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DEPARTMENT OF GEOSCIENCES

MERU UNIVERSITY OF SCIENCE & TECHNOLOGY

UN HABITAT FOR A BETTER URBAN FUTURE

Global Partnership for Sustainable Construction and Resource Efficiency

Workshop booklet

SUSTAINABLE DEVELOPMENT GOALS

www.geoscienze.unipd.it/workshop-KA107

Webmaster: Alberto De Lorenzi, Department of Geosciences, University of Padua

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BACKGROUND

The idea of this workshop was conceived as part of the collaboration between **Meru University of Science and Technology (Kenya)** and **University of Padua (Italy)**, funded by the **ERASMUS+ KA107 mobility programme**[1]. This collaboration aims at investigating sustainable construction materials, and addressing issues related to the mitigation of CO_2 emissions and overall environmental impact of the cement and concrete industry, reinforcing extant **scientific collaboration between the African Union and European Union**[2], and extending the scope of this collaboration to partners based in other continents.
The objective is to train a new generation of researchers on topics related to the sustainable built environment that meet the **Sustainable Development Goals**[3], within an international and multidisciplinary environment.
This workshop provides an overview of:
a) the global impact of the construction industry, not only from the point of view of CO_2 emissions, but also from those of primary resource depletion and landscape modification (*SDG 12*, *SDG 13*);
b) the most recent advances in cement science for sustainable and resilient cities and infrastructures, using local raw materials and drawing inspiration from the circular economy paradigm (*SDG 9*, *SDG 11*);
c) research networking, international mobility and student/staff exchange in the field of sustainable cement and concrete production (*SDG 17*).

MAIN TOPICS

• Role of international mobility (focus on exchange with African institutions and intra-African mobility) and partnership in achieving Sustainable Development Goals related to the construction industry;

• Role of multidisciplinary research (linking engineers, materials scientists, chemists, physicists, geoscientists, urbanists, architects);

• Sustainable supply chain and circular economy in the construction industry; effect of quarrying/mining on the landscape and society;

• Use of local raw materials for construction (clay, biomasses, industrial by-products).

[1] https://ec.europa.eu/programmes/erasmus-plus/resources/documents/erasmus-international-credit-mobility_en
[2] https://africa-eu-partnership.org/en/stay-informed/publications/science-au-eu-partnership-2018-report
[3] https://sdgs.un.org/goals

MEET THE ORGANISERS

Joseph Mwiti Marangu is a Chemistry lecturer and researcher at the Department of Physical Sciences, Meru University of Science and Technology in Kenya. He holds a Bachelor of Science degree (Chemistry), Master of Science degree (Chemistry) and PhD in Chemistry. His current research is mainly focused on development, characterization, testing, modelling and application of construction materials which include but not limited to; blended cements, alkali activated materials/geopolymers, concrete admixtures and soil stabilizers.

He has received the following awards;

1. Three year PhD Scholarship by the African Development Bank (AfDB).
2. Best innovation on 'Eco-friendly low Cost Cement' in the Built Environment and Housing Technologies Category for the year 2020 by the Kenya National Innovation Agency.
3. Cardiff University (UK) 2021: HEFCW GCRF Fellowship Award on Circular-Cement' Local resources for Affordable and Sustainable Infrastructures in Kenya'
4. Leaders in Innovation Fellowship award for the year 2020 by the Royal Academy of Engineering.

He is a member of the International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM). He is also one of the co-ordinators for the Erasmus+ KA107 mobility programme between Meru University of Science and Technology (Kenya) and the University of Padua (Italy).

He has published widely in scholarly journals and attended a number of international conferences and workshops on construction materials.

Luca Valentini (University of Padua, Italy) is an assistant professor at the Department of Geosciences. He holds a PhD in Earth Sciences awarded by the National University of Ireland Galway. His expertise and research interests lie at the intersection between applied mineralogy, materials science and physical chemistry. He is an active member of the RILEM Technical Committees on Calcined Clays as Supplementary Cementitious Materials and on Carbonation of Concrete with Supplementary Cementitious Materials. He currently collaborates with several academic institutions based in the African continent (Kenya, Ghana, Cameroon, Tunisia) on the use of local raw materials for sustainable construction. He is a member of the departmental Internationalisation Committee, and local coordinator of the Erasmus+ mobility flow between Meru University of Science and Technology and University of Padua.

