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Agricultural WastE as Sustainable 0 km building MatErial

DELIVERABLE D.T2.4.1

REPORT ON SELF BUILDING PACTICES

confimiindustria Albania – Associazione Imprenditori Italiani in Albania
Politecnico di Bari
Tehnopolis – Inovaciono Preduzetnički Centar
gal Molise – agenzia per lo sviluppo locale

Project number: ITALME-419

Work package: T2 Pilot action

Partner responsible for the deliverable: Politecnico di Bari

Dissemination level: PU - Public

Activity A.T2.4. Involving communities and farmers in public events to demonstrate self-building potentials, and explain environmental advantages of proposed technologies. This activity will be mostly developed in Molise with the supervision of PP2.

Deliverable D.T2.4.1. At the end of this activity a report summarizing the production processes in order to obtain repeatable performances with particular reference to hygrothermal and mechanical characteristics.

Status: Final

Date: 31/03/2022

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1. Introduction

Recently the construction sector is experiencing an increasing pressure for the use of more sustainable materials realized with natural and bio-based components, in particular derived from agricultural and organic waste which are able of reducing the environmental impact while improving indoor environment quality and energy consumptions. Mati-Baouche et al. (2014) judge the bio-based materials obtained from by-products of agriculture as an interesting alternative to those with from fossil carbon. Pacheco-Torgal et al. (2012) consider the reduction of the toxicity of building materials an important turning point towards the eco-efficiency of the construction industry. Several researchers demonstrated by various studies a significant boost to the use of biomass-based building materials (Raut et al., 2011; Korjenic et al., 2011; Palumbo et al., 2016; Binici et al., 2016a; Liuzzi et al., 2017). Asdrubali et al. (2015) illustrated the main hygrothermal and acoustic properties of innovative building materials with natural fibers (i.e. bagasse, cotton, straw). Liu et al. (2017) indicated the possible application fields of agricultural waste as building materials: panels, blocks, vegetable biomasses, multi-layer solutions, particles, slurries, coils, etc. Sagbansua and Balo (2017), studying the use of perlite and clay with corn oil as binder, found that the implementation of organic-based materials has produced a significant reduction of energy consumption. The addition of modified corn oil to the insulation materials determines a reduction of the final thermal conductivity. The lowest values of thermal conductivity were achieved with a percentage of 50% of the corn oil on the specimen mass. Gomes et al. (2018) studied hygrothermal and mechanical properties after adding hemp fibers to clay mortars. They proved that the addition of hemp fibers contributes to improve the final mechanical properties. The fibers addition in mortars enhances the shrinkage during drying, which meant that the volume did not decrease and there were no visible stress marks or cracking. In addition, the use of the fibers improves the thermal insulation properties. The aim of the present report is to focus on the sustainable production processes and techniques commonly adopted worldwide to get sustainable building components biomass based. This analysis leads to identify the physical, hygrothermal and mechanical performances repeatable on simple components that can be possibly made by local farmers or in general self-builders interested to use the by-products derived from pruning or industrialized processes.

2. Working methodology

The presented research was conducted on more fields with the aim to correlate the literature state of the art in term of the use of agro-waste in sustainable building materials to the possible applications to propose to local farmers or in general self-builders of the countries involved in the project. Two different lines of research were followed: the techniques of building suitable for industrialized processes and the technologies appropriate for self-building.
This kind of analysis was carried out extracting scientific research papers from national and international journals, searching the topic agro-waste, sustainable materials, mortars, panels. The following electronic data-bases were approached: Web of Science, Google Scholar, Scopus, ResearchGate. The search was performed using different combinations of material and properties-related and application-related keywords as shown. Thus, the total records obtained consists in 124 documents, that were cross-screened in order to eliminate records not concerning the topic of the report. Finally, the total documents selected were 61 research references to develop the structure of the present paper.

3. The agro-waste in building and self-building constructions

Considering the current negative environmental impact correlated to the production and use of building materials, international literature shows several studies of possible applications of natural resources and, in particular of agricultural waste in building components used for sustainable constructions. Based on the availability of the agro-waste, related to the country in which they derive from and the specific climate conditions, it can be considered that the use of the by-products can represent and important opportunity for the construction industry and also for self-building constructions.
Several studies, in-fact, demonstrated that agricultural fiber composites could replace wood-based materials representing good candidates because their water absorption capacity is comparable or, in some cases, even better to the wooden components (Arman et al., 2022).

