ICBBM EcoGRAFI 2017

International Conference on Bio-based Building Materials

and on

Ecological valorisation of GRAnular and FIbrous materials

June 21st – 23rd 2017

Clermont-Ferrand, France

Program guide

Chairmen:
Prof. Sofiane Amziane, Institut Pascal / UCA (Fr)
Prof. Pierre Breul, Institut Pascal / UCA (Fr)
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Foreword

Dear colleagues,

We are pleased to organise the 2nd International Conference on Bio-based Building Materials (ICBBM) together with the 1rst International Conference on Ecological Valorisation of Granular and Fibrous materials (EcoGRAFI), held on 21st-23rd June 2017 in Clermont-Ferrand, France.

We hope this conference will be highly successful and reach international audience. Nearly 200 papers have been submitted to ICBBM EcoGRAFI 2017, covering a wide range of diverse and original subjects from around the world. Topics covered in this conference include natural fibres, mechanical performances and biodurability of bio-based building materials, eco-friendly binders, methodology, rammed earth, and case studies. Over 120 papers will be presented during the five parallel sessions, in addition to a further 20 papers presented during the poster sessions.

We look forward to an outstanding technical calibre conference and are very grateful to the session organisers for helping us put the program together. Furthermore we are grateful to the authors for their efforts in providing their scientific contributions to the program and acknowledge as well our sponsors for their generous support that is critical for the success of the conference. Special thanks go to the International Technical and Scientific Committee for their help in revising papers. There is a program printed in this handbook but you may also access the online program: https://sites.google.com/site/icbbmecografi2017/home.

We hope you enjoy the conference and its events (described in the handbook). If you require any assistance during the conference please do not hesitate to contact us for help. We would like to thank the Organisers of this conference and the Local Organising committee for their diligent work and commitment to bring this conference to great success!

Prof. Sofiane Amziane,
Prof. Pierre Breul,
Dr. Mohammed Sonebi

Chairmen

Prof. Sofiane Amziane,
Polytech Clermont,
Institut Pascal, France

Prof. Pierre Breul,
Polytech Clermont,
Institut Pascal, France

Dr. Mohammed Sonebi,
Queen's University,
Belfast, United Kingdom

Conference Overview

Tuesday	16h-20h – Pre-registration at Polydôme 18h – Welcome reception	*Thursday*	8h30-10h – Plenary 4 & 5 10h-10h30 – Break 10h30-12h30 – Parallel sessions 12h30-13h45 – Lunch 13h45-14h30 – Plenary 6 14h30-15h10 – Poster session 15h10-15h40 – Break 15h40-17h – Parallel sessions 18h30 – Departure for the banquet 19h – Conference dinner
Wednesday	8h-18h – Registration 8h30-8h45 – Opening session 9h45-10h15 – Plenary 1 & 2 10h15-10h45 – Break 10h45-12h25 – Parallel sessions 12h25-13h45 – Lunch 13h45-14h30 – Plenary 3 14h30-15h10 – Poster session 15h10-16h10 – Parallel sessions 16h10-16h40 – Break 16h40-18h – Parallel sessions 18h – Free evening – Music festival	*Friday*	8h30-9h10 – Plenary 7 9h10-10h10 – Parallel sessions 10h10-10h40 – Break 10h40-12h – Parallel sessions 12h-12h30 – Round-table 12h30-12h45 – Closing ceremony

Parallel events *on Thursday (8h30-17h)*: JEMAB day
on Friday (10h40-17h): Atelier TyCCAO
on Friday (9h10-12h): Workshop on bio-adhesives

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A. Talon, Polytech Clermont
E. Toussaint, Polytech Clermont

Plenary speakers

Wednesday 21st 8h45 – *Vegetal concrete: sustainability, design, properties, durability and future R&D trends*

Prof. Sofiane Amziane

Sofiane Amziane is a full Professor of University of Clermont Auvergne since 2008 and he is the coordinator of materials Innovation Research Team of the Institut Pascal – UMR 6602 which is a part of CNRS. His main area of interest is turned since 2008 on bio based building materials, rheology of cement based material and reparation of RC structure with composite. He was the supervisor (or co-supervisor) of 17 concluded doctorates and published more than 60 full papers. He edited the first book related to Bio-aggregate-based Building Materials: Applications to Hemp Concretes as STAR of RILEM books and NIST report. He is member, chair or co-chair of several ACI and RILEM committees.

Dr. Mohammed Sonebi

Dr Mohammed Sonebi graduated from the University of Sherbrooke (Canada) with a PhD and MSc in Civil Engineering after completing a MEng degree at Bridges, Pavement and Structural buildings. He then joined University of Paisley (Scotland) as a postdoctoral research assistant and later as a Lecturer. He is now a Senior Lecturer at Queen's University Belfast. He has authored/co-authored more than 170 scientific papers and 17 books/chapters. He is a Senior Member of RILEM and Chair of RILEM-TC-266 and Voting member of American Concrete Institute (ACI) and Vice-Chair of ACI 522. He awarded the Best KTP Partnership and Excellence Engineering Awards 2013, a Finalist for Parliamentary Awards 2016 in category Innovation Leading to New Markets at Westminster (UK) with Bullivant Taranto Ltd..

Wednesday 21st 9h30 – *Challenges and opportunities of using alternative construction materials in the global housing sector – Environmental perspectives*

Dr. Guillaume Habert

Guillaume Habert is since 2012 Associate Professor and hold the chair of Sustainable construction at ETH Zurich. The main objectives of the research are to identify the relevant parameters that influence the environmental impacts of buildings and infrastructures, to quantify the improvement potentials for specific materials and structures and develop innovative constructive techniques adapted to the technical, economic and socio-cultural situation of specific territories. This involves interdisciplinary works dealing among others with Life Cycle Assessment, urban metabolism and material science. The current projects involve the development of clay based concrete, the use of excavation materials and the sustainability assessment of low carbon cement.

Wednesday 21st 13h45 – *Discrete modelling of building materials*

Prof. Farhang Radjaï

Farhang Radjai is Research Director at National Center for Scientific Research (CNRS) in France. He is the head of research team « Physics and Mechanics of Discrete Materials » at the Laboratory of Mechanics and Civil Engineering (LMGC) in University of Montpellier and MIT research affiliate at the CNRS-MIT research group « Multi-Scale Material Science for Energy and Environment ». He graduated in 1995 in theoretical physics and received his PhD on modeling granular materials in University Paris-Sud. His research has mainly focused on the rheology of granular materials using discrete modeling approaches and statistical analysis with applications to cohesive flows, underwater avalanche dynamics, multi-phase granular materials, agglomeration process, powder compaction and railway ballast settlement.

Thursday 22nd 8h30 – *Innovations in the use of bio-based aggregates in construction*

Dr Mike Lawrence

After careers in accountancy, book-selling and stone quarrying, Mike Lawrence became a Lecturer in low-carbon design in 2012 in the BRE Centre for Innovative Construction Materials at the University of Bath. He specialises in Natural Building Materials and in the optimisation of the fabric of buildings to minimise in-use energy consumption. He founded the Building Research Park and the experimental HIVE building in 2013. Mike is Principal Investigator for the EU funded HEMPSEC and ISOBIO projects and co-investigator on the ECO-SEE project and has published over 60 peer reviewed papers. He also worked with Bath Abbey on their Footprint Project to ensure that the proposed work has no impact on the historic fabric of the Abbey. Mike is a Trustee and Director of Earth Building UK Ltd, a charity dedicated to promoting the use of earth in construction in the UK and has been a member of two RILEM committees (TC BBM and Hygrothermal and Durability of BBM).

Thursday 22nd 9h15 – *Advances in laboratory characterization of materials*

Prof. B. Caicedo

Bernardo Caicedo is graduate in Civil Engineering at the Cauca University in Colombia (1986), DEA in geotechnics and structures, Ecole Centrale de Paris (1987), PhD in Geotechnics and Structures Ecole Centrale de Paris (1991). He is now Professor at Los Andes University since 1991. His main research topics are: physical modelling in geotechnics, unsaturated soil mechanics, and experimental geotechnics. Prof. Caicedo is member of the editorial board of Geotechnique Letters, Acta Geotechnica and the Journal of Transportation Geotechnics. He is also referee for several international journals, supervisor of 95 master thesis, 12 doctoral thesis in Uniandes. He is the leader of more than 65 research projects in pavements and geotechnics in Uniandes. He is the editor of one book and author of 80 conference papers and 36 journal papers.

Thursday 22nd 13h45 – *Non-conventional inorganic-bonded fiber composite materials for housing and infrastructure application*

Prof. H. Savastano

Holmer Savastano Junior got his doctor degree in the field of civil construction (USP, Brazil, 1992). He has a post doctorate in the CSIRO, Australia (1998-99) and extensive collaboration with international research groups and with the industry since 2001. Holmer coordinates the Research Nucleus on Materials for Biosystems, USP since 2012. He has published about 140 full scientific papers with more than 1,200 citations (Web of Science). His main interest is on composite materials, use of residual and non-conventional resources, sustainable and eco-friendly housing and infrastructure.

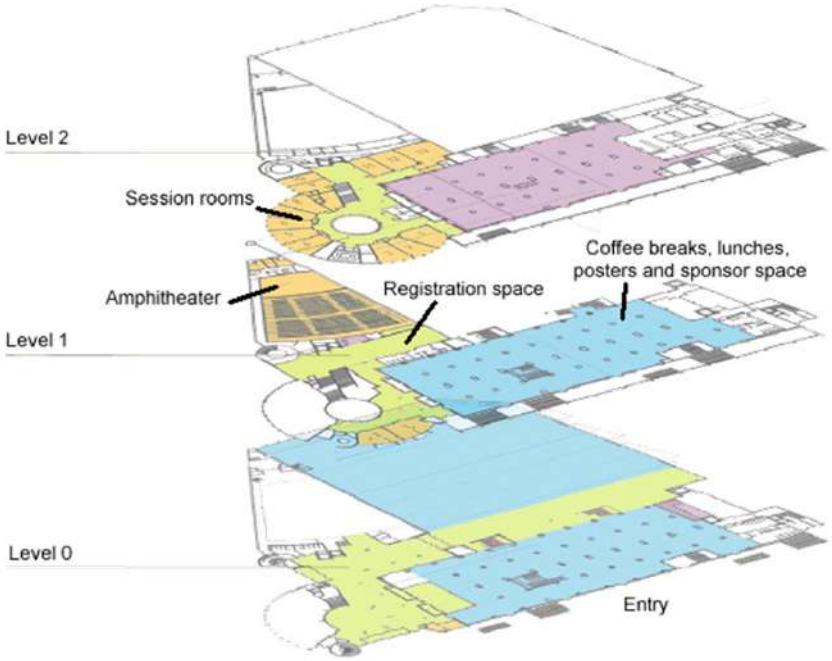
Friday 23rd 8h30 – *Concrete recycling: a new paradigm to face the challenge of circular economy*

Dr F. de Larrard

François de Larrard, PhD, is graduated from Ecole Polytechnique and Ecole Nationale des Ponts et Chaussées, Paris, France. He started his career at LCPC (now IFSTTAR), doing R&D in the field of concrete for bridges and pavement, with an emphasis on mix-design optimisation, fresh concrete rheology, high-performance concrete, innovative pavement concepts and sustainability. He joined the Lafarge group in 2011, where he holds a position of Scientific Director. François de Larrard has authored numerous papers, books, software programs and laboratory devices. In addition to his LafargeHolcim position, François is currently Scientific Director of the French national project Recybéton, a 44-partner group aiming at developing the process of recycling concrete into concrete in France.

Conference venue

The conference will be held in the **Polydôme Conference Center**. The rooms are given for each session in the following pages and will be indicated at the entry. The coffee breaks and the lunches will take place in the same place as sponsors and posters. Wifi will be available in the whole building. Free car parking is available at level -1 (entry by Serge Gainsbourg street).



Social program

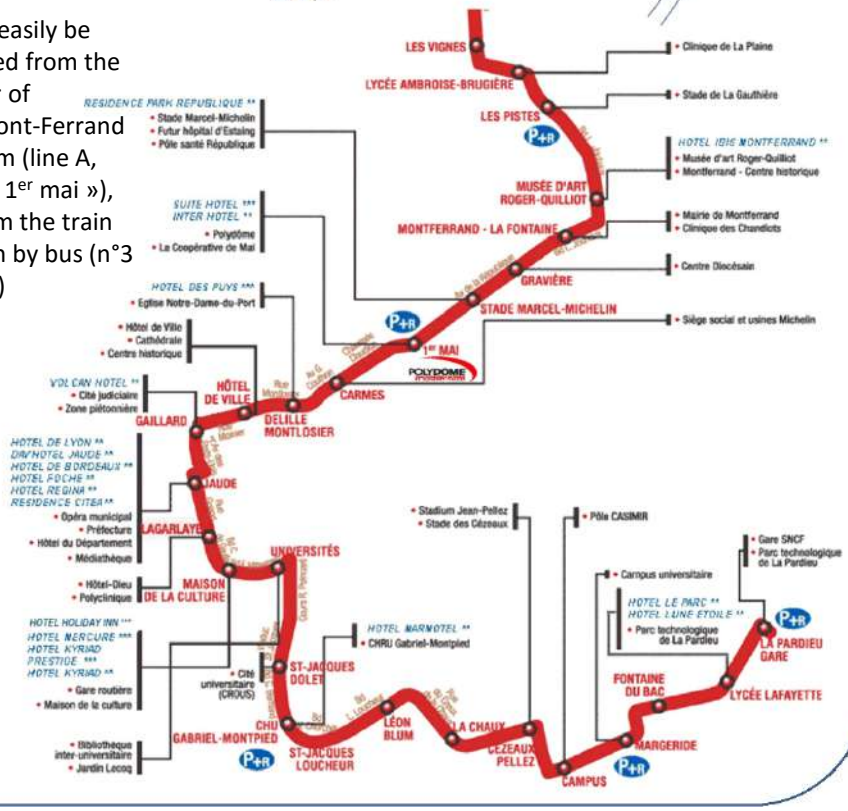
Tuesday 20th: registration (16h-20h) at Polydôme
18h: **Welcome Reception** « Cheese and Wine » at Polydôme with a sommelier

Wednesday 21st night: Summer **festival of music** in the City center (free)

Thursday 22nd :17h-18h30: free time
18h30: Departure in bus from Polydôme to the banquet place (only for the registered attendees)
19h: **Conference dinner** at the Domaine de Marrand
23h30: Return in city center in bus

The conference will be held in Polydôme Conference Center, in Clermont-Ferrand.

It can easily be reached from the center of Clermont-Ferrand by tram (line A, stop « 1er mai »), or from the train station by bus (n°3 or n°4)



Guidelines to speakers

Before the conference

Please ensure that you bring your presentation (in pdf or in ppt) to the conference on a memory stick or CD-Rom. Each lecture room will be equipped with a laptop running Windows 7 with PowerPoint and Adobe Reader, as well as with a laser pointer. Speakers will **NOT** be allowed to use their personal laptop computers for presentations.

Before the session

Visit the venue, check the room where your presentation has been scheduled and familiarize yourself with the space and A/V equipment.
On the day of your presentation, please report to the support staff near the lecture rooms prior to your session so that your presentation can be uploaded. Check it carefully (especially if you plan to use animations).
Meet the session Chair at the session room at least 15 min prior to the session start. Provide the session Chair with your filled *Speaker Information Form* and let him/her know how you would like to be introduced (name, title, and affiliation). The session Chair will inform you about the time of your presentation.
Sessions have been planned for presentations of 15min each + 5min for questions.

During your session

Please deliver your presentation **strictly within the allotted time**, leaving at least 5 min for questions. As your presentation nears the end, you will be alerted by the session Chair of the time left. Session Chairs are instructed to stop any presentation that runs over the allotted time. At the end of the presentation, the session Chair will invite questions from the audience (according to the time left).

Guidelines to poster presenters

Before the conference

Please ensure that your poster has been made in agreement with the template.

At your arrival to the conference

Support staff will help you to install your poster on the dedicated place.

The day of your session

Two poster flash presentation sessions are scheduled. Each poster owner will have 2-3 min (no more) to present his/her work to the whole assembly. For that purpose, the presenter can prepare 2-3 slides (in ppt or pdf) and upload them before the corresponding session. There are no strict poster sessions but the attendees may take benefit of the different breaks to come and read the posters.

At the end of the conference

You can let your poster installed until the end of the conference on Friday.

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Wednesday 21st

8h30	Opening session – S. Amziane, P. Breul & M. Sonebi – *Amphitheatre*
	Chair: S. Amziane & M. Sonebi – *Amphitheatre*
8h45	Plenary 1 – ***S. Amziane & M. Sonebi*** – Vegetal concrete: sustainability, design, properties, durability and future R&D trends
9h30	Plenary 2 – ***G. Habert*** – Challenges and opportunities of using alternative construction materials in the global housing sector
10h15	Coffee break

Session n°1 Chair *Room*	A1. Mechanical performances V. Picandet *1*	B1. Material treatments H. Savastano *2*
10h45	ID 133 - Evaluation of shear strength parameters of bio-based concretes by means of triaxial compression ***Morgan Chabannes***	ID 150 - Assessing a method of bamboo treatment and its effects on the durability and mechanical performance ***Anne-Cécile Grillet***
11h05	ID 143 - Experimental evaluation of straw bales mechanical performance ***Mirko Maraldi***	ID 248 - Conventional and microwave- assisted thermal treatment of *Dendrocalamus asper* bamboo ***Thaís Magalhães***
11h25	ID 218 - Mechanics of straw bales for building applications ***Thibaut Lecompte***	ID 256 - Physical and mechanical properties of rice straw treated with solution of potassium hydroxide from wood ash ***Conand Honoré Kouakou***
11h45	ID 290 - Mixed-mode interfacial fracture toughness of wood and adhesives ***Sina Askarinejad***	ID 274 - Effect of linseed oil and metakaolin on the mechanical, thermal and transport properties of hemp-lime concrete ***Joseph Sheridan***
12h05	ID 249 - Mechanical properties and durability of mortar with rice husk ash calcined at low temperature ***Chun-Tao Chen***	ID 306 - Effect of the use of autoclave on bio-construction materials ***H. Elaqra***
12h25	Lunch	

Wednesday 21st

Session n°1 Chair *Room*	C1. Natural reinforcements M. Ardanuy *5*	D1. Cementitious composites W. Srubar III *7*	E1. Granular materials F. Radjaï *9*
10h45	ID 296 – Fibrous raw materials from an alternative supply chain for building products ***Hans-Jörg Gusovius***	ID 166 - Experimental characterization of an agromaterial based on typha fibers and clay ***Ibrahim Niang***	ID 266 - Influence of saturation degree on sandy soils behavior: application to liquefaction ***M. Vernay***
11h05	ID 237 - Use of natural fibers to enhance tensile strength of concrete ***Charitha Seneviratne***	ID 169 - Using alternative binders for the development of flax fiber reinforced cementitious composites ***Jonathan Page***	ID 141 - Application technology of granule body as infilling material for ground improvement ***A. Ezoe***
11h25	ID 136 - Physical characterisation of hemp shiv: cell wall structure and porosity ***Yunhong Jiang***	ID 171 - Utilization of wood biomass ash (WBA) in the cement composites ***Ivana Carevic***	ID 152 - Physique characterization of biphasic clay medium using a dynamic cone penetrometer ***C. Sastre Jurado***
11h45	ID 244 - The use of human hairs as a fiber-reinforcement in cement-based mortars ***Alessandro P. Fantilli***	ID 179 - Mechanical properties of hemp yarn impregnation in cementitious matrix ***Hana ALjewifi***	ID 209 - Feasibility of sand filters to wastewater treatment in rural areas of Algeria: experimental study ***F. Bouteldja***
12h05	ID 245 - The compatibility between wool fibers and cementitious mortars ***Alessandro P. Fantilli***	ID 195 - Compressive stress strain behavior of workable bio-concretes produced using bamboo, rice husk and wood shavings particles ***D. O. J. Dos Santos***	
12h25	Lunch		

Wednesday 21st

Plenary session - Building materials as an opportunity for regeneration

G. Habert[1], E. Zea Camilla[2], N. Heeren[1], F. Pittau[1], S. Zingg[1]*
[1]Chair of Sustainable construction, ETH Zurich, Switzerland; [2]Centre for Corporate Responsibility and Sustainability, Zurich University, Switzerland; habertg@ethz.ch

Buildings and infrastructures create the framework of our daily life. Both production of building materials and construction create hundreds of millions of jobs all over the world. From a life cycle perspective only three area of consumption, food, private transportation and housing, together are responsible for 70 to 80 % of our environmental impacts and both housing and mobility are interdependent key elements of the built environment. With the Paris agreement, world leaders agreed to recognise that we have now a limited amount of time to drastically cut greenhouse gas emissions. In this feature, buildings play a pivotal role. They are both the main contributors to climate change and the place where reside the main opportunities for changes. In this presentation, we show how natural and anthropogenic material cycles can be transformed through the appropriate use of building materials. In particular, we will evaluate how the built environment can be a cost effective solution for decarbonation. This requires implementation of alternative building materials as well as the development of new modelling framework in order to grasp these opportunities.

A1. Mechanical performances

ID 133 - Evaluation of shear strength parameters of bio-based concretes by means of triaxial compression

Morgan Chabannes[1], Frédéric Becquart[1], Eric Garcia-Diaz[2], Nor-Edine Abriak[1], Laurent Clerc[2]
[1]IMT Lille Douai, Univ. Lille, LGCgE-GCE, F-59508 Douai Cedex, France; [2]C2MA, Ecole des Mines d'Alès, F-30319 Alès Cedex, France; morgan.chabannes@imt-lille-douai.fr

Recent decades have witnessed the emergence of plant-based building materials that combine crop residues with lime-based binders. This return to old building methods resulted in the development of hemp concretes. These ones are often used as infill materials manually tamped in timber stud walls. Considering precast industry, vibro-compaction of fresh material leads to improved compressive strength, rigidity and strain capacity before failure. In either case, the structural design practice of wood frame walls associated with hemp concrete does not assume any contribution of the plant-based material whereas hemp concrete may contribute towards the racking strength of the walls. In this context, it is necessary to study the shear behaviour of bio-based concretes since it is currently unknown. This work is intended to evaluate the shear strength of two different bio-based concretes by means of triaxial compression. Hemp shives and whole rice husks were used in this study. These aggregates were mixed with a lime-based binder according to the same mix proportioning and mixes were then vibro-compacted in cylindrical forms. Samples were cured at 23°C and 65%RH during 60 days before being tested under uniaxial and triaxial compression. The triaxial shear test was conducted on unsaturated specimens under drained conditions at atmospheric pressure and for growing effective confining pressures from 25 to 150 kPa. The results made it possible to estimate the peak friction angle and the cohesion of plant-based concretes. This work highlights the leading role of the aggregate type on the shear strength and leads to a first appropriate analysis of the links between the composition of the material (plant particles cemented with a binder) and its shear strength parameters. The shear strength of plant-based concretes was found to be significant and should be considered for design practice of building envelopes.

ID 143 - Experimental evaluation of straw bales mechanical performance

Mirko Maraldi[1], Luisa Molari[2], Giovanni Molari[3], Nicolo' Ragazzi[4]
[1]Alma Mater Studiorum - University of Bologna, Italy; [2]Alma Mater Studiorum - University of Bologna, Italy; [3]Alma Mater Studiorum - University of Bologna, Italy; [4]Alma Mater Studiorum - University of Bologna, Italy; luisa.molari@unibo.it

Over the last decades, the use of straw bales in construction has been continuously growing. This is due to a number of factors: the technique is environmental-friendly; straw is a natural material offering excellent thermal insulation, great breathability, fire resistance and has good mechanical properties; and

building cost can potentially be lower with respect to traditional techniques. Despite the growing interest in the field, little research has been devoted to the testing of single unplastered straw bales; moreover, a standard method for the tests is missing. In this paper, the mechanical behavior and the performance of straw bales is investigated by presenting the results of compression tests performed on bales of different materials and with different initial density. Bales were compressed using a hydraulic press and digital cameras and a 3D laser scanner were used to measure the lateral displacement of the bale. Force and the displacement of the bale in all the three directions were measured in real time without stopping the test; this allowed to account for the fact that the mechanical behavior of straw bales is time-dependent. Results show that bale density has a strong influence on the elastic modulus of the bales, whereas other variables such as bale orientation (flat or on-edge) and bale material have no significant impact on it. By using digital image correlation, it was observed that straw bales exhibit a typical deformation pattern which is due to the baling process. Measurements also showed that the Poisson's ratio does not remain constant along the longitudinal direction during loading and it is null along the transverse direction.

ID 218 - **Mechanics of straw bales for building applications**

Thibaut Lecompte, Antoine Le Duigou
IRDL-Univ.de Bretagne-Sud, France; thibaut.lecompte@univ-ubs.fr

Straw bales are seen as increasingly viable for building insulation and even for the construction of small load-bearing straw houses in the last decades, especially in view of the need to seek low environmental footprints. Straw bales can be used as load-bearing structures but they are currently mainly used as a filler insulation material associated with a timber structure. Up to present, very few studies are available concerning the mechanical behaviour of straw bales in buildings. This study aims at investigating the behaviour of straw bales and leads to recommendations for required bales densities. This allows to derive compression models which describe their behaviour in a wall. Therefore, the results show that, in the density range 90-110 kg/m^3, the elastic and strength characteristics are similar whatever the position of the bales (laid flat or on their edge). The behaviour of the straw bales is found to be in correlation with the straw wisps density, and then with the initial wisps packing into the bales. The bale must be considered has a system, consisting of the straw and the polymer links: when laid flat, it exhibits a particular type of deformation under single compression leading to a constant perimeter. In this position, the mechanical properties are controlled by two factors: (1) the packing density induced by the machine during the baling process, and by the elasticity and creep of the links; (2) the solid volume fraction of straw wisps, conditioned by the agronomic parameters and the pressure level in the baler.

ID 290 - **Mixed-mode interfacial fracture toughness of wood and adhesives**

Sina Askarinejad[1], Faezeh Shalchy[2], Joshua Gionfriddo[3], Nima Rahbar[1]
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This paper presents the results of a combined experimental and theoretical study of the fracture of wood/ adhesive interfaces. Thermoplastic and thermosetting adhesives are considered in this study as well as combinations of the two applied in sequence. Mode mixity dependence of interfacial fracture toughness is measured using Brazil-nut sandwich specimens. Interfacial fracture energies, Gc, between wood and adhesives are measured over a wide range of mode mixity. Two types of woods: pine and cedar in combination with three types of adhesives: a polyurethane adhesive, a resorcinol based adhesive and a phenol-resorcinol-formaldehyde adhesive are investigated in this study. The results show that interfacial fracture toughness generally increases with the increase in mode mixity. The trends in the overall fracture energies are also predicted using fracture mechanics models. The mode mixity dependence of interfacial fracture toughness will also be explained using a crack-shielding model that accounts for the crack profiles and the contact between mating asperities. The goal of this research is to more fully understand the interfacial toughness of wood and adhesive interfaces that exist in these types of repairs. The results can be used as a guide to design wood-based structures and furniture.

Wednesday 21st

ID 249 - **Mechanical properties and durability of mortar with rice husk ash calcined at low temperature**

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In past studies, rice husk ash (RHA) calcined at 1000 °C or higher was found active. They can be alkali-activated or induce pozzolanic reactions in cement hydrates. However, calcination at high temperature consumes much energy. In addition, most RHA is produced at an open-aired site. The burning temperature cannot be so high even in a power plant. In view of these issues, this study explores the mechanical properties and durability of mortar in the presence of RHA produced at low temperature. During the experiments, the rice husk was calcined under different temperature (400-1000 °C). Results showed that the properties of the RHA met the requirements in ASTM C618. Then, the mortar was prepared at w/c of 0.6, the cement in mortar was replaced by RHA by 5%-20% by volume, and the compressive strengths of the mortar were conducted. The 10% was found the optimum. Specimens with RHA calcined under 800 had higher strengths higher than those with RHA calcined at 1000 °C. However, the specimens with RHA calcined at 400 °C had the highest compressive strength at all ages possibly due to high remaining carbon content which absorbed water and reduced the w/c. Further results also showed that the shrinkage did not change significantly with the calcining temperature and dosage of the RHA, but the expansion due to alkali-silica reaction was effectively inhibited at 10%. RHA calcined by 400 °C had the best inhibition on expansion due to alkali-silica reaction (ASR) than that calcined by 800 °C or 1000 °C.

B1. Material treatments

ID 150 - **Assessing a method of bamboo treatment and its effects on the durability and mechanical performance**

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Bamboo is a natural material having a fast reproduction and excellent mechanical properties. The possibility to use bamboo for "green" constructions or to replace steel reinforcements in low-cost houses has been shown in the literature. However, when a natural material in general and bamboo in particular are expected to be a construction material, their durability is always questionable. Indeed, it is well known that these materials do not possess the same performance at the long-term, comparing to industrial materials. Several studies were carried out to search solutions which could improve the bamboo's durability, but a sustainable solution for the bamboo treatment still needs to be investigated. The present study explores the oil-heated treatment with different types of oils like flax or sunflower oils. The present investigation concentrates on mechanical properties and durability of treated bamboos, to assess the effectiveness of this treatment approach. First, bamboo specimens were treated with perspective to increase their durability. Eleven sets with different conditions of treatment were tested: treatment at 100°C or 180°C; with flax oil or sunflower oil, or without oil; treatment time of 1h, 2h or 3h; different cooling methods and cooling times. Then, mechanical and durability tests were carried out on untreated and treated bamboos: uniaxial compression tests, 3 points bending tests, water immersion tests and humidity tests. The results showed that some tested treatment method could increase both the durability and the compressive strength of treated specimens, comparing to untreated bamboo.

