The challenge of bio materials in the field of architecture through the scope of sustainability

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Abstract:

Nowadays sustainable development plans and quality of life criterions directed all the researchers and the industry towards the zero emission products especially in the construction field. On the other hand, bio materials are elected to be one of the sustainable categorized materials and recent advances in bio-based materials research have reached multiple solutions for the construction sector. But it did not sound all over the world, although such materials can play an effective role in architecture and the construction field. The paper is an over view that display and evaluate the usage of bio materials in the construction process all over the life cycle of the building; as means of sustainability to ensure its efficiency. The paper is shading on the advancements of timber to be a role model in evaluating the various known bio materials to reach the latest advancements in bio materials in architecture and the construction field.

Keywords:

Bio materials, bio-based materials, timber, sustainability, effective maintenance

الملخص:

في الوقت الحاضر، توجه خطط التنمية المستدامة ومعايير جودة الحياة جميع الباحثين والصناعة نحو منتجات خالية من الانبعاثات وخاصة في مجال البناء. ومن ناحية أخرى، تم اختيار المواد الحيوية لتكون إحدى المواد المصنفة المستدامة وقد توصلت التطورات الحديثة في أبحاث المواد الحيوية إلى حلول متعددة لقطاع البناء. لكن الأمر لم يتردد في جميع أنحاء العالم، على الرغم من أن مثل هذه المواد يمكن أن تلعب دورا فعالا في الهندسة المعمارية ومجال البناء. الورقة عبارة عن نظرة عامة تعرض وتقيم استخدام المواد الحيوية في عملية البناء طوال دورة حياة المبنى؛ كوسيلة للاستدامة لضمان كفاءتها. ويسلط البحث الضوء على تطورات الأخشاب لتكون نموذجا يحتذى به في تقييم مختلف المواد الحيوية المعروفة للوصول إلى أحدث التطورات في المواد الحيوية في مجال العمارة والبناء.

الكلمات المفتاحية: المواد الحيوية، المواد الحيوية، الأخشاب، الاستدامة، الصيانة الفعالة

أصبحت المواد الحيوية (BBCM)مؤخرًا نموذجًا يحتذى به للمواد المستدامة في المختبرات وتظهر تقدمًا سريعًا. ويتأثر وجود هذه التطورات بعاملين؛ الأول كان الإعلان عن أهمية جودة الحياة والاستدامة مما دفع الباحثين نحو التحدي المتمثل في تقليل استهلاك الطاقة في عملية البناء واستخدام المواد الخالية من الكربون، وأعلن الباحثون أن هذه المواد يمكن أن استخدامها كبديل لمواد البناء التي تلوث البيئة وتستهلك المزيد من الطاقة، كما أكدوا أن هذه المواد مستدامة حيث أنها تتمتع بالمرونة ويمكنها تخزين الكربون بكفاءة وموازنة الانبعاثات من المواد الأخرى، إلا أنها لا تزال تمتلك القليل من الخصائص التي لها تأثيرها. أما العامل الثاني الذي أثر في ظهور المواد الحيوية في مجال الهندسة المعمارية فهو وجود التصميم الحيوي الذي ظهر مؤخراً لإحياء الممارسة القديمة في النظام البيئي. ويؤكد على استجابة كل عنصر مبني للبيئة ويشير إلى استخدام الموارد المستدامة.

الكلمات المفتاحية:
المواد الحيوية، المواد الحيوية، الأخشاب، الاستدامة، الصيانة الفعالة

Introduction

Recently Bio based materials (BBCM) have become the role model for sustainable materials in laboratories and they show quick advances. The presence of these advances is affected by means of two factors; the first one was the announcement for the importance of quality of life and sustainability which pushed the researchers toward the challenge in the reduction of the energy consumption in the construction process and the usage of the zero carbon materials, and the researchers declared that these materials can be used as an alternative to the construction materials that polluted the environment and consumed more energy, they also confirmed that these materials are sustainable as they have flexibility and can efficiently store carbon and counterbalancing emissions from other materials, but they still have little properties that have to be controlled. (Anna, et al, 2019), (Jones, Brischke , 2017).

The second factor that influenced the appearance of the bio-based materials in the field of architecture was the presence of the Biophilic design which appeared lately to revive the ancient practice in the ecosystem. It emphasizes the response of every built element to the environment and refers to the use of sustainable resources. (Anna, et al, 2019)

On the other hand, the European Union made use of the availability of the bio-based products and the expert in using them in the European buildings in the twenty-first century, and they put it as one of the top strategies in the European Union's development strategies. On that role, Europe declared that bio-based materials are considered as the sustainable material resource for buildings in the recent era. (Anna, et al, 2019)

And timber as a famous biobased material gained more properties by means of the latest technologies and the improvements that made it one of the most important bio materials to be called a new concrete, as it is used strongly in architecture and in the urban context, and it proved its efficiency all over the life cycle of the building. so, it can be the role model of the latest advancement of the bio materials. (Randa, Gehan, 2016), (Randa, et al, 2019)

The paper aims to predict the main role of bio-based cellulosic (BBCM) materials in the life cycle of the building in form of sustainability using the advancement of timber to be the main criterion to evaluate the latest advances of the well - known bio materials; especially plants and cellulosic materials, in architecture and the urban context. The paper will be divided into five parts as shown in fig (1): 1st part is a literature review for bio materials, 2nd part displaying the progress of timber in architecture and the construction process, 3rd part draw the role of bio based cellulosic materials (BBCM) in sustainable architecture, the 4th part discusses the goals of bio based cellulosic materials (BBCM) in architecture and identifies the areas of interest of the researchers to develop the bio materials to be more sustainable and finally the conclusion.

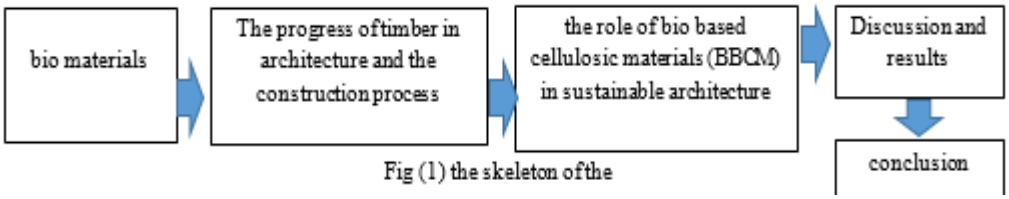

Fig (1) the skeleton of the

1. Bio materials:

They are natural materials that can response to the surrounding environment in a smart manner to be survived, and can interact with living systems. (Anwar, et al., 2016). They can be found in a wide range of natural resources like plants, animals, soil, marines, and also they can be fungi (Anna, et al, 2019), in the past; some of them were abundantly used in the urban construction as, wood, reed, bamboo, shown in figs (2), fig (3), fig (4).