WELCOME FROM THE ERASMUS MUNDUS PROGRAMME REPRESENTATIVE IN KENYA

The Visibility of Erasmus+ Scholarship Programmes in Kenya
Jane Nduta Wambura

Erasmus+ is a European Union programme that basically supports education, training, youth and sports in Europe. Over the years, several students from around the globe have benefited from the programs and it now has an estimated budget of 26.2 billion euros for the phase beginning 2021 to 2027. This will mean that this new phase will have a double focus on social inclusion, green and digital transitions and the promotion of young people's participation in democratic life as compared to the previous funding period.

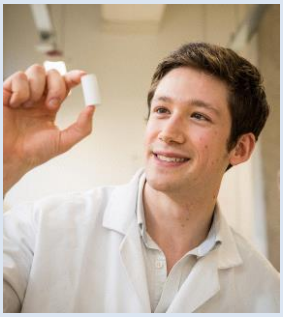
In Kenya, the Erasmus program has allowed short term mobilities from students, full term Erasmus joint master's beneficiaries, researchers, and staff to obtain credits and benchmarks in European countries as well as other African participating universities. With the ever-growing proposals and number of students in the last 4 years, it is evident that the numbers and the visibility of the program still needs to be improved. This will be for the benefit of students as well as staff in institutions with the new funding that has been rolled out. It is for this reason, that I am elated to see the partnership between the University of Padua and Meru University of Science and Technology come into fruition and I cannot wait to see the beneficiaries as soon as the program rolls out.

MEET THE SPEAKERS

Ghada Bassioni is Professor and the Head of the Chemistry Division at the Faculty of Engineering, Ain Shams University, Cairo, Egypt. She is an elected member of the executive bureau of the International Union of Pure and Applied Chemistry IUPAC, and a member of the Egyptian National Committee of Pure and Applied Chemistry, Egyptian Academy of Scientific Research and Technology. She was also appointed as the Egypt-Germany, Egypt-Italy and Egypt-Japan coordinator, Science and Technology Development Fund (STDF), Egyptian Ministry of Higher Education and Scientific Research from 2013-2021 and has been a member of the Global Young Academy from 2013-2018. She has been recognized with several national, regional and international awards. She is a Fulbright, Next Einstein Forum, African Science Leadership Program and "Lindau.Alpbach.Berlin." fellow since 2016. She has organized a significant number of scientific and gender-related workshops and conferences, and co-led the Women in Science working group of the Global Young Academy for several years.

Mark Bediako is an employee of the CSIR-Building and Road Research Institute, Ghana and currently the Head of the Advanced Material Science Division as well as the Civil and Materials Engineering Laboratory. He holds a PhD in Material Science Engineering, an MPhil in Materials Engineering and a first degree in Chemical Engineering all obtained from the Kwame Nkrumah University of Science and Technology in Kumasi, Ghana. He is a member of the Ghana Institution of Engineering and with the chemical/mining engineering section. Dr. Bediako's research works are focused on concrete sustainability and durability, cement science, supplementary cementitious materials and geopolymers. He has contributed to the world of research some significant number of research publications both locally and internationally. Currently he is researching on optimizing Ghanaian low grade calcined clays for concrete works as well as collaborating with University of Padua on the sustainable use of material resources for construction.

Raine Isaksson is associate professor in Quality Management in the department of Civil and Industrial Engineering, Uppsala University, Sweden. Raine's research focuses on how Quality Management can support Sustainable Development. Particularly quality and process-based system models are used to describe value networks. Raine has a particular interest in the building value chain which includes studies of sustainability of building materials in Sub Saharan Africa. Raine has a background as a chemical engineer and has some 20 years of experience as development engineer, line manager and consultant, including some 10 years of managerial work in Africa.



Alastair Marsh is a postdoctoral researcher at the University of Leeds, working on alkali-activated cements as well as the use of clays and soils in other types of construction. He has a background in materials science, and before starting a research career he worked as a sustainability consultant.