ID 248 - **Conventional and microwave- assisted thermal treatment of *Dendrocalamus asper* bamboo**

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The thermal treatment process of bamboo or wood can be used to improve the mechanical properties and enhance the dimensional stability. The aim of this work was to investigate the mechanical properties of the bamboo *Dendrocalamus asper* after thermal treatment using a microwave-assisted oven (MO) and

a conventional furnace (CF), normally used for this purpose. In the present study, prismatic samples of bamboo were heat treated in the presence of air at the temperatures of 120, 140 and 160°C with heating rate of 1°C/min and isotherm of 10 min. The treatment conditions were evaluated through axial compression tests, density and mass change. The bamboo in the as-received condition showed a mean moisture content of 92.65 %. The experimental results indicated that in average, 51 % more weight loss is observed using the MO than the CF process at the same temperature. However, the compression tests showed similar mechanical resistance after heat treatment in the MO and CF at 120 °C, with a modulus of elasticity MOE of 4.68 GPa and 4.73 GPa and compressive strength MOR of 77.41 MPa and 83.24 MPa respectively. These results suggest an increase of the stiffness and strength after the conducted heat treatments in comparison with the untreated bamboo, which showed a MOE of 3.40 GPa and a MOR of 73.67 MPa. The results of this study showed that the effects of the microwave interfered in the process of removal of compounds with low polarity, without compromising the structure of the material. The performed heat treatments provided materials with similar mechanical characteristics at different treatment temperatures.

ID 256 - **Physical and mechanical properties of rice straw treated with solution of potassium hydroxide from wood ash**

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The use of agricultural waste as alternate building material has had great deal of interest in recent years. Therefore, these wastes have often bad physical properties that need to be improved. This experimental research investigation aims to explain the influence of potassium hydroxide on the rice straw properties. The potassium hydroxide was obtained by crystallizing wood ash solution. Five solutions containing different ratio of potassium hydroxide were made and used to treat rice straw. Water absorption, direct tensile test and density were performed on straw to determine the influence of treatments on their physical and mechanical properties. Modifications in rice straw structure were investigated by dissecting microscope and scanning electron microscopy (SEM). All applied solutions resulted in a reduction of the water absorption capacity and increase in tensile strength. For improve physical and mechanical properties of vegetal straw, treatment with solution containing 8 kg/l of potassium hydroxide was recommended.

ID 274 - **Effect of linseed oil and metakaolin on the mechanical, thermal and transport properties of hemp-lime concrete**

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With the increasing concern given to pollution and climate change bio-based building materials have been pushed to the forefront of research in an effort to reduce the large carbon footprint of the construction industry in order to meet emission targets One of these materials is hemp concrete which is a bio-composite made up of the non-fibrous part of hemp called shiv, water and a lime binder. This study uses two different binders; hydrated lime as a control and a composite binder made up of 80% hydrated lime and 20% metakaolin. The effect of metakaolin addition into the binder is studied for its effect on the mechanical, thermal and transport properties. The pre-treatment of the aggregate with linseed oil is also investigated. It was found that the addition of metakaolin increased the compressive strength of the hydrated lime samples. It was also observed that in both cases the addition of metakaolin into the binder increased the capillarity water absorption of the samples. The addition of metakaolin reduced the thermal conductivity of hydrated lime samples when the test was done in the direction perpendicular to the fibre orientation. Finally, the pretreatment of the aggregate with linseed oil increased the compressive strength and modulus of elasticity of the samples and greatly reduced the material's capillarity absorption. Linseed oil pretreatment also lead to an increase in thermal conductivity of the samples.

Wednesday 21st

ID 306 - Effect of the use of autoclave on bio-construction materials

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The paper discusses the use of autoclave as acceleration method for increasing the strength of bio-construction materials. Three mixes where studied, they were prepared in order to have a CaO/SiO_2 around 1. Hemp fibers were mixed with three different binder, Lime and silica fume mix (CaO/SiO_2 = 1), cement and silica fume mix (CaO/SiO_2 = 0,96) and cement, silica fume and lime mix (CaO/SiO_2 = 0,95). Two curing temperature (110°C, 130°C and 180°C) used. The results show an increase of the strength of lime and silica fume mix from 0,5MPa to 4,4Mpa after autoclave at 110°C. While the cement and silica fume has an increase from 0,8Mpa to 1,5Mpa after autoclave at 110°C. The same mixes at autoclave 180°C show smaller increase in strength than autoclave at 110°C.

C1. Natural reinforcements

ID 296 – Fibrous raw materials from an alternative supply chain for building products

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In the traditional process fibre crops like hemp are mowed at harvest time, dried on the field and usually retted, too. An alternative supply chain proceeds chopping of the crop from the stand and its wet preservation thereafter. Bunker silos or foil wrapped silos are used for this storage procedure as known for example for animal fodder. The duration of wet preservation can be prolonged up to the next year's harvest without negative impact on mechanical properties of the single fibre element. By a new procedure the desired semi-finished or final product is processed from the preserved material directly, using the whole plant mass. This is carried out through an extruder mill and a refiner. A drying and further handling can follow in order to e.g. manufacture fibre boards. Further preliminary experiments were carried out for the utilization of wet preserved whole crop raw material as well as extruded respectively milled fibrous intermediates in mineral bonded building materials. Samples from the different stages of the supply and processing chain were analysed for their chemical composition, particle morphology and final product properties.

ID 237 - Use of natural fibers to enhance tensile strength of concrete

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Natural fibres such as coconut coir and pine needles are abundantly available and often end up as a waste material without much use. There is a potential to use these natural fibres to replace steel and polypropylene in fibre reinforced concrete. Many lightly loaded concrete structures require slightly higher concrete tensile strength than the tensile strength provided by plain concrete. Fibre reinforced concrete is identified as an alternative to plain concrete that can offer higher tensile strength. Although several studies were performed on steel fibre reinforced concrete and polypropylene fibre reinforced concrete, a limited amount of study is available on natural fibre reinforced concrete such as coir reinforced concrete. This paper discusses the behaviour of fibre reinforced concrete produced using coconut coir. Coconut coir is an abundantly available material in Sri Lanka with a high tensile strength in the range of 76 – 102 MPa. Adding coir into concrete can enhance the tensile strength of concrete as it has been observed in steel fibre reinforced concrete and polypropylene fibre reinforced concrete. Washed and dried coir material was added by 2%, 4% and 6% of the cement weight ratio to the concrete mix with a target cube compressive strength of 60 MPa. The size of the coir sample was varied by 10 mm, 25 mm and 40 mm. Coir fibre reinforced concrete (CFRC) cubes and cylinders were tested for compressive and flexural strength and compared with plain concrete samples. This paper discusses the application of natural fibres as reinforcing materials in concrete, research method adopted for the study and experimental investigation carried out of CFRC samples.

ID 136 - **Physical characterisation of hemp shiv: cell wall structure and porosity**

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Hemp shiv have been widely used as a plant aggregate incorporated into building composites such as hemp-lime due to their low thermal conductivity and high moisture buffer value. The aim of this research is to study the intrinsic physical parameters such as porosity and cell wall structure of hemp shiv, which could be responsible for the distinct thermal and hygric properties of hemp shiv. Scanning electron microscope observations of hemp shiv showed distinct microstructures. Incorporating the results of CT tomography showed greater detail of pore shape and pore connection structures of hemp shiv in 3D dimensions. The vessels exhibit little variation in size and no clear pore arrangement, which is a diffuse-porous distribution. The vessels are mostly solitary and three of them appear as two adjacent pores where the middle wall between them is clearly shared. The vessels are approximately 50 to 100 µm in diameter and are surrounded by relatively thick fibre cells. Thick-walled fibres are located between the vessels with a diameter from 1µm to 2µm. The pore frequency of hemp shiv (generally only measured on diffuse-porous woods) is around 20.8 Vessels/mm^2. Radial cells run top to bottom with bridging fibril in the central vessel and multiseriate rays were seen in axial view on the cross-section surface. Pits in the secondary wall, viewed from ray parenchyma cells in radial longitudinal section of hemp shiv, showed pit membranes which are generally intact in the circular pits, but some of them are ruptured. Intervessel pits are 2-4 µm in horizontal diameter. The porosity of hemp shiv had been studied by a combination of pycnometer, mercury intrusion porosimetry and CT tomography. The combination of three techniques and comparing the results of pore structure from different methods gained the insight into the complex pore system of hemp shiv.

ID 244 - **The use of human hairs as a fiber-reinforcement in cement-based mortars**

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As their mechanical response is better than in plain cement-based mortars, fiber-reinforced mortars are widely used in the construction industry. Specifically, the fracture toughness in tension increases with the volume and the aspect ratio (i.e., the ratio between length and diameter) of the fibers, which are generally made with polymeric (e.g., polyethylene, polyvinylchloride, etc.) or inorganic (e.g., glass, carbon, etc.) materials, or with steel. However, some vegetal fibers, such as sisal and coconut, have been also introduced in the last decades. To produce new mortars with natural fibers, the use of human hair as fiber-reinforcement is investigated in the present paper. According to UNI EN 196-1-2006, three point bending tests have been performed on three series of beams: plain mortar (M), mortar reinforced with 10 grams of human hair (H), and mortar reinforced with 10 grams of industrial polyethylene fibers (F). In all the cases, flexural strength is not modified by the presence of fibers or hairs. Conversely, with respect to plain mortars, the flexural toughness increases of more than 9 times and 8 times when human hairs and plastic fibers are respectively added. In other words, animal fibers, like hairs, do improve the toughness performances of cementitious mortars, and can effectively substitute fossil-based fibers.

ID 245 - **The compatibility between wool fibers and cementitious mortars**

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The addition of natural fibers residue in cement based materials can be a sustainable technological alternative for traditional dispersed reinforcement, and can improve the performance of brittle materials. The presence of a wool reinforcement can increase the fracture toughness and, at the same time, reduce the environmental impact of cementitious mortars. The beneficial effects are similarly to those observed in presence of vegetal fibers (e.g., hemp), which have been largely investigated in the literature. However, there are some limits in the use of wool fibers due to their chemical compatibility with the cement matrix, as they can dissolve in alkaline environments. In the present paper, to investigate the compatibility between wool fibers and cementitious mortars, laboratory prototypes have been taken into consideration. Three series of wool-reinforced mortar beams have been cast and cured in water (20°C) or in dry conditions (temp. ± 20 °C, ± 50% R.H.) for some days. Portland-limestone cement CEM II has been used, whereas the content of fibers has been limited to about 1% in volume to maintain the workability of the mortars. To investigate the chemical compatibility, and the subsequent effects on the mechanical

performances, prototypes have been tested in three point bending. After the mechanical test, the mortars microstructure was evaluated through SEM images and on thin section, in order to individuate a possible relationship between the dissolution of wool and curing conditions. The microstructure observation revealed the capability of wool fibers to bridge the cracks, and to reduce the brittleness of plain mortars. The differences in the mortars microstructure due to alternative curing conditions were also observed and described in the paper. Accordingly, wool could be effectively used to reduce the plastic shrinkage of cement-based composites, like the industrially manufactured polypropylene fibers.

D1. Cementitious composites

ID 166 - **Experimental characterization of an agromaterial based on typha fibers and clay**

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This work is part of the PNEEB / TYPHA project for the valorization of an invasive reed, Typha Australis, as thermal insulation for the building in Senegal. The Typha Australis is a reed about 3.5 meters high, very common in aquatic environments and in humid regions, particularly in the Senegal River valley. It is a plant made up of a stem and leaves very porous like many agro resources such as hemp and straw. A material based on Typha Australis aggregates and clay is prepared and its mechanical and hydric properties are determined. Its fire behavior is also evaluated. In this study, the influence of the morphology and the quantity of Typha on the behavior of the material is sought. For this, different formulations are tested. The first two formulations have almost the same binder quantity (clay and mixing water) but differ by the Typha fibers cutting mode: one from longitudinal plant cut and the other from a transverse cut. However, the third formulation comprises an aggregate produced by cross-cutting with a greater binder amount. Compression tests are carried out and the following properties are determined: Young's modulus and compressive strength. In addition, the hygrothermal behavior is characterized by measuring the moisture buffering value. The reaction to fire and the fire resistance are estimated. The results show a real impact of the fiber load and their typology on mechanical strength. This material is also an excellent moisture regulator regardless of the portion of Typha aggregate. Let us note the preponderant role of the clay on the capacity of exchange with the external moisture because of its strong hygroscopic power. The fire behavior is governed by the amount of clay, which is an incombustible and inflammable material

ID 169 - **Using alternative binders for the development of flax fiber reinforced cementitious composites**

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For several decades, fibers are used in cementitious materials to improve the toughness and post-cracking behavior. The most commonly used in cementitious composites are steel fibers, glass fibers and polypropylene fibers. But all these reinforcement materials have the disadvantage of being derived from non-renewable resources. Economic issues related to the rising costs of fossil resources, their increasing scarcity, and environmental impacts inherent to their production therefore lead to explore other material sources. Based on this observation, plant fibers could be a solution for the future of the construction industry. Among the plant fibers, flax stands out because of its high mechanical properties and its low density. The primary concern for plant-fiber reinforced cementitious composites is the durability of the fibers in the highly alkaline environment of the cement matrix. The flax fibers reinforced cementitious composites (FFRCC) may undergo a reduction in strength and toughness as a result of weakening of the fibers by a combination of alkali attack and mineralization through the migration of hydration products to the flax fiber lumen. This paper presents a way to improve the durability of FFRCCs by a replacement of the ordinary Portland cement matrix by alternative binders such as metakaolin, ground granulated blast-furnace slag or sulfo-aluminous cement. The properties of fresh mortars were first studied (workability,

entrapped air, fresh density). The mechanical properties (3-points flexural and compressive tests) were then tested after several cure periods: 7, 28, 90 and 180 days. The hydration of these composites was also studied by semi-adiabatic calorimetry and thermogravimetric analysis. The results showed a significant change in hydration of composites according to the binder used. The flexural strength and toughness have also been improved by the use of some alternative binders, such as sulfo-aluminous cement.

ID 171 - **Utilization of wood biomass ash (WBA) in the cement composites**
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European policy is strongly directed towards renewable energy sources (RES) all in order to achieve a more competitive, secure and sustainable energy system. As part of 2030 Framework for climate and energy, the European Union (EU) has put forward the share of renewable energy increasing to at least a 27 %. Therefore, solid biomass and forestry biomass will continue to be one of the major sources for bioenergy within the EU all in order to transition energy politic towards this goal. The growing trend of using biomass as a RES results also in a growth of the produced wood biomass ash (WBA) as one of the by-product in the energy production. As the amount of biomass ash and the price of its landfill grows, it is necessary to establish the sustainable management as a major challenge in a bioenergy production. The one of the possible option to reduce the environmental and social problems related to the disposal of WBA is its utilization in the construction sector. This paper presents preliminary results of testing mechanical and durability properties of cement composites made with WBA in different amounts per cement mass.

ID 179 - **Mechanical properties of hemp yarn impregnation in cementitious matrix**
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Natural fibres are achieving progress in their application; it is diversified into engineering constructions such as building materials. Today, hemp yarn uses as reinforcements in cementitious composites to replace synthetic fibres such as glass. For a sustainable economic development, natural fibres include low price, low density, high specific strength and elastic modulus, unlimited and sustainable availability, and low abrasive wear of processing machinery, as well as their availability as renewable resources. Mechanical properties of plant fibers are much lower when compared to those of the most widely used competing reinforcing glass fibers but their specific properties, especially stiffness are comparable to the glass fibers. This paper is an investigation on the effect of embedded continuous hemp yarn on the microstructure and mechanical properties of cementitious composites. The quantitative physical of yarn impregnation was done by experimental methods such as measurements of capillary rise using colored water permit to observe movement of water in celluloses hemp yarn. The results were discussed on the basis of the wettability of the yarn. Furthermore, measurement of porosity accessible to water according to procedure AFPC-AFREM. And mercury intrusion porosimetry (MIP) classic test authorizes to determine pores size associated to presence the yarn in the matrix and it compared to reference samples that qualitative and quantitative yarn impregnation. In addition, Flow rate measurements leads to measure the flow rate of water along the yarn and identical pore size. Pull-out test was used to determine the mechanical parameters at pre-peak and post peak zone. Extracted length enhances characterization un–impregnated yarn when the embedded length extract entirely. All physical parameters determined pervious have related to pull-out parameters in order to understand the correlation between physical and mechanical parameters.

ID 195 - **Compressive stress strain behavior of workable bio-concretes produced using bamboo, rice husk and wood shavings particles**
Daniele Oliveira Justo Dos Santos[1], M'hamed Yassin Rajiv da Gloria[1], Vanessa Maria Andreola[1], Marco Pepe[2], Romildo Dias Toledo Filho[1]
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The present study aims to produce workable bio-based concretes with consistence indexes around 265 ± 15 mm, free of pressing process with bio-aggregates such as bamboo particles, wood shavings and rice husk. To produce the concretes, a nominal water-to-cement ratio of 0.45, a cement amount of 687 kg/m^3 and a volume fraction of the bio-aggregates of 50%, were used for all mixtures. Appropriate compensating

water amounts and the use of adequate dosages of viscosity modifying agent (VMA) allowed obtaining bio-concretes of high workability without exudation and segregation. The fresh property used was the consistence index through the flow table test, while the hardened property determined was the compressive stress-strain behavior at 1, 7 and 28 days. The results showed workable and consistent mixtures, with mechanical properties that can allow industrial scale production of construction components.

E1. Granular materials

ID 266 - Influence of saturation degree on sandy soils behavior: application to liquefaction
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It is now admitted and demonstrated that granular soils are particularly sensitive to instabilities such as liquefaction. But currently, this type of risk is considered in practice only if the soil is fully saturated. Nevertheless, some authors have highlighted that even under unsaturated conditions, a soil sample could liquefy under cyclic loading. However, few studies have been published, and more data are needed. Influence of pore fluid compressibility of unsaturated soils when submitted to cyclic loading has been studied by various authors. On the first hand, air as a pore fluid modifies the volumetric behavior, and has a positive impact on the liquefaction resistance; it delays the occurrence of liquefaction. On the other hand, suction is a state variable necessary to fully describe unsaturated soils behavior, but is rarely taken into account in liquefaction studies. In this paper, influence of saturation degree on liquefaction behavior is studied. Both pore fluid compressibility and suction are under interest. A special experimental device has been developed, that will permit to consider both aspects. A water column equipment will permit to impose initial suction to the sample, while local sensors will give information about volumetric behavior during cyclic loading.

ID 141 - Application technology of granule body as infilling material for ground improvement
A. Ezoe, K. Harada, J. Ohbayashi, J. Otani
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In Japan, the ground improvement method called Sand Compaction Pile (SCP) method for reinforcing ground by driving piles consisting of sand and/or gravel has been widely applied as a typical compaction method. This method is based on the improvement principles of “compaction” and “consolidation drainage”, which arise from installing granular material, such as sand or gravel, into soft ground. The method has accumulated a lot of work results owing to its applicability to both sandy soil and clayey soil. However, as the production of fine sand with good quality as infilling material for the compaction method is decreasing yearly, it is foreseen that securing necessary amount of suitable sand in the future is becoming extremely difficult. Under such circumstances, in order to mitigate environmental impact, ground improvement technology which effectively uses surplus soil or waste by-products from construction sites has been developed and brought into commercial application; the SCP method has started using such granular wastes as infilling material. In this paper, the manner of installing such granular material uniformly and effectively into the ground for the SCP method is introduced, and the characteristics of the substitute materials to mitigate the environmental impact are also shown. Such substitute materials include industrial by-products like recycled crushed soil, slug and/or material made by mixing liquefaction-ejected sand and slug with grain size distribution appropriately adjusted. This paper also describes actual construction examples using those materials, together with their favorable improvement effects.

ID 152 - Physique characterization of biphasic clay medium using a dynamic cone penetrometer
C. Sastre Jurado, P. Breul, M.A. Benz-Navarrete, C. Bacconnet, Y. Haddani, R. Gourvès
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Bentonite waterproofing properties are often exploited in environmental engineering, to seal off soil infiltrations, and line the base of landfills. In this work, we have performed a laboratory compaction control study of different 5 different bentonite mixtures. For this purpose an experimental protocol was

performed, including laboratory test and more than 70 cone penetration test in calibration chamber, using the dynamic penetrometer Panda 2®. We have built a penetration test database. The goal is to calculate the calibration curve for each tested mixture, which represents the relationship between the dry density and the logarithm of the cone resistance, below the critical depth. Nevertheless, the material composition must be known, in order to apply these calibrations curves. Therefore we propose a data mining approach to characterize the material texture analyzing the penetration signal supplied by Panda test. For this aim, neural networks models have been used, in order to classify the penetrations curves but also to predict the measured dry density. The excellent achieved result confirm the framework interest. Finally, a linear discriminant analysis was used, yielding to a simpler and comprehensible model.

ID 209 - Feasibility of sand filters to wastewater treatment in rural areas of Algeria: experimental study

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The treatment of domestic wastewater by sand filters is a very interesting alternative technique to collective sewerage in rural areas. In order to assess the accuracy of this technique in Algeria, a feasibility study based on a statistics survey and an experimental study is carried out. The aim of the statistical survey is to determine the potential for the application of this technique by evaluating the rate of connection to collective sewerage networks and the existence of a sewage treatment system. The purpose of the experimental study is to assess the suitability of the local sands for this type of process. In this paper the treatment performance over time of two different sands (medium and coarse) are evaluated. The chemical analyses of wastewater and filtered water showed a removal ranges between 57 and 74% for medium sand and between 7 and 49% for coarse sand. During the test period the obtained results indicate a better performance of medium sand comparing to the coarse sand.

Wednesday 21st

13h45	Chair: P. Breul – *Amphitheatre* Plenary 3 – ***F. Radjaï*** – Discrete modelling of building materials
14h30	Chair: P. Breul – *Amphitheatre* Flash poster presentations ID 147 - Synthesis and characterization of fly ash hybrid cements with limestone ID 155 - Natural Cement PROMPT-UP Vicat ID 160 - Systemic approach to reduce energy demand and CO_2 emissions of processes that transform agroforestry waste into high added value products ID 163 - Hydrophobation of natural fibres for application in WPC materials ID 178 - On the effect of the exterior plaster on the hygro-thermal behavior of the multilayer wall: case study of exterior insulation rehabilitation ID 180 - Development of bio-based insulation materials for the improvement of thermal comfort of housing in Burkina Faso ID 181 - Hydrophobic sol-gel coatings on bio-based materials – Influence of catalyst and solvent concentration ID 202 - Influence of the binder alkalinity on micro-organisms present in hemp shiv used for hemp concrete ID 212 - Contribution to the design and the characterization of a fully bio-based insulated panel including sunflower pith *+ Flash talks of industrial sponsors*

Session n°2 Chair *Room*	A2. Mechanical performances A. Phelipot-Mardelé *1*	B2. Acoustic characterization P. Glé *2*
15h10	ID 285 - Drying shrinkage and strength of GGBS and sawdust incorporated OPC mortar ***Ominda Nanayakkara***	ID 219 - Acoustic properties of lime-hemp concrete produced by compression molding ***Edith-Roland Fotsing***
15h30	ID 198 - Characterization of mechanical properties of hemp-clay composite and hemp stabilized clay composite ***Brahim Mazhoud***	ID 207 - Evaluating and understanding the acoustical properties of biobased materials ***Philippe Glé***
15h50	ID 278 - Experimental study of lateral load resistance of unclassified timber walls ***Husam Ahmed Wadi***	ID 162 - Influence of liquid water on thermal and acoustical properties of hemp concretes ***Etienne Gourlay***
16h10	Break	

Wednesday 21st

Session n°2 Chair *Room*	C2. Hygrothermal properties P. Daman *5*	D2. Life cycle assessment G. Habert *7*	E2. Energetic behavior O. Jenck *9*
15h10	ID 293 - Experimental assessment of hygrothermal properties of clay – sunflower (*Helianthus Annuus*) and rape straw (*Brassica Napus*) bio-composites ***Yoann Brouard***	ID 186 - Carbon footprint of bamboo particles, rice husk and wood shavings-cement composites ***Lucas Rosse Caldas***	ID 153 - Energy evaluation of rammed earth walls and impact of solar gains on long term in-situ measurements ***L. Soudani***
15h30	ID 149 - The effect of cellulose nanocrystal (CNC) on the water permeability of early aged oil well cement ***Mohammad Reza Dousti***	ID 289 - Multi-objective optimization of bio-based thermal insulation materials in building modeling ***Alba Torres Rivas***	ID 176 - Measurement of latent heat released by large scale samples of porous biobased insulation materials ***F. Mc Gregor***
15h50	ID 168 - Assessment of a precats hemp concrete hygrothermal properties ***Billy Seng***	ID 241 - Lime and hemp concrete LCA: a dynamic approach of GHG emissions and capture ***Thibaut Lecompte***	ID 146 - Contribution to the study of concrete segregation (characterization using ultrasonic pulse velocity) ***Abdelouahab Grini***
16h10	Break		

Wednesday 21st

Plenary session - Discrete modeling of building materials

F. Radjai
LMGC, CNRS - University of Montpellier, France; MSE, MIT Energy Initiative, Massachusetts Institute of Technology, USA; franck.radjai@umontpellier.fr

Economic actors in building and materials are increasingly concerned with the challenge of adapting resources, performance and pollution of building materials to new social and environmental demands. If "splitting" matter into small pieces and components has driven technology and science since the Stone Age, we now begin to face the need for "building" matter and materials from an available range of components. Along this route, the architecture is an inspiring source for tailoring the composition and texture of materials to create new building units. This science of "archi-texture" has always been a major research challenge, but hardly driven by the need of preserving the environment at a global scale. It happens that the internal workings of materials that control their emerging properties and functionalities at the engineering scale involve to various degrees all physical scales down to the atomic scale. The cement concrete is a prototypical illustration of those workings with strength properties that are controlled as much by the volume fractions of its components as by the granular texture of its backbone and chemical interactions during the hydration process. Many new materials are designed and produced from such a multi-scale packing process of "grains" and "cements" of different mineral natures. This "additive" manufacture may involve processes such as grinding, mixing, wet agglomeration, sintering, melting, mechanical actions and molding. However, the engineering practice is mostly based on phenomenological approach. The "discrete modeling" is, in my view, the new paradigm for a fundamental understanding of such processes. The term "discrete" was introduced in the field of granular materials, where mainly frictional contact interactions between macroscopic particles are considered, as opposed to "continuum" modeling based on discretization of governing equations. But it can legitimately be extended to all particle-based modeling approaches, covering molecular dynamics, lattice-type discretization and material point methods. The rationale behind discrete modeling is to design particles and their interactions to reproduce expected physical behavior. As compared to pure discretization of governing equations (conservation laws, constitutive relations, thermodynamic couplings…), as in finite element methods, the discrete approach generally takes care of conservation laws by construction and accounts for the emerging behavior as resulting from a numerical homogenization process. Discrete methods are versatile and can be used to predict not only the behavior under applied forcing but also the microstructure, local stress transmission and kinematic fields at different scales. This approach can be used with conceptual particles, i.e. particles that represent building blocks that carry required properties, but also with real particles of different shapes, sizes and interactions. Obviously, the discrete approach can handle a finite number of degrees of freedom depending on the computational power and memory. For this reason, it should be employed with the greatest caution as an investigation tool for the prediction of collective behaviors of particles and in combination with the continuum approach. I will briefly introduce the discrete methods and illustrate several examples of their applications for a better understand of the origins of shear strength in packings composed of a variety of different particle shapes, the microstructure of unsaturated soils, the transmission of stresses in cemented granular materials and shale rocks, the hardness of wheat endosperm, and highly polydisperse materials.

A2. Mechanical performances

ID 285 - **Drying shrinkage and strength of GGBS and sawdust incorporated OPC mortar**

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Sawdust is an excellent bio based waste material that can be effectively used in replacing fine aggregate in concrete or mortar. The available research output related to sawdust incorporated concrete is limited however valuable information on strength of sawdust concrete can be found. This study aimed to obtain compressive strength, flexural strength and drying shrinkage of GGBS and sawdust incorporated mortar. The maximum size of fine aggregate and sawdust is of 2.36 mm and 1.18 mm, respectively. Mortar specimens were prepared by changing the amount of GGBS as 0%, 50% and 70%. The amount of sawdust

was kept constant. The measured density of sawdust mortar shows a significant difference with initial assumed density which questions the accuracy initial mix design of sawdust mortar. Water absorption in sawdust mortar at 7 days is approximately 14% with a slight decrease at 28 days. The highest compressive strength is achieved when the amount of GGBS replacement is 50%. The addition of extra alkali has not shown additional strength development or visible chemical reaction with sawdust. Drying shrinkage at 28 days in all specimens is in the range of 200-400 µm; however it is increasing up to 1000 µm at 90 days. The results show that the sawdust replacement in mortar could still maintain some structural properties however the effect on durability properties should be investigated further.

ID 198 - Characterization of mechanical properties of hemp-clay composite and hemp stabilized clay composite

Brahim Mazhoud[1], Florence Collet[2], Sylvie Pretot[2], Christophe Lanos[2]
[1]INSA Rennes, France; [2]Université de Rennes 1, France; brahim.mazhoud@univ-rennes1.fr

In order to reduce the environmental impact of hemp concrete, this study aims to replace lime binder by natural clay binder and to measure the effect on mechanical properties. Two kinds of materials are investigated. They are made with the same hemp shiv (Biofibat□, CAVAC France)) and differ from their type of binder. One is made of clay binder and the other of stabilized clay binder (stabilized with 5% of natural cement and 5% of lime based binder (Thermo□)).The two kinds of materials are manufactured with four Hemp/Binder ratios (from 0.4to 0.75) chosen regarding traditional mix proportioning of hemp concrete used for floor, wall and roof. The density of the composite materials varies with this ratio. The hemp clay composite (HCC) shows lower density than hemp stabilized clay composite (HSCC) (between 373 kg/m^3 and 510 kg/m^3 for HCC and between 410 kg/m^3 and 578 kg/m^3 for HSCC). The experimental results show that all formulations have ductile behavior. Note that formulations with highest H/B ratio show steadily increasing strength with deformation. Since the force–displacement curve does not show a peak in this case. The hemp stabilized clay composite has better mechanical properties than hemp clay composite. It is shown that mechanical properties depend strongly on the Hemp/Binder ratio. The compressive strength ranges from 0.021 to 0.026 MPa for hemp clay composite and from 0.026 to 0.059 MPa for hemp stabilized clay composite. The tensile strength ranges from 0.39 to 0.48 MPa for hemp clay composite and from 0.47 to 0.68 MPa for hemp stabilized clay composite. The results show that the mechanical performance of produced composite materials meets the requirements of the intended use. This study will be completed with an hygrothermal behavior analysis to promote this new type of environmentally friendly bio-based building material for buildings insulation.

