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Usage of Arundo Donax L. as a sustainable material in interior design and architecture

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ABSTRACT: Using renewable resources has become a considerable solution for most problems in Egypt nowadays. It plays a role in issues such as energy crises, scarcity of natural resources and climate change. This paper focuses on sustainable transformation by using traditional perennial plants, such as bamboo, Arundo Donax and others, as renewable resources in wood manufacture. Egypt is in critical need of alternative raw materials. Thus, this paper focuses on studying the usage of neglected yet affordable materials, such as Arundo Donax L., in buildings and digital fabrication. Arundo Donax has been cultivated throughout southern Europe, Asia, northern Africa and the Middle East for thousands of years. This paper aims to discuss the use of Arundo Donax, both in its original state and after fabrication, in the context of interior design and architecture.

1 INTRODUCTION

1.1 *Shallow water plants*

They are semi-aquatic plants, similar to the Arundo Donax and bamboo, which grow in humid places, as their growth needs an abundance of water. The amount of water can be determined according to the plant type, facilitating their growth along lakes, streams, drains and wet sites.

1.2 *Arundo Donax (Giant reed)*

Scientifically named Arundo Donax L., this tall perennial cane is also known as the giant reed, Mediterranean reed, Spanish reed, Donax cane, Arundo grass and family Poaceae (Gramineae). Arundo Donax is indigenous to areas surrounding the Mediterranean Sea. It was later cultivated and naturalised in other major continents in regions with warmer climates. Egypt, for instance, is one of the Mediterranean countries where Arundo Donax exists.

1.3 *Plant structure*

The Arundo Donax is a sturdy upright perennial grass species that grows in many clumps. The stems are 3–5 cm in thickness, 30–60 cm long and 2–6 cm broad with tapered tips and hairy tufts at the base. The giant reed has a widespread network of rhizomes under the soil surface, which are 5–30 cm in depth. The stem is a hollow segmented culm that measures from 1 cm to 4 cm in diameter and is able to branch. The culms' walls range from 2 mm to 7 mm in thickness and the internodes can reach 30 cm in length. Under optimal conditions, stems can grow up to 10 cm per day, as it is one of the fastest growing plants.

1.4 *The relationship between Arundo Donax and the surrounding environment*

Arundo Donax is a sustainable plant that causes CO_2 sequestering, soil erosion reduction, water regulation, speedy growth, low use of nutrients and primary energy. Furthermore, the Arundo Donax is an economic plant that is produced locally and, therefore, is of a low cost and creates local jobs and additional income for farmers.

Moreover, this plant resists salinity, humidity and wind pressure due to containing a high percentage of lignin, also known as wood fibres, in the plant tissues. Table 1 lists the mechanical properties of the stem.

Table 1. The mechanical properties of Arundo Donax.

Property	Estimated value
Density	2,295.00 N/m^3
Mean tensile strength	32.17×10^4 N/m^2
Mean bending strength	130.00×10^4 N/m^2
Mean compressive strength	66.50×10^4 N/m^2
Mean bearing strength	26.68×10^4 N/m^2

*Source: Institute of environmental studies and research, Ain Shams University.

2 DIFFERENT USAGES OF ARUNDO DONAX

2.1 *The use of Arundo Donax in Egypt*

Arundo Donax is used locally to make fences, woven baskets and kites. Ancient Egyptians wrapped their dead in the leaves, and used canes to make fishing rods, walking sticks and writing tools. This plant exists in many places in Egypt, as it is one of the Mediterranean countries, as shown in Table 2 below.

Table 2. The existence of giant reed in Egypt governorates.

Governorate*	Places
Cairo	Qubba Palace—Saffron Palace
Giza	Orman Park—Giza Zoo
Alexandria	Rural areas and slums
Sharqiya	
Gharbiyah	13 shares – 15-karat – 95 acres
Dakahlia	Bridges, canals and banks
Monoufia	Bridges, canals and banks
Behera	Bridges, canals and banks
Qalyubiyah	100,000 Inch/Acre
Fayoum	
Suez	Large areas cannot be counted
Port Said	Al Manzalah Lake
Matrouh	Trace amounts at Siwa Oasis

*Source: The centre of progress and development of small industries, Ain Shams University.