Fig (2) The usage of wood as the construction system of heritage buildings (Knut Einar Larsen, 2016).

Fig (3) The usage of reed in the 3rd century, Lower Austria. [1]

Fig (4) The Philippines used Bamboo in their vernacular architecture [2]

Biomaterials used in building construction have many advantages, as they are tolerant, renewable, of low impact on the natural environmental. At the same time their manufacturing does not need amounts of energy, for example: The wood manufacturing consumes 10% of energy used in manufacturing steel (Odeen, 1985).

Factors influencing the usage of bio materials in architecture in the past various between aesthetics, functionality, and safety, but lately within the scope of sustainability the factors influencing the usage of any material are being wide; they included zero-carbon emission, sustainable maintenance, low cost and many sustainable categories, accordingly bio- materials are not efficient to be used in their natural form. (Anwar, et al., 2016), (Anna, et al, 2019) Many of their properties need to be improved, such as dimensional stability, thermal stability, fire resistance, biotic and abiotic degradation resistance, and mechanical properties. On this mission;

experts and researchers are working to get new solutions to improve these defects in such materials to be efficient as sustainable materials so it can be used as a trend in the building construction market. And lately, novel improvements have appeared which are the presence of bio-based composite materials as well as being more effective and environmentally friendly protective treatments, such as thermal treatments, compaction, saturation, and chemical modifications. The same revolutionary progress is observed in surface treatments, including innovative coatings and the integration of nanotechnologies. (Anna, et al, 2019) In the civil engineering field so many advanced bio-based materials have spread as; bio- concrete, bio-plastics, bio- admixtures, bio- asphalt. (Anwar, et al., 2016) but in the architectural field various bio- materials appeared to play a role in the building life cycle, as; timber- straw-reed-and so many materials.

2. The progress of timber in architecture and the construction process:

Wood is classified as stalk bio materials that have low impact on the environment as, trees absorb CO2 from the atmosphere and store carbon in the wooden tissue. (Charlotta, 2017), (Knut, Nils, 2016), (Tellanes et al. 2017). In the past wood was the main construction material

used in most of the urban context all over the world but it suffers while facing the environmental conditions, as it shows inefficiency in its dimensions, durability and appearance. (Randa, et al,2019) but properties of wood were modified by means of chemical and biological agents. Moreover, several treatments were used (Randa, et al,2016), (Randa, et al,2019) and most modifications of wood targeted the material molecular levels and converted it to industrial products known as timber products, as shown in fig(5).

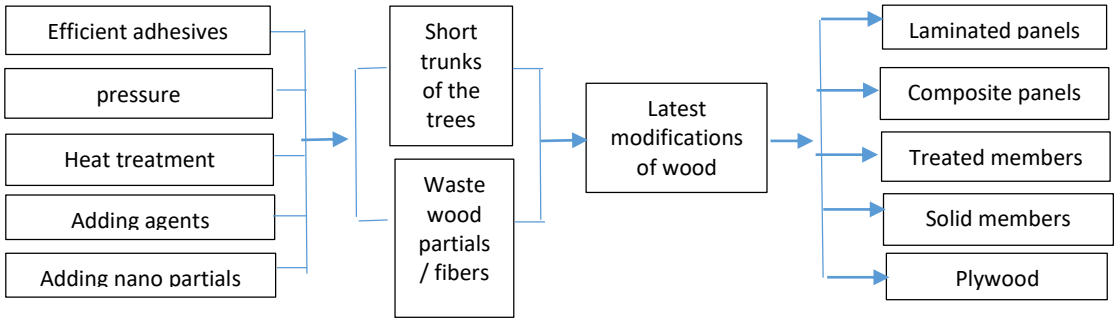

Fig (5) the factors affected wood to be an advanced timber product, Reference: The author; (Randa, 2016)

The main feature of sustainability in timber appeared as follows:

2.1 Efficient structure system

Wood gained its efficiency as a structure system by means of various developments appeared in the industry of timber as follows:

2.1.1 laminated sheets: Advanced technology offers light weight timber construction and solid timber construction, as the production of the various kinds of the laminated sheets; Glue-laminated timber (GLT), Structural composite lumber (SCL), Cross-laminated timber (CLT), Dowel-laminated timber (DLT). Nail-laminated timber (NLT) and cross-nail laminated timber and interlocking cross-laminated timber (ICLT). (David. 2011) That give numerous shapes of frame patterns and bearing wall construction systems that made the appearance of the tall timber buildings, as shown in fig (6) and the presence of the unique bearing units, as shown in fig (7)

fig (6) Wood-framed apartment construction in Vancouver, Canada [3]

fig (7) Prefabricated smile building of 12 industrial-sized tulipwood, CLT panels by CLT pioneers, Züblin-Timber in Germany [4]

As well as these advancements offered wide span timber structures as shown in fig (8)

fig (8 a) Large span beams

fig (8 b) Curved beam

fig (8) Span timber structures: Glulam structures [5]

2.1.2 Flexible members: Modifying the properties of the small trunks through steam and high-pressure to give durability and flexibility possess timber greater quality to dare the hyperbolic roofing systems, (Virginia, 2010), as shown in fig (9).

fig (9a) Kengo Kuma unveils "blossoming" glass and timber villas for Bali Inhabitant [6]

fig (9b) Mechanical Wood Arquitectura Viva [7]

fig (9) The manufacturing of the hyperbolic roofing systems

2.1.2 Wood cement composite: Wood elements are sensitive while used as structure system in wide spans more than nine meters as it has defects in the deflection and vibration considerations, so lately adding concrete and composite action helps to provide the necessary stiffness, and the final product is known as Timber-Concrete Composite Systems which leads to lower carbon emissions, also, cement is added to waste wood to form Wood-Cement Composites that can be used as building unit blocks and it can be used as a bearing wall unit. [8], [9]

2.2 Durability and Elegant feature

In the latest era wood gained its elegant feature with durability as facing the environmental condition without any decay by means of various advancements as follows:

2.2.1 Wood polymer composites: Polymers get used to be added to Wood to form elastic and flexible product that can be used as smart envelope cladding materials, land scape realm elements and elegant doors. The well-known wood polymer composite is wood plastic composites (WPC) which sounded since the 1980s, and developed in the 1990s with the development of solid wood plastic composites as comprising approximately 50% wood fiber in polyethylene. This product has high durability, flexibility, and strength, more over they are available in a wide range of design and colors. Moreover, it reduces the installation costs and the required maintenance. It also does not need any paintings as finishing as it has optimum performance, as shown in fig (10).