ID 278 - Experimental study of lateral load resistance of unclassified timber walls

Husam Ahmed Wadi, Sofiane Amziane, Mustapha Taazount
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Wood is one of the most widely used in many countries as a building material for low and high level constructions because this material has an excellent physical properties and environmentally friendly. Timber walls are the structural system that designed for purpose of resisting lateral loads and transmitting these forces to the foundations in a ductile behaviour. According to the European Standard, the timber shear wall consists of timber frame and sheathing board connected together by fasteners. The sheathing board can be from different materials such as Gypsum, Plywood, Fibre board and OSB. This paper is mainly focusing on mechanical behaviour of unclassified timber – framed walls under lateral loading (i.e. seismic and wind loads). Unclassified wooden planks have been used to construct the wall unit with three layers for each wall in cross perpendicular planks form. In this research an experimental study of timber framed walls were investigated in order to determine the lateral load resistance. Diagonal struts, under tension and compression positions, have been used at cross plank walls to investigate the differences in horizontal resistance. This work is compared to Board (OSB) panels. An analytical modelling for the cross plank wall has been studied to investigate the behaviour of this wall under the horizontal forces. Comparison between the theoretical modelling and the experimental results have been made for cross plank walls, on the other hand, a comparison between the Eurocode 5 calculations and experimental studies has been studied for OSB panels. Based on the data and results obtained from the experimental tests, this study confirms on the first hand that the cross plank walls without diagonal strut have around double horizontal strength than (OSB) panels and on the other hand the diagonal strut significantly increases the lateral load resistance of cross plank walls in particular under compression position.

Wednesday 21st

B2. Acoustic characterization

ID 219 - **Acoustic properties of lime-hemp concrete produced by compression molding**

Edith-Roland Fotsing[1], Thibaut Lecompte[2], Annie Ross[1]
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In order to efficiently contribute to sustainable development, building materials must take into account the energy consumption, the environmental impact of the chosen materials as well as the indoor comfort of the construction. As a mixture of plant based aggregates and a hydraulic aerated binder, lime/hemp concrete has proven to have interesting mechanical, hygrothermal and thermal isolation properties. Additionally, the porous nature of the hemp particles gives lime/hemp concrete the potential of being used as an acoustic absorption material for domestic buildings. For these reasons, lime/hemp concrete has been increasingly used as an environmentally friendly construction material. The present study deals with the characterization of the acoustic properties of lime/hemp concrete manufactured by compression molding. In particular, for a given lime/hemp mass ratio, the influence of particle orientation (anisotropy), density, thickness, as well as a density gradient was investigated. While the anisotropy does not affect the acoustic properties, the gradient of density tends to broaden the frequency range for the acoustic absorption. The impedance and the absorption coefficient of the material with a density gradient were evaluated and compared using a model based on the multilayered fluid approach. Finally, it was also shown that the absorption coefficient of lime/hemp concrete can be effectively modelled using the multi scale approach given the double scale porosity of the hemp particles. The outcome of the present study will help establishing the molding parameters to obtain concrete with interesting properties, both for mechanical and acoustical purposes.

ID 207 - **Evaluating and understanding the acoustical properties of biobased materials**

Philippe Glé[1], Emmanuel Gourdon[2]
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Biobased (porous) materials are key solutions to deal with current environmental issues in buildings and other fields. Many studies cover the topic of their performances today, but these studies do not systematically account for the specificities of biobased materials. The goal of this presentation is to make a global review of the acoustical properties of these new materials, and to present an adapted demarch to characterise, model and optimise their performances. Two kind of biobased materials will be principally discussed, fibrous (wools) and granular (loose and concrete). The fibers/particles can come from hemp as well as flax, sunflower, colza, miscanthus, and kenaf cultures. In all cases, the final materials (wool, board, concrete...) present specificities in comparison with conventional ones. These include a mulitscale porosity, a wide distribution of fiber/grain size, a strong anisotropy and an hygroscopic behavior. These specificities have to be taken into consideration, during the characterisation process but also during

B2. Acoustic characterization

the modelling step by choosing a suitable model in agreement with the effective microstructural dissipation. This presentation will start with a global review covering last decade publications on the topic, where the different kinds of materials will be classified and analysed. Then, general guidelines will be proposed on the basis of previous works to handle with these materials acoustical properties. Finally, the different possible ways to optimize these properties will be highlighted with various examples of application.

ID 162 - **Influence of liquid water on thermal and acoustical properties of hemp concretes**

Etienne Gourlay[1], Geoffrey Pot[2], Philippe Glé[1], Emmanuel Gourdon[3], Arnaud Feeser[1]
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Hemp concrete is a composite material obtained by mixing together a binder and hemp particles (the non-fibrous fraction of the hemp stem called “shiv” or “hurd”). It enables to build sustainable buildings (for new buildings construction or existing buildings renovation) as filling material of a load-bearing structure and to store approximately 35 kg of CO_2 per square meter of wall built with a thickness of 30 cm over 100 years. This material is characterized by a very porous microstructure (porosity greater than 70% for a “Wall” mixture) leading to physical performances at the same time unique and technically very interesting. Hemp concretes are characterized by their lightness (dry density of about 400 kg/m^3 for a “Wall” mixture) but also by an important mechanical ductility (compressive strain higher than 10% is possible). Moreover, they can reach good levels of thermal insulation and sound absorption (dry thermal conductivity of 80 mW/(m.K) and acoustic absorption higher than 80%) and have a strong hygroscopic behavior. In recent years, many studies have measured the influence of water vapor on the durability of thermal and acoustical properties of hemp concretes. However, the influence of liquid water has never been studied. In this paper, the evolution of thermal and acoustical performances of hemp concretes when liquid water is added was measured. Then, the experimental results were compared with analytical models to predict the evolution of thermal and acoustical properties of hemp concretes exposed to liquid water.

C2. Hygrothermal properties

ID 293 - **Experimental assessment of hygrothermal properties of clay – sunflower (*Helianthus Annuus*) and rape straw (*Brassica Napus*) bio-composites**

Yoann Brouard[1], Naima Belayachi[2], Mohan Ranganathan[1], Dashnor Hoxha[2], Stephane Meo[1]
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The purpose of this investigation is the experimental characterization of the hygric and thermal properties of four clay/vegetable aggregates mixes. In order to evaluate the hygrothermal behavior of these biocomposites based on different aggregates, moisture buffer value, sorption/desorption isotherm and thermal conductivity were investigated here. This work is carried out in the framework of the BIOCOMP project which aims to develop those locally produced biocomposites to be used as building’s interior insulating plasters. This, to offer refurbishment solutions for vernacular buildings in Touraine, Center of France. Sunflower stem and rape straw are considered as agricultural byproducts aggregates whereas local clay is used as binder. In this study, the samples were prepared with the following vegetables: rape straw, sunflower bark, sunflower pith and a mix of sunflower pith and bark. For a same binder:aggregates and water;binder weight ratio, we obtained samples with different densities and different properties depending on the aggregates. The hygric and thermal performances of those mixtures make them competitive in comparison to hemp-lime concrete and could therefore offer a wider variety of refurbishment solutions having a low embodied energy.

ID 149 - **The effect of cellulose nanocrystal (CNC) on the water permeability of early aged oil well cement**

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Well cementing is one of the most crucial steps in any well completion. Oil well cement paste is employed to fill the annulus between the casing string and the well bore. However, since the cementing process

takes place at the end of the drilling process, a satisfying and acceptable job may not be performed. While pumped inside the annular space between the casing and the ground formation, oil well cement has to isolate and protect the casing from any kind of damage. Therefore, the durability of the cement paste utilized in oil well cementing is extremely important to any individual involved. In the absence of aggregates, concerns arise both in the short term performance including fluid loss (filtration) and flowability, and in the long term as in shrinkage cracking and permeability of the cementitious slurry. Nowadays, various commercial additives are produced and employed in oil well cements to address the durability issues. In this study, cellulose nanocrystal (CNC) is utilized as a replenishable and non-toxic additive to oil well cement paste, in order to reduce the permeability of the system. Early aged hollow cylindrical specimens dosed with CNC were tested by using a pressurized permeability cell. Furthermore, the water permeability of the specimens were evaluated using Darcy's law for laminar flow. The results were then compared to the water permeability of neat oil well cement paste with no additive.

ID 168 - **Assessment of a precats hemp concrete hygrothermal properties**

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The present work aims at measuring the hygrothermal properties of a precast hemp concrete. When available, different experimental techniques were applied to explore the impact of the chosen protocol on the results. The specific heat capacity is assessed through differential scanning calorimetry (DSC) and effusivity measurements. The impact of moisture content on this parameter is then evaluated. The thermal conductivity is the second thermal studied property. The guarded hot plate method is used for measuring the dry thermal conductivity of precast hemp concrete at different temperatures. These results are completed with hot wire measurements which are also used for assessing the impact of water content on the thermal conductivity. As far as the hygric properties are concerned, we measured the sorption isotherm using both the saturated salt solutions method and the dynamic vapour sorption (DVS). Finally, the water vapour permeability was measured applying the dry cup method, a focus was made on the influence of the interface vapour resistance at the top of the cup.

D2. Life cycle assessment

ID 186 – **Carbon footprint of bamboo particles, rice husk and wood shavings-cement composites**

Lucas Rosse Caldas[1], M'hamed Yassin Rajiv da Gloria[1], Daniele Oliveira Justo Santos[1], Vanessa Maria Andreola[1], Marco Pepe[2], Romildo Dias Toledo Filho[1]
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The growing concentration of greenhouse gases (GHGs) increases more and more the heat trapping in the atmosphere, leading to a rise in global temperatures, also known as global warming. For these reasons, in the last decade, in order to counteract this phenomenon, a special effort has been made also in the construction sector by developing new sustainable building materials and, moreover, one of the most promising solution is the possible employment of forest waste as a raw material for the production of cement based construction systems. In this context, the present study aims at evaluating the carbon footprint production of bio-based cementitious composites (BBCCs) produced with three types of bio-aggregates: bamboo particles, rice husk and wood shavings. The carbon footprint of the BBCCs was calculated using a life cycle perspective following the guidelines of ISO 14067:2014. The biogenic carbon was quantified based on the carbon content of the bio-based materials, considering the landfill process in the end-of-life stage. System boundaries were established according to a cradle-to-gate approach, based on data collection (in literature and laboratory) regarding the raw material production, transportation and processing. The results were presented in three ways: (1) the amount of CO_2e emissions to produce 1m³ of composite (kgCO_2e/m³), (2) the amount of CO_2e emissions considering the 1MPa strength of the composite (kgCO_2e/m³.MPa), (3) the amount of CO_2e emissions to produce 1m³ with 1MPa strength considering the dry density of the composite (MPa.CO_2e index./dry density). The wood shavings composite was the most carbon efficient, while the rice husk showed to be the lowest efficient. Finally, the main criteria for a low carbon footprint bio-based material were described in order to help designers.

D2. Life cycle assessment

ID 289 – **Multi-objective optimization of bio-based thermal insulation materials in building modeling**

Alba Torres Rivas[1], Mariana Palumbo[2], Laureano Jiménez Esteller[1], Assed Naked Haddad[3], Dieter Boer[1]
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Energy efficiency in buildings is a key objective of nowadays policies. To achieve this goal, three main strategies can be implemented: modify users' behavior, implement passive measures and implement active measures. Those strategies and the reduction of the energy consumption during the use phase imply both, an initial investment and an environmental impact. The equilibrium between them and their efficiency benefits should be evaluated in advance to any intervention. The present work implements a passive measure, an insulation layer in the building envelope, as example. Mathematical programming and multi-objective optimization methodology is used on a building-like cubicle, which energy consumption has been evaluated combining EneryPlus and JEPlus software. Polyurethane and seven commercial and experimental bio-based thermal insulation materials are compared. The cost and the environmental impact associated to each solution have been quantified using the life cycle assessment methodology. The results show that bio-based materials can reduce the cost and the environmental impact compared to conventional insulating materials. In our study, hemp offered the most balanced solution, achieving a reduction of 14% and 36% in cost and environmental impact respectively for the climate in Lleida.

ID 241 - **Lime and hemp concrete LCA: a dynamic approach of GHG emissions and capture**

Thibaut Lecompte[1], Annie Levasseur[2], Dominique Maxime[2]
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Lime and hemp concretes are well known and studied as low-impact materials for building. During the last two decades, a few studies have shown their interest in terms of environmental impacts such as embodied energy, air pollution or GHG emissions. On the other hand, new carbon footprint calculation methods were proposed to assess the value of temporarily storing carbon in long-lived products such as building structures and insulation. This is an important aspect for bio-based materials, as they capture and store carbon. From an environmental point of view, it would be of interest that GHG emissions due to crop, manufacturing, transportation, construction, demolition and end-of-life could be compensated by the beneficial effect of a long-term carbon storage. The principal aim of this study is to evaluate the long-term effect on climate change of using LHC in building. GHG emissions and uptakes were assessed using a dynamic life cycle assessment approach for several scenarios: 1) different crop practices for hemp (in the French context, surveys of 2014-2015 provided by the Cetiom), and 2) different mixes and formulations for the LHC, i.e. two classical ones: sprayed and cast LHC, and a more innovative one: compacted LHC. Whatever the formulation, a woody structural frame is necessary, composed of local timber wood (less than 100km from construction site). To take into account the emission dynamics, plants growing (trees and hemp) and carbonation of lime into the walls were considered. Optimum scenarios were compared, by taking the minimum and maximum impact for each mixes (different crop practices, transportation of lime and hemp, end-of-life scenarios). As a result, some LHC with high hemp/lime ratio, low-impact crop practices, and a proper end-of-life scenario could be a solution to stock carbon and keep a positive effect on climate, even on the long-term (more than 100 years).

E2. Energetic behavior

ID 153 - Energy evaluation of rammed earth walls and impact of solar gains on long term in-situ measurements

L. Soudani, A. Fabbri, M. Woloszyn, A-C. Grillet, J-C. Morel
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Available throughout the world and used in construction for thousand years, earthen materials are well known for their interesting properties. The later relies on their abilities to buffer moisture and improve indoor air quality while keeping the internal temperature relatively stable. In Rhône-Alpes, France, the rammed earth technic is the most spread and consists in compacting layers of earth, one by one, within a

framework. The objective of the paper is to highlight the living comfort provided by non-insulated rammed earth walls, for different orientations, from in-situ measurements over more than two years. The study points out the important role of solar irradiance on the thermal balance of the house, and thus the importance of a good architecture.

ID 176 - Measurement of latent heat released by large scale samples of porous biobased insulation materials

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This study provides experimental quantification of the phase change of water in porous biobased composites on a large scale sample. A double climatic chamber was used to expose biobased insulation materials of 0.9 m x 0.9 m to various climatic conditions with a focus on the impact of vapour pressure variation. Heat flux, temperature and relative humidity variations were monitored within and on the surface of the material. The energy released due to the enthalpy of adsorption and condensation could be measured through the heat flux meters installed on each side of the wall and the variation of the internal temperature of the material. The test presented in this study consisted at increasing relative humidity in the climatic chambers on both sides of the wall from 50% RH to 80% RH. Adsorption and condensation process within the hygroscopic porous material can be measured by the heat flow meters. This heat flux is responsible for an increase of the surface temperature of the material. Considering these results the implication of the generated heat flux and specifically the variation of surface temperature on the indoor thermal comfort is discussed.

ID 146 – Contribution to the study of concrete segregation

A. Grini, A. Benouiss
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Segregation is the unintentional separation of the fresh components of concrete or mortar, which can be caused by bad proportioning, insufficient mixing, or excessive vibration. Segregation can have negative impacts on the mechanical, transport, and durability properties of the cured product. While there are several tests that can measure concrete at the beginning of hardening or in its fully hardened state, these are generally based on the percentage of the coarse aggregates between the top and the bottom of the samples. Consequently, the results do not provide a full description of the state of the material or a basis for its long-term performance. To begin to address this deficit, this paper investigates the potential of using ultrasonic pulse velocity (UPV) as a means to identify and characterize segregation in traditional and self-compacting concrete (SCC), which is known to be particularly prone to segregation, because of its high fluidity level.

CIDECO

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GESTION DU PATRIMOINE ET DES INFRASTRUCTURES

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Directeur général de CIDECO

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Wednesday 21st

Session n°3 Chair *Room*	A3. Durability S. Marceau *1*	B3. Innovative materials A. Fantili *2*
16h40	ID 144 - Development of a thermocompression manufacturing process adapted to flax-epoxy laminated composites ***Thomas Cadu***	ID 187 - Superabsorbent biopolymers for mitigating autogenous shrinkage in cement-based materials ***Anastasia Aday***
17h00	ID 200 - Durability of natural fibers reinforced calcium aluminate cement matrices ***Lucia Fernandez***	ID 269 - Utilization of mine tailings as partial cement replacement ***N.M. Sigvardsen***
17h20	ID 228 - Experimental study about the effect of adding fan palm fibers on the durability of the concrete when exposed to severe chemical environments ***Meheddene Mohammad Machaka***	ID 139 - Supersulfated cements based on volcanic raw materials ***Karina Luna-Cabrera***
17h40	ID 203 - A multi-scale analysis of hemp-based insulation materials ***Guillaume Delannoy***	ID 188 - Lime-hemp concrete (LHC) enhancement using magnesium based binders ***Maris Sinka***

Wednesday 21st

Session C3 is dedicated to Dr Mike Lawrence from University of Bath for all his achievements in the bio-based building materials field.

Session n°3 Chair *Room*	C3. Hygrothermal properties L. Van Schoors *5*	D3. Valorisation of domestic wastes R. Nima *7*	E3. Innovative materials B. Caicedo *9*
16h40	ID 214 - Hygrothermal behaviour of a hemp concrete block, experimental and numerical results ***Mounir Asli***	ID 270 - Reuse of polyethylene fibres from discarded fishing nets as reinforcement in gypsym-based materials ***Ida Maria Gieysztor Bertelsen***	ID 231 - Eco-bricks: A construction time capsule for inorganic materials with potential of being recycled ***Federico C. Antico***
17h00	ID 154 - Assessment of hygrothermal behaviour of an experimental timber-framed house ***Sihem Guernouti***	ID 261 - Utilisation of cement kiln dust for the activation of fly ash in low strength applications ***Hoda Beltagui***	ID 235 - Physical-mechanical characterization of fiber-reinforced mortar incorporating pig hair ***Gerardo A. Letelier***
17h20	ID 205 - Hygric and thermal characterization of composites coupling recycled or raw bio-based materials and starch ***Sylvie Prétot***	ID 223 - Multicriteria analysis of hemp particles' impact on physical and thermo-mechanical performances of hemp concrete ***César Niyigena***	ID 284 - Contribution to the study of the influence of polycarboxylate superplasticizers on the fluidity of cement paste ***Alya Harichane***
17h40	ID 156 - Totora used as thermal insulation: properties and potential ***Leyda Aza***		

Wednesday 21st

A3. Durability

ID 144 - **Development of a thermocompression manufacturing process adapted to flax-epoxy laminated composites**

Thomas Cadu[1,2], Laetitia Van Schoors[2], Olivier Sicot[1], Sandrine Moscardelli[2], Loic Divet[2], Emmanuel Keita[2], Stéphane Fontaine[1]

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This study focuses on the optimization of a manufacturing process adapted to flax fibers based composites in which the components are controlled. Twelve plies unidirectional composites samples were prepared by thermocompression using unidirectional flax fibers and fluid epoxy-amine resin. Temperature cycle was chosen to limit fibers degradation during fabrication. Different parameters have been studied to evaluate their influence on the mechanical properties of composites. 0° tensile specimens were tested at a 1mm/min crosshead speed. Measures were performed with a 50mm gauge length extensometer and a 100kN load cell. Furthermore, DSC analyses were performed to obtain information about cross-linking of the matrix. Properties are in accordance with the literature. Using 3bar pressure, fiber content was found to be around 46% (in volume). The density of the composite was measured using Archimedes' principle and was valued to 1.28 when the fibers' one was 1.45.

ID 200 - **Durability of natural fibers reinforced calcium aluminate cement matrices**

Lucia Fernandez, Josep Claramunt, Monica Ardanuy

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In this paper an alternative study is carried out by using calcium aluminate cement intead of Portland cement whose objective is to obtain mixtures having improved durability of vegetable fibers. Calcium aluminate cement is constituted by monocalcium aluminate as major phase and hydration products are hydrated calcium aluminate, of hexagonal or cubic nature with aluminum hydroxides depending on the hydration temperature and absence of portlandite that has been recognized as responsible for the low durability of the natural fibers. The durability of calcium aluminate cement composites reinforced with nano- and micro- cellulose fibers is evaluated. Two hydration temperatures were studied, 20 and 40ºC. The nanocelluloses were in the form of nanofibrillated cellulose -obtained from sisal pulp by the application of

a high intensity refining process- or as nanocrystals –obtained from acid hydrolysis of pure microcellulose-. The microfibers were in the form of sisal or cotton linters´ pulp. 40x10x160 mm prismatic specimens of calcium aluminate cement with 2% by weight of two types of nanofiber and two types of microfiber were manufacturated in order to analyse their mechanical properties. The results indicate that the mortar improves the mechanical behavior of the material at 28 days, with flexural strength increases of 20% over the Portland cement mortars. Regarding durability, calcium aluminate cement specimens behaves similar to Portland cement in relation to the adhesion mode, but keeps intact the mechanical properties of the fibers. SEM photographs of fracture section show the surface of the fibers with very little degradation compared to those of Portland specimens. These results indicate that the absence of calcium hydroxide of the matrix prevents the chemical degradation of cellulose.

ID 228 - **Experimental study about the effect of adding fan palm fibers on the durability of the concrete when exposed to severe chemical environments**

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Adding fiber to concrete became a common practice to improve its durability, but for environmental purposes, it is preferable to use natural fibers instead of synthetic ones. In addition, using fibers prepared from tree waste that improve many concrete physical and mechanical properties is environmentally effective and costly preferable. Natural fibers extracted from fan palm trees that were cured chemically when used in concrete may result in improvement in concrete physical and mechanical properties. On the other hand, one of the major challenges that faces the commercial use of natural fibers in concrete is its durability. For that reason, an experimental program was conducted to study the durability of the fibers by measuring the volume stability of the concrete when exposed to different severe environments. The investigation recorded the length change of concrete bars with 1% fiber volume fraction and without fibers when exposed to sea water, solution with 2% $MgSO_4$, 2% Na_2SO_4 & NaOH for a period of one year. The study was performed on three grades of concrete 30,40, and 60 MPa to monitor the effect of concrete grade on the results. From the results, it can be concluded that adding fan palm fibers to concrete significantly improve its resistance when exposed to $MgSO_4$, Na_2SO_4 & NaOH environment. After one year of exposure to harsh environment, the expansion of concrete bars for length change measurements was recorded for the concrete with fibers and compared to that of control mixture (without fibers). The reduction was between 20% to 40% for different concrete grades and solutions. In summary, fan palm fibers maintain their durability in concrete when exposed to severe chemical exposures. In addition, adding natural fibers to concrete decreases concrete bar expansion thus improves its durability.

ID 203 - **A multi-scale analysis of hemp-based insulation materials**

Guillaume Delannoy[1], Sandrine Marceau[1], Marielle Gueguen-Minerbe[1], Dinarzed Diafi[1], Issam Nour[1], Philippe Glé[2], Etienne Gourlay[2], Sofiane Amziane[3], Fabienne Farcas[1]
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The market of building insulation materials based on natural and renewable resources grows increasingly since 80's. This comes amid reduction objectives of the environmental and energetic impact of buildings. Hemp concrete is one of these materials. It is based on hemp shiv and a mineral binder mixed with water. Its high porosity (> 70%) provides thermal insulation, hygrothermal and acoustic properties, as well as lightness. In this study, two "wall" formulations are manufactured with one type of hemp shiv and two commercial binders: a prompt natural cement and a formulated binder based on lime. 90 days of curing (65% RH – 20°C) ensure the hardening of the material. Then a multi-scale analysis of hemp concretes properties is conducted. First the hydration and carbonation of binders is investigated. The porosity of the material is also measured. Then the relation between these properties and the functional properties of hemp-concretes (thermal, hygrothermal, acoustical and mechanical) is established and discussed. This work is the first step of a larger study on the hemp concrete durability. After hardening, specimens have been placed in natural and accelerated aging conditions. The evolution of the properties presented in this paper will be investigated in an upcoming study.

Wednesday 21st

B3. Innovative materials

ID 187 - **Superabsorbent biopolymers for mitigating autogenous shrinkage in cement-based materials**

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Availability of water plays an essential role in the hydration of ordinary portland cement. At low water-to-cement (w/c) ratios, for example, hydration processes can rapidly deplete water. The increased demand for more water exacerbates surface tension-induced stresses within fine capillary pores, which causes shrinkage of the cement paste. This phenomenon, termed autogenous shrinkage, is often prevented with sufficient curing, namely by keeping the surface of the concrete continuously wet. However, such conventional curing methods are not sufficient for ultra-high-performance concretes, which are produced with very low w/c ratios. In these applications, autogenous shrinkage is mitigated via the use of internal curing approaches, either by inclusion of prewetted lightweight aggregates or superabsorbent polymers (SAPs). SAPs are ultra-hydrophilic polymer networks capable of absorbing 100,000% of their dry weight in water. A variety of acrylic-based monomers are typically employed in the preparation of SAPs, as are a number of aggressive solvents and time- and energy-intensive polymerizations. This paper presents recent experimental efforts on synthesizing and characterizing superabsorbent polymers from biorenewable resources and principles of green chemistry. In this work, the chemical synthesis and physical swelling of superabsorbent biopolymers are investigated in (a) water and (b) synthetic concrete pore solutions. Results demonstrate that biobased SAPs that absorb in excess of 20,000% their weight in water can be synthesized using ambient-condition polymerizations and green solvents, thus offering a potential biobased solution to successfully mitigating autogenous shrinkage in ordinary portland cement paste and mortars.

ID 269 - Utilization of mine tailings as partial cement replacement

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Depositing mine tailings entail major economic costs and negative environmental impacts. Thus finding an alternative to depositing is of interest. This study focused on the use of mine tailings as partial cement replacement, thereby preventing depositing the mine tailings. At the same time, such use would reduce the CO_2 emission related to the production of cement. Mine tailings from two different mines Zinkgruvan (Sweden) and Nalunaq (Greenland) were both tested as 5 and 10 % cement replacement. All mortar specimens with mine tailings had lower compressive strength compared to a reference specimen at 7, 14 and 28 days of curing. Both mine tailings showed contributions to the pozzolanic activity. This tendency was more profound for Zinkgruvan. No evidence of either mine tailing containing minerals acting as nucleation sites was, however, seen. The specimens containing mine tailings were compared to a specimen containing a 10 % replacement of cement with coal fly ash, commonly used in Denmark. The compressive strength of specimens containing mine tailings exceeded the compressive strength of the specimen containing coal fly ash, indicating further the amorphous content of volcanic decent contained in the mine tailings to contribute to the pozzolanic activity and thus increase the compressive strength. Mine tailings have a high content of toxic chemical elements, but no significant amount of chemical elements was seen leaching from neither the pure mine tailings nor the mortar specimens containing mine tailings. Overall, the results show that these mine tailings have potential as a mineral admixture for substitution of cement in concrete.

B3. Innovative materials

ID 139 - **Supersulfated cements based on volcanic raw materials**

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Considering that the production of Portland cement (PC) accounts for more than 8% of the anthropogenic CO_2 and that that such figure will increase in the future, sustainable development would benefit from the development of alternative binders of low energy demand and low CO_2 emissions. Various raw materials, natural or byproducts, have been studied for the development of various green families of binders, such as the partially replaced PC or the alkali activated cements; one interesting alternative are the supersulphated cements, which are commonly formulated using about 80% blast furnace slag and a source calcium sulphate and an alkaline activator that is commonly clinker of PC. This investigation verses on the formulation and characterization of a novel supersulphated-type binder based on volcanic pumice, activated with PC and 2 sources of calcium sulfate, PC). The experimental design was based on the Taguchi method, which considered factors such as the variation of the composition of the binder and curing temperatures within the range of 20 to 60°C; a selection of 4 factors using 2 and 3 levels led to an orthogonal array L18 (21x33). After 28 days, the optimal composition showed 20.2MPa for a paste made of 70%pumice-20%PC-10%Anhydrite with an initial curing at 60°C for 22h at 60°C then at 20°C. In general, the pastes showed a trend towards higher strengths and also showed hydraulic behavior. The strength was favored by the initial curing at higher temperature and higher PC contents. The microstructures showed that the pumice reacted although not very actively. Thermal analysis evidenced the formation of C-S-H, ettringite and gypsum. Some of mortars were cured under water and showed strength stability, which further evidenced the formation of C-S-H. A general discussion on the effects of the experimental parameters on strength and reaction products will be discussed.

ID 188 - **Lime-hemp concrete (LHC) enhancement using magnesium based binders**

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Although at the Paris Climate Conference 2015 all the major CO_2 emitting countries agreed on reducing the carbon dioxide emissions, it is still on the rise. As building material industry is one of the largest producers of CO_2, it should find solutions how to limit the emissions, one of which is to find new materials which have negative CO_2 balance, as well as low thermal conductivity for energy saving during its lifespan. A lime-hemp concrete (LHC) can be one of such solutions as it has negative CO_2 emissions balance(around 80kg/m^2) and low thermal conductivity(0,07-0,09 W/m.K). Even though LHC has been gaining popularity and recognition over the past years, it is still not used enough to give significant contribution to lowering the global CO_2 emissions. One of the reasons is that the material has low mechanical strength and can be mostly used only with supportive load bearing frame that makes it appropriate mostly for low rise buildings. This can be improved by enhancing the binder strength either by supplementing or substituting it with magnesium based binders. Made mostly of calcined MgO and magnesium salt compounds, these binders show greater early and overall compressive strength compared to hydraulic lime binders used in LHC. Magnesium based binders also are not affected by the organic water soluble constituents that reacts with calcium ions in hydraulic lime thus delaying or preventing hydratation process. Several different MgO binders are being tested in this research, which are tested for mechanical strength, thermal conductivity, water absorption, shrinkage and microbiological stability to understand how the addition of magnesium binders affects important LHC properties. The results obtained suggest that the MgO binders are viable alternative for the hydraulic lime as their superior compressive strength allow for lower amount of binder to be added which enhances the thermal conductivity.

