Engineering, Structural Materials and Biomaterials: A Review of Sustainable Engineering Using Advanced Biomaterials

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Abstract – This paper introduces the state-of-the-art biomaterials that may be used to build in a way that is both environmentally friendly and long-term. Concrete, polymers, admixtures, asphalt, and soils are all examples of these materials. It is only because of natural selection that biomaterials may have desirable characteristics that would otherwise be impossible. They are known for characteristics that cannot be replicated in a laboratory setting. These characteristics develop throughout time and by natural means. Biomaterials' naturally occurring characteristics are ideal for meeting the demands of the building industry. Biomaterials having negligible or very negligible linear coefficients of thermal expansion may be utilized in different building applications. They aid in the reduction of internal strains because to their resistance to any change in length brought on by variations in temperature. Biomaterials have various benefits over synthetic materials, including lower production costs and less of an impact on the environment. Use of biodegradable materials may help alleviate the environmental problem caused by the dumping of synthetics. Cracks in the concrete are patched by the live bacteria inside it, making the material stronger.

Keywords – Biomaterials, Bio-Concrete, Bioplastics, Bio-Admixtures, Bio-Mediated Soils, Sustainability

I. INTRODUCTION

Biomaterials are any substances that have some kind of effect on biological organisms. We can trace the use of biomaterials in the building industry back in time in light of this explanation. Timber, among other materials, has a long history of usage in the building industry. This renewable material has been used for millennia in the construction of building framework, roofing, and flooring. But, as the chemical industry advanced, people began using more synthetic materials in their building projects. Despite these advancements, biomaterials have always been a component of building. Chemicals derived from natural sources were also widely utilised to produce high-tech building materials with improved properties. Now more than ever, industries are looking to its distant past in a desperate hunt for biomaterials that can meet the current construction demands. The global community is also searching for long-term solutions to our natural resource issues. This search is critical for the future of humanity.

The construction industry often makes use of biomaterials in a variety of applications. Some biomaterials, such as wood, are used in their natural state, while others undergo chemical processing to enhance their properties. These materials come from a broad variety of resource, such as soils, plants, animals, and industrial biotechnological processes. Not only is wood being used in building, but so are a variety of crops grown specifically for that purpose. Despite their restricted waterproof interior application, they represent a major advancement in the building industry. In the current era, hemp shive concretion with a lime binder may be used to strengthen concrete, and this method can also be used to build walls. Moreover, linseed oil is often used in paints, and wool is commonly used in insulation. The Straw bale farmhouse in mid-Wales, Britain, is a great example of bio-based building. It has a concrete foundation and is made of forest-harvested wood and big bales of firmly compressed straw. The insulation provided by these straw bales is 10 times that of prefabricated blocks. The roof is insulated further with wool from the farm's sheep. Chemically manufactured building materials go through a series of procedures and material interactions, such as those involving coupling agents, to obtain their final qualities.

Biomaterials, in contrast to synthetic materials, may give the same benefits without requiring a long list of chemical interactions to achieve them. As a consequence of these process improvements, biomaterials may be used that have much less energy invested in them. Biomaterials have the potential to be very efficient in regulating temperature and keeping things at a consistent temperature for long periods of time [1]. They not only improve the quality of life in a home, but also provide a highly economical means of heating and cooling the interior. Fatty acids found in animal fat and plant oils power bio-based phase control technologies. They are resistant to fire and have a high latent heat.

In addition, they are very stable, long-lasting, and harmless. Comparatively, other inorganic PCMS are more expensive. Timber and other biomaterials have an even lower thermal diffusion coefficient of 0.08 mm^2/s. Biological admixtures, also known as "biomaterials," are functional molecules that are mixed in with traditional building supplies to boost their effectiveness. Bitumen was utilized by the Sumerians as organic binders and water repellent in mud and straw mixes as far back as 3000 B.C. Renowned Roman architecture was made feasible by the employment of maximally improved construction materials manufactured from particular chemicals taken from natural resources.

This article provides a critical analysis of environmentally friendly biomaterials, which are utilized in the construction industry. The materials discussed in this paper include concrete, polymers, admixtures, asphalts, and soils. The rest of the paper has been organized as follows: Section II, III, IV, V, and VI focuses on bio-concrete, bio-plastics, bio-admixtures, bio-asphalt, and bio-mediated soils, respectively. Section VII reviews the concept of biomaterials and sustainability. Lastly, Section VIII draws final remarks to the research.

