia Bessette**, Vicat	**Material treatments** Location: **Room 3** Chair: **Vincent Sabathier**, LMDC	**Mechanical Properties 1** Location: **Room 4** Chair: **Jonathan Page**, Université d'Artois
12:15pm - 1:45pm	**Lunch** Location: **Barcelona School of Building Construction (EPSEB) of the Universitat Politècnica de Catalunya**			
1:45pm - 2:15pm	**Key note 3 : Patience Tunji-Olayeni, Nigeria** Location: **Amphiteater (Plenary)** Chair: **Prof. Evelyne Toussaint**, Université Clermont Auvergne			
2:15pm - 2:45pm	**Key note 4 : Jamal Khatib, Lebanon** Location: **Amphiteater (Plenary)** Chair: **Prof. Evelyne Toussaint**, Université Clermont Auvergne			
2:45pm - 3:30pm	**Poster Flash talks 1** Location: **Amphiteater (Plenary)** Chair: **Dr. Laia Haurie**, Universitat Politècnica de Catalunya			
3:30pm - 4:00pm	**Coffee Break** Location: **Barcelona School of Building Construction (EPSEB) of the Universitat Politècnica de Catalunya**			
4:00pm - 6:00pm	**Case studies 1** Location: **Amphiteater** Chair: **Christophe Lanos**, Université Rennes 1	**Durability 1** Location: **Room 2** Chair: **Sandrine Marceau**, Université Gustave Eiffel	**Mechanical Properties 2** Location: **Room 3** Chair: **Mahfoud Tahlaiti**, ICAM	**Test methodology** Location: **Room 4** Chair: **Malo Leguern**, ESITC Caen

Conference Agenda

DAY 2 : THURSDAY 17th June

Date: Thursday, 17/June/2021				
9:00am - 9:30am	**Key note 5 : Raul Fanguero, Portugal** Location: **Amphiteater (Plenary)** Chair: **Pr. Sofiane Amziane**, Université Clermont Auvergne			
9:30am - 10:00am	**Key note 6 : Merta Ildiko, Austria** Location: **Amphiteater (Plenary)** Chair: **Pr. Sofiane Amziane**, Université Clermont Auvergne			
10:00am - 10:30am	**Coffee Break** Location: **Barcelona School of Building Construction (EPSEB) of the Universitat Politècnica de Catalunya**			
10:30am - 12:30pm	**Earth materials 1** Location: **Amphiteater** Chair: **Philippe Evon**, LCA-ENSIACET	**Hygrothermal properties 1** Location: **Room 2** Chair: **Salah Eddine Ouldboukhitine**, IUT Clermont Auvergne, Institut Pascal	**Innovative admixtures 1** Location: **Room 3** Chair: **Elhem Ghorbel**, CY Cergy Paris Université, L2MGC	**Valorisation of agricultural by-products** Location: **Room 4** Chair: **Philippe Poullain**, Université de Nantes
12:30pm - 2:00pm	**Lunch** Location: **Barcelona School of Building Construction (EPSEB) of the Universitat Politècnica de Catalunya**			
2:00pm - 2:30pm	**Key Note 7 : Bruce Playle, USA** Location: **Amphiteater (Plenary)** Chair: **Dr. Stéphanie BONNET**, Université de Nantes			
2:30pm - 3:10pm	**Poster Flash talks 2** Location: **Amphiteater (Plenary)** Chair: **Dr. Stéphanie BONNET**, Université de Nantes			
3:10pm - 3:40pm	**Coffea Break** Location: **Barcelona School of Building Construction (EPSEB) of the Universitat Politècnica de Catalunya**			
3:40pm - 5:40pm	**Earth Materials 2, concrete, bamboo** Location: **Amphiteater** Chair: **Francesco Pittau**, Politecnico di Milano	**Hygrothermal properties 2** Location: **Room 2** Chair: **Camille Magniont**, LMDC	**LCA** Location: **Room 3** Chair: **Thibaut Lecompte**, IRDL-Univ.de Bretagne-Sud	**Mechanical Properties 3** Location: **Room 4** Chair: **Mohammed Sonebi**, Queen's University Belfast
5:45pm - 11:00pm	**Banquet**			

Conference Agenda

DAY 3 : FRIDAY 18th June

Date: Friday, 18/June/2021				
9:00am - 10:40am	**Case studies 2** Location: **Amphiteater** Chair: **Belén Gonzalez-Fonteboa**, University of A Coruña	**Earth Materials 3** Location: **Room 2** Chair: **Céline Perlot**, UPPA	**Innovative admixtures 2** Location: **Room 3** Chair: **Ildiko Merta**, TU Wien	**Modeling** Location: **Room 4** Chair: **Heura Ventura**, Universitat Politècnica de Catalunya
10:40am - 11:10am	**Coffee Break** Location: **Barcelona School of Building Construction (EPSEB) of the Universitat Politècnica de Catalunya**			
11:10am - 12:30pm	**Acoustics** Location: **Amphiteater** Chair: **Sylvie Prétot**, LGCGM - université de Rennes1	**Durability 2** Location: **Room 2** Chair: **Philippe Glé**, Cerema	**Hygrothermal properties 3** Location: **Room 3** Chair: **Florence Collet**, Université de Rennes 1	**Other Innovative Materials** Location: **Room 4** Chair: **Kamilia Abahri**, ENS Paris Saclay
12:30pm - 1:00pm	**Key note 8 : Alessandro Fantilli, Italia** Location: **Amphiteater (Plenary)** Chair: **Dr. Mariana Palumbo**, Universitat Politècnica de Catalunya			
1:00pm - 1:15pm	**Closing Ceremony** Location: **Amphiteater (Plenary)** Chair: **Prof. S. Amziane**, Université Clermont Auvergne Chair: **Dr. M Sonebi**, Queen's University Belfast			
1:15pm - 2:15pm	**Lunch** Location: **Barcelona School of Building Construction (EPSEB) of the Universitat Politècnica de Catalunya**			

Keynote speakers

Keynote 1 : Rafat SIDDIQUE

Use of Industrial Byproducts in Design and Development of Sustainable Greener Concrete for Circular Economy

Time:

Wednesday, 16/June/2021: 9:00am - 9:30am

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Monica Ardanuy**, Universitat Politècnica de Catalunya

Keynote 2 : Mariana PALUMBO

Bio-based decarbonisation

Time:

Wednesday, 16/June/2021: 9:30am - 10:00am

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Monica Ardanuy**, Universitat Politècnica de Catalunya

Keynote 3 : Patience TUNJI-OLAYENI

Adoption and Diffusion of Bio-Based Building Materials (3BM) through Active Stakeholder Engagement: A case of Bio-Based Supplementary Cementitious Materials (2BSCMs)

Time:

Wednesday, 16/June/2021: 1:45pm - 2:15pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Evelyne Toussaint**, Université Clermont Auvergne

Keynote 4 : Jamal KHATIB

The potential use of Bio-Fibers in the Eastern Mediterranean Construction Industry

Time:

Wednesday, 16/June/2021: 2:15pm - 2:45pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Evelyne Toussaint**, Université Clermont Auvergne

Keynote 5 : Raul FANGUERO

Natural Fibers: from nano to macro scale

Time:

Thursday, 17/June/2021: 9:00am - 9:30am

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Sofiane Amziane**, Université Clermont Auvergne

Keynote 6 : Ildiko MERTA

Advanced natural fibre reinforced composites-potentials and challenges

Time:

Thursday, 17/June/2021: 9:30am - 10:00am

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Sofiane Amziane**, Université Clermont Auvergne

Keynote 7 : Bruce PLAYLE

Bioregional Design : Toward Zero Carbon Future, Naturally!

Time:

Thursday, 17/June/2021: 2:00pm - 2:30pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Ana Maria Lacasta**, Universitat Politècnica de Catalunya

Keynote 8 : Alessandro FANTILLI

Sheep wool as fiber reinforcement of gypsum composites

Time:

Friday, 18/June/2021: 12:30pm - 1:00pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Mariana Palumbo**, Universitat Politècnica de Catalunya

Natural reinforcements

Time:
Wednesday, 16/June/2021: 10:30am - 12:30pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB) 300

Session Chair: **Su Taylor**, Queen's University Belfast

(ID: 275)

SHEAR BEHAVIOR OF BAMBOO REINFORCED CONCRETE BEAMS

Jamal Khatib[1], Ali Hussein Jahami[1], Mohamed Sonebi[2], Adel Elkordi[1]
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This research work aimed to study the usage of Bamboo strips as shear reinforcement in reinforced concrete (RC) beams. Four beams were considered in this study. The flexural reinforcement for all beams was the same. As for shear reinforcement, one beam was reinforced with conventional shear reinforcement with spacing (s=180 mm), while the other three beams were reinforced with bamboo strips with three different spacings (s=180 mm, s= 90 mm, and s=60 mm). The beams were subjected to a four-point bending test to plot the load-deflection curve for each beam. Results showed that the beam reinforced with bamboo strips spaced at 180 mm has 30% higher shear capacity than the beam with conventional shear reinforcement at the same spacing. Also, as the spacing of bamboo strips decreased, the shear capacity of beams increased nonlinearly.

(ID: 219)

PRELIMINARY STUDY ON NEW MICRO TEXTILE WASTE FIBER REINFORCED CEMENT COMPOSITE

Payam Sadrolodabaee, Josep Claramunt, Monica Ardanuy, Albert de la Fuentea
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Large amounts of nonrenewable resources are depleted by the construction industry in addition to the generation of million tons of mineral waste and carbon dioxide gas every year. For the sake of a more sustainable consumption pattern of building materials, as well as for reducing the waste flux to landfills, the use of recycled materials and wastes should be researched and motivated. One of the promising wastes is textile waste from residues of the garments and textile industries. The recycling and reusing of textile waste would be beneficial for reducing CO2 emissions and energy intake. In this sense, there are already some studies regarding the thermal behavior of this type of material, however, the engineering design properties of textile waste fiber reinforced cement composites to identify the proper application have not been deeply investigated. Hence, the objective of this study was to evaluate the potentiality of using textile waste fiber as reinforcement in the cement paste. To this end, the composites with three different treatments were made and the optimum treatment was chosen based on the flexural test. The result is the feasibility of using this kind of fiber as reinforcement of mortar elements with dewatering treatment.

(ID: 273)

FLEXURAL BEHAVIOR OF SIX SPECIES OF ITALIAN BAMBOO

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The good mechanical performance of bamboo, coupled with its sustainability, has boosted the idea to use it as a structural material. In some areas of the world it is regularly used in constructions but there are still countries in which there is a lack of knowledge of the mechanical properties of the locally-grown bamboo, which limits the spread of this material.

Bamboo is optimized to resist to flexural actions with its peculiar micro structure along the thickness in which the amount of fibers intensifies towards the outer layer and the inner part is composed mostly of parenchyma. The flexural strength depends on the amount of fibers, whereas the flexural ductility is correlated to the parenchyma content.

This study focuses on the flexural strength and ductility of six different species of untreated bamboo grown in Italy. A four-point bending test was carried out on bamboo strips in two different loading configurations relating to its microstructure. Deformation data are acquired from two strain gauges in the upper and lower part of the bamboo beam. Difference in shape and size of Italian bamboo species compared to the ones traditionally used results in added complexity when performing the tests. Such difficulties and the found solutions are also described in this work.

The main goal is to reveal the flexural behavior of Italian bamboo as a functionally graded material and to expand the knowledge of European bamboo species toward its use as a structural material not only as culm but also as laminated material.

(ID: 298)

DURABILITY OF BAMBOO BIO-CONCRETE EXPOSED TO NATURAL AGING

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In recent years, several studies on the durability of cementitious materials combined with vegetable fibers have been developed. In order to understand the properties of these materials in different environmental conditions, they can be subjected to accelerated aging through several cycles of controlled variations of humidity-temperature, wetting-drying, freezing-thawing. However, analyzes that expose such materials to real conditions of use during their useful life are scarce. As a result, this study analyzed the physical, thermal and mechanical behavior of bamboo bio-concretes produced with different volumes of bio-aggregates, which were exposed to the natural aging of the summer in the city of Rio de Janeiro (Brazil). The cementitious binder was is composed, by mass, of cement (30%), metakaolin (30%) and fly ash (40%). The water-to-cement ratio was as 0.30. The mixtures were produced with bamboo volumetric fraction of 30%; 40% and 50%. After 3 months of natural aging during the

Brazilian summer (from December to March), the property determined in the hardened state was the compressive strength. In addition, a visual analysis by photograph was also realize. The results revealed that higher the volumetric fraction, higher the decrease of compressive strength. The visual analysis showed several changes of the external aspect of the bio-concretes.

(ID: 105)

MECHANICAL PROPERTIES AND DURABILITY OF BAMBOO FIBERS/BAMBOO-FIBER-MIXED SPRAY MORTAR FOR SLOPE PROTECTION

Kazuo Fujiyoshi[1], Takao Ueda[2], Hitoshi Takagi[2], Masayuki Tsukagoshi[3]

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Conventionally, short fibers such as steel and synthetic fibers have been mixed into spray mortar used for slope protection to enhance resistance against cracking and durability. However, in the quest of higher performance fiber-reinforced mortar with reduced impact on the environment, natural fibers such as bamboo fibers may play a vital role. Thus, the tensile strength and the bond strength of bamboo fibers used for spray mortar were examined by laboratory tests. The mechanical properties of bamboo-fiber-reinforced spray mortar were examined under cyclic wet and dry conditions along with its resistance against freezing and thawing by a spray test. It was confirmed that 0.75% mixture of bamboo fibers in spray mortar successfully improved mechanical properties and durability. These include adhesion strength to the base surface following exposure to cyclic wet/dry conditions and overall resistance against freezing/thawing. Moreover, higher compressive strength, flexural toughness and adhesion strength to the base surface were achieved by further mixing in vinylon fibers or fly ash in addition to bamboo fibers.

(ID: 203)

DEVELOPMENT OF GHG EMISSIONS CURVES FOR BIO-CONCRETES SPECIFICATION: CASE STUDY FOR BAMBOO, RICE HUSK, AND WOOD SHAVINGS CONSIDERING THE CONTEXT OF DIFFERENT COUNTRIES

Lucas Rosse Caldas[1,2], Carolina Bezerra[1], Francesco Pittau[3], Arthur Araújo[1], Mariana Franco[1], Nicole Hasparyk[4], Romildo Toledo Filho[1]

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Bio-concretes are receiving special attention in recent research as an alternative for climate change mitigation due to their low carbon footprints. Different bio-based materials can be used, e.g., wood shavings, bamboo, rice husk, and coconut. However, various methodological parameters can influence the carbon footprint of bio-based materials, especially bio-concretes, like biogenic carbon, amount of carbon in dry matter, rotation period of bio-aggregates, and type of cementitious materials. It is important to have easier ways of estimating the carbon footprint of bio-concretes, using parameters and data easily available. This research aims to evaluate the (1) carbon footprint of different mixtures of three bio-concretes (wood bio-concrete - WBC, bamboo bio-concrete - BBC and rice husk bio-concrete - RBC), and the (2) development of GHG emissions curves for bio-concretes specification based on easily available data (such as density, biomass content, and compressive strength). Based on experimental data, the carbon footprint was performed using the Life Cycle Assessment (LCA) methodology. In order to extend the findings of this study, the context of the following four countries was evaluated: Brazil, South Africa, India, and China. In addition, the replacement of Portland cement for Supplementary Cementitious Materials (SCMs) are evaluated hypothetically. The results show that the increase of biomass content in bio-concretes and the replacement of Portland cement by SCMs leads to a radical decrease in life cycle GHG emissions. The percentage of carbon in biomass is a critical factor for reducing the carbon footprint. The WBC was the biomass that performed better for this parameter. The presented GHG emissions curves can be a useful way to estimate the carbon footprint of bio-concretes and can be adapted to other kinds of bio-concretes and countries.

Cementitious composites

Time:
Wednesday, 16/June/2021: 10:30am - 12:30pm

Location: **Room 2**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Laetitia Bessette**, Vicat

(ID: 235)

INTERACTIONS OF BIOBASED RHEOLOGY MODIFYING AGENTS WITH SUPERPLASTICIZERS IN CEMENT PASTE

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Organic admixtures are an indispensable component of modern concrete. Thus, their purposeful application is not only technically and economically viable but in addition an inevitable tool to make concrete more environmentally friendly. In this context, the use of polysaccharides has increasingly gained interest in the built environment as sustainable resource for performance enhancement. However, due to its origin, biopolymers possess a vast variety of molecular structures which can result in incompatibilities with other polymers present in concrete, such as plasticizers. The present study highlights effects of the joint application of different polysaccharides such as diutan gum and different types of starches and polycarboxylates with respect to their influence on cement hydration, binding capacity of calcium ions and structural build-up of cement pastes.

(ID: 153)

A NEW APPROACH TO OPTIMISE THE GRANULAR SKELETON OF NON-SPHERICAL SHAPED BIO-BASED MATERIALS: APPLICATION ON CEMENTITIOUS MATERIALS

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To limit the depletion of resources and to valorise waste, natural by-products can be used as potential aggregate in cementitious materials. Bio-based materials usually have a different shape than conventional aggregates and a higher porosity. Then, the direct replacement of conventional aggregates appears tricky and formulations must be adapted. This study proposes a new approach to optimise the granular packing of bio-based by-products used for full (100%) aggregate replacement applied to oyster shell (OS) mortars. The approach is based on the estimation of loose bulk and oven-dried densities of crushed OS particle classes to afterwards, optimise the porosity of the combined mixtures. To evaluate the efficiency of this new approach, the optimized skeleton is compared to three other 100% OS granular skeletons and one siliceous sand skeleton (0/4 mm). For this purpose, mortar samples were casted with these four different aggregate skeletons and compared through mechanical tests (compressive tests at 7 and 28 days). According to the granular skeleton optimisation results, the new approach shows very good results in the decrease of the porosity of the OS aggregate mixtures. Besides that, it is shown that the traditional approach of mimicking an ideal grading curve is not suitable for non-spherical aggregates such as bio-based materials because it leads to comparatively higher mixture porosity. Concerning the mechanical properties, the use of bio-based materials generally decreases the resulting material strength but the granular skeleton optimisation showed to compensate this, limiting the compressive strength loss.

(ID: 197)

IMPROVED MAGNESIUM CEMENT FOR DURABLE HEMP COMPOSITE BOARDS

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Hemp concrete is a well-known bio-based building material, but due to its relatively low compressive strength is mainly used as an insulation material with a load-bearing wooden frame. There are possibilities to expand hemp concrete application in construction by substituting traditional lime with magnesium cement. Magnesium oxychloride cement is a material already known for some time and nowadays used in building board production. Strength, lightweight, ease of use are advantages that highlight relatively new magnesium oxychloride type boards compared to traditional sheeting materials such as plywood, gypsum plasterboard and fibre-cement board. Therefore, similar parameters are thought to be reached by producing magnesium oxychloride hemp board. In this work, magnesium cement water resistance was studied and possibilities to improve it was examined by adding fly ash and nanosilica. Among the nanomaterials used in building materials, nanosilica has gained significant interest by performing a beneficial effect in improving the mechanical properties of concretes. In addition, due to its ultrafine size and high chemical reactivity, the performance of nanosilica is much better with a lower amount of admixture required. Results show that applied nanosilica slightly reduced the compressive strength of magnesium cement in a dry state, but at the same time significantly increased its water resistance. Hemp magnesium oxychloride cement board prototype samples were produced and demonstrate promising results for further manufacturing of hemp composite boards.

(ID: 175)

EFFECT OF MIX PROPORTIONS ON FRESH AND RHEOLOGICAL PROPERTIES OF CEMENTITIOUS MIXTURE CONTAINING NATURAL FIBER: MODELLING USING FACTORIAL DESIGN

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This paper aims to discuss the influence of mix composition of cement mortar on fresh and rheological properties of cement mortar. Two different natural fibers, basalt (BA) and sisal (SL) are selected based on fresh and rheological behavior for its usability in a cementitious mixture. The workability and rheological behavior are evaluated by flow table test, cone penetrometer and slump test of the mixture. A full factorial design method was used to investigate the effects of four mix components: dosage of cement content (B), percentage of fly-ash (FA) by mass of cement, dosage of basalt fiber (BA) and dosage of superplasticizer (SP) along with a water/binder ratio of 0.41. A mathematical model which predicts the main effect and interactions of these components for each of the measured properties are derived using the factorial design. The proposed mixtures consist of two levels of binder content as 550 kg/m3 and 650 kg/m3, FA as 5% and 20% by mass of cement, BA as 1 kg/m3 to 3 kg/m3 and SP as 2 kg/m3 to 4 kg/m3. By reducing the number of test batches needed, the mathematical models produced with this method can expedite optimizing the mixture proportions of cement mortar to achieve desired fresh and rheological properties.

(ID: 147)

COMPARATIVE STUDY OF METAKAOLIN AND ZEOLITE TUFF INFLUENCE ON PROPERTIES OF HIGH-STRENGTH CONCRETE

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Composite admixtures which include active pozzolanic components and high-range water reducers, allows to obtain high-strength, particularly dense and durable concrete to achieve a reduction in resources and energy consumption of manufacturing.

Zeolite, containing a significant amount of active silica, can serve as one of the alternative substances to resources and energy consuming mineral admixtures like metakaolin and silica fume. The deposits of zeolites are developed in Transcarpathia (Ukraine), USA, Japan, New Zealand, Iceland and other countries. It is known that zeolite tuffs exhibit pozzolanic properties and are capable to substitution reactions with calcium hydroxide.

However, the high dispersion of zeolite rocks leads to a significant increase in the water consumption of concrete. Simultaneous introduction of zeolite tuffs with superplasticizers, which significantly reduce the water content, creates the preconditions for their effective use in high-strength concrete.

Along with dehydrated (calcined) zeolite, natural (non-calcined) zeolite expresses itself as an effective mineral admixture of concrete. When using non-calcined zeolite, the effect of increasing in compressive strength at the age of 3 and 7 days is close to the effect obtained when using dehydrated zeolite: 8-10% and 10- 12%, respectively, and 28 days the strength growth is 13-22%. The use of non-calcined zeolite has a significant economic feasibility, so it certainly deserves attention. There were compared the effect of zeolite to metakaolin

The results of the research indicate that the use of composite admixtures, consisted of calcined (non-calcined) zeolite tuff of high dispersity and superplasticizer of naphthalene formaldehyde type, allows to obtain concretes classes C50…C65.

(ID: 270)

INCORPORATION OF ORGANIC LIQUIDS IN CEMENT-BASED MATERIALS – NOVEL APPLICATIONS FOR WASTE MINERAL AND SUNFLOWER OILS

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This research presents preliminary results on a novel cement-based material able to incorporate organic liquids, either mineral or vegetable oil (e.g. sunflower oil) for Civil Engineering applications, such as thermal insulation, fire retardation or radioactive waste conditioning.

Material treatments

Time:
Wednesday, 16/June/2021: 10:30am - 12:30pm

Location: **Room 3**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Vincent Sabathier**, LMDC

(ID: 261)

SHEEP WOOL AS FIBER-REINFORCEMENT OF GYPSUM COMPOSITES

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Depending on the intended use, some cement-based construction materials, such as paste, mortar and concrete, need to be fibre reinforced. In these materials, fibres play the same mechanical role as ossein, the elastic collagen fibres in animal bones that guarantees the resistance to fracture. Although commonly used fibres are made of various materials, such as steel, glass, polymers etc., animal and plant fibres can also be used in building materials. Among them, wool of sheep, a waste material in several countries, can effectively reinforce pastes, mortars and concretes. In addition to the research already performed in the field of cement-based composites, the use of sheep wool as reinforcement of gypsum-based composite is experimentally investigated herein for the first time. As a result, sheep wool reinforcement provides high fracture toughness, due to an excellent adhesion, and could be a valid alternative to the current industrial fibres in reinforced gypsum manufacts.

(ID: 283)

VALORIZATION OF VEGETAL FIBERS IN ANTI-FISSURATION SCREED MORTAR FORMULATION

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Natural fibers are becoming a striking alternative for industrial applications because of their low cost, lightweight and renewable raw material composition. These types of fibers show better properties in comparison to other conventional materials when are used as reinforcement in the mortar and concrete formulations. France is the world's leading flax producer, with more than 106,000 ha and the leading European hemp producer with 17,000 ha. The given data are from 2018 and still increasing. Because of these facts, the development of this type of material, especially in France, has so much potential.

The proposed work enters in one part of the FIBRABETON project which consists of integrating natural fibers into high-performance structural concretes and screed mortar formulations. The project FIBRABETON is carried out with ESTP, FRD and Vicat and subsidized by ADEME, Grand Est region and FEDER.

The study is focused on the natural fibers (hemp, flax, miscanthus and bamboo) integration effect in anti-fissuration screed formulation. Different fiber content from 0,4wt% to 0,8wt% is tested. Workability (slump test for 0 minutes to 180 minutes), shrinkage test, flexural and compression at 7, 28 and 90 curing days for different natural fiber percentages are performed. For different fibers dosage, the compressive strength values reach up to 34 MPa which is slightly less than the control formulation value. As for workability, it is found that most formulations with fibers have a good performance from 0 to 180 minutes, since a certain fluidity is necessary for the laying of the screed. Favourable shrinkage values have been also obtained, where no formulation exceeded 800 µm/m at 28 days. The hemp formulation being the most performing with a minimum shrinkage value of 200 µm/m. Taking into consideration all these parameters and the low cost of fiber, hemp formulation is the optimal choice in this part of FIBRABETON project.

(ID: 247)

PLANT BIOMASS USED FOR GREEN CONCRETE: A REVIEW OF TREATMENT METHODS

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Human activities require a growing need for raw materials. In order to contribute to sustainable development, many business sectors are focusing on biomass valorization. Whether from dedicated crops or first industrial processing, it generates materials with high potential that can be used in many fields. Non-food uses mainly concern the energy, chemical, and construction sectors. Whatever the intended application, a pre-treatment stage is essential to clean the material and/or to access a specific fraction. An additional modification may occur in order to endow the material with a new function thanks to a process known as functionalization.

Uses of plant fractions (aggregates) in combination with cement offer advantages like low-density materials with attractive thermophysical properties for building. However, their development is limited by the compatibility of crop by-products with hydraulic binders such as Ordinary Portland Cement (OPC). This includes delays in setting time and hydrophilic character of vegetal components and their interaction with an alkaline environment. The aggregate/cement interfaces can therefore be

strongly affected. In addition, the diversity of crop by-products and mineral binders increases the level of complexity. In order to overcome these drawbacks, the treatment of plant fractions before their use with mineral binders may result in significant benefits. In this way, various treatments have been tested, but the methods used at an industrial scale remain relatively under-researched.

The purpose of this review is therefore to highlight the mechanisms involved in each specific process, thus justifying the operating conditions specific to each. This bibliography study aims to highlight potential treatments that could apply to biomass before their mixing with cementitious binders. According to the objective, a distinction can be made between extraction processes as hydrothermal or solvent treatments, assisted or not, and structural modification processes as surface treatments, impregnation, or grafting.