C3. Hygrothermal properties

ID 214 - **Hygrothermal behaviour of a hemp concrete block, experimental and numerical results**

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Any material or construction product operates in an environment wherein temperature and humidity

have random behavior. In this environment and despite these variations, the material must be able to ensure a sustainable manner, the functions for which it was implemented (thermal, mechanical, acoustic ...). Hygrothermal behaviour of a material is related to its nature (components) and its porosity, therefore, all materials do not have the same characteristics with respect to the hygrometric variations, thermal and hydric. The work carried out underline actually the difficulty of the subject studied. Indeed, the physical transfer of water vapour and liquid water within a material is complex. However, it should assess the behaviour of a material with respect to these phenomena in order to optimize its use. In our methodology to treat the coupled heat and mass transfer within bio-based material, we proceed as follow: we implement a mathematical model taking into account thermal and hygric transfer phenomenon first. Then a series of measurements is done in order to get thermal, hygroscopic and physical properties of the studied material, which are used as input parameters for the mathematical modelling. For the purpose of the model validation, experimental facility is carried out, which consist of instrumented a sample and a wall made of hemp concrete (manufactured block), the boundary conditions and within the materials the temperature and relative humidity are assessed and logged by thermocouples and humidity sensor's. Various ambient conditions (controlled and random) are used in order to examine the hygrothermal behaviour of hemp concrete and observe its response firstly, and asses the mathematical model's ability to predict the hygrothermal behaviour on the other hand. The experimental and the simulated data are compared, analysed and discussed, a general conclusions and statistics are provided in order to enhance the present work.

ID 154 - **Assessment of hygrothermal behaviour of an experimental timber-framed house**

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The context of very high energy efficiency and the development of bio-materials bring new questions about heat and mass transfer and their impact on the actual energy performance, comfort, health and the risk of components degradation. This is particularly true for old buildings built before 1948 with very hygroscopic materials. If the humidity has an effect on the thermal performance of the building envelope, it influences also the interaction between the building and it constituent materials and the air indoor quality, and therefore, the effects on the comfort and occupant health (risk of mould growth). Indeed, the preservation of envelope components is based on a hygrothermal balance of parts that constitute it. Any intervention on buildings that shifts this balance can cause disorders. In particular, a thermal insulation of walls when it's poorly designed or badly implemented can generate condensation in walls or on their surfaces and cause structural pathologies. To provide some answers to these questions, an experimental timber-framed cell was constructed. It allows the study of both global and detailed hygrothermal behaviour at both wall and building scales. It is a timber-framed and cob cell with two zones (dry and wet) of about 16m² with two mechanical systems of ventilation (double-flow ventilation and Positive Input Ventilation). The aim of this paper is to present the hygrothermal behaviour of this cell without and with insulation under several boundaries condition. The experimental cell and its monitoring set-up are presented. Four configurations are studied: Case1: without both ventilation and insulation; Case2: with a mechanical ventilation and without insulation; Case3: without ventilation and with internal thermal insulation; Case4: with both mechanical ventilation and internal thermal insulation. The indicators of hygrothermal comfort and of risks of pathologies related to humidity are calculated and compared for the studied configurations.

ID 205 - **Hygric and thermal characterization of composites coupling recycled or raw bio-based materials and starch**

Lydie Thieblesson[1,2], Florence Collet[1], Sylvie Pretot[1], Christophe Lanos[1], Honoré Kouakou[2]
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This project is realized in partnership between the Laboratory of civil engineering and mechanical engineering (Rennes, France) and the Laboratory of Geomaterials (Abidjan, Ivory Coast). The objectives of this work are to develop and characterize composites used for ceilings or interior walls and realized with eco-materials. The considered raw materials are issued from local recycled or bio-based materials: recycled paper (granules or cellulose wadding) and wood fiber. Aggregates or fibers are bonded with starch. This study investigates several water to starch ratio for each kind of load. For paper granules, two

loads to binder ratio are also considered. After hardening and drying, the density of produced composites ranges from 300 to 600 kg/m^3. These composites are then characterized on thermal and hygric point of view. The thermal conductivity is measured with transient state method (Hot Wire) after weight stabilization of composites at dry point at 20°C. For the same load to binder ratio, the thermal conductivity is about 0.10 W/(m.K) for wood-fiber composites, 0.11 W/(m.K) for paper granules composites and 0.15 W/(m.K) for cellulose wadding composites. For higher load to binder ratio, the thermal conductivity increases to 0.16 W/(m.K) for paper granules composites. The thermal conductivity is not only dependant on density. The characterization of hygric behavior is based on the measurement of moisture buffer value (MBV) following the NORDTEST protocol. This value characterizes the ability of materials to moderate variations of ambient relative humidity. It is thus a good indicator of its effect on hygric comfort of users. The developed composites are all classified as very good or excellent hygric regulator according to the Nordtest classification. For the same load to binder ratio, cellulose wadding composites show the lower MBV, while wood fiber and paper granules composites have similar MBV value. The MBV increases with granules paper content.

ID 156 - **Totora used as thermal insulation: properties and potential**

Leyda Aza[1], Mariana Palumbo[1], Ana Lacasta[2]
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An important part of the environmental impact generated by human activity is the extraction and use of construction materials; confronting this issue creates the need to develop new alternatives and to experience change towards sustainable construction. The use of natural resources gives significant opportunity to reduce the negative effects of the material production, especially in petroleum derivate products. These effects are the emission of greenhouse gasses (CO_2), the consumption of energy and the emission of toxic substances in the environment, among others. A problem that occurs across the Andean high zone in Peru is the mortality rate from respiratory diseases due to extreme temperature variations every year; its cause is not the direct impact of extreme weather conditions (snow, hail or frost), but mainly the low conditions of thermal comfort inside the houses. This project aims to address the development of a new thermal insulator from a plant source, the Totora (Schoenoplectus tatora), an aquatic plant present in the Titicaca Lake - Perú. This has been analyzed for its thermal behavior and various tests have been made which revealed its characteristics and its potential for the use in buildings. In this project two different processes of panels have been elaborated, using the entire cane and the crushed cane. The values obtained in the tests of thermic conductivity resulted between (λ): 0,046 a 0,058 W/mK which proof its insulating potential. Furthermore, the material shows other advantages: the raw material used is renewable and the necessary resources for its fabrication come from natural origin. All this indicates that this insulation can be an efficient alternative and is of low environmental impact. This material could be used to improve the conditions of thermal comfort inside the houses around the Andean high zone in Peru, where they are faced with extreme variations of temperature.

ID 270 - **Reuse of polyethylene fibres from discarded fishing nets as reinforcement in gypsym-based materials**

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In this study, the potential of reusing plastic fibres from discarded waste fishing nets of polyethylene (PE) as fibre reinforcement in gypsum-based building materials is investigated. The fishing nets were not reprocessed, but simply washed and cut to monofilament fibres by an industrial operation. The fibre length was ranging from 1 mm (pulp) to 65 mm, and the diameter from 0.25 mm to 0.35 mm. Gypsum-based prisms and cylinders were cast with these fibres (fibre addition of 0.5 – 2.00 wt%). Mechanical properties such as compressive strength and three-point bending strength of fibre reinforced cylinders and prisms were determined by laboratory-scale testing. A decrease in first-crack strength of the prisms was observed. However, the addition of waste PE fibres resulted in improved post-crack behaviour.

Wednesday 21st

ID 261 - **Utilisation of cement kiln dust for the activation of fly ash in low strength applications**
Hoda Beltagui[1,2], Mohammed Sonebi[1], Kevin Maguire[2], Su Taylor[1]
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Cement kiln dust (CKD) is a by-product of the cement manufacturing process, the composition of which can vary widely. Recent years of using alternative fuels have resulted in higher chloride and alkali contents within CKDs; as such, this limits the applications in which CKDs can be utilised. Due to the high alkalinity of CKDs, they can potentially be utilised in the activation of pulverized fuel ash (PFA) for low strength un-reinforced applications. The potential reactivity of a CKD can be estimated from its composition; mainly, that which contains higher free-lime content will be more reactive than that containing higher unreactive calcium carbonate content. This study focuses on the hydration kinetics and mechanical properties of a CKD with 29.5% free lime blended in various proportions with PFA and Portland cement. Paste samples using a water-to-binder ratio of 0.35 were cast in 40 x 40 x 160 mm moulds, and the resulting compressive strengths measured at 28 and 56 days. The hydration products at 56 days were investigated by X-ray diffraction and thermogravimetric analysis. The results show that the CKD, containing high free-lime content, has the potential to activate PFA and provide sufficient mechanical properties for low strength applications.

ID 223 - **Multicriteria analysis of hemp particles' impact on physical and thermo-mechanical performances of hemp concrete**
César Niyigena, Sofiane Amziane, Alaa Chateauneuf
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The hemp concrete is considered as an eco-material due to its environmental assets. Its constituents are mainly the hemp particles, binder and water to which admixtures are added eventually. The quality of hemp particles is very sensitive to the nature of soil where it is produced and also to its transformation process, which results in properties variability of hemp particles. And this may be a barrier to development of hemp concrete industry. The herein study aims to evaluate scientifically the impact of this variability on hemp concrete performances. This study is carried out through two main steps: (1) predicting the impact of hemp particles on the hemp concrete, (2) hemp concrete characterization. In the first step, a multicriteria analysis (particle size distributions, etc.) highlights the significant variability of the hemp particles and allowed to classify them into three groups. In the second step, the tests carried out on hemp concrete resulted in low, medium and high mechanical performances as predicted. A factor close to 10 is observed between the minimum and maximum compressive strengths. However, the density and the thermal conductivity are of low variability. The performed analysis show that the interaction between the hemp particles and the binder is likely to contribute to the mechanical response.

E3. Other innovative materials

ID 231 - Eco-bricks: A construction time capsule for inorganic materials with potential of being recycled
Federico C. Antico, María J. Wiener, Gerardo Araya-Letelier, José I. Borgoño, Daniel Durán, Rodrigo Ortúzar
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Eco-bricks, PET (Polyethylene terephthalate) bottles filled with inorganic waste materials, had become an accessible and low cost material for community development projects in regions where industrial recycling might not be yet available. Eco-brick proponents consider it is a valid recycling way to reduce waste disposal volumes. However, both the PET bottles used as shell of the Eco-bricks as well as the mixed materials used as filler, could be better recycled if more sophisticated separating and valuing process were implemented. Moreover, the Eco-brick performance as construction material depends highly on the materials used to manufacture them and the skills of the workforce involved. There is limited data available on the Eco-bricks characteristics and performance from past and current construction projects. This research work suggests making Eco-bricks filled with a single inorganic waste type. This way, it would work as a time capsule with potential of recovering the filling material when other ways of adding value would be available within those communities that currently have no better recycling options. In order to validate the proposed Eco-bricks, we performed an experimental characterization to address density, filler

volume, radial shrinkage and elastic modulus. Results are compared with reference properties of similar products currently available in the construction market.

ID 235 - **Physical-mechanical characterization of fiber-reinforced mortar incorporating pig hair**

Gerardo Araya Letelier[1], Federico Carlos Antico[1], Joaquín Urzua[2], Rodrigo Bravo[3]
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The use of natural fibers in mortar could improve its mechanical and durability properties, while mitigate the impact of disposing a biological waste like animal hair. Waste valorization has been incorporated in the construction industry over the last decades, and the use of waste to improve properties of cement-based materials has been attracting research attention worldwide. Cement-based materials tensile strength and fracture toughness are poor; and combined with drying shrinkage at early ages, increases the potential of cracking onset and propagation. To control cracking development, steel, glass and synthetic fibers, have been successfully used. In contrast, the use of waste-valorized fibers as reinforcement to cement-based materials has undergone limited research. This investigation addresses the physical-mechanical characterization of pig hair, which is a waste produced by the food-industry worldwide, and fiber-reinforced mortars incorporating pig hair. This composite material is intended to reduce the environmental impacts by valuing waste materials in construction applications while improving mechanical and durability properties. Characterization of pig hair showed absorption values around 100%, aspect ratios ranging from 150 to 350 and tensile strength average value of 90 MPa. Mortar compressive, flexural and impact strength, bulk density, porosity, dynamic modulus of elasticity, age of cracking and induced tensile stress characteristics tests were conducted in mortar specimens with 0, 2, 4 and 8 kg of pig-hair per m^3 of mortar. The results showed that impact strength, indicator of toughness, can increase up to five times when compared to plain mortar. At the same time, the age of cracking is also improved when pig hair is incorporated. Moreover, the compressive and flexural strengths, bulk density, porosity and the dynamic modulus of elasticity of fiber-reinforced mortar, with the aforementioned pig-hair content, are not significantly affected.

ID 284 - Contribution to the study of the influence of polycarboxylate superplasticizers on the fluidity of cement paste

Alya Harichane, A. Benmounah
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The new concrete often incorporates several organic which interact with the various constituents of the cements and cause some problems of hardness and workability. In the present study, Portland cement was used to make cement paste with two types of superplasticizer; SP1; SP2; based on polycarboxylic ether. Marsh cone test was adopted to check the combined effects of the following factors on the fluidity namely the type, the molecular weight and the dosage of the superplasticizer. The results of this work show that SP1 presents a high fluidity with high molecular weight.

Thursday 22nd

	Chair: M. Sonebi – *Amphitheatre*
8h30	Plenary 4 – ***M. Lawrence*** – Innovations in the use of bio-based aggregates in construction
9h15	Plenary 5 – ***B. Caicedo*** – Advances in laboratory characterization of geomaterials
10h	Coffee break

Session n°4 Chair *Room*	A4. Innovative admixtures L. Ottosen *2*	B4. Earth materials T. Lecompte *5*
10h30	ID 300 - Effectiveness of starch ethers as rheology modifying admixture for cement based systems ***Eleni Vasiliou***	ID 108 - Using alginate biopolymer to enhance the mechanical properties of earth-based materials ***Fakkhredine Menasria***
10h50	ID 190 - Incidence of the water-soluble compounds contained into lavender and sunflower bioaggregates on the hardening process of mineral binders ***Vincent Sabathier***	ID 109 - Mechanical enhancement of casted and compacted earth-based materials by sand, flax fiber and flax fabric ***Fakhreddine Menasria***
11h10	ID 131 - Effect of guar gum derivatives combined with superplasticizers on properties of Portland cement-pastes ***Alexandre Govin***	ID 151 - An exploratory study on earthen material stabilized by geopolymer ***Quoc-Bao Bui***
11h30	ID 273 - Effect of viscosity modifying agent on the mechanical and transport properties of hemp and rapeseed straw concrete ***Joseph Sheridan***	ID 299 - Light earth performances for thermal insulation: application to earth-hemp ***Théo Vinceslas***
11h50	ID 259 - Beneficial reuse of refinery spent caustic solution in alkali-activated infrastructure materials ***Sarah Lynn Williams***	ID 170 - Fire behavior of bio-based earth products for sustainable buildings ***Aurélie Laborel-Préneron***
12h10	ID 305 - Properties of a new binder based on lime ***R.V. Ratiarisoa***	ID 201 - Mechanical and thermal performances of cob materials ***Tuan Anh Phung***

Thursday 22nd

Session n°4	C4. Valorisation of agricultural by-products	D4. Reinforcement of soil
Chair	P. De Bruiijn	J. Otani
Room	*7*	*9*
10h30	ID 123 - Cementitious material with bio-based recycled agricultural waste ***Bhooma Nepal***	ID 117 - Binder systems for the stabilization of contaminated soils- A review ***T.G. Bikoko***
10h50	ID 140 - A review of the use of sugarcane bagasse ash with a high LOI content to produce sustainable cement composites ***Marco Antonio Maldonado-García***	ID 294 - influence of fines on strength and shrinkage of soil concrete ***Duc Chinh Ngo***
11h10	ID 292 - Elaboration and physical characterization of an agro-material based on sugar beet pulp and potato starch. ***Hamze Karaky***	ID 281 - Life cycle assessment of retaining wall backfilled with shredded rubber tire-sand mixture ***H. Djadouni***
11h30	ID 125 - New particleboards based on agricultural byproducts: physicochemical properties with different binders ***Angelique Mahieu***	ID 243 - Mechanical properties of volcanic scoria for using as lightweight aggregate concrete ***W. H. Juimo***
11h50	ID 221 - Chemical and hygrothermal characterization of agro-resources' by-product as a possible raw building material ***Florence Collet***	ID 208 - Improving the characteristics of a clay soil for use in road projects ***F. Bouteldja***
12h10		ID 307 – Experimental and numerical study of embankment reinforced by geosynthetics under hydraulic stresses ***Aurélie Talon***
12h30	Lunch	

Thursday 22nd

Plenary session - Innovations in the use of bio-based aggregates in construction

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Bio-based materials have been used in construction for millennia. Of course, timber used as a structural material goes back to pre-historic times, but other materials have also been used extensively. Amongst the wide variety of materials, one can cite roofing materials such as turf, reeds, grasses, leaves and shingles, and walling materials such as woven reeds and grasses, wattle and daub, and clay bricks such as adobe. Indeed adobe is probably the earliest form of construction material which makes use of bio-aggregate, since it uses straw as a reinforcement within a clay-based matrix. Sophistication of construction techniques gave rise to smooth surface finishes such as lime and clay plasters, which tend to have low tensile strength. The inclusion of reinforcement in the form of animal hair or plant fibres became commonplace in order to resolve this technical problem. Until the Industrial Revolution, construction professionals tended to incorporate bio-based materials within their designs without giving it a second thought. The advent of mass production of bricks, concrete and steel, brought with it a change in mind-set, with the predominant paradigm being strength and durability. This tended to exclude bio-based materials as they were seen as having inconsistent properties and being subject to decay. There followed a hiatus in their use for well over 100 years. The 1973 oil crisis, followed swiftly by a second crisis in 1979 produced a long term impact on global politics and the global economy, ultimately leading to the creation of the 1992 United Nations Framework Convention on Climate Change and the 1997 Kyoto Protocol. These events encouraged scientists and practitioners to reconsider the use of less energy intensive materials, including bio-based materials. Since construction is responsible for 1/3 of global carbonemissions, it has become an imperative to develop solutions to lessen the impact of this sector. Amongst other approaches, the use of bio-aggregates within a cementitious matrix has been the subject of research since the 1980s. Early research included the use of wood chips to replace mineral aggregates in concrete to produce lighter, better insulating concrete. Not all developments came out of the laboratory however, and one particularly fruitful strand was developed by a practitioner in France, Charles Rasetti, who renovated la Maison de la Turque, a timber-framed building in Nogent-sur-Seine, using lime and an aggregate made from the woody core of the hemp plant. The good thermal performance of this building stimulated other practitioners to follow suit, and the technical problems, primarily linked to the high water demand of the aggregate, stimulated academic research. The field of bio-based aggregates has extended to cover a wide range of different plant sources, including hemp, flax, rape, wheat and rice straw, maize and other agricultural feed-stocks. This paper explores the way in which this research has developed, both to overcome technical problems associated with the aggregates and also to develop innovative materials and solutions. Exciting developments covered by this paper include the outcome of three EU funded projects HEMPSEC, ECO-SEE and ISOBIO, as well as insights from ongoing research at the University of Bath.

Plenary session - Advances in laboratory characterization of geomaterials

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This paper presents some innovative apparatus for the characterization of geomaterials based on advanced techniques. These devices were conceived to study the properties of saturated soils, compacted materials, unbound granular materials, argillaceous rocks and asphalt mixtures. Also, some of these equipment permits to assess the effect of the environmental variables in the behavior of geomaterials. Also, regarding the performance of geotechnical works, the paper presents a methodology to study the effect of the soil variability in the comportment of these works. The paper is divided into three sections: (i) advanced characterization of homogeneous materials, including compacted soils, unbound granular materials, asphalt materials and rocks; (ii) characterization of the interaction between soils and atmosphere, and (iii) laboratory characterization of the effect of soil variability. Regarding compacted materials, the paper presents two devices that allow studying soil compaction with a precise characterization of the mechanical and hydraulic paths during compaction. For unbound granular materials the paper presents a large-scale hollow cylinder apparatus that permits to study the effect of stress rotation on the mechanical properties of the material and the evolution of permanent strains. As well, for asphalt mixtures, the paper presents a hollow cylinder apparatus conceived to study the effect of stress rotation and environmental conditions (temperature and relative humidity) on the behavior of

these mixtures. Regarding argillaceous rocks, the paper presents a new device to study the strength of these particular rocks depending on the environmental conditions, particularly the effect of the relative humidity or the suction level. The behavior of geomaterials under variable climatic conditions involves several coupled thermodynamic relationships most of them expressed in a nonlinear form. For this reason, the study of the effect of environmental variables on the behavior of geomaterials requires simulating the interaction of each climatic variable separately and eventually reproducing extreme climates. For this purpose, the paper presents a climatic chamber specifically conceived to study the interaction between geomaterials and the atmosphere. One of the main characteristics of natural geomaterials is their variability in their properties. In the last ten years, the effect of this variability on the performance of geotechnical works has been studied using numerical models. However, these models require assuming particular constitutive models that usually oversimplifies the material behavior. This paper presents an example of an experimental methodology to study the effect of soil variability. Regarding this subject the paper presents first a methodology for reproducing soils with controlled variability, then the paper presents some results of the behavior of shallow foundations over variable soils.

A4. Innovative admixtures

ID 300 - **Effectiveness of starch ethers as rheology modifying admixture for cement based systems**

Eleni Vasiliou[1], Wolfram Schmidt[1], Maria Stefanidou[2], Hans-Carsten Kühne[1], Andreas Rogge[1]
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Polysaccharides are important rheology modifying admixtures in the building material sector. The use of starch is becoming increasingly important, due to many ecological and economic advantages. In the construction sector, starch ethers are being used as thickeners and as means to increase the yield stress. The starch ethers that are available on the market differ in their behaviour, which can vary greatly depending upon the binder system and mortar composition, e.g. solid volume content, binder type, additional admixtures. In view of the limited knowledge about the influence of molecular modifications associated with cement based systems, some fundamental rheological functional mechanisms were analysed in this study. The differently modified starch ethers used were derived from potatoes. They varied in their charges and degrees of hydroxypropylation. The setting and the flow behaviour of all examined variations of starch ethers were analysed in cement pastes. In order to illustrate the effects of the starch ethers that were used, the water-cement ratio (w/c) was held constant in all the mixtures [Schmidt 2012]. The results indicated significant differences in setting and flow behaviour.

ID 190 - **Incidence of the water-soluble compounds contained into lavender and sunflower bioaggregates on the hardening process of mineral binders**

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In building materials, the incorporation of plant aggregates into mineral matrix is an eco-friendly promising solution as these biobased building materials can answer to the new requirements for thermal and hydric performances. Nevertheless, plant aggregates can have deleterious effects on the hardening mechanisms of cementitious binders. The aim of this study is to evaluate the incidence of the water-soluble compounds contained into bioaggregates on the hardening process of three mineral binders (CEMI 52.5 cement, lime-based commercial binder, metakaolin-based pozzolanic binder). Two vegetal by-products were selected (lavender and sunflower) because of their large availability in France. Distilled lavender straw is the by-product of the steam distillation process applied to lavender plant. Sunflower bark aggregates were obtained by the fractionation of the entire stalk. The chemical composition of the two bioaggregates was first studied by the ADF-NDF method of Van Soest and Wine. The cellulose, hemicellulose and lignin contents were thus determined. In addition, the water-soluble components were estimated by measuring the mass loss of the bioaggregates after 1 h in boiling water. Large differences were highlighted concerning the content in water-soluble compounds of the two plant aggregates. Model

pastes were then elaborated with a solution obtained by soaking lavender or sunflower powder in demineralized water for 48 h and then filtering. The properties of the pastes were compared with those of neat pastes of the three mineral binders. The setting time (followed by isothermal calorimetry), the hardening mechanisms (followed by X-ray diffraction and thermogravimetric analysis) and the mechanical performance of the different binders were clearly and variously influenced by the lavender and the sunflower extractives at early ages. The level of the impact on the cementitious and pozzolanic binders can be correlated with the content in water-soluble compounds. Concerning the lime-based binder, it was less impacted by the water-soluble species.

ID 131 - **Effect of guar gum derivatives combined with superplasticizers on properties of Portland cement-pastes**

Alexandre Govin[1], Wolfram Schmidt[2], Marie-Claude Bartholin[1], Philippe Grosseau[1]
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Chemical admixtures allow to the create a huge variety of fresh and hardened state properties in cementitious materials. In the case of self-compacting concrete, plasticizers or superplasticizers are introduced with the aim to decrease the yield stress and the viscosity of the materials. However, in order to prevent segregation and bleeding, and to improve the water retention of cement-based system, stabilizing agents or viscosity agents are often introduced in addition. Among these admixtures, polysaccharides are most commonly used. The aim of this study lies in providing an understanding of competitive or synergetic effects induced by the combination of stabilizing agents based on hydroxypropyl guar (HPG) and superplasticizers on properties of cement pastes. Two polycarboxylate superplasticizers (PCE), exhibiting different charge densities, and three different HPGs (different amount of hydroxypropyl groups and hydrophobically modified) were studied. It could be found that the combination of HPG with PCE superplasticizer strongly modifies the rheological behavior of cement pastes. Despite the presence of HPG, the viscosity of the pastes strongly decreased with increasing dosage of PCE. The viscosity was even close to the viscosity of a cement paste with PCE only. However, the use of HPG in combination with PCE allows maintaining a significant yield stress in the cement paste compared to PCE alone. The increase in the charge density of the PCE seemed to amplify the drop of the viscosity and to reduce the gain on the yield stress induced by HPG. The results also highlight a delay in the setting-time of the cement paste by adding HPG and PCE. The delay induced by HPGs is significantly lower than that generated by PCEs. However, the combination of the both kind of admixtures lead to a slightly shorter setting compared to the PCE alone.

ID 273 - **Effect of viscosity modifying agent on the mechanical and transport properties of hemp and rapeseed straw concrete**

Joseph Sheridan[1], Mohammed Sonebi[1], Sue Taylor[1], Sofiane Amziane[2]
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In recent decades sustainability, carbon footprint and pollution have become significant issues on a global scale. It is widely recognised that the carbon footprint of the construction industry is something that can be reduced and this has led to sustainable materials being used more and more widely to meet emissions targets. Two of these materials are hemp concrete and rapeseed-straw concrete which are bio-composites made of the bio-aggregate, water and a lime binder; in this investigation Vicat prompt natural cement (PNC). The addition of a viscosity modifying agent (VMA) is studied for its effect on the mechanical and water transport properties. It was found that the use of a VMA was very effective at countering the two biggest weaknesses of bio-aggregates as it reduced the capillarity absorption of the concrete significantly and also greatly increased the compressive strength and modulus of elasticity of the material.

ID 259 - **Beneficial reuse of refinery spent caustic solution in alkali-activated infrastructure materials**

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A4. Innovative admixtures

Over the past half-century, societal awareness of the detrimental effects of environmental pollution resulting from human activity has increased, and this newfound awakening has given an impetus to research on sustainable construction materials. In particular, research efforts are aimed at developing greener alternatives to portland cement, production of which accounts for 5-10% of global anthropogenic carbon dioxide emissions. Alkali-activated materials, which can be produced almost entirely from industrial by-products, have received considerable interest in this regard. Previous studies on waste-based alkali-activated materials have focused almost exclusively on reuse of solid waste (e.g., fly ash, slag); however, these materials require a highly-concentrated solution of alkali-hydroxides and/or alkali-silicates (typically 8-14M) to catalyze geopolymerization. Although the environmental and economic impact associated with consumption of excessive amounts of virgin alkalis and safety concerns associated with handling highly-alkaline solutions could substantially threaten the scalability of these materials, little work has been aimed at addressing these issues. In the current study, aqueous alkaline waste from industrial caustic washing of hydrocarbons (deemed unsuitable for regeneration or purification processes due to the presence of contaminants) was used as an activating solution for alkali-activated concrete in place of a conventional virgin alkali solution. The impact of impurities in the waste activator, particularly organics and heavy metals, on mechanical properties, mineralogy, and thermal stability of the materials was assessed. Results suggested that this toxic waste stream, for which there are currently few options available for beneficial reuse, could be used to produce alkali-activated materials in place of virgin alkalis without compromising performance.

ID 305 - Properties of a new binder based on lime

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The purpose of this research is to investigate the physical, chemical and mechanical properties of an eco-friendly binder based on hydrated lime $Ca(OH)_2$ and optimized sugarcane bagasse ash (SCBA). It is a lightweight binder performed with low energy consumption and low CO_2 emission materials. The SCBA was sieved and the physical and chemical effects of removing the coarse particles present in this ash were analyzed. Experimental investigations revealed that sieving procedure improves both finesse and reactivity of the raw SCBA and increases by 30 % the compressive strength of the binder based on SCBA and $Ca(OH)_2$.

B4. Earth materials

ID 108 - Using alginate biopolymer to enhance the mechanical properties of earth-based materials

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Natural materials such as sugars or biopolymers are commonly used to stabilize and enhance the mechanical properties of earth-based building materials. Among them, brown seaweed polymers such as alginate have been recently used to improve the design of earth building materials. With its molecular structure, alginate can form a strong network with clay particles that strengthens the material. We here focus on the mix-design of earth based materials using a model earth-based materials based on a mix of sand and kaolinite and a real raw earth materials. We have worked on two forming processes of the material: casting and static compaction. The fluidity of the castable earth has been reached by using disperant to reduce the apparent yield stress of the material. The gelification of the alginate has been advantageously used to shorten the demoulding time. For both forming processes, alginate has been shown to significantly increase the compressive strength of the earth-based material. Compressive strengths as high as 8 MPa has been obtained for alginate dosage of 4% (in mass). We have also highligthed that the key factors controlling the strength of the earth-based materials were the dry density and the alginate dosage.

ID 109 - **Mechanical enhancement of casted and compacted earth-based materials by sand, flax fiber and flax fabric**

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Earth-based materials are commonly reinforced with bio-based materials such as straw. In this study, we use high performance bio-based flax fibers and fabrics. The aim of this work is to find reinforcements that are able to improve the mechanical strengths and the ductility of an earth-based matrix. We also try to describe the reinforcement mechanisms are also described. In a first step, a kaolinite-based clay soil is mixed with sand to design a earth-based mortar with the highest density at the dry state. The sand dosage is found using mix-design method commonly used for concrete. We show that, at the same water content, the compressive strength at the dry state only depends on the dry density of the sample (and does not depend on forming process and use of dispersant). In a second strep, the mix-designs exhibiting the highest compressive strengths are chosen for both casting and compaction. Then, different amounts of fibers or fabrics are used to reinforce the studied mortars. We found that those reinforcements significantly increase the compressive strength of all tested samples. This result is very interesting because this is not always the case for other mineral matrix such as mortar and concrete. Such comparison with concrete helps us to understand the reinforcement mechanisms for fibers. This study shows that concrete mix-design methods are very helpful to increase the density at the dry state and the mechanical strength of earth-based materials. It also highlights that natural fibers and fabrics really enhance the mechanical behavior of earth even for compressive load.