Jose Fernando Martirena-Hernandez graduated in Civil Engineering in 1983. He was awarded his PhD degree in 1988, and Doctor in Sciences (Dr.Sc.) in 2004, in subjects related to construction and materials. Part of his post graduate education has taken place in Central Europe (Germany and Switzerland) as Fellow of the Alexander von Humboldt Foundation. Professor Fernando Martirena is the director of the *Centro de Investigación y Desarrollo de Estructuras y Materiales*, CIDEM (Centre for Research & Development of Structures and Materials) at the Universidad Central de las Villas in Cuba. As RILEM Senior member he chairs the TC on Calcined Clays created in 2018. He has strong connections with the industry, mostly related to the swift introduction of LC3 in commercial practice.

Federico Monica is an Architect and a PhD in urban planning specialized in the analysis of urban areas and informal settlements in sub-Saharan Africa.
He is a consultant for NGOs and International agencies on issues related to urban development, participatory planning and interventions in informal neighborhoods, and he developed projects in 15 different African countries.
He is the co-founder of Taxibrousse studio, a consulting firm for international development and the founder of Placemarks, a project related to the assessment of Africa changing landscapes trough satellite images.
He is the author of several publications on the issues of urban development and informality in sub-Saharan Africa.

Jackson Wachira Muthengia is an established scholar and a University administrator. He has a Master of Science and PhD in Chemistry specialising in Cement Chemistry with the following as key areas of interest:

1. Use of non-conventional building materials including lime-pozzolana cement
2. Substitution of Ordinary Portland Cement (OPC) with low cost cement materials.
3. Use of self-repairing concrete or mortar by incorporating bacteria in concrete or mortar.
4. Chemical kinetics with key interest in adsorption and degradation of;

a) Fertilizers in farming and irrigation waters with regard to mosquito breeding waters and adsorption of key elements by plants

b) Re-use of industrial sludge with key interest in cooking and cosmetic oil sludge.

Muthengia has been the Dean of various schools at the University and now the Registrar (Academics, Research and Extension). He has won several research and development grants including the Global Challenges and Networking Fund, NACOSTI, National Research Fund (NRF), British Council Scholarship Grants among others.

Mauricia Nambatya is a Civil Engineer with an MPhil degree in Engineering for Sustainable Development from the University of Cambridge, UK and a BSc. Civil Engineering degree from Makerere University, Kampala.

She is the Country Manager of Haileybury Youth Trust (HYT Uganda), an Ashden Award winning organisation for sustainable buildings that trains young men and women in making interlocking bricks and construction of school infrastructure using the same.

She is passionate about empowering the next generation with skills for employment to improve livelihoods while protecting of the fragile environment in which we thrive.

Kolawole Adisa Olonade was awarded a PhD degree in Civil and Environmental Engineering from the University of Lagos. His area of specialisation is structural and material engineering.

He is a cement and concrete expert. He pioneers the use of cassava peel ash as replacement for cement in concrete, which granted him the German-African Innovation Incentive Award in 2018 by the German Government. He has been a Guest Scientist at BAM, Berlin and at University of Sao Paulo, Brazil.

He is a Fellow of the Nigerian Society of Engineers and initiator of Society of Cement and Concrete Researchers in Nigeria. He is an active member of RILEM and has participated in three Technical Committees.

Presently, he is a Senior Lecturer in the Department of Civil and Environmental Engineering, University of Lagos, Nigeria.

Mike Otieno is an Associate Professor in the School of Civil and Environmental Engineering at the University of the Witwatersrand in South Africa. He holds a First Class Honours Bachelors degree in civil engineering from the University of Nairobi, and Masters and PhD degrees in civil engineering from the University of Cape Town. He is registered with both the Engineers Board of Kenya and the Engineering Council of South Africa. His interests are in the fields of concrete technology, durability, service life prediction and repair and rehabilitation of reinforced concrete structures. He also has a strong passion in the progressive development of the next generation of academics and researchers on the African continent.

