

RILEM State-of-the-Art Reports

Sofiane Amziane
Florence Collet *Editors*

Bio-aggregates Based Building Materials

State-of-the-Art Report of the RILEM
Technical Committee 236-BBM



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RILEM State-of-the-Art Reports

RILEM STATE-OF-THE-ART REPORTS

Volume 23

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Sofiane Amziane · Florence Collet
Editors

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Editors

Sofiane Amziane
Polytech Clermont-Ferrand
Clermont-Ferrand
France

Florence Collet
Université de Rennes 1
Rennes
France

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Preface

Global warming, energy savings, and life cycle analysis issues are the factors that have contributed to the rapid expansion of plant-based materials for buildings, which can be qualified as environmental-friendly, sustainable and efficient multi-functional materials. These materials are obtained from the processing of hemp, flax, miscanthus, pine, maize, sunflower and bamboo.

The work of the Technical Committee (TC 236-BBM) was dedicated to the study of construction materials made from plant particles. Are concerned building materials containing as main raw material renewable, recyclable and easily available plant particles. However, the work was relatively centred on hemp because hemp shiv is the bio-aggregate that is the most widely used in building materials and the most studied in the literature.

This state-of-the-art report reflects the current knowledge on the assessment of the chemical, physical and mechanical properties of bio-aggregate and vegetal concrete. It presents an overview on the several possibilities developed worldwide about the use of plant aggregate to design bio-based building materials. The first five chapters relate to the description of the vegetal aggregate. Then, hygrothermal properties, fire resistance, durability and finally the impact of the variability of the method of production of bio-based concrete are assessed on Chaps. 7–9.

Vegetal aggregates are generally highly porous with a low apparent density and a complex architecture marked by a multi-scale porosity. Chapters 1–5 give an overview on the physical properties of the vegetal aggregate and the methods to assess these characteristics.

These geometrical characteristics result in noteworthy hygrothermal performances. This is one of the essential characteristics, which differ from vegetal concrete compared to the tradition mineral-based concretes. Chapter 6 gives the state of the art of previous studies on hygric and thermal properties of bio-aggregate based building materials. Hygric characteristics such as sorption isotherms, water vapor permeability and moisture diffusivity are given. The ability of bio-aggregate-based building materials to moderate ambient relative humidity may be valued using moisture buffer value. Thermal properties (thermal conductivity, thermal diffusivity conductivity and specific heat capacity) are then reported. Finally, concluding

remarks on hygrothermal behavior with simultaneous heat and mass transfer are provided.

Chapter 7 concerns behaviour of bio-aggregate based building materials exposed to fire. Discrepancies between fire reaction and fire resistance are highlighted in this chapter. Various results of fire reaction test performed on bio-based materials are reported. Bio-aggregates are often in Class F, while concretes range in class B1. In some of the presented case studies, render and plaster play a key role in the fire resistance. EI 90 fire resistance appeared to be accessible with conventional technologies.

Chapter 8 deals with the impact of biological and environmental ageing on the durability of the multiphysical performances of vegetal concretes. It is important to note that in the case of hemp concretes, hygrothermal changes can also lead to specific disorders, such as variations in dimensional stability, of microstructure and of functional properties (mechanical, acoustical and hygrothermal properties). Moreover, the growth of microorganisms can also be observed and further aggravates the pathologies mentioned above. All these evolutions may as well lead to variations in the functional properties of the materials during their use.

Chapter 9 investigates the effect of production parameters including curing conditions (65% vs. >95% RH), time of demoulding and specimen geometry (cylinder vs. cube) on the concrete's strength which relates to density and therefore to thermal and hygric properties. It studies hydration in the concrete's microstructure and measures the compressive strength development at intervals between 1 day and 1 month.

Moulding time and curing conditions influence drying and therefore may impact binder hydration and consequently strength evolution. Specimen geometry may affect drying and can also determine how strain builds up in the concrete and thus when failure occurs.

The state-of-the-art report is followed by an appendix containing a TC report which presents the experience of a working group within the RILEM Technical Committee 236-BBM 'Bio-aggregate based building Materials'. The work of the group was dedicated to the study of construction materials made from plant particles. Are concerned building materials containing as main raw material renewable, recyclable and easily available plant particles. These materials are obtained from the processing of hemp, flax, miscanthus, pine, maize, sunflower, bamboo and others. However, the work of the round robin test has been centred on hemp because hemp shiv is the bio-aggregate that is the most widely used in building materials and the most studied in the literature.

