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The Relationship between Nature and Architecture in Construction and Material Selection (The Case of Mycelium)

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(Illustrations drawn by Levent BURGAZLI)

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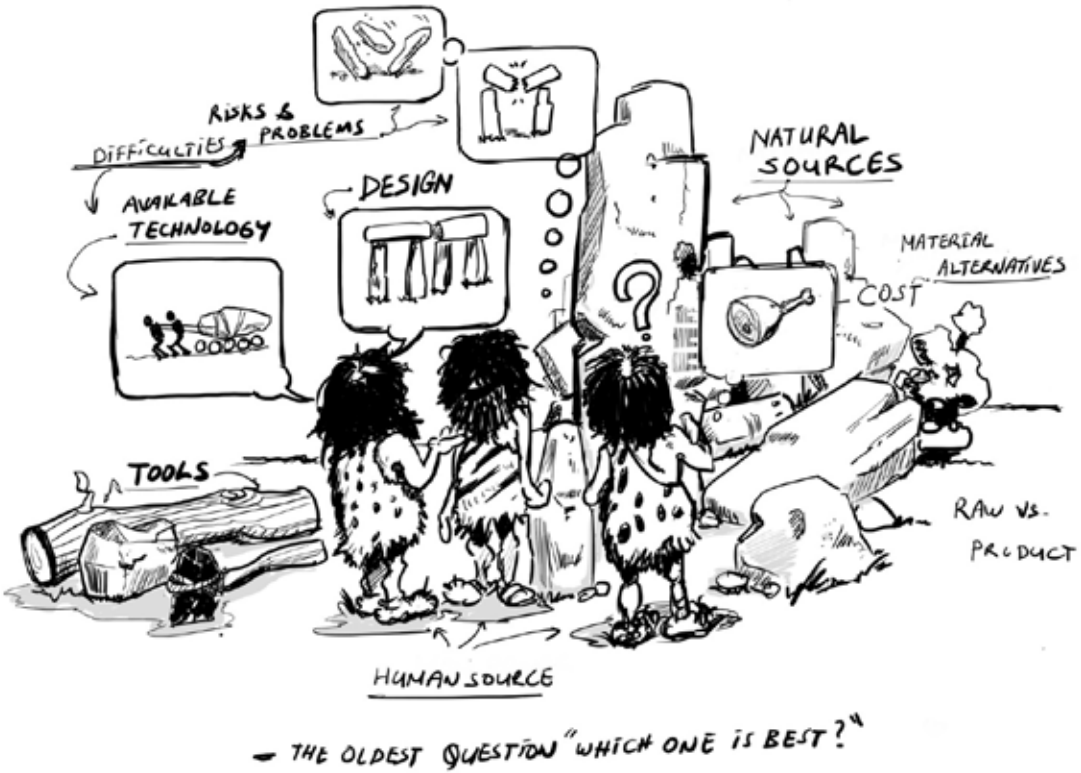
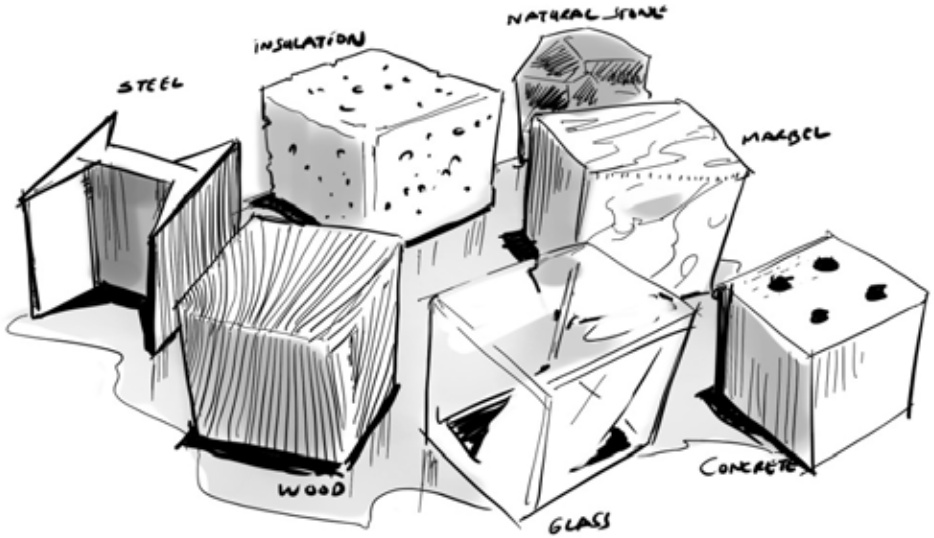
Abstract Each new structure replaced in the nature dissolved the destroyed nature. This lost space can be an opportunity to establish the relationship between architectural structures and nature. When we discuss about the architecture, one of the first words that comes to our mind is usually clay; but in fact, the nature including the entire structure of human life and architecture, which lies as part of nature in its pronoun. Using bioengineering techniques and material in today's architecture improves the relationship between buildings and nature. This research is qualitative research in terms of objective and descriptive-analytical and descriptive analysis in terms of method which tries to study the relationship between architecture and nature. The data collection method in this research is based on literature review and the study of theoretical foundations. Here, it has been tried to have a short review of relationship between natural materials and design thoughts and focus on mycelium, as natural material case-study of the research. The results show that studying and focusing on natural materials and sciences can help architecture and cities to be more sustainable and fresh.





