Preface to "Engineered Materials for Sustainable Structures"

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Abstract. The development of sustainable, reliable and resilient materials and technologies is one of the most compelling challenges of scientific and technological research in the construction sector. To achieve this goal, multiple research areas must work together along the entire product chain, from design to testing, from manufacturing to end-of-life provision. In this collection of papers, we present the last advances in the field of sustainable materials and structures as they appear in the proceedings of the 2021 edition of the international workshop "*Engineering Materials for Sustainable Structures*" (EM4SS'21) organised by the University of Modena and Reggio Emilia under the auspices of the Italian Industry Association for composite materials (Assocompositi). This collection of proceedings focuses over four main topics, ranging from the investigation of the mechanics of composite materials to the discussion of the important issues connected to durability and reliability, from the analysis of corrosion of rebars embedded in exotic matrices to assessing life-cycle (LCA) and end-of-life provisions of partially recycled composites. All together, these different viewpoints and approaches to modern composite systems help form an updated and broad-minded picture of the current trends in complex material development and management, possibly enlightening future trends and prospects.

Introduction

The rate of advancement in the field of composite systems has increased considerably over the last decades and stands at the basis of the significant progression in the emergence of new systems, while deepening the understanding of existing consolidated solutions. The ever-growing demand for novel high-performance and environmentally-friendly materials and processes for the construction sector clashes with the unsustainable impact of large-scale production of cement based materials worldwide, whose carbon dioxide emissions account for about 8% of the total world emissions. It is worth reminding that the largest part of such impact is due to the hardening process itself, as opposed to the burning of fossil fuels during cement production. Therefore, it appears fair to say that the construction industry that we see today is destined to undertake large paradigm changes in the near future, to be able to meet the impending demands related to climate change. In this context, it is conceivable that alternative materials and technologies will displace existing processes, in perhaps one of the farthest reaching technology shifts of our times. Both the academic and the industrial communities are joining efforts in this direction, as documented by the numerous collaborative industrial projects and scientific researches currently active in the field [6, 3]. The magnitude of the challenge that we face in the effort of drastically reducing the environmental impact of human activities is best framed by the United Nations 17 goals to change our world, all of which share the quest for a sustainable development [1].

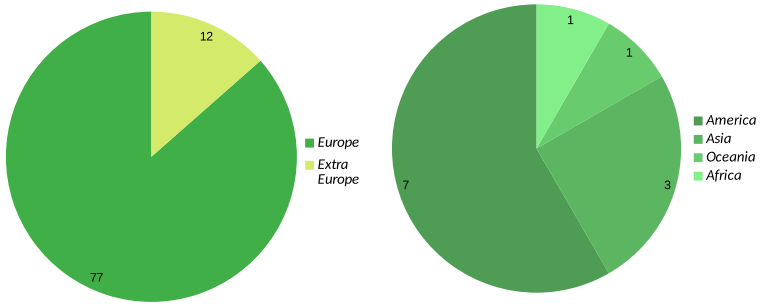

Fig. 1: Provenance of the speakers of EM4SS'21 International Workshop.

In this framework, the Project "IMPReSA", funded by the Emilia-Romagna Region (Italy) through the European Regional Development Fund (ERDF) [7], gathers the expertise of four Italian Research Centres and four companies to develop novel construction materials and processes with reduced demand for resources and energy inputs [2, 5]. An interesting application of this new paradigm for the construction sector is represented by developing its role as a pathway to funnel waste, in an attempt to lengthen the technological lifespan of materials and avoid recourse to landfilling. This approach is in line with the EU policy of Zero Waste Europe and especially with its cap on landfilling, according to the Landfill Directive [8]. Conversely, its implication in terms of product performance, waste stability and end-of-life processing calls for further studies and careful design.

Plastic waste is a natural target for being locked in construction products because it is a material already widely used in cement matrices in the form of virgin plastic fibres, aimed at reducing curing shrinkage and improving toughness [4]. The paradigm shift consists of moving from virgin plastic, that is a non renewable resource, to low-grade plastic obtained from recycling consumer plastic waste, whose low technological value usually means landfilling or thermal energy recovery is reverted to. On the other hand, impactful recycling processes, such as chemical conversion, can be hardly a suitable candidate for waste management. This special collection gathers 33 research papers presented at the first edition of the International Workshop "Engineered Materials for Sustainable Structures" (EM4SS'21), organised by the University of Modena and Reggio Emilia. The symposium gathered researchers alongside industrial partners active in the field of sustainable technologies and mechanics of complex materials and structures. Five topical areas are involved, in order to capture the multifaceted concepts of material design and processing in this framework. Over ninety talks were delivered, with representative speakers from all the continents (Fig.1). A special session was devoted to recent advances in the development of new low-impact binders, as meaningful alternatives to ordinary Portland cement, in conjunction with the use of new aggregates, such as recycled plastic. A dedicated session aimed at composite materials conveying the most recent studies in *Textile- and Fibre-Reinforced Concrete* was also organized. In this spirit, fundamental knowledge was developed in the field of mechanics to better focus the complicated mechanisms involved in the *strength and failure of composite systems*. Accordingly, a special session was reserved to present the most recent and sophisticated analytical and numerical tools in predicting and estimating the behaviour of construction materials and composites. Again, long-term performance of novel construction materials plays a crucial role in determining resilience and reliability of modern structures. This and related problems were discussed within the special session on *durability and corrosion*, whereas all the compelling sustainability and *life-cycle assessment* issues, alongside with the most recent certification protocols and guidelines, were discussed in a specifically dedicated forum. A concise overview of the topics gathered in this proceedings collection is reported hereinafter, with the specific purpose of introducing the broad spectrum of areas and topics which were touched upon in this Conference.