(ID: 217)

MODIFICATION OF FLAX FABRICS BY PRE-IRRADIATION GRAFTING OF PHOSPHORUS-BASED FLAME RETARDANTS

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This work is focused on the modification and the functionalization of flax fibers aiming to improve their flame retardancy by grafting a phosphorus-based flame retardant (FR) dimethyl(methacry- loxy) methyl phosphonate (MAPC1). The pre-irradiation method was used and the grafting process follows three main steps. First, flax fibers were irradiated under electron beam at a dose ranging between 5 and 100 kGy, then the irradiated fabrics were impregnated by dipping them into an aqueous solution containing the MAPC1 monomer; finally a washing step of the treated fibers allows to remove unreacted monomers units and the free oligomers and polymers chains which are not covalently bonded to the flax structure. The presence of radicals on the flax fibers after irradiation has been confirmed by Electron Paramagnetic Resonance (EPR). Grafting efficiency was assessed by infrared spectroscopy (FTIR) and quantified using Inductively Coupled Plasma (ICP-AES). The location of the grafted phosphorus polymer chains was assessed by Scanning Electron Microscope coupled with Energy Dispersive X-ray spectrometer (SEM-EDX) using phosphorus mapping of modified fibers. The effect of phosphorus grafting on thermal properties and fire behavior of flax fibers was studied using thermogravimetric analysis and pyrolysis combustion flow calorimetry.Different parameters have been studied such as radiation dose, temperature and duration of the grafting reaction and monomer concentration. In particular, it has been observed that MAPC1 is grafted in a homogeneous way into the bulk of the elementary flax fibers leading to high phosphorus rate of around 2 wt% for a dose 10 kGy and up to 7 wt% for a dose 100 kGy leading to high charring and low flammable fibers.

(ID: 179)

EXPLOITATION OF SILICON DIOXIDE (SIO2) NANO-PARTICLES TO STABILIZE AND IMPROVE THE PROPERTIES OF WOOD

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Wood is an excellent construction material with various advantages. However, this material suffers from a few weaknesses, such as dimensional instability and low durability in alkaline environments. These issues are associated with wood's hollow vascular structure and thus its high water uptake capacity. This research aims to stabilize wood properties and reduce its water uptake through a dip-coating method using an aqueous colloid of SiO2 nanoparticles. SiO2 is a dense ceramic material with good chemical stability. This ceramic is compatible with cementitious materials, and it is readily available and affordable, making it a right candidate for this application. The current study looked into the effect of the impregnation on the physic-mechanical properties of spruce wood. Density analysis, Water absorption tests, Dynamic Mechanical Analysis, and Impact tests were conducted on the non-treated and SiO2-treated spruce wood samples, and promising results were obtained. SiO2 impregnation under vacuum pressure demonstrated a significant increase in wood density. By the same token, it reduced the porosity, which led to a significant reduction in water uptake of spruce wood samples. The obstruction of wood vascular structure substantially increased the stability of the wood properties and decreased the variability of storage modulus (E) and loss modulus (E'). In conclusion, this project was able to put forth a solution to mitigate the instability of wood properties where this material is used under high humidity or in wet conditions.

(ID: 121)

ENVIRONMENTAL PERFORMANCE OF WOOD BIO-CONRETES WITH DIFFERENT WOOD SHAVINGS TREATMENTS

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The wood bioconcrete (WBC) production is a solution for the advancement of sustainable construction, since it has the potential to recycle wastes generated in wood processing. However, the chemical incompatibility between plant biomass and cementitious matrix leads to the need for previous biomass treatments. In order to carry out waste treatments, besides energy consumption, calcium hydroxide (Ca(OH)2) solutions were used, which contribute to the increase of environmental impacts during the production of WBC. A Life Cycle Analysis (LCA) methodology was used, with scope from the cradle to gate, for the evaluation of different mixtures of WBC produced in laboratory. One heat treatment and two alkaline treatments with immersion in Ca(OH)2 solution were evaluated. The environmental modeling was performed by SimaPro, using the Ecoinvent database, and primary data collected in the laboratory. The potential environmental impacts were related to the compressive strength of WBC (in MPa) as an ecoefficiency indicator. Considering the functional unit of structural performance, the alkaline treatment with two immersions was the one that generated less environmental impacts.

Mechanical properties 1

Time:
Wednesday, 16/June/2021: 10:30am - 12:30pm

Location: **Room 4**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Jonathan Page**, Université d'Artois

(ID: 157)

FIRST STEP TOWARDS THE UPSCALING OF THE PRODUCTION OF WASHING FINES – HEMP COMPOSITE. STUDY OF MULTIPHYSICAL PROPERTIES

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This study is a first step towards the upscaling of the production of washing fines – hemp composite.

Actually, such composites were developed and characterized on multiphysical point of view in previous studies [1,2]. The washing fines come from washing mud of a gravel production site. In order to well control the formulation, the washing mud are fully dried, and then milled. The washing fines are stabilised with a binder mix (5% Portland Cement, 5% Thermo ®). The binder matrix (washing fines, binders and water) is mixed on the one hand while the hemp shiv is pre-wetted on the other hand. Finally the pre-wetted hemp shiv is mix with the binder matrix paste and composite are moulded under 0.1 MPa compaction.

The process of washing fines preparation allows a high control of formulation but is both energy and time consuming, and thus, is not interesting for industrial production. More, the potential industrial partner for future study does not want to use Portland cement, for environmental issue. So, the main objective of this study is to reduce the process of washing fines preparation. The use of Themo® binder only is also mandatory.

In a first time, this study shows how to reduce the preparation of washing fines, based on a target mud density defined from the previous formulation study. The binder matrix paste is then produced by mixing washing mud with binder. The hemp shiv is no longer pre-wetted. Once the new production protocol is validated, composites are produced by moulding under 0.1 MPa compaction, like previously. More, several stabiliser contents are considered.

Then, the produced composites are characterised on multiphysical point of view. The investigated characteristics are mechanical behaviour under compressive strength, thermal conductivity and moisture buffer value. The results are compared to the previous study and the effect of stabilisation on multiphysical properties is also investigated.

[1] B. Mazhoud, F. Collet, S. Pretot, C. Lanos, Development and hygric and thermal characterization of hemp-clay composite, Eur. J. Environ. Civ. Eng. (2017) 1–11. https://doi.org/10.1080/19648189.2017.1327894.

[2] B. Mazhoud, F. Collet, S. Pretot, C. Lanos, Characterization of mechanical properties of hemp-clay composite, in: 2nd Int. Conf. Bio-Based Build. Mater., RILEM Publications S.A.R.L., Clermont-Ferrand, France, 2017: pp. 329–337.

(ID: 130)

EFFECT OF NATURAL AND POLYPROPYLENE FIBERS ON EARLY AGE CRACKING OF MORTARS

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Throughout time, the use of lignocellulosic resources has been implemented in the development of building materials. Among these resources, natural fibers are used as mineral binders reinforcement due to their specific mechanical properties. This experimental investigation focused on effect of flax and hemp fiber reinforcement on the resistance of mortars to cracking due to restrained plastic shrinkage. Results were compared with polypropylene fiber reinforcement and with control mortar without fibers. The dosage of fibers added to the mortar mix were respectively 0.25% - 0.5% by mass of binder for polypropylene fibers and 0.5% - 1% for flax and hemp fibers. All fibers have a similar length of 12mm.

The cracking sensitivity was evaluated using two different methods. The first consists in casting the mortar in a metal mold with stress risers whose criteria are inspired by the ASTM standards. The second consists in pouring the mortar on a brick support. In order to assess the effect of fibers on cracking due to restrained plastic shrinkage, the number of cracks, total crack area and maximum crack width within the first 24 hours after casting were determined using digital image treatment. Results showed that flax and hemp fibers were more effective limit the propensity for restrained plastic shrinkage cracking compared to polypropylene fibers. With a natural fiber content of 1% by mass of binder, maximum crack width was reduced by at least 90% relative to control mortar-based specimens. Within the limits of our study, natural fibers can be considered as an interesting and ecological alternative to polypropylene fibers.

(ID: 129)

NATURAL FIBERS VS SYNTHETIC FIBERS REINFORCEMENT: EFFECT ON RESISTANCE OF MORTARS TO IMPACT LOADS

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Given their specific properties, their natural and renewable sources and their low environmental impact in production, natural fibers offer an opportunity for the development of eco-friendly cement-based composites.

The main objective of this experimental work is to evaluate the resistance to impact load of mortars incorporating natural fibers or polypropylene fibers at 28 days. The assessment was carried out according to an experimental protocol developed in our laboratory. The method consists in dropping a metallic ball on a square shaped specimen of 30x30x2 cm3 to determine the

energy supported by each sample. For each specimen, the number of blows required for the first crack initiation and for the total collapse of specimen are detected using a device allowing to measure the speed of ultrasonic waves. The device was fixed on the specimen itself. In order to fulfill the mechanical identity card of the composites, flexural and compression tests were also carried out at 28 days. In this experimental protocol, two types of binders were considered (cementitious and pozzolanic) with different fiber percentages of polypropylene (0.25% and 0.5% by binder mass) and of natural fibers (0.5% and 1%). All fibers have a length of 12 mm.

Results show that natural fiber reinforcement could be considered as an ecological alternative to polypropylene fiber one to improve the resistance of mortars to impact loads

(ID: 226)

EFFICIENCY OF BIO-SOURCED COMPOSITES IN CONFINING RECYCLED AGGREGATES CONCRETE

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This research investigates the efficiency of using Flax Fibers reinforced bio-sourced Polymer by comparison to traditional system based on Carbone Fiber Reinforced Epoxy Polymer in order to confine recycled aggregates concrete.

Four concrete formulations of resistance class C35 / 45 have been formulated by incorporating recycled aggregates from demolition waste (0%, 33%, 50% and 100%). The same formulations comprising an air entraining agent so that the level of occluded air is about 4% were also investigated. The main objective is to discuss than to propose design codes for recycled aggregates concretes and to evaluate the effectiveness of confining them using bio-sourced composite by comparison to traditional ones. To hit this target, the developed approaches are both experimental and analytical.

The first part is experimental and aimed to characterize the mechanical behavior of the materials: the resins, the unidirectional composites used in the confining process the unconfined concretes (effect of incorporating recycled aggregates on the overall mechanical characteristics) and the confined ones.

The second part of this work is dedicated to analytical modeling of mechanical behavior of confined concrete with composite under compression.

This work outlines that EC2 should be revised and propose other relationships between the mechanical characteristics and the mean compressive strength. The incorporation of recycled aggregates from demolition wastes at ratios higher than 33% leads to a decrease of the mechanical properties of the concretes and requires taking it into account in the design codes. Confining recycled aggregate concrete by bio-resourced composite seems to be efficiency by comparison to carbon epoxy ones encouraging its application for concrete structures in civil engineering.

Analytical models from the literature are discussed. A modified one based on the established design codes is proposed and applied for the prediction of the compressive behavior of confined recycled aggregates concretes.

(ID: 280)

USE OF HEMP FIBRES IN 3D PRINTED CONCRETE

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The use of fibres as reinforcement of 3D printed concrete is widely known and applicable in many situations. However, most of those fibres are not produced from renewable resources. Natural fibres are commonly considered as an ecological alternative. In order to contribute to improvement of the sustainability of 3D printed concrete, natural fibres such as hemp fibres can replace those synthetic fibres. The objective of this study is therefore to study the possibilities of adding hemp fibres for 3D printing purposes.

Due to the comparable properties of hemp and synthetic fibres, the natural fibres tend to be suitable for printing purposes. Mixes are made at laboratory scale using batches of 1 – 3 kg. The study examines the effect of adding hemp fibres for the mechanical and fresh state properties of hemp-based concrete. Mechanical properties from bending tests and direct tensile tests show comparable properties of mortars containing hemp fibres and mortars containing synthetic fibres. The fresh state behaviour of the designed concrete mix showed promising and comparable results for a mix based on 0.5wt% of hemp fibres.

One of the major issues regarding the use of natural fibres is the irregularity and high water uptake of the fibres. Due to its high hydrophilicity natural hemp fibres take up much water and can therefore degrade. For this study the effect of water uptake did not have much influence on the mixing and printing purposes. By printing a wall element on laboratory scale the use of hemp fibre-reinforced 3D concrete is validated.

(ID: 144)

STATIC AND LONG TERM COMPRESSION BEHAVIOR OF HEMP SHIV FOR FLOATING FLOOR APPLICATION

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This study is focusing on the compression behavior of hemp shiv layers for bio-based floating floor applications. An experimental campaign was performed to measure the instantaneous and creep behavior of different hemp shiv. On the one hand, a proper compression protocol (compression die design, layer height and aspect ratio) was developped and assessed. On the other hand, the effect of particle size distribution and moisture content were studied, on both the static and the long-term compressive behaviors of shiv layers. Finally, a modeling was developed. The model validity ranges from 0 to 5 kPa and with moisture contents up to 20%. It was used to define the maximum acceptable initial height of the shiv layer to guarantee a limited long-term deformation of the floating floors made of hemp shiv layers.

Case studies 1

Time:
Wednesday, 16/June/2021: 4:00pm - 6:00pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Christophe Lanos**, Université Rennes 1

(ID: 214)

SUCCESSFUL CIRCULAR BIO-BASED CONSTRUCTION INITIATIVES: FIVE ESSENTIALS FROM CASE STUDIES

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There are challenges surrounding circularity and the application of bio-based material in construction, but also potential. This paper aims to identify success and fail factors for the initiation phase of construction projects that help to realize affordable circular and bio-based. This was specifically investigated for initiators of construction projects, like real estate professionals, property owners and developers. We describe based on case studies what these actors should focus on and pursue before actual construction starts.

For the purpose of this paper, desk research was done and interviews were held with people involved in exemplary projects (case studies). The interviews focused on choices that were made during the initiation phase that were decisive for the degree of circularity and the extent to which bio-based materials were applied. Motivations and consequences were covered. We found that are five essentials for successful circular bio-based construction. These five essentials form the outline of this paper:

1. AFFORDABLE cost-effective & inclusive reuse,
2. FLEXIBLE prepare for future functions,
3. PASSIVE stay cool & healthy with bio-based materials,
4. INTEGRAL continuously reflect on circular bio-based benefits
5. TRADITIONAL OWNERSHIP keep it, simple.

In one case, all five were put into practice, while in other cases it was three or four. The five essentials and cases in this paper can be used as inspiration for product and process and could help realize affordable and feasible circular bio-based constructions. By focusing on the essentials, initiators have guidance to prevent valuable resources (including energy) going to waste, today and in the future.

(ID: 253)

EXPERIMENTAL BUILDING USING MUSSEL SHELLS AS BUILDING MATERIAL: CASE STUDY

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The construction sector is a key generator of greenhouse emissions, so the use of alternative low-emission building materials is a growing tendency. This work describes and analyses an innovative sustainable building that includes mussel shells in all its constructive elements. This material is a by-product of the canning industry that is nowadays landfilled. Mussel shells were used as aggregate in the concrete strip footing (foundation) and in the exterior and interior coating mortars (walls), and as loose-fill material for the whole envelope insulation (floor, walls, and roof). The results from both the laboratory and the constructive process were useful to improve the solutions and to develop a building with low energy consumption. The energy demand of the building was assessed using the Passive House Planning Package (PHPP) software and the blower door test was carried out to measured air tightness. Finally, mussel shells are compared with other commercial building solutions considering the thermal behaviour, material characteristics and installation, concluding that mussel shell materials meet the requirements for energy efficient and sustainable buildings.

(ID: 168)

INFLUENCE OF THE TIMBER STRENGTH CLASSES ON THE ENVIRONMENTAL IMPACTS OF HOUSING FLOORS

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This study intends to compare the environmental impact of various timber solutions for housing floors in which the type of solidwood (softwood and hardwood) and the strength classes (C18 to C35 and D24 to D35) vary. The literature review showed that the majority of papers that compare the environmental impacts of timber products do not take into account with their strength classes. This study proposes a method based on the Life Cycle Assessment (LCA) approach to define a structurally equivalent functional unit in order to compare the environmental impacts of timber solutions for building's floors. The proposed method follows five steps: definition of the functional equivalence; definition of structural solutions; structural analysis; design of structural products; and calculation of the volume of structural products. The LCA method was used to: i) calculate the environmental impacts of various structural solutions considering a cradle-to-cradle system boundary, and ii) compare the Global Warming Potential (GWP) (with CO2 sequestration) of various structural configurations. The results showed that the increase of strength classes decrease the majority of environmental indicators. In contrast, the increase of strength class increases the GWP impacts.

(ID: 218)

CONSTRUCTION FIELD MONITORING OF A COB PROTOTYPE BUILDING

Athmane Azil[1], Malo Le Guern[1], Karim Touati[1], Moussa Gomina[2], Nassim Sebaibi[1], Mohamed Boutouil[1], François Streiff[3], Steve Goodhew[4], Hasna Louahlia[5]

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Cob is an earthen building material made by soil, fibres and water used for millennia. However, cob construction disappeared out during the nineteenth century. These last years, it is experiencing a renaissance in Northwestern France and Southern England. Due to a limited technical knowledge, the investigation of engineering properties is important for modern design practice and code requirements. Moreover, to ensure building properties, it is necessary to have same quality mix along the building phases.

The aim of this study is to determine material variation during the monitoring of a cob prototype building in Normandy. This study will include mix composition, water content, density, strength properties, and thermal conductivity. Samples shape used were cylindrical □110 x H220 mm and prismatic 300 x 300 x70 mm.

Results indicated that there is variation in cob mix (water content, materials proportions) between three different lifts. These variations lead to different densities and, consequently, to variables compressive strengths 0.99 to 1.38 MPa and thermal conductivities from 0.610 - 0.816 W.m-1·K-1.

(ID: 257)

PHYSICAL PROPERTIES AND HYGROTHERMAL BEHAVIOR OF MYCELIUM-BASED COMPOSITES AS FOAM-LIKE WALL INSULATION MATERIAL

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This research aims to study mycelium-based composites (MBC) by assessing their performance as foam-like wall insulation material. Various substrates have been selected to get optimized performance of the composite. Results showed that a prolonged growing period arose a denser mycelium outer layer in MBC, which rendered better water resistance due to the hydrophobicity of mycelium. Thermal conductivity and mechanical properties are highly dependent on substrate choices than other parameters of MBC, which coincided with the literature. Additionally, influences of accelerated aging test and moisture buffer capacity of MBC were first studied in this research. The results indicated that MBC not only maintained good functional performance after the accelerated aging test (i.e. drying and wetting cycles) but also constituted good moisture buffer capacity. This means that MBC has key material essences to apply as internal wall insulation material and become one of the layers in vapor-permeable building envelope systems to passively regulate indoor relative humidity and thermal comfort.

(ID: 174)

RESEARCH FOR SUBSTANTIATION TO UPSCALE BIO-BASED MATERIALS IN THE CONSTRUCTION INDUSTRY

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The building construction industry is slowly adapting bio-based materials. To accelerate this process, it is necessary to gain more proven data about technical issues. This should also fit in the social-economical and juridical context of the construction industry. In this paper we will highlight the main drivers and research that is going on in the Netherlands. Including a cross border project that works on this topic.

With the growth of the bio-based materials, products and building concepts, the demands from the contractors are getting more severe. In the period when bio-based materials where only used by the frontrunners the technical demands were less strict. There are many private houses build with bio-based materials because the owner and user of the building was strongly environmental focussed and was convinced by the physical advantages of these materials. Other technical demands, financial and juridical issues are less important. Now that bio-based materials are getting more attention of bigger contractors (social housing organisations, real estate developers and governmental bodies) the demands for proven technical performance are getting higher. This gives a boost to involve researchers in the bio-based sector.

Circular Bio-based Construction Industry (CBCI), is an Interreg 2 Seas project with partners from UK, Belgium and the Netherlands and observers from the same countries including France. The focus of this project is providing tools for the upscaling of circular, bio-based building. We work on economic and cooperation models, technical issues (demountability, building physics, environmental impact (LCA)), education and procurement. We built prototypes for testing (façade, construction and insulation) these prototypes will be incorporated in living labs, real life building projects.

Bio Iso, this SIA-RAAK project has started end 2020 and will go deeper in the building physical properties of bio-based insulation materials. In combination with the Dutch building methods and climate circumstances. In this project research institutes are involved, and also suppliers and builders.

CO2 neutral renovation; in the Dutch building sector there is, as in other European countries a large demand for building concepts with low or no energy use. To create large scale solutions the building sector supported by the government has developed concepts to create an industrial approach. In this project we researched the market's approach and looked at the options to develop CO2 neutral renovation concepts with the use of bio-based materials. In this project we also optimized the concepts to make use of the special features of bio-based materials (cooling in the summer). It is good to see that there are many initiatives to accelerate the uptake of bio-based materials in the construction industry. There is a great challenge for the bio-based researchers to communicate their findings to help the transformation of the building sector.

Durability 1

Time:
Wednesday, 16/June/2021: 4:00pm - 6:00pm

Location: **Room 2**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Sandrine Marceau**, Université Gustave Eiffel

(ID: 229)

BIOLOGICAL STABILISERS IN EARTHEN CONSTRUCTION: A MECHANISTIC UNDERSTANDING OF THEIR RESPONSE TO WATER-INGRESS

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Earthen construction is re-gaining popularity as an ecological and economical alternative to contemporary building materials. While building with earth offers several benefits, its performance due to water ingress is a concern for its widespread application. This limitation is often solved by adding chemical stabilisers such as Portland cement and hydraulic lime. Chemical stabilisers are a subject of widespread debate as they increase the cost and embodied energy of the structure, and reduce the desirable characteristics of raw or unstabilised earth. This along with perceived environmental performance, renewability and proven effectiveness in traditional earthen construction has led to a growing interest into biological or organic stabilisers. Although the strengthening mechanism of biological stabilisers is widely covered in scientific studies, discussion regarding the water-resistance is limited. This review aggregates the research from the field of earthen construction and geotechnical engineering and extends it to explain the possible mechanism responsible for the water-resistance behaviour of biologically stabilised earthen materials. This study includes a wide range of traditional and industrial biological stabilisers derived from animals (cow-dung, casein, chitosan), plants (starch, guar gum, cactus mucilage, lignin, tannin) seaweeds (alginate, agar, carrageen) and microbes (xanthan gum, gellan gum). A conceptual model of water-ingress in unstabilised earthen block is proposed and the response of biological stabiliser to water ingress and related physico-chemical and physical factors is discussed using the model at microscale (stabiliser interaction with clay, sand) and macroscale (hydraulic conductivity of block). Properties of stabilisers such as hydrophobicity, stability under wet condition or interaction with cation has a dominant effect on the overall response to water ingress. Key gaps have been identified in the existing knowledge that are necessary to investigate in order to understand the water-resistance behaviour comprehensively. The study concludes with a brief assessment of biological stabilisers based on their performance and feasibility to use in contemporary earthen construction.

(ID: 245)

RISK FOR MOULD GROWTH ON HEMP-LIME AT DIFFERENT RELATIVE HUMIDITIES

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Microbial growth often thrives in humid conditions, at high relative humidities. Moulds are complex organisms; many types of mould are able to survive strong variations in humidity and temperature, such as those on building façades. For some building materials a critical relative humidity is determined, which functions as a theoretical threshold; at this (or lower) relative humidities microbial growth will likely not occur.

Hemp-lime is a building material that consists of hemp shiv (the woody core parts of the hemp stem) and building lime. It is a material that can be used for walls, and even though it has been used for more than 20 years, thusfar little is known about its critical moisture levels for microbial growth.

The aim of this research was therefore to determine at what relative humidity microbial growth occurs on carbonated hemp-lime material, and to study if there is a protective influence of a carbonated lime binder on the hemp shiv. The objective was to study microbial growth on hemp shiv, hemp-lime and on hemp with a thin layer of lime at three relative humidities (75%, 85% and 95%) and at two different temperatures (15°C and 23°C); conditions that could occur naturally in a hemp-lime façade exposed to high rain loads in a northern European climate.

Hemp shiv seems to have a relatively low resistance to microbial growth, similar to that of wood. However, because the hemp is protected by lime it can withstand much higher relative humidities without microbial growth occuring on the material. The critical moisture level for hemp-lime seemed to occur between 75 and 85 % RH, while the material was completely without microbial growth at 75% RH. The lime had a protective effect on the hemp and acted as a mould inhibitor, both over time and with varying temperature and humidity.

(ID: 234)

EFFECT OF IMMERSION/FREEZING/DRYING CYCLES ON THE HYGROTHERMAL AND MECHANICAL BEHAVIOR OF HEMP CONCRETE

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Hemp concrete is one of the most used bio-based materials in the construction industry due to its hygrothermal behaviour and its low environmental footprint. This is mainly due to the complexity of the microstructure of these materials and their highly breathable nature. However, their use remains limited due to the lack of databases and guarantees regarding the evolution of

their functional properties over time. In this paper, an experimental investigation has been performed to answer this problematic. The aim is to investigate the influence of accelerated ageing on the properties of this material through a succession of immersion/freeze/drying cycles. Materials (aged and reference) were characterized at the same time in order to make possible the comparability of results and to highlight the effect of ageing on the properties of hemp concrete. Results revealed a significant change in the microstructure of this material. As a consequence, this induced significant changes in its hygrothermal and mechanical properties. Compressive strength and water vapor permeability have decreased by 57% and 40% after ageing, respectively.

(ID: 295)

INFLUENCE OF FIBRE TREATMENT AND MATRIX MODIFICATION IN MECHANICAL PROPERTIES OF FLAX FIBRE REINFORCED MORTARS AFTER FREEZE/THAW CYCLES

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The aim of this study was to examine the influence of flax fibre protection with the linseed oil and a matrix modification with cement substitution with metakaolin (in 10wt% and 15wt%) on the mechanical properties of cement-based mortars under severe environmental conditions of freeze/thaw cycles. Cement-based mortars (with the dimension of 40x40x160 mm3) were reinforced by 10mm long discrete flax fibres (Linum usitatissimum) and exposed to 51 freeze/thaw cycles under laboratory condition. Their compressive and flexural strengths, as well as specific energy absorption capacity were measured after freeze/thaw cycles and compared to the results of mortars cured for same time in water.

Under freeze/thaw cycles mortars reinforced with linseed oil-treated fibres showed the same range of degradation of the compressive and flexural strengths, however, a more pronounced degradation of energy absorption capacity compared to non-treated fibre reinforced mortars was observed.

The matrix modification, by partial cement substitution with metakaolin showed optimistic results under freeze/thaw cycles. The compressive strength when cement was partially substituted with metakaolin (in both dosages) increased whereas the flexural strength was slightly lower in case of 10wt% substitution and markedly lower under higher (15wt%) cement substitution. The most relevant is that the decrease of the energy absorption capacity of the fibre reinforced mortar was completely prevented when cement was substituted with metakaolin. It is shown that the energy absorption of the non-treated fibre reinforced mortars increases by 27% when cement was substituted with metakaolin (both 10wt% and 15wt%).