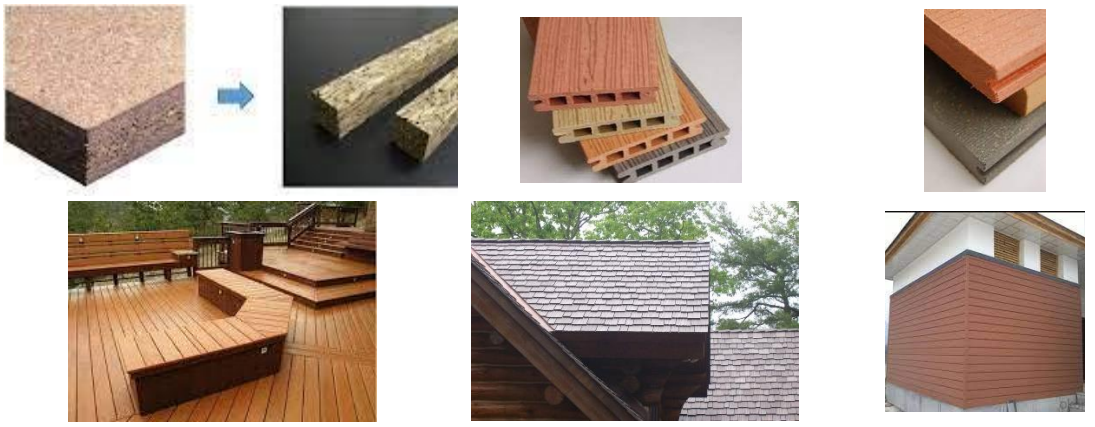

fig (10) Wood Plastic Composites: A Growing Alternative to Timber | Architecture & Design [10]

2.2.2 Organic and inorganic Composites: Added more elegant feature to wood products used in architecture, Wood wool cement panels are spread to be decorative panels that used as an acoustic and heat insulator and it is fire resistance, as shown in fig (11). Also, wood straw composites that form acoustic panels acting as anti-fire, as shown in fig (12).

Fig (11) Advanced wood wool panels [11]

Fig (12) Advanced wood and straw panels as an anti-fire [12]

2.2.3 Nano technology applications: Nano technology added smart properties to wood as the nano coatings and nano composites added more efficiency for wood, so it can be able to face any environmental conditions as humidity, sun rays, cold weather, fire and insect's effect. The dimensional stability is enhanced, the color remains constant, thermal conductivity is reduced, equilibrium moisture content is lowered and hydrophobicity is increased. (Randa, et al,2016), (Randa, et al,2019).

2.2.4 The transparent timber: Recently, researchers have reached the transparent timber by means of bleaching agents and using acrylic, so the final product used in the envelope of the building as a transparent isolated material, and also it was used within the interior design elements, as shown in fig (13), fig (14).

fig (13) Usage of transparent wood in the envelope of the building [13]

fig (14) Usage of transparent timber as internal partitions [14]

2.2.5 Robotic Timber Construction (RTC): It is one of the latest digital fabrication techniques used in manufacturing full scale dimension voids or models. It aids in the presence of the elegant

feature of timber in architecture, as it facilitates the implementation of the advanced digital design of nonstandard timber structures by means of robots. The group of Gramazio Kohler Research at ETH Zurich used this technique to produce a new perspective on automated timber construction in the 4th dimension, and CNC joinery, and cutting helped in such advanced process. (Jan, et al, 2016) shown in fig (15), fig (16). One of the optimized Robotic Timber Construction is the sea urchin prefab pavilion as the production of ultra-thin plywood strips just 3-5mm thick (thin fibers and stretching plates) assembled by industrial sewing machine to form 3 D units that get once more assembled by means of robots in site to form hyperbolic form. As 151 laminated segments of weighs 780kg which is a light weight to cover a span of a total area of 85 m^2 in Stuttgart University's ground floor, as shown in fig (17).

fig (15) Demonstration object of "The Sequential Wall" series, Gramazio Kohler Research, ETH Zurich, 2008 [15]

fig (16) Metropol Parasol Structure [16]

fig (17) Robots build sea urchin prefab pavilion using biomimicry [17]

3.The role of bio based cellulosic materials (BBCM) in sustainable architecture

Plant cellulosic bio-based materials are classified to stalks, grass, leaves, flowers and recycled or waste products. Some of the famous bio-based cellulosic materials are followed in their advancements as case studies as follows:

3.1 Grass materials: Bamboo:

It is an abundant material available in high quantities, especially in Asia. Can be used in the building construction in its based form as it is categorized in the plant kingdom as giant grass. Moreover, it can be used as recyclable material. (Rashmi et al, 2019), (Audrey, 2019)

a. Bamboo as a structural member: It is used instead of timber in the non-timber product countries, and it is said that it is the future of Asian countries. Its density is low and it has high mechanical strength, but although it has low durability than wood it has an ease of workability and is stronger as a tensile member and it can be used as horizontal members less than 3.6 m long by no need for middle supports, its tensile strength is similar to steel (Rashmi et al, 2019), (Audrey, 2019). Bamboo exists as form of many species, but the preferred one that can be used in technological applications is the Phyllostachys Pubescens, which is long to reach 20 meters height and 18 meters in diameter. Bamboo contributed in forming circular buildings, and hyperbolic structures, also it contributed in forming stairs and claddings as shown in fig (18), fig (19), fig (20).