II. BIO-CONCRETE

In the modern age, concrete is considered as one of the most globally used construction materials, and has several important applications [2]. Many buildings, dams, storage vessels, seaports, highways, bridges, tunnels, and subways have been built using it. Cement, water and aggregates (both fine and coarse) make up the bulk of a concrete mixture. Being the backbone of the mixture, cement is essential to concrete. It is used to bind an aggregate and fill spaces between smaller and larger particles. Concrete's numerous useful properties—including its higher compressive stiffness, durability, availability, compatibility with reinforcing bars, cheap cost, easy preparation, and the capability of casting in a wide variety of forms and sizes—make it a popular material option. Despite its many benefits, concrete is prone to cracking, which may let harsh chemicals into the building.

Concrete's durability and strength may be significantly reduced due to cracks. It is possible to create cracks in both a plastic and a hardened condition. During the plastic stage, cracks may occur as a consequence of things like plastic settlement, formwork displacement, and plastic shrinkage due to prompt water loss from the surface of concrete. Cracks can also occur in hardened places as a result of things like weathering, dimensional stability, thermal stiffness, errors in details and designs, continual overloading, external load, and chemical reactions. In addition, the tensile durability and toughness of concrete buildings are often rather low. Embedded steel bars are often used to strengthen concrete, which increases its durability and tensile strength. Reinforcing bars help limit fracture breadth by reducing the effects of plastic shrinkage, but they cannot stop cracks from forming in the first place.

There is no question that the development of cracks may pose a significant risk to the longevity of concrete, even if they do not immediately compromise its strength in the early ages. Several nations across the globe devote a significant portion of their annual budgets to the maintenance of their already-built cementitious buildings. Estimates put the direct cost of crackrepair and maintenance at \$147/m^3 of concrete, but the cost of producing concrete is just \$65-\$80/m^3. It is thus essential to take preventative measures to limit and eventually eliminate fracture development. There are two main categories for dealing with concrete flaws: passive and active solutions. When cracks are treated using active procedures, not only are they filled on the outside, but they also mend on the inside.

Passive treatments, such as the application of chemical mixes or polymers, may be done on the outside of the concrete to improve its durability and prevent the entry of aggressive materials. After cracks have been identified, passive treatments include injecting or spraying sealants into the fissures. Common chemical components of sealants include chlorinated rubber, polyurethane, siloxane, acrylics, waxes, and epoxy resins. It is true that passive treatments may be used on many pre-existing concrete buildings, but they're not without their drawbacks. Chemical sealers have a number of drawbacks, including a lack of durability, poor adhesion to concrete, and a high risk of deterioration and age delamination, and mismatches in thermal expansivity coefficient between the two.

Self-healing treatments, or active treatment methods, may function autonomously in a variety of environments and across a variety of fracture orientations. They may also activate instantly upon the creation of a fracture, preventing the fissure from widening. Polymeric material encapsulation, autogeneous healing, and calcium carbonate microbial production are the three basic strategies that may be used to generate a self-healing methodology in concrete. It would be wonderful if there were a cure that could mend cracks an infinite number of times without losing efficacy, lasting a long time, being widely distributed, and being widely accessible. When water or moisture is present, a natural process called autogenous healing may fix fractures in concrete.

In the process of autogenous healing, fractures are filled by the carbonation of soluble calcium hydroxide or the hydration of dry cement particles. Calcium hydroxide, formed when calcium oxide is hydrated, may react with atmospheric carbon dioxide. The formation of calcium carbonate may be regarded as a product of these processes in Equations 1 and 2. One of the most adaptable and practical fillers for fractures, porosities, and voids in concrete is calcium carbonate because of its availability in nature and affinity with cementitious formulations.

$$CaO + H_2O = Ca(OH)_2 \tag{1}$$

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O \tag{2}$$

In order for autogenous healing to be effective, conditions like humidity and water in the ecosystem, the un-hydrated cement quantity, and the nature of the concrete matrix are crucial. It has also been shown that autogenous repair can only fill fissures between 0.1 and 0.3 mm in size. In order to facilitate better autogenous healing, it is helpful to decrease the water-to-cement (w/c) ratio. Although decreasing the water-to-cement ratio necessitates additional cement manufacture, increasing the cement content has a negative impact on shrinkage and workability. Another kind of active therapy is the encapsulation of polymeric material. This approach may help repair fractures since the healing ingredient turns into foam when exposed to water. Chemicals released from hollow fibers embedded inside concrete may be used to fill cracks, although these substances do not behave the same as concrete formulations and can even cause cracks to grow in some circumstances.

In addition, this method necessitates capsules that are amenable to being blended with concrete and that can maintain their integrity when embedded in a cement matrix. The embedded capsules must keep the healing agent safe for an extended length of time without negatively impacting the workability or mechanical qualities of the concrete. Encapsulation is a challenging procedure for commercialized self-healing concrete as a result of the aforementioned requirements. The limitations of current therapies have increased the desire for novel, active therapy approaches. Increasingly, researchers' attention has been drawn to biotechnological techniques as a potentially useful means of addressing problems connected with passive and active therapies. The biomineralization process is the foundation of the biological healing process [3]. If this novel treatment procedure can be successfully implemented, it will significantly reduce cement output and the need to repair concrete buildings.