Daman K. Panesar Ph.D., P.Eng. is a Professor with the Department of Civil and Mineral Engineering, University of Toronto, Canada. Panesar's research activities are focused on the sustainability and durability of cement-based materials and structures with application to underground, nuclear, transportation and building structures. She serves on various national and international committees such as: Chair of Canadian Standard CSA-N287.5; Advisory Board Member and Division I Chair for the International Association Structural Mechanics in Reactor Technology; Research Management Committee for the India-Canada Centre for Innovative Multidisciplinary Partnerships; Member of the RILEM Technical Activities Committee. She also serves on the editorial board for Cement and Concrete Composites, Canadian Journal of Civil Engineering and RILEM Technical Letters

Alicia Regodon Puyalto is a Sustainable Housing Expert, part of the UN-Habitat´s Land Housing and Shelter Section, Global Solutions Division. Alicia assesses sustainable and future proof buildings and construction within the environmental, cultural, and financial paradigm of the 2030 agenda.

An international architect with a multidisciplinary background in architecture and urbanism. She has developed her career across Europe, Brazil, China, and Australia. With a human-centered and participatory approach to buildings and construction, Alicia has been part of public and private sector aiming to strengthen the sustainable buildings and construction strategies from the environmental, social, and financial perspective and searching for innovative and pragmatic solutions that are human centered and environmentally conscious.

Alicia balances her professional career with her research with the Buildings and Construction Department at the ETSAM, Technical University of Madrid.

Nonkululeko Radebe is a scientific researcher at the Karlsruhe Institute of Technology (KIT), Germany, and is carrying out a PhD in Physical chemistry. Her project is focused on the development and optimization of combined rheological and spectroscopic techniques in order to simultaneously study the physical and chemical properties of cementitious materials. She is a member the Sub-Saharan Africa representative on the RILEM Youth Council (RYC) which aims to attract, engage with and facilitate networking between young researchers and more experienced researchers. Apart from being a researcher, she is also passionate about education and involving young children in science through mediums of art, which is done through her organization, ArtScie, a development programme based in South Africa.

Kyle Riding is a Professor of Civil Engineering at the University of Florida. He obtained his Ph.D. in Civil Engineering from the University of Texas at Austin in 2007. He is a licensed professional engineering in Florida, Kansas, and Nebraska. His research currently focuses on novel cementitious materials and systems, ultra-high-performance concrete, concrete microstructure and durability, and concrete test methods. He is currently the chair of the Concrete Materials Technology committee of the Precast/Prestressed Concrete Institute and ACI Committee 231 Properties of Concrete at Early Ages. He is a voting member of ACI Committee 201 Durability of Concrete, ACI Committee 207 Mass Concrete, and ACI Committee 236 Material Science of Concrete committees. He is a member of the International Union of Laboratories and Experts in Construction Materials (RILEM), Systems and Structures (RILEM) committee 282-CCL: Calcined Clays as Supplementary Cementitious Materials and leads the task group on calcined clay performance in concrete. He is an Associate Editor of the American Society of Civil Engineering (ASCE) Journal of Materials. Dr. Riding was awarded the Wason Medal for Materials Research by the American Concrete Institute for his work on concrete materials in 2011, the ACI Young member Award for Professional Development in 2013, and the Transportation Research Board Concrete Section Best Paper Award in 2017. Dr. Riding teaches courses on concrete material science, microstructural characterization of cementitious systems, concrete durability, concrete structural rehabilitation, and railroad engineering.

Wolfram Schmidt obtained a Dipl.-Ing. degree from RWTH Aachen and a PhD from Technical University of Eindhoven. He has been working at the Federal Institute for Materials Research and testing since 2005, where he is responsible for the laboratory for concrete rheology and chemical concrete admixtures. He is secretary of the German Rheological Society, member of fib and RILEM officer. He is initiator of various educational and scientific networking programmes, among others ISEE-Africa (Innovation Science, Engineering, Education), the ACCTA conference series (Advances in Cement and Concrete Technologies in Africa) and the pan-African interlaboratory proficiency testing scheme PACE-PTS. In 2018 he was awarded the German-African Innovation Incentive Award for research on the conversion of bio-based wastes to high-tech concrete constituents He is also involved in a variety of activities related to sustainable construction, one of which has been the GLOBE Global Consensus on Sustainability in the Built Environment.