1. Introduction:

All human activities and measures are a manifestation of nature, and this fact has a root and foundation in nature. Accordingly, all human innovations in the field of life sciences and skills are nothing but the discovery of a corner of nature, and there is nothing as an invention. What we call it invention is in fact the same as an actualization of the existing and current macro-concepts and laws in nature, which have existed from the beginning of the universe and are repeated, and only we were unaware of them.

All this is an introduction to illustrating the relationship between components and elements of nature and how they affect the everyday human life and finally, how these factors affect human architecture. Great architectural achievements can be achieved through the precision and exploration of the natural phenomena architecture on the scale of the particle and the macro, including the intricacies, plants, animals, and human existential dimensions in the broader horizons. In fact, architecture can be defined as a new phenomenon which is the achievement of a regular and mutual relationship between human and nature. Ultimately, architecture will have hierarchical and reciprocal relationship with human as its creator and, with nature as its basis. Architectural design is impossible without communicating with humans and their surroundings. Human, nature, and architecture all three form the human life cycle and the movement of this cycle is not possible except through the continuous and regular connection between these three main loops of the human life chain (Golparvar Fard, 2009).

With more deliberation on the technology, we get the clues that lead us to nature. Today, wherever technology is discussed, the image of the same important technological achievements that meets the basic needs for today's and tomorrow's human beings comes to mind, but if we look at the technology path, we are more or less aware of the origin of some phenomena, for example, any industrial or building phenomenon is inspired by a natural pattern (Golabchi and Khorsand Nikoo, 2014).

But today, with the advent of science and technology, every day we understand more and more, and everyday old beliefs are replaced by newer ones. In this regard, architects with a different look at the fungi have come up with a new idea about the design of their self-healing greenhouses, that, using bio-engineering methods, a special type of porous bricks with mycelium base has been built which will surely be able to transform the practices of the building industry.

The reason for the choice and the main differentiation aspect of mycelium or fungus branches, as the case of this research, is that they have the ability to recover themselves and grow again in the event of injury. Also, the mechanism of making or, more precisely, the cultivation of this material is that the mycelium grows during the vegetative period of the fungus on the agricultural byproducts and they are strapped around like cotton wool, they look like white mildew but in general, they form different structures. The plan uses living organisms that are compatible not only with the environment and nature around them, but also have recycling capabilities and also have high strength. It is from the base of nature and can be restored to nature. In this research, this way has been used to construct temporary and portable housing with different uses in hot and dry areas, using existing plants in the region. So that this method is used in line with nature-friendly architecture, and with a new approach to nature-oriented architecture, as a new human need today, to maintain its own.

2. Nature and Architecture

This research introduces the new technology for the use of natural thoughts and materials in the design and construction as well as the use of them in the creation and construction of buildings in line with nature. The combination of bamboo, straw, palm leaves and other plants in warm and dry areas with mycelium in creating temporary residences with lightweight and portable structures is a new way of using unlimited natural resourc-