fig (18) Wan-awards-entry-flower-field-bamboo-pavilion-south-china-university

fig (19) Thailand-pavilion-bamboo build

fig (20) Bamboo is used as stairs material

b. Bamboo as panels (boards): Bamboo exists in form of panels of various shapes; the first one is the nonbearing load wall panels as accumulated sticks in frame panels, and the native fibers can be modified chemically or thermally as its properties can be enhanced. (Knapic, et al., 2017) and the treatment can give bamboo a potential for using it instead of solid wood in bio composite structural uses, but waterproofing treatments are needed to improve the mechanical property of the composite. (T. Schloesser, 2000), (L. O'Dell Jane, 1997), (L. T. Drzal, 2004), (S. Corradi, 2009), as shown in fig (21). The common use of bamboo Composite panels is in decking (flooring) which is the spread shape of panels in the global market, as bamboo replaces hardwoods in the traditional composite decking. These panels have elegant feature with high workability and durability, the recycled plastics shared in their mixture, so they act as water proofing, the finished boards are protected by capping from the four sides to give them stiffness that exceed three times the stiffness of the traditional composite boards. These decking are treated against fungi and mold by cooking the sugars out of the bamboo and then compressing the bamboo strips into a phenolic resin under heat. The common types of deck are: Fused bamboo. [18] Cali Bamboo, [19] Bam Deck Pro 360, and Infinity deck. Mainly the advanced decking is formed from a mixture of 60% recycled bamboo and 40% recycled HDPE (high density polyethylene). These boards are treated against scratches or stains so it gives elegant feature. Infinity deck is an improved deck that resists heat and sun rays, fig (22) another advanced application appeared for bamboo deck in the market, it is x Beam composite bamboo which also formed of recycled bamboo fibers and HDPE plastic, but it has hollow channeled like Inno Deck which make it lighter than a solid composite, shown in fig (23). Bamboo is also used in laboratories as glue laminated panels by means of Robotic fabrication process to produce improvements to bamboo panels to be used as bearing panels. (Chung, et al,2022)

Fig (21) Low Energy Bamboo House / AST 77 Architecten [20]

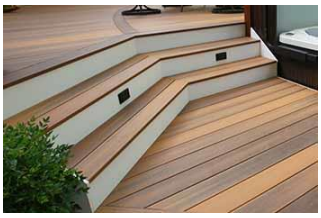

Fig (22) Bam Deck Pro 360 [21]

Fig (23) x Beam composite bamboo by Zome Tek [22]

c. Bamboo as a composite concrete: Researches in laboratories used bamboo fibers instead of synthetic fibers as reinforcement for structural-concrete beams, and the results showed

acceptable bearing loads exceeding that shown while fiber reinforced polymers (FRP). The proto type product is recommended to be used in low-cost constructions and low-rise buildings which do not need high factor of ductility. (Alireza, et al., 2020)

3.2 Shoots or leaves:

3.2.1 Rigid shoots: Reed: It has unique properties to keep it as a sustainable building construction material a long time ago in various regions in the world, as it is cheap and can offer a structure for low-tech buildings with high thermal properties. It is easy to maintain or repair and can last for more than 50 years if it is kept well ventilated (Almusaed, Almssad, 2015). (Hayley, Serdar, 2020), (Greef, Brischke, 2017), (Piesik, 2017), (Ferenc, Ulrike, 2010). But it can easily be deteriorated by means of rot, fungi, insects and fire (Elizabeth, Adams, 2005). Reed in its base form used mainly in roof construction and in forming light weight panel form construction, that can be coated by mud or cement grout to protect it and give it strength, as shown in fig (24). Reed shoots height various between one to seven meters, so it has flexibility while using it in the construction process, (Packer, 2017). And the most famous and well-described roof-thatcher can be found in the Tigris and Euphrates valleys in Iraq, [33] shown in fig (25).

Fig (24) The usage of reed in forming vernacular buildings. (Marwa, 2015)

b. Digital fabrication (iterative aspect), Robotic Assembly Processes: Nowadays the researchers used to develop the use of reed in Australis by means of the digital fabrication for creating circular buildings and hyperbolic structures as shown in fig (26), the objective was to create macro scale units by robotic assembly, and this resulted in reed-based system that can create a variety of structures. (Hayley, Serdar, 2020)

Fig (25) Reed home in Iraq. [23]

Fig (26) Iterative aspect for using reed as structure element. [24]

b. Reed panels: Researchers conducted proto type applications in the laboratory to investigate the appropriateness of reed especially (Arundo donax) to be a substitute of percentage of wood in the Iranian particle boards, as the boards composed of 40% reed, 12% urea formaldehyde resin in the board surface layers and these layers are compressed under press temperature 185 °C and the resulted reed board showed good bearing product. (Mohammad, et al, 2010)

3.2.2 Smooth leaves: Hemp: It is widespread plant of low density (110 kg/ m3), insulation property and mechanical resistance of its fibers which give it the bonus of highly being used in the construction industry. It is used as composite products challenged in the manufacture of blocks, panels, insulation products, hempcrete, and lime–hemp mixtures, recently, hemp was used to produce cupboards and many furniture products. (Réh, Barbu,2017)

a. Hempcrete construction blocks and panels; Hemp shared in creating a new composite form of concrete called Hempcrete or sometimes called hempcrete. It is formed from the waste fibers of the hemp with Lime Binder from limestone to act as a bonding agent, impacting its durability, strength, and setting time. It is used in forming blocks as shown in fig (27), and commonly used as panels formed by pouring the mixture or spraying it in supported skeletons, as shown in fig (28). But these products need to be protected from earth humidity so the blocks and the panels are to be raised from earth through isolated material and they have to be coated by plasters to be elegant in feature and to be protected from rain effect. Also, it is not a bearing material so they are used as un-bearing walls and roofs.

Australia is one of the famous producers to the hempcrete, but the first built construction of non-weight bearing infill walls appeared in France in the beginning of the 20th century, this materials product has many advantages as follows: [25], [26]

• High insulating products of high thermal mass so it is an excellent insulation alternative to subfloors, walls, attics.
• Used as temperature and humidity regulator for buildings.
• Highly acoustical on both sides.
• Lightweight and breathable product of low cost.
• Unbreakable and flexible as a structural product.
• Totally organic product of no carbon emissions.
• Rodent repellent and fire resistant.

Fig (27 a) Hempcrete blocks [25]

Fig (27 b) French Regional Government Office multi-story building using hemp block infill walls (Rachel Bevan and Tom Woolley, 2008).

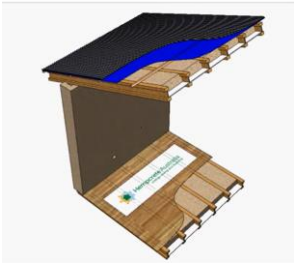

Fig (28) Hempcrete panels can be erected in 2 months [26]

Fig (27) The usage of hempcrete blocks as un-bearing units.