ID 151 - **An exploratory study on earthen material stabilized by geopolymer**

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Earth is an ancient building material which has been recently the focus of scientific research because of the significant heritage of earthen buildings throughout the world. Moreover, a renaissance of earth constructions has been observed due to sustainable properties of this material. However, the disadvantage of earthen material is its low strength and its sensibility to the water content. To enhance the durability and the mechanical characteristics of earthen material, hydraulic binders are currently added (cement or lime). These hydraulic binders have high embodied energy and therefore increase the embodied energy of the stabilized earth material. In order to find an alternative binder, other elements are tested. This paper presents an exploratory study which uses furnace slag as a stabilisant for earthen material. Indeed, furnace slag is an industrial waste and their recycling is positive for the environment impact. The mixture of furnace slag and other adjuvants can create geopolymer in the material. The present study investigates the geopolymer effects on two types of earthen material: rammed-earth and soil-geopolymer-concrete (more water). The results show that geopolymer should be more adapted for soil-concrete than for rammed-earth. Indeed, RE specimens stabilized by geopolymer did not present a significant improvement of compressive strength comparing to the unstabilized RE specimens. Soil-geopolymer-concrete specimens had double compressive strength comparing to unstabilised soil-concrete specimens. However, the results obtained on specimens stabilized by geopolymer were still relatively low (<3 MPa). The geopolymer formula, the amount and type of clay present in the soil used could have influences on the results.

ID 299 - **Light earth performances for thermal insulation: application to earth-hemp**

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Lime-hemp is one of the most studied bio-based concrete for thermal insulation in R&D programs. Using other mixtures is possible by changing either the agricultural resource (straw, linen…) or the binder (type of lime, earth…). The replacement of lime based binder by an earth based binder can significantly reduce

the material embodied energy. The typical volumetric mass of a dry lime-hemp mixture is about 330 to 400 kg/m^3, which corresponds to a thermal conductivity about λ = 0,11 W.m^{-1}.K^{-1} (measured with hot plates, at 20°C and 50% relative humidity). The present study aims to evaluate the impacts of raw materials variability (earth and hemp) on hemp-earth performances. This work is performed in the framework of the ECO-TERRA R&D project in collaboration with four French research laboratories, short circuit hemp producers and craftsmen specialized in hemp and earth constructions. This first article is focused on the thermal conductivity, and mention preliminary results of the mechanical characterizations. The results are compared to lime-hemp materials.

ID 170 - **Fire behavior of bio-based earth products for sustainable buildings**

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Construction is one of the most polluting industrial sectors. For this reason, developing sustainable building materials is a world-wide interest. Earth as a building material is thus increasingly studied because of its low environmental impact and its ability to regulate indoor moisture and to improve occupant's comfort. Moreover, earth is a well-known non-combustible material. Recent studies deal with unfired earth bricks with plant aggregates incorporated to the earth matrix in order to lighten and improve various properties of the composite materials. However, these vegetal additions, of combustible nature, raise questions about the fire-behavior of the bio-based material. To our knowledge, the fire-behavior of this kind of materials has not been investigated in the literature. The present paper is a preliminary study about the fire reaction of earth bricks containing 0%, 3% and 6% weight content of barley straw or hemp shiv. A pyrolysis combustion flow calorimetry (PCFC) was done to predict the fire-behavior of the plant aggregates. Other tests were performed on the composites to determine their flammability, their thermal insulation and their mechanical strength after high temperature exposure. The following conclusions were reached. The PCFC test has shown a peak of heat release rate around 350°C for the plant aggregates, which corresponds to the degradation of the cellulose. The ignition-extinction test has proved that the material is still non-flammable even with vegetal additions. Thermal conductivity of the composites decreased when the experienced temperature increased (until 800°C) due to the higher porosity. The higher was the plant aggregates content, the more stable was the material to fire, meaning that the rise of temperature was delayed. Concerning mechanical performance, a strength drop was observed for composites around 400°C before a slight increase until 800°C thanks to the firing of the earth.

ID 201 - **Mechanical and thermal performances of cob materials**

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Soil is the first construction material used by man, widely available and low-energy consuming (Quagliarini *et al.* 2010). Indeed, about 30% of the current world population lives in earthen structures and, in developing countries, this rate rise to 50%, mostly rural (Houben *et al*. 2006). Moreover, earth-based materials allow an improved balance and control of thermal and acoustic indoor climate compared to industrial construction materials. However, most of earthen structures do not reach current requirements in terms of mechanical, thermal or architectural (Aymerich *et al*.2012). To respond to these requirements, a work at scientific and craftsman levels is necessary. Cob is an earth construction type wide-spread in Normandy. In this study, the mechanical behaviour cob is studied. Two different mixes currently used for cob constructions are firstly characterized. In traditional cob, straw is usually used. Straw can act as a thermal insulation material which allows creating pleasant indoor temperatures during unpleasant weather conditions (Bouhicha *et al*. 2005). Moreover, adding vegetable fibres can reduce materials thermal conductivity (Khedariet *et al*. 2005). An important characteristic for soil-based materials is water content. Usually, in building field, the required water content is the Proctor optimum. However, cob making is done traditionally with an higher water content in order to have a plastic mix. In this study, several earth-fibres formulations are developed by varying fibres' content as well as soil mixes. Mechanical and thermal behaviour of these materials is then determined and assessed according to fibres characteristics and content used and soil mixes characteristics. Results show that a higher fibre content lead to a weaker thermal conductivity of cob. This is due to a lower thermal conductivity of straw than soil and, also, to a smaller density of earth-fibre compared to earth only.

Thursday 22nd

C4. Valorisation of agricultural by-products

ID 123 - **Cemetitious material with bio-based recycled agricultural waste**

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Fibre reinforced concrete (FRC) is a significant achievement of modern construction. Fibres increase the ductile capacity of concrete by enabling it to undergo large deformation before failure. The tensile strength of concrete is increased whereas it would otherwise only be strong in compression. Although FRC has several advantages, the use of steel fibres means it only provides little contribution towards sustainability; therefore a shift towards new and innovative building materials is an urgent necessity. Most manmade fibres such as steel, synthetic or polymer are industrially manufactured and widely used. Such fibres are non-degradable, non-renewable and expensive. In this research, natural and innovative biodegradable fibres, their preparation and properties and interaction with concrete has been highlighted. Agricultural fibres viz. rice and wheat straw have been used. Rice and wheat is a staple food all over the world. After harvesting the commercial crop there remains huge quantities of straw produced. This straw has generally been seen as a waste product and disposed of, since it has a very few economic benefits. One of the major problems of today is the disposal of straw by open air burning and its impact on air pollution has been well documented. Thus the wastage of straw could be minimized if viability viable use for it can be found in the construction industry. Being a relatively new material, in this research, the chemical and physical properties of agricultural fibres have been studied. The influence of the addition of fibres in both fresh and hardened concrete has also been investigated. The findings present an interesting insight into agricultural fibres. Due to its easy availability and low-cost, straw has the potential to be a promising bio based construction material.

ID 140 - **A review of the use of sugarcane bagasse ash with a high LOI content to produce sustainable cement composites**

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In recent years, agricultural wastes have been employed as supplementary cementitious materials to produce sustainable cement composites. One of these wastes is the sugarcane bagasse ash (SCBA). The SCBA is available in large quantities in developing countries such as Brazil, India and Mexico, and its disposal is causing different environmental issues. The SCBA has high amounts of silicon, aluminum and iron oxides as major components. Several researchers report that the high amount of these oxides leads

to the improvement of the mechanical and microstructural properties of cementing composites containing the SCBA. On the other hand, a high amount of unburned carbon, commonly expressed by the loss on ignition (LOI), could be also present in the SCBA due the inefficient burning process of the bagasse in the boilers in sugar mills. It has been reported that this high LOI content in the SCBA change the water requirement and the rheological properties of cement binders. This might adversely affect the mechanical, microstructural and durability properties of hardened cement composites prepared with this material as well. In order to decrease the LOI content of the SCBA the combination of sieving, grinding and recalcination have been proposed; however, these methods are highly demanding in energy and generate additional contaminants. Sieving is the less energy demanding procedure and appears to be an interesting approach to post-treat the existing SCBA in open damps. Based on the above, this paper presents a review on the effects of the use of SCBA with a high LOI content to manufacture cement composites.

ID 292 - **Elaboration and physical characterization of an agro-material based on sugar beet pulp and potato starch.**

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In this paper, we describe a potential route to improve the value of the sugar beet pulp in the manufacture of ecological lignocellulosic insulation concrete panels. These panels could on the one hand, reduce the energy consumption of buildings and therefore the associated CO_2 emissions, and on the other hand, could ensure a good thermal, hygrothermal and acoustic insulation of buildings. This study aims to describe the making and characterization of a 100% vegetable agro-material based on the sugar beet pulp and potato starch. Chemical analysis of the beet pulp was carried out using the sequential extraction method with different solvents (cyclohexane, ethane, water, soda, HCl ...), to determine the pulp components, its behavior, and its chemical and physical characteristics. Mixtures of the sugar beet pulp, potato starch and saturated lime water were prepared for different starch / pulp mass ratios, then the drying method was optimized since pulps can withhold large quantities of water and lead to important deformations of the panels. For this reason several drying methods were investigated: freeze drying, drying under vacuum, ventilated or static oven at 40 °C, or drying in a controlled humidity chamber.

ID 125 - **New particleboards based on agricultural byproducts: physicochemical properties with different binders**

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Because the timber market is more and more competitive, the particleboard manufacturers are looked for new sources of vegetal raw material supply. In the same time, the use of healthier, safer and more environmentally friendly materials become a priority in the building sector. In this context, some agricultural byproducts as annual plant steams can be an interesting alternative. In fact these resources are abundant, renewable and safety raw material. Moreover their porous structure gives them interesting properties for building materials as lightness and thermal insulation capacity. In order to diversify raw material supply sources of a particleboard manufacturer, two agricultural byproducts have been studied: flax shives and sunflower bark. The particleboards are made at a laboratory scale by thermocompression of vegetal raw particles at two target densities: 350 or 500 kg/m^3. Flax shives and sunflower bark are tested alone or in blend of various proportions. The vegetal particles are bonded by different methods: with a classical synthetic binder (urea formaldehyde resin) at 20% w/w as used in commercial products; without addition of any binder. In that case water is sprayed on the vegetal particles before the forming process at 80% w/w. The lignocellulosic compounds contained in the agroresources can act as binders; with a biosourced binder, incorporate at different rate with the vegetal particles. The observed mechanical behavior (by bending test and internal bond) for the particleboards can be very different in function of the agroresource, the particle size and the binder used. The different materials are also compared by their thermal properties, behavior with water and resistance to fire. With optimization of the formulation and the process, both studied agroresources can be used in particleboards for applications as furniture or door panel and efficient 100% biosourced panels can be obtained.

Thursday 22nd

ID 221 - **Chemical and hygrothermal characterization of agro-resources' by-product as a possible raw building material**

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The ISOBIO project proposes an innovative strategy to bring bio-based construction materials into the mainstream. A key innovation consists of the use of bio-based aggregates from a local culture, with green binders for the production of ecofriendly composites. This work aims to combine existing technologies in order to develop bio-based panels with high insulating properties, low embodied energy, low embodied carbon and hydrothermally efficient. This study aims to value the agro-resources' by-products from flax, hemp, corn, rape and wheat, provided by one of the project partner, for find out new alternative materials that respond to sustainable development criteria. In the present work, the chemical characterization of agro-resources' by-product are studied by Van soest method and Phenol sulfuric method to determine the content of cellulose, hemicellulose, lignin and polysaccharides. Measurement of thermal conductivity and Moisture Buffer Value are also achieved in these raw materials to determine their hygrothermal properties at bulk density. Thermal Conductivity and MBV evolve according to the density whatever the agro- resources type. All these materials have different properties but they are all excellent hygric regulators. These results suggest that agro-resources's by-product may be used as a raw building material but not for the same types of use. In fact, some raw materials would be more suitable for thermal insulating products and others would be better suited to indoor facing panels.

D4. Reinforcement of soil

ID 117 - Binder systems for the stabilization of contaminated soils-A review

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The contamination of soil or soil pollution is a serious worldwide problem emanating from a wide range of industrial activities and other processes including mining operations, various chemical industries leading in many cases to a mixture of contaminants in the soil. Contaminated soils are of concern as, depending on the concentration and speciation of the contaminants present, they may lead to damage human health, plants, wild life, property or ecological systems in total. Some contaminants may also cause fire or explosion hazard or may be corrosive and damage building materials or services. In this context, comprehensive treatability studies would usually be needed in order to design the suitable binder(s) for the contaminated soil. The development of binders, which define the limits of operating variables that lead to acceptable performance, would be highly desirable in order to maximize the treatability studies and aid in developing a better understanding of the controlling parameters in stabilization treatments. Although there are many reviews on stabilization technology, very few have considered in depth binders thus single as well as binders of different combinations for the stabilization treatment of contaminated soils. Hence, this paper seeks to fill that gap in the literature by providing useful insight into some of the works done by previous researchers on binders to treat contaminated soils and helps to form a sound platform for further research on binders and additives to conventional stabilizers.

ID 294 – Influence of fines on strength and shrinkage of soil concrete

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Shrinkage cracking of soil concrete can cause the infiltration of water and impact their safety margin and life time. Thus, considering shrinkage of soil concrete is important. In this paper, an experimental investigation on autogenous and drying shrinkage of soil concrete is reported. The results show that the rate of shrinkage of soil concrete increased with the percentage of clayey soil. In addition, shrinkage results associated with the weight-loss measurements allow to describe the drying process.

D4. Reinforcement of soil

ID 281 - Life cycle assessment of retaining wall backfilled with shredded rubber tire-sand mixture

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The applications of scrap tire-derived recycled materials in civil engineering applications have been increasing largely because of their potential economic and environmental benefits. This paper presents a comparison between a traditional retaining wall backfilled with sand alone and an alternative retaining wall backfilled with sand-tire chips mixture. Life Cycle Assessments (LCA) for two construction methods were made. The cumulated energy demand (CED) and climate related CO_2 emission for primary, prefinished and finished products, their transport to the manufacturer and to the construction site as well as their installation are determined. The comparison showed a considerably smaller CED and CO_2 emission for sand-tire chips mixture solution.

ID 243 - Mechanical properties of volcanic scoria for using as lightweight aggregate concrete

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The concept of non-destructive testing (NDT) is to obtain material properties "in place" specimens without the destruction of the specimens and to do the structural health monitoring. Ultrasonic pulse velocity and Schmidt rebound hammer technique are some of the most popular non-destructive techniques used in the assessment of concrete properties. It is not possible with volcanic scoria from "Djoungo" quarry in littoral region of Cameroon to obtain normal size samples for mechanical destructive testing. This study investigates the physico-chemical, mineralogy properties, and mechanical properties by non-destructive testing methods of volcanic scoria of "Djoungo". The volcanic scoria were characterized using various instrumental techniques including X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD), Ultrasonic Pulse Velocity (UPV) and Schmidt Rebound Hammer (SRH). The Uniaxial Compressive Strength (UCS) was performed using empirical equations. For mechanical properties, fifteen rock samples were tested. The results are shows that, the UPV is around 1.36 to 2.88 km/s, the Schmidt rebound number is around 11 to 37, dynamic modulus and UCS are around 2.7 to 14 GPa and 0.24 to 26.34 MPa respectively.

ID 208 - Improving the characteristics of a clay soil for use in road projects

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In road infrastructure projects, it is often to find materials that have poor quality and unfavorable to reuse in embankment. This problem is amplified when it comes to reuse these materials in high embankments because of the pathologies related to this type of earthwork. To valorize these materials, the treatment with lime and/or hydraulic binders is considered as a solution for these natural materials. In this context, the objective of this work is to study the behavior of soft clay soil widely present in region of Guelma (Algeria) for its reuse in high road embankments. After geotechnical identification of this clay soil, mechanical performance tests are performed before and after treatment for different dosages and several curing times. These identification tests were pursued by oedometer and shear tests. The results obtained after treatments are satisfactory and show a significant improvement in mechanical properties. It is concluded that stabilization of clay with lime and cement mixture is cost-effective for construction of high embankments. Nevertheless the optimization of treatment should be performed and the requirements of implementation must be defined.

ID 307 - Experimental and numerical study of embankment reinforced by geosynthetics under hydraulic stresses

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At the world scale, soil erosion mechanism causes the major part of failure of hydraulic works. The presented study consists into understanding the behavior of embankment reinforced by alveolar geosynthetic under hydraulic stresses. This study contains two aspects: experimental study and numerical modeling. The experimental study aims at reproducing at reduced scale, into a permeability pond, a dyke that has been reinforced by geotextile in order to avoid an internal erosion. Then, we study its behaviour by applying a hydraulic head. We also study the variants of the solution implemented. The numerical study aims at highlighting the mechanisms that we experimentally observe.

Thursday 22nd

13h45	Chair: S. Amziane– *Amphitheatre* Plenary 6 – ***H. Savastano*** – Non-conventional inorganic-bonded fiber composite materials for housing and infrastructure applications
14h30	Chair: E. Toussaint – *Amphitheatre* Flash poster presentations ID 220 - Thermo-hydro-mechanical behavior of unsaturated compacted recycled asphalt aggregates ID 226 - Mechanical behaviour of wooden framework buildings with sprayed hemp concrete ID 230 - Feasibility of bamboo as primary structural material for telecommunication poles ID 240 - Numerical study on strengthening concrete beams reinforced by CFRP with near surface mounted technique ID 242 - Engineering properties of natural pozzolans of "Djoungo" (Cameroon) as supplementary cementitious materials for use in mortars and concretes ID 262 - Extruded earth bricks: mechanical and hygrothermal properties, an anisotropic behaviour ID 272 - Preparation and physico-mechanical characterization of gypsum-corn husk boards for construction purposes ID 286 - Experimental investigation of cement mortar reinforced with natural fibers ID 297 - PEPIN Bio ID 302 - Variability of hemp shives: study through IBIS and CHANVRISOL projects *+ Flash talks of industrial sponsors*

Session n°5 Chair *Room*	A5. Test methodology E. Toussaint *2*
15h40	ID 192 - Predicting freeze-thaw deterioration in wood-polymer composites ***Kristen M. Hess***
16h00	ID 216 - An assessment of the thermal storage capacity of hemp-lime using the Transient Performance Ratio method. ***Aidan Reilly***
16h20	ID 239 - Experimental characterization of cement composites using prism technique ***Rahma Messaoudi***
16h40	ID 280 - Correlations between pozzolanic evaluation methods, electrical conductivity and chemical shrinkage test ***Ur Iván Hernández-Toledo***

Thursday 22nd

Session n°5 Chair *Room*	B5. Case studies M. Lawrence *5*	C5. Valorisation of recycled minerals E. Gourlay *7*	D5. Granular materials N. Saiyouri *9*
15h40	ID 110 - Phase Change Material cement-lime mortars for thermal retrofitting of facades ***Cynthia Guardia***	ID 250 - Biochar as a carbon sequestering construction material in cementitous mortar ***Souradeep Gupta***	ID 175 - Granular media particle size distribution characterization by Pandoscopy® images analysis – Application to railway ballast ***S. Barbier***
16h00	ID 211 - Bio-based plaster for improved indoor air quality ***Daniel Maskell***	ID 276 - Biochar as an bond enhancement in fiber-reinforced mortar ***Harn Wei Kua***	ID 183 - Experimental investigation and modelling of the hydromechanical behavior of compacted earth ***A. Fabbri***
16h20	ID 213 - Monitoring and thermal characterization of flax shives for building insulation ***Emmanuel Antczak***	ID 277 - Biochar as carbon-sequestering wall plaster and wall pellets ***Harn Wei Kua***	ID 215 - Characterization of the mechanic behavior of lateritic soils ***Y. Gansonré***
16h40	ID 132 - Sustainable insulation of historical wooden and stone buildings with lime-hemp ***P.B. Strandberg-de Bruijn***	ID 283 - Preliminary investigation on use of sewage sludge ash as partly cement replacement in lightweight aggregate concrete ***Lisbeth M. Ottosen***	ID 222 - Compressibility models of agro-resources' by-product ***Christophe Lanos***

Thursday 22nd

Plenary session - Non-conventional inorganic-bonded fiber composite materials for housing and infrastructure applications

H. Savastano Jr.[1], V. Costa Correia[1], G. Mármol[1], S.F. Santos[2]*
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This presentation highlights the potential of agro-industry waste such as fibers, husks and ashes as valuable raw material for construction. Other so-called non-conventional materials, such as bamboo fibers, cellulose pulps and nanofibrillated cellulose are characterized and evaluated for reinforcing application after appropriate treatments for their stabilization and better adherence to inorganic matrices. Vegetable fibers in the macro, micro and nanometric scales have been used as reinforcement in cementitious materials. In the nanoscale, the nanofibrillated cellulose has the advantage of having good mechanical performance and high specific surface, which contributes to improve the adhesion between fiber and matrix. In hybrid reinforcement, with micro and nanofibers, nanofibrillated cellulose forms bonding with the matrix and acts as stress transfer bridges in the nano-cracking with corresponding strengthening of the cementitious composite. It is given special attention to clinker free inorganic binders for the matrix formulation. As alkali environment is been proved as the main factor for lignocellulosic fibers degradation, the reduction of the binder alkalinity becomes an approach to this problem. Calcium hydroxide, [$Ca(OH)_2$] from Portland cement hydration products, interacts with lignocellulosic tissues and modifies their polymerization degree and crystallinity as well as reacts to form new compounds. The reduction of $Ca(OH)_2$ has been satisfactory achieved by its interaction with pozzolanic materials. Pozzolan materials are mineral additions to Portland clinker that promote the reaction with $Ca(OH)_2$ to form denser structures: Calcium Silicate Hydrates gels (C-S-H). Another mechanism to reduce binder alkalinity is the replacement of Portland cement by other clinker-free binders. This is the case of magnesium based cement. In this type of cement only traces of calcium are present, so little interaction with fibers occurs. This binder matrix produces mainly magnesium hydroxide [$Mg(OH)_2$] and Magnesium Silicate Hydrates (M-S-H) as the main compounds. Technical properties of this cement for fiber-cement production are equal to Portland cement, significantly reducing fiber degradation over time. It was assessed the efficiency of two processes in laboratory scale: slurry dewatering and extrusion. These results suggest that extrusion process collaborates to organize better microstructure of the fiber cement than slurry dewatering process. However, it depends on rheological characteristics of the fresh cement paste. Besides, curing process also is important. Accelerated carbonation at early age of the fiber cement is a developing technology and a strategy to partially mitigate the problem with durability with filling of $CaCO_3$ content and, consequently it decreases porosity, promotes a higher density in the interface guarantying a good fiber–matrix adhesion and a better mechanical behavior. Processing and curing are recognized as key steps in the fabrication of the composites such as fiber cement sheets, with their subsequent characterization and performance assessment under monotonic and cyclic loadings. Degradation tests are also crucial for the evaluation of the durability of the resulting materials and components in real applications exposed to different environmental conditions as roofing, partitioning or ceiling elements. As the main result, this talk aims to show how to achieve properly more sustainable high performance components based on engineered natural raw materials for civil construction and infrastructure.

A5. Test methodology

ID 192 - Predicting freeze-thaw deterioration in wood-polymer composites

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Natural fiber-reinforced polymers are currently used in a variety of low- to high-performance applications in the automotive, packaging, and construction industries. Previous studies have demonstrated that natural fibers (e.g., flax, hemp) exhibit good tensile mechanical properties and have positive environmental and economic attributes such as low cost, rapid renewability, and worldwide availability. However, natural fibers are inherently susceptible moisture-induced changes in physical and mechanical properties, which can be unfavorable for in-service use. This study illustrates how a micromechanics-based modelling approach can be used to help facilitate durability design and mitigate the deleterious effects of freeze-thaw deterioration in wood-plastic composites (WPCs). The model described in this study predicts the critical

fiber volume fraction (Vcrit) at which damage to the composite will occur under certain environmental conditions for different WPC formulations of hardwood and softwood fiber reinforcement and polymer matrix types. As expected, the results show that Vcrit increases (a positive result) as anticipated in situ moisture content decreases. In addition, results suggest that fiber packing distribution directly influences Vcrit and that Vcrit increases as the mechanical properties of the polymer matrix increase. In sum, the study demonstrates how predictive modeling can be applied during the design phase to ensure the durability of WPCs.

ID 216 - **An assessment of the thermal storage capacity of hemp-lime using the Transient Performance Ratio method.**

Aidan Reilly, Oliver Kinnane
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The peculiar combination of properties possessed by hemp-lime concrete means it offers the potential for a low cost, sustainable and thermally effective solution that can be integrated into the building envelope. Its unique hygrothermal characteristics give it the potential to enhance internal environments in new build and in retrofit scenarios. Thermal mass effectively damps fluctuations in temperature, and this can be an important contribution to the overall energy use. Hemp-lime has long been proposed to offer excellent thermal mass performance, yet this is not quantified. This paper uses the Transient Performance Ratio (TPR) method, developed by these authors, to compare the performance of hemp-lime concrete walls with traditional solid wall and cavity wall constructions in a range of climates. Hemp-lime offers good potential to influence the internal environment positively and with low energy from space heating, but this varies across climates.

ID 239 - **Experimental characterization of cement composites using prism technique**

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The supervision of the quality test for concrete in situ by the classic method (destructive) is still facing to a lot of criticism. The recent studies showed that due to the difference in the conditions of implementation, samples taken during concreting do not reflect the real behavior the concrete of the construction. One of possible alternatives to solve this problem it is the recourse to the non destructive testing that allows us to follow and to diagnose the mechanical, rheological or even pathological performance of cementitious materials in real time without altering them for the future use. The choice of non destructive testing equipment must satisfy the criterion that a low variation of component of the tested material engenders a strong modification of measurement; this is considered one of the factors which prove the reliability of the test. As part of this, our choice was the use of recent immersion ultrasonic technique based on the of prismatic samples, the present research focuses on the use of this method to monitor the evolution of a local cement pastes with several variants of percentages of the ratio (w/c) for 28 days. In order to generate both longitudinal and transversal waves, it is necessary to vary the position of the piezoelectric transducer (transmitter/receiver) around the test specimen. In order to achieve the objective of this work, we presented the experimental procedure followed (prism method), the algorithm used to estimate parameters of reflected ultrasonic echo signals, then we proceeded to the analysis then to the interpretation of obtained results and we will show in particular the evolution of reflection coefficient during hardening. Results accord with literary; the use of the method of "prism technique" for the evaluation of the characteristics of cimentitious materials seems advantageous especially as they provide the results immediately.

Thursday 22nd

ID 280 - **Correlations between pozzolanic evaluation methods, electrical conductivity and chemical shrinkage test**

Ur Iván Hernández-Toledo[1], Pedro Leobardo Valdez Tamez[1], Gerardo del Jesús Fajardo San Miguel[1], Pedro Montes García[2], Alejandro Durán-Herrera[1]

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The use of pozzolans is one of the main strategies of the cement industry to reduce the CO_2 emissions; however, one barrier to increase the use of pozzolans is the local availability. Rapid pozzolanic evaluation methods can facilitate the search for new pozzolanic materials and their quality control. The pozzolanic activities of eleven materials which include two class f fly ash, two silica fumes, metakaolin, ground granulated blast furnace slag, ground glass, sugar cane bagasse ash and three natural pozzolans were evaluated with two types of ordinary Portland cement and calcium hydroxide (CH). The strength activity index (mortar mixtures at 7 and 28 days of age), the Chapelle test (10.57 g/L CH and 4 g/L pozzolan suspension at 80 °C for 16 h), chemical shrinkage (cement pastes with 10 or 20% of pozzolan at 60 °C for 3 days) and a proposed electrical conductivity method (800 mg/L CH and 302.7 mg/L pozzolan suspension) were compared. Simple and multivariable linear regression analysis were employed to identify possible correlations between methods and physicochemical characteristics of materials. Only a significant correlation (R2=0.84) was found between the CH consumption of Chapelle and the loss of conductivity of conductivity tests. Based on this finding, the proposed conductivity method may be useful for estimate the CH consumption of the Chapelle method.

B5. Case studies

ID 110 - **Phase Change Material cement-lime mortars for thermal retrofitting of facades**

Cynthia Guardia, Gonzalo Barluenga, Irene Palomar

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The poor thermal performance of many dwelling units built from 1940 to 1980 produces a low energy efficiency under the present thermal standards. In order to fulfil comfort and energy efficiency requirements, these facades need to be retrofitted. In many cases, External Thermal Insulation Composite System (ETICS) are used to increase thermal insulation, although this solution does not consider the thermal inertia. New mortars with improved thermal insulation and inertia are investigated as an innovative solution. Twelve cement-lime mortars were designed, using: white cement, air lime, siliceous aggregate (0-4 mm), lightweight aggregate (LWA) (expanded perlite), short cellulose fibres and 10 and 20% of a Phase Change Material (PCM) -microencapsulated paraffin wax. PCM's nominal melting temperature was 23 ± 1 °C. An experimental program was carried out to assess the effect of PCM on the physical and thermal performance of the mortars. Two different scenarios were considered to evaluate the temperature effect on the PCM-mortar performance. Bulk density, open porosity, capillary absorption, vapour permeability, thermal conductivity and compressive strength were characterized. PCM produced significant changes on the mortar thermal properties and a synergetic effect of PCM and LWA was identified.