One strategy consists of embedding capsules containing bacterial spores, calcium lactate, and nutrients for concrete. The capsules' protective role is to delay the onset of contact until after the fractures have formed. Porous expandable clay particles may also be used to enclose bacterial spores and organic minerals precursor chemicals before introducing them into the concrete framework. During the formation of fissures, these capsules burst and the spores become active upon contact with water, transforming calcium lactose and nutrients into limestone. The resulting limestone is what stops water from leaking through the concrete's fissures. The following equation (3) describes the formation of the resulting limestone.

$$CaC_6H_{10}O_6 + 6O_2 \rightarrow CaCO_3 + 5CO_2 + 5H_2O \tag{3}$$

Nonetheless, research has demonstrated that in addition to the direct process stated in the aforementioned equation, this bacterium also experiences an indirect process that results in limestone. The slow indirect process is a natural occurrence in concrete, caused by the interaction of biologically generated CO_2 molecules (according the Eq. 3 above) with the $Ca(OH)_2$ minerals included in concrete substrate, which is illustrated by the following equation (4).

$$5CO_2 + 5Ca(OH)_2 \rightarrow 5CaCO_3 + 5H_2O \tag{4}$$

As CO_2 is being produced at the outer surface of the cracks, it may react directly with any Portlandite particles that have not been pushed out by the water. These two procedures (in the two equations) may produce a total of six calcium carbonate equivalents, which is more than enough to effectively fill any gaps. The bacterial spores have a long shelf life, lasting up to 20 decades in dry circumstances and withstanding the impact of severe power-driven forces. Yet, their durability is drastically compromised when they are placed in the concrete without any kind of protection. Although it may seem counterintuitive, the pore size of concrete actually shrinks dramatically throughout the setting process from cement stone paste to solidified concrete. Since this phenomenon likely occurs when the width of pores are minimized to 1 m, the typical sizes of the Bacillus spore, safeguarding the bacterial spore before they are integrated to the concrete mixtures greatly extends their life-time. Hurley, Habibzadeh-Bigdarvish, Lei, and Yu [4] have shown that bacteria introduced into concrete in a controlled environment remain viable for up to six months.

The influence of temperature on the self-healing process is of major importance since concrete buildings are subjected to severe weather conditions, including direct sunshine. Experiments have been conducted to learn how temperature changes affect the self-healing phenomena. An experiment was conducted at three distinct temperatures: 80 °C, 50 °C, and 20 °C; 30% Increasing the temperature of a fracture from 20 °C to 80 °C reduced its permeability to 3%. To be more precise, water's permeability falls dramatically with increasing temperature because its viscosity rises. As a result, we may infer that concrete's self-healing abilities increase with increasing temperatures. In addition, the internal climate of the concrete has a significant impact on the effectiveness of bacterial spores in promoting fracture repair. Bacterial spore activity is often significantly dampened in environments with a pH higher than 12.

So, it is preferable to deliver the germs through carefully chosen carriers. Based on the findings of an experiment conducted using silicone-gel and polyurethane carriers, bacteria contained inside silica gel demonstrated more activity than those contained within polyurethane. Polyurethane can indicated to have an increased possibility of a bacterial transmitted for self-healing concrete, despite the fact that limestone deposition was lower (25%) in polyurethane than in silica gel

(11%). This is because specimens repaired by polyurethane encapsulated bacteria had a greater strength restoration (60%) and a lower water coefficient of permeability (1010-1011 m/s) than those healed by silica gel encapsulated bacteria (5% strength restoration, 107-109 m/s water permeability coefficients). It has been discovered that the self-healing procedure boosts the concrete's mechanical qualities, which is another key component that has attracted the attention of scientists in the last few years. When ultra-high strength concrete that had been injured by freeze-thaw activity was subjected to bacterial-induced healing, the resonance frequency significantly increased. In addition, the compressive strength of mortar cubes was shown to increase when microbiologically produced calcium carbonate was used.

The concrete mixes including bacteria demonstrated marginally greater deflection capability and modulus of elasticity recovery after breaking and healing than the control combinations without a bio-based healing agent. This method for healing relies on contact with water. Nonetheless, crack repair may become necessary in times of drought. The bacteria may be stored in hollow plant fibers, which function as reservoirs for the healing agent due to their huge storage capacities for liquids. In addition to this, extremely absorbent polymers packed with water may be added to the concrete. These polymers may be utilized to make self-healing concrete by forming water-filled pockets in the material. An intriguing thing occurs when these hyper absorbent polymers are depleted of their water content; the rain replenishes them.