2.2 *Usage of Arundo Donax internationally*

- *Energy crops, biofuel and cultivation*

Energy crops are plants that are produced with the sole purpose of using their biomass energy while reducing carbon dioxide emissions. Biofuels, derived from lignocellulose plant

material, represent an important renewable energy alternative to transportation fossil fuels. Stem and rhizome have the ability to sprout after removal from the mother plant and are then used for clonal propagation.

- *Musical instruments*

The cane is rendered into reeds, which are used in the production of clarinets, saxophones, oboes, bassoons, bagpipes, flutes and other woodwind instruments. For example, the ancient end-blown flute, ney (nai), is made from the same reeds.

3 ARUNDO DONAX IN ARCHITECTURE

3.1 *Usage of Arundo Donax as a traditional building material*

Many inherited methods of building rural houses in Egypt using the Arundo Donax exist. The most common building method is the Lattice, or *Chebika* which is named after the method of attaching the rods together. A linkage appears in its construction as an ornamental unit. Since the plant is available locally, it is possible for each resident to build his own house. Similarly, the building process is simple for an unprofessional builder. The building process starts by cutting the reeds, allowing them to dry well, collecting every ten poles in a beam and tying them by simple ropes to form the construction.

3.2 *The walls*

The beams are grouped vertically, placed together in batches and attached to proper ropes. Another layer of beams is then added horizontally and attached to the vertical layer. Then, an inclined layer of reed beams is added in order to strengthen the two perpendicular layers. The height of the wall is 6 metres tall, the room's area is 6*4 m^2 and its height is about 3 to 4 metres tall. These calculations include the part of the wall that is built below ground level to support the building, as shown in Figure 1. The building is insulated by using plastic and stucco, and then piles of rice straw and papyrus are added. Finally, the walls are covered by mud that is mixed with rice straw and hay and painted with lime.

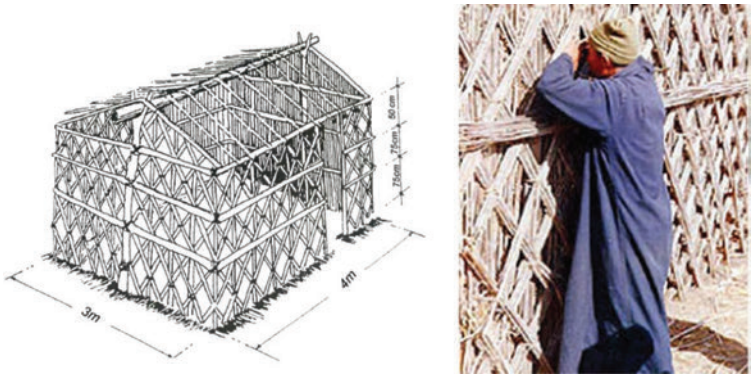

Figure 1. The common method of building in Al Manzalah Lake: Lattice (Chebika).

3.3 *The ceiling*

The ceiling may be built by using the same steps as for the building of the walls or by creating a layer of single rods that are attached to each other and hitched tightly by thin robust ropes. This is specifically applicable along the short side of the room. The second layer is then added perpendicularly to the first one and parallel to the long side of the room. Finally, and to carry the ceiling, camphor wooden poles are used.

3.4 *Disadvantages and solutions*

The main disadvantage of this plant is its flammable nature. It is also difficult to use reeds in constructions that have wide spans and long heights. However, as a solution to its flammable nature, the use of epoxy, which is a mixed fireproof material that is rich with aluminium, stops it from catching fire and is used to cover the outer surface of the plant. Meanwhile, the latter disadvantage could be dealt with by using wooden trusses for a wider span.