Innovative Building Materials

The Session ”Innovative Building Materials” deals with modern advances in Materials science and Technology, with specific application to the construction field. Contributions span from alternative binders and recycled composite aggregates for structural conglomerates, to the investigation of the mechanical behaviour of prefabricated blocks made of hempcrete. Moving towards new trends in building construction, new frontiers in the development of concrete mixtures and highly automatised machinery suitable for 3D-printing are currently subjected to deep investigation in view of their gamechanging potential. On the other hand, restoration of historical masonry and concrete buildings is still a challenge and a handful of contributions report on the development of engineered composite materials for structural retrofitting. An innovative application of rice husk ash as active pozzolanic material in lime-based composites is also presented in this Section.

Advanced Composite Materials for Structural Purposes

The Session ”Advanced Composite Materials for structural purposes” reports on new frontiers in the field of composite materials with emphasis on inorganic and ceramic matrix composites for structural retrofitting and rehabilitation of civil and industrial buildings. Researches investigate fibre-reinforced cementitious matrix (FRCM) from different perspectives, moving from the material viewpoint to the structural application. In the former case, the Section reports on experimental and analytical studies on the bond quality within the FRCM laminate and between the FRCM and the substrate, as well as on the efficiency of steel-reinforced grout (SRG) connectors. Moving to the structural framework, an investigation on the application of FRCM in strengthening masonry walls against shear is presented. Some numerical simulations are put forward to predict the efficiency of natural FRCM as a lightweight solution to strengthen masonry, compared with some established technologies, especially adopted in the Mediterranean area, involving timber frames. An interesting state-of-the-art review is also reporting on geopolymer-based fibre-reinforced materials (FRGM), which represent a more viable technology for structural restoration of buildings. Moving to fibre-reinforced concrete (FRC) for industrial screeds and pavements, research papers report on the use of recycled synthetic macrofibres in concrete for industrial pavement. Spotlight is set on the analytical model of the pull-out mechanism, which drives the overall response to failure of this kind of composite systems.

Mechanics of Solids and Structures

The Session reports on state-of-the-art and new concepts in the mechanics of solids and structures, includingmultiscaleandasymptoticmodels,homogenizationandinstability,nonlinearelasticity,wave propagation and reflection, plasticity, fracture mechanics. In more detail, we present contributions on a variety of topics of solid mechanics, like advanced micro- or nano-electromechanical (MEMS/NEMS) systems to be implemented as actuators in various fields, microstructure incorporation in continuum models through the couple stress theory, sophisticated wave propagation models in silver-mean quasicrystalline-generate wave guides. A couple of contribution address damage of complex structures, focussing on adhesive butt joints under torsion and concrete elements in frames, by means of imperfect interface and Bouc-Wen models, respectively.

Durability and Corrosion

This Session investigates long-term performance of construction materials, through the investigation of new aspects in structures durability and steel corrosion, with emphasis on normal or stainless steel immersed in innovative and sustainable materials. For instance, reinforced concrete, alkali-activated cement or concrete, fly ashes, slags, metakaolin, etc. with or without the use of recycled aggregates (biomassby-productsorplastic)areconsidered. Inparticular, the Section focus seson corrosion aspects of concrete and fibre-reinforced concrete, such as corrosion and passivation

mechanisms, protective coatings, critical chloride content, long-term corrosion resistance, durability against ageing due to de-icing salts, and monitoring methods.

Environmental and Life Cycle Assessment

In this Session, modern issues related to end-of-life disposal and impact and sustainability of construction materials are discussed. The main topic here is to assess environmental impact, circular economy capabilities and the most recent legal requirements in the construction marked (CAM, EPD, etc.). Light is shed on the current awareness of the research and industrial communities towards a sustainable and affordable built environment, gathering the most recent challenges and new perspectives on waste recycling, specifically addressing recycled content in building materials. Relevant case studies and life-cycle assessment (LCA) of newly issued industrial products are then illustrated and discussed.

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Committees

Dedication

This proceeding collection is dedicated to the memory of Prof. Cecilia Monticelli (UNIFE) and Prof. Igor Sevostianov (NMSU), whose recent passing away has deeply saddened all those colleagues who had the pleasure to meet them and appreciate their overwhelming passion for their research work.

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