ID 211 - **Bio-based plaster for improved indoor air quality**

Daniel Maskell[1], Carla da Silva[1], Keith Mower[2], Chetas Rana[2], Richard Ball[1], Martin Ansell[1], Andrew Thomson[1], Ulrike Peter[3], Pete Walker[1]

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People in industrialised countries spend approximately 80% of their time indoors. As such, the internal environment quality can have a significant impact on occupant health and wellbeing. Additionally, the demand for increased building energy efficiency has the potential to degrade Indoor Air Quality (IAQ) through a reduction of air exchange rates. In many forms of construction, the walls and ceilings are plastered, providing a large surface area exposed to the indoor environment. There is a growing recognition of the important role this surface may have on IAQ through regulation of relative humidity. Another, less well known, impact is that porous coatings have the potential to adsorb Volatile Organic Compounds (VOCs) from the air, which offers further potential to improve IAQ. This paper presents work

from the development of a novel bio-based plaster with improved hygrothermal performance and VOC sorption characteristics. Cellulose flakes, used for blown insulation, were added into a cement-lime substrate in three different proportions. A range of mechanical, hygrothermal, VOC emission and VOC adsorption properties were investigated to evaluate the potential of the bio-based cement-lime plaster to improve IAQ. The bio-based cement-lime plaster resulted in an improved thermal conductivity and an improvement in the material's moisture buffering capacity and VOC adsorption capacity. With 5% addition of cellulose flakes, the hygrothermal performance increased by over 25%. This material also showed the ability to capture VOCs and formaldehyde from the air, reducing the concentrations of these compounds by up to 22% and 70 % respectively. Therefore, the impact of the implementation of this plaster includes potential benefits regarding better operational performance of the building and improved occupant health and wellbeing.

ID 213 - **Monitoring and thermal characterization of flax shives for building insulation**

Emmanuel Antczak[1], Mounir Asli[1], Franck Brachelet[1], Didier Defer[1], Alain Lucas[2]
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This work involves the study of flax shives, natural product derived from flax production. We want to valorize it as a local resource for thermal insulation of building, not having undergone transformations apart from the addition of a biological fire retardant, guaranteeing a low impact on the environment. Flax shives arise from flax plant that is grown in Western Europe. From retting flax phase to scutching, flax fibers are separated from the stem. When grinding, the central stem is broken into small fragments called flax shives who represent about 50% of flax production. The developed research focuses on flax as additional fiber for cementitious materials such as manufacturing flax concrete blocks. The use of flax in the building sector essentially concerns the insulation. This solution mobilizes the short fiber flax, called tow. The insulation is usually available in soft rolls or semi-rigid panels of wool. Currently, the shives are used as bedding for animals or are integrated in the component mixture of particle board. The main scientific issues related to the study of heat and mass tranfer that determine the evolution of the thermal characteristics of the material and its durability. First, we propose a laboratory analysis of hygrothermal behavior of shives by conventional thermal methods for characterizing thermal conductivity and volumetric heat (flow meter methods), sorption/desorption curves are also determined. These values are implemented in a computer code (COMSOL), and are correlated with temperature and relative humidity in situ measurements. The experimental site is and independent house in wich the old insulation of the attic (glass wool) was replaced by flax shives. We followed the hygrothermal behavior of this new insulation during one year. This work takes place as part of a project named "Researchers-Citizens" of the "Hauts de France" region

ID 132 - **Sustainable insulation of historical wooden and stone buildings with lime-hemp**

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In this multidisciplinary project lime-hemp is studied as a thermal insulating material for the renovation of historic timber and brick buildings*. Focus is on buildings in the historic city of Visby on the Swedish island of Gotland in the Baltic sea. Many historic buildings in Visby have over the past decades been thermally insulated with materials such as mineral wools and polystyrene. Due to this, damage caused by moisture and microbial growth has increased. As a consequence, cultural and historical values have been damaged. Lime-hemp is a sustainable building material that consists of hemp shiv and building limes. It works differently than conventional insulating materials; in addition to good thermal insulation properties, it also has good thermal mass and moisture buffering capacity. This project will study the durability of the lime-hemp, especially microbial growth and moisture problems, and opportunities for renovation of historic buildings, while creating a good indoor climate and preserving historical values. Lab-studies as well as full-scale studies are conducted. The aim of the project is to sustainably improve energy efficiency while preserving historical values, without durability problems.

* The project started in September 2016 and results are not expected until earliest autumn 2017. The article will therefore give an outline of the project and some preliminary findings.

C5. Valorisation of recycled minerals

ID 250 - **Biochar as a carbon sequestering construction material in cementitous mortar**
Souradeep Gupta, Harn Wei Kua
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Recent efforts to attain carbon negative construction practices in Singapore and other developed countries leads to a search for construction materials that can reduce net carbon emission associated with concrete constructions. One such material is biochar which can sequester fixed carbon in its structure. Therefore, using biochar as a mixed-in component in cementitous material can reduce the net greenhouse emission associated with concrete constructions. Our study focuses on application of biochar derived from mixed-wood saw dust as a cement replacement in mortar. Experimental findings suggest that, due to its fine particle size and micro-filler effect, up to 4% cement replacement by biochar yielded slight improvement in compressive strength while reducing sorptivity by about 70% after 28 days. Improvement in strength and permeability of mortar by incorporating biochar suggest that it can be successfully deployed as a carbon sequestering concrete construction material. Durable and strong infrastructure means reduced vulnerability to damage and thus need for subsequent repairs over its service lifespan. This will help contribute toward economic and environmental sustainability of buildings.

ID 276 - **Biochar as an bond enhancement in fiber-reinforced mortar**
Harn Wei Kua, Sin Yee Cynthia Tan, Souradeep Gupta
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This study focuses on the evaluation of using biochar to enhance the strength performance of cement mortar reinforced with polypropylene (PP) fibers. Biochar was produced with mixed wood sawdust that was discarded from a local sawmill. It was then divided into two groups, with one group being subjected to dosage of carbon dioxide until it reached saturation. Results showed that when reinforcing PP fibers are coated with CO_2-dosed biochar, the cement mortar experienced a 16.09% and 17.91% reduction in compressive and flexural strength respectively. However, fibers that were not saturated with CO_2 recorded improvement of 19% for both compressive and flexural strength respectively over control samples containing PP fibers not coated with biochar. This phenomenon can be explained by the micro-filler effects afforded by the biochar particles, which serves to strengthen the bond between the surface of the PP fibers with the mortar matrix. These results highlight the potential usefulness of biochar as a sustainable carbon sink that can also be used as a bond and strength enhancement for cement mortar.

ID 277 - **Biochar as carbon-sequestering wall plaster and wall pellets**
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Biochar has recently been explored as an alternate construction material. While it has been deployed as road construction, there is an emerging trend of using biochar as concrete admixture and other non-structural innovative building elements. This study explores the use of biochar as a component in wall plaster and pellets that are used to fill cavities for interior non-structural wall panels. In the first study, biochar was mixed with plastering material and the carbon dioxide (CO_2) adsorption capability of this

material mix was compared to that of control samples (made up of pure plaster). It was found that biochar increased the net CO_2 adsorption capability by more than 4 times. However, contrary to some claims in the literature, we found no evidence that the biochar in this mixture can significantly remove total volatile organic compounds (TVOC) from the indoor air. In a separate study, biochar was used to coat pellets that were used to fill cavities in sandwich wall panels. The biochar was found to increase the net CO_2 adsorption capability by about 6 times (compared to control samples that were plaster pellets without biochar coating). There was also no significant increase in the removal rate of TVOC due to the biochar. These results indicated clearly that biochar can be effective as a regulating agent for indoor CO_2 level, which is a determinant factor for the infamous Sick Building Syndrome. Further, we argue that using biochar this way will reduce more CO_2 than if the gas is merely captured and sequestered through mineralization and deployment in construction projects. In fact, the use of biochar-containing construction materials to capture and then "lock" atmospheric CO_2 in building and structures can potentially reduce atmospheric CO_2 level by additional 25%.

ID 283 - **Preliminary investigation on use of sewage sludge ash as partly cement replacement in lightweight aggregate concrete**

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This work focuses on major properties for lightweight concrete where two types of ashes, wood ash and sewage sludge ash, partly replace the cement binder. Blocks of lightweight concrete were cast in the laboratory. The blocks were cast after different recipes where the amount of ash differed: 0, 15, 20, 25, 30, 35 or 35% cement was replaced with ash. From each block, 12 test specimens were drilled (75 mm in both diameter and height). Porosity and density, compressive strength and leaching of heavy metals were measured on the specimens from each recipe. It was found that up to 25% cement replacement with wood ash or 30% sewage sludge ash did not reduce the compressive strength significantly. These replacement percentages without strength loss are high compared to concrete with stone aggregates, and it is related to the fact, that the lightweight aggregates are determining the strength in the lightweight concrete. In addition to maintaining the strength, the porosity and density were similar to the reference lightweight concrete without ash, and the leaching of heavy metals met the limiting values. Thus the results were very encouraging, and indicate that the use of these ashes as replacement for cement in lightweight concrete may have a potential, which may be even higher than in concrete with stone aggregates.

ID 175 – Granular media particle size distribution characterization by Pandoscopy® images analysis – Application to railway ballast

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The mechanical behavior of geological granular media, such as soil, can be related by their mineralogical, physical and state properties. In case of purely granular soils (gravels, sands…), physical properties such as particle size distribution, shape and angularity play a major role on their behavior. These parameters are obtained mainly through laboratory tests on samples collected in the field. However, in many cases, sampling is an onerous or sometimes very difficult task and samples can be importantly disturbed. To meet this need, some in-situ methods have been developed at the end of the last century. Pandoscopy® is one of the most developed because of its timeliness, portability and reliability. Previous studies allowed the development of a methodology for measuring in-situ particle size distribution through automatic analysis of Pandoscopy's® images. However, its application to coarse media where some grains are larger than the observation window, as railways ballast, needed improvement. Therefore, a complement to this method is proposed. In this article we introduce and discuss the latest advances in development of Pandoscopy® tests, specifically for determining the particle size distribution of large size particles. In-situ tests have also been conducted to determine the particle size distribution of the railway ballast (coarse granular medium) was conducted. The overall results prove the interest of this method, while exposing some of its limits, and allows to validate the reliability of the implemented image analysis.

Thursday 22nd

ID 183 – Experimental investigation and modelling of the hydromechanical behavior of compacted earth

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The development of earth based buildings is of concern in the actual context of sustainable development, energy consumption and greenhouse gas reduction. However, due to lack of scientific knowledge, there is currently no clear recognized guidance for their set-up, or means of measurement to guarantee their performance. In particular, the mechanical behavior of earthen materials is strongly influenced by the water molecules which are adsorbed on the pore surfaces. In that context, this study aims at assessing the couplings between the stress, strain and the humidity fields in the partially saturated compacted earthen material. The impacts of the hygrothermal processes on the mechanical behavior (hardening/softening and swelling/shrinkage phenomena) are estimated through experimental investigation on centrimetric samples in a temperature and hygrometry controlled triaxial cell. The obtained relations are analyzed in the light of a fully coupled poromechanical model which allows quantifying the evolution of the mechanical behavior induced by daily variations of temperature and humidity.

ID 215 – Characterization of the mechanic behavior of lateritic soils

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The degradation of roads network in tropical countries is a major concerned nowadays. In Burkina Faso, the degradation rate on all network of 61399 km, is approximatively 60%. Many analysis link this problem to the specific environment of roads in their areas, but also to the limited knowledge on the real elasto-plastic behavior of lateritic soils, used for these roads construction and maintenance. The use of rational standards for road design requires the knowledge of soil and materials modulus. This parameter is important to control the deformations of pavement layers. The current methods do not allow obtaining directly this parameter, but via various correlations leading to its estimation with many errors. To answer to this problematic in order to develop appropriate methodologies for road conception and a better way to estimate the modulus, we led a study to characterize the behavior of laterites from Burkina Faso. Two (02) samples of lateritic soils are studied in laboratory, since the identification to the characterization of their mechanic behavior. From there, some mechanic parameters such as the oedometric and the penetrometric modulus have been calculated. The most important and the additional information in these investigations are the relationship between the dry density, the penetrometric modulus and the oedometric modulus. This article presents in the one hand the importance of lateritic soils in road engineering and in the other hand, the process and the results of the mechanic behavior characterization of these soils.

ID 222 – Compressibility models of agro-resources' by-product

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One way of bio-sourced aggregate valuation is the production of thermal insulation panels coupling aggregates and a binder. Cohesion can be obtained by heating and compression of mixed components. Master the compression step is crucial for the influence of the fabrication process. In the present work, the compressibility of a mix of different sizes flax shiv is studied through experimental designs. The aim is to predict the compactness of the composite according to the mixture design and the stress level applied during the compaction process. For this study, a specific trial protocol is used. It consists in successive compression cycles performed on a given mass specimen placed in a cylindrical rigid container. The behavior of the raw materials is analyzed through the evolution of the compressive stress versus sample compactness. Using analogy with soil mechanic, the analysis of compressing curves leads to identify settlement and consolidation curves. Usual, compression models were considered to fit the experimental data and to determine the relationship between compressive stress and compactness. Then experimental design analyzing the models parameters evolutions leads to the optimization of mix proportioning.

Friday 23rd

8h30	Chair: S. Amziane – *Amphitheatre* Plenary 7 – ***F. de Larrard*** – A new paradigm to face the challenge of circular economy

Session n°6 Chair *Room*	A6. Innovative admixtures A. Perrot *2*	B6. Case studies F. Khadraoui *5*	C6. Fibres and biological processes A. Fabbri *11*
9h10	ID 127 - Strength development of mortars using a magnesium silicate hydrate binder system under different curing conditions ***Hung Tran***	ID 234 - Removal of dissolved and particulate contaminants from aqueous solution using natural flax fibres ***Bouamama Abbar***	ID 158 - Influence of the type of dry yeast on precipitation rate of calcium carbonate in bio-based repair materials ***Prima Yane Putri***
9h30	ID 145 - Bio-based admixture to remediate microcracks in mortar ***Ali Amiri***	ID 138 - Designing and building a children's bamboo and hemp playground. ***Gie Steenput***	ID 157 - Mechanical performance of hemp fibre modified mortar ***I. Merta***
9h50	ID 271 - Hygrothermal behavior of a date palm concrete ***Nawal Chennouf***	ID 217 - Industrial scale-up of bio-based insulating panel production ***Valentin Colson***	
10h10	Coffee break		

Friday 23rd

Session n°7 Chair *Room*	A7. Innovative materials F. de Larrard *2*	B7. Hygrothermal properties F. Collet *5*
10h40	ID 122 - Calcium sulfate: an alternative for environmentally friendly construction ***Miguel Angel Guerra-Cossío***	ID 225 - Is hemp lime concrete a mix of hemp and lime? ***Christophe Lanos***
11h00	ID 128 - Projection formed and precast hemp-lime: better by design ***Joe Williams***	ID 227 - Thermal insulation materials from renewable resources: thermal and hygric performances ***Marie Viel***
11h20	ID 142 - Development of a bio-based plasterboard ***Daniel Maskell***	ID 303 - From hydrophilic to hydrophobic wood surface thanks to fluorination ***Martial Pouzet***
11h40	ID 148 - The compressive strength of mycelium derived from a mushroom production process ***J.B. da Conceição van Nieuwenhuizen***	ID 199 - Effect of water on the characteristics of polyethylene / flax fiber composites. ***Laetitia Van Schoors***
12h00	Round table - *Amphitheatre*	
12h30	Closing ceremony - *Amphitheatre*	

Friday 23rd

Plenary session - Concrete recycling - A new paradigm to face the challenge of circular economy

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France is currently producing about 17 Mt/year of demolished concrete, most of this material being used in road subbases or embankments. However, this flow should increase in the near future, although less and less new roads are to be built. Another 20 Mt of mixed demolition materials, a good part of it being concrete or natural rock is also available. Therefore there is a duty both for the society and the planet to make the best use of this resource, in order to preserve the natural resource and to avoid waste material landfill. Based on this reality, a national project was set in 2012, gathering 47 partners among which representatives of all construction stakeholders. Partially funded by the French Ministry of Ecology, Recybéton encompasses five fields of activities: research on material processing; research on recycled materials and structures; research on sustainable development; standards and regulations; dissemination, among which demonstration sites. The paper aims at presenting the main outputs of the project, which will produce various deliverables: a scientific book (to be released), a guide (under preparation), a number of proposals to adapt standards and regulations, and, last but not least, five experimental constructions, including a parking lot, a bridge, a public, various buildings and industrial constructions.

A6. Innovative admixtures

ID 127 - **Strength development of mortars using a magnesium silicate hydrate binder system under different curing conditions**

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A magnesium silicate hydrate (M-S-H) binder system was studied to develop low CO_2 emission cementitious materials. The binder system contained 60% magnesium oxide and 40% silica fume. M-S-H mortar mixtures were prepared with a fixed water content of w/c=0.40, compared to a control mix using Portland cement (PC). A polymer-based superplasticizer was used to improve the workability of the M-S-H mixtures. Samples were cured at different moist and curing temperatures for compressive strength tests performed at 7, 28 and 90 days. It is found that curing conditions have a significant influence on the strength development of mortar mixtures using M-S-H binder systems. Ambient conditions increase early strength for M-S-H binders, however, reduces long-term strength over 90 days. This curing regime surprisingly results in higher strengths at 28 and 90 days age for M-S-H samples compared to PC. Heated treatment increases early strength, however, decreases the long-term strength of M-S-H samples over 90 days curing period. M-S-H binders have slow strength development compared to PC. The highest compressive strengths of M-S-H samples cured in different regimes at 7, 28, 90 days were 50, 53 and 71 MPa while PC samples cured in water at 21oC at these ages had higher strengths of 55, 75, and 86 MPa, respectively.

ID 145 - **Bio-based admixture to remediate microcracks in mortar**

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Factors affecting durability of cement-based materials are generally associated with each other. 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 structures. Recently, interest in using biomineralization processes for self-healing applications in cement-based materials has gained a broader attention. Biomineralization is a biochemical process in which microorganisms stimulate the formation of minerals, and in this particular case calcium carbonate ($CaCO_3$). Due to the restricted environment of cement paste matrix, the main challenges are to determine the biological pathway for biomineralization and to find a microorganism that can tolerate the high alkaline conditions, can survive the mixing process, and can remain viable with limited access to nutrients and space to remediate cracks. This paper summarizes the results of a study undertaken to investigate the possible application of a bio-based admixture consisting Sporosarcina pasteurii (*S.pasteurii*) cells and urea-corn steep liquor (UCSL) nutrient medium to remediate flexural cracks in cement-based mortar. To develop biogenic self-healing agent, vegetative *S. pasteurii* cells were grown in UCSL medium and then mixed with cement and sand. Incorporation of cells as well as the nutrient media to the bacterial mortar did not affect the compressive negatively. Biogenic $CaCO_3$ crystals were

observed inside the flexural cracks and precipitates were able to seal cracks as large as 0.2 mm and decrease the permeability of the material.

ID271 - Hygrothermal behavior of a date palm concrete

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The environmental quality of a building generally aims to take into account both the stakes of sustainable development, social and economic. For these reason, several researchers are recently interested to introduce the biobased materials for the new and renovated buildings to reduce simultaneously energy consumption, gases emission and agricultural production. Studies carried out on new biobased building materials, which contains date palm fibers (DPF), have showed their both thermal insulation efficiency and mechanical reliability.In order to characterize the behavior and the effectiveness of this material both in terms of energy saving and indoor environmental quality. We have focused our investigation on the study of the hydric behavior of DPF concrete. The buffer moisture was estimated on the outdoor environment at isothermal condition according to the NORDTEST method then at non-isothermal condition. The results showed that the DPFC could be classified as an excellent moisture and heat regulator thanks to its absorption capacity and low thermal conductivity

ID 234 - Removal of dissolved and particulate contaminants from aqueous solution using natural flax fibres

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The aim of this paper is to present the results of two different tests: (i) Batch experiment to quantify the sorption potential of flax fibre tows for lead ions from aqueous solution. The influences of contact time, pH, initial concentration, and adsorbent dose on the adsorption process were studied. Results revealed that adsorption rate initially increased rapidly, and the optimal removal efficiency was reached within about 1h. The adsorption isotherms could be fitted well by the Langmuir model. The RL value in the present investigation was less than one, indicating that the adsorption of the metal ions onto flax fibre tows is favourable. (ii) Column tests to characterize the influence of flax fibre geotextile on the transfer and retention of suspended particles (Kaolinite) in a saturated sandy filter, with and without flax fibre geotextile, under steady-state flow. Analysis and interpretation of the effects of geotextiles on transport and retention of suspended particles (SP) were aided through mass balance computation, elution curves and deposition profiles. Results showed that the use of flax fibre geotextile not only enhances the overall retention of the filter but also increases its lifetime.

ID 138 - Designing and building a children's bamboo and hemp playground.

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Part of the final year of the curriculum of the building engineer at the Avans University Tilburg, AB&I, department of architecture, is a course named "Building with Bamboo". Within this course students can earn 2x 3 E.C. over a period 2x 10 days. From September 2015 up to January 2016 the subject of the course involved the designing and building of a children's playground made out of bamboo and hemp. The playground is situated on the inner courtyard of a primary school in Antwerp, Belgium, with children between 6 and 12 years of age. This particular school attracts a high number of children who do not speak Dutch, the native language. In order to help establish faster a better communication with these children, they were invited to come up with ideas for their new playground. Our building engineer students transformed these ideas into 6 proposal which were on display at the primary school. One design was chosen by the children and their parents. Prior to the execution of the playground our

students prepared IKEA-like manuals in order to involve the children of the primary school with the construction of their bamboo playground as much as possible. Parts of the playground were prefabricated and a mock-up was made with the help of the children. Eventually the playground, a 3-dimentional labyrinth made out of bamboo and hemp, measuring 5x5x5m, was erected in 4 days by 40 students. Protection against decay due to sun and moisture exposure was implemented. Special care was given to the foundation of the bamboo poles and lashing techniques used to connect the bamboo pole structure. A maintenance manual was given to the teachers of the primary school. A follow up to study the decay of bamboo and hemp expose to a West-European climate is planned.

ID 217 - **Industrial scale-up of bio-based insulating panel production**

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ISOBIO Project aims to produce highly insulating panels from bio-resources. This study focuses on the constrains associated to the production of panel at the industrial scale using thermal treatment. Three types of processes are considered (wet processes for rigid panels, dry processes for rigid or flexible panels and Stramit process®) and the limits of each process are identified according to the formulation characteristics (moisture content, binder type and content), binding mechanisms (melting, thermosetting or drying), process parameters (pressure, time and temperature) and targeted material properties (density and thickness). Cavac Biomatériaux industrial oven is used to study the dry and wet processes for the production of rigid panels. The temperature distribution in the material thickness was recorded. Difficulties to reach sufficient temperature level for high panel thicknesses or for high water content are observed. As a consequence, an excessively long drying time is needed to produce rigid panel using the wet process. Only small panel thicknesses are possible options. The addition of thermosetting binder is an alternative way to reduce water content and processing time. Rigid panel are easily produced using the dry manufacturing process and a hydraulic press with hot plates. Various tests are performed adjusting panel characteristics and formulations. Interesting results are obtained with hemp shiv bonded with a bio-based thermosetting binder. The binder content ranged from 5% to 23% and the targeted density from 155 to 245 kg/m^3. Mechanical characterization shows that the binder formulation, proportion, water content and panel density are crucial parameters to be adjusted to optimize panel manufacturing process and properties. The dry process appears more versatile than wet process and leads to lower processing time. It allows the production of hemp shiv insulation panels within a large range of density and having compressive and flexural strength reaching 1 and 1.7 MPa respectively.

C6. Fibres and biological processes

ID 158 - Influence of the type of dry yeast on precipitation rate of calcium carbonate in bio-based repair materials

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The cracking in concrete promotes deterioration such as the corrosion of reinforcing rebar, thus repairing in the filling of the crack is being implemented. Recent years, improving sealing efficiency using bio-based materials associated with microbial metabolic processes leading to precipitation of calcium carbonate has been intensively studied. In this study, the rate of initial reactions was calculated by examining the influencing factors on the precipitation rate that depends on the constituents of bio-based materials comprising yeast, glucose, and calcium acetate mixed in Tris buffer solution. Furthermore, the effects of the types of dry yeast on the amount of calcium carbonate precipitation were also investigated. The investigation showed that calcium carbonate precipitates as crystals depending on the types of constituents used in the mixtures and pH levels within 24 hours after mixing. The precipitation was assessed by Fourier Transformed Infra-Red spectroscopy (FT-IR). Hereafter, calcium carbonate precipitation was observed for all the types of dry yeast tested in this study. It was shown that the decrease of pH led to a change in calcium carbonate precipitation. Also, all the types of dry yeast commercially available which was tested in this research can be used as a microorganism in the bio-based repair materials.

C6. Fibres and biological processes

ID 157 – Mechanical performance of hemp fibre modified mortar

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In this research the mechanical performance of mortar reinforced with fibres of hemp (Cannabis Sativa L) were experimentally evaluated. Bast hemp fibres of 10 mm in length with six different dosages per volume, starting with 0.25 vol% up to 1.5 vol% increasing in steps of 0.25, were mixed in the matrix. The fibres were added to the matrix in two different conditions: wet and dry. The compression strength, flexural strength and flexural toughness of the composite were evaluated. The addition of hemp fibres was found to decrease the mortars compression and flexural strength but significantly improved the flexural toughness of plane mortar. The increase in fibre dosage resulted in increase of the flexural toughness. On the other hand the compression strength of mortar decreased with the addition of fibres. Both the compression strength and flexural toughness slightly decreased in case if wet fibres were mixed in the matrix.

A7. Innovative materials

ID 122 - **Calcium sulfate: an alternative for environmentally friendly construction**

Miguel Angel Guerra-Cossío[1], Javier Rodrigo González-López[1], Ricardo Xicoténcatl Magallanes-Rivera[2], Antonio Alberto Zaldívar-Cadena[1], Mayra Zyzlila Figueroa-Torres[1]
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One of the challenges of the construction industry today is to develop and promote the use of environmentally friendly (eco-friendly) materials. The production and use of Portland cement clinker as a construction material is part of the problem because of its high generation of CO_2 in its manufacture. Therefore, alternative materials that mitigate in some extent this situation become an important task. The use of calcium sulfate in any form as a construction material has been limited due to its high solubility and low development of mechanical strength. However, its use as an alternative cementitious material provides a notable decrease on greenhouse gases produced when it is compared to the manufacture of other hydraulic cementitious materials, since the temperatures required in its manufacturing are relatively low. Therefore, in this study the feasibility of reuse of waste gypsum from the ceramics industry by milling and calcination was evaluated. This calcium sulfate was used as main component in the manufacture of ternary cementitious mixtures. Cementitious test materials were manufactured with CaSO4 synthesized from waste gypsum, ground granulated blast furnace slag and silica fume. Small additions of K_2SO_4, $Ca(OH)_2$ and Portland cement clinker as chemical activators were used. The addition of blast furnace slag and silica fume to the calcium sulfate systems improved its properties and prevented the dissolution in wet environments. The compressive strength achieved by some systems was near 20 MPa, showing that this material may be a feasible option for the manufacture of masonry or elements with low structural strength requirements with a proper behavior in wet environments.

ID 128 - **Projection formed and precast hemp-lime: better by design**

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Projection forming and off-site pre-casting of hemp-lime panels are alternatives to traditional in-situ casting that can offer several production benefits: minimised on-site time, improved quality assurance and lower drying times. The direction of compacting force applied with these methods is perpendicular to that of traditional on-site cast material and, in the case of projection formed, applied by different means. As a result the internal structure of the material will be aligned and shaped differently with consequent implications for the physical properties that must also be considered when selecting a method of production. This paper reports on the mechanical and thermal properties of hemp-lime produced by projection and by casting in two directions: vertical as per in-situ casting and horizontal as per pre-casting. The internal structure of the material in each case was assessed through image analysis and used to explain the measured differences in properties. The results indicate the importance of the orientated internal structure in determining the performance of this material and show that projection or horizontally precast manufacture can provide inherent performance improvements over traditionally cast material in addition to the logistical benefits.

Friday 23rd

ID 142 - **Development of a bio-based plasterboard**

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The use of gypsum plasterboard is ubiquitous within the construction industry and equates to an approximate 3.5% of the UK's green house gas emissions. Production alone accounts for 67% of gypsum plasterboard's life cycle global warming potential. Developing alternative boards, using materials with lower life-cycle impacts, offers significant scope to reduce current environmental impacts of plasterboard use. There has been an increase in research that demonstrates the potential of plasters with bio-aggregates to enhance indoor environmental quality. Board solutions that contain bio-aggregates within the core will help to further develop this potential. Such boards can be used in a conventional manner reducing on-site barriers to adoption, while offering a value added product with improved hygrothermal performance. This paper presents the development of an alternative plasterboard composed of hemp shiv which is bound by mineralogical aggregate composition. Boards were developed using of clay to ensure a low embodied environmental impact. The results of the different binding mechanisms of the clay based plasterboards were experimentally investigated and compared to conventional gypsum plasterboard. A range of mechanical and hygrothermal properties were investigated to establish the potential of a bio-based plasterboard. Standard test methods developed for gypsum plasterboard were used to establish the flexural, shear and impact resistance of the boards, while the investigation of hygrothermal properties considered the thermal conductivity, moisture buffering performance and isotherms. The alternative plasterboard had up to five times better moisture buffering properties compared to a gypsum plasterboard and a significantly lower thermal conductivity. While significant improvement of the hygrothermal properties has been observed, there has been a reduction in the mechanical performance of the alternative boards. However, rationale is presented indicating that the alternative plasterboards developed could be adopted in a comparable manner to conventional plasterboards, resulting in an improved indoor environmental quality with a reduced environmental impact.

ID 148 - **The compressive strength of mycelium derived from A mushroom production process**

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This paper presents the context of the research and a literature review into the state of the art of creating mycelium products. A theoretical framework is described, the production process of mushroom farmers is researched and used to create mycelium composite with good mechanical properties, with a focus on compressive strength. The main goal of the research is to create blocks of mycelium composite that can be used in the building industry and can be tested on compressive strength in a wall configuration. Collaborating with local mushroom farmers and bio polymer specialists the influences of the type of mycelium, the growth (circumstances), the (type of) substrate, and the processing on the mechanical properties of the mycelium blocks are researched. Series of specimen and blocks with different properties and growing conditions are produced together with the mushroom farmer and tested. A rudimentary exploration of joining techniques and possible shapes of the blocks supports the design and construction of three small wall specimen with mycelium composite blocks. These proofs of concept are tested on compressive strength. The results are presented in this paper.