3.5 *Advantages*

These houses are suitable for places that have a high temperature, humidity and heavy rains. Economic plants are sold for 35 Egyptian pounds, by the metre squared, in Al Manzalah Lake of Port Said. The plant is suitable for weak clay soil that cannot carry heavy constructions, such as concrete. Soil subsidence causes concrete to collapse, while the lightweight Arundo Donax can be easily carried by the soil. It also facilitates quick construction, so that ten workers can build one hundred housing units in three days. It was used until recently in the making of booths in the markets and for ceiling coverages in the cafes of slums, as shown in Figure 2.

Figure 2. A café whose ceiling is covered by Arundo Donax in the outdoor area, (Middle, Right). A booth in El-Maamora market, (Left). Place: El-Maamora El-Balad, Alexandria, Egypt.

4 ARUNDO DONAX IN INTERIOR ARCHITECTURE

4.1 *Mixing Arundo Donax with natural wood in interior architecture*

Arundo Donax rods are used in interior architecture, furniture design and ceiling cladding, as shown in Figure 3. The reeds are used as appropriate thermal insulators and sound absorbers as they prevent echoes, especially when they are used as an integrated building unit. This is possible by a distortion in the sound waves caused by their bumpy surfaces.

Figure 3. Usage of Arundo Donax in ceiling design supported by natural wood in two different interior spaces.

4.2 *Arundo Donax items in interior design*

The rods are used in the making of decorative interior items and lighting units. The items are produced by forming the proper rods and merging them with other materials, such as fabrics and wood, as in the designs shown in Figure 4.

Figure 4. Arundo Donax decorative and light items, Gift Shop, Alexandria, Egypt.

4.3 *Arundo Donax partitions with metal frames*

This is an experiment to examine the ability of Arundo Donax as thermal insulation. The thickness consists of three partitions. Each partition contains Arundo Donax rods and metal frames with lengths of 2.5, 4 or 5 centimetres, a depth that ranges from 100 or 150 to 200 centimetres and a height of 180, 240 or 260 centimetres. The poles are knitted by galvanised metal wire with a diameter of 2 mm. The two sides of the partition, with a length of 5 centimetres, are covered with a layer of mixed cement and sand with a thickness of 2 centimetres, as shown in Figure 5. Thus, this results in a durability against fire that lasts for half an hour.

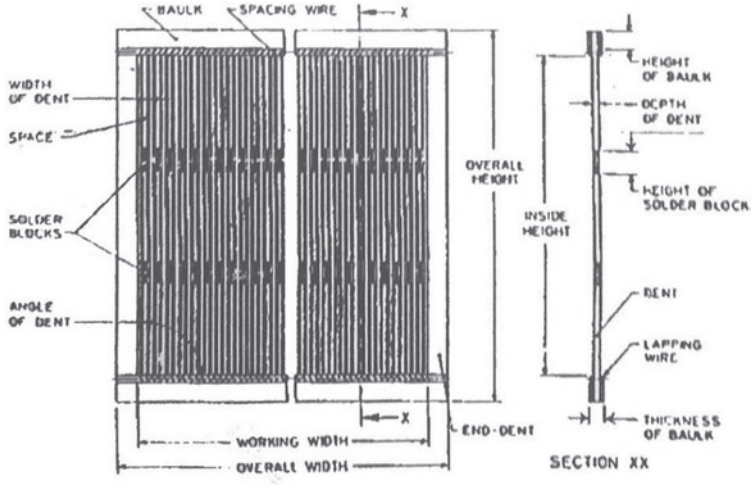

Figure 5. The details of the Arundo Donax partition used to examine combustion and thermal insulation.

5 EXAMPLES OF ARUNDO DONAX ORGANIC STRUCTURES

5.1 *Water universal exhibition*

This pavilion, known as the water university exhibition, was constructed in Zaragoza, Spain back in 2008. It is a shaded structure that allows access to the Pavilion of Citizen Initiatives. The pavilion was designed by Canayaviva in collaboration with the architect, Ricardo Higueras, as shown in Figure 6.