The hempcrete panels are flexible to be used in several scales as shown in fig (29), and flexible to be used in forming circular configurations as shown in fig (30).

Fig (29) Seven-story office building in Clermont Ferrand which uses hemp lime blocks, and hempcrete panels as shading units on the façade. (Rachel, Tom, 2008)

Fig (30) Hempcrete can take various shapes as it is a flexible material formed by a casting technique. Morocco combines hemp and solar to go totally off grid [27].

b. Hempcrete as fluid products: The workability of the hempcrete used in making the challenge of using it in casting hyperbolic structures, as shown in fig (31).

Fig (31) Twine House by Antony Gibbon [28].

c. Hempcrete insulation panels: These panels are expanded in the construction markets; their shape is similar to wood fiber boards and they can be used between the wall layers of the building construction. (Anna, et al, 2019).

3.3 Flowers: Cotton:

a.**Concrete by the use of cotton**: Cotton waste (CW) and limestone wastes (LPW) are used to examine their potential in creating new building blocks of low cost and lightweight composite. And the resulted product showed smooth elegant surface that can challenge the current concrete bricks in the market. The mixture can be used also in forming ceiling panels. (Halil, Paki, 2008) Also cotton woven is used to be a reinforcement material in concrete instead of steel especially for lightweight structures. Seven structures of cement-cotton woven fabrics are used and their composites with cement are tested in tension, compression, and bending. It was found that using cotton woven fabrics improves the behavior and the strength in both tension and bending. However, when used in compression, layered fabrics decrease the compressive strength of the cement elements. (Mohamed Mohie Eldin, 2017)

b.**Cotton fibers as insulation material:** The development of textile manufacturing techniques and the reinforcements composite in the woven cotton leads to the presence of filigree textile façade, or rhomboid textile blinds as shown in fig (32), which represent an insulation product used on the envelope of the building, as the space between fibers became in the nano scale and the orthogonal sets of yarns seems to be as a continuous material. And yarns can be woven in form of 2D pattern in two layers or more to give the yarns durability and avoid its crimp, moreover the interlock and 3D weavings link serval warp and weft yarn layers are techniques to get large thickness.

Fig (32 a) Filigree textile facade

Fig (32 b) The usage of rhomboid textile as an envelope

Fig (32) Filigree textile in King Fahad National Library by Gerber Architekten, Riyadh, Saudi Arabia [29]

Mainly, investors of the textile industry are working on the development of the durability of the textile to resist tension forces and environmental effects as sun rays, humidity and wind effect, moreover they are looking for the development of the sewage treatment, water recycling system used in the textile manufacturing, energy saving, environmental protection and green production. [30], (Philippe, et al, 2017). Nowadays PVC-coated polyester fabric, PVC Colorful Mesh and silver coatings added treatments to cotton textile fabrication as it improved the quality of the textile as it gives it high tensile strength, tear strength and adhesion strength, cold resistance, UV protection, environmental protection and the textile becomes inflatable products. It is widely used for curtains, tents, umbrellas, sunshades. [31], [32]. The Sound forms by Flanagan Lawrence, London, United Kingdom used the white PVC-coated polyester fabric and treated cotton, extensive research on acoustics and materials have indicated that it is an ideal vessel for unique acoustic projection and has strength and durability, more over it has self-cleaning capabilities, shown in fig (33). Also, Zenith de Strasbourg by Massimiliano and Doriana Fuksas, Strasbourg, France is another example for massive building space using Atex 5000 TRL from Valmiera Glass Group, the textile shows its smartness as it is opaque at day when the sun hits it, but at night the canvas looks translucent as light appeared from the inside, revealing its steel casing beneath. Moreover, the coating system shows best acoustics and optimized cost management. fig (34)

fig (33) Sound forms by Flanagan Lawrence, London, United Kingdom [33].

fig (34) Zenith de Strasbourg by Massimiliano and Doriana Fuksas, Strasbourg, France [34].

3.4 Waste plant products; Straw, Coconut shell, Peanut shell, Corn stalk:

3.4.1 Straw: It is a natural abundant fiber which is considered to be an affordable building material all over the world. Elderly it was used as roofing for buildings, and it lasted for long

times when it was protected from the moisture. It was sounded for its durability and its insulating property (Walker, et al., 2017), (G. Garas, et, al, 2009). Straw can get mold while exposed to moisture, so the researchers are directed to protect it from moisture and humidity [35]. The most popular straw used in construction is the Rice straw, which has high flexibility and do not breakdown but can be grinded, it has high efficiency in rainwater and has a heat insulation property, so elder farmers used it in forming the roofs of their homes (M. I. El-Gammal and A. A. Shakour, 2001).

Straw advanced products that appeared in architecture are straw blocks, straw panels, and the straw concrete. And the latest advance introduced in the market is the printed straw homes by means of robots as mixing straw, mud, limestone and build homes, [36].

a. Straw blocks: It is a sustainable application for straw spread in USA since the 19th century and was used in Europe in the beginning of the 20th century in form of bales as load-bearing walls, to prove that straw-based construction is a durable option. (B. King,2006), as shown in fig (35), fig (36). Some banks in the United States of America were ready to give loans to promote this technique as a strategy for maintaining the natural environment from pollution. [37] Straw walls were used to be generated from straw bale layer as a core that must be coated by protective layer as plasters, or cement and sometimes hard wood is used, moreover thermal insulation layer can be used. This technique is characterized by slow absorption of humidity, which led to protection from growing bacteria (Ghadie, et al, 2022), (Walker, et al., 2017). The bales represent the module block, is of total thickness of about 48 cm and the thickness of the plaster is about 3.5 cm. (Walker, et al., 2017) This method of construction is announced as Straw-insulated homes. Straw proved its efficient isolation from the sever hotness or coldness, as straw walls are vapor-permeable ensuring healthy air inside the house. (Guglielmina et al, 2020). The researchers promoted that it is important to use organic finishes on straw walls to permit the air exchange between indoors and outdoors through these walls, and the proposed mixture is of clay, sand, and straw. (Walker, et al., 2017). Straw bales also appeared as non-bearing load system as shown on fig (37).

fig (35) The first rice straw building. Nebraska (bearing load system [38].