WORKSHOP ABSTRACTS

International and Intra-African Cooperation - Challenges and Opportunities

G. Bassioni
Faculty of Engineering, Ain Shams University, Cairo, Egypt

The journey towards African cooperation in development efforts and unity began about 60 years ago and has grown with the formation of some founded organizations through and because of the African Unity treaties highlighting this yearning for regional integration and cooperation. Fostering cohesion and solidarity among African countries within the global governance and trading system were a natural consequence. On a scientific research level empowerment of young people 'flowing' across African borders and scholars moving between the continent's universities to exchange knowledge and ideas with fellow Africans were observed. Acknowledged via African fora that make these efforts visible were witnessed. This helped promote greater intra-Africa internationalization. But what are the actual challenges that face Africans in this process? What are the opportunities?

Resource efficient housing in Burkina Faso and Sri Lanka. A multidisciplinary approach to strengthen the sustainable buildings and construction sector

A. Regodón Puyalto
Land Housing and Shelter Section, Global Solutions Division, UN-HABITAT, Nairobi, Kenya

The buildings and construction sector accounted for 36% of final energy use and 39% of energy and process-related carbon dioxide (CO_2) emissions in 2018, 11% of which resulted from manufacturing and procurement of building materials and products such as steel, cement and glass (GlobalABC, 2019)— making the building sector the single most significant industry in terms of emissions. With the building stock set to double by 2050, emissions, energy and resource consumption of the sector are set to increase.

The *SDG12 Resource Efficient Housing* programme is a multidisciplinary approach developed by UN-Habitat, UNEP and UNOPS to support governments in transforming their buildings and construction sector towards sustainable and resource efficient constructions.

The objectives of the program are, to strengthen national commitments and objectives for sustainable buildings and construction and to reinforce the technical resources in mainstreaming sustainability, resource efficiency, and climate change in the sustainable buildings and construction (SBC) sector to achieve the 2030 Agenda and the Paris Agreement goals.

To achieve this, a holistic approach to sustainability, with a focus on the material value chain has been developed, integrating local and international multi-stakeholders' expertise, a roadmap approach for the countries and developing and implementing a set of tools and resources to strengthen the countries SBC strategies.

Potential of bio-wastes as Replacement for Cement in Africa

K.A. Olonade
Department of Civil and Environmental Engineering, University of Lagos, Nigeria

Production of ordinary Portland cement has been implicated as a major emitter of global greenhouse gases contributing heavily to climate change. Meanwhile, different techniques are being developed to tame the carbon footprint of cement. Alternative source of energy, system optimization, use of supplementary cementitious materials (SCMs) and geopolymer techniques amongst others approaches developing. But in Africa, substantial quantities of bio-wastes are generated, which could be explored for use as SCMs. In this presentation, strategies to utilize bio-wastes for producing high-performance cement-based products are highlighted, which consequently guarantee sustainable construction. Challenges, prospects and expected action plans are equally presented.

Effect of Selected Important bacteria on Physic Mechanical Properties of Cement Mortar

D. Mutitu[1], O. Mulwa[2], R. Ngari[3], K. wa-Thiong'o[3], J. Muthengia[1]
[1]University of Embu, Department of Physical Sciences, Kenya
[2]Savannah Cement Limited, Athi River, Kenya
[3]Kenyatta University, Department of Chemistry, Kenya

Cement based structures are subject to degradation from a variety of sources. The sources may be induced from internal or external aggressive agents. Among the most common aggressive agents are sulphates and chlorides. Repair of degraded cement based structure is of paramount interest to most constructions. The repair includes physical, mechanical and chemical methods. Recent studies have shown that bio-chemical processes, using micro-organisms are viable methods of repairing concrete. This presentation will cover use of select important bacteria in degradation and repair of degraded cement mortar and use of beneficial bacteria to improve on the physicomechanical properties of cement mortar at laboratory levels. The degrading bacteria used include *Thiobacillusthioparus* and*Starkeya novella* while the beneficial bacteria considered are *Bacillus flexus*, *Bacillus megaterium* and *Lysinibacillussphaericus*. The cement mortars were prepared in the laboratory using Ordinary Portland Cement, and Portland Pozzolana Cement. The mortars were subjected to either deteriorating bacteria and tested for physicomechanical performance, or subjected to deteriorating bacteria for 56 days of curing and remediated with beneficial bacteria and tested for phsycomechanical performance, or subject to beneficial bacteria and tested for mechanical performance. The physicochemical performance tested included cement paste setting time, compressive strength, sorptivity tests, chloride and sulphate diffusivity and mineralogical analysis. The results show that the degrading bacteria degrade the mortar through the action of acidification which causes mortar disintegration and reduce physical performance of the mortar. The effect is more degrading when the bacteria is incorporated as mix water as opposed to attack from external source. The beneficial effect on non-deteriorated mortar is more when the bacteria is from internal source than external. The remediation of degraded mortar follows the same pattern but also depend on the type of bacteria incorporated.