(ID: 224)

EFFECT OF VISCOSITY MODIFYING AGENT ON THE PERFORMANCE AND DURABILITY OF HYBRID BIO-BASED CONCRETE

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An experimental investigation was conducted in order to study the water absorption, mechanical performance, thermal properties and durability of hybrid hemp-rapeseed composite materials. The hybrid composite material is made with 50% hemp shives and 50% rapeseed fibres. The purpose of this study is to investigate the influence of the incorporation of viscosity modifying agent (VMA) on hybrid concrete. Four mixes were made for: shuttered walls and roof insulation with and without VMA. In first stage, the water absorption of hybrid composite fibres was measure. The compressive strengths of these mixes at 7 and 28 d were then determined in order to compare the mechanical behaviour of the hybrid composite materials made with VMA and the capillary absorption and coefficient of thermal conductivity were also measured. Finally, the durability regarding weathering and carbonation were conducted. The performances of mixes made with VMA are compared to reference mixes.

(ID: 304)

COMPATIBILITY OF PLANTS WITH A MINERAL BINDER

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Hemp concretes are the most widely used biobased concretes in France. However, their growth is still limited by the lack of knowledge and high variability of the performances of biobased concretes, especially for their mechanical properties. These results are related to interactions between the mineral binder and plant compounds that modify the hydration of the cement. In this work, the interactions between cement and eight types of hemp shiv, and a flax shiv are studied by isothermal calorimetry. The setting delays observed in the presence of plants are interpreted by analyzing the molecules extracted from these plants in water. A link can be observed between the setting delay and the coloration of the extract solutions or their concentration in reducing sugars and in polyphenols.

These results constitute a basis in the objective to define an indicator enabling to predict the compatibility between plants and mineral binders.

Mechanical properties 2

Time:
Wednesday, 16/June/2021: 4:00pm - 6:00pm

Location: **Room 3**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Mahfoud Tahlaiti**, ICAM

(ID: 246)

ORGANIC BRICK

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In recent years, 3D printing technology has become increasingly popular. The main reason for this can be considered as its ability to be customized and to optimize physical and mechanical properties for specific applications. The rising pattern in the architecture design field today has a craving for the multifaceted nature, both functional and geometrical of individualized customization. Clay is one of the earliest known materials used in construction, and the most widely used building material on the planet. Our ancestors have performed the tasks of mixing water with dust to make clay, then shaping it into bricks, bricks into buildings, and buildings into cities for more than ten thousand years.

This study investigates customized 3D clay brick as a new building material (building component) by employing resources that are eco-friendly, locally available, inexpensive, and driven from recycled sources or waste streams.In this experiment, four different fiber types (acrylic, PVA, glass, polypropylene), four different fiber lengths, and different fiber contents (0.0%- 0.3% - 0.6% by volume of the mixture) have been investigated with different clay treatment. The specimens were fabricated in the laboratory and tested with unconfined compression loading. The strength and ductility of the clay specimens were then analyzed based on the experiment results. Several experiments have been conducted during the study for understanding the effects of different fibers when mixed with clay in order to identify which type of fibers and which size has the most effective influence on its compression strength. Furthermore, it has been tested also the water absorption of the 3D printed brick. A case study has been developed to show the actual potential of 3D printed clay bricks for a small housing complex. The project is located in Abuja, Nigeria, at a time of exponential population increase and associated lack of affordable housing. The 3D printed blocks are structural and they embed a cooling function, thanks to their geometry and the presence of cooling pipes directly in the wall. The result is a highly flexible envelope, designed to be resilient energy efficient.

(ID: 251)

SYNTHESIS OF THE CURRENT KNOWLEDGE CONCERNING THE CONSTRUCTION OF FRENCH TRADITIONAL COB BUILDING CALLED BOURRINE FOR GIVING RECOMMENDATIONS

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The museum of the “Bourrine du bois Juquaud” is a tourist site located in the town of Saint Hilaire de Riez in France. It presents the daily life of the inhabitants of the marsh in the early twentieth century and their traditional earthen houses called Bourrine. The Bourrine is a cob construction with reed roof. The earth used for walls is soil from marshlands added with dune sand and straw fibres but some part are without fibres like coating applied on walls. By now, the knowledge acquired on the implementation of these mixtures for the lifting of the walls are oral knowledge and it is necessary to ensure the preservation of this traditional heritage. Currently the done reparations present cracks due to shrinkage. This study aims to well define the mixtures by a scientific approach. The earth and dune sand were analyzed by taking cores from different existing bourrines and also by extracting soil on site. Different mixtures were produced by varying the proportion of earth sand and water. The linear and .volumic shrinkage were measuring. Corrections were done to get the best mixture for manufacturing and repairing the Bourrines.

(ID: 220)

EARTH HEATING PANELS AS A LOW-EMITTING, COST-EFFECTIVE AND ROBUST ENERGY SYSTEM FOR BUILDING RENOVATION

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Renovation of the building stock in Europe is urgent to decrease the environmental impact from the building sector and meet the United Nations climate action goals. To be able to evaluate the total amount of greenhouse gas emissions and costs holistically, the whole life cycle needs to be assessed. Life cycle assessment (LCA) and life cycle costing (LCC) are two well-known approaches to analyze the economic and environmental performance of a building. However, it is often hard to define a robust scenario for a renovation due to numerous uncertainties, which occur during the production, operation and end-of-life stage. One can cite the loss of performance of insulation and heating systems, the replacement time of installation or the future energy prices as well as the future climate. The replacement of oil boiler with heat pump has shown a good performance regarding costs and CO2 emissions. However, due to the flow and return temperature differences, often the current heat distribution system needs to be replaced as well, which is normally done with conventional radiators or the floor heating. In this paper, we analyse a new possibility of a heat distribution system with earth heating panels, which are more cost-effective and environmentally-friendly than conventional solutions such as radiators or floor heating. First, we develop a methodology on the integrated

assessment of LCA and LCC for the renovation scenarios and adapt the analysis of the heat pump renovation solution with conventional radiators system and the earth panels for two typical residential buildings located in Switzerland. Through the rigorous statistical treatment, we then apply the possible sources of uncertainty and perform the uncertainty quantification using polynomial chaos expansion to compare the distributions of two outcomes.The results show that the solution with the earth panels have lower overall environmental impact and costs and also perform better compared to the solution with radiators in terms of thermal comfort especially during the overheating time in summer. It has also been noticed that the solution with the earth panels is more robust in investment cost and embodied emissions comparing to the solution with the conventional radiators.

(ID: 260)

INVESTIGATION ON THE STABILIZATION OF ZN-AL LAYERED DOUBLE HYDROXIDE CLAY INCORPORATED IN DICALCIUM SILICATE PHASE

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Layered Double Hydroxide (LDH) is ionic clay that is characterized by the union of metal cations and OH- hydroxides. They can be prepared by direct co-precipitation of metal salts at controlled pH. The preparation is carried out from an acid solution of Zn(NO3)2.6H2O, Al (NO3)3.9H2O and a basic solution of Na2CO3 and NaOH, with a Zn/Al ratio = 3, the pH is stabilized between 9 and 9.5 at a constant temperature of 45°C. The objective of this research is to incorporate Zinc and Aluminum elements at different percentages in dicalcium silicate phase to produce C2S phase incorporating LDH clays. The characterizations of the developed phases by DRX and SEM indicate the formation of stoichiometric LDH phases Zn6Al2(OH)16CO3.4H2O and non-stoichiometric Zn0.61Al0.39 (OH)2(CO3)0.195.xH2O, the incorporation of Zn in the belitic phase C2S. The obtained micrographs by SEM(EDAX) analysis show new morphology of the formed compounds.

(ID: 155)

EVALUATION OF BIO-BASED EARTH ENGINEERED MORTARS FOR LOW ENERGY AND CARBON BUILDINGS IN TROPICAL AND SUBTROPICAL CLIMATES

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Improving the thermal performance of low-income housing in developing countries, located in tropical and subtropical regions, is one of the main challenges of the building sector. The use of mortars as building cladding is a current practice in many developing countries. Bio-based (such as bamboo particles) and earth materials have shown interesting potential for improving some thermal properties of covering mortars. In addition, bio-based earth mortars can have a lower carbon footprint than conventional mortars (typically made of cement or cement with lime) used in the building sector. The aim of this study is the evaluation of the life cycle GHG emissions of different mixtures of an engineered bio-based earth mortar mixed with bamboo particles, earth, and different cementitious materials (Portland cement, hydrated lime, metakaolin, and fly ash) and water. Four mixtures are evaluated: without bamboo particles, with 3%, 6%, and 9% of bamboo particles in volume. The thermal-energy performance and carbon footprint of these mortars are evaluated. From physical tests carried out in the laboratory, thermal-energy simulations are carried out in DesignBuilder software considering a case study of a social housing project in Brazil, evaluating tropical and subtropical climates. Finally, the carbon footprint was performed, using the Life Cycle Assessment (LCA) methodology considering a cradle-to-gate scope. When compared with two conventional mortars (made of cement and hydrated lime), the bio-based earth mortar presents better thermal-energy performance and a lower carbon footprint. We can conclude that there is a potential to improve the thermal-energy performance in low-income housing and, at the same time, to reduce the mortar carbon footprint. This mortar can be produced where bamboo and cementitious materials are available, which is the case in several developing countries that are expected to have a substantial housing demand for new buildings in the coming years.

Test methodology

Time:
Wednesday, 16/June/2021: 4:00pm - 6:00pm

Location: **Room 4**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Malo Leguern**, ESITC Caen

(ID: 148)

DENSITIES OF HEMP SHIV FOR BUILDING, PART I: MULTISCALE CHARACTERISATION

Philippe Glé[1], Thibaut Lecompte[2], Arthur Hellouin de Ménibus[3,4], Hélène Lenormand[5], Santiago Arufe[5], Camille Chateau[6], Vanesso Fierro[6], Alain Celzard[7]

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This paper aims to qualify and quantify the various scales of porosities and densities in plant particles packings (hemp shiv) used for building applications. These characteristics are key parameters for the understanding of the mechanical, thermal and acoustical behaviors of materials such as loose aggregates or hemp concretes.

A study was built around this topic, and enabled to evaluate skeletal, particle and packing densities and associated level of porosities. Many experimental methods have been used to characterize these parameters: manual and automated packing density evaluation, fluid and powder pycnometry, mercury intrusion and X-ray computed tomography. These measurements were performed as a function of particle size and level of aging by immersion in water. It was finally shown that :

- smaller particles have higher packing and particle densities,

- aged particles present a strong evolution of their microstructure, visible through lower packing and particle densities and higher skeletal density,

- powder pycnometry is the most representative method to measure particle density while X-ray computed tomography enables to characterize individual particles and to validate the range of data in terms of particle density.

- mercury intrusion porosimetry results should be taken with caution due to the “ink-bottle” effects but enable to qualify pore size distribution.

This communication is in connection with a second part dealing with the modelling applications.

(ID: 146)

DENSITIES OF HEMP SHIV FOR BUILDING, PART II: MODELLING APPLICATIONS

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This article concerns stacks of plant particles (hemp shiv) used for building applications. The different densities: bulk density, particle density and true density were measured (Part I). The aim of this paper is to evaluate the physical behavior of hemp shiv layers in terms of water absorption, compression, thermal characteristics and acoustic behavior, as a function of the densities (and porosities) of the particles.

Modeling of water demand, thermal conduction, acoustics and compression behavior of shiv beds is proposed. This modeling induces the density parameters of the raw particles and should make it possible to predict the behavior from the different density values. Thus, the experimental results and the modeling are compared. They show that:

- Water absorption can be correlated with open porosity, but must also take into account particle swelling

- The compression behavior of the stack is determined by the three density scales

- Thermal conductivity is not very well described with the usual multiphase modeling.

- Acoustic dissipation involves inter-particle porosity, and only part of the intra-particle porosity

(ID: 173)

HEALING THE EUROPEAN BUILDING STOCK WITH BIO-BASED MATERIALS: DO WE HAVE ENOUGH AVAILABLE LAND?

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The use of biomass for construction is a promising strategy to store carbon and decrease the construction sector's carbon footprint. When carbon is stored in the building stock for the duration of its lifetime, this, at a large scale, can beneficially alter the atmospheric carbon balance. Massive biomass usage requires large cultivation areas, which can lead to unwanted land use change. While land use change has been intensely studied, the impact of heavy biomass use for construction has not.

This paper aims to determine how much biomass- namely timber for new structures and biogenic fibers for thermal insulation - and the relative land occupation would be needed to satisfy the material demand of the EU residential building stock up to 2050. Based on present land occupation, the potential for biogenic material use was determined. Three systems were distinguished: built environment (BE), biomass resource pool (BRP), and material transformation and processing (MTP) as a connector representing the transformation of raw biogenic materials into ready-to-use construction material. Four alternative construction technologies were studied: wood, cork, straw and hemp.

The comparison of existing cultivation area and demanded land, suggests possible land scarcities for the respective raw materials. Resource scarcity and abundance, as well as material-based practicability for the technology options, could therefore be determined. Finally, a traditional LCA (cradle-to-gate) was conducted to measure the carbon storage and CO2-eq emissions. The results indicate that the existing forests and fields used for cereal production are more than sufficient for supplying straw and timber-based construction materials. Cork is only favourable for turning buildings into carbon sinks at the local scale in Southern dry countries and the current legal limitations for hemp cultivation hinder this material's potential at a large scale.

(ID: 296)

MORTAR TO REPAIR RAMMED-EARTH WALLS' SURFACES: DO WE STILL NEED IT?

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A rammed-earth technique has been echoed worldwide due to being conceived not only as an environment-friendly method of construction but also standing as an alternative method to arguably replacing cement. The technique however shows several pitfalls. One concerns the lengthy process of curing upon erecting the rammed-earth walls due to the low process of a chemical reaction occurred throughout the curing stage. A second bias followed from the slow curing and concerns the degradation accentuated at the outer wall's texture, particularly at the edges, due to effects of the weather cycle. These drawbacks have been observed while accomplishing a funded research project. This article has at its stake remedying the above pitfalls. A natural sandy limestone shows a low percentage of calcium carbonate needed for a cohesive mixture. The method suggested here is based on an experiment that uses minerals of the fruits' and vegetables' waste as a binding substance. Curing time in this method has been reduced to the half. It is also suggested here that each stage has its importance, including mixing the soil particles dry and wet, compacting the moistened soil mixture, a well-made formwork and curing, towards remedying the above pitfalls.

(ID: 210)

THE WEIGHTED PLUNGER TEST : RHEOLOGICAL MEASUREMENT FOR EARTH-BASED BUILDING MATERIALS

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Earth-based building material processing is a challenge for new constructions. Moreover, field measurements to obtain the rheological properties of fresh materials are required in building applications. However, existing field-oriented tests were designed for more flowable materials, and new protocols for stiff materials are rarely available. This paper develops a field-oriented test of yield stress for earth-based building materials accurate enough to identify small variations for demanding applications. We use a weighted plunger test to measure the yield stress accurately. The development of yield stress measurements for fresh earthen materials will help implement new building techniques on the field.

(ID: 221)

SUBSTITUTION OF SYNTHETIC FIBERS BY BIO-BASED FIBERS IN A STRUCTURAL MORTAR

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The use of bio-based material is now widespread in insulation concrete, for example hemp concrete. The bio-based materials in concrete provide many advantages: lightness, sound and thermal insulation, hydrothermal regulation while contributing to a reduction in the environmental impact due to the carbon capture during the plant growth. The development of materials incorporating plant is therefore an important objective for the construction. The next step is to introduce bio-based materials in structural mortars and concrete.

The project FIBRABETON proposes to substitute synthetic fibers by bio-based fibers in screed and structural concrete. After a selection of biomass on the resources availability, separation and fractionation are the key step in processing to obtain technical naturals fibers. Bulk fiber shaping and packaging methods for easy handling and transportation are tested. Then, functionalization of technical naturals fibers by physical & chemical treatments to improve the durability with cement paste is carried out. The second step concerns the introduction of fibers treated or not in mortar and concrete formulations. The variation of nature of the biomass, shape fibers and dosage in concrete are studied. The workability, the compressive strength and withdrawal resistance are measured in order to obtain the best formulation parameters. The evolution of properties over time is also evaluated.

The project FIBRABETON is carried out with ESTP, FRD and Vicat and is subsidized by ADEME, Grand Est region and FEDER.

Earth materials 1

Time:
Thursday, 17/June/2021: 10:30am - 12:30pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Philippe Evon**, LCA-ENSIACET

(ID: 230)

WHAT MAKES COW-DUNG STABILISED EARTHEN BLOCK WATER-RESISTANT?

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The water-resistance of cow-dung has made it a widely used stabiliser in traditional earthen structures in several Asian and African countries. Multiple studies have shown improvement in water-resistance with cow-dung addition, but none provides insight into this behaviour. The present study investigates the water-resistance behaviour of cow-dung stabilised earthen blocks through an extensive experimental program to identify and characterise the components of cow-dung responsible for its water-resistance. Fresh cow-dung was collected and separated into fibers (>63 µm), medium-sized microbial aggregates (1-63 µm) and small-sized microbial aggregates (0.5-7 µm). Each component was mixed with soil and samples were prepared at different water contents (optimum water content corresponding to the highest dry density and water content higher than optimum) and compacted with 2.5 MPa force to prepare compressed blocks. The water-resistance of these blocks were evaluated through the immersion and modified drip/rain test. It was found that the small-sized microbial aggregates are almost entirely responsible for water-resistance behaviour of cow-dung stabilised earthen blocks. Small-sized microbial aggregates were further characterised by gas chromatography, Mercury intrusion porosimetry, N2- BET surface area, Zeta potential measurement and electron microscopy. The results indicate that the small-sized microbial aggregates are composed of clay-sized negatively charged particles that are rich in fatty acids. The hydrophobicity of these particles is hypothesised to be responsible for water-resistance behaviour. These insights are further used to produce stabilised blocks that performed at least 30 times better than the unstabilised blocks in both water-resistance tests. The study concludes with practical recommendations for the use of wet cow-dung over dry cow-dung and reduction of fibres to increase the water-resistance of earthen blocks.

(ID: 164)

EARTH-BASED MORTARS: MIX DESIGN, MECHANICAL CHARACTERIZATION AND ENVIRONMENTAL PERFORMANCE ASSESSMENT

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The incorporation of sustainable materials in the civil construction sector has grown in recent years to minimize environmental impacts. Among these materials, the use of earth, a local raw material that does not require much energy for its processing, appears as an advantageous and promising alternative. Earth mortars stabilized with natural binders, when compared to conventional mortars, can have technological, economic and environmental advantages. The objective of this work was to develop an earth-based mortar stabilized with mineral binders using a 1:3 binder to aggregate mass proportion, and to evaluate its fresh and hardened state properties, as well as its environmental impacts using Life Cycle Assessment (LCA) with a cradle to gate scope. The selected materials were divided in four groups: (i) cement, hydrated lime, fly ash and metakaolinite (binders), (ii) natural sand and coarse fraction of the earth (aggregates), (iii) calcium chloride and superplasticizer (additives) and (iv) water. In the matrix formulation the clay fraction from earth constituted the majority of the binder. The selection of supplementary cementitious materials as additional binders provided improvements in workability and mechanical properties of the mortar. A mix design was carried out using different cement (5; 7.5 and 10%) and fly ash (11; 13.5 and 16%) mass percentages. The water/binder material ratio, superplasticizer content and calcium chloride content were 0.65; 2% and 1%, respectively. The results showed that an increase in fly ash content combined with a decrease in cement content provided an increase in workability and a decrease in mechanical properties of mortars. Nevertheless, the mechanical performance of the mortars remained above the minimum values prescribed in Brazilian construction codes. From the results analysis it was concluded that partial replacement of cement by fly ash provided greater workability in the fresh state and reduced the environmental impacts of the earth-based mortar.

(ID: 156)

PHYSICAL, THERMAL AND MICROSTRUCTURAL CHARACTERIZATION OF EARTH MORTARS STABILIZED WITH INCORPORATING AIR ADDITIVE

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In recent years, the search for non-conventional materials has intensified, aiming to reduce environmental impacts in the civil construction sector as a strategy for more sustainable development. Among these materials, earth mortars are a promising option, as they have technological, economic, and environmental advantages. Due to the absence of literary data on the use of air-incorporating additives (AEA) in earth mortars, the objective of this article is to verify the influence of the incorporation of AEA (0,10, 20, and 40% of the total volume of the mixture) in the mechanical properties (compression strength at 28 days), physical

(total water absorption by immersion), thermal, and microstructural (scanning electron microscopy) of the referred mortars. The study was carried out in a stabilized earth mortar, with a 1:3 mass mix proportion (binder: aggregate). The raw materials used were constituted by binders (cement, hydrated lime, fly ash, metakaolinite), aggregates (sand, a coarse fraction of the soil), additives (AEA, calcium chloride, superplasticizer), and water. The water-binder material ratio (a / bm) was fixed at 0.65, and the consumption of binder and aggregate was 461.71 and 1385.12 kg, respectively, per m3 of the mixture. The tests demonstrated that the incorporation of the additive influenced the behavior under compression (strength and stiffness reduction), thermal performance (conductivity reduction), and physical behavior (absorption and voids index´s increases) compared to the mixture without AEA. From the analysis of the results, it was found that the incorporation of air in the mortars led to an increase in porosity, directly influencing the thermal insulation capacity, measured by thermal conductivity. Microstructure changes were observed through SEM images, corroborating the influence of the AEA. Under compression loads, the stiffness reduction decreases the risk of eventual cracking, however, the reduction in strength should be controlled to meet normative limits.

(ID: 227)

RECOVERY OF EXCAVATED MATERIALS AS AN ALTERNATIVE SOLUTION TO EARTH BUILDING MATERIALS

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The tunnel excavation works generates huge quantities of earth. These excavated materials are mostly stored in landfills. This paper proposes alternative solution consisting in using excavated earth in replacement of raw earth for earthen constructions. Such alternative proposal aims to lower the environmental footprints.

However, numbers of factors affect and limit the use of excavated earth as building material like their gradation, the clay content, the chemical composition, the amount of water content etc ...

Hence, the excavated material was, firstly, characterized using differential and gravimetric thermal analysis (DTA / GTA), infrared spectra (FTIR), microscopic images (SEM) and X-ray diffraction. The results show that the excavated earth is, mainly, composed of dolomite (57%), calcite (26-27%), quartz (0-7%) and clay (2-9%). The excavated earth gradation was determined by wet analysis and shows that it is mainly constituted of gravel (16.3%), sand (22.2%), fine particles (35.5%) and water (26%).

Hence, sand, fine particles and water extracted from excavated earth are used to elaborate mortars stabilized with cement, lime and slag. Short hump fibers were used also to diminish shrinkage cracks. The quantity of stabilizers was fixed to 5% by weight of the excavated earth while the Water/solid ratio was maintained constant and equal to 0.58.

Three-point flexural and compressive tests were performed to characterize mechanical properties of the 5 mortars formulations up to 28 days curing time in controlled environment.

(ID: 184)

EXPERIMENTAL OUT-OF-PLANE BEHAVIOUR OF A RAMMED EARTH SUB-ASSEMBLAGE SUBJECTED TO SEISMIC INPUTS

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Rammed earth technique is spread worldwide, representing the local identity of many cultures for which they must be preserved. Yet, rammed earth heritage is also well known for its high seismic vulnerability and despite the increasing concern for this aspect, few investigations were conducted on dynamic response of such structures. In this framework, an experimental program was undertaken on a rammed earth mock-up by means of shake table tests carried out at Laboratório Nacional de Engenharia Civil (LNEC) in Lisbon. To investigate the out-of-plane behaviour of rammed earth walls, a mock-up was built in real scale with a U-shape plan and then subjected to a series of increasing seismic inputs. The results are here discussed in terms of crack pattern, damage, displacements and base shear coefficient. In conclusion, the model behaved as a rigid block to earthquake simulations.

(ID: 191)

WATER STABILIZATION OF CLAY BRICKS WITH IMPROVED TANNIN AND IRON MIXES

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Weak water resistance is a big obstacle for clay materials to overcome in the modern construction industry. Compared to the hydraulic stabilized additives, bio-additives have lower carbon footprint and have been used in many vernacular construction techniques to immobilize clay. In this work, the traditional recipes of tannin and iron have been revisited, in particular the question of pH and iron solubility has been explored. Oak tannin and FeCl3 were chosen and their influence on the properties of clay materials in terms of rheological properties, compressive strength and water resistance were characterized in the lab. Based on the results, tannin can reduced the yield stress of paste while with the addition of FeCl3, the yield stress of tannin dispersed pastes increased to a value similar to the reference sample but lower than the value contain only FeCl3. The increase was attributed to the complex reaction between tannin and Fe3+. The iron-tannin complexes can also increase the samples' strength and water resistance. TG and SEM were used to understand their functioning mechanisms and results reveal that the improvement is due to the complexes accumulation and oxidation on the sample's surface. The complexes were oxidized into macromolecular compound during the drying, and make the surface layer more dense. Although the oxidized compound didn't change the hydrophilic properties of the sample's surface, they prevent the ingression of water. Further improvement tailoring pH and iron solubility allow then to stabilize the iron-tannin complex in the matrix and avoid surface migration. These results are very promising as they allow to produce a fluid earth material which is water-resistant. This opens a wide range of application potentials and can help to mainstream earth materials in construction.

Hygrothermal properties 1

Time:
Thursday, 17/June/2021: 10:30am - 12:30pm

Location: **Room 2**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Salah Eddine Ouldboukhitine,** Université Clermont Auvergne

(ID: 189)

COMPARISON OF NUMERICAL HMT CODES TO SIMULATE MBV TEST OF HEMP-EARTH COMPOSITES

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The major environmental impacts are due to the building sector, mostly in the matter of the utilization of non-renewable raw materials, discharge of greenhouse gases and waste production. Therefore, it is important to develop original eco-friendly building materials. Bio-based and earth materials are growingly used for the building envelops thanks to their numerous benefits such as slight environmental impact, great hygrothermal performances, effective regulation of the perceived indoor air quality and human comfort. Actually, the phenomena of mass transfer through these materials is complex and has a great impact on the performances of building envelope. Therefore, it is important to identify and understand the hygrothermal phenomena to be able to simulate the envelop behaviour accurately. Nevertheless, the classical models that depict hygric transport within building materials seem inappropriate for bio-based materials as they are simplified on several points of view. The correlation that exists between water content and relative humidity is mostly modelled by one curve, either the adsorption isotherms or the mean of the adsorption and desorption isotherms. The hygric storage capacity is often overstated and the hysteresis is neglected. The sorption phenomenon is considered as instantaneous. This comes to not close enough prediction in moisture transfer.

