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Innovative use of giant reed and cork residues for panels of buildings in Mediterranean area

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ABSTRACT

The environmental impact of buildings has to be assessed not only in reference to the energy consumed by their use but also with reference to the energy inside materials with which they are made of. The "Sick Building Syndrome" (SBS) is increasing. It was discovered that the major causes are linked to chemical contaminants from indoor sources such as building materials, inadequate ventilation, excessive use of Heating, Ventilation and Air Conditioning (HVAC) and volatile organic compounds (VOCs). The insulation building materials have a relevant role in the SBS for the capacity, not only to limit the use of HVAC but also to limit the emission of pollutants inside a building environment. The present paper reports an up- to- date review of some innovative uses of wastes deriving from agricultural production in order to build walls and partitions for Mediterranean houses. Some test methods of building elements, made with giant reed and agglomerate cork which are two typical natural materials of the Mediterranean area, are illustrated. These vegetal materials are often residues deriving from agricultural production, the agricultural residues are often a problem for farmers or firms because the organic wastes are considered dangerous and the disposal of such material is very expensive, therefore the reuse of the wastes is the best way to recycle these materials. This paper analyzes a cavity wall panel made with a wood skeleton on which two double crossed layers of giant reed stems were fixed and a multilayer agglomerated cork wall with a double cavity multilayer BOTH 20CM THICK. The dynamic thermal analysis carried out for the houses with the proposed walls highlights a better environmental performance of buildings with agglomerated cork and with giant reed walls rather than brick walls. The production of CO_2 for the indoor environmental thermal control of the house with giant reed walls is less than 1/2 and the house with agglomerated cork walls is less than 1/4 compared to the brick wall house.

1. Introduction

Throughout the world, buildings are responsible for about 1/3 of the greenhouse gas emission and consume about 40% of resources (United Nations Environment Programme (UNEP, 2016). The environmental impact of buildings has to be assessed not only in reference to the energy consumed by their use (Porto et al., 2015) but also with reference to the energy inside materials with which they are made of (Asdrubali et al., 2015). Pollution of buildings not only refers to the external environment but also the internal one and influences the occupant's life. The request of green buildings is developing all over the world. Over the last few years, people are increasingly concerned about the quality of life inside buildings. On the other hand the "Sick Building Syndrome" (SBS) is increasing (Wargocki et al., 1999). It was discovered that the major causes are linked to chemical contaminants from indoor sources such as building materials, inadequate ventilation, excessive use of Heating, Ventilation and Air Conditioning (HVAC) and volatile organic compounds (VOCs) (Yu and Crump, 1998). The insulation building materials have a relevant role in the SBS for the capacity, not only to limit the use of HVAC but also to limit the emission of pollutants inside a building environment. The disposal of buildings could have another hard impact on the environment. In fact building materials could become wastes, therefore, hard to dispose of. When building materials are natural or derived from organic materials, the disposal would not represent a critical source of environmental pollution (Palumbo et al., 2015). Unfortunately most of insulation materials

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used derive from mineral wool (52% of market share) and plastics (41%), whereas only a small part is natural. Furthermore, natural materials, during their growth, capture the CO_2 of the environment, improving it. Definitely, the correct use of natural materials as insulation for buildings could give a lot of advantages such as:

- lower energy necessary to produce building elements
- lower energy to control indoor environmental temperature
- better well-being and comfort for the building's occupants
- lower impact to the environment during the phases of use and disposal
- CO_2 environmental capture

Furthermore, if natural materials are derived from agricultural or forestry wastes, the advantages increase greatly.

In the past the use of agricultural or forestry residues was widely utilized in rural farms as building components (e.g. roofs, walls, sheds, fences, etc.), or as complementary materials (e.g. insulation materials, tie elements, claddings, etc.) (Väisänen et al., 2016).

The use of these materials was carried out with scarce knowledge but with the best of experience. Sometimes the real characteristics and performances of these materials were little known and for this reason their potentials and utilization were not often the best. The knowledge of the behavior of the material leads to designing and applying new and more efficient building solutions, with optimum use of the materials that come from agricultural wastes and residues (Curling et al., 2017) (Valenti et al., 2017).