Figure 6. Pictures for the pavilion constructed in Zaragoza, Spain in 2008.

5.2 *Casa de Laila structure*

Another example is the Casa de Laila structure, as shown in Figure 7. It is a multiple use open space that is 9 metres long that was built in the Alhaurín el Grande in Malaga, Spain in 2013. The structure covering is full of canes with mud, lime, hemp and aggregates and was designed by Canayaviva.

Figure 7. Picture of the Casa de Laila structure.

6 ARUNDO DONAX A ZERO WASTE MATERIAL

6.1 *Zero waste*

The GrassRoots Recycling Network (GRRN) defines the zero waste design principle as one that goes beyond recycling, by taking a whole-system approach to the vast flow of resources and waste through human society.

6.2 *Arundo Donax example for zero waste (Radical Ship Pavilion)*

An installation, which resulted from a workshop, was created in September 2016 by the LAN laboratory for natural architecture, within the Festival of Mediterranean Literature, in order to design an intervention of 'Urban Land Art' using natural materials, as shown in Figure 8.

Figure 8. Picture for the Radical Ship.

This structure can be reused by taking the rods and redesigning them in a new way for a new purpose, for example, fences and interior units, such as chairs, tables and lighting units, by using manual or digital construction methods, as shown in Figure 9.

Figure 9. Suggested new forms for the structure.

7 ARUNDO DONAX IN DIGITAL FABRICATION

7.1 *Digital fabrication*

This is a process that uses Computer-Aided Design (CAD) and additive and subtractive manufacturing machines, such as a CNC router, laser cutting and 3D printing, to allow designers to produce material digitally with great accuracy.

7.2 *Applications of Arundo Donax in digital fabrication*

The designs inspired by the pattern are formed when the rods of Arundo Donax are sliced, as shown in Figure 10. The digital method uses Rhino and Grasshopper software and it can be produced by using a CNC mill.

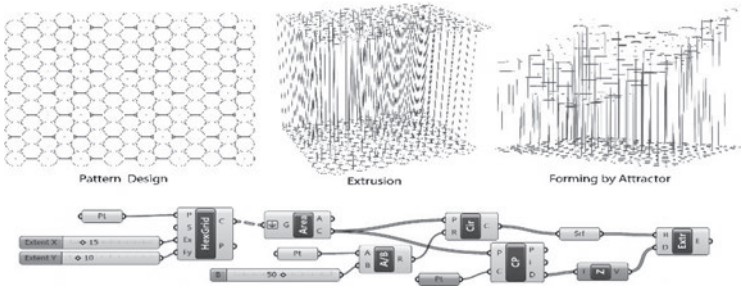

Figure 10. Form developing.

The rods can be linked together with metal connectors or be tangled together using tight ropes. The shape can be used either indoors or outdoors. After developing the form by using Grasshopper, the item can be modified by Rhino, 3Ds Max and other software. To get a suitable design and create a proper environment around it, a rendering of the scene is necessary to observe the overall view, as shown in Figure 11.

Figure 11. The orthogonal projection of the fabricated chair (Left). Final render after editing on 3Ds Max (Right).

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 *Conclusions*

Arundo Donax can be used with other materials, such as natural wood, bamboo and fabricated materials, as a complementary material in the manufacturing process. This shows the importance of improving visual manifestation by searching for the proper methods of treating forms using local materials. Arundo Donax is one of many sustainable solutions that can be used as a thermal insulator. The importance of reforming shallow water plants, such as the Arundo Donax and bamboo, stems from the possibility of its use in interior design and architecture.

8.2 *Recommendations*

Attention must be paid to the digital fabrication methods to find the best ways of implementing modern and parametric designs by using local environmental materials. Proper cultivation of the Arundo Donax by using modern techniques is significant for producing the best types of plants in Egypt. It is essential to implement the proper treatment on the materials and to use them in the manufacture and building processes, especially since such urban fabrication should maintain the identity and nature of these areas.

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