This paper deals with numerical study of hygric transfer within Hemp-Earth building material by using TMC code. TMC is a code that was developed at the LGCGM (Moissette and Bart, 2009) and has evolved over the years to improve the simulation of the hygrothermal behavior of bio-based materials. The TMC code was validated regarding EN 15026 standard (Moissette and Bart, 2009). Nevertheless, this code shows slight weaknesses to accurately simulate dynamic solicitations, like for MBV test. Then, (Oumeziane et al., 2015) integrates the hysteresis phenomena to the TMC code, thus a clear improvement of the numerical simulations on desorption phase was shown. Finally, (Reuge et al., 2020) add a model of kinetics on moisture storage within TMC code, thus, approving the simulation of experimental test results. This study deals with the simulation of MBV test of Hemp-Earth building material. A numerical assessment is established between WUFI and TMC codes. The results highlight the need to include hysteresis and kinetics to simulate accurately dynamic hygric phenomena.

(ID: 141)

EXPERIMENTAL INVESTIGATION OF THE COMPATIBILITY OF LIME COATING WITH INSULATION STRAW BIOCOMPOSITE

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The use of eco-friendly materials as building materials is one of the innovative solutions for dealing with environmental disorders caused by the construction sector. Among these materials we find biocomposites based on vegetable aggregates, which have proven their effectiveness as insulating materials in numerous studies. Despite the growing interest in these materials and the recognition of their performance, their use remains hampered by the lack of implementation rules specific to these materials to move towards a control of their use and their durability affected by the conditions of use and climate to which they will be exposed at the level of a building. The objective of this work is to study the compatibility of a protective coating with a block support of biocomposites based on cereal straw. It is in fact a mixture of vegetable aggregates (straw), a binder composed of lime and additives also obtained from a renewable source [1]. These additives (air-entraining agent, casein protein and a biopolymer) have been added to improve both the fibre-binder interface and the porosity of the binder. The use of these biobased materials for external or internal thermal insulation of the building requires the application of a coating to protect them against climatic aggressions and to give them an aesthetic appearance. The lime-based coatings, air-entraining agent and casein protein selected for this study have been the subject of an experimental investigation as part of the PEPITE project financed by the “Region Centre Val De Loire” [2]. In order to assess the compatibility of these coatings with the straw-based insulating material, we were interested in studying the adhesion between the biocomposite and the coating after ageing cycles in accordance with the EN 1015-21 standard. The samples (biocomposite + coating) were subjected to two types of ageing, one using water and the other using a saline solution of sodium sulphate (Na2SO4). The results of the adhesion tests after ageing showed that the cohesive fracture (at the level of the substrate) is a pattern observed in all the studied systems. In Addition, It has been found that the coating to which a percentage of fine fibres has been added undergoes considerable degradation after ageing with salt, demonstrating the need for an additional layer of fibre-free outer coating to protect it in the long term.

(ID: 140)

EXPERIMENTAL ANALYSIS OF THE BEHAVIOR OF STRAW BIOBASED COMPOSITE EXPOSED TO HIGH TEMPERATURE

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In view of the climate emergency and the need for energy transition, the use of materials with low environmental impact based on plant co-products or from recycling is strongly encouraged. Biobased materials have been developed in recent years and

have shown interesting performances, particularly for the thermal insulation of buildings. Nevertheless, their use is still hampered by the lack of rules for their use and control of their behaviour in normal or accidental conditions of use such as excess water or fire. In this work, the behaviour of biocomposites based on cereal straw exposed to high temperatures was studied. The objective is to evaluate the effect of this temperature increase on the mechanical strength of the material and its thermal properties using different heating scenarios.

The biocomposites considered for this study were developed as part of the PEPITE project funded by the "Region Centre Val de Loire" [1, 2]. They are materials composed of two different binders: lime, and plaster, straw aggregates and additives (air-entraining agent, casein protein and a biopolymer). After preliminary tests and the use of temperatures of (800°C and 1000C) according to the ISO-834 curve in order to simulate fire, two temperatures were chosen for the study 200°C and 210°C, using four different heating speeds to study their impact on the behaviour of biocomposites. The samples were also tested in both dry and wet states in order to compare and understand the degradation process of the materials. After exposure to temperature, thermal conductivity and mechanical compressive strength tests were carried out where possible if the sample was not destroyed. The results showed that the use of additives had negative effects on the behaviour of the materials with respect to temperature increase. These organic materials burn faster than reference samples. Composite based on gypsum plaster shows a better reaction to fire than biocomposite based on lime. Nevertheless, lime-based composite has a higher resistance than plaster-based composite. The samples do not generate significant cracking. Furthermore, the thermal conductivity of gypsum plaster-based composite is lower than that of lime-based composite. It should be noted that the heating rate has a significant impact on the behaviour of the material, the slower the rate, the more the material is degraded.

(ID: 154)

EXPERIMENTAL AND NUMERICAL STUDY OF HYGROTHERMAL BEHAVIOUR OF A WASHING FINES HEMP TEST WALL

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In order to face the building energy issues and environmental impact bound, it appears that bio based materials are a promising tracks that offer thermal and environmental performances in order to reduce the consumption of energy and of non-renewable resources. For this purpose, in a previous study, the LGCGM worked on the development of Washing Fines Hemp composites and characterized them on multiphysical point of view. Such materials show low thermal conductivity and high moisture buffer ability. The "wall formulation" was used to produce a test wall that is set up in a dual-climate test room where the rooms are air-conditioned to simulate indoor and outdoor climates (regarding temperature and relative humidity).

This paper investigates the characterization of hygrothermal behaviour of Washing Fines Hemp composites at wall scale under typical Tunisian summer climate. It consists in an experimental study, supplemented by numerical simulation. The first part of this paper focuses on the experimental method. Firstly, it presents the test wall, then the experimental device and the metrology implemented in ambient conditions and at various depths of the wall, and finally the hygrothermal solicitations (indoor and outdoor climates). The second part gives the experimental results. The monitored ambient conditions are compared to the set values. The temperature and relative humidity achieved are satisfactory and well describe day/night cycles. The experimental hygrothermal response of the wall to such solicitations is analyzed from the variations in temperature and relative humidity across the wall. Finally, this study is completed with a dynamic simulation. The WUFI Pro V6.5 software is used to simulate the experimental sequence. Numerical and experimental results are compared. The simulation allows to complete the analysis of the hygrothermal behavior of the wall.

(ID: 254)

HYGROTHERMAL BEHAVIOUR OF AIR LIME COATINGS WITH MUSSEL SHELL SAND

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Air lime coating mortars with mussel shells exhibit useful hygrothermal properties related to humidity and temperature regulation. Introducing mussel shell sand produces a significant increase in pore volume, changing mortar's microstructure and reducing density. This is attributed to the flaky and irregular shape of the shell particles that present also traces of organic matter. In this work, the natural aggregate is replaced by mussel shell sand in increasing percentages of 25%, 50% and 75%. Additionally, a mortar with 0% of sand replacement is used as baseline of reference. These mortars are tested focusing in two main parameters, in first term, thermal conductivity. And also absorption and desorption cycles, at 80 and 50% relative humidity. The results are very positive for mussel shells specimens, it can be concluded that the use of mussel shell aggregates can improve the hygrothermal properties of air lime coating mortars. Another interesting result is a subjective property such as the aesthetic quality of the finishing, the results is pleasing and, combined with the promising hygrothermal properties opens a good opportunity for mussel shell mortars.

(ID: 228)

OVERCOMING THE PERCEPTUAL GAP: WORLDWIDE PERCEIVED COMFORT SURVEY OF EARTHEN BUILDING EXPERTS AND HOMEOWNERS

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Earthen building materials are a critical future for sustainable construction because they are locally available, minimally processed, and waste-free. However, despite their advantages, earthen materials still face challenges for comprehensive implementation. First, their technical data vary significantly, making it challenging to quantify their true performance for different

climates and environmental contexts. Second, people mistakenly perceive these materials as low-tech and poor in their performance. Lastly, building codes and standards do not comprehensively represent these materials worldwide.

This work identifies perceptual barriers that hold back the broader implementation of earthen materials in order to ascertain possible solutions and assess the performance of earthen buildings and perceived comfort among primary resources such as practicing professionals and people who live in earthen houses. The results of an online survey of 126 earthen building experts and homeowners are presented, providing important insights regarding a range of barriers to, and motivating factors for, the implementation of earthen materials, as well as design and thermal performance aspects of existing earthen homes.

The results of the surveys show that, of the various earthen building techniques, light straw clay requires the lowest maintenance, and construction of adobe and/or clay plaster encountered the least barriers to implementation. The energy performance of existing earthen homes show that all types of earthen materials reduce the need for cooling, in all climate zones. Insulation over earthen walls was shown to increase occupants' perceived comfort levels, but only slightly. Additional results provide significant recommendations for future research on thermal performance and comfort guidelines for earthen structures.

This study contributes to the development of environmental and policy measures that could be used by policymakers by synthesizing technical and environmental data and by identifying means of improving the perception of natural building.

Innovative admixtures 1

Time:
Thursday, 17/June/2021: 10:30am - 12:30pm

Location: **Room 3**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Elhem Ghorbel**, CY Cergy Paris Université, L2MGC

(ID: 181)

SELF-DESICCATION OF A VERNACULAR CSA BINDER

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The fast precipitation of ettringite in conventional Calcium Sulfoaluminate (CSA) cement causes rapid stiffening of the cement paste and is directly associated with short setting times and self-desiccation. To extend the time during which those types of cement remain workable, retarding admixtures can be used. However, retarders may affect the amounts and types of hydration products formed and as a consequence the ability of hydrated cement to chemically bind water. This work investigates the influence of two natural-based admixtures on the self desiccation ability of a vernacular CSA ternary binder used as earth stabilization. Vicat measurements were used to study the efficiency of citric acid and sucrose as retarding admixtures on the setting time of stabilized earth. A quantitative study of the self-desiccation ability of the binder was performed on dried binder pastes using thermogravimetric analysis (TGA). Results show that both admixtures have a significant impact on the setting time of the binder. Furthermore, TGA showed that the self-desiccation ability of this vernacular CSA binder is significantly reduced when citric acid at high dosages is used, both at early hydration and after 14 days. On the contrary, the use of sucrose does not affect the water chemically bound at early age but can maximize bound water after 14 days of hydration.

(ID: 259)

PERFORMANCE OF ALFA FIBRES IN CEMENTITIOUS MATERIALS EXPOSED TO DIVERSE SURFACE TREATMENTS

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Alfa plant presents a great ecological and socio-economic interest in the Maghreb countries. It is used in several fields of applications such as craft production and paper industry. However, a few research work has been realized on the valorisation of Alfa fibres in the construction sector. The main objective of this work is to develop an Alfa fibre-reinforced mortar with significant mechanical properties for the facade panel's manufacturing. It was highlighted that Alfa fibres enhance the flexural strength of reinforced mortars. Therefore, a decrease in the flexural strength of the composite after 90 days of curing. In addition, the incorporation of Alfa fibres reduced the compressive strength of the composite. In this regard, to enhance the mechanical properties of the composite, various treatments were explored: alkaline treatment with sodium hydroxide, hydrothermal treatment by water boiling, and coating with sulfoaluminate cement. It was noted that the treatments could provide a partial elimination of the non-cellulosic components and enhance the Alfa fibre roughness. Raw and treated Alfa fibres were incorporated into cement mortars at different lengths of the (10 and 20 mm) with an addition ratio of 1 %vol.. Compared to untreated fibres, fibres treated chemically provide an improvement of 38 % of the flexural strength at 28 days for both fibres length. Unlike the coated fibres, the efficiency of treatment was noted at 90 days of curing. Otherwise, a slight increase in compressive strength was observed compared to the untreated fibres mortar. These results were approved by porosity accessible to water and calorimetric tests.

(ID: 236)

CONTRIBUTION ON THE USE OF HOUSEHOLD WASTE AS BIO-ADMIXTURE

Ilham Aguida BELLA[1], Nabil BELLA[1], Aissa Asroun[2], Sara SADDIKI[1]
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Nowadays, production activity and consumption generate waste products, which is often associated with the deterioration of our environment and with multiple risks directly affecting human health. Is considering as a waste: any residue from production, transformation, or use process, any substance, material, product, or more generally any movable property abandoned or that its holder intends to wildness.

Wastes can be classing according to their origin (agricultural, municipal, industrial, healthcare activities) or according to the type (compostable or biodegradable, inert, recyclable, ultimate, or dangerous).

Waste rallying is an ancient culture in Islamic homes where sorting is the most practical technics', whether we are talking about household or organic waste. Organic waste can be household waste (peelings of fruits and vegetables, leftover meals, or meat) or from gardens and green spaces (grass clippings, crushed plant debris, dead leaves, etc.)

Material recovery, commonly known as recycling, consists of directly reintroducing waste into a production cycle from which it originates in total or partial replacement of living raw material. If we add organic substance and energy, we get the word biomass, defined as all organic substance transformed into energy. The material obtained after methanisation or degradation is often a viscous material with a dispersing effect.

In the civil engineering field, the incorporation of chemical admixtures is now a practical technics' used for improving the properties of concrete, such as improved workability, decreasing the water demand, increasing strength, etc.

However, chemical admixtures have some disadvantages such as environmental pollution during both their manufacture and their use, else, there are rare somewhere.

Because of this background, bio-admixtures appear principally useful, due to their environmental effect and friendly properties, bio- admixtures are substances obtained from a biodegradable product also resulting from the methanisation.

The objective of this research is the valorization of household waste used as a bio-admixture. Moreover studying its effect on cement path workability, start/end of the cement setting.

(ID: 213)

STARCH REINFORCEMENT OF RAW EARTH CONSTRUCTIONS

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The restoration, the protection, or the creation of earthen buildings require improving the mechanical strength of the material. The first way to do that is to use inorganic additives, but these additives change the structural properties of earth and have a high carbon footprint. In contrast, the other way to consolidate is the use of organic additives such as vegetal derivatives that rearrange the minerals in the earth, with the lowest carbon footprint as they are from waste management.

After preliminary tests with ten different organic additives from traditional recipes, we found that starch improves the earth strength up to 50 %. In this study, we related the mechanical strengthening to the physicochemical interactions between clays and starch. On one side, we focus on three clays that represent the three main groups of clays: kaolinite, illite and montmorillonite. On the other side, we look at different starches origins and compositions according to a variation of the ratio amylose and amylopectine. For this study, we mainly focused on compressive test and rheological tests.

We showed that the improvement of the mechanical strength with starch is depending on clay nature and their chemistry. Then, we can recommend formulations based on the earth nature for new sustainable buildings. Furthermore, we can understand why it was an interesting way to use starch as a strengthening agent in traditional recipes and how it could be used to repair and protect buildings made of earthen material.

(ID: 243)

TRADITIONAL GYPSUM PAVEMENTS WITH NATURAL ADDITIVES

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In traditional architecture, the construction systems used have always been linked to the material resources of the environment. The basic materials that characterise this architecture are earth, ceramics, wood, stone, lime and gypsum. Of all of those, gypsum has always been one of the most modest and little-known materials.

In the areas of extraction of gypsum in the Iberian Peninsula, the use of this material as a conglomerant was not limited to the interior lining of vertical and/or horizontal walls or to interior decorations, as is the case today, but proved to be a very versatile material, which could be used both in structural elements and in finishing elements. Some of the most significant examples of the use of gypsum in these areas are the vaulted ceilings of poured plaster, interior staircases, floors and exterior cladding.

This study shows the preliminary results of an investigation in progress on the recovery of traditional gypsum pavements. Three types of traditional commercial gypsum are tested with the addition of natural products such as collagen, coconut soap, potassium soap, olive oil and marshmallow root; the hygroscopic behaviour of the samples has been evaluated on the basis of capillary water absorption and contact angle, due for their high hygroscopicity. On the other hand, the thermal conductivity of the samples has also been studied in order to assess their behaviour in the incorporation of this material in radiant floor systems.

(ID: 225)

β-CYCLODEXTRIN SUBSTITUTED POLYOXYETHYLENE IN THE SYNTHESIZE OF POLYCARBOXYLATE SUPERPLASTICIZERS

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In this study, the starch-based material β-cyclodextrin was used as the original material to substitute petrochemical product-polyoxyethylene (HPEG) to synthesize concrete admixture polycarboxylate superplasticizer (PCE). During the synthesis, β-cyclodextrin was first grafted on the PEO chain to prepare β-CD-HPEG by click reaction. Then β-CD-HPEG was used to substitute the macromonomer HPEG to synthesize β-CD-PCE. When the substitution amount HPEG was 3%, the synthesized β-CD-PCE showed better dispersion ability.

Valorisation of agricultural by-products

Time:
Thursday, 17/June/2021: 10:30am - 12:30pm

Location: **Room 4**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Philippe Poullain,** Université de Nantes

(ID: 122)

COMPREHENSIVE CHARACTERIZATION OF AGRICULTURAL BY-PRODUCTS FOR BIO-AGGREGATE BASED CONCRETES FORMULATION

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The valorization of available agricultural by-products is important for the development of bio-aggregate based concretes as eco-friendly solutions for building materials. However, their diversity requires to assess their potential of use in vegetal concretes. This study aims to propose simple and relevant multi-physical characterization methods for plant aggregates. Basic and complementary characterizations were carried out on hemp shiv as a reference plant aggregate, and nine by-products available in the South-West part of France, i.e., oleaginous flax shiv, sunflower pith and bark, coriander straw, wheat straw, wheat chaff, corn shuck, miscanthus stem and vine shoot. The basic characterizations performed were those recommended by the TC-RILEM 236 BBM, i.e., particle size distribution, bulk density, water absorption and thermal conductivity. Complementary characterizations have also been proposed, taking into account the possible environment of the binder and the vegetal concrete manufacturing method. The additional tests developed or adapted from previous research assess the following properties: the content of water-soluble compounds at pH 7 and 12, the wet compacted dry density, the real water absorption after compaction and the compression behavior of these compacted aggregates. This complete characterization highlights the distinct behavior of the different agroresources and allows to correlate these characteristics to the use properties of hardened composites.

(ID: 159)

MECHANICAL COMPRESSION AND CRUSHING PROPERTIES OF A STRAW-LIME MATERIAL

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The aim of this study was to determine the compressive mechanical properties and the energy absorption characteristics of a bio-composite material based on lime, wheat straw, and additives (protein and entraining agent). The selected samples with fiber to binder ratio of 30% were subjected to compression tests at different strain rates (1 mm/min, 10 mm/min, and 100 mm/min), in the perpendicular and parallel directions to fiber orientation. Image analysis supported with Digital Image Correlation (DIC) method is performed to follow longitudinal and lateral deformations, thus making it possible to evaluate elastic properties. The results show that the highest density and compressive strength in the parallel direction are ~349 kg/m3 and ~0.101 MPa, respectively. The perpendicular specimens at 100 mm/min of speed test showed the highest values of densification strain, stress plateau, energy efficiency, and absorbed-energy of 47.27%, 0.32 MPa, 16.98 %, and 13.84 kJ/m2, respectively. The values of Young's modulus identified with DIC are significantly different from those determined by the slope of the linear part of the stress-strain curve. A slight influence of strain rate on mechanical properties is observed.

(ID: 187)

THE IMPACT OF RICE STRAW PARTICLE SIZE ON THE MECHANICAL AND THERMAL PROPERTIES OF STRAW LIME CONCRETES

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The use of bio-based concretes performed with lignocellulosic aggregates constitute an interesting solution for reducing the energy consumption, greenhouse gas emissions and CO2 generated by the building sector. Indeed, bio-based materials could be used as an alternative of traditional materials such as expended polystyrene and mineral resources (e.g. glass and rock wools) for insulation. Furthermore, these bio-based concretes are known for their interesting insulation properties, indeed they allow to enhance thermal properties of buildings and enables moisture management which lead to design efficient building materials. For this purpose, bio-based concrete using rice straw as aggregate are studied in this present work. The impact of the characteristics of rice straw particle (particle size distribution, bulk density, and water absorption capacity, etc.) on both the mechanical and thermal properties of the bio-based concrete are investigated. Five formulations of rice straw concrete are examined, compared and then classified in terms of their insulation and mechanical properties. The assessments are based on the measurement of density and thermal conductivity. The variation of compressive strength in function of the characteristics (mean particle length) of rice straw particle are assessed and discussed. The investigation covers also the porosity and density. Tests are also carried out on agricultural by-products with a view to highlight their chemical, physical and structural proprieties. The results show that the use of large particles with low water absorption capacity induce lighter concretes with the density between 339 and 505 kg/m3 and lead to a high compressive strength with a high mechanical deformability. Furthermore, it appears that an increase in the average length of rice straw particle lead to decrease of thermal conductivity of bio-based concretes. It varies from 0.062 to 0.085 W/m.K .

(ID: 176)

MECHANICAL PROPERTIES AND FRACTURE ENERGY OF CONCRETE BEAMS REINFORCED WITH BASALT FIBRES

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Fibre-reinforced concrete (FRC) is employed for a number of reasons throughout the construction industry, with assorted fibre types being used for different applications. Typically, steel fibres can give additional tensile strength to the member, while flexible fibres may be used in large sections, such as floor slabs, to control crack width and improve the handling ability of precast sections.

For a number of reasons, including durability concerns, environmental considerations, thermal performance, etc, alternatives to the currently available fibres are being sought. This study examines the potential of using basalt fibres in reinforced concrete sections comparing it to steel fibres and plain concrete mix. It was tested mixes containing 0.5% and 1.0% of basalt fibres measuring 25mm length, 0.5% of the same material with 48mm length and steel fibres measuring 50mm by 0.05%, 0.1%, 0.15% and 0.2% of the concrete volume.

For the mechanical performance analysis, the 3-point bending test was led and the fracture energy, Young's modulus and tensile strength in different moments of the tests were calculated.

When compared to the control mixtures and to the steel-fibre-reinforced concrete, the mixes containing basalt had a reduction in their elastic modulus, representing a decrease into the concrete brittleness. At the same time, the fracture energy of the mixtures was significantly increased with the basalt fibres in both lengths. Finally, the flexural strength was also higher for the natural fibre reinforced concrete than for the plain concrete and comparable to the results obtained from the addition of steel fibres by 0.15%.

(ID: 115)

EFFECTS OF 0-30% WOOD ASHES AS A SUBSTITUTE OF CEMENT ON THE STRENGTH OF CONCRETES

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To fight against the high cost and the increasing scarcity of cement and at the same time to reduce the CO2 greenhouse gases emission associated with the production of Portland cement, two types of wood ashes as a substitute of cement in the production of concretes were investigated. In this paper, we substituted cement by two types of species of wood ashes namely, avocado and eucalyptus ashes following the proportions going from 0 to 30 % on one hand, and on the other hand, we added these two types of species of wood ashes namely, avocado and eucalyptus ashes following the proportions going from 0 to 10 % by weight of cement in the concrete samples. After 7, 14 and 28 days of curing, compressive strength tests were conducted on these concrete samples. The findings revealed that using wood ashes as additives/admixtures or as a substitute of cement in the production/manufacturing of concrete decreased the compressive strength of concrete. Hence, it can be said that wood ash has a negative influence on the strength of concrete. At three percent (3%) and ten percent (10%) of addition, the wood ash from eucalyptus specie offers better resistance compared to the wood ash from avocado specie, whereas at five percent (5%) of addition, the wood ash from avocado specie offers better resistance compared to the wood ash from eucalyptus specie. At thirty percent (30%) of substitution, the wood ash from eucalyptus specie offers better resistance compared to the wood ash from avocado specie. The compressive strengths increase with the increase of curing age.

(ID: 177)

EXPERIMENTAL INVESTIGATION ON THE FRACTURE ENERGY AND MECHANICAL BEHAVIOUR OF HEMP AND FLAX FIBRE FRC COMPARED TO POLYPROPYLENE FRC

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Natural fibre reinforced concrete is been studied for many years. The most common fibre materials currently adopted are steel, glass and synthetic fibres. Apart from the high oxidation and cost, their environmental impact is a serious issue to be considered.

This study assesses the feasibility of replacing polypropylene fibre with hemp and flax fibres. According to the inventory of carbon and energy (ICE) the embodied energy of polypropylene (PP) is 95.4MJ/kg and the embodied carbon is 4.98kgCO2/kg during its lifetime. It represents approximately 3 times more than the estimated values for vegetable fibres. Flax and hemp fibres are widely cultivated around the world, are affordable and natural. Different concrete mixtures reinforced by 0.5% to 1.0% of hemp, flax and polypropylene fibres were tested and their post-crack flexural tensile strength, elastic's modulus, compressive strength and fracture energy were evaluated. It was found that mixtures containing hemp fibres presented properties slightly superior to those containing polypropylene under same proportion.

Although both compressive and tensile strength were reduced for the mixes containing flax fibres, the Young's modulus was 49% smaller and could be an interesting approach for applications that require better elasticity from the concrete, such as industrial floors and structures that may be submitted to impact.

Earth materials 2, concrete, bamboo

Time:
Thursday, 17/June/2021: 3:40pm - 5:20pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Francesco Pittau,** Politecnico di Milano

(ID: 138)

SEASHELLS AND OYSTER SHELLS: BIOBASED FINE AGGREGATES IN CONCRETE MIXTURES

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The construction industry is the largest global consumer of materials. As cities get bigger to accommodate the increasing urban population, the earth's natural resources supply chain is being pushed to the limit.

Among the primary materials needed in construction, sand plays a fundamental role; now the second most used natural resource behind water, sand is the primary component in concrete and glass, and it is also used for land reclamation and oil exploration. On the other hand, natural sand production is a slow process; as a result, sand is consumed at a faster pace than it's replenished. We are facing sand scarcity, which could be the key of the economic development in the 21st century.

One way to reduce consumption of sand is to optimize the use of alternative materials in the concrete industry. Due to the popularity of concrete, even small percentages of saving can determine large benefits. This could have a twofold effect on the construction industry, if we consider that concrete production contributes every year to 5% of the total carbon emissions.

This paper reports the exploratory study on the suitability of aquaculture byproducts as fine aggregates in concrete mixtures. In this study, seashell grit, seashell flour and oyster flour were analyzed. Starting from a standard control mixture, these aquaculture byproduct were used as sand replacements, with increasing substitution percentages (10%, 30% and 50% respectively). All the mixtures were characterized in fresh and hardened states (workability, air content, compressive strength, modulus of elasticity and water absorption). The obtained mixtures were compared among them and with the control mixture.

Based on compressive strength, which was measured at 7 and 28 days, seashell grit provided the most promising results: the compressive strength of the concrete cubes was found to be larger than for conventional concrete cubes. Moreover, the compressive strength of the cubes was larger, when larger percentages of seashell grit were used, with the highest value obtained for 50% substitution.

A different behavior was observed for both oyster flour and seashell flour, in which the compressive strength of the tested cubes decreased with the increase of the substitution percentage. For these mixtures, only the 10% sand substitution provided results comparable with the control mixture, while for higher substitution percentages, a reduction of the compressive strength was observed.

