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Agricultural WastE as Sustainable 0 km building MatErial

DELIVERABLE D.T2.2.1

REPORT ON THE REQUESTED PROPERTIES

Project number: ITALME-419

Work package: T2 Pilot action

Partner responsible for the deliverable: Politecnico di Bari

Dissemination level: PU – Public

Activity A.T2.2. The activity is related with the definition of the structural and hygrothermal properties that the building components to be developed as prototypes should have. A detailed snapshot of the specific requirements and technical features will be produced. At this stage, the four locations, and the relevant public buildings where the pilot actions will be enacted will be identified, based on a matrix of criteria including: 1. representative role of the building to increase the impact of the demonstrator; 2. possibility to have, within the same building, a "reference case" to better demonstrate (by comparison) the potential of the innovative materials; 3. ease of access for persons interested in understanding the potential of the technology; 4. proximity to locations where the innovative components are made, so to further reduce the environmental impact due to transport.

Deliverable D.T2.2.1. A detailed snapshot of the structural and hygrothermal properties will be produced as guidelines for the realization of energy efficiency building components.

Status: Final

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1. Introduction

To achieve a satisfactory quality of buildings it is necessary to consider a set of aspects that are interconnected and influence each other. The choice of adequate building assemblies allows to achieve the high hygrothermal and mechanical performances buildings, guaranteeing energy efficiency and structural resilience. Furthermore, the selection of sustainable materials let to design buildings able to minimize all adverse environmental impacts due to the resource depletion. Therefore, materials are the essential components of buildings construction and play an important role in achieving the goal of sustainability and in enhancing the overall performances of a building. Consequently, evaluating the inherent properties of building materials and their impacts on the environment has becoming the key to design green buildings.

Thermal insulation is a major contributor and obvious practical and logical first step towards achieving energy efficiency and occupants comfort. In fact, the use of thermal insulation in buildings does not only reduce the reliance upon mechanical air-conditioning systems, but also extends the periods of indoor thermal comfort especially in between seasons. The thermal performance of building envelope is determined by the thermal properties of the materials used for its construction which influence its ability to absorb or emit heat flux. The operating temperature and the material moisture content are the major factors affecting the effectiveness of the insulation treatment (Le DuongHung et Zoltán, 2021). For this reason, it is important to characterize the used materials focusing on their hygrothermal behaviour which is usually defined as the simultaneous and inter-dependent occurrence of absorption and release of heat, and absorption and release of vapour (Hall, 2010).

Both the hygric and thermal performances of building materials are strongly affected by their microstructure which is characterized through their physical properties. The heat or vapour transfer in a porous medium can be attributed to a wide range of parameters of which the most important is the total volume of void space (i.e. bulk porosity).

Because of the wide range of applications as well as of manufacturing processes, building materials should meet different requirements, including not only the hygrothermal properties but also the mechanical ones.

In the Table 1 are summarized the most important technical properties which are commonly experimentally tested in order to characterize the behaviour of building materials for evaluating their ability in guarantying the thermal comfort. Only some of the listed properties are reported by the technical datasheets of the building materials (Table 2, Table 3, Table 4, Table 5) providing useful information for the choice of the building components that satisfy the requirements. For example, with reference to the thermal properties, the thermal conductivity is the main parameter commonly defined to evaluate the intrinsic ability of a material to transfer or conduct heat. At the macroscopic level, the thermal conductivity largely depends on the materials density which represents the essential physical properties provided by the datasheets. Taking into account the hygric behaviour, the water vapour resistance coefficient is usually used to characterize the materials. Concerning with the mechanical behaviour, the flexural and the compressive strength as well as the elasticity modulus are provided by the datasheets.

The analysis of the scientific literature shows that agro-waste can represent a raw material for the production of building components with different functions, i.e. plasters and mortars; bricks; insulating materials; or loose-fill insulation. In the next paragraph, a snapshot of the structural and hygrothermal properties of the different building components is produced. The aim is to provide guidelines useful for supporting each partner in the choice of the best sustainable materials able to guarantee the building energy efficiency and the occupants thermal comfort.