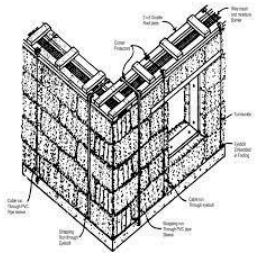

fig (36) Rice straw bales common concept of gathering using supports [39].

fig (37) Rice Straw Bale Residence (non- bearing load system) [40].

The straw Cement Bricks: It is the 2nd announced improvement for the straw block in the laboratories as various applications have been done to get suitable and workable straw cement blocks or bricks.

In Egypt a group of Egyptian researches used to create it by mixing sliced rice straw in form of rough and fine collections, cement and water with specific mixing ratios. They produced brick blocks are of dimensions 25*12*6 cm of low density regarding to the cement brick density, also

its manufacturing did not cost much. It had a challenging thermal insulation property, fire resistance and adequate mechanical properties. (Heidi, 2015)

In Thailand and some countries; they have improved cement blocks in laboratories by replacing cement by little amounts of straw, and they resulted in bearing blocks of good properties while using rough straw by weight does not exceed 200 grams as it can bear more than 1 Kg/cm^2 and has heat insulation property, of lower cost than the cement block and of lighter weight. (Suchat, Sakda, 2022).

Straw Lego Blocks: Shown in fig (38), California produced these blocks of standard dimensions 30.5cm x 30.5cm x 61cm, the block density is twice what was found in straw bales that allow it to bear stresses of simple loading and its weight is 14kg, polyurethane binder is used to hold the straw fibers in these blocks, the cavities found in the blocks can be filled by stiff bars or concrete. [41]

Robotic applications on straw blocks: Robotic application is used to assemble and build simple buildings as shown in fig (39), more over advanced and complicated shells used the robotic aid to convert the digital design to the implementation form as shown in figs (40) [42].

Fig (38) Lego Blocks from Straw [41].

Fig (39) The usage of robots in the uniform building of bearing walls from straw blocks.

Fig (40) The robots used in forming complicated structures from straw blocks In Iran, by ADAP group [42].

b. Straw panels: It is the progress of the straw construction elements in the global market especially the European and the United States of America markets, one of the famous straw panels is Eco-Cocoon Wall Panels, as shown in fig (41), its properties are as follows:

- The panels are engineered as fully structural with a double wooden frame to be efficient to support floors and roofs without using any extra materials.
- Its density is more than 100 kg per m^3 which support it with both thermal and energy efficiency and solidity.
- They are durable that can stand in fire for two hours, moreover they resist mold.
- They have ease in workability as; the panels can be assembled by even a self-builder without a crane on site within days.
- The panels modules are flexible to suit any design as they are made to measure down to 1-millimeter precision.
- It has the flexibility to be coated by various plasters or cladding, and a combination of materials are possible.

Fig (41 a) Straw panels (Eco-Cocoon) as Wall Panels [43]

Fig (41 b) Straw panels (Eco-Cocoon) can be coated easily [44]

Fig (41) The usage of the famous straw panels (Eco-Cocoon) as Wall Panels

Compressed-straw panels are development of "Compressed Agricultural Fiber" (CAF) panels that were created in Sweden in 1935, and in 1940 developed in Britain and sounded as Stramit. and lately Agri board Industries produced the structural insulated panels. These panels have compressed-straw cores and conventional OSB skins, shown in fig (42). Mainly the Stramit process spread all over European countries, Australia, and the U.K. The compressed panels have developed to be used in the complementary elements of the building construction as doors of high feature, shown in fig (43). Also, it was introduced in acoustic panels while added to wool and wood as shown in fig (44), it shows its efficiency as the appearance of the tallest straw building in the world that is labeled as passive house that is found in France. (Alcorn, Donn, 2010) Shown in fig (45).

Fig (42) Using Agri board (compressed-straw cores and predictable OSB skins) as structural insulated panels. [45]

Fig (43) The usage of compressed straw panels as doors [46].

Fig (44) TianGe 20mm Thickness Straw Acoustic Panels Wood Wool Insulation Board Acoustic Panels for Ceilings [47].

Fig (45) 7-storey modular building in France by Herbert Gruber [48].

c. Straw concretes: Researchers from Polytechnic University of Valencia, UPV and San Paolo State University have developed a new type of sustainable concrete by using the ash of the sugar cane straw instead of 30% of the Portland cement that resulted in cheap concrete and less polluting product. The scientists discussed that this kind of product can get benefit in Brazil that

produce every year millions of tons of sugar cane, which represent about 20% of sugar can straw all over the world. (J.C.B. Moraes, et al., 2015).

3.4.2 Coconut shell

Coconut shell has high strength modulus that can give it the challenge to be used in concrete reinforcement. and innovative products concerning the building construction in the scope of fine art have been developed by means of this material.

Coco mosaic tiles: They are produced in Indonesia; it is the recipient of the 2011 Bronze GAIA award for Innovative and Green Products at the Building Materials Exhibition in Dubai. The tiles are made from coconut shell chips and recycled wood that are cut and assembled by skillful artisans. Each tile is handmade and uniquely created. It is an eco-friendly product as low emission adhesives, polishes, and paints are used in manufacturing. The tile can be easily cut to size and shaped using a regular wood saw, they have a unique texture and used as a wall finish, floor tiles, ceilings, and furniture. Moreover, they are lightweight, durable, and can be easily maintained, shown in figs [48], [49], (46).

Fig (46) Coconut floor and wall tiles (mosaic)

a.Coconut shell (CS) blocks/ concrete filler: CS is used as eco-efficient material in producing blocks or concrete; scientists used to produce hollow and compacted blocks with various orientations of the shell inside the block matrix to deduce its durability as a reinforcement material and results indicated that CS products as concrete filler for blocks is durable as it has durable chemical constituents. And it can be used as bear loading units with elegant feature that can be used for slabs to give aesthetic appearance. On the other hand, it saves cost and energy and has thermal insulation property. Moreover, it provides an efficient use for solid waste. (Kushwanth, et al, 2021)