The research allowed also to observe that for the three aggregates, workability of concrete decreases with fineness modulus decrease. For mixtures in which shell and oyster flour were used with 30% and 50% substitution percentages, it was necessary to increase the quantity of mixing water to allow a minimal workability.

In conclusion, considering the promising results of the seashell grit, it is suggested to study further the characteristic of the material, also considering its environmental and physical properties, including acoustic and thermal performances. Higher substitution percentages should also be investigated.

This research adds to the relevant literature in matter of biobased concrete or green concrete, aiming at finding new biobased sustainable alternatives in the concrete industry.

(ID: 267)

HYDRO-MECHANICS COUPLING ON RAMMED EARTH MATERIAL: DRYING EXPERIMENT AT STRUCTURAL SCALE

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Rammed earth structures are very sensitive to hydric conditions. Experimental studies have been undertaken to understand the link between liquid water transfer and mechanical behavior at a structural scale. This study was done on a prismatic rammed earth sample of 15cm x 15cm x 45cm, structured as a wall element with several layers. Samples were subjected to one-dimensional drying in an indoor environment. Humidity and temperature sensors were placed on each layer inside the sample. The kinetic of drying was monitored by continuous weighing the sample and humidity measurement at a regular interval. Results of water content evolution suggest that samples dry in two stages; the first stage is associated with a relatively high evaporation flux of 13.88 g m-2h-1 while the second stage has a very low flux of moisture evaporation. Unconfined compressive strength was performed in drying samples after 0, 2, 6, and 8 weeks of drying. In parallel, digital image correlation was used to determine the stiffness of samples. Results show an increase in compressive strength by the rate of 98 kPa per week in the first two weeks, then this rate reduces to 23 KPa per week after 8 weeks. These experimental results will allow enhancing the 3D hydro-mechanical numerical model developed in the laboratory.

(ID: 133)

MECHANICAL PROPERTIES OF RAMMED EARTH STABILIZED WITH LOCAL WASTE AND RECYCLED MATERIALS

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Traditional techniques of construction using natural and locally available materials are nowadays raising the interest of architects and engineers. Clayey soil is widely present in all continents and regions, and where available it is obtained directly from the excavation of foundations, avoiding transportation costs and emissions due to the production of the binder. Moreover, raw earth is recyclable and reusable after the demolition, thanks to the absence of the firing process.

The rammed earth technique is based on earth compressed into vertical formworks layer by layer to create a wall. This material owes its strength to the compaction effort and due to its manufacture procedure exhibits layers resembling the geological strata and possessing high architectural value. The hygroscopic properties of rammed earth allow natural control of the indoor humidity, keeping it in the optimal range for human health. Stabilization with lime or cement is the most common procedure to enhance the mechanical and weather resistance at once. This practice compromises the recyclability of the earth and reduces the hygroscopic properties of the material. The use of different natural stabilizers, fibers, and natural polymers by-products of the agro&food industry, can offer an alternative that fits the circular economy requirements. The present study analyses the mechanical resistance of one Italian earth stabilized with different local waste and recycled materials that can allow the final recyclability of the material.

(ID: 250)

VARIABILITY ASSESSMENT OF THE COMPRESSIVE AND TENSILE STRENGTH OF FIBRED EARTHEN COMPOSITES

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Earthen composites (rammed earth, cob, adobe, daub, CEB…) are experiencing renewed interest from builders due to the many advantages of these building materials, and in particular their eco-friendliness. Nevertheless, the widespreading of these materials, as certified materials and conforming to construction standards, comes against the lack of data concerning their mechanical properties. Indeed, the literature generally gives the average values of the properties without indicating the number of specimens tested neither the distribution of the data. Yet, the mean value of the compressive strength is not enough to assess the reliability of a given earthen composite to build a wall and it would be better to indicate the value of a defined percentile (characteristic value just like with concrete composites).

The aim of this paper is to analyze the data about the mechanical properties (tensile and compressive strength) obtained on different formulations of cob including natural fibres or not. The tests performed allowed to determine the probability density function and the average values, the standard deviation and the percentiles, for the various properties.

(ID: 274)

USING MUNICIPAL SOLID WASTE INCINERATION ASH (MSWI-BA) IN CONCRETE

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The physical and mechanical properties of concrete cubes and cylinders containing municipal solid waste incineration bottom ash (MSWI-BA) has been investigated. This research used four concrete mixes. A proportion of 1(cement): 2(sand): 4(coarse aggregate) by weight was used in the control mix. However, the sand was partially substituted with 20%, 40% and 60% MSWI-BA in the other three mixes. The water to cement ratio was kept constant in all mixes. There was an increase in compressive and tensile strength as well as the elastic modulus are increased when 20% of sand is replaced with MSWI-BA. However, beyond 20% these properties were reduced.

(ID: 306)

BAMBOO CONNECTION TECHNOLOGY FOR LIGHTWEIGHT STRUCTURES

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Bamboo construction is often related to traditional and vernacular architecture, which is found mostly in rural areas, where, for the construction, local people apply diverse techniques learned in an empirical way and passed on from generation to generation. However, in the last years, many modern constructions with bamboo have been developed around the world. At the same time, many connections have been designed for permanent and ephemerals lightweight structures. However, most of them do not have standardization and mechanical testing, because it is expensive or there are no means to do it. Therefore, it is required to create a technology classification for the most used existing connections, starting with the traditional way to join canes until the contemporary connections developed with high technology. In this context, connections are a challenge to be developed, as currently there is no normative in bamboo to follow and create standardization.

Hygrothermal properties 2

Time:
Thursday, 17/June/2021: 3:40pm - 5:20pm

Location: **Room 2**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Camille Magniont**, LMDC

(ID: 272)

IMPACT OF BIOBASED SURFACTANTS ON HYGROTHERMAL BEHAVIOUR OF GYPSUM FOAMS

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Reduce the impact of the building sector has become a key point of sustainable development. The production of lightweight materials for the building industry is therefore a must. To produce such materials, foaming is a process commonly used to trap air bubbles and achieve a range of low densities. A sufficient low thermal conductivity and an acceptable ability to regulate humidity variations in order to limit overall energy consumption are the sought properties. In this study, a direct foaming method is applied to formulate gypsum foams using a commercial Plaster and two biobased foaming agents based on proteins. An anionic surfactant (α- olefin sulphonate sodium salt) is used as a reference surfactant. Varying the mixing time, protein content and water content, gypsum foams were produced. The foam volume is measured continuously during the mixing step and the foam homogeneity is controlled. The densities of fresh foams and of the hardened foams are used to identify the links between formulation and foams properties. Gypsum foam specimens with different densities ranging from 300 to 750 kg/m3 are produced. The thermal conductivity and the Moisture Buffer Value measurements are performed. Such properties appear directly linked to the porosity and pore connection of the foams. The obtained results highlight the contribution of biobased surfactant to the performance of gypsum foams.

(ID: 190)

CONTRIBUTION OF BINDER AND HEMP SHIV TO SORPTION PROPERTIES OF HEMP CLAY COMPOSITE

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This study investigates the sorption isotherm of two kinds of hemp clay composites made with the same hemp shiv (Biofibat®, CAVAC France) and two types of binder: a clay binder (HCC) and a stabilized clay binder (HSCC). The natural clay comes from washing mud from a gravels production site. The stabilized clay is made of natural clay stabilized with 5% of commercial lime-based binder and 5% of Portland cement. The hemp shiv used in this study is a commercial product Biofibat.

For each kind of binder, four hemp to binder mass ratios (H/B) are considered (from 0.4 to 0.75). The water demand of each binder depends on its composition. Thus, in order to reach the same consistency of the mixtures, the total water content W is adjusted conserving the same WB/B and WH/H ratios with W = WB+WH.

After mass stabilization the densities of produced samples ranges between 402 kg/m3 and 578 kg/m3 for HSCC, and between 362 kg/m3 and 481 kg/m3 for HCC. Whatever the binder matrix, the density decreases with the hemp shiv content. For a given hemp shiv content, the density is higher with stabilized clay.

Sorption isotherms are measured according to the discontinuous method. The sorption isotherm is measured at 23°C. Relative humidity used for this study are 0, 35, 50, 65, 80 and 90 % RH.

The sorption curves of the developed composites are sigmoid modelled using GAB model. In the considered relative humidity range, the water contents are slightly higher for HSCC than for HCC.

Over the whole range of the considered relative humidity, whatever the type of binder, the water content increases linearly with the hemp content. Linear parameters obtained for each relative humidity are used to evaluate the separated contribution of the hemp shiv and of each binder to the water content of the composite.

The adsorption isotherms of hemp shiv, binder of HCC and binder of HSCC are obtained. We observe that the two curves obtained for the hemp shiv are almost superimposed. The water contents obtained for hemp are in the range of sorption curves found in the literature. The adsorption isotherm of the binder of HCC in the composite has negative values. Therefore, this binder matrix degrades the sorption of the mixture. On the other hand, the adsorption isotherm of the binder of HSCC is positive. The obtained values are in the range of the values obtained in literature for earth bricks.

The estimated water contents of composites is in agreement with the experimental values obtained for all the composites. Then, we are able to predict the sorption curve for such kind of matrix and implementation whatever the hemp to binder ratio is.

(ID: 149)

THERMAL AND MOISTURE BUFFERING PROPERTIES OF NOVEL HEMP-LIME COMPOSITES INTEGRATED WITH MICROENCAPSULATED PHASE CHANGE MATERIALS

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Higher requirements for buildings' energy performance and indoor environmental quality have prompted new technologies such as latent heat storage with phase change materials capable of storing and releasing significant quantities of heat per unit mass near room temperature. Conventional building materials (e.g., gypsum, concrete) used for mixing with microencapsulated phase change materials (MPCM) often contain high embodied energy. Hempcrete is a sustainable biocomposite material that can significantly reduce a building's embodied energy and energy consumption while enhancing indoor environmental quality. This

research aims to develop a new low-carbon latent heat storage material composed of hempcrete and MPCMs with improved hygrothermal properties for sustainable buildings. Eight hempcrete composites were created using different design mixes using hydrated lime, metakaolin, hydraulic lime, and recycled crushed brick. Furthermore, eight hempcrete-MPCM composites were made using two MPCM types, four MPCM melting temperatures, and two MPCM concentrations. The characterization of composites' thermal and moisture properties includes measuring thermal conductivity, volumetric heat capacity, and moisture buffer capacities. The findings suggest that the developed hempcrete-MPCM samples have a higher heat storage capacity than the hempcrete due to their higher volumetric heat capacity. Moreover, hempcrete-MPCM samples have lower thermal conductivity than hempcrete samples in the same density range and testing orientation. The average moisture buffering value for the hempcrete and HPCM samples of 2.78 and 2.76 (gm/m2 RH%), respectively, indicates excellent moisture buffering performance. The results suggest that the optimal integration of MPCMs requires a thorough consideration of the operating temperature and percentage of MPCMs within the hempcrete concerning the specific application and performance objectives.

(ID: 162)

BIO-STABILISED EARTHEN BLOCKS: A CRITICAL STUDY ON COMPRESSION TESTS OF IMMERSED SAMPLES

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Currently, much consideration is given to earthen building materials regarding their highly sustainable properties. Numerous studies have highlighted their structural ability but their water sensitivity is still limiting a potentially more spread use. To limit this sensitivity several studies have recently brought out the positive effects of bio-stabilisers such as linseed oil or xanthan gum. These recent developments allow bio-stabilized earthen materials to be resistant to immersion in water. Also, a French experimental standard (XP P 13-901) for compressed earth blocks already asks for a minimal compressive strength after a two-hour immersion that is overly severe and is difficult to satisfy without the addition of high contents of hydraulic binders.

In this paper, a critical study of this compressive test after immersion is conducted on bio-stabilized (linseed oil and xanthan gum) samples of different Breton earths. Some testing adjustments are suggested and the water-diffusion in the samples is followed and linked to previously obtained capillary absorption coefficients. It is shown that the effect of immersion on the mechanical strength depends on the sample size and that an equivalence between size and immersion time can be made based on an equivalent penetration depth.

Linseed oil and xanthan gum help to significantly increase the compressive strength of the earthen materials after immersion and allow to avoid the addition of hydraulic binders in earthen blocks to obtained a strong water resistance. The water diffusion in the sample during the immersion can be linked to capillary absorption behaviour, thus a water content and a compressive strength after a given time of immersion could be easily predicted.

(ID: 303)

SENSITIVITY STUDY ON THE PARAMETERS OF A HYGROTHERMAL TRANSFER MODEL OF AIR, HEAT AND MASS TRANSFER

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The energy performance of buildings represents a major challenge in terms of sustainable development. The buildings and buildings construction sectors combined are responsible for over one-third of global final energy consumption and nearly 40% of total direct and indirect CO2 emissions. In order to reduce the energy consumption of buildings and their harmful impact on the environment, special attention has been paid in recent years to the use of bio-based materials. Several works have been carried out in the last decades in order to model the coupled heat, air and moisture transfers in the building envelope but the difficulties lies in the identification of numerous parameters that the HAM proposed models use. In the present paper, a sensitivity study regarding the HAM parameters is implemented in order to apprehend the most determining parameters during the transfer processes. A reduced model based on these parameters is then determined.

(ID: 301)

EXPERIMENTAL INVESTIGATION ON EVAPORATION RATE FOR ENHANCING EVAPORATIVE COOLING OF PERVIOUS PAVEMENT CONTAINING RECYCLED RUBBER

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Traditional impermeable pavements such as asphalt have dark surfaces and high thermal inertia. During hot weather, they tend to absorb and store solar radiation, which promotes the development of urban heat islands (UHI). Furthermore, permeable pavements are effective in mitigating the urban heat island effect via evaporative cooling. There are many studies in the literature on the hydraulic and mechanical characteristics of permeable pavements, but a few studies focus on the impact of evaporative cooling of these pavements. In this study, 3 types of permeable pavements based on pozzolan, recycled rubber and polyurethane resin were studied during 3 hot days. The objective was to quantify the cooling effect in these innovative permeable pavements compared to a traditional impermeable asphalt pavement. The results of this experiment show that the cooling effect in the new types of draining pavements can last up to two days in the weather conditions of this experiment compared to the traditional asphalt pavement. The evaporation rate and surface temperature of permeable pavements vary in opposite directions. In addition, evaporation in pervious pavements is controlled by the availability of water near the surface. This study is a preliminary step in the design of pavements that contribute to the valorization of rubber waste, to the stormwater management and to the reduction of the effects of urban heat islands during heat waves.

Life Cycle Assessment (LCA)

Time:
Thursday, 17/June/2021: 3:40pm - 5:20pm

Location: **Room 3**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Thibaut Lecompte**, IRDL-Univ.de Bretagne-Sud

(ID: 145)

IMPACT OF GHGS TEMPORAL DYNAMICS ON THE GWP ASSESSMENT OF BUILDING MATERIALS: A CASE STUDY ON BIOBASED AND NON-BIO-BASED WALLS

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In a static Life Cycle Assessment (LCA), the global warming potential (GWP) is calculated assuming Green House Gas (GHG) impact to be independent of their emission or uptake timing.

This study investigates if this approach is adequate to fully capture the global warming impact (GWI) of building materials. Static LCA (sLCA) was compared to dynamic LCA (dLCA) on two case studies, a conventional wall made of concrete and mineral wool, and a bio-based wall made of wood and straw.

The main results are:

- sLCA do not allow to evaluate the real GWI of building materials. This might mislead the comparison of building materials.

- GWP indicator might be estimated at 100- and 500-year-TH to better support mitigation in the building sector;

- The relative metric in kgCO2 equivalent misleads conclusions. Absolute global warming indicators calculated with dLCA might be fairer to compare building materials' GWI;

- sLCA with at 100 years GWP indicator and a relative metric in kgCO2e, which is the approach currently used in the French building sector, disadvantages bio-based solutions compared to conventional ones;

- dLCA applied to an alternative functional unit — maintaining a housing function during several centuries — demonstrates that temporary carbon storage induced by bio-based materials do not lead to dramatic carbon release for future generations.

(ID: 167)

HOW DOES A CLIMATE-NEUTRAL BUILDING CAN LOOK LIKE?

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The climate crisis is urging us to act fast. Buildings are a key leverage point to reduce greenhouse gas (GHG) emissions, but the embodied emissions related with their construction remain often the hidden challenge of any ambitious policy. Considering that a complete material substitution is not possible, we explore in this paper a material greenhouse gas (GHG) compensation where fast-growing bio-based insulation materials are used to compensate building elements that necessarily release GHG. Different material diets as well as different building typologies are modelled to to assess the consequences in term of bio-based insulation requirement to reach climate-neutrality. The material diets are defined according to the gradual use of herbaceous materials, from the insulation up to the structural level: mineral, woody and herbaceous. Our results show that it is possible to build climate-neutral buildings with sufficient energy performance to fulfill current standards and with building components thickness within the range of current construction practices. This paper evidences that it is technically feasible and that climate-neutrality in the construction sector just depends on the future we choose.

(ID: 135)

LIFE CYCLE ASSESSMENT OF CIRCULAR BIO-BASED CONSTRUCTION

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The construction sector is a large consumer of non-renewable resources and it is responsible of 44% of global energy related CO2 emissions. Circular economy is an emerging strategy that has potential to make significant improvements in the construction industry, by taking efficient and sustainable actions against climate change. The principles of circular economy are to minimise the waste of resources, by maximizing materials' performances, whilst in use, and recycle and regenerate them at the end of their service life. Natural materials can potentially be suitable in this strategy, due to the use of renewable resources, carbon sequestration potential, and high suitability for reuse and recycling.

The development of bio-based wall panel is a first step into the integration of a circular economy approach in the construction sector. In this study, vapour responsive bio-based panel prototypes with low thermal transmittance (U<0.20 W/m2K) are being designed, taking into consideration the burdens and benefits of natural materials over their entire life cycle. The challenge is to assess the environmental impact of the panels during their design and production, maximise performance and life span, when in use, and regenerate and recycle panel components at the end of the service life.

In this paper, a life cycle assessment of a prototype bio-based panel designed with circular economy principles is investigated. The environmental impact of the panel is analysed to investigate limitation in assessing emissions and use of resources in a circular prospective. The objective of the research is to integrate environmental impact analysis during the early stage of panel

design. This will put the basis for the development of a sustainable and circular building industry and for identifying area of improvements for the development of sustainable circular panels with expected hygrothermal benefits conferred using bio-based materials.

(ID: 204)

LIFE CYCLE ASSESSMENT OF A WALL MADE OF PREFABRICATED HEMPCRETE BLOCKS

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Hempcrete is a natural building material obtained mixing hemp shives (i.e., the woody core of the hemp plant) with a lime-based binder and water. Hempcrete as construction material is gaining increasing interest as the EU aims to achieve net zero emissions by 2050. This material has, in fact, the ability to uptake carbon dioxide from air (i.e., via carbonation) and to store carbon for long time. The goal of the present work is to deeper analyze the environmental profile of hempcrete, in order to assess its potentials in reducing emissions of construction sector. Specifically, Life Cycle Assessment (LCA) of a non-load-bearing wall made of hempcrete blocks is carried on. The analysis encompasses the whole life cycle from the extraction of raw materials to the end of the service life. The analyzed blocks are produced by an Italian company. Only aerial lime is used as binder, microorganisms are added to the blocks to accelerate carbonation. The impact on climate change is assessed through the GWP 100 method proposed by IPCC. Preliminary results reveal a nearly neutral carbon budget.

(ID: 255)

EVALUATION OF GHG EMISSIONS FROM THE PRODUCTION OF CROSS-LAMINATED TIMBER (CLT): ANALYSIS OF DIFFERENT LIFE CYCLE INVENTORIES

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The Cross-Laminated Timber (CLT) has been receiving special attention in recent research as an alternative for climate change mitigation since it is a renewable source and can remove and stock high amounts of CO2 from the atmosphere. Some countries, such as Brazil, still do not have mature and large CLT industry. However, the development of this industry in other countries is expected since the CLT is considered the main wood material to be used in high-rise mass timber buildings. It is particularly important to have environmental information, especially concerning the climate change impacts, in terms of life cycle greenhouse gas (GHG) emissions, for this product to increase its competitiveness in a new market. In this context, this research aimed to evaluate three different Life cycle inventories (LCIs) for CLT production of studies from Japan and the United States. Based on the first findings, we summarized the critical items in the LCI of CLT production and listed some actions for the reduction of GHG emissions that occur in this process. The LCIs are adapted considering the context of Brazil (a country with a cleaner electricity matrix) and China (a country with the highest share of fossil fuels). The main inconsistencies present in the LCIs are presented and discussed. The GHG emissions are concentrated in the following hotspots: (1) Roundwood production; (2) electricity consumption; and (3) adhesives production for CLT production. Therefore, the reduction of the consumption of these materials and activities should be encouraged for the decrease of GHG emissions. The data of Roundwood used in the modelling severely affects the final results. Their GHG emissions are related to the consumption of diesel in forestry activities. This research brings insights into the evaluation of the life cycle GHG emissions from the production of CLT.

(ID: 194)

REFLECTIONS ON THE ENVIRONMENTAL IMPACT OF 'VEGETARIAN' BUILDINGS, AND ON THE RELIABILITY OF DATABASES

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This paper proposes some considerations stemming from the analysis of seventeen ecologically oriented buildings, that show different approaches to "vegetarian architecture" – a theoretical stance based on principles learnt from agriculture and nutrition, which advocates building with natural materials, free of chemicals and as little processed as possible, as well as a preference for simple technologies and passive solar design. The case studies were selected in various countries and climates ranging from Europe to Japan.

The research includes a systematic investigation of the constructional characteristics of each building, and the inventorisation of all their components.

The embodied energy and 'embodied carbon' associated to phases A1 to A3 ('cradle to gate') were then calculated, based on two open access databases, ICE and Ökobaudat. The building materials were aggregated in three macro-categories (vegetal; other natural; and man-made materials), to verify if the selected cases can be really dubbed as 'vegetarian'.

The comparison of the results allowed a discussion of the design solutions in terms of building form, as well as of efficient use of building materials and construction technologies. The interest in verifying whether such 'vegetarian' buildings have a lower environmental impact than conventional buildings led to note that at the present time there is still a lack of credible benchmarks, due to the absence of systematic reviews of average environmental impact values in literature. Moreover, LCAs are usually calculated with proprietary software and only seldom by adding up the single components manually, as it was done here.

The sometimes disorienting discrepancy between the two databases and their change over time suggested a reflection on the databases' assumptions and their reliability.

It was also found that mainstream databases are ill-suited to calculate the impact of 'vegetarian' constructions, as they don't cover organically grown, little processed building materials, which imply labour-intensive building technologies.

Mechanical properties 3

Time:
Thursday, 17/June/2021: 3:40pm - 5:20pm

Location: **Room 4**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Mohammed Sonebi.**, Queen's University Belfast

(ID: 269)

INFLUENCE OF PALM OIL FIBERS LENGTH VARIATION ON MECHANICAL PROPERTIES OF REINFORCED CRUDE BRICKS

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Crude bricks are composite materials manufactured with sediments and natural fibers. Natural fibers are waste materials and used in construction materials for reinforcement. Their reuse in manufacturing reinforced crude bricks is eco-friendly and improves mechanical and thermal characteristics of crude bricks. Factors such as type of fibers, percentage of fibers, length of fibers and distribution of fibers inside the bricks have significant effect on mechanical, physical and thermal properties of biobased composite materials. It can be observed by tests such as indirect tensile strength, compressive strength for mechanical characteristics, density, shrinkage, color for physical properties, thermal conductivity and resistivity for thermal properties, and inundation test for durability of crude bricks.

In this study, mechanical and physical characteristics of crude bricks reinforced with palm oil fibers are investigated and effect of change in percentage and length of fibers is observed. Crude bricks of size 4*4*16 cm3 are manufactured with dredged sediments from Usumacinta River, Mexico and reinforced with palm oil fibers at laboratory scale. For this purpose, sediments and palm oil fibers characteristics were studied. Length of fibers used is 2cm and 3cm. Bricks manufacturing steps such as sediments fibers mixing, moulding, compaction and drying are elaborated. Dynamic compaction is opted for compaction of crude bricks due to energy control.

Indirect tensile strength and compressive strength tests are conducted to identify the mechanical characteristics of crude bricks. Physical properties of bricks are studied through density and shrinkage. Durability of crude bricks is observed with inundation test. Thermal properties are studied with thermal conductivity and resistivity test. Distribution and orientation of fibers and fibers counting are done to observe the homogeneity of fibers inside the crude bricks. Finally, comparison between the mechanical characteristics of crude bricks manufactured with 2cm and 3cm length with control specimen was made.

(ID: 232)

INFLUENCE OF THE VARIABILITY OF LIMESTONE AND FLY ASH ON THE SETTING AND MECHANICAL PROPERTIES OF A MOROCCAN COMPOSITE CEMENT

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The Moroccan cement industry is looking for new processes to effectively minimize the high

energy costs associated with cement manufacturing. This work presents the effect of three types of limestone with different chemical compositions and different CaCO3 contents on the physical and mechanical properties of resulting composite cements by the addition of fly ash in the proportions by weight of: 5 % and 10 %. The samples are studied in order to evaluate the interaction between different types of limestone and fly ash. Ternary cements based on fly ash induce a significant prolongation of the setting time compared to binary cements based on limestone. The substitution of clinker by limestone induces an improvement in mechanical strength compared to ternary cements in the first days; at 28 days, cements prepared with fly ashes reach significant strength due to their pozzolanic reaction.

(ID: 223)

RHEOLOGY, MECHANICAL PERFORMANCE AND PENETRABILITY THROUGH FLAX NONWOVEN FABRICS OF LIME PASTES

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The use of plant fibers as a reinforcement for fragile matrices could be an option to improve the sustainability of the construction materials. These reinforcements can be in different forms as short fibers, long fibers or woven or nonwoven. The mechanical performance of the composites is significantly related to the adhesion between the matrix and the fibers. In the case of nonwoven reinforcement, to get a good adhesion, the penetration of the paste is a key point. That is why this study addresses the relationship between rheology, penetration through the nonwoven fabrics and the mechanical properties of various lime pastes with different contents of water and metakaolin (MK). The effect of binder's grinding is also evaluated. The results indicate that MK pastes with higher w/b ratios penetrate better into nonwovens, Grinding has a negative effect on penetrability despite improving the mechanical properties of the pastes.

(ID: 108)

AN EXPERIMENTAL INVESTIGATION ON SUITABILITY OF USING SISAL FIBERS IN REINFORCED CONCRETE COMPOSITES

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Fiber reinforcement is widely used in construction engineering to improve the mechanical properties of concrete such as compressive and tensile strengths. Concrete is strong in compression but weak in tension and is a brittle material. In the construction industry, strength, durability and cost are among the major factors for selecting the suitable construction materials. During this investigation, the mechanical properties of sisal fibers reinforced concrete (SFRC) were assessed namely, flexural strength, tensile strength ad interfacial bond strength. The said properties were assessed in two types of reinforcement namely, randomly oriented sisal fibers and parallel oriented sisal fibers reinforcement. In both cases the sisal fibers were varied in volume fractions so as to establish the optimum value.