BRICKS AND MASONRY

Bricks as masonry components have been predominantly used in the construction industry since the early centuries (Figaredo et al., 2018). Traditionally, the brick-making processes involves three fundamental steps: mixing the raw materials (usually earth-based materials such as clay and water), molding and drying, and finally, firing them to obtain appropriate strength. A big issue of the fired brick production process is the generation of substantial amounts of harmful gases. Luby et al. (2015) found that high pollution levels derives from brick production due to the coal technology used to fire the bricks. A second disadvantage of the process stems from their excessive usage of non-renewable materials such as water, facilitating the consumption of natural resources (Figaredo et al., 2018).

The incorporation of agricultural waste products enhances the final properties of the bricks. Kazmi et al. (2016) utilized rice husk ash and sugarcane bagasse ash for the manufacture of clay bricks, by incorporating 5% of the by-products on the clay weight. The findings obtained showed that the bricks' compressive strength and modulus of rapture decreased as higher quantities of by-products were incorporated into the fired clay bricks.

Taurino et al. [29] focused on the manufacture of light-weight bricks by integrating wine wastes such as wine less, grape seeds, and stalks with clay. The findings obtained showed that bricks with the highest mechanical and physical properties were produced from the use of 5% weight of the wine or less. Similarly, the density of the bricks was also reduced by up to 13% based on the concentration of wine waste used. The flexural strength of the bricks also decreased based on the concentration of wine waste used.

Fig.1 – Typical fired bricks realized with agro-waste ([KIIT Bhubaneswar, IIT Hyderabad Develop Bio-Bricks From Agro Waste - odishabytes]())

Fig.2 – Typical unfired bricks realized with agro-waste (Rautray et al. 2021)

CONCRETE

Between the industrialized components made with agro-waste concrete is also highly used in the construction industry. Prusty et al. (2016) observes that concrete comprises a mixture of cement, fine aggregate, and coarse aggregate, all of which are derived from natural resources. Subsequently, as the demand for housing increases,

significant pressure is mounted on the non-renewable natural resources, thereby sparking research on the use of alternative agro-waste materials to produce concrete. Modani and Vyawahare (2013) investigated the effect of replacing untreated sugarcane bagasse ash by a volume of fine aggregate in concrete with different ratios. Compressive strength, sorptivity test and tensile strength were performed. The findings achieved showed that with the compressive strength, a specimen with 10% replacement demonstrated better results than those that without it. Additional tests also showed that the tensile strength and sorptivity decreased as the level of SCBA was increased. The results of the study have a significant economic implication, since they indicated that SCBA could be used as a viable alternative to aggregates in concrete production. Prusty et al. [29] have also weighed on the issue, revealing that in India, about 10 million tons of sugarcane are treated as waste, and as such, suitable conversion and application as construction materials facilitate their disposal.

Fig.3 – Sample of concrete made with agro-waste (Garas et al., 2015)

PANELS FOR INSULATION

Agro-wastes have also been deployed in the manufacture of insulation materials for buildings. Liu et al. (2017) affirm that the use of biomass such as agro-residues, economical plants, and forest residues in thermal insulation material is one of the main topic of several researches in the last few decades. Hemp, straw, coconut, wood, and flax were the main fibers used for insulating panels while, on the other side, sisal, reed, grass, and pineapple were currently under study and less used.

Mechanical characteristics such as hardness, flexural strength, compression strength and bulk density were measured. The findings underlined that the increase in density resulted in a decrease of thermal aspects and increase of mechanical features of the blocks. Benfratello et al (2013) confirms that hemp, as a biomass residue, provides excellent thermal insulation properties for buildings.

Liu et al. (2017) observed that hemp and straw are highly popular as thermal insulators. Comparing the flexural and compressive strengths of the composites with agro-waste against polystyrene insulation blocks, the results achieved demonstrated that the blocks have good thermal conductivity less than 0.046 W/mK. Sing et al. (2022) also investigated the use of wheat and barley straw fibers in the manufacture of light-weight composites for building insulation showing that the linseed oil used as flame retardant contributing also to prevent the degradation of the composite.

Fig.4 – Typical insulation panels made with agro-waste (https://retaildesignblog.net/)

LOOSE-FILLING INSULATION AND BALES

Straw-bale construction consists in a building method that uses bales of wheat, rice, rye straw as structural elements or insulation filling. Several researches have shown that straw-bale construction is a sustainable technique due to the use of sustainable materials and the less final energy needed for heating and cooling.

