A Research on the Improvement of Soil Building Material with Biological Additives and Factory Production of Soil Building Elements:

BIRE-PAN

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In the process of developing ecological strategies for sustainable cities, natural materials and construction methods are combined with design-production technologies. development is an important research area. This research project, which shows that soil building material can be developed with biological additives and that soil building elements can be produced in the factory with modern mold technologies and automation facilities, is developed with university-industry cooperation and interdisciplinary research, and is actively used in the architectural application environment, complying with the regulations, reflecting the natural aesthetics of the soil with contemporary architecture. can be realized as a design-production system.

Climate change is a global priority that directly affects the discipline of architecture. As part of the Sustainable Cities and Communities goal, the United Nations emphasizes the importance of using local materials and energy efficiency in architecture (Url-1). Harmonizing material resources and waste management with natural cycles in architectural design and production processes is becoming increasingly important. In this context, developing ecological strategies in architecture, interdisciplinary research and university-practice collaboration are becoming increasingly important.

Increasing the use of natural building materials in the construction sector and conducting research that updates local construction methods with contemporary production technologies support ecological strategies. In this context, earthen materials and construction methods within our architectural tradition are being carried to current research platforms (Url-2). The ability of earthen buildings to be produced with local materials and craftsmanship, the healthy environment they create with moisture and heat balance in the space, their affordability, and their ability to dissolve in nature when their use is completed are ideal features for the search for sustainable materials. Soil building material recipes, mechanical and physical properties, acceleration of labor-intensive construction methods with production technologies and compliance with building standards a r e among the issues being studied in this field. The diversity and natural aesthetics of earthen building construction methods enable earthen architecture to gain a place in the current practice environment in the world.

Ruhi Kafesci- son (Kafescioglu, 2017), Bilge Işık and the architects they trained are our pioneers in this field, who put forward the vision of contemporary earthen structures in the Earthen Structures Working Group established at ITU and introduced plastered adobe to researchers. The YBE institute (Url-3), which brings the concepts and principles of building biology to the agenda of architects in Turkey, and the adobe network symposiums (Url-4), where adobe research is shared on an international scale, are important addresses for earthen building research. On earthen building construction methods, earthen building elements, earthen plasters

young groups, practitioners and academics are working in solidarity to keep the issue on the agenda (Url-5). Although the number of practices in Turkey has started to increase in recent years, in Europe earthen buildings have been a part of architectural practice for many years. For example: Martin Rauch (Url-6) and Anna Herringer (Url-7). These examples make the need for the development of earthen building material recipes and adaptation to contemporary construction methods more evident in order for earthen building practices to increase in our country and to be demanded by architects.

The BIRE-PAN project, supported by the Istanbul Bilgi University RDI Priority Areas Research Projects Support Program, is a 3-year research project designed by full-time professors from the departments of architecture, bioengineering and construction (Url-8). The aim of the project, titled Design and Production of Biologically Additive Compressed Earth Panels as Precast Building Elements, can be summarized as preserving the superior properties of earth building material in terms of sustainability, improving its weak properties with biological additives; designing building elements and components that are mass-produced but allow for diversity; and increasing the demand for earth structures thanks to the speed and standard that factory production will provide.

The significant thresholds that the interdisciplinary research team (*), comprising bioengineering; civil engineering; architecture, earth architecture and natural materials expertise; manufacturing; building biology and communication expertise, overcame during the project deserve to be mentioned as topics: The most important criterion that we discuss with our stakeholders while passing through these thresholds, which we can describe as the development of biologically additive soil building material recipes; numerical design of soil building elements; factory production of rammed earth blocks and panels with molds; construction of prototype spaces; measurement and sharing of results, is to carry out the process in accordance with the life cycle analysis approach and sustainability criteria.

Soil Building Material Development and Lab tests (Herbal, Bacterial)

Examples of buildings produced with precast earth panels and blocks where earth building elements are produced in the factory are found in the literature (Url-9). In these examples, it has been determined that cement additives or solutions that are not suitable for human health and sustainability criteria have been used to stabilize the earth building material. The aim of the project is to use biological additives in soil building components and to reach appropriate standards in terms of sustainability. In the project, with an interdisciplinary study, various plant wastes and bacteria were integrated with soil materials. These new mixtures were evaluated in terms of various performances such as structural strength, water resistance, shrinkage and lightness.

In this process, samples were produced to compare existing recipes, such as plaster adobe, with new recipes. Biological additives were identified and procured. A series of tests were conducted to determine the physical, mechanical and microstructural properties of the BIRE recipe: Different mixtures were prepared for tests such as compressive strength, flexural strength, modulus of elasticity, capillary water absorption, pH, density, shrinkage, thermal conductivity, XRD and SEM to determine the microstructural properties, the machines and apparatus required for each test were set up, and the tests were repeated at the time intervals required by each test.

The bioengineering working group prepared various recipes with peanut shells, corn cob outer leaves, sunflower stalks and rice husks, taking into account that the plant material that can be added to the soil is agricultural waste and not used in priority areas. The effects of these herbal additives on lightweighting, water resistance, shrinkage cracks or structural strength of earth blocks or panels were evaluated through tests. The recipe tested with rice husk was taken as the basis for production in the factory due to its availability.