The mechanical properties of flexural and tensile strengths were found to increase considerably with increasing fiber volume fractions until an optimum volume fraction is reached, thereafter, the strengths were found to decrease continuously. The prominent increment of 32.4% in flexural strength at fiber volume fraction of 2.0% parallel reinforced fiber concrete composite was observed. There was very small increment on both flexural and tensile strength for randomly oriented chopped sisal fibers reinforced concrete (SFRC). The Interfacial bond strength was found to be 0.12 N/mm2 and was observed to be prominent for chopped sisal fibers reinforced concrete specimens tested for flexural strength. During failure, fiber pull-out was observed and the composite was observed to behave in a ductile manner whereby the fibers were able to carry more load while full fracture had occurred on the specimen. The water absorption capacity of the SFRC was found to increase with increasing sisal fiber volume fraction

(ID: 118)

INFLUENCE OF HIGH TEMPERATURES ON THE MECHANICAL PROPERTIES OF THE WOOD BIO-CONCRETE

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The use of wood wastes in the production of bio-concrete shows high potential for the development of civil construction, since this material, in addition to having low density, increases the energy efficiency of buildings in terms of thermal insulation. However, a concern arising from the production of bio-concretes with high amounts of plant biomass is how this material behaves when subjected to high temperatures. Therefore, this work aims to evaluate the influence of temperature on the mechanical properties of wood bio-concrete. The mixtures produced have plant biomass contents of 40, 50 and 60% by volume, the cementitious matrix being composed of a combination of cement, fly ash and metakaolin. Uniaxial compression tests and scanning electron microscopy (SEM) were performed, with bio-concrete at age of 28 days, at room temperature (reference) and after exposure to temperatures of 100, 150, 200 and 250 ºC. The density and compressive strength of the bio-concrete gradually decreased with increasing biomass content. Up to 200 ºC, reductions in strength and densities of less than 19% and 13%, respectively, were observed. At 250 ºC, reductions in mechanical properties reached 87%. Analysis performed by SEM showed an increase in the number of cracks in the wood-cementitious matrix interface and wood degradation by increasing temperature.

(ID: 185)

CUSTOMISING MICROSTRUCTURAL AND MINERALOGICAL CHARACTERISTICS OF HYDRATED LIME USING BIOPOLYMERS

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The study of lime-based systems is vital to the design of new sustainable building materials. Air lime (calcium hydroxide, Ca(OH)2) is a binder that has attracted considerable attention for its ability to capture CO2 from the atmosphere, its low-cost and low-energy production process. Furthermore, Ca(OH)2 is an important phase of hydrated Portland cements, and lime-based mortars have shown high elasticity and the ability of self-healing. The performance of lime-based building materials can be enhanced by the addition of organic compounds that can modify the mineralogy and microstructure of Ca(OH)2.

In this study, the effects of four biopolymers including starch, inulin, pectin, and calcium lignosulfonate, on the microstructure and mineralogy of lime have been investigated. Hydrated lime was produced by slaking quicklime in water. Two sets of hydrated lime batches were produced for each polymer: (i) the polymer was previously dissolved in water and subsequently mixed with lime, and (ii) the polymer was added as a dry powder to the already hydrated lime at the end of the slaking process. Characterisation of the batches was performed using scanning electron microscopy, X-ray diffraction and laser diffraction. Results indicate that biopolymers affect the nucleation and growth of Ca(OH)2 crystals. This influences the microstructure and crystal aggregation of hydrated lime in colloidal suspension, which will have important implications on the use of biopolymers in Portland cement applications and in the use of lime as a binder for mortars.

Case studies 2

Time:
Friday, 18/June/2021: 9:00am - 10:40am

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Belén Gonzalez-Fonteboa**, University of A Coruña

(ID: 262)

REED AS A THERMAL INSULATION MATERIAL: EXPERIMENTAL CHARACTERISATION OF THE PHYSICAL AND THERMAL PROPERTIES

Raphaele Malheiro, Adriana Ansolin, Christiane Guarnier, Jorge Fernandes, Lívia Cosentino, Sandra Silva, Ricardo Mateus

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The building sector plays a significant role in reducing global energy use and carbon emissions. In the European Union (EU), the building stock represents 40% of total energy use and in which cooling and heating systems represent over 50%. Portugal is one of the EU countries where the consequences of energy poverty are most evident due to the families' financial inability to adequately climate their homes. The reasons are several, but they are mainly linked to buildings' poor passive thermal performance, resulting from inadequate adaptation to the climatic context and reduced thermal insulation. Thus, it is necessary to develop solutions to increase buildings' thermal performance and contribute to reducing their potential environmental impact, which arises mainly from the significative use of active systems. In this sense, the natural building materials are a promising solution, reducing energy use and carbon emissions related to buildings. This research studies the potential use of reed found in Portugal (Arundo donax) as a thermal insulation material. Its physical characterisation and the influence of geometry configuration on its thermal performance are evaluated. Its durability was studied too. Reed stalks were used to carry out the physical and durability tests. A reed board (150 x 150 mm) was built, and its thermal performance was tested in a hotbox. According to the results, the characteristics of reeds found in Portugal make it suitable to be used as a building material. Furthermore, regardless of the configuration studied, the reeds have a satisfactory thermal performance to be used as thermal insulation, in accordance to the requirements defined by Portuguese law, λ <0.065 W/(m.ºC) and Re ≥ 0.30 (m2.ºC)/W. However, to maximise its thermal performance, it is essential to consider how the reed is positioned in the insulation board. There is a trend to the mould growth in the reed, but only under favourable conditions. Additionally, considering the abundance of reed throughout the Portuguese territory, this is an eco-friendly and low-cost option that gathers all requirements to be more used in the construction market.

(ID: 125)

DYNAMIC THERMO-HYGROMETRIC TESTING CAN LEVEL THE PLAYING FIELD FOR BIO-BASED MATERIALS IN INSULATION STANDARDS

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Biobased insulation materials have worthwhile additional properties when compared to conventional materials. They have the potential to reduce the embodied energy in a building's materials as well as properties that help them keep a building cool. Current legislations and testing practices hold back certification of biobased insulation materials. In the Netherlands legislation NEN 2778 is currently not taking the dynamic thermo-hygrometric properties into account and the biobased materials score unnecessarily worse than traditional insulation materials. For a good determination of the physical building quality of biobased insulation materials, it is important that the moisture contents and energy flows are dynamically determined. Compared to insulation materials such as mineral wool, biobased materials can accumulate moisture. The biobased materials need time to respond to changing conditions on the surfaces of the material. There is a shifting temperature and moisture gradient throughout the material, from warm to cold side, from moist to dry side.

(ID: 110)

ANALYSE OF THE EVOLUTION OF THE HYGROTHERMAL PROPERTIES OF THE HEMP-BASED MORTAR WITHIN THE FRAMEWORK OF THE TOTAL WEATHERING PROTOCOL

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The use of bio-based composites for building insulation is interesting from the point of view of hygrothermal performances, economic and environmental benefits. Among different types of organic fibers for these materials, the hemp is interesting because of its huge availability in France and its low price. Nevertheless, the wide application of the hemp-based insulation mortars is hampered due to the luck of database on its durability. This paper consists in better understanding of the evolution of the hemp-based composite and of its hygrothermal properties. The main objectives are, first, to study the evolution of the hemp insulation mortar microstructure and properties under the accelerated aging cycles and second to characterize and analyze the interconnection between observed changes. Experimentally, the protocol of accelerated aging inspired of standardized one was proposed, the microstructural characteristics and the hygrothermal properties, as the total porosity, the thermal conductivity and the moisture buffer value (MBV) before and after the aging cycles was identified. The MBV characterization was performed for both hemp mortar and hemp shives. The obtained results reveal the increase of the hemp mortar porosity and the decrease of

the thermal conductivity of the hemp mortar. Furthermore, the MBV value of hemp mortar changes slightly unlike that of the bulk hemp which is explained by the influence of the mineral matrix. These results consist of data for better forecast on the degradation of the hemp mortar.

(ID: 282)

DEVELOPMENT OF AIRLAID NON-WOVEN PANELS FOR BUILDING'S THERMAL INSULATION

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As the need to ensure thermal comfort in buildings is constantly evolving, new technologies continue to emerge with the aim to develop efficient thermal insulation materials. This study aims to explore a textile technology using Airlaid process to develop non-woven fabrics made of natural fibers extracted from Posidonia Oceanica's waste for assessing their suitability for insulation products in construction field. This technology offers the feature to develop isotropic non-woven structures by orienting randomly the fibers on the fabric surface. The web composed of a mixture of Posidonia Oceanica fibers and a propotion of thermoplastic fibers is then thermally bonded in an oven followed by cooling in order to ensure the solidification of the bonding areas. The prepared panels are then analyzed for the thermal conductivity. It was found that their thermal conductivity is close to commonly used thermal insulation materials with an average value of 0.03553 W(mK)-1 which allows the non-woven panels to compete with widely-used insulation materials for building's field.

(ID: 290)

STRAW MATERIAL: END-OF-LIFE CYCLE ANALYSIS SCENARIO

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Bio-based materials end of life is analysed from straw builders and farming practices. This paper proposes a classification of constructive straw systems according to their selective disassembly processes. According to EN 15804 standard, end-of-life (EoL) cycle analysis scenarios are used to create Environmental Product Declarations (EPD).

These data will be used:

- for architectural projects conception in respect to"RE2020" new French regulation.

- as an awareness-raising approach for the long term design of constructive systems.

Earth materials 3

Time:
Friday, 18/June/2021: 9:00am - 10:40am

Location: **Room 2**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Céline Perlot,** UPPA

(ID: 196)

EFFECT OF PLANT FIBRES ON THE VARIABILITY OF EARTHEN MATERIALS

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Earthen materials have different nature components and present a high variability comparing to conventional materials; researchers try to settle it down for a future normalization as environmentally efficient material. But there is a need in energy to do it, either directly (compaction, Organic matter extraction, particle sieving and mixing to get the best particle size distribution …) or indirectly by including inefficient materials from an environmental perspective (cement, limestone ...). The aim of this study is to follow the variability problematic of cob materials by comparing and understanding variation level of the hygrothermal characteristics due to fibres nature and fibres content. We found that plant fibres (hemp, flax and hay) act as a stabilizer for dry bulk density; at 1% fibres substitute, hemp fibre composites show the highest coefficient of variation on the thermal properties (6.1% on thermal conductivity, 18.74% on specific heat capacity) but flax fibres show the highest mean values. Increasing hay stalk content induces the spread of the hygrothermal properties inside their range of variation.

(ID: 160)

EROSION BEHAVIOUR OF BIO-STABILISED EARTHEN MATERIALS

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Development of earthen building materials is an integral part of the numerous answers that the construction sector can provide to the actual accelerated climate change issue. However, these materials present a wide variability, even at the local scale, and their water durability can be difficult to ensure. In order to improve their durability regarding water and avoid its prejudicial effect on earthen material's properties, the stabilisation with bio-polymers is an increasingly studied solution.

In this paper a ten-minute erosion drip test is developed and performed for various combinations of Breton earths and bio-based additions or surface treatments (linseed oil, xanthan gum, casein, alginate, vegetal varnish and tannins). The final pitting depths and eroded volumes are compared and the evolution of erosion during the test is monitored. These results are also linked to previously obtained water capillary absorption coefficients.

The obtained results enable to highlight the impact of bio-based additions on erodibility of earthen materials: linseed oil and xanthan gum help to protect the earth-based samples from erosion. Other original parameters characterizing the erosion of the samples during the drip test are suggested. Limitations of this type of erosion tests are also brought out.

(ID: 286)

FIRE BEHAVIOR OF RAW EARTH BRICKS: INFLUENCE OF WATER CONTENT AND CEMENT STABILIZATION

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This study focus on the effects of both water content and cement stabilization on the fire behavior of earth bricks. To observe the effect of cement stabilization, two materials are formulated: raw earth with only soil and water, and stabilized bricks with soil, water and cement (3.5% by mass of soil). Since the material's mechanical strength can strongly influence its fire behavior, the raw bricks were compacted at 50 MPa to reach a compressive strength similar to the one of stabilized bricks. Four different water contents were tested; dry state obtained with oven drying and three others achieved through equalization at 50%, 75% and 100% of relative humidities. Bricks are then subjected to an ISO 834-1 standard fire. Results show that water content has caused a thermal instability behavior on the raw earth bricks after equalization at 50% and 75% relative humidities. Thermally stable bricks displayed a noticeable diffusion of cracks on their heated face. Furthermore, cement stabilization helps to prevent from thermal instabilities.

(ID: 192)

TACKLING VARIABILITY OF CLAY TO PROVIDE A ROBUST EARTH BINDER

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Locally available and with infinite recycling possibilities, the use of earth as building material leads to one of the lowest environmental impact in the construction sector. Recent advances in the earth materials field have been made based on concrete

and ceramics technologies to facilitate its uses in dense areas. It is possible to modify clay particle interactions and the material's whole behavior by adding inorganic dispersants and flocculants into clay paste. Earth becomes easy to cast and unmold into formworks, and by removing cement in its composition, poured earth can reach a low CO2 emission rate. Even if this technology is promising, further work has to be performed, as it cannot be implemented on earth from excavation sites with high variability. Tackling the clay nature variability is now the main issue to push this product on the market with robust properties.

This research investigates the robustness of the poured earth binder. In this way, several clays (three montmorillonites, two kaolinites, and binary mixes at different proportions) were investigated. Their dense volume fraction (Φm) were determined following the water demand protocol with Vicat apparatus and compared to their consistency properties (liquidity and plasticity limits). A correlation between the water amount in a paste at Φm and the limit of liquidity is found. Different clay pastes prepared with different water to clay ratio were tested to define if clay nature influences their consistency evolution. The results showed that clay nature for paste with high solid volume fraction does not influence constituency's evolution when the results are normalized by their dense packing fraction. It can be suggested that for a clay binder with a consistency close to Φm, which might be mandatory for poured earth application, only the swelling capacity might influence the mix design.

(ID: 104)

INFLUENCE OF FIBER ON UNCONFINED COMPRESSIVE STRENGTH OF RAW EARTH MATERIAL BY MIXTURE DESIGN

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Building construction technology using raw earth material is already known and used since ancient times. The raw earth material is low cost, abundant, requires very low energy to manufacture and does not generate waste. Thanks to such advantages, raw earth material is used in various construction sites all over the world. This eco-material of the future, may eventually be a good alternative to cement concrete, which is very energy-intensive in terms of gray energy.

The shrinkage and swelling can cause cracks in raw earth material. To minimize the cracks, either natural or synthetic fibers have been included in raw earth materials. Then, a raw earth treatment by binders and vegetal fibers is one of the techniques applied to improve strength and ductility. Statistical combinations of five-component mixtures composed of Portland cement, loam, lime, fiber and water were formulated with a D-optimal mixture design to evaluate how fibers affect the raw earth material. The effect of fibers in raw earth material is evaluated in term of the unconfined compressive strength (UCS). Economical, ecological and workability constraints are considered to set up a mixture design.

The purpose of this paper is to study the influence of flax fibers on the unconfined compressive strength of a raw earth material. In that goal, the design of experiments has been used to establish model formulations targeting the sought strength after 28, 60 and 90 days curing-time. The obtained results indicate that the mixture design approach can be an important tool to study the effect of fibers on the unconfined compressive strength of cement-based materials consisting of several components.

Innovative admixtures 2

Time:
Friday, 18/June/2021: 9:00am - 10:40am

Location: **Room 3**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Ildiko Merta,** TU Wien

(ID: 166)

MIX DESIGN AND OPTIMISATION OF MARINE CONCRETE CONTAINING GGBS

Luke Oakes[1,2], Mohammed Sonebi[1], Giuseppina Amato[1], Adeline McCartney[2]
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Marine concrete structures are subject to extreme degradation potential over their lifetime due to the highly aggressive environment in which they are placed. Common methods of deterioration include corrosion exasperated by chloride ion diffusion, sulphate attack and surface abrasion. As such careful mix design processes must be followed to allow the creation of durable structures with a long service life.

In order to understand the effect of mix parameters on concrete behaviour, a factorial design was used in this paper to identify the relative significance of primary mixture parameters and their coupled effects (interactions) on fresh properties of SCC that are of special interest to precast applications. Several SCC mixes tested in order to evaluate to determine several key responses that affect the fresh properties of precast concrete, including filling ability (slump flow and V-funnel, T50), and passing ability (J-ring), and compressive strength at 1d, 3d, 7d and 28 d. Mix parameters modelled in this investigation included the binder content, binder type, w/cm, and sand-to-total aggregate ratio (S/A). The factorial design can identify potential mixes with a given set of performance criteria that can be tried in the laboratory, hence simplifying the test protocol needed to optimize SCC.

(ID: 193)

MICROSTRUCTURAL CHARACTERIZATION OF PREFABRICATED HEMPCRETE BLOCKS

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Sustainable building materials have been developed to reduce the polluting emissions and the exploitation of natural resources of the building sector. Among these materials, an outstanding category is that of nature-based solutions which are produced recovering waste or by-products of agricultural cultivations and using them as vegetal aggregates to replace the traditional ones. This paper focusses on hempcrete which is produced mixing the by-product of industrial hemp cultivation (i.e. shives) and lime to obtain a sustainable, breathable and insulating material. The strength of hempcrete develops through carbonation of the binder that, leading to the formation of calcium or magnesium carbonates and mineralization of shives, determines the microstructure and hence most of the characteristic properties of the material. The aim of this research is to investigate how carbonation influences the microstructure of hempcrete when different recipes are used for blocks production. The study consists in the characterization of the material through techniques as XRD (X-ray diffractometry), SEM (scanning electron microscopy), TG-DTG (thermogravimetric analyses) and FT-IR (Fourier transform infrared spectroscopy). Moreover, the evolution of carbonation is studied analyzing samples at different maturation times. The investigation of the development of carbonation reaction is crucial to evaluate the environmental performances of the material as, for example, to quantify the carbon dioxide uptake. Also, periodic characterization allows to assess the durability of hempcrete and to select the best mix design according to the designed application and the corresponding service conditions.

(ID: 152)

A STUDY OF SIZE VARIATION OF PALM KERNEL SHELLS AS REPLACEMENT OF COARSE AGGREGATE FOR LIGHTWEIGHT CONCRETE PRODUCTION

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Utilization of palm kernel shell (PKS) as alternative to conventional materials for the construction industry is desirable to promote sustainable development. The purpose of this study is to investigate the properties of lightweight concrete produced with different sizes of PKS as coarse aggregate replacement. PKS of sizes 6, 8, 10, 12 mm and mixed of all the sizes were used to replace coarse aggregate in concrete mixes which resulted in producing 60 cubes and 60 beams at 7, 14, 21 and 28 days of curing. The tests performed on the concrete specimens include compressive strength, flexural strength, dry density, scanning electron microscopy (SEM) and the energy dispersive spectroscopy (EDS). The average compressive strength for 28-day of curing were 4.10, 3.83, 5.17, 6.50 and 5.77 N/mm2 for concrete with coarse aggregate replacement of PKS sizes of 6, 8, 10, 12 mm and mixed content respectively. The average flexural strength recorded for 28-days of curing were 0.84, 0.94, 1.76, 2.19 and 1.47 N/mm2 for concrete with coarse aggregate replacement of PKS sizes of 6, 8, 10, 12 mm and mixed content respectively. The average dry density for 28-days of curing were 1509.73, 1497.00, 1624.13, 1685.00 and 1610.47 kg/m3 for concrete with coarse aggregate replacement of PKS sizes of 6, 8, 10, 12 mm and mixed content respectively. The SEM test indicated a highly porous structure of the PKS. The study recommends the use of 12 mm PKS size as replacement of coarse aggregate for the production of lightweight concrete.

(ID: 119)

DEVELOPMENT OF A BIO-MODIFIED SUSTAINABLE SELF-HEALING MORTAR

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Despite its negative perception in the society, concrete is still the most used building material in the construction sector. Due to its brittle nature, concrete can crack under stress and these cracks are one of the main reasons for a decrease in service life in concrete structures. Therefore, it is crucial to detect and recover microcracks, then to repair them as they were developed to wider cracks. Recent research in the field of concrete materials suggested that it might be possible to develop a smart cement-based material that is capable of remediate cracks by triggering biogenic calcium carbonate (CaCO3) precipitation. The main challenge of the application is to extend the viability of the cells against restrictive environment of cement-paste. These cells have to tolerate highly alkaline conditions of cement paste, can survive the mixing process, and can remain viable with limited access to nutrients. This paper summarizes a study undertaken to investigate the self-healing efficiency of Sporosarcina pasteurii (S. pasteurii) cells immobilized on zeolite and metakaolin. The bacterial cells were immobilized to minerals with their nutrient. To obtain the bio-additive, half of the minerals were saturated with a nutrient medium consisting of urea, corn-steep liqueur (CSL) and calcium acetate and the cells with immobilized to the other half without nutrients. Screening of the healing process was done with ultrasonic pulse velocity (UPV) testing and stereomicroscopy. With this approach, the cracks on mortar surface were sealed and the water absorption capacity of the so-called self-healed mortar decreased compared to its counterpart cracked mortar samples.

(ID: 266)

PHYSICO-CHEMICAL CHARACTERIZATION OF THE ELECTRIC ARC FURNACE SLAG (EAFS) OF THE SONASID-JORF STEELWORKS - MOROCCO

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The steelmaking process results in the by-product formation of electric arc furnace slag (EAFS). Slag is recovered at two different stages of the steelmaking process, the first recovery is black and the second is white. The present research focuses on the composition differences between the two types of slag from SONASID-Jorf steel in Morocco. A granular separation of the white and black slag was carried out to monitor the chemical and mineralogical composition. XRD and Fourier Transform Infrared Spectroscopy are performed on the samples in this paper. The white and black slag is studied in order to determine their behavior in a cement matrix of mortar based on cements composed of other additions.

Modeling

Time:
Friday, 18/June/2021: 9:00am - 10:40am

Location: **Room 4**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Heura Ventura**, Universitat Politècnica de Catalunya

(ID: 170)

AN EXPERIMENTAL STUDY ON CLAY AND SAND MIXES TO CLARIFY A NON-LINEAR HOMOGENIZED MODEL FOR EARTH CONSTRUCTION MATERIALS

Elsa Anglade, Alain Sellier, Jean-Emmanuel Aubert, Aurélie Papon
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Due to its ecologic interest and large availability, a renewed attention is paid to earth as building material. Indeed, raw earth consumes CO2 only during its processing and transportation, and it provides a natural hygrothermal comfort. However, its mechanical properties are highly linked to its composition, which causes an important variability of performances. That is why any soil must be characterized before being used as a building material. The aim of this study is to propose a model able to predict the mechanical, thermal, hydric, and acoustic behavior of a reconstituted soil according to its composition. As earth is a heterogeneous material, the model is based on homogenization procedures. The sand is considered as spherical inclusions inside a clay matrix. The particularity of the model stands to consider both positive and negative effects of volume variation and mechanical properties of clay under hydric variations. The model parameters are determined according to an original experimental campaign, which is conducted on various mixes of a single type of clay (kaolinite), a sand and water. The experimental study provides the properties of the mixes versus water content and sand content to test the ability of the homogenization model to assess the main properties of this material.

(ID: 244)

A DUAL-SCALE NUMERICAL MODEL FOR THE DIFFUSIVE BEHAVIOUR PREDICTION OF BIOCOMPOSITES BASED ON RANDOMLY ORIENTED FIBRES

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This work aims to present a multi-scale numerical approach based on a 2D finite element model to simulate the diffusive behaviour of biocomposites based on randomly dispersed Diss fibres during ageing in water. So, first of all, the diffusive behaviour of each phase (fibres/matrix) as well as of the biocomposite was determined experimentally. Secondly, the microstructure of the biocomposite was observed by optical microscope and scanning electron microscope (SEM), and then regenerated in a Digimat finite element calculation software thanks to its own fibre generator: "Random fibre placement". Finally, the diffusion problem based on Fick's law was solved on the Abaqus finite element calculation software. The results showed an excellent agreement between the experiment and the numerical model. The numerical model has enabled a better understanding of the diffusive behaviour of water within the biocomposite, in particular the effect of the fibre/matrix interface. In terms of durability, the layered structure of this biocomposite has proven to be effective in protecting the plant fibres from hydrothermal transfer, which preserves the durability of the material.

(ID: 199)

MICRO-MACRO MODELLING APPROACH OF VEGETAL WOOLS THERMAL CONDUCTIVITY

Clément Piegay[1], Philippe Gle[1], Etienne Gourlay[2], Emmanuel Gourdon[3], Sandrine Marceau[4]
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In the next years, a major renovation will be carried out on French buildings.

In order to respond to a significant demand, bio-sourced insulators made from vegetal fibres such as flax and hemp are now becoming essential materials. They have thermal properties equivalent to more conventional materials and they are able to store large quantities of carbon dioxide in a short time.

Experimental characterisations of vegetal wools thermal conductivity as a function of their density show the existence of an optimum coupled conduction-radiation value. This specific point, as well as the properties of vegetal wools are related to the large variability of shapes and sizes of their fibres.

In order to take this specificity into account, it seems particularly relevant to use micro-macro modelling methods to predict the thermal conductivities related to both conduction and radiation heat transfer phenomena.

In a first time, a self-consistent method (SCM) based on a cylindrical geometry is used as a modelling approach for conduction phenomena. Then, an empirical approach based on an equivalent fibre radius value is used as a modelling approach for radiation phenomena. Then, by coupling these two approaches, it is possible to obtain an equivalent thermal conductivity of fibrous materials as a function of density. In a third step, this method is validated by comparison with experimental data. So, for each studied material, it is possible to evaluate the ranges of preponderant densities for radiation phenomena and those for conduction phenomena. Finally, using this method it is possible to determine a thermal coupled conduction-radiation optimum conductivity value and thus to optimise the thermal performance of vegetal wools.

(ID: 277)

3D MODELLING OF HYDRIC TRANSFERS IN SPRUCE WOOD WITH CONSIDERATION OF SORPTION HYSTERESIS

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Buildings are responsible for a large portion of the total energy consumption, and have a heavy environmental impact. Wood is one of the most used bio-based building materials, as it helps reducing the environmental footprint of the construction sector. Spruce wood is widely available in France and therefore massively used in buildings. It had interesting thermal and acoustic insulation performances and a good hydric regulation property. Spruce wood microstructure is highly heterogeneous and multiphasic, which makes it harder to apprehend.

On the other hand, sorption hysteresis phenomenon is responsible for the moisture accumulation in porous building materials. It is often neglected in hygrothermal transfers modelling, which leads to incorrect water content values.

The aim of this work is to investigate the influence of the sorption hysteresis phenomenon on the hydric transfers of spruce wood. The heterogeneity of the microstructure is also considered through 3D tomographic reconstructions included in the modelling.