The first round robin test of the TC 236-BBM was carried out to compare the protocols in use by different laboratories (labs) to measure initial water content, bulk density, water absorption, particle grading and thermal conductivity. The aim is to define a characterisation protocol derived from those used by different laboratories.

This first round robin test was carried out on one variety of hemp shiv. Nine laboratories from European universities and research centers were involved (Table 1).

Table 1 Participating Labs

Letter	City	Labs
A	Bath (UK)	BRE Centre for Innovative Construction Materials/University of Bath
B	Clermont Ferrand (France)	Institut Pascal
C	Lorient (France)	LIMatB/Université de Bretagne Sud
D	Lyon (France)	DGCB/ENTPE
E	Paris (France)	IFSTAR
F	Rennes (France)	LGCGM/Rennes 1
G	Toulouse (France)	LMDC/Université de Toulouse/UPS/INSA
I	Combloux (Belgium)	Combloux-Agro ressource—Université de Liège

The test results of 7 laboratories constitute a set of statistically representative data in order to propose recommendations to characterise hemp shiv after analysing the different methodologies in use in these laboratories. In addition to 7 laboratories, in the last round-robin test on “Variability of mechanical properties of hemp concrete”, Vicat (France), Queen’s University Belfast (UK), and Trinity college Dublin (Ireland) were involved in the comparison of the results between different laboratories. The results were published elsewhere (2016)¹.

Finally, this state of the art on bio-based materials allows to show both advantages and limitations that can be expected in plant-based building materials.

Ongoing research will certainly provide more insights that are not included in this book. But in terms of performance already demonstrated, we already have peace of mind about the potential for the benefit of biomaterials compared to conventional solutions that have a strong impact on our environmental.

Clermont-Ferrand, France

Prof. Sofiane Amziane
Chair of TC 236-BBM

¹Niyigena, C., Amziane, S., Chateauueuf, A., Arnaud, L., Bessette, L., Collet, F., Lanos, C., Escadeillas, G., Lawrence, M., Magniont, C., Marceau, S., Pavia, S., Peter, U., Picandet, V., Sonebi, M., Walker, P., Variability of the mechanical properties of hemp concrete, (2016) *Materials Today Communications*, 7, pp. 122–133.

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Gilles Escadeillas, Université de Toulouse, UPS, INSA, LMDC, France.

Harald Garrecht, Universität Stuttgart, Institut für Werkstoffe im Bauwesen (IWB), Stuttgart, Deutschland.

Etienne Gourlay, CETE de l'Est—Laboratoire Régional de Strasbourg, France.

André Klatt, Universität Stuttgart, Institut für Werkstoffe im Bauwesen (IWB), Stuttgart, Deutschland.

Christophe Lanos, Université de Rennes 1, LGCGM, France.

Mike Lawrence, University of Bath, BRE Centre for Innovative Construction Materials, UK.

Camille Magniont, Université de Toulouse, UPS, INSA, LMDC, France.

Sandrine Marceau, Université Paris-Est, IFSTTAR, France.

Sara Pavía, Department of Civil Engineering, Trinity College, Ireland.

Ulrike Peter, Lhoist, Lhoist Recherche et Développement S.A., Belgium.

Vincent Picandet, IRDL, Université de Bretagne Sud, France.

Mohammed Sonebi, School of Planning, Architecture and Civil Engineering, Queen's University Belfast, UK.

Peter Walker, University of Bath, BRE Centre for Innovative Construction Materials, UK.

Other Contributors:

Thibaut Colinart, IRDL, Université de Bretagne Sud, France.

Guillaume Delannoy, Université Paris-Est, IFSTTAR, France.

Yunhong Jiang, University of Bath, BRE Centre for Innovative Construction Materials, UK.

César Niyigena, Institut Pascal, Clermont Université, France.

Vincent Nozahic, Institut Pascal, Clermont Université, France.

Sylvie Pretot, Université de Rennes 1, LGCGM, France.

Pierre Tronet, IRDL, Université de Bretagne Sud, France.

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