In the current literature, bacteria are included in building materials and biomaterials research with their ability to increase the strength of building materials and self-repair. In the BIRE-PAN research, the bacteria identified by the bioengineering team, taking into account previous studies, were obtained from a laboratory in Germany, propagated in TÜBİTAK / MAM laboratories and tested in Istanbul Bilgi University laboratories. For logistical reasons, the bacteria could not be added to the soil recipe in the prototype space built, but it was found that the strength of the soil samples with bacteria was high, especially in compression tests. The research experimented with how to work with disciplines such as bioengineering and civil engineering in the process of developing building materials and how natural materials can be developed with contributions from nature and principles learned from nature.

> "Although the project was small in scale, its widespread impact was huge; it was shared through interviews and articles on architectural practice, education and academic platforms. the intense interest shown shows that when such systems are developed, the demand for ecological building will increase."

Design of Earth Structural Elements

Earthen architecture has existed in almost all climatic zones and geographies with its robustness, durability, economy, diversity of local materials, craftsmanship and construction methods, and applications in different contexts, styles and scales; the earthen building heritage is concentrated in the central and southern zone (Houben & Guillaud, 1994). In today's contemporary applications of earthen architecture, which is a part of cultural heritage and architectural tradition with these features, examples are encountered in which current production methods such as mold technologies, prefabrication, 3D casting, and die casting are used.

In the design of the BIRE-PAN system, the focus is on the wall system as a building component; geometric research has been carried out on the flat, textured and perforated wall patterns that will be formed by the arrangement of the earth blocks produced in the factory and compressed in the mold. Six types of blocks and structural elements were designed for the T- and I-shaped blocks that fit together like Legos on all axes, special jamb elements for the door openings and L panels that cover the load-bearing skeletal system. In the design of the blocks, geometric investigations of the wall patterns were studied with numerical models, form, size and pattern experiments were carried out with physical models taken from 3D printers in university production laboratories; when the design developed, the production of real-scale prototypes was started in Fibrobeton's factory in Düzce (Url-10).

Factory Production of Earth Building Elements

During the design and production process of the earth building elements, Fibrobe- ton production team worked together with the Fibrobe- ton production team on the dimensioning of the blocks, mold design, material standardization, compaction-sieving automation, and the association of building components. During the design development process, many prototypes were produced in the production area in the factory. As a result of this R&D process, the soil mixture for production in the factory was brought to a standard, mold types were determined, the ambient conditions under which the blocks will dry under normal weather conditions without baking and energy consumption were determined, and work-worker-duration-cost plans were made. The minimum size where the design-production process of BIRE-PAN soil blocks and building elements will be tested was determined.

A workflow program was made and an application project was drawn for the construction of a space in the loading dock. All material supply, mold design, block-panel production, labor and application process costs were covered by Fibrobeton and the prototype space application was carried out by the team in the factory.

Prototype Space Construction

The feasibility and sustainability of the design-production system was tested by constructing a BIRE-PAN Observation Room of approximately 20 ^{m2}.

In order for earthen architecture to become widespread in cities, instead of masonry system where blocks are the carrier, the scenario of realizing the walls added to the existing skeleton systems (reinforced concrete, wood, steel) as inner and outer infill walls with earthen blocks was adopted. For the BIRE-PAN Observation Room, a light steel skeleton system was anchored on the concrete floor in the open R&D area. In the 20 ^{m2} closed space, one door and window opening was positioned according to the use and orientation. Approximately 1100 building elements were produced in two and a half months, and the application of all building elements on the construction site was completed in 2 weeks. At the end of the construction process, flat, textured, hollow wall patterns were tested; earthen jambs specially designed for door and window openings were applied; insulation to prevent thermal bridges between the skeleton system and earthen walls was wrapped, and the details of the junction with Fibrobeton's UHD terrace roof panels were tested. At the end of the 3-year research process, a closing event was organized open to all stakeholders and anyone interested in earth architecture, and a technical visit to the BIRE-PAN Observatory was organized after the process findings and film presentation.

Advanced Goals

Due to time and budget constraints, bioclimatic measurements could not be carried out in the prototype space; determining the performance of building biology in terms of energy efficiency, indoor air quality, etc. was left for further research. Although the project was small in scale, its widespread impact was great; when shared through interviews and articles in architectural practice, education and aka- demic platforms, the intense interest in earth architecture and the proposed system confirmed that the demand for ecological buildings will increase when such systems are developed (Url-11).

In the process of developing ecological strategies for sustainable cities, the development of natural materials and construction methods through design-production technologies is an important area of research. This research project, which shows that soil building material can be improved with biological additives and that soil building elements can be produced in the factory with modern mold technologies and automation facilities, can be developed with university-industry cooperation and interdisciplinary research and can be implemented as a design-production system that is actively used in the architectural application environment, complies with the regulations, and reflects the natural aesthetics of the soil with contemporary architecture.

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Url-1 <https://sdgs.un.org/goals>

Url-2<https://conf-earth.sciencesconf.org/?lang=en>

Url-3<https://www.yapibiyolojisi.org/yapi-biyolojisi- ecology/>

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Url-10<https://fibrobeton.com.tr/proje-tamamlanan- projects-fibrobeton---duzce-uretim-tesisleri-90> Url-11<https://www.youtube.com/watch?v=_ XTRQcKEc3k>

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