Building a multidisciplinary international network as a young researcher: A personal story

N.W. Radebe
Institute for Technical Chemistry and Polymer Chemistry, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Research is progressing increasingly to more multidisciplinary activities. To realize the potential benefits of interdisciplinarity for future sustainable research activity, effective collaboration between experts from diverse disciplines is required. The role of an international network is increasingly more crucial as local and global challenges overlap. Although local problems often require local solutions, having an idea of previous solutions to similar problems aids in problem solving design efficiency. From the perspective of an interdisciplinary early career researcher, the approach to forming interdisciplinary networks is specific to ones needs and intentions. Additionally, collaborations can take shape in different forms and between different hierarches of researchers. Often it viewed as a top down approach were a student interacts with a professor or a senior scientist of a different field but even peer to peer relationships that are already built in the first years of university are a part of ones interdisciplinary network. Some practical examples of this will be shared and a personal journey of how one can go from studying one topic in a more chemistry focused field in the Southern Hemisphere to a more physics and engineering related topic in the Northern hemisphere.

An overview on changing landscapes – the use of satellite images to raise awareness about the effects of urbanization

F. Monica
PlaceMarks Africa, Italy

Urbanization rates in Africa have been the highest in the world for years, and as a result of this huge growth many of the continent's landscapes are rapidly changing.
On the one hand, the endless suburbs are growing in a disorderly manner, expanding the urban footprint more and more, on the other hand the supply and extraction of building materials radically change natural or rural areas.
The effects of these phenomena are evident along many roads of sub-Saharan Africa but can be perceived globally only through a view from above.
The paper proposes a reflection on the role of satellite images in the research and dissemination of information on urbanization challenges not only through the use of professional applications, GIS tools and algorithms but mainly thanks to free and accessible tools that allow a broad audience to acquire knowledge, investigate issues and raise awareness about the transformations of the landscape in progress.

Making concrete more sustainable – the use of alternative materials

M. Otieno
School of Civil and Environmental Engineering, University of the Witwatersrand, Johannesburg, South Africa

Inasmuch as concrete is still a universal material of choice for construction especially in developing countries, the process making and using concrete comes with negative socio-economic and environmental impacts which cannot be ignored. The growing scarcity of cement- and concrete-making materials such as water, mineral aggregates and so on only serves to aggravate the situation. Nevertheless, we have to proactively explore ways of making cement and concrete more sustainable while not compromising its desired engineering properties. This talk will focus on the use of alternative materials especially in the African context, and will take the approach of encouraging research on the use of locally available alternative concrete-making materials.

Research, resources and client requirements – how can we achieve more widespread adoption of Interlocking Stabilised Soil Blocks (ISSB)?

A. Marsh[1], M. Nambatya[2]
[1]School of Civil Engineering, University of Leeds, Leeds, United Kingdom
[2]HYT Uganda, Jinja, Uganda

Interlocking Stabilised Soil Blocks (ISSB) are a modern form of stabilised earth construction. They are made of soil (sourced on-site) mixed with a small (6-8 wt.%) amount of cement, and manually compacted with a mechanical block press. ISSB are growing in popularity in Uganda for a variety of construction projects, including school classrooms, community centres, settlements for displaced peoples and water storage tanks. They offer a more sustainable, higher quality alternative to fired clay bricks, and also prevent deforestation from firewood harvesting to fuel brick kilns. To reduce the cement requirement (which dominates the material cost and embodied carbon of ISSB), we are undertaking a research project investigating the use of rice husk ash as a supplementary cementitious material. We will share some of the material and resource challenges raised during this research so far (including sourcing rice husk ash, quality control of rice husk ash, and adapting testing programmes to Covid). We will also explore the broader challenges around adoption and acceptance of ISSB by potential clients (including quantifying environmental and cost performance, and validating long-term durability performance), and our perspectives on how these can be overcome.