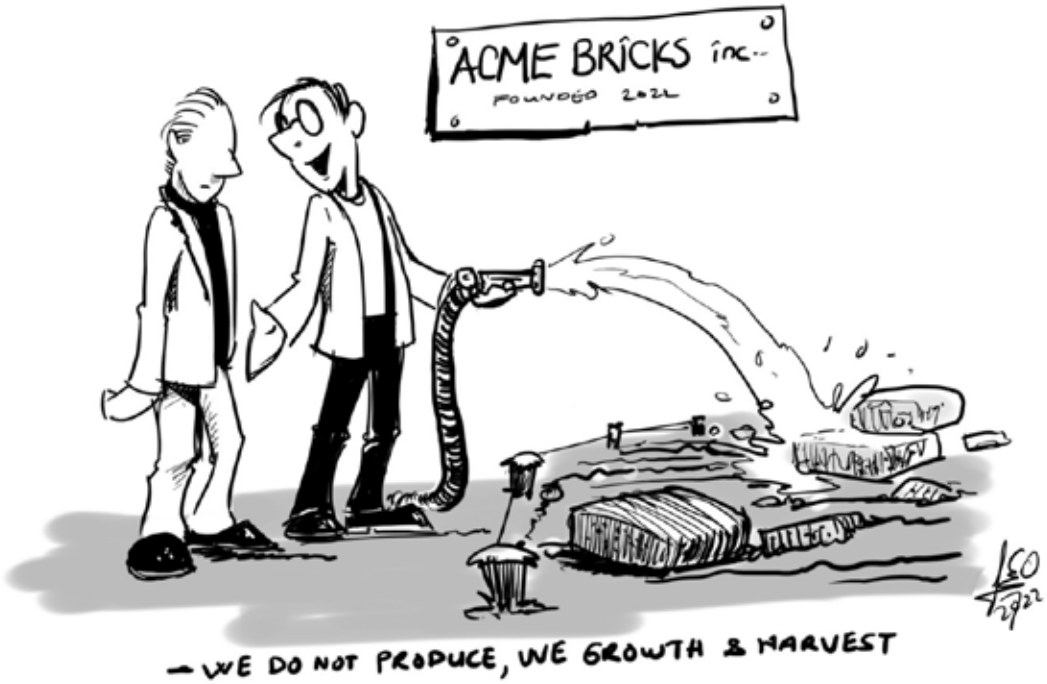
es, such as proteins and bamboo to maintain resources and energy from the point of view of reducing resource consumption and reducing pollutant production and thus reducing the pressure of the building industry on the environment. Also, this method, produces cheap, affordable, and environmentally compatible materials using modern construction technologies which are considered as acceptable alternatives to existing materials that are in conflict with nature.

One of the American architects David Benjamin, director of the Living Architectural Corporate in New York City, with a different look at the fungi, came up with a new idea about the design of self-healing greenhouses. This American designer developed a special type of mycelium-based porous bricks, using bio-engineering methods. Mycelium or rhizomes are branched and interconnected strands that form the fungus tissue and, the feature of these strands is that they have the ability to heal themselves and grow again in case of injury. The construction mechanism or, more precisely, the cultivation mechanism of these bricks is that the mycelium grows along the straw during the growing period of the fungi, and are strapped around the straw like cotton warps and appear to look like white mildew, but in general form a different structure. The plan uses living organisms that not only are compatible with the environment and nature around them but also have recycling feature, they also have high strength and are green in one word, it is from the base of nature and can be restored to nature (Stott, 2014).

The use of this fungal material will not end here but in another design, the material which had already been introduced to the industry has been able to useful in the architecture and it could definitely evolve the practices of the building industry and especially for places where access to materials is difficult, these bricks, which require only a small amount of early material and some sunlight, can be considered as very good materials (Safaee, 2016).

To date, a few small structures have been made of fungi-based building materials, and even there are companies that produce home and industrial furniture. Many other companies also use fungi for designing tiles, boards, foam-replacement materials and biodegradable packaging. On the other hand, fungi grow fast and do not produce carbon or waste (Flagel, 2020).

Philippe Ross, one of the co-founders of Myco Vertex Company, has several inventions for the "Mycelium Engineering Process" which builds cheap and lightweight brick. Blocks can then be used to create cheap but durable buildings. The mycelium yarn is a vegetative part of the fungi, and is used in the process of engineering as a glue. Ross has discovered that due to the proper substrate and growth conditions, a fungal producing strain can be grown in any form and with any volume under sunlight. He made chairs, tables and easy baskets full of parasitic fungi and sawdust. After that, he began to nurture interconnected bricks and complete structures from fungal producing strains and found that he had accidentally faced great issues (Rezaee, 2020).