First examples of straw houses can be found on the African plains since the Paleolithic Era. In European countries several examples of straw houses exist in Germany dated back to 400 years ago and straw roofs were found in northern Europe and Asia. In 1800 the American settlers used straw bales as blocks to build temporary shelters in agricultural fields while harvesting crops.

Wang et al. (2018a, b) affirmed that straw bales can provide significant benefits in terms of costs, human health, and environmental sustainability. Several researchers worldwide have underlined the remarkable properties of straw bales as insulating and load-bearing materials (Cascone, 2018; La Gennusa, 2017, Buratti, 2018).

Due to their advantages, straw bales were mainly used in traditional rural buildings to improve environmental sustainability. Barbaresi et al. (2017) proposed straw bales as retrofit strategy for thermal behavior improvement in unconditioned farm buildings, taking into account the wine-ageing requirements. Sabapathy (2019) found that the best moisture content of straw bale for sustainable buildings should be below 20% (estimated as a percentage of the total weight of the bale) mineralized in such a way that the wall is free from seeds attracting rodents and various type of molds.

Fig.5 – Typical straw-bale house (www.terrabuildingdesign.it)

MORTARS AND PLASTERS

Different researchers (Liuzzi et al, 2016, 2017, 2020) attempted to add various materials to improve and optimize the physical, mechanical and hydric properties of plaster, avoiding the structures disintegration or corruption of the final components.
The addition of silica contributes to the improvement of the mechanical properties, the use of the fiber components derived from the biomass enhances the hygric and thermal performances reducing the bulk density and increasing the porosity. Khalil et al (2014) investigated the use of the rice husk in the gypsum plaster. A slight addition of low percentage of fibers contributes to improve the compression strength.

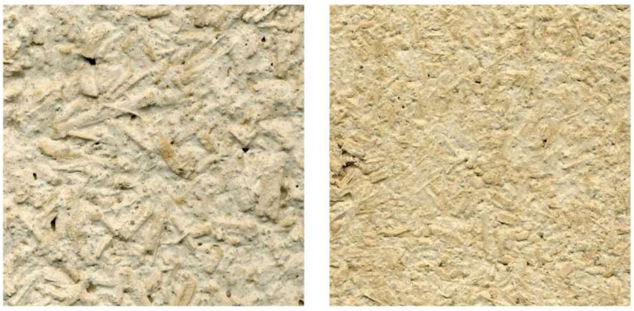

Fig. 6 : Two samples of lime plaster with different fibers size (Mazhoud et al., 2016)

THERMAL AND MECHANICAL PERFORMANCES

The studies above mentioned and the deliverables DT2.2.1 allow to deduce some suitable and possible characteristics of the building components realized by self-building techniques.

AGRO-WASTE BASED BRICKS			
Technical data	Bulk density	<500 [kg/m^3]	ISO 12570:2000
	Thermal conductivity	<0.15 [W/mK]	EN 12667:2002
	Vapour resistance factor	<5 [-]	ISO 12572:2016
	Flexural strength	3.0-6.0 MPa	
	Compressive strength	2.0-12 MPa	
	Elasticity Modulus	0.57-1.7 GPa	-
	Reaction to fire	Class E	EN 13501-1:2010

4. Conclusions

The analysis performed has highlight the sustainable production processes and techniques commonly adopted worldwide to get sustainable building components biomass based. This report has the aim to identify the physical, hygrothermal and mechanical performances repeatable on simple components that can be possibly made by local farmers or in general self-builders interested to use the by-products derived from pruning or industrialized processes.

In conclusion, the framework built by the present report is strictly connected to the next deliverable D.T2.4.2 in which a framework of the thermal tests executed in laboratory is shown. The present and the next deliverable D.T2.4.2 are fundamental for the final production of the building prototypes that will be executed at the end of the project and monitored.

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This project is co-financed by the European Union under the instrument for Pre-Accession Assistance (IPA II)
This document has been produced with the financial assistance of the Interreg IPA CBC Italy-Albania-Montenegro Programme. The contents of this document are the sole responsibility of Politecnico di Bari and can under no circumstances be regarded as reflecting the position of the European Union and of the Interreg IPA CBC Italy-Albania-Montenegro Programme Authorities.