



Review

Plant aggregates and fibers in earth construction materials: A review



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HIGHLIGHTS

- Earth-based products with plant aggregates as a sustainable material are reviewed.
- Physicochemical and mechanical properties of plant aggregates or fibers are reviewed.
- Mechanical, hygrothermal and durability performances of the composites are reviewed.
- Further investigations are needed to promote these materials.

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ABSTRACT

Earth as a building material is increasingly being studied for its low environmental impact and its availability. Plant aggregates and fibers have been incorporated into the earth matrix in the aim of enhancing performance for thousands of years but scientific studies began quite recently. The present paper reviews the state of the art of research on the influence of these various natural and renewable resources in unfired earth materials such as compressed earth blocks, plasters, and extruded and stabilized blocks. This review, based on 50 major studies, includes characterization of the particles and treatments, and recapitulative tables of the material compositions, and the physical, mechanical, hygrothermal and durability performances of earth-based materials. A lack of references on hygroscopic and durability properties was observed. Future research orientations are thus suggested to promote and develop this type of sustainable material, which provides a solution for saving energy and natural resources.

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1. Introduction

The impacts of buildings on the environment and on the health of their occupants have now become priority issues. Indoor air quality is considered as a major risk factor for human health and improving the environmental quality of buildings has become a major objective, which could be attained by improving their hygrothermal performance and by using safe construction materials with low impact. For many reasons (heritage, ecological, economic, proximity ...), construction materials that have been used by Human for thousands of years, such as earth and/or bio-based materials (wood, fiber and plant aggregates) are being reconsidered as pertinent materials. Earth is still the most widely used construction material in many countries in the world. Even today, around one third of human beings live in earthen houses and, in developing countries, this figure is more than one half [1]. In advanced economies, earth construction was abandoned in favor of concrete for several decades after the Second World War but earth is again becoming attractive nowadays because of its low environmental impact and because it is known to be a natural humidity regulator and to improve comfort inside buildings. It is usual to strengthen and/or to lighten the earthen construction materials by adding plant aggregates. This review results from the bibliographic survey realized prior to the BIOTERRA research project, which aims to characterize the mechanical and hygrothermal properties of building materials (blocks and plasters) composed of earth and bio-based aggregates. The project started in 2014 and is supported by the French National Research Agency. The consortium is composed of 9 French partners (5 laboratories, a technical center and three industrial partners).

The growing interest in traditional earth building has led to numerous publications during the past ten years, mainly on compressed earth blocks and rammed earth buildings, including two recent reviews. Pachego-Torgal and Jalali have written a review on the environmental benefits of earth for future eco-efficient construction [2] and Danso et al. have studied the enhancement of soil blocks in a quantitative review [3]. However, the paper by Danso et al. focused on the effect of binder (chemical or organic) and

aggregate or fiber additions on the properties of earth blocks, and only a small part of it concerns plant or animal aggregates or fibers. Furthermore, the systematic use of chemical binders to stabilize earth blocks is open to debate [4].

The review presented here deals with the plant aggregates and fibers used in earth construction materials in general (blocks, earth plasters, rammed-earth, cob and wattle and daub). It is based on 50 published studies of earth-based composites with plant aggregates and also includes an analysis of 8 more works on some of the natural fibers found in the initial 50 studies. The review is separated into three parts. The first presents the plant aggregates used in earth construction materials (origins, characteristics and treatments used to improve performance). In the second part, the compositions and the manufacture of earth-based composites are presented. In this part, the subsections correspond to the technique used (earth blocks, earth plasters and a last part grouping rammed earth, cob, and wattle and daub). The third and last part of the paper is composed of 4 sections that present the effects of plant aggregates on the properties of earth-based composites. The four types of properties studied are: physical properties (density, shrinkage, water absorption and sound insulation), mechanical properties (compressive strength and elastic modulus, tensile and flexural strength, and adhesion between earth plasters and wall), hygrothermal properties (vapor permeability, sorption-desorption and thermal conductivity) and durability (resistance to water, resistance to wind-driven erosion, resistance to freezing/thawing, biodegradation and microorganism development).

2. Plant aggregates and fibers used in earth construction materials

2.1. Origins and characteristics of plant aggregates and fibers

Studies of many kinds of bio-aggregates according to the location, and hence the availability, of the materials can be found in the literature. The origin of these bio-aggregates can be plant or animal, but plant products are found in the majority of cases. Only

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