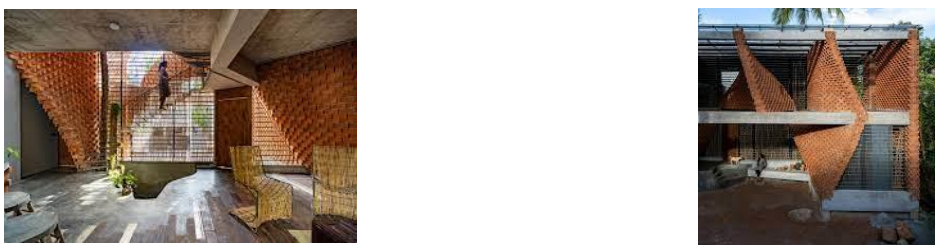

Fig (47) Coconut bricks

Concrete shell is also used to replace cement in the concrete composites in the laboratories, as it is used in concrete by the percentage 10 - 20%, it is used in its form and in a fly ash form and

the results showed that the large amount used of CS decreases the density of the concrete but decreases the concrete Workability and its durability to compressive and tensile stresses, and the use of either shapes of CS as fine ash or the native form gives approximate results. (Amarnath, Ramachandrudu, 2012), (S U Azunna, 2018)

3.4.3 Peanut shell

a.Ceramic materials: Researchers in the laboratory produced applications to examine the ability of using peanut shell in the manufacture of ceramic materials, they treated amount of it by various temperatures from 950 ºC to 1000 ºC and used little amounts of peanuts fibers of about 5% - 15% to be added to the ceramic mixture in sequenced applications and examinations and they resulted in improving the ceramic product as; it has acceptable weight with reasonable porosity, and improved strength with response to its volume. (Nancy, et al, 2018).

b. Peanut as composite concrete: Peanut shell ash is used in laboratories to be examined for its behavior, will be replacing cement in concrete, and the used amount were from 0% to 30% of cement, and results showed that the acceptable amount to be used from peanut shell in the concreate as a replacement of cement has to be from 10% to 15% to get reasonable weight for concrete with reasonable tensile and compressive strength, also it was observed that peanut shell ash improve the tensile strength more than the compressive strength. (Nadiminti Venkata, Polinati Satya, 2017)

3.4.4 Corn stalk: It has good physical characteristics, so it can share in producing building materials with thermal insulation and eco-friendly.

a. Corn stalk blocks: They are proto type blocks produced in the laboratories, the famous blocks are: Mushroom brick technology, and corn and sunflower stalks brick. Both are un bearing blocks; the first is the lightweight bricks formed of the mixture of corn stalk waste and living mushrooms as used for making 13 m high building as shown in Fig. (48) to be the latest trend of using mycelium-based composite materials in architecture. (Attias, et al ,2017). While the second proto type block used corn and sunflower stalks brick to be added to biopolymers and soil and the product was co-financed by the European Regional Development Fund (ERDF) to promote the economic and social integration of projects, the blocks are used in forming two prototype 5×5-metre structures built from a light wooden frame as shown in fig (49) in two climatic zones to test the construction formulas to detect the hygrothermal behavior and energy efficiency, and the applications will be finally monitored in 2024. [51]

Fig (48) The 13-m-tall tower in Benjamin -New York is made of corn stalks . [50]

Fig (49) A prototype construction from corn and sunflower stalks by Valles school of architecture. [51]

b. Corn stalk as panels used in building construction: Particleboards were manufactured in the laboratories from mixtures of corn stalks and woodchips, as they were mixed at ratios 0, 25, 50, 75 and 100 % respectively while using Urea formaldehyde as a binder in 3-layers particle boards, and the results showed that the increase of corn stalk in the mixture generally diminished the mechanical and physical properties. (Cengiz, et al., 2016)

Another application in the laboratory for producing composite rigid ceiling boards by using cement (Cem), corncob (Ccb) and sawdust (Swd), and the results showed that while the ratio of the mixture is 50:10:40 both of the Modulus of Elasticity and Modulus of Rupture increase and both of water absorption and Thickness Swelling decrease, and cement content is inversely proportional to the physical properties and directly proportional to the mechanical properties. (Atoyebi, et al., 2019)

c.Recycled concrete (vegetal concrete): Various application used in laboratories to enhance properties of concrete especially its weight, so Corn stalk fly ash is used to replace amount of cement in the mixture of concrete. And the results showed that while using a little amount of fly ash by the percentage from 10% and 20% from cement, the compressive strength of concrete decreased, but splitting tensile strength was improved, at the same time while increasing the percentage of Corn stalk fly, as concrete density decreases with almost 25% compared to reference concrete. (Catalina, et al., 2018)

Another study was done to reduce the cost of concrete manufacturing by using corn cob ash and saw dust wastes ash as amounts to replace cement, But it was concluded that the use of the bio ash as a partial replacement for cement in concrete leads to the reduction of the workability of concrete and leads to non – load bearing structures, and the recommended percentage of using these substitutes is not more than 10% to maintain the concrete strength (K. A. Mujedu,2014)

d. Corncob as a Raw Insulation Material: Corncob particleboard, a lightweight corncob-based concrete for nonstructural purposes, and a lightweight corncob-based Concrete masonry unit (CMU) are the laboratory research products, as the researchers used to study their thermal performance, and the results showed that this agricultural waste may have potential as a thermal insulation product (Jorge, et al. 2016).

4.Discussion and results:

This part of the paper discusses the advanced biobased cellulosic materials as elegant urban context and durable efficient architectural and construction elements.

4.1 New technological applications to modify the physical and mechanical properties of bio based cellulosic materials (BBCM) and give them elegant form:

- Latest technologies have employed these materials in their efficient form, as used the fibers of weak materials and recycled it to form flexible durable composites, and these composites are treated by agents especially plastic polymers to give them strength to bear stresses and protect them from humidity and fire, so they shared efficiently in the building construction as blocks, panels and flexible units. Also, they challenged in the external envelope of the building with elegant and durable form without need to maintenance for long times, especially as they are treated against fungi and mold by cooking sugars out of them. They get used also in internal elements of buildings in form of interior materials. Moreover, they shared efficiently in the urban scape units and elements.

• Timber is the most durable bio cellulosic material and it get the most improvements so solid timber appeared to suit the concept of the high-rise buildings and coped with the mega structures. Researchers are making use of bamboo to be advanced and reach the main properties of solid timber.

4.2 The robotic applications used the progress of manufacturing standardized units to share in the reduction of time used to produce the elegant bio-based architectural products and challenged in the building construction and envelope, also it reduced the usage of labors and improved the quality of forms and products. Also, it copes with the hyperbolic configurations,

4.3 Durability of bio based cellulosic materials (BBCM) in composite concrete

All the bio cellulosic materials shared in the production of the composite concrete to enhance the properties of concrete and give it more sustainable properties, as; the insulation property, the low cost, the light weight, and the durability for the tension stress, but the usage of such materials as composites by percentage more than 10% decreases the strength of the concrete and convert it to un bearing concrete, also it increases the time of the concrete workability.