Ecoatio Company also uses fungus as a binding agent for keeping frame building wood pieces, as well as durable, non-inflammable, and lightweight element for packaging. Also, civil engineers at Clemson University are examining and testing fungi-based building materials in terms of strength, fire resistance, and insulation. Eddie Paolo, a member of the Myco Vorx group, has come to the conclusion that these bricks can surprisingly resist the pressure and shear forces. Also, if you put together two bricks at the time when their fungal producing strands are still alive, they will combine together that the connector between them is as strong as the bricks. In fact, it's a fairly soft piece that your finger can press it and so light that floats on the water and is tight enough to absorb a bullet. It also has a strong thermal and acoustic insulation and can withstand heavy hammering. The fungal tower, Hi-Fi is the first tower made with agricultural products and fungal mycelium. This group has been focusing its experiments on building design with agricultural products for many years and aims to design buildings which is the combination of natural ecosystems, materials, environment, technology and culture. This group has used biological systems, bio-based computers and bio factories to achieve its goal. In this structure, mycelium is used to provide building materials which

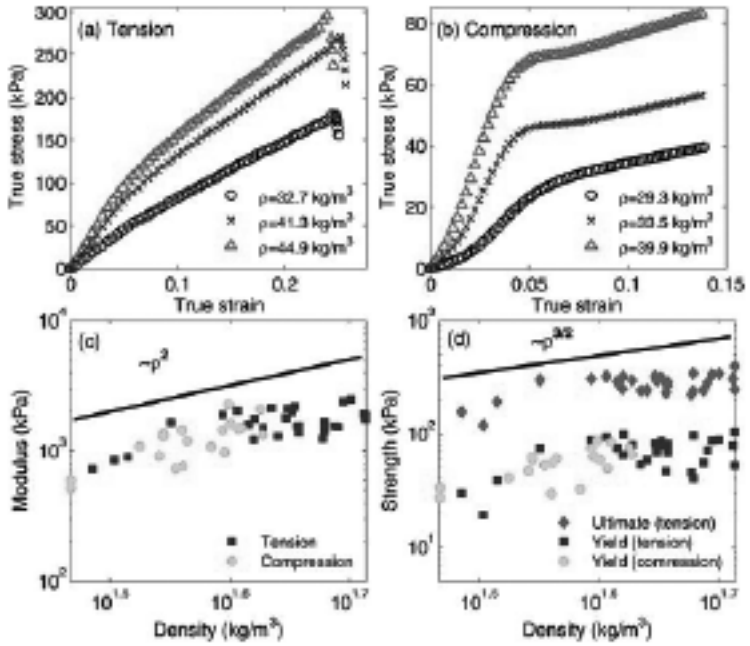


Figure 2 Effect of sample density on the stress-strain response in tension (a) and compression (b); Variation of the elastic modulus (c) and of the yield and ultimate tensile strength (d) with material density. Solid lines in (c,d) indicate the expected scaling for open cell foams.
(Source: MacLaren, 2015)

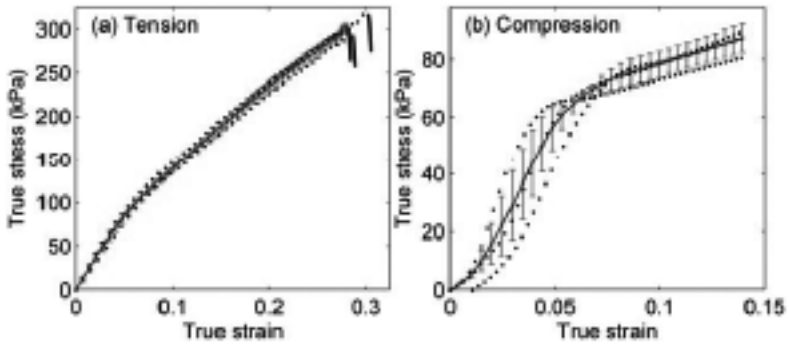
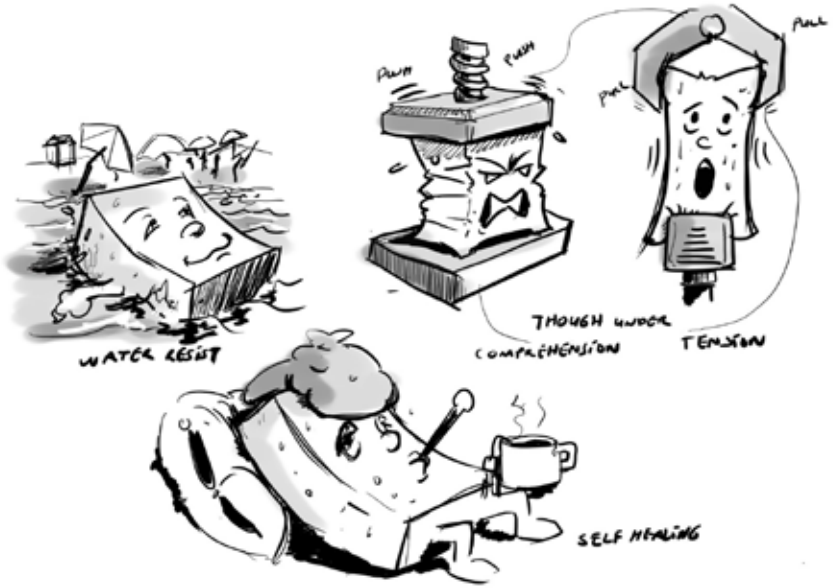


