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Poster 1/2

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CiAUD Centro de Investigação em Arquitetura, Urbanismo e Design

FCT Fundação para a Ciência e a Tecnologia

Protecting Heritage in Harsh Environment by Biopolymers

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Keywords
Soil treatment, chitosan biopolymer, shear strength, chitin, green technology, Adobe architecture

Partner Institutions
Universidade de Lisboa

Expected Future Partner Institutions

OBJECTIVES

Main Research Question: Which biopolymers are more suitable and cost-effective for reinforcing clay and adobe structures?

Secondary Research Questions:

- What are the destructive and destructive factors and undermining the sustainability of the adobe architecture?
- Can this chitosan be a step towards a practical way of protecting adobe structures?
- What eco-friendly materials can be used to strengthen clay?
- General Goal: The main purpose of this study is to investigate new biological technologies that are capable of strengthening clay and adhesive structures, as well as their comparison with traditional stabilizers that will use computer modeling and specialized laboratories in this process.
- Specific Goal: Investigating the possibility of improving soil strength properties by adding chitosan biopolymer to soil
- Investigation of the effect of curing time on the resistance properties of improved soil

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ABSTRACT + IMAGES

Many of the old heritage buildings and even many current buildings in the world are made of adobe, which is a sustainable, inexpensive, and environmentally friendly material. The adobe buildings react harmoniously against gravity or lateral forces, but structural fractures and sudden forces such as natural disasters or moisture leakage are the main causes of making them vulnerable, especially against earthquakes. Strengthening and reinforcement of adobe materials have long been discussed, and techniques such as adding materials to adobe or plastering adobe walls have been used to increase its resistance.

The present study has been carried out to strengthening adobe structures against severe weather conditions, including frost and wind erosion resistance. To this end, Chitosan biopolymer can be used to prevent water infiltration and reduce the possibility of freezing as well as increased resistance to wind erosion.

Adobe is the most basic construction material that dates back to about 5000 years ago. According to UNESCO statistics, 10% of the world's registered heritage is comprised of adobe structures. Adobe has beneficial properties that make it an ongoing construction material for its low environmental pollution, affordability, high thermal performance, optimum for winter heating, and summer cooling. Adobe production requires only 1% of the energy needed to produce Portland cement and can make a better balance of moisture inside the building. Other advantages include easy and inexpensive production, having good acoustic behavior, fire-resistance, and since it is made of soil, it is environmentally friendly.

The discovery of natural Pozzolanic materials such as volcanic ash led to the creation of more durable structures. After the Industrial Revolution, conventional Portland cement was used as the most widely used material not only in construction but also in soil stabilization and reinforcement.

Nowadays biological methods have been investigated as an alternative to traditional soil recovery methods and their effect on improving soil mechanical properties has been proven.

In recent years, the use of environmentally friendly materials such as biopolymers has become commonplace in the field of geotechnical engineering. So far, these materials have been used to modify geotechnical properties such as resistance, permeability, erosion.

The second most abundant biopolymer in nature after cellulose is chitin, derived from the hard outer covering of crustaceans and shrimp and beetles as well as the fungus stem. More than 45% of shrimp processing involves waste from the outer shell of the shrimp and these wastes are one of the environmental problems. These dietary and fishery waste makeup about 50 to 70 percent of the raw material's weight and contain valuable compounds such as chitin and protein.

The chitosan biopolymer is one of the chitin derivatives, mainly derived from the hardcover of marine animals.

Biopolymers such as xanthan gum and chitosan are widely used in the production of viscosity modifying additives in cementitious materials. It is possible to modify the properties of cementitious materials using nanotechnology and to produce nanoparticles such as Nano-chitosan and nitrocellulose. Although the use of chitosan in high-performance super-lubricants has benefits in terms of structure and environmental protection, the specification needs to be amended on the chemical structure of chitosan and this requires finding an economical and efficient way to chemically modify the chitosan structure.