B7. Hygrothermal properties

ID 225 - **Is hemp lime concrete a mix of hemp and lime?**

Brahim Mazhoud[1], Marie Viel[2], Florence Collet[2], Annabelle Phelipot-Mardelé[2], Christophe Lanos[2], Sylvie Prétot[2]
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Hemp lime concrete is a mix of hemp shiv glued in a mineral binder. Such concrete is characterized by low thermal conductivity and interesting hygric properties. The aim of this study, realized in the frame of the European ISOBIO Project, is to understand which is the contribution of each component of the hemp lime concrete to the thermo-hygric properties of the mix. The study focuses on the case of a commercial hemp shiv (Biofibat®, CAVAC France) and a lime based binder (Thermo®, BCB). The measurement of thermal

conductivity and Moisture Buffer Value are performed on some conventional hemp lime concrete formulations varying hemp shiv to binder ratio. On the other hand, the same measurements are performed on hemp shiv alone (at different densities) for several grading, showing that thermal conductivity and MBV evolve according to the density. The last measurements are realized on samples realized with Thermo lime matrix foamed to achieve sufficiently low densities ranging from 400 kg/m^3 to 1200 kg/m^3. The comparison of results obtained on each component and on mixes for the same range of densities is full of interest to understand the synergetic effect of the mix. The data are used to adjust a homogenization model useful for the optimization of the mix proportioning.

ID 227 - **Thermal insulation materials from renewable resources: thermal and hygric performances**
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The European ISOBIO project aims to develop new bio-based building insulating materials which contribute to reduce environmental impacts of buildings. The developed materials shall have low embodied energy and low carbon footprint and shall contribute to reduce energy needs of buildings ant to ensure high hygrothermal comfort of users. This study investigates the valuation of agro-resources as bio-based aggregates and as binding material to produce wholly bio-based composites. Two types of aggregates: hemp shiv and corn cob residues (obtained after alkali treatment on the corn cob), and five types of green binders are investigated. Specimens are produced to characterize thermal and hygric properties of developed composites and to identify the best mixture between aggregate and binder. They show interesting thermal and hygric properties. They have low thermal conductivity ranging from 0.067 to 0.148 W/(m.K) and depending on the mix (aggregate with binder). They are excellent hygric regulators (MBV >2 g/(m².%RH)). These results suggest that developed composites can be used as building materials but not for the same types of use. In fact, some composites would be more suitable for thermal insulating products and others would be better suited to indoor facing panels.

ID 303 - **From hydrophilic to hydrophobic wood surface thanks to fluorination**
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The availability, the ecologic and economic aspects of the wood are advantages which explain the very wide application scope of this material (paper industry, furniture, carpentry and building). However, the wood is a hygroscopic material especially sensitive to the ambient humidity and temperature. The swelling and the removal caused by the water absorption and desorption lead to crack and deformation in the wood volume, rendering it incompatible for such applications. In this study, dynamic fluorination using F_2 gas was applied to wood samples to decrease its hydrophilic character. The covalent grafting of fluorine atoms on wood surface was underlined by Fourier-Transform infrared spectroscopy and ^{19}F solid state Nuclear Magnetic Resonance. It revealed that the wood, which is hydrophilic initially, acquires a hydrophobic character comparable to that of the Teflon, thanks to fluorination. A good durability of this treatment was also determined by aging tests under ambient atmosphere and under UV irradiation. Moreover, this treatment allows obtaining hydrophobic character without major structural (morphology, density and color) and mechanical changes with short duration treatment. The conservation of these properties after fluorination, a treatment without toxic solvent and temperature, represents a remarkable advantage over existing physical and chemical wood treatments.

ID 199 - **Effect of water on the characteristics of polyethylene / flax fiber composites.**
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Bio-based composites have been widely developed in recent years, especially in the automotive, leisure and shipbuilding sectors, and they are gradually penetrating the building industry. These materials have the advantage of presenting good mechanical properties, associated with a low density. Today the implementation processes are more and more mastered, but there is the problem of their durability under service conditions, because of the highly hydrophilic property of natural fibers. Indeed, the behavior of these composites in the presence of water and humidity or under thermal stresses and biological attacks is yet to be explored. The objective of this study is to identify degradation mechanisms of polyethylene-matrix composites reinforced by short flax fibers. The materials have been subjected to

hydro and hygrothermal ageing at 30 and 80° C up to 2 years. The determination of the water diffusion coefficient in the composite and the mass increase, allowed us to highlight slight and important degradations according to the intrinsic characteristics of the materials, such as the percentage of fibers, the quality of the fiber/matrix interface and the ageing conditions. These changes obviously have consequences for mechanical properties. A multi-scale analysis, based on following chemical, microstructural and morphological characteristics, has shown that water mainly exerts a physical constraint, such as plasticization, whereas, at high temperature, leaching phenomena and hydrolysis of some fiber components have been identified. Finally, the biological degradation of these materials was studied. As part of this study, it was shown that the micro-organisms are responsible for selective consumption of fiber components resulting in a drop in mechanical properties.

ID 147 - **Synthesis and characterization of fly ash hybrid cements with limestone**

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The alkaline activation of different hybrid cements fabricated with fly ash, portland cement and limestone powder was evaluated. The alkaline activators were Na_2CO_3, Na_2SO_4, NaOH and $(COONa)_2$), with a variation of the modulus (Na_2O/SiO_2=0.1–0.3), a water/binder ratio of 0.5 and curing at 23ºC with relative humidity above 95%.The characterization was carried out in relation to the elemental and mineralogical chemical composition, particle size distribution and morphological observation obtained by scanning electron microscopy. Pastes systems were prepared with different proportions of fly ash, Portland cement and limestone, using 30% maximum of Portland cement and limestone for the production of all pastes. The results of compressive strength showed that the samples with lower molar relations (Na_2O/SiO_2=0.1), with high proportions of Portland cement (30%) and limestone (10%) showed a compressive strength higher to 30 MPa at 28 days of curing. The alkaline activator that showed higher resistance was Na_2SO_4 reaching the 30 MPa at 28 days of curing. The alkaline activator that showed lower resistance was NaOH with 5MPa. The same tendency was observed in all other systems. According to the characterization, the main products of the reaction a gel type (C,N)-A-S-H and C-S-H.

ID 155 - **Natural Cement PROMPT-UP Vicat**

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VICAT, a family firm founded 160 years ago looks to the future. We propose a range of high-performance materials, products, and services consistent with the constant evolution of the construction industry. Through its cement plants, aggregate quarries, concrete batching plants, finishing products for the building industry, etc., wherever it is located the Group is devoted to furthering local development, fostering local employment, and treating the environment responsibly. In order to answer challenges of our times, Vicat R&D department has developed new building solutions in eco-construction. The group is equipped with laboratories which allowed us to increase our knowledge on the combination of binders and bio sourced materials. Our natural cement, Prompt Vicat, has a perfect compatibility with plant aggregate, burnt at low temperature like lime, it is the ideal mineral binder to manufacture bio-sourced solutions. Original and successful in terms of thermal, hygrothermal, mechanical properties and durability, these new building solutions in eco-construction, in particular hemp concrete, are competitive insulation solutions, in particular for the precast industry where a mass production is possible, in order to obtain a very competitive construction material with a low environmental footprint. Due to its property of rapid hardening, the Prompt Vicat can be used on the existing manufacturing process of the precast industry, to manufacture panels or factory blocks

ID 160 - **Systemic approach to reduce energy demand and CO_2 emissions of processes that transform agroforestry waste into high added value products**

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REHAP project has been recently granted by the European Commission in the CALL: H2020-SPIRE-2016 (Grant Agreement number: 723670). REHAP's 16 partners aim at revalorizing agricultural (wheat straw) and forestry (bark) waste through its recovery, and primary (sugars, lignin, tannins) and secondary (sugar acids, carboxylic acids, aromatics and resins) processing to turn them into novel materials, and considering Green Building as business case. The project will provide reductions in utilization of fossil resources of 80-100%, and energy utilization and CO_2 emissions above 30%. Specifically, building blocks (1,4 and 2,3-Butanediol, esterpolyols), materials (polyurethanes, phenolic resins, modified hydrolysis lignin) and products (wooden boards, insulation foams, cement, adhesive) will be obtained. Developed processing technologies (chemo/thermo/enzymatic and fermentation) will be optimized at pilot scale (TRL6-7) for further exploitation and replication of results. All products will be integrated in a prototype to demonstrate industrial applicability into the Green Construction sector. Project novelties and partner implications: Processing of lignocellulosic waste, optimization of the obtaining of building blocks and

scaling-up of the processes. Current processes demonstrated at R&D level by REHAP partners will be transferred to the industrial environment. Starting from fractionation and purification processes developed by VTT, new chemical routes will be developed by innovative companies such as BIOSYNCAUCHO, NOVAMONT and TECNALIA and VTT as singular building blocks developers. Conversion, optimization and scaling-up of new building blocks as well as bioresins and products developed therefrom (biophenolics, bioesterpolyols, biosuperplasticizers and non-isocyanate polyurethanes/NIPUs). Companies engaged with these new routes are FORESA, CUSA and RAMPF. Demonstration of the technical-environmental-economic feasibility of the product use in the construction sector, FORESA, COLLANTI, LAFARGEHOLCIM and RAMPF, all of them responsible for creating different industrial solutions. Finally, will be designed a prototype system based on all the particular developments, capable of reaching the market, as a solution for Green Buildings as a case study.

ID 163 - **Hydrophobation of natural fibres for application in WPC materials**

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The objective of the present study was to improve the method of hydrophobation of natural fibres for its application in WPC. For outdoor applications such as in decking's and ventilated facades is desired improved durability against weathering. This problem is associated with the water adsorption of the natural cellulosic fibres. Commercial paper sizing agents AKD was used for the optimisation of surface hydrophobation of natural fibres (wood; Rettenmaier BK 40/90, rice husk, flax and hemp fibres). Parameters studied included: Application method, AKD brand, concentration, pH, elimination of extractives, catalyst and influence of temperature and pressure. As results, an important improvement against wetting was seen using contact-angle measurements on water drops. Anyhow the dynamic water vapour adsorption did not change notably by the AKD-treatment. Finally treated fibres was prepared as compound to confirm potential reduced water adsorption of the resulting WPC material. The influence of the processing conditions was studied by hot pressing, injection moulding and extrusion of the modified natural fibres and PP. Mechanical performance of the WPCs was determined in terms of bending and tensile test. It was concluded that the AKD treatment had a positive effect in the mechanical and water absorption properties of the composites. The processing conditions influenced in the water uptake of the composites being the best procedure injection moulding and pressing. This work was performed within the EU-project HIFIVENT (GA: 605891) FP7-SME-2013.

ID 178 - **On the effect of the exterior plaster on the hygro-thermal behavior of the multilayer wall: case study of exterior insulation rehabilitation**

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In a general context of the sustainable development and the environmental concerns, the first action for decreasing the energy consumption is an effective building insulation starting with the refurbishment of old building that do not respond to the current regulation. This growing interest for the energetic renovation is reflected in research of efficient materials and no expensive techniques. Renovation of buildings, in particular to improve their energy performance is complex. Indeed, it is essential to take into account the specificities of existing materials to ensure the comfortable environment and avoid damage of the structure. The use of bio-based materials is a very important solution to meet this challenge with low environmental impact, good hygro-thermal properties and low cost. One of the techniques used for the energetic renovation by using these materials, is the exterior insulation. The insulation material is added to the existent wall hence the importance of a coating plaster which have both aesthetic and technical role. The main objective of this work is to study the hygrothermal behavior of the multilayer wall in the case of the exterior thermal renovation by using a straw concrete, and the role of the coating plaster to avoid the dew point in the interface insulation material/concrete blocks. Different plasters are used, based on cement, lime or gypsum for the comparison reasons and the choice of the efficient plaster in the real conditions of refurbishment. The numerical calculations are carried out using WUFI with in-situ temperature and humidity boundary conditions. The optimal thickness of the plaster will be proposed for the renovation in the case of various existent stone, concrete, brick walls for representing different configurations.

ID 180 - **Development of bio-based insulation materials for the improvement of thermal comfort of housing in Burkina Faso**

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Burkina Faso is located in the heart of Africa, where the average temperature during the dry season is about 40 ° C. 75% of the population is located in rural areas, but in the last years, there is a big migratory flow to the cities, in an irregular process of urban expansion, where most of the houses are made with walls of concrete blocks and metallic roofs, generating a big lack of thermal comfort and habitability conditions.

The main objective of this cooperation project is to develop a local thermal insulation material, with low environmental impact, which can contribute to improve the living conditions in this new urban areas of Burkina Faso. For this, we use biomaterials, locally available, that results as wastes or byproducts of agricultural industry, in specific, peanut shells and sorghum canes. We have worked on the development and selection of diverse formulations, looking to obtain a rigid and lightweight panel, by making different specimens, varying the particle size, the type of binder (fishtail glue, bones glue, nere extract, lime or earth) and proportions between dry material and binder. Several properties have been evaluated, such us thermal conductivity and difussivity, mechanical features and fire reaction behaviour. The results for specimens made with peanut shells, in a 70/30 proportion, seems to have good cohesion and thermal conductivity, as well as specimens made with sorghum in proportion 80/20. In both cases, the values for thermal conductivities are between 0.064 W/(K·m) and 0.070 W/(K·m). These values are closer to those presented in thermal insulating products on the market. With these raw materials and natural binders, it is possible to develop bio-based insulation materials, renewable and locally available, suitable for application in developing countries.

ID 181 - **Hydrophobic sol-gel coatings on bio-based materials – Influence of catalyst and solvent concentration**

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The impact of depositing sol-gel coatings on the hydrophobicity of a bio-based material was investigated in this study. Bio-based materials have tendency to absorb large amounts of water due to their highly porous structure and presence of hydrophilic hydroxyl groups in their structure. For this purpose, two sets of silica sols were prepared to study the influence of catalysts and solvent concentration on the hydrophobicity of hemp shiv. The first set of silica sols were prepared using different acidic (hydrochloric acid and nitric acid) and basic (sodium hydroxide and ammonium hydroxide) catalysts while keeping the concentration of precursors and solvents constant. The hydrophobicity of sol-gel coated hemp shiv increased significantly when using acid catalysed sols resulting in water contact angles of up to 100° using sessile drop method. Therefore, the next set of silica sols was prepared with acidic catalysts using higher concentration of solvent. Hemp shiv coated with ethanol diluted sols showed better hydrophobicity when compared to undiluted sols. This difference in hydrophobicity can be attributed to the change in surface roughness. It was found that silica sols containing higher concentration of solvent provide a uniform coating layer covering the hemp shiv entirely. In contrast, undiluted sol coatings developed minor cracks on the hemp shiv surface as observed under 3D optical profilometer. Therefore, the use of diluted hydrophobic silica sols offers potential for treatment of extremely hydrophilic bio-based materials by sol-gel technology. For practical application of coatings on bio-based materials, diluted silica sols are of interest due to longer shelf life, reduced cost and lower environmental impact of precursors.

ID 197 - **Properties of modified phosphogypsum binder**

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Limited results on modifying properties of gypsum binder based on phosphogypsum were reported.

Phosphogypsum is common by-product of Ukrainian chemical fertilizers plants. However, it has limited use in local construction industry. At the same time the deposits of natural gypsum will depleted in several decades and there is a need find alternative waste by-product gypsum. The main disadvantages of phosphogypsum binder are the need of neutralization of harmful admixtures, aggregation of its particles during grinding and high water demand. Therefore, there is need in modifying admixtures to facilitate the manufacturing process and achieve sufficient performance characteristics of binder. The paper reports on an investigation of the influence of composite modifying admixture consisted of slacked lime and superplasticizer on water-binder ratio, strength properties and peculiarities of structure forming of the binder. The results of compressive strength of specimens made with modified binders varied from 20 to 24 MPa and flexural strength varied 10 to 12 MPa at the age of 28 days. According to SEM data, the morphology of CaSO4·2H2O was not related to the type and portion of admixtures. However, at the application of optimal values of superplasticizer and slaked lime denser disposition of crystals is observed.

ID 202 - **Influence of the binder alkalinity on micro-organisms present in hemp shiv used for hemp concrete**

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Hemp concrete is a material based on hemp shiv and a mineral binder. It is used for thermal and acoustical building insulations. Presence of bacteria and mould has been reported in the literature on hemp concrete, especially in high humidity condition. Micro-organisms may come from raw materials themselves or from external contaminations. On one hand, micro-organisms are present in the environment, especially in air, and may contaminate the materials after its fabrication. On the other hand hemp shiv is very sensitive to humidity and is able to store 35% of its weight of water at 100% RH. The hygroscopic behavior of hemp and its organic nature make the material subject to mould growth. Moreover the process used to separate fibers from the stem called retting involves the action of micro-organisms. So it is known that micro-organisms are initially present in hemp shiv. However the alkalinity of the binder (pH > 12) of the hemp concrete does not allow many micro-organisms to grow or even leads to high mortality. This study investigate the provenance of the micro-organisms observed in hemp concrete. For that purpose the influence of the pH on the micro-organisms present initially in hemp shiv is studied. With a stomacher, micro-organisms are extracted in water with SDS (1%). Then, the suspension is inoculated in potato dextrose agar medium after dilution. This protocol is used on shiv on a bulk state and after contact with water and different types of mineral binders (lime-based and prompt natural cement). The concentration of moulds is determined and their identifications are conducted by microscopic observations.

ID 206 - **Light-weight claydinte and sawdust concrete based on supersulfated cement**

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The paper gives coverage on the peculiarities of the properties of two types of lightweight concrete: claydite concrete and sawdust concrete. The first one is based on claydite produced in Western Ukraine and Moldova, for the second one sawdust of the most common local coniferous trees was applied. There was used supersulfate cement composed of blast furnace granulated slag, phosphor-gypsum and Portland cement in the research. The calcium chloride was used to reduce retardation and superplasticizer for reduction of water demand and increasing the strength performance. High specific surface of supersulfated cement facilitates intensive hydration of CaO from slag glass and binding it into new formations. That increases the strength of light-weight concrete. With claydite, the process occurs with binding of free lime and gypsum with aluminates from slag and aggregate. The results obtained with the claydite concrete were varied between range of average density of 960 to 1490 kg/m^3 and compressive

strength from 7 to 21.5 MPa. Such concrete can be applied for structural and thermal-insulating elements (walling blocks and panels). As supersulfated cement had low operating pH due to the limited content of alkali, it led to a positive influence on sawdust aggregate and didn't result to a significant extraction of tanning agents. With sawdust concrete, the average densities were varied from 410 to 720 kg/m^3 and compressive strength from 0.34 to 4.7 MPa, which can be used for thermal insulating elements.

ID 212 - **Contribution to the design and the characterization of a fully bio-based insulated panel including sunflower pith**

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The building construction sector has a major impact on the environment, mainly in terms of raw material use, greenhouse gas emissions and waste production. Within this context, the present study aims at evaluating the potential of the pith extracted from sunflower stalks as a potential raw material to design insulated panels with reduced environmental footprint. The first part of this study consisted of the development of an easy and low cost procedure for pith collection. The objective was achieved through the combination of a preliminary stage of grinding and a second phase of separation using a tilted conveyor belt and a blowing system. The pith fraction collected with this technique presented a level of purity higher than 90%. The second part focused on the optimization of the molding conditions to form the insulated panel. The influence of three parameters was studied: the pith particle size fraction (small, medium and coarse), the weight content in a starch-based binder (5% or 10%) and the initial loading height (6.5, 7.5 or 10 cm). The last part was dedicated to the assessment of the performances of the sunflower insulated panel and its comparison with a conventional thermal insulation material: the expanded polystyrene (EPS). The optimal formulation, despite a higher dry density (47.1 kg/m^3), presented a dry thermal conductivity of the same order of magnitude as EPS (0.034 W/m.K). Nevertheless, due to its higher hygroscopic behaviour, the conductivity of the equilibrated sunflower panel at 60 % RH and 25 °C was 23% higher than that of EPS. Concerning the mechanical performances, the compressive strength of the sunflower panel overtopped the EPS (+11%) while its flexural strength was conversely lower (-11%). Finally, the two panels differed strongly in their water vapor permeability, the sunflower panel being ten times more permeable than EPS.

ID 220 - **Thermo-hydro-mechanical behavior of unsaturated compacted recycled asphalt aggregates**

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The asphalt aggregates arise from the demolition of asphalt road layers and are recycled with either hot mix asphalt or warm mix asphalt. The ORRAP project (Optimal Recycling of Reclaimed Asphalts in low traffic Pavements) analyses the cold recycling of asphalt aggregates from low traffic road layers, without binder addition. The required conditions for their reuse in low traffic roads is one of the main objectives of this project, considering that they represent 70% of national road network in France. From an experimental point of view, the effects of the temperature and the water content on the thermo-hydro-mechanical behavior are key elements. First, the granulometry and the compacting conditions of the different aggregates will be studied. The laboratory study will concern these cohesive granular materials which will be then subjected to triaxial tests with repeated loadings and different temperatures (between 15 and 35°C). The reversible and irreversible behaviors of the samples will be studied and the results will be used for the development of a model which takes into account the resilient behavior and the long-term behavior. The goal is to build a model of a road structure, by finite or discrete element analysis, considering traffic mechanical solicitations and hydric environmental solicitations. Technically, the temperature will become a state variable, for the classic models of non-linear elasticity which are developed for the mechanical behavior of the unsaturated granular soils. Then, there are two options for the modeling. The first solution consists in developing an elastoviscoplastic model, to take into account the effect of the temperature on plastic deformations. This model can be developed in Cast3M FEM framework for pavement modeling. The second option is the modeling of triaxial tests with repeated loadings and road structure using discrete elements simulations in LMGC90 framework, which employs Contact Dynamics method.

Posters

ID 226 - **Mechanical behaviour of wooden framework buildings with sprayed hemp concrete**

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This work, realized with the support of Developpement Chanvre, presents a study of characterization of the mechanical behaviour of wooden framework buildings with sprayed hemp concrete. The main aim is to quantify the bracing stiffness brought by the hemp concrete. The study was conducted in two phases: first in lab on small elements, and second in situ on a real building. To determine the contribution of each component, the work in lab consisted in testing five elements of different compositions: the first was a wooden frame, the second a hemp concrete wall, the third combined wooden frame and hemp concrete, and the fourth a coating is added; the fifth introduced a modified wooden frame. The tests consisted in applying a vertical load to simulate the weight of one level, and second in adding a horizontal load to shear the wall. The horizontal load was increased to the break. For each walls, a displacement-load curve was obtained, allowing a comparison of their behaviour. The study shows that the hemp concrete doubles the bracing stiffness, but in addition it brings a useful supplement of ductility. In the second phase, a two levels building was monitored with geophones, to tape its movements under ambient mechanical noise. The first modes were determined, and by modelling the building and by adjusting the stiffness parameters to fit the real modal frequencies, the stiffnesses of the walls were estimated. The values are in agreement with the lab test. Furthermore, the behaviour under regulatory earthquake was estimated, and showed the type of building is well designed with respect to this risk. In conclusion, the filling of hemp concrete plays a non-negligible role in the mechanical behaviour of wooden framework building and has to be included in the dimensioning, what is not the current case in France.

ID 230 - **Feasibility of bamboo as primary structural material for telecommunication poles**

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Bamboo is an exceptional lightweight and tough construction material for buildings and furniture that may be used for producing low cost small telecommunication pole structure. In this paper feasibility of using bamboo for such structure is examined. First, compressive and tensile load capacity of bamboo is examined by designing an appropriate joint system. Initially, this joint system comprises of making three holes at each end of bamboo and attaching a steel nut through these holes that transferred load to the testing machine. Test Results using such joint system suggested that bamboo sample of approximately 77 mm diameter and of length 1.5 meter may take up to 146 kN compressive and 60 kN tensile load. Longitudinal splitting through the center of the holes in the joints was observed as main cause of failure. For improvement, thin steel plate jacket type joint incorporating five nuts is designed and fitted at each end of bamboo. Compressive and tensile load test using such joint on bamboo sample of same diameter and length suggest that both tension and compression capacity is increased by approximately 100 % compared to previous joint system. In this case, sample failed due to shear and bearing stress at the joint. Incorporating safety factor to these experimentally observed load capacity of bamboo, a sample 5m high telecommunication pole type frame was designed to support one 0.9 meter diameter microwave dish and two GSM antennas for 210km/hr wind zone as per appropriate code. Steel plate was used to attach the pole to the foundation base. A sample telecommunication pole was satisfactorily installed over a 6m high building.

ID 240 - Numerical study on strengthening concrete beams reinforced by CFRP with near surface mounted technique

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nature that can either be linked to a change of use of the building, where it may be linked to a weakening of the structure. Various methods of strengthening are available, but most old methods have disadvantages that arise in the difficulty of execution and the low contribution of the bearing capacity of the structural element. By against the reinforcing techniques using composite materials are more interesting because they have many advantages from the perspective of mechanical properties and ease of execution. The most widespread technique for reinforcement by composite materials is the externally bonded reinforcement technique (EBR), which consists in bonding the plates of carbon fiber reinforced.

polymer (CFRP) on the outer surface of the structural member with an appropriate epoxy resin. However, using the EBR process in the case of beams results in several situations of premature ruptures which are caused by the delamination of the composite, thus preventing the development of its full bending capacity. In order to remedy this problem, we have chosen to use a new technique of reinforcement with composite materials, namely the near surface mounted technique (NSM). The NSM technique consists in inserting strips of CFRP laminate into slits made beforehand at the level of the concrete coating of the elements to be reinforced. In this study, a numerical investigation was carried out on rectangular reinforced concrete beams reinforced with NSM-CFRP using the ATENA finite element code. A parametric study was also carried out in this research. The numerical results were compared with the experimental results of the beams tested by other researchers with the same reinforcement configurations. Overall, numerical behavior laws are rather well-suited to those obtained experimentally and the parametric study has also yielded interesting results.

ID 242 - **Engineering properties of natural pozzolans of "Djoungo" (Cameroon) as supplementary cementitious materials for use in mortars and concretes**

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In this study, physico-chemical investigations have been carried out on the possibility of using Cameroonian volcanic scoria as raw supplementary cementitious materials (SCMs) for mortar or concrete production. The research had made some suggestive results and conclusions. Powders of less than 100 µm of eight sampled "Djoungo" natural pozzolans from volcanic origins have been subjected to chemical and mineralogical analysis, specific surface, absolute density, granulometry and pozzolanic activity tests. The results obtained showed that, mortars or concretes can be produced from samples studied. The samples contain significant amounts of glassy or amorphous phase ready to dissolve in an alkaline solution

ID 262 - **Extruded earth bricks: mechanical and hygrothermal properties, an anisotropic behaviour**

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The study focuses on the mechanical, thermal and hydric properties of extruded earth bricks. The bricks used for testing were produced following an extrusion process in various French brickworks located in the north, the center and the west of France. Different types of bricks, all solid blocks without perforation, were used. The compressive strength, the thermal conductivity and the water vapour permeability tests highlight anisotropic behaviour of the bricks depending on the extrusion direction during the production process. The results confirm that the extrusion process has a major influence on the orientation of clay layers and has an impact on the mechanical and physical properties (perpendicular or parallel to the direction of extrusion). It could be interesting for brick manufacturers to take this feature into account during their processes and so improve the characteristics of their bricks for wall construction by adapting the laying direction of the brick to the geometry of their bricks and the direction of their extrusion.

ID 272 - **Preparation and physico-mechanical characterization of gypsum-corn husk boards for construction purposes**

Virginia Barbieri, Cristina Siligardi, Tiziano Manfredini
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Nowadays most of indoor non load bearing walls are made of or lined with gypsum-based products chosen by architects for their performance and different properties, e.g. low cost, fire resistance, thermoacoustic properties, aesthetic aspect etc. The main drawback associated with these type of materials, like panels, is their brittleness under stress. Failure without significant deformation occurs without warning, thus representing a safety issue. It is not without reason that civil engineers prefer ductile fractures over brittle ones since time is allowed for people to leave the building before it collapses. Hence, methods that potentially could modify brittle failure of gypsum products are of interest. A viable way to reach this goal is the introduction of vegetal fibers as reinforcement. This approach is particularly attractive considering the huge amounts of agricultural fibrous residue waste that annually are accumulated in different parts of the world. In this context, corn husk, being a by-product of maize

cultivation, is a great resource of low-cost biofiber and thus an excellent candidate as filler for the production of fiber-gypsum boards. The aim of this work is thus to study the potential application of corn husk as filler for manufacturing gypsum-corn husk boards destined as lining material of inner walls and ceilings. The influence of some parameters (i.e. fiber dimension, amount of added fibers, water to gypsum ratio) on the physical and mechanical properties of gypsum was evaluated. The fibers were subjected to chemical pre-treatments in order to improve their adhesion to the gypsum matrix. The surface of the fibers was studied using FTIR and SEM. The mechanical properties of the composite materials were investigated and discussed. The mechanical tests showed that even small additions of fibers lead to an enhanced toughness of the composites, but the compressive strengths was reduced compared to pure gypsum.

ID 286 - **Experimental investigation of cement mortar reinforced with natural fibers**

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The big demand of energy in the building is one of several factors that have an impact our life and environment. One of the promising alternatives to this problem of is the thermal insulation of building with the use of biomaterials from vegetal and agriculture waste. These biomaterials need a low energy consumption for their production, reduces CO_2 emission and is renewable materials. In this work, several samples constituted with cements, sand and reinforced with a several concentration (from 5 wt. % to 30 wt. %) and size of date palm fibers (DPF) were prepared. Compressive strength and thermal conductivity measurement were conducted on these biomaterial samples according standards. The results showed that the compressive strength and thermal conductivity decreases with increase of DPF content. An optimal composition of this bio-concrete was find taking into account mechanical and thermal properties according RILEM classification. Finally, we have shown that our material may has great potential for use as an insulating material with favorable compression strength in the field of construction, as it can also improve the comfort level and participate to solve the problem initially noted.

ID 297 - **PEPIN Bio**

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Regulation concerning environmental communication for construction and decoration products require to realize EPD (Environmental Product Declaration). An EPD permits to companies to communicate, transparent and comparable informations, about the life-cycle environmental impact of their products. Moreover, the new French label E+, C-, which prefigures the new "responsible building" regulations, is also based on the EPD of construction products. EPD are therefore essential today when a manufacturer wants to put a building product on the market. Completing them is complex and costly, and usually involves external experts. Moreover, EPD are carried out for a given product and changes on the product (change of constituents, improvement of the dosages, etc.) require to rmake new EPD. All of this represents a significant cost for manufacturers (often SMEs) and is a brake on innovation process. The object of PEPIN Bio project is to create a parameterized tool allowing the actors of the biobased industry (mostly manufacturers) to produce their EPD via a web interface. Thanks to this tool, EPD will be economically and technically accessible for companies that develop and produce biobased building materials, which are mostly small and medium-sized companies and do not always have the possibility to have these skills internally. Such a tool is innovative for the sector because it does not exist today for this particular building products family in strong development. The project will be based on European standards (EN 15804, Ecoinvent environmental database ...). The data will be modelled from SimaPro software. A web interface will then be created so that the manufacturers can realize individual or collective EPD of their product(s).