Figure 1 Generic stress-strain behavior of mycelium in (a) uniaxial tension and (b) compression (compressive stresses are shown as positive). The dotted lines (black) represent the range of tests performed on three specimens of comparable densities and the solid lines (blue) represent the corresponding mean responses
(Source: MacLaren, 2015).

are involved in the carbon cycle of the earth (McLaren, 2015).
This structure is the first building made from fungi. In fact, we will be able to use natural materials in building construction with a slight change in building materials and considering the structural sustainability. Biological systems have amazing and adaptive features such as self-regulation, self-healing, and correction. These features have made fundamental changes to human life.
As it mentioned, David Benjamin has worked on the subject of biology, design, and computing for several years; he has tested various ways in which living biological systems can be used as bio-based computers or bio-plants. Finally, he found that the materials made from mycelium are the best option. These building materials have a high capacity for healthy interaction with the Earth's carbon cycle. David Benjamin and the Ecoatio company have made bricks with mycelium, which are very sturdy and resistant to water. The compounds of these bricks are stems of cereals, bushes and mycelium. Bricks made will be rigid five days after the installation. This structure is the first building made from



fungi. In fact, we will be able to use natural materials in building with a slight change in building materials and considering the structural sustainability. Biological systems have amazing and adaptive features such as self-regulation, self-healing, and correction. Now imagine the changes created by these properties in the human life. The construction industry is ready to accept these new ideas. Biological systems have significant characteristics, including adaptation, self-organization, rehabilitation and regeneration. Imagine if future buildings have these features, our way of life generally changes (Stott, 2014).
The mechanism of the construction or, more precisely, the cultivation of these bricks is that mycelium grows along the straw during the growing period of the fungi, and are strapped like cotton warps around the straw and appear to look like white mildew. But in general, they form different structures.
(Hugo, 2016).

3. Use of Natural Materials in Buildings:
Considering the sustainability theme in recent decades to protect the environment, applied sciences and architecture science to meet the needs of future generations, and consequently, building that can also be risky for the environment and nature and, it also has the ability to be designed and estimated, and be used on the basis of identifying useful climate factors in each region. Sustainability thinking and design attitude are especially important to adapt environmental design to architecture. In other words, sustainable architecture uses design tools and construction methods and creates appropriate relationships between the environment and the building to minimize the negative effects of construction in the environment and causes achieving the goals of sustainable development by meeting the social and psychological needs of individuals.
Nature as a pattern; affects many of the strategies leading to architectural creativity. Nature is always present and indivisible, and is very powerful as a tool for inspiration. Its presence is observed in metaphor, imitation, variability of form, and also in obvious materials and, architects have respected and examined it from time to time, with proper approaches and have considered it as an inspirational tool (Antonius, 2003).
Nature and architecture in conscious coexistence naturally affect the process of each other and they are connected as they keep their unique features protected, and they are experimenting with interesting and vibrant structures, boundaries and common ground. Hence, the architect sees his structures not in opposition to the forces of nature, not in unconsciously giving to it, but in coordination with the forces, so that the human and nature in his structure appear to be united (Haj Hassan and Ghorbaninia, 2016).
Each new structure replaced in nature dissolves the destroyed nature. This lost space can achieve an opportunity to communicate with nature again. In fact, nature involves the entire structure of human life and architecture, which lies as part of nature in its pronoun, begins to connect closely so that the architecture live and breathes in harmony with the beat of the nature of the surrounding texture.
Considering the belief that there are systems in the nature of both visible and invisible, and their discovery is performed as soon as they begin to be understood, gives meaning to the understanding and accepting the natural guidelines in the structure of architecture. Thus, in this system, there is a thinking that not only does not ignore the geometry of natural structures, but it take advantage of it in time and if does not found it appropriate, with gradual awareness of nature system goes beyond it, look somewhere beyond the horizon of nature (Zamani, 2006).
With a slight change in building materials and considering the structural stability, we will be able to use natural materials in building. Biological systems have amazing and adaptive features such as self-regulation, self-healing, and correction (Ghavampour, 2013).
3.1. Morphological and Mechanical Properties of Mycelium
The morphological and mechanical properties of mycelium have been examined through a combination of microscopic imaging, mechanical testing, and computational modeling. The results show that mycelium compress the non-linear contractile behavior of strain and stress. The mycelium also shows the same mechanical behavior subjected to stress and uniform compression. In Fig. 1, black and white dot lines represent a range of stress responses of three samples of densities comparable to frequent experiments, while the blue lines indicates the corresponding responses. The tensile curve also shows that strain pressure and almost linear hardening to failure occur at low pressure (Abràmoff and Magalhães, 2004).