Opportunities for alternative binders in block production - the case of Sub Saharan Africa

R. Isaksson, M. Rosvall,
Uppsala University, Sweden

Cement is the third largest source of anthropogenic emissions of carbon dioxide (CO_2), accounting for approximately 8% of global emissions in the world. Reducing emissions from the cement, the binder in concrete is a necessity. However, population growth and consistent high demands for infrastructure has caused the global emissions due to cement production to be continuously increasing. Yet, the questions to be answered are: Why do we keep concrete as the largest manufactured product on Earth by mass and the second most used substance in the world after water, although it has such a major environmental footprint? Why cannot other building materials replace concrete? The answer is clear and simple: there is no other alternative to concrete, which is a very versatile, widely available building material that can be used by everybody! Our modern developed societies require a built environment that is unimaginable without the widespread use of concrete that allows construction anywhere, at low cost, of complex and massive shapes. Portland Cement (PC) is currently the main driver for both price and CO_2 emissions for residential housing in sub-Saharan Africa (SSA). Excluding modern multistorey constructions in urban centres, a considerable part of residential housing in countries in SSA such as Uganda and Tanzania is built with concrete or sandcrete blocks. Providing shelter and housing to the growing population is a necessity, as access to housing is one the most basic human needs. Hence, it is important to provide access and simultaneously minimize the associated environmental impact. Utilizing locally abundant and economically viable materials to partly or fully substitute PC for residential housing needs could significantly increase affordability and reduce the carbon footprint. Combating both poverty and climate change in least and lowly developed countries. Uganda, Tanzania and Kenya all have natural pozzolanic material available in form of volcanic ash along the rift valleys, kaolin clay and high output of agricultural by-products. For example, Uganda is estimated to extract around 1 Mt volcanic ash annually, and kaolin clay reserve Pugu in Tanzania is estimated to be the largest reserve in Africa. This presentation quantifies opportunities for cheaper and lower carbon building blocks in Sub Saharan Africa.

Multidisciplinary approaches towards an inclusive, circular urban built environment

W. Schmidt
Bundesanstalt für Materialforschung und Prüfung (BAM), Berlin, Germany

In this century, along with climate changes, urbanisation is one of the most critical challenges humanity faces. It is inevitable that the expected growth is created as sustainable and resource saving as possible. However, urban growth will require enormous amounts and movements of construction materials, which in return will coin economic developments on the one hand along with ecologic impact on the other hand. And sustainability in the context of urbanisation goes far beyond this, as environmental challenges of urban growth in Africa are intimately linked to fundamental socio-economic aspects.

At the same time African urban growth perspectives offer a unique opportunity to develop yet unexperienced sustainability potentials. Local material solutions can create livelihoods, the availability of space and resources offers opportunities to create socio-economically responsive urban regions that can be future-oriented without losing tradition and cultural heritage. The absence of historically grown regulative frameworks for construction materials and technologies offers potentials for leapfrog innovation in terms of materials and construction technologies. The presentation proposes materials technologies that can help enhancing livelihoods in green, circular urban construction technologies. Technologies, value chains and stakeholder involvement are introduced and critically discussed, and case studies are presented to highlight feasible ways forward.

Some engineering, transport mechanism and embodied carbon of Ghanaian low grade calcined clay concrete

M. Bediako
Advanced Material Science Division, CSIR-BRRI, Ghana

The huge demand for concrete for residential and infrastructure development around the globe especially in developing countries is creating economic and environmental problems as well as scarcity of finite concrete materials. However, the use of cheaper alternative materials to partially replace cement is known to have positive influence on environment and cost of concrete as well as resource depletion of concrete constituents. This work used ACI method of concrete design to produce class 30MPa concrete utilizing calcined low-grade clay as partial replacement of cement between 10 and 50 wt.% and results compared with concrete containing no calcined material. Some engineering properties considered were compressive and flexural strength. For studies on transport mechanisms, the study considered volume of permeable voids (VPV) and chloride penetration. Embodied carbon of the various concrete produced were also estimated. The results of the study showed that even at high replacement value of 50wt.% of Portland cement with the calcined material, the characteristic strength of 30MPa was achieved with low chloride penetration as well as highly reduced embodied carbon as compared to the control and the other concrete mixes.