(ID: 178)

PROPERTIES OF PHRAGMITES AUSTRALIS FOR INSULATING CONCRETE APPLICATION

Mathilde Honoré, Sylvie Pimbert, Thibaut Lecompte

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The common reed, Phragmites australis, is a plant species quite similar to the currently used bio-based aggregates and available on most continents. The latter is considered as an invasive plant mainly found in wetlands. This natural product is independent of agricultural issues and does not require any chemical inputs, unlike other plants such as miscanthus, flax or hemp. Reed harvesting is therefore a part of the wetland management approach allowing the development of a material with various properties. Until today, it is still very little studied. Its mechanical resistance and its availability make this plant a renewable and efficient material. The Phragmites australis reed can be used for a valorisation in eco-construction as a substitute material of hemp shiv in insulating concrete. This work presents the different properties focussing on Phragmites australis chemical composition, hydrophobicity nature and how this character could be explained. To that end, wettability and also water adsorption measurements were carried out on plant flour and aggregates in comparison to miscanthus, wood and hemp shiv properties. Formulations based on reeds of different origins and using different binders (lime and earth) were tested in compression and with thermal conductivity measurements in order to evaluate the behaviour of the reed as a material for building use.

Acoustic properties

Time:
Friday, 18/June/2021: 11:10am - 12:30pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Sylvie Prétot**, LGCGM - Université de Rennes 1

(ID: 263)

INVESTIGATION OF THERMAL, MECHANICAL AND ACOUSTIC PERFORMANCE OF BIO-MATERIALS BASED ON PLASTER-GYPSUM AND CORK

Said Bouzit[1,2], Francesca Merli[2], Mohammed Sonebi[3], Sofiane Amziane[4], Cinzia Buratti[2], Mohamed Taha[1]

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The building sector is one of the biggest consumers of energy in the world and it is pushing the scientific community to find various alternative solutions to solve the problem of thermal insulation of buildings. Therefore, the selection of appropriate building materials is a major challenge for improving the thermal comfort and energy performance of buildings. In this scenario, the interest of plaster-based composites as insulating materials increases, in particular for new applications, as insulators for the building envelope, and this deserves to be studied. In this investigation, new plaster-based composites with cork were produced and tested at lab scale, in order to obtain cheap solutions with improved thermo-physical and acoustic performance. The results show that it is possible to improve the thermal, mechanical, and acoustic performance of construction biomaterials by using plaster as a binder and cork as a natural reinforcement: thermal conductivity was equal to 0.097 W/m.K, the compressive strength to about 2.30 MPa, and the transmission loss to about 40 dB.

(ID: 288)

LINK BETWEEN ACOUSTIC AND HYGROTHERMAL BEHAVIOR OF HEMP SHIV AND PITH COMPOSITES

Mohamed Said Abbas[1,2], Antonin Fabbri[1], Mohammed Yacine Ferroukhi[2], Philippe Glé[3], Emmanuel Gourdon[1], Fionn Mcgregor[1]

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Bio-based materials are an environmentally friendly alternative to classic construction materials, yet their generally low density can lead to poor acoustic properties. The acoustic performance of hemp shiv and sunflower pith composites is therefore analyzed using Kundt's tube. Although the loose aggregates present an exceptional sound absorbing behavior, it can be notably worsened in the presence of certain binders. The Transmission Loss is nevertheless enhanced by the binders, although it does not exceed 20 dB in most cases. For both properties, the type of binder has been found to be the most influential parameter. Through the Kundt's tube method, it is also possible to determine the geometrical parameters of the composites' microstructure, which have been observed to be similar for materials presenting comparable hygrothermal properties and containing the same binder. In a previous work, an experimental correlation was found between the thermal conductivity and the interparticle porosity of the aforementioned composites, which is compared to theoretical thermal conductivity models from literature without finding any apparent correspondence.

(ID: 281)

EFFECT OF THE TREATMENTS OF THE SURFACE ON MECHANICAL PERFORMANCE OF CONCRETE CONTAINING CHEMICAL ADMIXTURES

Catherine Campbell[1,2], Gareth Jackson[1], Mohammed Sonebi[1], Su Taylor[1]

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The aim of this paper is to investigate two different concrete mixes, one with Limestone Powder (LSP) and the other with Ground Granulated Blast-Furnace Slag (GGBS), both mixes containing superplasticizer, in order to analyse their compressive strengths at 7 and 28 days, their abrasion resistance and slip resistance. The two mixes are treated with two different surface protection finishers, applied on the surface after the concrete has cured and analysis of how these finishers affected the abrasion resistance and slip resistance of the concrete is discussed.

(ID: 106)

MECHANICAL AND ACOUSTIC PERFORMANCE OF MISCANTHUS – LIME COMPOSITES FOR USE IN BUILDING ENVELOPES: A PRELIMINARY EXPERIMENTAL INVESTIGATION

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The environmental burdens attributable to buildings remain relatively high. The built environment is responsible for more than one-third of the global energy consumption and nearly 40% of global CO2 emissions. In the context of increasing the sustainability of the built environment, bio-based building materials have gained a growing interest for their application in building envelopes. Miscanthus giganteus (elephant grass) is a perennial, cost effective and sustainable source of fibres for the development of bio-composites. This experimental study evaluates mechanical and acoustic properties of miscanthus - lime composites for their potential use in renovations and new-build houses, in South West England. The impact of binder to aggregate mass ratio and

density on compressive strength is investigated. Moreover, the effect of aggregate particle size on the acoustic performance of miscanthus - lime composites is presented. It is shown that the initial fresh density has little effect on compressive strength compared with that of binder content. The acoustic tests results show that the use of small size particles improves the acoustic performance of miscanthus - lime composites with recorded high transmission loss and sound absorption coefficient values.

Durability 2

Time:
Friday, 18/June/2021: 11:10am - 12:30pm

Location: **Room 2**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Philippe Glé**, Cerema

(ID: 136)

WATER SENSITIVITY OF HEMP-FOAM CONCRETE

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The necessity to build energy-efficient and low environmental impact buildings favors the development of light-weight concretes as foam concretes known for their high porosity. In this context, experimental protocols were developed in this work to study the effects of hemp shiv and the production methods on the water sensitivity of bio-based foamed concrete. Foam concrete incorporates several materials and compounds: cement, protein-based foaming agent, ground granulated blast–furnace slag, metakaolin as a binder, and hemp shives as bio-based aggregates. The study investigated first the effect of the incorporation of hemp shiv (from 0 to 15 vol%) and then the elaboration method, comparing direct mixing of the constituents versus preformed samples on the resulting physical properties, the sorption-desorption and the water absorption by capillarity of hemp-foam concretes. Obtained results show increasing in porosities with increasing in hemp shiv contents. Additionally, the hemp shiv increases the adsorption and the capillary absorption of water. Moreover, the preformed method renders results in more sensitive concrete to water than the direct methods since the variation of porosity.

(ID: 201)

BEST PRACTICE GUIDELINES TO COPE WITH THE MOISTURE SENSITIVITY OF FLAX AND HEMP FIBRE COMPOSITES

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In this proceeding, best practice guidelines to cope with the moisture sensitivity of flax and hemp fibre composites are introduced. Differentiation is made between general guidelines, and guidelines for the indoor and the outdoor climate.

(ID: 258)

MYCELIUM COMPOSITES AND THEIR BIODEGRADABILITY: AN EXPLORATION ON THE DISINTEGRATION OF MYCELIUM-BASED MATERIALS IN SOIL

Aurélie Van Wylick, Elise Elsacker, Li Li Yap, Eveline Peeters, Lars De Laet
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In the search for environmentally friendly materials, mycelium composites have been labelled as high potential bio-based alternatives to fossil-based and synthetic materials in various fields. Mycelium-based materials are praised for their biodegradability, however no scientific research nor standard protocols exist to substantiate this claim. This research therefore aims to develop an appropriate experimental methodology as well as to deliver a novel proof of concept of the material's biodegradability. The applied methodology was adapted from a soil burial test under predefined laboratory conditions and hands-on preliminary experiments. The mycelium composite samples were placed in a nylon netting and then buried in potting soil with a grain size of 2 mm for different time-intervals ranging between one and sixteen weeks. Results showed that mycelium, which acted as the binder, had the tendency to decompose first. A weight loss of 43% was witnessed for inert samples made of the fungal strain Ganoderma resinaceum and hemp fibres after sixteen weeks. The disintegration rate in this method however depended on various parameters which were related to the material's composition, its production method and the degradation process which involved the used equipment, materials and environmental properties.

(ID: 123)

EXPERIMENTAL STUDY ON RESTORATION OF DETERIORATED TIMBER DUE TO TERMITES BY RESIN FILLING

Takashi Yajima, Kei-ichi Imamoto, Chizuru Kiyohara, Mikako Yamada

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There are many valuable wooden buildings in the world, because timber has been used all over the world as a building material for a long time. However, there is an issue that timber deteriorates due to various factors. Therefore, in order to preserve these valuable wooden buildings, it is necessary to appropriately repair or reinforce treatment. One of the treatments is the resin filling method. In this method, filling the resin in order to restore the strength into an internal cavity caused by deterioration. It has become clear that it is possible to recover the strength using this method, however, we are still conducting construction based on the rule of thumb.

Therefore, authors examined the resin characteristics in order to inject the resin in stable manner and ensure strength recovery. Authors focused on deteriorated timber due to termites, because Japan has a very high amount of such type of timber.

Authors reports the following four aspects of the characteristics of resin filling into timber.

1. The Area velocity is determined by the injection pressure, width of the gap, and viscosity of the resin.

2. The resin spreads concentrically in the gap of wood, but there is no regularity in the random gap like deteriorated timber due to termites.

3. Authors proposed a new coefficient for the application, of a theoretical formula to deteriorated timber due to termites.

4. Authors proposed a flowchart of resin filling method to perform stable construction.

Hygrothermal properties 3

Time:
Friday, 18/June/2021: 11:10am - 12:30pm

Location: **Room 3**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Florence Collet**, Université de Rennes 1

(ID: 114)

THERMAL INSULATION BLOCKS MADE OF SUNFLOWER PITH PARTICLES AND POLYSACCHARIDE-BASED BINDERS: INFLUENCE OF BINDER TYPE AND CONTENT ON THEIR CHARACTERISTICS

Aurélie Laborel-Preneron[2], Clara Ampe[1], Laurent Labonne[1], Camille Magniont[2], Philippe Evon[1]
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Co-product of sunflower cultivation, pith of stem has a little exploited insulating potential. Blocks in which pith particles are glued together using a starch-based binder have already been obtained. However, they are highly water-sensitive. Replacing this binder with others has been considered here.

Polysaccharide-based binders were tested, chosen for their more hydrophobic character: sodium alginate (from brown algae), chitosan (from the exoskeleton of crustaceans), Citrus pectin (co-product of fruit juice industry), and a modified starch (sodium octenyl succinate starch). Like starch, these binders are physically binding. They are first solubilised in water (except chitosan, dissolved in 2% acetic acid). The solution is then mixed with pith particles before cold compression molding for 90 sec. Lastly, the block is dried at 40°C until all water is removed.

A 10% binder content was initially considered. The blocks were all cohesive (density from 42 to 44 kg/m3). Their characterisation included density, compressive strength, thermal conductivity, and water absorption capacity and resistance via capillary absorption tests on wet sponges.

Chitosan and pectin-based blocks show the best properties. Contrary to chitosan, pectin is a cheaper and abundant agro-industrial co-product. Both blocks are easily machinable. That made of chitosan has very good water resistance, being still not disintegrated after more than a week. The pectin-based block has an improved compressive strength (0.77 MPa for elastic modulus instead of 0.53 MPa with starch). In addition, it absorbs 1.5 times less water than starch. Finally, thermal conductivities of pectin and chitosan-based pith blocks are in the same order of magnitude as for starch (39.8-40.1 mW/m.K), and close to values from commercial materials (e.g., polystyrene).

Pectin and chitosan were then tested at three rates (5%, 10% and 15%). A significant improvement in the blocks' compressive strength was observed with the increase in binder rate, while thermal conductivities varied little.

(ID: 169)

HOW RELIABLE IS THE THERMAL CONDUCTIVITY OF BIOBASED BUILDING INSULATING MATERIALS MEASURED WITH HOT DISK DEVICE?

Thibaut Colinart[1], Mathilde Pajeot[1], Théo Vinceslas[2], Arthur Hellouin De Menibus[3,4], Thibaut Lecompte[1]
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Thermal conductivity is of high importance for insulating materials since it strongly influences the thermal performance of the building. Generally, it is recommended to measure this property with steady-state methods like guarded hot plate (GHP) or heat flow meter (HFM). These methods are reliable, but steady-state condition can take a long time to be reached. Therefore, transient methods were developed to speed-up the measurements. For instance, the hot disk transient plane source method is a widely used standard technique (ISO 22007-2) for measuring thermal conductivity of various materials. In the last 20 years, this technique has been applied also to bio-based insulating materials. However, overestimated thermal conductivity (compared to steady state method) are frequently measured. More generally, such differences are also observed for low thermal conductivity materials.

The aim of this work is to evaluate the influence of numerous factors to explain the origin of these differences. The factors include the experimental setting parameters, the measurement analysis parameter or even the discrepancies between the theoretical model and the real experimental set-up. The analysis is performed for a light-earth biobased concrete made of raw earth and hemp shiv. Recommendations are proposed in conclusion.

(ID: 276)

IMPROVING PERFORMANCE OF THERMAL MODIFIED WOOD AGAINST TERMITES WITH BICINE AND TRICINE

Dennis Jones[1,2], Lina Nunes[3], Sonia Duarte[4]
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The desire to incorporate wood in modern construction has led to a considerable increase in the use of wood modification techniques, and especially thermal modification. However, thermally modified wood has poor performance against termites. The concept of using a combined chemical and thermal modification has been undertaken through the impregnation with either bicine or tricine prior to modification. This paper considers the effects of these chemicals on the activity of termites and considers their mode of action in terms of termite survival and on their effects on the symbiotic protists present within the termite gut.

(ID: 171)

SORPTION IN BIO-BASED BUILDING MATERIALS: IMPROVEMENT OF THE LOCAL KINETICS MODEL AND APPLICATION TO THE SIMULATION OF THE ISOBIO WALL STUDIED IN A DEMONSTRATOR

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A bio-based multilayered wall has been developed in the framework of the European ISOBIO project. A key point was to be able to perform proper simulations of the hygrothermal transfers occurring through the wall: local predictions are of first importance to characterize the behavior of the wall and thereafter its ability to ensure comfortable hygrothermal conditions inside buildings. Previous studies proved that the conventional assumption of an instantaneous equilibrium between local relative humidity and water content according to the sorption isotherm is not relevant for bio-based porous materials, where in practice a slow sorption kinetics occurs. In the present study, an improved expression of the local kinetics is proposed and validated by sorption experiments. Then, the case of the reference ISOBIO wall submitted to a given real climate (Wroughton HIVE demonstrator, UK, Feb 2018) is investigated: simulations based on the classical approach (TMC code) or considering the sorption kinetics (TMCKIN code) are compared to the measurements. It appears that TMC simulation underpredicts the relative humidity dynamics whereas TMCKIN simulation considering the improved expression of the local kinetics is in good accordance with measurements. Finally, an alternative configuration of the ISOBIO wall is numerically studied, showing that a better hygric behavior can be obtained.

Other innovative materials

Time:
Friday, 18/June/2021: 11:10am - 12:30pm

Location: **Room 4**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Kamilia Abahri**, ENS Paris Saclay

(ID: 161)

LINSEED OIL AND XANTHAN GUM: PROMISING STABILISERS FOR EARTHEN BUILDING MATERIALS

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In the current context, the development of new bio-based and local building materials is becoming mandatory. Among them, earthen materials have a strong potential to be used as sustainable structural materials but their variability and their water sensitivity impact their mechanical properties that are difficult to guaranty. Recent developments have emphasised the ability of some bio-based additions to help to ensure these properties: linseed oil and xanthan gum are part of them.

In this paper three different Breton earths, representative of a certain local variability, are studied. The impact of the selected bio-based additions on earths' rheological behaviour is followed in order to adapt it to different forming processes. Then, the mechanical properties of different earth-addition combinations at the dry state, exposed to hygric variations and immersion are investigated for different forming processes.

The findings highlight the fact that xanthan gum and linseed oil have a relevant ability to stabilise earthen blocks, that can be processed using different promising forming methods.

(ID: 163)

EVALUATION OF A MARINE DREDGED SEDIMENT AS RAW MATERIAL COMPARED TO VOLCANIC SCORIA FOR THE DEVELOPMENT OF LIME-POZZOLAN ECO-BINDERS

Salim Kourtaa[1,2], Morgan Chabannes[1,2], Frédéric Becquart[1,2], Nor-Edine Abriak[1,2]

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In the context of global warming, the built environment offers relevant opportunities to reduce GHG emissions that underlie climate change. In particular, this can be achieved with the development of low-embodied energy building materials such as bio-based concretes. Hemp concrete has been the subject of many investigations in the field of non-load bearing infill walls in France since the early 1990s. In addition to hygrothermal performances, the use of crop by-products definitely helps to limit the carbon footprint. Hemp concretes are often produced by mixing the plant aggregates with lime-based binders. The latter have many benefits among which the water vapor permeability. However, CO2 emissions due to the decarbonation of limestone for the production of lime largely contribute to the overall environmental balance of these materials. The use of natural pozzolans (volcanic scoria) combined with hydrated lime goes back to the Greco-Roman period and reduces the carbon emissions. Nonetheless, it does not necessarily meet the issue related to the depletion of granular natural resources. Hence, this study deals with the design of a new low-carbon binder based on a marine dredged sediment seen as an alternative strategic granular resource that can be considered as renewable. The studied sediment comes from the Port of Dunkirk in the North of France and is mainly composed of clay, silt and quartz sand. It was finely ground and compared to lowly reactive basaltic pozzolans. Lime-pozzolan pastes were prepared and stored in a moist environment under room (20°C) and high temperature (50°C). The hardening kinetics of pastes was followed through mineralogical studies (TGA, XRD) and compressive strength development. Furthermore, microstructural and porosity investigations were performed. The results showed that the hardening of pastes with the marine sediment is suitable when the samples are stored at 50°C and make it possible to use such a binder for precast bio-based concretes.

(ID: 142)

ASSESSMENT OF THE INFLUENCE OF THE TYPE OF FILLER MATERIALS ON THE PROPERTIES OF CEMENT GROUTS

Ahmed Abdalqader[1,2], Mohammed Sonebi[1], Neil Thornton[2], Su Taylor[1]

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Cement grouts have many purposes in various civil engineering applications such as precast construction, soil stabilization and structural rehabilitation. Using filler materials as a component in cement grouts has been increasingly implemented. The incorporation of such fillers not only does improve the fresh and hardened properties of grouts but also contributes to the decarbonization of grouts by reducing the amount of Portland cement, thereby lowering the carbon footprint of grouting materials. This study aims at assessing the influence of various filler materials on the properties of cement grouts. Three different fillers were used in this study: commercial limestone, commercial pure dolomite, dolomitic quarry dust. These fillers were assessed in terms of their effect on the spread, flowability, cohesion and compressive strength at 3, 7 and 28 days. The results show that fresh properties of the grout were dependent on the type of fillers. Dolomitic quarry dust improved the workability and flowability more than the commercial limestone and dolomite did. The compressive strengths of cement grouts did not change significantly with the incorporation of the fillers. However, cement grout samples including quarry dust exhibited slightly higher 28-d compressive strength than other samples although the same mix had lower 1-d compressive strength than other mixes. This study highlights the benefits of utilizing quarry dust in cement-based binders without compromising the performance.

Poster flash talks 1

Time:
Wednesday, 16/June/2021: 2:45pm - 3:30pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Laia Haurie**, Universitat Politècnica de Catalunya

(ID: 279)

DEVELOPMENT OF ANIMAL FIBRES COMPOSITES FOR CONSTRUCTION APPLICATIONS

Anna Alfocea Roig, Sergio Huete Hernandez, Alex Maldonado Alameda, Jessica Giro Paloma, Josep Maria Chimenos Ribera, Joan Formosa Mitjans
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Climate change has become one of the world's leading threats. Currently, the construction industry has a high environmental footprint. For this reason, the scientific and technological sector is looking for new materials to reduce the environmental consequences of this division. It is well known that the valorisation of different by-products can contribute to the reduction of the energy global consumption and CO2 emissions. Magnesium Phosphate Cement (MPC) can be obtained by using Low Grade Magnesium Oxide (LG-MgO) as a by-product from the industrial process of magnesite calcination. In this research, a Sustainable MPC (Sust-MPC) for different construction purposes is developed by using LG-MgO along with monopotassium phosphate KH2PO4 (MKP) as raw materials. The increasing use of synthetic fibres in clothing, as well as China's competitive prices on Animal Fibres (AF) market, have led to a commercial interest fibre decrease for wool-like AF in Spain. This study aims to formulate a Sust-MPC cement with Animal Fibre (AF) to reduce the cost of the new material (Sust-MPC-AF) and to increase the thermal insulation, allowing the use of Sust-MPC-AF in several potential applications. Besides, it should be emphasized that the final pH of Sust-MPC is neutral, which allows containing natural fibres. To develop Sust-MPC-AF, some properties such as thermal conductivity, density, Modulus of Elasticity (MoE), flexural strength, and economic cost were evaluated using the Design of Experiments (DoE). The DoE studies allowed obtaining a model for further optimization considering minimum thermal conductivity and cost dosages. The formulation 30L-25EW presents the minimum conductivity (λ=0.140 W·m-1·K-1). Therefore, two optimal dosages (36L-25EW and 24L-22EW) are obtained by considering mixing variables such as AF/Cement ratio (AF/C) and AF/Extra Water ratio (AF/EW).

(ID: 200)

INFLUENCE OF CURING CONDITIONS ON COMPRESSIVE STRENGTH DEVELOPMENT OF GEOPOLYMER CONTAINING RICE HUSK ASH CALCINED AT LOW TEMPERATURE

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Geopolymer is produced by the geopolymeriziation of the mixture of the raw materials containing high silica or alumina and the alkali solution in the absence of the Portland cement. However, it has deficiencies, including the high heat release at early age, high shrinkage, and high strength reduction in the long term. In view of these issues, this study explores the mechanical properties of the slag-based geopolymer produced by replacing some volume portion of the slag by the rice husk ash (RHA) pre-calcined at 400 °C. During the sample preparation, the slag-RHA geopolymer was made by the mixing solution of 5M sodium hydroxide (NaOH) and the water glass (WG) with modulus of 3 at different volume ratios and then cured in various environments, including the ambient air curing, moisture curing, and water curing. Results showed that both the ratio of the sodium hydroxide to the water glass and curing conditions influenced the compressive strengths. In each curing condition, the optimum ratio leading to highest strength was found at 1:1. For those plain specimens without RHA, air curing induced the highest strength of 83 MPa at 7 days and 88 MPa at 28 days. The moisture curing and the water curing induced similar 7-day strengths around 41 MPa, but the moisture curing induced the lowest 28-day strength of 36 MPa. In the presence of RHA, those specimens with 10% RHA under air curing had 28-day compressive strength of 105 MPa, even higher than the plain, but those with 20% RHA had much lower compressive strength of 71 MPa. On the contrary, the specimens with moisture curing and water curing had much lower 28-day strengths of 55 MPa and 50 MPa, respectively. In the long term, the moisture curing always induced more fluctuate and lower strengths than the water curing. In summary, the mix prepared with 10% RHA, NaOH:WG=1:1 and air-curing is recommended since it had the highest 28-day strength and sustainable long-term strength. The water curing induced much lower strength but steady strength development. The moisture curing also induced lower strength but much greater strength changes in the long term.

(ID: 242)

DEVELOPMENT OF PREFABRICATED ELEMENTS FOR CONSTRUCTION WITH RAPESEED CONCRETE

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Today, research is carried out in France and in Europe for the integration of hemp, miscanthus or flax aggregates in concrete. However, few projects have focused on adding value to rapeseed straw. Rapeseed today, with more than 1,500,000 Ha cultivated in France, represents an important mobilizable resource for the development of an industrial sector of bio-based concrete.

CODEM and COOPENERGIE have for several years developed insulating concrete formulations like hemp concrete, based on recommendations of the professional rules for hemp concrete in construction. The results of the various studies carried out have made it possible to formulate insulating concrete fillings that are at least as efficient as hemp concrete with an improved LCA and price. The agricultural cooperatives involved in COOPENERGIE wish not to limit themselves to filling concretes used on site, by developing industrial products.

Following this work, the BIP ADEME Colza project was submitted by 4 partners (CODEM, Coopénergie, Laboratoire des Technologies Innovantes (University of Picardie Jules Verne) and Point P). This project started at the end of 2018 and it receives funding from ADEME and the Hauts de France region

The BIP-Colza project aims to develop prefabricated elements in rapeseed concrete. Crushing rapeseed straw makes it possible to prepare aggregates, more efficient than those of hemp or flax in some cases, for obtaining high performance lightweight biobased concretes.

During this project, we sought to formulate rapeseed concretes in agreement with industrial specifications with 2 functional objectives: (1) self-supporting insulating blocks and (2) insulating-load-bearing blocks.

In order to assess the impact of the variability of rapeseed straw on the performance of the concretes formulated in this project, we studied the influence of several parameters, such as:

- Geographical origin (oceanic climate and continental climate under oceanic influence). This is how we sampled rapeseed straw in the departments of Marne, Somme and Aisne.

- The year of harvest (two different years)

- The type of crushing (impact or shear)

- The morphology and size of the aggregates used (3 granular classes)

The results obtained show that the criteria mentioned above directly influence the properties of rapeseed aggregates, as well as the performance of the materials formulated for the two applications targeted in this project.

(ID: 139)

DEVELOPMENT OF A MULTI-STAGE PROCESS FOR THE COLLECTION, FRACTIONATION AND SEPARATION OF CORN AND SUNFLOWER STALKS TO OBTAIN BIO-BASED CONSTRUCTION MATERIALS

Philippe Evon[1], Laurent Labonne[1], Camille Magniont[2], Aurélie Laborel-Preneron[2], Guyonne De Langalerie[2], Méryl Lagouin[2], Mariana Palumbo[3], Laia Haurie[3], Teresa Masjuan[4], Marius Simon[4]

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Co-funded by the European Regional Development Fund (FEDER) as part of the POCTEFA 2014-2020 program, the SAVASCO project (2020-2022) aims to structure a cross-border value chain (between France and Spain) for corn and sunflower stalks for construction.

Today, construction materials are mainly derived from non-renewable raw materials. Of mineral or petroleum origin, their extraction and processing have major environmental impacts: greenhouse gas emissions, energy consumption, etc.

However, some agricultural wastes such as corn and sunflower stalks have promising thermal insulation and hygroscopic regulation performances for the formulation of building materials. Moreover, these raw materials are renewable and also widely present in the POCTEFA territory.