In this paper some test methods of building elements, made with giant reed and agglomerate cork which are two typical natural materials of the Mediterranean area, are illustrated. Furthermore an innovative solution for new building components is proposed, which improves the performance of *Arundo donax* L. and cork.

2. Reuse of agriculture residues for building materials

The use and reuse of residues and wastes of the agriculture and forestry industry has always belonged to the traditional Mediterranean traditional rural culture. According to farmers, wastes do not exist but are only resources to recycle (Pinto et al., 2012). Although the properties of natural material residues are characterized by a lot of environmental and producing factors such as weather conditions, soil contents, planting, harvesting, working methods of the main materials, there is a similar use of these materials in most of the Mediterranean countries (Holzapfel, 2016). For example the stem of *Arundo donax* L. is used, in Italy as well as in Spain, to make the walls of a house or a shelter for animals.

2.1. Arundo donax L

Arundo donax L., commonly known as “giant reed”, is a potentially high yielding non-food crop with hollow stems. Giant reed is one of the most environmentally friendly cost effective crops and has a large prospective use in development so much as to be considered as the major biomass crop. It could meet market requirements for energy, paper pulp production and construction of building materials but it can also cause serious problems such as the outbreak of fires in the dry seasons and obstruct the free flow of rivers causing serious problems to structures and bridges (Andreu et al., 2013) (Fig. 1). However, giant reed has never been cultivated as a crop because there is yet no market for it.

In Mediterranean areas, giant reed grows widely naturally along stream and river banks. In good environmental conditions, the height can reach more than 10 m. (Garden, 1997). The nodes located along the stem, which are at a distance of about 20 cm from each other, give it a greater strength. The stem has a thickness of 0.2 cm–0.6 cm and an average external diameter of 2–3 cm or even 4 cm (Speck and Spatz, 2003). The underground rhizomes of giant reeds are woody and fibrous and penetrate as much as one meter deep into the soil and allow the vegetative reproduction. The giant reed has been traditionally employed for building fences and temporary shelters for man and animals. They have also been used as props for plants, as windbreakers or as shading barriers. The use of giant reed as a construction material can be improved with our current technology and knowledge, which allow us to set behavior models, increase their resilience and improve safety. Although the mean tensile strength of the culm of giant reed (TS = 248 Mpa) is more than bamboo (TS = 230 Mpa) (Ahmad and Kamke, 2003) it is not used as a high performance structural material in the same way as bamboo. In some countries with a hot dry climate the giant reed is used as building components. For example in the swamps of southern Iraq the traditional houses, called " Mudhif, were built with large and thick arches of giant reed culms. The arches built of giant reed were bundled into were by giant reed bundled into columns and then bent across and tied to form a curved geometrical shape. This building system creates a pre-stressing of the arches that are IS initially inserted into the soil at opposing angles (Fig. 2).

Fig. 1. Culm of *Arundo donax* L.

The shape of the buildings is defined by the number and the diameter of the arches. For the Boom Festival 2010 in Idanha-a-Nova in Portugal, the architect Jonathan Cory-Wright, proposed a similar building system (Cory-Wright, 2018). The shelters were built joining together arches of giant reed, and it was the best example of modern architecture with giant reed, that highlighted the best performance of this vegetal material. In Italy and in Spain giant reed is used only in some parts of the buildings, for example for walls or for ceilings. After the earthquake in 1908 in the southern part of Calabria, to take advantage of the light weight of the culms, giant reed was used for cavity walls in the reconstruction of many buildings and refurbishments (Barreca, 2012). In several Countries of Mediterranean areas, giant reed was also used with plaster in some structural elements (e.g. floor slabs and roof slabs) until around 1960, especially in rural buildings, but also in some buildings in the city. We can find them in interior elements and also in exteriors under cover (Fig. 3), but always with the cane protected from the water. This use has been supported by the practice of