In this research, we will try to make use of Iranian and Portuguese climate compatible biopolymers as an alternative to the current soil stabilizing materials and also reinforce earth and adobe structures concerning morphological and reversible principles as well as environmental impact and its cost-effectiveness concerning production and test of a functional material.

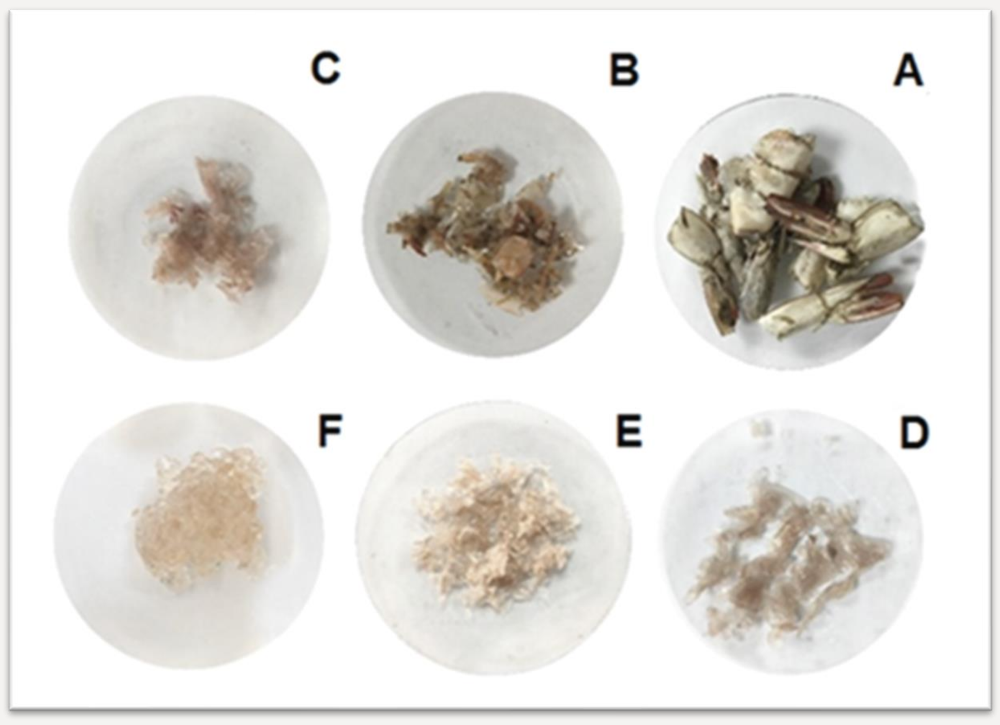

Fig 2. Steps to prepare chitosan gel from shrimp skin lesions

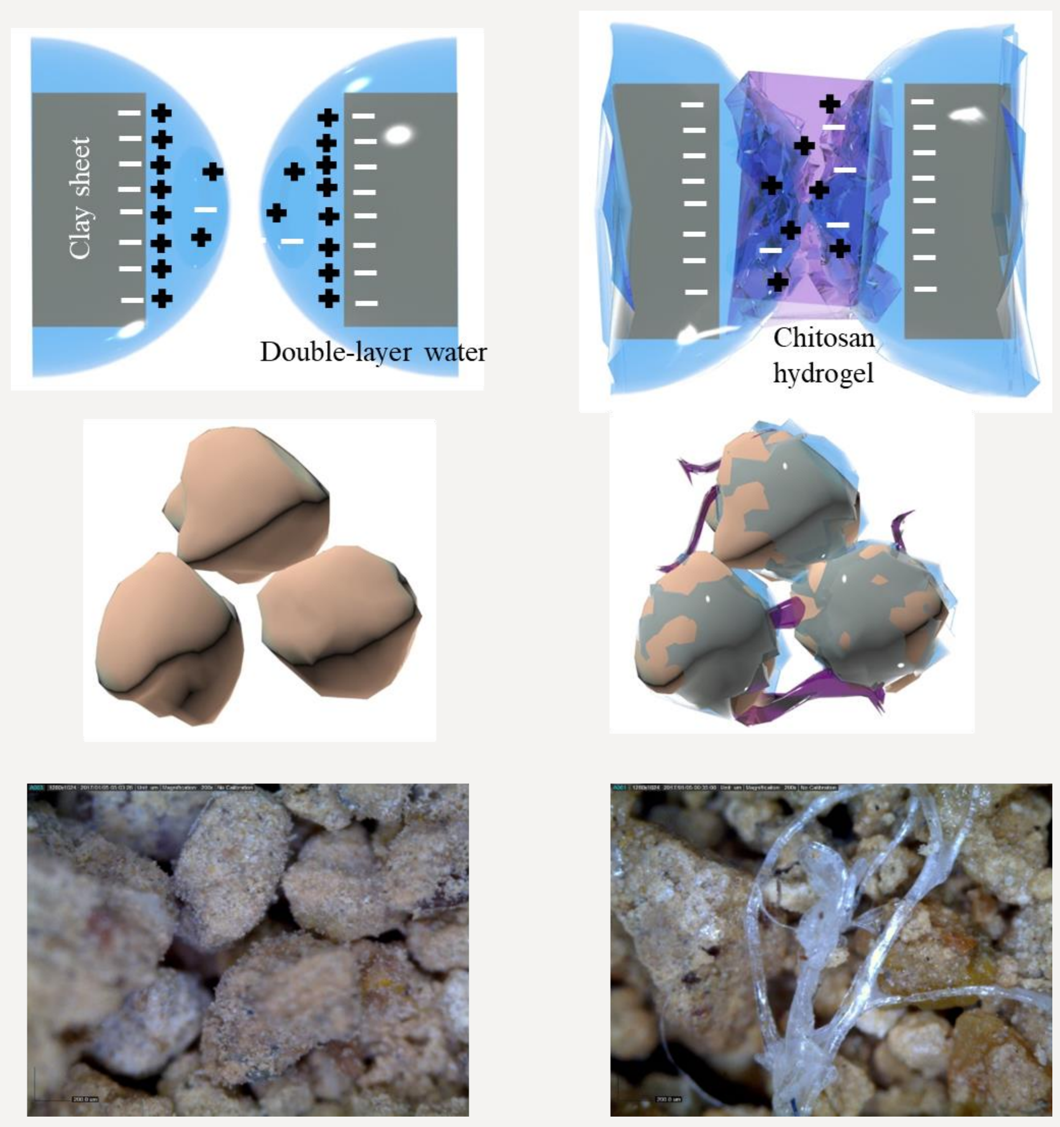

Fig 3. Clay-biopolymer interaction

Fig 1. Arg-e Bam, the largest adobe building in the world. Bam, Kerman, Iran

Fig 4. Sand-biopolymer interaction

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Poster 2/2

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SCIENTIFIC RELEVANCE FOR THE DISCIPLINE

We define heritage science broadly as anything involving the application of scientific methods for measuring change, analyzing materials, protecting them from decay, and consolidating vulnerable components. This encompasses a common distinction between applications of science to advancing understanding (of both material change and heritage environments), and intervening to modify, manage, or arrest material change. The latter area is sometimes referred to as 'conservation science and includes both preventive conservation based on scientific understandings of agencies and processes of deterioration (sometimes referred to as 'environmental conservation'), as well as remedial conservation, which may include adding or removing materials using techniques originally developed through scientific research.