Action number 3 of the project aims to develop a multi-stage process for collecting, fractionating and separating corn and sunflower stalks at moderate cost for the production of plant aggregates of bark and pith, with controlled physico-chemical characteristics. Field collection is carried out in collaboration with FCAC, and the plant aggregates are obtained thanks to the use of the industrial tools available in LCA.

In this action, the multiphysical performance of plant aggregates is evaluated, and their impact on the material's performance is also studied. Two types of construction products are manufactured: a lightweight plant concrete including bark particles, and a semi-rigid lightweight insulating panel formulated from pith aggregates.

This work is made possible by combining the tools and skills of LCA (exhaustive chemical characterisation of plant aggregates), LMDC (physical properties, and mechanical and hygrothermal performance of plant aggregates and composites) and UPC (fire behaviour and durability of plant aggregates and composites).

At the end of this action, a qualification framework for plant aggregates will be drawn up. The process developed will enable the production of plant aggregates in sufficient quantities for the construction of two instrumented cells planned as part of project's action number 5.

(ID: 205)

BUILDING INSULATION PERFORMANCE

Arthur Hellouin de Menibus[1,3], Jérémie Boucher[2,4], Pierre Delot[1,5], Jules Delsalle[2,6], Coralie Garcia[1,7], Yves Hustache[8]

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Building insulation is nowadays mostly designed based on the material thermal conductivity. Indeed, most requirements to reach a building performance minimum level or to obtain a grant for thermal renovation end by a minimum thermal resistance per type of wall. Even a small thermal conductivity difference between two materials might consist a large commercial advantage, since it would affect the thickness needed to reach a given thermal resistance level.

However, several studies since the 50' have shown that wall real performance, defined as the ability to resist heat flow, is not only defined by the thermal conductivity at 10°C measured in static conditions. A scientific study from Roels et al. 2017 shows that the discrepancy level between designed and measured heat loss might exceed 100%. The real wall performance is in itself a rather complex problem, which encompass questions at the material, wall and building scale as well as the quality of technical achievement.

Bio-based insulation material bring additional scientific complexities due to the ability to interact significantly with water. On one hand, this affect the result of different characterization methods in laboratory, since heat and water mass transfer are coupled

phenomena. On the other hand, it affects the wall response in real conditions. For instance several studies has shown the ability of south-oriented hemp-based wall to clip temperature peak due to water evaporation.

All french bio-based insulation producers team up for the first time to manage this problematic situation. They set up the project called “Building Insulation Performance” (BIP), to clear out what are the gaps in the actual definition of wall thermal performance and to look after alternative metric that might be more appropriate to define wall performance. The first phase of this work was finished in november 2020, and the second phase would be starting in 2021 with the support of a scientific council which was brought together specifically to support us on this theme. The poster will give an overview of the approach and of the different scientific locks identified.

(ID: 183)

DESIGN AND PROPERTIES OF A NEW ECO CONSTRUCTION MATERIAL BASED ON WASHED OLIVE HUSK ASH

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Olive Pomace or olive husk is the solid residue of olive oil extraction,It is one of the mediterranean agriculture's most abundant by-products which makes it a priority to be valorised (Nefzaoui,1991). biobased building materials were studied and investigated more in a forme of a concrete/lime based mortars and concretes whereas the major disadvantage of these materials is the concrete and lime production process emissions that has reached 1.50±0.12 GtCO2 in 2018 (Andrew, R. M, 2019), therefore more attention is needed to be poured on earthen materials, compressed Stabilized Earth Brick (CSEB) provides an overall contribution to sustainable development in terms of energy quality , cost saving and environmentally friendly construction materials (F. Venny Riza et al., 2010). to investigate the influence of adding olive husk to the CSEB, four types of CSEB bricks were investigated with different percentages of these additives (0%,5%, 10% ,20%), the bricks were manufactured under the same compressive strength of 10MPa using a hydraulic press. unconfined compression tests were made to assess the mechanical performance also thermal properties were determined: conductivity was evaluated using hot wire method (CT-meter) , diffusivity, density,sorption isotherm and capacity also were determined.The findings showed a significant effect of olive husk on both the mechanical and thermal behaviour of the CSEB bricks.

(ID: 294)

EXPERIMENTAL INVESTIGATION ABOUT THE DEVELOPPEMENT OF STRUCTURAL HEMP CONCRETE BY VAPOTHERMAL CURING

Reine Karam[1,2], Frederic Becquart[1,2], Nor-Edine Abriak[1,2]

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The cement industry is a sector known to be responsible for one of the major sources of CO2 emissions. As atmospheric CO2 levels have increased dramatically in recent decades, efforts are deployed to develop new construction materials with a lower carbon footprint (Gartner, 2004). In this context, vegetal concretes are promising. The positive environmental impact of these materials is due to the atmospheric CO2 absorbed during the photosynthesis of plants and trapped inside the materials during their entire life cycle, thus reducing their carbon footprint (Amziane, 2016). Vapothermal treatments used generally for energy recovery from biomass (Funke et al., 2013; Yeoh et al., 2018), have been also used in construction materials field (autoclaved cellular concrete and sand-lime bricks) and have led to a significant influence on the mechanical properties of these mineral materials.

The objective of this experimental research is to evaluate the mechanical performances of hemp concrete cured by vapothermal process, which can potentially overcome the compatibility problem of the vegetal / mineral matrix.

Blocks (40 x 20 x 20 cm) of hemp concrete (60% in volume) in association with a mineral binder based on lime (with no cement) are performed. The samples undergo a vapothermal cure in a closed autoclaved system under determined water vapour pressure and a temperature not exceeding 200°C. The temperature is chosen so as to respect a compromise between the good integrity of hemp shives and an efficient curing of the lime-based binder. Following the vapothermal treatment, a mass loss monitoring of the blocks is carried out and unconfined compression strength tests are performed after drying.

The results show mass losses of about 25-30% and mechanical strengths higher than 3 MPa (dry density ~ 750 kg/m3). These experiments open up the possibility of formulating a green autoclaved vegetal concrete (without cement) with structural properties.

(ID: 297)

HYGROTHERMAL STUDY OF A WALL BUILT WITH PREFABRICATED RAPESEED CONCRETE BLOCKS

Maya Hajj Obeid

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45% of annual energy consumption is due to the building sector, which is the most energy-intensive sector in the world. This sector is responsible for 23% of greenhouse gas emissions. The RT2020 provides a strategy to reduce energy consumption, and one of its solutions is to use low-energy building materials and develop local industries. So Bio based materials are increasingly being used as construction elements in the building envelope due to their low environmental impact and hygrothermal performance. Their use would lead to a reduction in greenhouse gas emissions and would address the issue of depletion of natural resources.

There are several types of bio-based materials. In this study, we are interested in studying rapeseed concrete. This material has good thermal and hygric performance.

In order to carry out the numerical simulation, several material parameters are required. A large experimental campaign on hygrothermal characteristics is carried out. The parameters calculated are thermal conductivity with values of 0.08 W/m.k, sorption curves, water vapor diffusion, capillarity and porosity.

The aim of this study is to investigate the influence of the dynamic temperature and humidity cycle, as well as the influence of the different climates on the wall made of precast blocks of rapeseed concrete.

This numerical simulation of heat and moisture transfer is carried out on the WUFI 2D software. In the first place, the wall alone is studied. In the second part, a coating will be applied on both sides of the wall in order to compare the results of the two cases studied. The evolution of temperature, the water content and mould for 1 year will be studied in different depths of the wall in the two cases considered. The performance of the wall will be highlighted thanks to the addition of a coating.

This study shows that coating in the two sides protect the wall from the condensation risks and mod growth having a great influence on rate of dryness. In addition, different climates were tested affecting the hygrothermal performance of the wall. To complete the study, these types of walls should be compared with an experimental hygrothermal study.

(ID: 132)

3D PRINTING OF BIO-BASED BUILDING MATERIALS

Maris Sinka, Jelizaveta Zorica, Genadijs Sahemenko, Diana Bajare

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The construction industry is one of the largest emitters of CO2 because the production of traditional building materials is highly energy-intensive and uses considerable amounts of raw materials. This research aims to decrease the negative environmental impact of the construction industry by providing biocomposites with a low environmental impact due to their bio-based components and efficient use of the materials through 3D printing. Agricultural waste products—hemp shives—are used in these materials as a filler together with three different types of fast-setting binders—magnesium, calcium sulphoaluminate (CSA) and those that are gypsum-based. The study determines the setting time and compressive strength of these binders, as well as the formation of biocomposites of different densities for different applications; extrusion tests and preliminary life cycle assessment (LCA) are also performed. Results show that biocomposites with hemp shives and fast setting binders have a possible application in 3D printing due to their shape stability and buildability, as well as relatively high compressive strength, which allows for load-bearing use at high densities and thermal insulation use at low densities, although printability at low binder content remains a significant challenge. Preliminary LCA results show that CSA and gypsum binders have the lowest environmental impact from the binders considered.

(ID: 256)

CHARACTERIZATION OF CEMENT COMPOSITE PLATES REINFORCED WITH NONWOVENS OBTAINED FROM TECHNICAL WASTE FIBRES

Laura Gonzalez[1], Josep Claramunt[2], Monica Ardanuy[1], Heura Ventura[1]

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Due to the current global concern about sustainability, the construction and building sector is focusing into the search for new construction systems with the aim to reduce its contribution to the climate change. It is estimated that it produces around 36% of the CO2 emissions and 40% of the energy consume in the EU, and around 39% of CO2 emissions and 36% of the energy consumption in the world. Since this impact is mainly generated during the construction and the operational phases, systems such as ventilated façades can surely help to reach this goal by providing better insulation of the buildings. Moreover, the use of high performance panels made of more sustainable materials as panels for the cladding in these systems can also contribute to reduce the impact in the construction phase.

In order to cope with the sustainability, performance, durability, cost effectiveness and safety requirements, the use of multilayer composite panels made of cementitious matrix and reinforced with textile structures such as nonwovens has already been proposed. The reinforcing structures —nonwoven fabrics made from natural fibers of a renewable nature and good mechanical properties— allowed to prepare a multilayer composite in which the amount of cement matrix used was reduced and the mechanical properties where clearly improved. However, further effort has been done to explore alternative raw materials from agricultural and industrial wastes, with the aim to step towards the circular economy approach. In this sense —considering the widely known problem of the recyclability of textile wastes— a less explored possibility is the use of post-consume textile wastes to develop such reinforcements.

Therefore, in this study, we present the characterization of Portland-cement based composite materials reinforced with nonwovens obtained from technical waste fibers. To that end, the aramid-viscose fibers were recovered from post-consumer technical garments for thermal protection —from firefighters' polo shirts—. The nonwovens, produced by carding and needle-punching technology, were used to produce a four-layer sandwich-like structure with Portland cement matrix. The composite plates obtained were then characterized by flexural testing, which revealed excellent mechanical properties, pointing out the viability of such a reinforcement for the production of high-performance panels intended for their use in ventilated façades.

(ID: XXX)

CEMENT-BASED COMPOSITE MATERIALS REINFORCED WITH VEGETABLE FIBERS AND INCLUSION OF PHASE CHANGE MATERIALS (PCM)

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This work analyses the behaviour of flax fiber nonwoven reinforced cement composites that incorporate phase change materials (PCM). The objective is to design a product suitable and feasible to be used in building roofs, sustainable and thermally efficient.

The raw material used in this study is flax fibre which was supplied by Fibers Reserche Development of the Technopole de l'Aube, Champagne (France). We made a basic composition of Portland cement Type I, water and reinforcing. Two types of organic PCM paraffin waxes were considered: RT21 and RT28 by Rubitherm RT series. During a first phase, an analysis of the integration of the fibre with the PCMs was carried out and then the integration of the PCM with the fibre cement was analysed. In order to test the mechanical properties of the proposed matrix compositions, a total of 36 specimens of 40 x 40 x 160 mm3 were prepared. For each composition, the evolution of their properties with respect to the curing time was analysed. The mechanical tests were carried out in accordance with the UNE-EN-196-1 standard, testing in bending and compression modes.

According to our preliminary results, the composites developed with reinforcing nonwoven fibres and PCM have a good mechanical behaviour and can be potential candidates in the development of building envelope panels. Other aspects, in particular thermal properties, will be analysed in further studies.

Poster flash talks 2

Time:
Thursday, 17/June/2021: 2:30pm - 3:10pm

Location: **Amphiteater (Plenary)**
Barcelona School of Building Construction (EPSEB)

Session Chair: **Stéphanie Bonnet**, Université de Nantes

(ID: 291)

INNOVATIVE BIO-BASED SOLUTIONS FOR THE BIOCIDAL TREATMENT OF CELLULOSE FIBERS

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Bio-based insulation materials like cellulose fibers or vegetal fibers are used in wall and roof cavities (attic) to separate thermally and acoustically the inside and outside of the building. These materials could be attacked by fungi, fungal proliferation inside buildings can have adverse effects on the health of building residents (Lee, T. et al., 2006) (Portnoy, J. et al., 2005), for this raison the fibers should be treated to avoid fungal development. Until now, boron salts like boric acid are added preferably to some of these insulation materials, mainly, as a flame retardant, in addition to increasing the resistance of materials to ignition, it also acts as antifungal treatment.

The boron salts are classified as Reprotoxic Category 1B (CLP Regulation) in accordance with European Regulations and therefore meet the exclusion criteria. The approval of these substances meeting the exclusion criteria should not be renewed. These products shall also be withdrawn from the market. For these raisons, manufacturers have to substitute rapidly these boron salts (Opinion of the Biocidal Products Committee 2020, Annex XV restriction report proposal for a restriction 2014).

Groupe Berkem works to develop ecologically friendly, safe and useful antifungal additives for building materials. Groupe Berkem R&D laboratories have developed innovative bio-based solutions for the fungicidal and/or insecticidal treatment of these fibers which cover many sectors (textile, plastic, building, etc.). The efficiency of one of these products was challenged using an evaluation test including control cellulose fibers, boron-treated cellulose fibers, and new product- treated cellulose fibers, the fibers were exposed to the action of five fungal strains under controlled temperature and humidity conditions over 28 days. At the end of the incubation period, the fungal development was evaluated by observation and by the determination of the fungal flora using colony-forming unit method. To be sure of the validity of the test, two fungal forms were tested: the resistant form with the spores and the active form with pre-germinated spores (sporeling).

The results showed that the fibers with the tested bio-based product are fungal resistant as boron treated fibers. This product does not contain boron salts and is formulated with a lower quantity of active agents, with a lower impact on humans and on the environment, and with the same or higher performance, thanks to the addition of biobased boosters. The Groupe Berkem bio-based boosters are 100% plant-based solutions that allow active agents to reach their optimal performance when formulated. This product formulated in aqueous phase, already marketed, is more than 80% biosourced thanks to raw materials of biosourced (vegetable) origin (Messaoudi et al., 2018).

(ID: 233)

OVERCOMING ENVIRONMENTAL CHALLENGES FOR USING COMPOSITE MATERIALS IN A CIRCULAR BUILDING SOCIETY

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A composite material is a combination of two or more constituent materials which have improved characteristics when together than they do apart. Fiber reinforced thermoset materials, are as a composite material, relatively young and more and more being used in the construction sector. Especially the high stiffness and strength to weight ratio makes them interesting compared to concrete and steel. They can be lighter, more efficient, more durable and require less maintenance than traditional materials. They can be used for building facades, cladding, domes, roofing and other architectural structures, but also for products that ranges from infrastructural like bridges, masts to furniture like sanitary ware and counters. But there is a major challenge for this material.

Since the industrial revolution rapidly increasing global warming, the growing shortage of scarce earth materials and growing waste problem cause for growing concerns. Materials are a major cause of global warming, because we often have to mine the materials, we want to transport them around the world, and then purify, process and transport them again all over the world. For a sector like construction, this means that materials, among them composite materials, account for more than 30% of the total CO2 emissions.

In addition, more and more materials are becoming scarce. The raw materials for the production of electronics, plastics like polyester and PET, fire-resistant additives and glass fiber are coming under increasing environmental pressure. The EU published in 2020 their list of Critical Raw Materials (CRM's), that are crucial to Europe's economy. Cobalt, one of the CRM's, is being used as an accelerator to polymerize the polyester resin at room temperature conditions. Next to that 40% of all mined Borium, another CRM, is being used in glass fibers, for glass wool insulating, but also for glass fiber reinforced composites, to make the glass fibers less brittle. How to overcome the disappearing of these ingredients?

The construction sector has a waste problem and fiber reinforced thermoset composites are one of the topics. In The Netherlands 40% of all waste is coming from construction industry, and a facade section of fiberglass polyester can go nowhere after the use phase. Landfilling is no longer possible in view of EU regulations and incineration is problematic, because the glass pollutes the ovens. There is only a small possibility to use a small part of the waste material for concrete industry.

Within this framework the size of the problem thermoset composites cause has been identified. A possible strategy has been developed how to make use of the interesting properties of these materials in a circular building and construction society. By

making use of biobased raw materials for the resin, the fibers, fillers and additives the use of the CRM's Cobalt and Borium can be prevented. Biobased materials can lower the CO2 footprint of composite materials. Different way's of how to deal with end-of-life waste: a physical, chemical and biological techniques have been tested and taken up in the scenario's.

(ID: 198)

STUDY OF FIREPROOFING TECHNIQUES AND THEIR IMPACT ON THE ACOUSTIC PERFORMANCES OF VEGETAL WOOLS

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Bio-based materials, such as vegetal wools, have now become an essential part of the green buildings envelope. Indeed, these materials, which offer acoustic performances at least similar to conventional materials, provide a response to the management of natural resources and to the storage of atmospheric carbon dioxide.

Nevertheless, with vegetal fibres composed by high proportions of both cellulose and hemicellulose, these materials are classified as both inflammable and flame propagating elements. Therefore, vegetal wools are generally misclassified concerning their fire reaction and their fire resistance.

In order to comply with the European standard concerning the fire classification of building materials, it is necessary to carry out a fireproofing treatment on vegetal wools. The impact related to the use of this type of treatment on the microstructure of fibrous media and therefore on their acoustic performances is still little known.

As a first step, it seems particularly relevant to identify both the flame retardants and the different fireproofing techniques used for fibrous insulators.

Then, based on this work, for each identified technique, it is possible to predict the acoustic performance of vegetal wools using micro-macro homogenization modelling approaches. This modelling approach can be applied directly in the case of monolayer structures corresponding to the techniques of treatment within the materials.

It can also be combined with the transfer matrix method in the case of multi-layer materials with the addition of a treated cladding.

Then, by using variation ranges of the input microstructural parameters, it is possible to study and characterize the impact of these different fireproofing treatment types on the performance of vegetal wools.

(ID: 212)

THE EFFECT OF MICROSTRUCTURAL MODIFICATIONS ON THE PHYSICAL AND MECHANICAL PROPERTIES OF NATURAL FIBERS-CEMENT BOARDS

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This paper presents the development of natural fiber-cement boards intended to be used as building components. The investigation focused on how several different parameters affected the physical and mechanical properties. The parameters taken into account in this investigation were the following: type of fibers (i.e. flax fibers and milkweed fibers), fiber/cement ratio, water/cement ratio, and fibers treatment. The flexural strength, thermal and acoustic insulation properties of the natural fiber-cement boards were determined after 28 days of curing. Results of this study indicated the relationships between the mix ratios, the microstructural properties, and the final mechanical, physical and insulation properties of the boards.

(ID: 215)

UPCYCLING FIBERS FROM END-OF-LIFE CLOTHES & TEXTILE REMNANTS FOR SUSTAINABLE BUILDING MATERIALS: CLOSING THE LOOP FOR A CIRCULAR ECONOMY (RECYBUILDMAT)

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This project focuses on developing and characterize sustainable building materials based on cement or lime matrix mixed with nanosilica produced from corn or rice straw agricultural byproducts and nonwoven fabrics produced from fibers recovered from textile waste and functional materials, mainly designed to be applied on thin panels for their application in ventilated façades, pavements and reinforcement of masonry structures, as well as for the development of multifunctional sandwich panels for applications in façades or roofs.

Using fibers and additives recovered from textile wastes, textile remnants and agricultural wastes as raw materials for building products will lead to a reduction of the environmental problems associated with the waste accumulation, as well as to more sustainable building materials, all this directly related to the transition towards a circular economy. Moreover, the development of this project will allow advancing in the knowledge of the recovering of raw materials from wastes, and on the combination of these fibers and additives with cement- or lime-based materials to produce building products for various applications.

The project is approached from a multidisciplinary perspective, including working packages related with the Textile and Materials Engineering field and working packages involving Construction and Building Technology. The results will help to develop new sustainable building materials with a high content on raw materials recovered from waste and that, -applied on panels for ventilated façades, floors and roofs or for strengthening masonry-, will contribute to improve the energy efficiency of the buildings and to reduce the emissions generated for the construction sector.

(ID: 300)

FLAX FIBERS COMPOSITE MADE UP BY 3D PRINTING

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This preliminary work deals with potential use of additive manufacturing to print a bio-based composite. For this, mixture of clay and flax fibers was used. First, we proceeded to the optimization of the printability conditions by ensuring that the water dosage allows a good extrusion with a continuous volume flow rate. Moreover, the yield stress obtained must allow to deposit several layers without loss of stability. This criterion was verified and then we printed a square element of 20 cm length where 4x4x16cm3 specimens were cut and used to evaluate bending strength.

We have shown that under some conditions we are able to print with different layers this composite. To improve the limit height of a printed element, additional tests are necessary to increase the resistance of this type of composite. This study will be continued by Optimizing mix design using other additives and introducing of reinforcement.

(ID: 302)

A MODEL FOR ASSESSMENT OF HEAT AND MOISTURE TRANSFER HOLLOW A HEMP CONCERTE WALL USING FINITE ELEMENT METHOD

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The energy performance of buildings represents a major challenge in terms of sustainable development. The buildings and buildings construction sectors combined are responsible for over one-third of global final energy consumption and nearly 40% of total direct and indirect CO2 emissions. In order to reduce the energy consumption of buildings and their harmful impact on the environment, special attention has been paid in recent years to the use of bio-based materials. In the present paper, a model of heat and moisture transfer hollow hemp concrete wall is proposed using finite element method. The energy and mass balances are expressed using measurable transfer drivers as temperature water content and vapor pressure and coefficients related explicitly to the macroscopic properties of material as thermal conductivity, specific heat, and water vapor permeability. The proposed model is implemented in MATLAB code and validated through experimental measurements.

(ID: 305)

CREEP STUDY ON STRAW BALES WALLS

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Straw bales are known to be an excellent thermal and acoustic insulation and they can be used as load-bearing structures like the Nebraska technique. In France, there is no official standard for such methods, only a professional reference (RFCP, 2018). Few research studies have been carried out and among them, many were experimental and focused on the mechanical properties of straw bales systems for compression and shearing phenomena. Creep has not really been investigated yet and it can cause settlement problems during the onsite construction phase. Therefore, the objective is to build an experimental dataset in order to develop a multi-parameter creep behaviour model. According to the litterature, the impacting parameters are the bales density, the preloading and loading levels, and the bracing systems. The experimental setup required some specific environmental conditions and an elaborated instrumentation system. The latter has enabled to measure humidity and temperature and moreover the pictures taken by the camera has given information via digital image correlation technique regarding the walls deformation and the probable straps relaxation.

(ID: 307)

MEDIUM DENSITY MATERIALS BASED ON CLAY AND BY-PRODUCTS OF CORN AND SUNFLOWER STALKS. THERMAL AND ACOUSTIC ASPECTS

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Agricultural by-products obtained from sunflower and corn stalks can have multiple applications when introduced as aggregates in clay-based materials. Due to their low weight, these plant by-products can provide lightness and good thermal and acoustic performance, making them suitable for use as interior elements (cladding, wall panels or false ceilings). This article explores these two aspects, thermal and acoustic, for a variety of formulations.

The introduction of bio-based materials in building construction represents a renewable and biodegradable alternative to other conventional materials. In the case of agricultural by-products, locally sourced, the advantages are even greater. The stalks of both corn a sunflower plants consist of an outer bark and a white, spongy pith inside. Because of its spongy structure, pith is characterised by an extremely light weight and low thermal conductivity. In previous papers (Palumbo, 2018) a thermal insulation system based on corn pith was developed and characterized in terms of hydrothermal behaviour. In the present work, medium density panels formulated with clay and the aforementioned plant by-products have been developed and analysed with the aim of obtaining satisfactory solutions from the thermal and acoustic points of view.

Thermal conductivity has been correlated with density, obtaining, as expected, that the lower the density, the lower the conductivity. Acoustic absorption has been determined in an impedance tube, using a procedure based on measurements of the transfer function between two microphones (Novais, 2020). In general, samples with a higher percentage of plant aggregates showed a higher acoustic absorption. Significant differences have been observed depending on the type of aggregate (corn pith, sunflower pith, or a mixture of pith and bark). The results obtained are satisfactory and promising.

(ID: 120)

BIO-BASED RHEOLOGY MODIFIERS FOR CEMENT-BASED MATERIALS

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Implementation of digital manufacturing revolutionizes the construction industry with the potential of freeform architecture, less raw material consumption, reduced construction costs, and increased worker safety. Cement-based materials with their thixotropic nature enable the progress of this technology and provide an alternative manufacturing system. These parameters can be achieved by using advanced admixture, like viscosity modifying agents (VMAs). VMAs can improve the yield stress and viscosity of cementitious systems and reduce material deformation under its own weight during additive manufacturing concrete. Recent studies showed that bio-based admixtures, such as welan gum, diutan gum or even bacterial cells can be utilized as VMAs in mortars, which can improve the stability and buildability of the printed material (Azima and Başaran Bundur, 2020; Khayat and Saric-Coric, 2000; Pei et al., 2015; Schmidt et al., 2013; Sonebi, 2006). This study was undertaken to evaluate the possible use of bacterial cells and nano clays as VMAs in cement-based systems. To achieve this goal, the gram-positive Bacillus megaterium cells were grown in specified nutrient media and then harvested from the inoculum by centrifuging. Then, these cells were suspended in mixing water without any extra intervention and their influence on the rheology of cement paste was investigated. Besides, a comparative based analysis was done by using nano montmorillonite (NM) While the bacterial cell amount was kept at 1% of the cement weight, the NM was added by 0.5% of the cement. All cement paste samples included 20% fly ash (FA) in the mix. The rheological evaluation was done by establishing a flow curve and calculating the change in static yield stress as an indicator of thixotropy. Figure 1 summarizes the flow curves for cement paste samples and the change in static yield stress with time. Our results showed that the incorporation of only B. megaterium cells improved the static yield stress and thixotropy of the sample compared to both control sample and sample containing 0.5% NM. In addition, the cells decreased the dynamic yield stress of the mix indicating a higher fresh state stability without sacrificing the workability. However, incorporation of bacterial cells with NM decreased the efficiency of both VMAs in terms of improving the yield stress and thixotropy. This might be due to the dispersive effect of negative surface charge of cells with nano clays. Further studies are being done to understand the interaction of cells with nano-clays.

NOTES

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