The diagram of strain and bi-directional strain of mycelium depend heavily on the density. Figure 2 shows the stress response of grown mycelium sample strain in slightly different conditions with different densities. For cell solids, and ultimate tensile strength with material density, the expected values for open cellular foams are shown.
Interestingly, the variation of all these quantities with the density is similar to that expected for open cell structures, despite clear differences between the network architecture and that of cellular materials precisely, we observe that the modulus varies with the square of mycelium density and strength varies. Several researchers have reported similar scaling with density for other low density materials such as polymeric foams, cancellous bone and collagen gels. In stress, the linear elastic material reaction is at low pressure, and then the material is produced and falls before the rupture. On the other hand, biopolymer has the same behavior as with cellular open foam, under uniform compression, until the pressure stress curve shows. In addition, when it is subjected to continuous loading and unloading cycles, mycelium can exhibit a foamy behavior as a biologically active material that has a high resistance and strength. Mycelium is composed of thin filaments called hyphae. In fact, a set of masses of the hyphae is called mycelium. The mycelium is a vegetative part of a fungi or colony of fungus-like bacterium, which is made up of a group of branches, called hyphae. Hyphae is sometimes known as syphilis. The fungus is not propagated by seed or energy absorption through photosynthesis. The fungus is also replicated through spores. Mycelium actually begins to grow like the roots of the plant, and it can also move around. The fungi receive nutrients from the environment through the mycelium. In a way that the hyphae will break down the biopolymers into small units such as monomers by enzyme secretion on the wood of rotten trees or other layers. Then, the fungus acquires the ingredients by absorbing monomers. These mycelia are a wide range of species that can grow up to hectares and merge with other mycelium. Also, mycelium is an important source of nutrition for many invertebrates which is very beneficial for the organic part of the soil, which can decompose decaying plant matter (Asefi and Imani, 2012).

4. Conclusion:

Based on mentioned studies of this research, it has been concluded that according to structures and bionic aspects of natural materials, they can be used as the main factors of the buildings to increase the friendly relationship of architecture and nature and can have many other positive effects in eliminating or reducing the use of toxic and nature damaging substances, in the construction industry, reducing the consumption of non-renewable resources and using plants and native tree wastes and availability, energy consumption and less pollution production and when applied has adaptation with the climate and ultimately, trying to maintain the identity of native architecture and adaptation to nature. We presented morphological and mechanical characterization of a novel biomaterial derived from fungal mycelium. Mycelium, as a project case, can be used at the base of the building. The experimental results revealed the most significant characteristics of mycelium under tension and compression. In tension, the material response is linear elastic at low strain, and then the material yields and undergoes strain hardening before rupture. On the other hand, the bio polymer behaves similar to open cell foam under uniaxial compression, where the stress-strain curve shows an initial linear-elastic regime followed by a plateau regime with softened response. Furthermore, when subjected to successive loading and unloading cycles, mycelium exhibits strain dependent hysteresis and stress softening effect from cycle to cycle that by using such kind of natural materials, the relationship between architecture and nature can be improved more and the cities and lives can be more sustainable and fresher.

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