EXPECTED ECONOMIC AND SOCIAL IMPACT

The demand for a new concept of heritage, in which monuments and landscapes are considered active factors in creating a sense of history, is esteemed not only from a scientific and academic perspective, but as well as part of a more sensitive and efficient strategy to link cultural heritage and tourism, by bringing an integrative perspective to the forefront. Implementing such strategies is strictly correlated with the ability to support decision-makers and to increase people's awareness towards a more comprehensive approach to heritage preservation. In the present work, a robust socioeconomic impact model is presented. Moreover, this work attempts to create an initial link between the economic impacts and natural hazards induced by the changes in the climatic conditions that cultural heritage sites face.

RESEARCH PLAN AND TASKS

Due to the large volume of problematic soils in the southern provinces of Iran, with a large number of adobe structures built in these areas, an appropriate approach is needed to stabilize these soils and adobe structures; a method that, in addition to its efficient performance, also causes the least damage to the environment and also does not damage the originality. In recent years, the use of environmentally friendly materials such as biopolymers has become commonplace in the field of geotechnical engineering. So far, these materials have been used to modify geotechnical properties such as resistance, permeability, erosion.

The second most abundant biopolymer in nature after cellulose is chitin, derived from the hard outer covering of crustaceans and shrimp and beetles as well as the fungus stem. More than 45% of shrimp processing involves waste from the outer shell of the shrimp and these wastes are one of the environmental problems. These dietary and fishery waste makeup about 50 to 70 percent of the raw material's weight and contain valuable compounds such as chitin and protein. A significant amount of shrimp fishing in the south of Iran (47000 tons in 2019) including Khuzestan, Bushehr, Sistan and Baluchestan and Hormozgan provinces as well as shrimp cultivation in provinces such as Golestan, West Azarbaijan, Zanjan, and Kermanshah. Available in the body of this aquatic species to improve the problematic soils of Iran.

The chitosan biopolymer is one of the chitin derivatives, mainly derived from the hardcover of marine animals. To make chitin, after removing the mussels or lacquer from the marine animals, they are decontaminated in a 5 wt% protein solution and then in the 2% wt% hydrochloric acid solution. Then the minerals are removed in a 2 wt. % Hydrochloric acid solution. If the degree of acetylation obtained is less than 50%, the material derived from crustaceans is chitin and when the degree of deactivation is greater than 50%, the material is called chitosan.

It is widely used as a biodegradable and biodegradable biopolymer in various fields such as food, agriculture, cosmetics, and medicine. Chitosan has many applications in the field of civil engineering. Biopolymers such as xanthan gum and chitosan are widely used in the production of viscosity modifying additives in cementitious materials. It is possible to modify the properties of cementitious materials using nanotechnology and to produce nanoparticles such as Nano-chitosan and nitrocellulose. Although the use of chitosan in high-performance super-lubricants has benefits in terms of structure and environmental protection, the specification needs to be amended on the chemical structure of chitosan and this requires finding an economical and efficient way to chemically modify the chitosan structure.

Methods:

This applied-developmental research will be done using empirical-analytical methods, and its data collection will be through various techniques of library study, laboratory examination, field study, and hypothetical-inductive analysis.

The literature review in this study addresses the subject, principles and related concepts to soil solidification in different physical, chemical and mechanical methods, and a variety of effective mechanisms in this field; and various experiments on soil consolidation and solidification and also earth material will be studied using different natural and synthetic additives, either organic or inorganic, to achieve necessary criteria to select the most appropriate new additives to improve the adobe properties against severe weather conditions and proper laboratory methods to measure and evaluate specimens. The practical part of the dissertation deals with the preparation of appropriate raw materials to make the adobe and Chitosan biopolymer, the laboratory study of soil and specimens.

The laboratory studies of this research will be conducted out based on ASTM International Standards, the American Association of State Highway and Transportation Officials (AASHTO), and the British Standards Institute (BS), in three main stages:

It is worth noting, although there are standards for geotechnical and soil mechanics engineering to investigate the soils physical and mechanical properties, most of these experiments have been designed to evaluate soil in civil engineering, and in the meantime, there is no standard to evaluate traditional materials in adobe and mud-brick buildings; therefore, the laboratory methods provided in these standards must be partially adapted to the design objectives to evaluate the building materials such as soil; and in some cases, new methods should be invented and presented.