ID 302 - **Variability of hemp shives: study through IBIS and CHANVRISOL projects**

Hélène Lenormand[1], Arthur Hellouin de Ménibus[2,3], Jean-Baptiste Besnier[1], Nathalie Leblanc[1]
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There is a growing interest in the study of biobased materials for thermal insulation, in order to reduce the environmental impact of building works. In the composition of biobased insulating materials, different agricultural by-products can be used and the impact of their intrinsic characteristics on the required performances for thermal insulation must be studied. The variability of the agricultural by-product is an essential parameter to consider. Indeed, the properties of vegetal particles that come from plant stalks, such as hemp, colza, sunflower or flax, might be influenced by the plant growth conditions and their after harvest processing. The following variability sources might be relevant to consider: weather conditions, soils nature, plants organization, variety, retting process, defibration, crushing, sieving. The present study is focused on the characterization of ten hemp shives, coming from all over France hemp producers. The investigated physico-chemical properties are water absorption and sorption, bulk density, particle size distribution and dust ratio. The results are compared to other biomass resources: flax and colza. These characterizations were performed in the framework of two projects: 1. The IBIS project, “Isolants BIosourcéS pour le bâtiment” (“biosourced insulators for building sector”). One of the aims is the development of a spraying insulation mortar lightened with biobased particles; 2. The CHANVRISOL project, “développement de la filière CHANVre en circuit court pour l’ISOLation des bâtiments normands” (“development of hemp production in short circuit for buildings insulation in Normandy”). One of the aims is to characterize several hemp raw products, to evaluate their variability and their impact on the required performances for thermal insulation (thermal conductivity, hygroscopic behaviour…).

Room 11

JEMAB 2017 propose à tous les acteurs de la construction une journée d'information et de débats sur les solutions biosourcées autour de sujets tels que les évolutions de la réglementation, les systèmes et produits biosourcés présentés par les industriels ou encore la mise en place du GDR Matériaux Biosourcés. Cette journée , organisée par RECI et BioBuild Concept, s'articule autour de quatre ateliers axés sur les sujets stratégiques de la filière construction biosourcée :

ATELIER 1 : Le végétal au cœur de l'architecture bioclimatique
Le végétal prend une place de plus en plus importante dans les approches d'écoconception des bâtiments et, plus largement, dans une architecture bioclimatique intégrant l'environnement du bâti. Si le recours aux matériaux biosourcés ouvre de larges perspectives, la végétalisation des toitures, des murs et des espaces environnants répondent à des objectifs tant techniques qu'environnementaux ou sociaux. Sous le format d'une table ronde et en privilégiant les échanges, cet atelier permettra de conforter les approches et les visions à différentes échelles : matériaux, bâti, architecture, quartier, etc.

ATELIER 2 : Les solutions biosourcées pour l'écoconception des bâtiments
Les matériaux et solutions biosourcés évoluent rapidement et l'offre se consolide de jour en jour, tant par l'arrivée de nouveaux produits que par les évolutions qualitatives des solutions existantes. Les fabricants de matériaux et leurs partenaires confirment leur professionnalisme et leur capacité à répondre aux exigences de performances et de fiabilité du secteur. Durant cet atelier les producteurs et les centres d'innovation mettront en avant leurs innovations, leurs démarches et leurs propositions au travers de présentations courtes et imagées. Les participants pourront ensuite échanger avec eux dans l'espace d'exposition du congrès lors des différentes pauses.

ATELIER 3 : La réglementation bas carbone : ambitions et réalités
La réglementation concernant les performances énergétiques des bâtiments évolue rapidement depuis plusieurs années. Elle connaît actuellement un tournant majeur avec l'ambition d'aller d'une approche « énergétique » à une approche « environnementale », notamment avec la future RBR 2020 (règlementation bâtiment responsable) et, pour ce qui est déjà en place, avec l'arrivée du labels BBCA ou du label d'état E+C-, préfiguration d'une règlemention 2018. Ces évolutions, ainsi que différents décrets et arrêtés récents (bonus de constructibilité, végétalisation des établissements commerciaux, bâtiments publics neufs) devraient favoriser le recours aux matériaux biosourcés. Cependant, les performances environnementales de ces matériaux sont-elles réellement prises en compte ? Les critères retenus sont-ils à la hauteur des attentes, en particulier en ce qui concerne le stockage du carbone ? Quelles seront les prochaines évolutions ? L'objectif de cet atelier est d'éclairer ces questions en s'appuyant sur l'expertise de personnalités particulièrement impliquées dans la démarche et de dégager une ligne d'action propre à donner la place qui leur revient aux constructions biosourcées.

ATELIER 4 : GDR Matériaux de Construction Biosourcés et Cluster RECI : les clés de la structuration de la filière
La filière de la construction biosourcée regroupe de nombreux acteurs extrêmement diversifiés par leurs activités, leurs dimensions, leur répartition géographique ou encore leurs ambitions. La mise en synergie de ces acteurs, la cohérence de leurs actions et leur capacité à s'organiser sont des paramètres indispensables du développement significatif de cette filière. Les besoins de structuration sont mis en avant depuis de nombreuses années et nécessitent l'émergence d'outils appropriés, en adéquation avec le contexte. Ce quatrième atelier propose d'échanger sur ce thème en s'appuyant sur la présentation de deux organismes fédérateurs qui se mettent en place. D'une part, le Cluster RECI dont l'ambition est d'accompagner le développement du marché biosourcé de ses adhérents et, plus largement, de la filière. D'autre part, le GDR Matériaux Biosourcés (Groupement de Recherche), dont l'objectif est de favoriser et de coordonner la dynamique d'innovation et de R&D particulièrement active dans le domaine.

Thursday 22nd

JEMAB

10h	Accueil des participants – *Room 11* ***Christian Marie**, Président de RECI*
10h30	Ouverture ***José Caire**, Directeur Villes et territoires durables de l'ADEME*

ATELIER 1 : Le végétal au coeur de l'architecture bioclimatique

10h50	Table ronde et débats ***Christian Hackel**, M'Cub, member de RECI* ***Christian Charignon**, architecte, urbaniste, gérant de Tekhnê architects et urbanistes* ***Sébastien Sperto**, Directeur d'études projets urbains, Agence d'Urbanisme de Lyon* ***Laurent Arnaud**, Chef du département Bâtiments durables du CEREMA, member de RECI*

ATELIER 2 : Solutions biosourcées innovantes

11h45	CIDECO Centre d'Innovation et de Développement pour l'Ecoconstruction ***Alaa Chateauneuf**, CIDECO*
11h52	La laine du Massif central dans tous ses états ***Stephen Poeuf**, Terre de Laine*
12h	NOVIDEM, l'isolant qui cartonne ***Christian Marie**, NOVIDEM*
12h07	Les solutions biosourcées en ciment naturel ***Marco Cappelliarri**, VICAT*
12h15	BIOSYS, le bloc de chanvre à emboîtement ***Nicolas Guillaume**, Vieille Matériaux*
12h22	Garantir les performances du béton végétal projeté ***Laurent Goudet**, AKTA*
12h30	Les développements régionaux de la construction en paille ***Jean-Baptiste Thévard**, ACCORT-Paille & RFCP*
12h	Déjeuner - Buffet

ATELIER 3 : Labels et réglementation carbone

13h45	Réglementation bas-carbone : ambitions et réalités Table ronde et débats ***Bernard Boyeux**, BioBuild Concept* ***Emmanuel Acchiardi**, DHUP, Sous-Directeur de la Qualité et Développement Durable dans la Construction* ***Hélène Genin**, déléguée générale, BBCA* ***Gérard Deroubaix**, Directeur du Pôle Environnement – Economie et Bioressources FCBA*
14h45	Pause

ATELIER 4 : Structuration de la filière construction biosourcée

15h	Recherche, production, industrie, maîtrise d'oeuvre, entreprises : quelle(s) organization(s) pour structurer et représenter la filière de la construction biosourcées ? Table ronde et débats ***Denis Dangaix**, ARENE Ile de France* ***Sofiane Amziane**, Polytech'Clermont, GDR Matériaux Biosourcés* ***Thibault Chastagnier**, ITECH Bois, RECI* ***Jean-Michel Grosselin**, PAVATEX, Association des Industriels de la construction biosourcée (AICB)*
16h	GDR Matériaux Biosourcés : lancement et fonctionnement ***Sandrine Marceau**, IFSTTAR, GDR Matériaux Biosourcés* ***Christophe Lanos**, INSA Rennes, GDR Matériaux Biosourcés*
12h30	Conclusions ***Emmanuel Acchiardi**, DHUP, Sous-Directeur de la Qualité et Développement Durable dans la Construction*

18h30	Départ pour le repas de gala *Domaine de Marrand*

Friday 23rd

Atelier TyCCAO

Room 11

L'atelier de concertation TyCCAO (Typha Combustible et Construction en Afrique de l'Ouest) est le premier atelier de travail d'un ambitieux programme de valorisation des roseaux du fleuve Sénégal, programme soutenu par le Fond Français de l'Environnement Mondial (FFEM). Cette rencontre s'inscrira dans le cadre d'un voyage d'étude en France des chercheurs et étudiants sénégalais et mauritaniens, voyage organisé par les porteurs de TyCCAO, notamment, par BioBuild Concept.

Workshop on Bio-adhesives

Room 7

9h10	*Application of a bottom-up approach to study bio-adhesives molecular conformation* ***Dr. Ellie Fini & Dr. Albert Hung***
9h25	*Alteration of silica fume surface properties to reduce their agglomeration and enhance their effectiveness to improve asphalt resistance to oxidation* ***Dr. Nader Abutalib***
9h40	Multi-functional bio-based nano-composites using bio-resin ***Dr. Nima Rahbar***
9h55	Surface modification of silica nanoparticles with bio-resin ***Dr. Lifeng Zhang & Sidharth Karnati***
10h10	Developing a bio-based nano-composite via intercalation of sodium montmorillonite ***Dr. Albert Hung***
10h25	Break
10h40	Commercial potential of bioresins and their success in thermosetting composites: an overview ***Rebecca E.M. Lutton, Su Taylor, Mohammed Sonebi & Adrian Murphy***
10h55	Synthesis and characterization of a bio-based binder for application as a binder for hemp concrete ***Thomas Le Hen, Shahrzad Hosseinnezhad*** & ***Daniel Oldham***
11h10	Technological innovation on bio-adhesive: lab to market place ***Dr. Mahour Parast***
11h40	Panel discussion and questions
12h	Lunch

Learning objectives and target audience

The SAB symposium was organized with support from the National Science Foundation (NSF), NC A&T and Polytech Clermont-Ferrand. The objective of the SAB symposium is to convene prominent leaders in the area of bio-based construction materials to discuss the current state-of-the-art and near term challenges to promoting a bio-based economy. This symposium will enable participants to discuss and identify critical knowledge gaps in bio-based materials, and to develop strategies to accelerate research and discovery while proposing innovative and transformative solutions.

Application of a bottom-up approach to study bio-adhesives molecular conformation

Dr. Ellie Fini, NC A&T State University

The study focuses on characterizing interaction mechanisms between bio-adhesive and petroleum based asphalt using atomistic modeling along with experimental approach. Molecular dynamics simulations utilizing reactive force fields is being conducted to study how the two materials interact and affect rheological and aging characteristics of the bio-modified asphalt. It was shown that introduction of bio-asphalt to petroleum based asphalt changes the chain conformation and molecular packing of petroleum based asphalt extending its amorphous region. The interchain interactions between the long alkyl chains of the bio-adhesive and those of the asphalt molecules' side chains disturb stacking of the aromatic cores of the asphalt molecules. This in turn, can facilitate segmental motion in asphalt molecules and increase amorphous components as evidenced by our experimental results through XRD and TEM as well as molecular dynamic simulations. The result of the study can lead to engineering bio-modified asphalt with specific rheological properties to be used in pavements in presence of high RAP and RAS mixes. The study results so far has shown that introduction of bio-adhesive at reduced mixing and compaction temperatures can help reduce the stiffening effects caused by the introduction of high percentages of RAP. This in turn, can facilitate application of higher percentages of RAP in new construction while enhancing pavement sustainability.

Dr. Fini is an Associate Professor of Civil and Environmental Engineering at North Carolina A&T State University and the Director of Sustainable Infrastructure Material (SIM) lab, which includes a fully equipped Superpave binder and mixture laboratory as well as surface morphology and physiochemical characterization equipment. She received her Ph.D. at the University of Illinois at Urbana-Champaign in 2008 on characterizing interfacial properties of adhesive and sealants. Her research activities, which are at the boundaries of civil, biological and agricultural engineering, focus on the production, characterization and atomistic modeling of bio-binder from bio-mass, synthesis of recycling agents and rejuvenators as well as rubberized and bituminous adhesive and sealants. She has ample experience in the area of bio-asphalt and bio-based construction materials including physicochemical and rheological characterization as well as performance evaluation of asphalt with respect to durability and moisture damage as well as low temperature cracking characterization.

Alteration of silica fume surface properties to reduce their agglomeration and enhance their effectiveness to improve asphalt resistance to oxidation

Nader Turki Abutalib[2], Daniel Oldham[1], Elham Fini[1]

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This paper investigates the effects of adding biomaterials such as bio-char and bio-binder to reduce asphalt oxidative aging and disperse the agglomeration of silica fume particles in silica fume modified binder. The performance characteristics of silica fume modified binder (with and without biomaterials) are compared with those of base asphalt. The following research hypotheses were investigated: silica fume will enhance asphalt's aging resistance; and biomaterials will act with a higher percentage of

agglomerated silica fume particles in asphalt to increase the effectiveness of aging resistance while elevating the agglomeration effect. A rotational viscometer was used to study the effect of adding bio-char and bio-binder to silica fume modified binder on the high-temperature properties of the asphalt binder. Fourier transform infrared spectroscopy analysis was used to determine the chemical compounds of the biomaterials-modified silica fume modified binder matrix. Scanning electron microscopy was used to observe the surface morphology and analyze microstructure characteristics of materials. It has been shown that the introduction of 4% silica fume to asphalt can reduce asphalt oxidative aging. However, the challenge in using 8% silica fume was found to be the agglomeration of silica fume nano-particles to form micro-size clusters, which can reduce silica fume's effectiveness while making asphalt binder more susceptible to shear. The results indicated that the addition of biomaterials to SFMB with 8% silica fume significantly helped disperse the silica fume agglomeration and improve the aging resistance of the silica fume modified binder.

Nader Abutalib is a NCAT PhD graduate, Computational, Civil Engineering. Managing pavement projects at Transportation Department, Makkah, KSA. He had been working North Carolina A&T State University in the Innovation Center on asphalt sustainability characterization. His work focuses on the study of functionalization of silica fume and bio-materials to reduce asphalt aging. He Joined NC A&T in August 2012 to work on asphalt oxidative aging reduction with bio-material functionalization.

Multi-functional bio-based nano-composites using bio-resin

Dr. Nima Rahbar, Worcester Polytechnic Institute

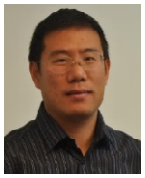
This talk focuses on the fundamental ideas arising from understanding the mechanisms behind the superior mechanical properties of biological materials through two specific examples of nacre and bamboo. The mechanical behavior and toughening mechanisms of abalone nacre-inspired multilayered materials are explored. In nacre's structure, the organic matrix, pillars and the roughness of the aragonite platelets play important roles in its overall mechanical performance. A micromechanical model for multilayered biological materials is proposed to simulate their mechanical deformation and toughening mechanisms. The modeling results are in excellent agreement with the available experimental data for abalone nacre. The results demonstrate that the aragonite platelets, pillars and organic matrix synergistically affect the stiffness of nacre, and the pillars significantly contribute to the mechanical performance of nacre. It is also shown that the roughness induced interactions between the organic matrix and aragonite platelet, represented in the model by asperity elements, play a key role in strength and toughness of abalone nacre. The highly nonlinear behavior of the proposed multilayered material is the result of distributed deformation in the nacre-like structure due to the existence of nano-asperities and nano-pillars with near theoretical strength. Finally, tensile toughness is studied as a function of the components in the microstructure of nacre. Bamboo, a fast-growing grass, has higher strength-to-weight ratios than steel and concrete. The unique properties of bamboo come from the natural composite structure of fibers that comprises mainly cellulose nanofibrils in a matrix of intertwined hemicellulose and lignin called lignin-carbohydrate complex (LCC). Here we have experimentally and numerically studied mechanical and fracture properties of bamboo at multiple scale. We have utilized atomistic simulations to investigate the mechanical properties and mechanisms of the interactions of these materials in the structure of bamboo fibers. It is shown that a control hemicellulose model has better thermodynamic and mechanical properties than lignin while lignin exhibits greater tendency to adhere to cellulose nanofibril. Therefore, the role of hemicellulose found to be enhancing the mechanical properties while lignin provides the strength of bamboo fibers. The study suggests that the abundance of hydrogen bonds in hemicellulose chains is responsible for improving the mechanical behavior of LCC. The strong van der Waals forces between lignin molecules and cellulose nanofibril is responsible for higher adhesion energy between LCC/cellulose nanofibrils. We also found out that the amorphous regions of cellulose nanofibril have the weakest interface in a bamboo fiber. They ultimately determine the strength of fibers.

Dr. Rahbar joined WPI in August 2012 as an Assistant Professor. His research interests are in the area of bioinspired design of materials with an emphasis on mechanical and thermal properties across multiple scales. Dr. Rahbar has also won several awards including TMS Young Leader's award in 2013, Air Force Summer Faculty Fellowship Award in 2013 and NSF CAREER award in 2012. Dr. Rahbar recently received the 2015 Outstanding Reviewer award from the ASCE Journal of Nanomechanics and Micromechanics. His graduate students have received multiple best poster awards in national and international meetings. Currently, he is the chair of Biomaterials committee of TMS.

Surface modification of silica nanoparticles with bio-resin

Dr. Lifeng Zhang and Sidharth, Karnati, NC A&T State University

This study focuses on surface modification of silica (SiO_2) nanoparticles with silane coupling agents as well as bio-binder. The surface-modified silica nanoparticles were characterized and confirmed by FTIR. Effects of silane coupling agents and bio-binder on size, agglomeration (stability), and morphology of the surface-modified silica nanoparticle were characterized by dynamic light scattering (DLS) and scanning electron microscope (SEM). The results indicated that surface modification of silica nanoparticles with silane coupling agents and bio-binder could improve silica nanoparticle stabilization in asphalt and further improve its property.



Dr. Zhang is currently an assistant professor of nanoengineering at the Joint School of Nanoscience and Nanoengineering (JSNN) of North Carolina Agricultural and Technical State University and the University of North Carolina at Greensboro. He earned his Ph.D. degree in Fiber and Polymer Science and Engineering from the University of California at Davis in 2006. Dr. Zhang has a firm background in fiber and polymer materials. He has gained his research interests in materials at nanometer scale. The advanced nanomaterials developed in his research have seen a wide range of applications such as energy conversion and storage (e.g. dye-sensitized solar cells and supercapacitors), optical/gas/bio sensors, photo-catalysis, ballistic protection, biomedical uses (e.g. bio-separation, antimicrobial fabrics, dental composites, scaffolds for tissue engineering and controllable drug release), and etc.

Sidharth Reddy Karnati is a doctoral Student of Nano Engineering at North Carolina A&T State University; he completed his master degree in Mechanical Engineering in 2014 focusing on fracture mechanics of composite materials (Carbon fiber/Epoxy), modified mixed-mode fracture criteria using mode I, II and mixed mode (I-II) fracture testing for composite materials. His PhD study is on surface modification of nano-fillers in order to provide better properties (increased fracture resistance) in composite materials and improve properties like resistance to aging in asphalt binder. He has ample experience in material characterization of modified materials (silica nano particles and nano fibers) along with mechanical characterization (fiber/epoxy system). Also has experience in physicochemical, rheological characterization and in performance evaluation of asphalt with respect to durability and moisture damage.

Developing a Bio-based Nano-composite via Intercalation of Sodium Montmorillonite

Dr. Albert Hung, NC A&T State University

Polymer-clay nanocomposites have been proven to yield improved thermal stability and mechanical properties, compared to pure polymeric materials. However, creating nanocomposites with enhanced thermo-mechanical properties requires good compatibility and dispersion of the clay within the polymeric matrix. This paper introduces a bio-residue (BR) made from waste bio-mass to modify montmorillonite clay for use with linear low density polyethylene (LLDPE). The so called organo-clays were compounded, melt blended and injection molded with LLDPE, and the thermomechanical properties of the resulting nanocomposites were investigated with oscillatory rheometry, TG, XRD, ATR-FTIR, and TEM to assess the compatibility of the organo-clays and the polymer. The structure of the organo-clays ranged from partially intercalated to fully exfoliated. Hansen solubility parameters showed that almost all of the identified compounds in the Bio-Residue (BR) are soluble with polyethylene and can be used as compatibilizers.

Modeling based on density functional theory showed that an interplay between electrostatic screening and dispersion interactions determines interlayer spacing in polymer-clay nanocomposites. Organo-clay can have significant interactions with LLDPE, however, further improvement is needed to enhance homogeneity of the nanocomposite. The results showed that BR is a promising, inexpensive, and environmentally friendly compatibilizer for clay/polyethylene nanocomposites.

Dr. Hung is a Senior Research Associate at North Carolina A&T State University and a member of the Sustainable Infrastructure Material (SIM) lab. He received a Ph.D. in Materials Science and Engineering from Northwestern University in 2007 on the effects of patterning and spatial confinement on order in self-assembling systems. His interests and experience extend across the fields of materials science, chemistry, and biomaterials, specifically in the areas of colloidal and molecular self-assembly, microscopy and materials characterization, lithography, physics and chemistry of soft matter, surface science, biomimetics, and nanotechnology. His current research activities involve the chemical and morphological characterization of bituminous asphalt binders to elucidate the molecular and nanoscale effects of environmental exposure and chemical modification.

Commercial potential of bioresins and their success in thermosetting composites: an overview

Rebecca Emily Margaret Lutton, Su Taylor, Mohammed Sonebi, Adrian Murphy
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This paper reviews the current research in developing resins from bio-based sources. There are many economic drivers to encourage the development of biopolymers and composites derived from natural sources which are sustainable and replace the harmful toxins inherent in traditional petroleum-based composites. There has been much work on the use of natural fibres to replace synthetic fibres but the area of bioresins is relatively nascent. This focused review attempts to summarise the more promising bioresins derived from oils and other natural polyols such as carbohydrates and sugar alcohols for use in thermosetting resins which may be applied to the construction sector. The currently commercially successful bioresins are also discussed as well as their applications in industry. The review highlights the many successes in the area of bioresins and how they are comparable in many ways to conventional petroleum-based resins; however, there is need for more research and development to improve the technology around the extraction and processing of these bioresins. Further, there needs to be more direct comparisons to currently used composites to instil industry-confidence and therefore, cement the success of bioresins in the future.

Synthesis and characterization of a bio-based binder for application as a binder for hemp concrete

Thomas Le Hen[1], Shahrzad Hosseinnezhad[2], Daniel Oldham[2]
[1]Polytech Clermont–Ferrand, [2]NC A&T State University

This study tries to combine two technologies, the hemp concrete and the bio-oil produced from thermochemical transformation of swine manure, in order to improve their properties and enrich their applications. The study is based on the hypothesis that replacing the mineral binder usually used in hemp concrete by a bio-sourced binder can reduce the drying time, the energy consumption and the greenhouse gas production of the composite. This study is conducted in a two-step approach: the first one consists in develop a formulation of binder from the swine manure bio-oil that have properties compatible with it use in a hemp concrete composite. The second step consist to prove the viability of this binder for hemp concrete and to emerge the best ratio for the insulating application.

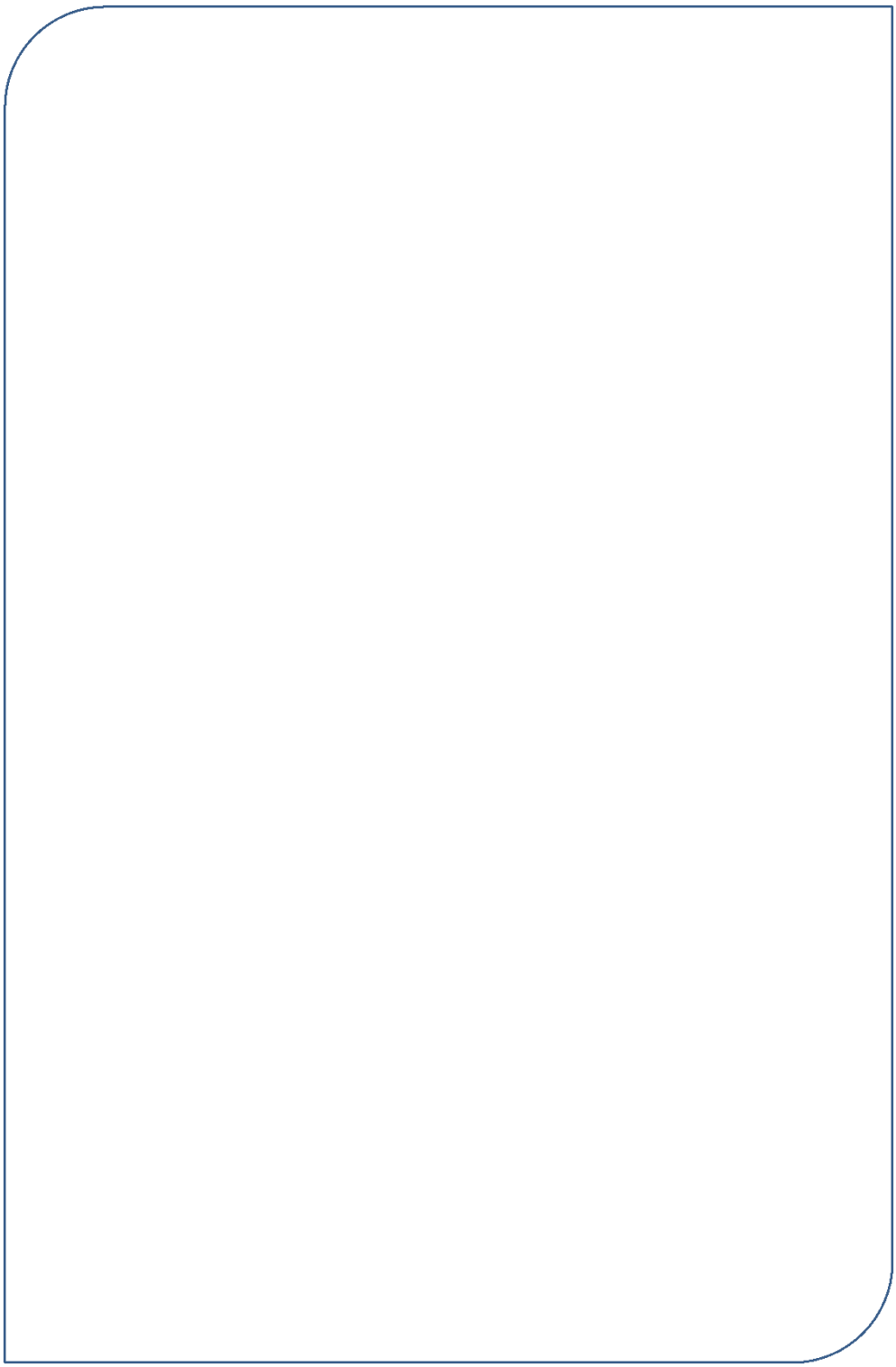
Le Hen Thomas is a last year master student in civil engineering at Polytech Clermont-Ferrand and a visiting researcher at North Carolina A&T State University in the Innovation Center for Materials, Method and Management. His work is focused in the study of hemp based composite for insulation under supervision of Pr. Amziane. He Joined the Dr. Fini's team at NC A&T in March 2017 to work on the development of a new bio-sourced binder to be used in the formulation of hemp concrete.

Technological innovation camp and bio-resin lab to market transition

Dr. Mahour Parast, NC A&T State University

The presentation discusses the opportunities and challenges associated with technology commercialization of bio-resin and bio-based construction materials. To address technological innovation and product development for bio-based materials, NSF Innovation Corporation (NSF I-Corps) program will be discussed, which outlines the path from invention to product development and technology commercialization. A case study will be presented to demonstrate the path from basic research to technology commercialization for the bio-binder technology.

Mahour Mellat Parast is an Assistant Professor of Technology Management at North Carolina A&T State University. His current research is focused on supply chain risk and resilience management, and process and product innovation. His scholarly works have appeared in several peer-reviewed journals such as Journal of Operations Management, International Journal of Production Research, International Journal of Production Economics, International Journal of Logistics Management, and Production Planning & Control. He is a member of Decision Sciences Institute (DSI), Production and Operations Management Society (POMS), and Academy of Management (AOM). Mahour received his Ph.D. in Industrial & Management Systems Engineering from University of Nebraska-Lincoln, M.S. from Iran University of Science and Technology (Industrial Engineering), and B.S. from Sharif University (Industrial and Systems Engineering). He has several years of industrial experience working as quality manager and strategic planner in the auto industry, electric power industry, and agriculture industry. He has been the principal investigator of several research and technology commercialization projects. In 2012, Mahour joined the bio-adhesive research team to evaluate commercialization of bio-adhesive technology as part of NSF Innovation Corps (I-Corps) project. He serves as the President and co-founder of the Bio-Adhesive Alliance (BAA), Inc., a spin-off company from NC A&T State University that produces bio-adhesive for construction and pavement applications from animal bio-waste.



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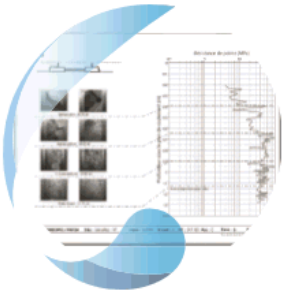

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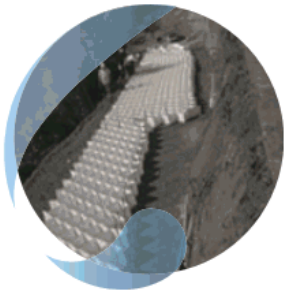

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