Category	Target value	Definition
Physical properties	Bulk density [kg/m^3]	the mass of a substance per unit volume considering both the solids and the pore space.
	Porosity [-]	measure of the voids over the total volume.
Thermal properties	Dry thermal conductivity [W/(m·K)]	the rate of heat transfer through the unit thickness of a material per unit area per unit temperature difference.
	Dry thermal diffusivity [m^2/s]	measure of the ability of a material to conduct thermal energy relative to its ability to store thermal energy.
	Specific heat capacity [J/(kg·K)]	the amount of heat to be supplied to (or taken out of) the unit mass of a material in order to increase (or decrease) its temperature by one degree.
Hygric properties	Water vapour permeability [kg/(m·s·Pa)]	the amount of water vapour that crosses, per unit of time, a unit of surface of the material, for a sample of unit thickness, when there is a unit difference in vapor pressure.
	Water vapour resistance coefficient [-]	measure of the material's reluctance to let water vapour pass through.
Mechanical properties	Flexural strength [MPa]	the maximum stress applicable to a material before it yields/fails in a bending test.
	Compressive strength [MPa]	the maximum stress applicable to a material before it yields/fails in a compression test.
	Elasticity Modulus [GPa]	the ratio of the applied stress and the subsequent deformation of the material. It determines the rigidity of the material itself.
Fire resistance properties	Reaction to fire [class]	response of a product in contributing by its own decomposition to a fire to which it is exposed, under specified conditions.

2. Datasheets

Table 2: datasheet of agro-waste based plasters and mortars.

AGRO-WASTE BASED PLASTERS AND MORTARS			
 Source: Mazhoud et al., 2016.		 Source: https://www.impresedilinews.it/ricehouse-di-tiziana-monterisi-al-klimahouse-2019/.	
Characteristics		Made with agro-waste available in the involved countries as reinforcement for natural or conventional plasters or mortars.	
		Hygrothermal and acoustic comfort.	
		Resistance to frost, insects and rodents.	
		Durability and fire resistance and absence of smokes during fires.	
		Environmental friendliness because made following a sustainable process with zero CO_2 emissions.	
		Percentage content of waste more than 40%.	
Installation		The installation is usually carried out by hand. Finally, the walls can be covered with vegetal paints.	
Applications		The agro-waste mortars and plasters ensure enormous versatility being used for internal or external building walls. For internal applications plasters based on earth, clay or lime could be used. For external applications plasters based on lime are preferable.	
Technical data	Bulk density	<1000 [kg/m^3]	ISO 12570:2000
	Thermal conductivity	<0.2 [W/(m·K)]	EN 12664:2002
	Vapour resistance factor	>2 [-]	EN 1015–19:1998
	Flexural strength	0.16-2.6 MPa	EN 1015-11:2007
	Compressive strength	2.0-14.0 MPa	EN 1015-11:2007
	Elasticity Modulus	2.82-4.08 GPa	-
	Reaction to fire	Class E	EN 13501-1:2010

Table 3: datasheet of agro-waste based bricks.

<table>
<tr><th colspan="4">AGRO-WASTE BASED BRICKS</th></tr>
<tr><td colspan="2">
Source: https://www.prespaglia.com/.</td><td colspan="2">
Source: https://beleafmagazine.it/2019/10/04/il-climatizzatore-del-futuro-il-biomattone-in-canapa/.</td></tr>
<tr><td colspan="2" rowspan="7">Characteristics</td><td colspan="2">Made with agro-waste available in the involved countries as matrix and natural or conventional binders (i.e. hydraulic lime, clay).</td></tr>
<tr><td colspan="2">Hygrothermal and acoustic comfort.</td></tr>
<tr><td colspan="2">Resistance to frost, insects and rodents.</td></tr>
<tr><td colspan="2">Durability, fire resistance and absence of smokes during fires.</td></tr>
<tr><td colspan="2">Good load bearing.</td></tr>
<tr><td colspan="2">Environmental friendliness because made following a sustainable process with zero CO_2 emissions.</td></tr>
<tr><td colspan="2">Percentage content of waste more than 40%</td></tr>
<tr><td colspan="2">Installation</td><td colspan="2">The installation of the bricks is carried out by gluing the blocks with a thin layer of lime mortar. The blocks can be finished with sand, clay, or lime mortar sufficiently transpired to avoid the formation of mold.</td></tr>
<tr><td colspan="2">Applications</td><td colspan="2">The agro-waste bricks ensure enormous versatility being used for masonry where the structural elements are made of wood, steel or concrete armed. They can be used for build internal or external walls; in the latter case it is necessary to add a layer of plaster for external use.</td></tr>
<tr><td rowspan="7">Technical data</td><td>Bulk density</td><td><500 [kg/m^3]</td><td>ISO 12570:2000</td></tr>
<tr><td>Thermal conductivity</td><td><0.15 [W/mK]</td><td>EN 12667:2002</td></tr>
<tr><td>Vapour resistance factor</td><td><5 [-]</td><td>ISO 12572:2016</td></tr>
<tr><td>Flexural strength</td><td>3.0-6.0 MPa</td><td></td></tr>
<tr><td>Compressive strength</td><td>2.0-12 MPa</td><td></td></tr>
<tr><td>Elasticity Modulus</td><td>0.57-1.7 GPa</td><td>-</td></tr>
<tr><td>Reaction to fire</td><td>Class E</td><td>EN 13501-1:2010</td></tr>
</table>

Table 4: datasheet of agro-waste based insulating materials.