Contribution of the research to the focus area: The overall purpose of this study is to study the adobe structures to identify the methods of reinforcement of these buildings to preserve the monuments of historical value and to transfer them to the future, and on the other hand to observe the universal principles and rules of restoration and non-damage to the environment. The necessities of the present research are discussed in the following aspects:

General Requirements: Enables the transfer of Iran's and Portugal ancient cultural heritage to future generations.

Special Requirements: Given the certainty of the destructive earthquake force on the valuable adobe buildings of Iran and Portugal, and due to the exhaustion of these buildings, it is important to explain the principles of retrofitting for those kinds of buildings.

Scientific Requirements: It is necessary to elaborate on the basic principles and strategic principles and modern scientific rules and models for the seismic improvement of the clay-historical buildings of Iran and Portugal and to advance the scientific boundaries in this field.

Developmental Requirements: The discovery of applied techniques in reinforced adobe building methods is invaluable

Preparation of chitosan gel from shrimp skin lesions

Shrimp skin will be used to make chitosan. The preparation method is as follows. First, the skin of the prawns is completely cleaned, and the contents inside them are drained. Then wash with water and dry for two days. After this step, the bark of the prawns will be crushed and ready for the next step. The next step is to put the crushed skin in 7% HCl solution 24 hours at ambient temperature. After this stage, the solution's materials will be thoroughly washed with water and placed at an ambient temperature of 10% NaOH for 24 hours and subsequently washed and finally stored in ethanol for 24 hours. Up to this point, what is achieved is chitin, which is converted to chitosan due to DE acetylation. For this purpose, Caitlin 50% NaOH solution at 110°C will be sprayed on the magnetic mixer for one hour. Then washed with distilled water and placed at 50°C for 12 hours for drying.

Work schedule:

The study to be undertaken following the defined will be elaborated in clarifying the following aspects:

- 1-Preparation of the samples
- 2-Chitosan biopolymer coating experiments
- Characterization
    - Static contact angle
    - Scanning electron microscopy
    - Thickness of the coating layer
    - water absorption test
    - Kars Capillaryten tube test
    - Durability test
    - Acid resistance test
    - Evaluation of the disadvantageous effects induced by the treatments
    - Influences of freezing-thawing cycles on the microstructure of adobe black
    - Influences of freezing and thawing cycles on wind-sand flow structure of adobe black?
    - Influences of freezing and thawing on wind erosion strength

EXPECTED SCIENTIFIC RESULTS

The main purpose of soil remediation is to modify soil engineering properties such as resistance, permeability, and durability to wet cycle and drying with environmental considerations. The discovery of applied techniques in reinforced adobe building methods is invaluable, with the necessity of preserving the shape or form and physical organs of these buildings and stabilizing their stability, reliability, and durability conditions. To elaborate on the basic and strategic principles of modern scientific rules and models for the seismic improvement of the historical masonry buildings of Iran and to enhance the scientific boundaries in this field

Preserving the country's, Iranian and Portuguese, adobe architectural heritage as one of the most important national assets.

Investigating the possibility of improving soil strength properties by adding chitosan biopolymer to soil

Investigation of the effect of curing time on the resistance properties of improved soil

Investigation of the effect of added Chitosan percentage on the soil resistance properties

BUDGET: € 1.000,00

The expected outcomes and expenditure of the project stages are as the following:

Phase 1: Achieve an optimum mix design of biopolymer. (€200)

Phase 2: Mechanical and durability tests such as unconfined compression test, wet & dry test, freeze-thaw test. (€250)

Phase 3: Microstructural tests such as SEM, XRD, and FTIR. (€250)

Phase 4: Conducting a pilot test in a heritage building. (€300)