The complexity of introducing a novel cement in the context of Climate Change mitigation

J.F. Martirena-Hernandez
Universidad Central “Marta Abreu” de las Villas, Cuba

Cement production is accountable for approximately 8% of global CO_2 emissions. More than 80% of cement is producing in developing countries, where infrastructure is not yet created. Cement production depends on the availability of limestone, which is the main component of clinker (70-80%), and energy. Cement production in Africa is affected by the scarcity of limestone throughout the continent, so often clinker must be imported at high prices from Europe and elsewhere. Kaolinitic clays, however, are abundant in most African countries. If they are processed through thermal treatment and combined with limestone, the blend can replace up to 50% of clinker without compromising properties of the resulting cement. This novel cement formulation is known as “LC3” (www.lc3.ch), and has been developed by a consortium of research institutions in Switzerland, India and Cuba. Implementation of LC3 could become a sustainable pathway for Africa to increase local cement production with affordable, local raw materials. Further, the new cement can reduce up to 40% of carbon emissions, allowing developing countries to choose a green path for their development needs. The challenge is to build technical capacity for the assessment of local raw materials on site; this implies a collaborative work between the industry and the academia, with international support, to educate young generations of engineers and scientists on the new developments.

US experience and future potential use of local clay materials as an SCM

K. Riding, A. Zayed
University of Florida, Gainesville, USA
University of South Florida, Tampa, USA

Calcined Clay has been used in the United States as a locally-available material for 90 years. This material has had an excellent history of use to increase durability by reducing heat of hydration, mitigating the effects of alkali-silica reaction, and reducing chloride permeability. While other supplementary cementitious materials (SCMs) like fly ash and slag cement took over the market for several decades due to low costs, calcined clay is seeing a renaissance. Calcined clays are available widely in the U.S. Southeast and have the potential for development and use. While these materials have the potential to reduce cost and greenhouse gas emissions compared to Portland cement only mixtures, interest in the U.S. is principally related to durability. As part of a recent study, locally available the research team collected, calcined, and tested for strength and durability against carbonation, chloride ingress, and sulfate attack kaolinite-bearing clays in Florida and Georgia. Their durability was compared against that measured for industrially produced calcined clay. Locally-sourced calcined clays can have excellent service life against corrosion and sulfate attack if the water-cementitious material ratio and gypsum addition are proportioned properly.

Availability and sustainability of industrial by-products used in cement-based construction materials

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Nations around the world have developed roadmaps and strategy frameworks with aims to reduce climate impacts associated with construction of structures and infrastructure. Several of these roadmaps have identified approaches and targets at each stage of the value chain. There is a general consensus that there is a need to actively push a multi-pronged approach at all levels of the value chains in order to achieve the target reductions. These global efforts towards sustainable design and construction warrant efficient use of resources. In particular, the basic trajectory shows that the global demand of industrial products leads to an increase in waste production, and at the same time, the average cost is increasing for disposing and managing industrial waste. Thoughtful use of industrial waste is only one aspect that contributes to sustainable construction. Important and practical aspects pertaining to decision making surrounding material choice are: (i) local availability, (ii) consistency of quality; (iii) conformance with codes and specification; (iv) trade-offs between material properties, and economic and environmental burdens and benefits and (v) methodological choices associated with life cycle assessment. Some of these aspects will be illustrated with a case study example. Fly ashes, collected from coal-fired power stations serving three Indian communities namely, Banga, Roorkee, and Nagpur. The mineralogical, chemical, and physical properties of the investigated fly ashes varied over a wide range and were assessed in accordance with codes related to chemical requirements (IS 3812, CSA 3001, and ASTM C618) for use as a pozzolan or supplementary cementitious material in concrete. Economic and environmental assessments pertaining to material design decisions are also addressed.