<table>
<tr><th colspan="4">AGRO-WASTE BASED INSULATING MATERIALS</th></tr>
<tr><td colspan="2">
Source: https://www.prespaglia.com/.</td><td colspan="2">
https://www.steacom.it/12-bioedilizia.</td></tr>
<tr><td colspan="2" rowspan="6">Characteristics</td><td colspan="2">Made with agro-waste available in the involved countries as matrix and natural or conventional binders (i.e. hydraulic lime or clay).</td></tr>
<tr><td colspan="2">Hygrothermal and acoustic comfort.</td></tr>
<tr><td colspan="2">Resistance to frost, insects and rodents.</td></tr>
<tr><td colspan="2">Durability, fire resistance and absence of smokes during fires.</td></tr>
<tr><td colspan="2">Environmental friendliness because made following a sustainable process with zero CO_2 emissions.</td></tr>
<tr><td colspan="2">Percentage content of waste more than 40%.</td></tr>
<tr><td colspan="2">Installation</td><td colspan="2">The installation of the panels is carried out by applying them to the walls using glues and anchors. Finally, they can be covered with a natural mesh and eco-friendly finishes sufficiently transpired to avoid the formation of mold (i.e. earth or cocciopesto plasters).</td></tr>
<tr><td colspan="2">Applications</td><td colspan="2">The agro-waste panels ensure enormous versatility being used as external or internal thermal insulation. In the latter case, they could be finished with vegetal paints. Furthermore, the panels could be applied on the existing facades for energy efficiency refurbishment.</td></tr>
<tr><td rowspan="7">Technical data</td><td>Bulk density</td><td><600 [kg/m^3]</td><td>ISO 12570:2000</td></tr>
<tr><td>Thermal conductivity</td><td><0.10 [W/(m·K)]</td><td>EN 12667:2002</td></tr>
<tr><td>Vapour resistance factor</td><td>>2 [-]</td><td>EN 12086:2013</td></tr>
<tr><td>Flexural strength</td><td>3.0-6.0 MPa</td><td>EN 12089:2013:</td></tr>
<tr><td>Compressive strength</td><td>2.0-12 MPa</td><td>EN 826:2013</td></tr>
<tr><td>Elasticity Modulus</td><td>0.57-1.7 GPa</td><td>-</td></tr>
<tr><td>Reaction to fire</td><td>Class E</td><td>EN 13501-1:2010</td></tr>
</table>

Table 5: datasheet of agro-waste based loose-fill insulation.

AGRO-WASTE BASED LOOSE-FILL INSULATION		
	 https://www.peterbarry.co.uk/blog/when-insulating-inside-the-box-try-thinking-outside-the-box/.	
Characteristics	Made with agro-waste available in the involved countries used in “loose” or in “bales” form.	
	Hygrothermal and acoustic comfort.	
	Resistance to frost, insects and rodents.	
	Fire resistance and absence of smokes during fires.	
Installation	The insulating panels are obtained without using any binders. The wastes are used in “loose” or in “bales” form obtained through simple processes of pressing and packaging. The installation is carried out filling in the cavities between two wall faces with the waste materials. Before the filling operation, it is necessary to check that the facings have the sufficient compressive strength to withstand the pressure of the insulating laid material.	
Applications	The agro-waste panels in “loose” or “bales” are usually used for external walls.	
Technical data	Bulk density	<300 [kg/m^3]
	Thermal conductivity	<0.07 [W/(m·K)]
	Vapour resistance factor	<2 [-]
	Flexural strength	0.33-0.50 MPa
	Compressive strength	0.05-6 MPa
	Elasticity Modulus	150-300 kPa
	Reaction to fire	Class E

3. Conclusions

A detailed snapshot of the structural and the hygrothermal properties of the building materials made with agro-waste was developed. The aim of the present deliverable was to provide guidelines containing the technical requirements of the different types of the building components (plasters/mortars, bricks, insulating panels, or loose-fill insulation) suitable for high energy efficiency buildings. This deliverable is prior to the next activity A.T2.3 concerning the implementation of the prototypes. The document represents a support for the designing of the building assemblies that will constitute the demonstrators in the four countries. Furthermore, the deliverable provides recommendations useful to the stakeholders in choosing the best prototype solution. This latter one could be different in each country or a unique one for all the partners.

4. References

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