4.4 Flexibility in bio based cellulosic materials (BBCM)

The latest advances of bio cellulosic materials aided in the presence of the various shapes of the structural units as bocks in its various forms to reach the Lego form, also the panels, the composite concrete, the durable members, so the bio cellulosic materials appeared in the various forms of construction, configurations, and elements of the urban context, also it contributed in the production of the smart insulators.

4.Conclusion:

1st: Some bio based cellulosic materials (BBCM) in the past were popular and contributed in building construction and they showed efficiency as heat insulators, and some of them has the efficiency in resisting stresses as wood, bamboo and reed. But they were all weak materials as being used in their raw form as several of their properties needed to be improved, such as dimensional stability, thermal stability, fire resistance, biotic and abiotic degradation resistance, and mechanical properties. Nowadays BBCM are of wide range as the presence of hemp, cotton, coconut shell, peanut shell…etc. especially while using the concept of recycling waste cellulosic materials. Since the announcement for sustainability; these materials were one of the top priorities of the recent development strategies of the advanced cities to reduce the energy used in building construction, also as they have no impact on the natural environment, so these materials are developed as their properties improved by means of latest technology, shown in fig (50)

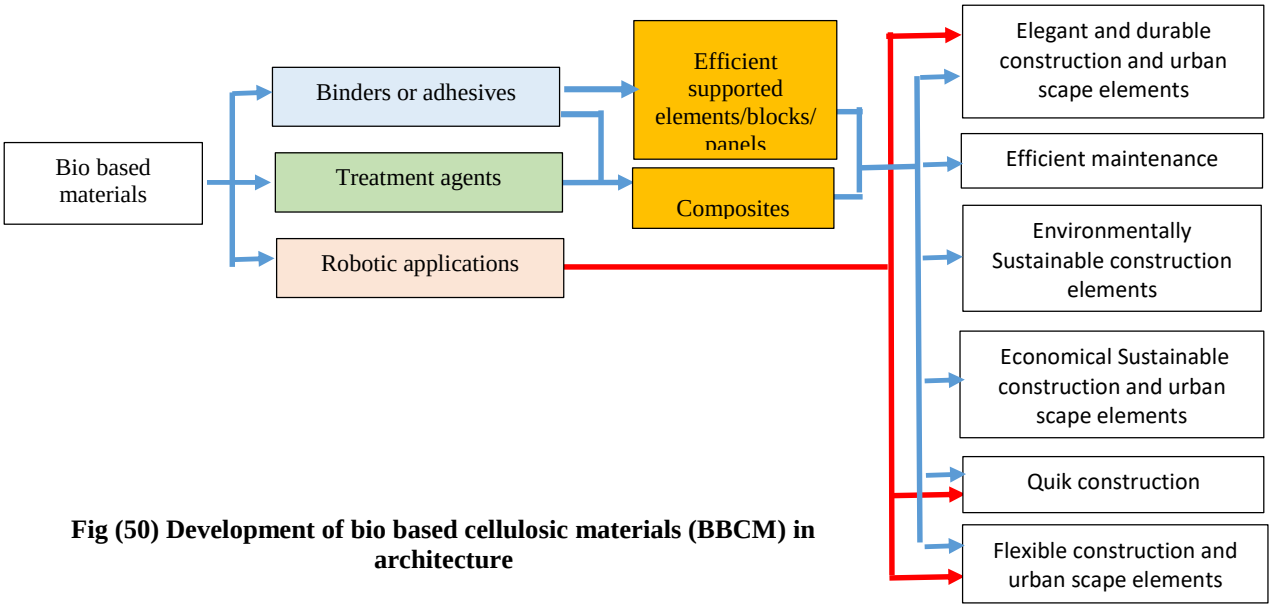

Fig (50) Development of bio based cellulosic materials (BBCM) in architecture

2nd: BBCM shared in the urban architectural context by various shapes and various norms of efficiency, and laboratories declared the efficiency of their share as composite materials that can enhance the construction elements and give it sustainable goals as improving their physical properties, as shown in table (1):

Table (1) Efficiency of BBCM in the urban architectural context

Points of comparison			BBCM								
Shapes of sharing in architecture		Efficiency	Timber	Straw fibers	Reed	Hemp	Bamboo	Coconut shell	Corn stalk	Cotton fibers	Peanut shell
Sharing as structural system element	Composite/ non composite blocks	Durability as bearing loads	*	*				*		*	*
		Elegant feature		*				*	*	*	
		Daring environmental condition	*	*		*		*	*	*	*
		Robotic manufacturing	*	*		*		*	*		
		Flexible to form	*	*		*		*	*	*	

		circular shapes									
	Panels	Durability as bearing loads	*	*	*	*	*			*	
		Elegant feature	*	*		*	*		*	*	
		Daring environmental condition	*	*		*	*		*	*	
		Robotic manufacturing				*	*				
		Flexible to form circular shapes	*			*				*	
	members	Covering wide spans	*		*		*				
		Robotic manufacturing	*		*		*				
	Casting form as concrete	Hyperbolic Envelope Covering wide spans				*				*	*
		Efficient durable Slabs		*					*	*	*
Sharing in the outer envelope	claddings	Elegant feature	*				*			*	
		Daring environmental condition	*				*		*	*	

		Robotic manufacturing	*				*			*	
	Shading elements	Elegant feature	*			*	*			*	
		Daring environmental condition	*			*	*			*	
		Robotic manufacturing	*			*	*			*	
	Envelope material	Non-bearing brick walls	*	*		*		*	*	*	*
		Elegant feature	*			*	*		*	*	
		Daring environmental condition	*	*		*	*		*	*	
		Non-bearing panels	*	*	*	*	*	*	*	*	
		Robotic manufacturing	*			*	*		*	*	
Sharing in the interior elements and materials		Elegant feature	*	*			*	*		*	*
		Durable material	*	*			*	*			
Used as insulator layer		High efficiency in insulation	*	*	*	*	*	*	*	*	
Sharing in the land scape realm		Elegant feature	*				*				
		Daring environ	*				*				

	mental condition									
Percentage of advancements		90%	50%	17%	60 %	70%	33 %	47%	77%	20%

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