III. BIOPLASTICS

Bio-plastics are polymers created from renewable sources of biomass such as oils, vegetable fats, maize starch, woodchips, straw, sawdust, and recycled food materials among others. Bio-plastics can be processed from biopolymers e.g., polysaccharides (e.g., alginate, cellulose, chitosan, and starch), and proteins (e.g., geltin, soy protein, and gluten), while others are produced synthetically from sugar derivatives (e.g., lactic acids), and lipids (fats and oils) derived from either plants or animals, or organically-created through the process of fermentation of lipids or sugar. Petro-based polymers, which include most common plastics, are created from either natural gas or petroleum. One benefit of bioplastics is that they don't have to rely on fossil fuel—a limited, unequally distributed resource with ties to petroleum geopolitics and environmental repercussions throughout the world—as a raw material. When biomass is utilized not just as a raw material but also as a source of energy, for example, life cycle evaluation researches reveal that particular bio-plastics could be made with a minimized ecological footprints compared to their fossils equivalents. Nevertheless, the production of certain bioplastics is less efficient than that of fossil plastics, leading to a larger carbon footprint as a byproduct.

Polymers' adaptability and ease of production are unparalleled. Around 23% of global plastic consumption is used in the civil engineering sector, with the vast majority of this having high energy needs during manufacture. Plastics are an essential material for architects and designers because they improve the longevity, performance, and energy efficiency of buildings of all types. Roofing, walls, windows, fences, and pipes may all benefit from the usage of plastic. The widespread use of these methods is to blame for plastics' massive ecological impact. Their production has a negative implication on the ecosystem and contributes to the depletion of fossil fuels. Moshood et al. [5] have been hard at work developing sustainable, renewable, and biodegradable plastic production methods to mitigate these negative impacts. The use of bio-plastics as an alternative to traditional plastics has been met with widespread praise. **Fig. 1** presents the process of plastics manufacturing from plants and petroleum.

Compared to their petroleum-based counterparts, biocomposites are just as strong for how little they weigh. Fencing, railing, walls, framework, doors, ornamental, and insulation panels are all simple applications. Bio-plastics that can withstand high temperatures have been developed, and this is true regardless of the progress and improvement of polymerization processes. Despite its benefits, bio-plastics are more expensive to create than plastics made from petroleum, thus new technologies are needed to bring down the price of bio-plastics. The employment of cheaper raw materials, e.g., agricultural wastes, food processing wastes, liquid wastes from waste-water treatment facilities, and the organic part of municipal trash, are some simple methods to address this cost problem.

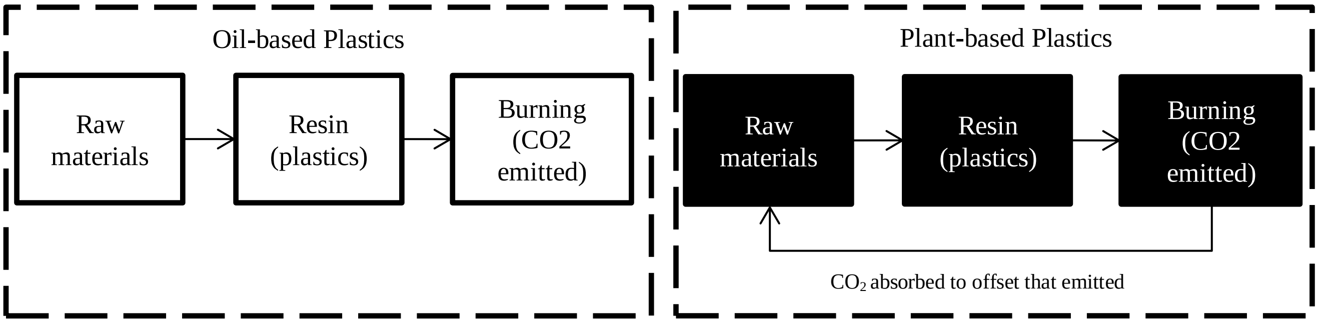

Fig 1. Plastics Manufacturing from Plants and Petroleum

As materials like petroleum are just fossilized biomass, the difference between bio-plastics made from non-fossil sources and those made from fossil sources is mostly irrelevant. Degradability or non-degradability (durability) in plastics is therefore determined by molecular framework and not by whether or not biomass utilized as raw materials has been fully fossilized. The bio-plastics that are biodegradable e.g., polybutylene succinate, polyhydroxyalkanoates, polylactic acid are available, as are long-lasting bioplastics like biopolyethylene (bio-created analogues of polyethylene terephthalate and polyethylene derived from fossil fuels), or Bio-PET. In order to prevent further plastic pollution, bioplastics should be recycled in the same manner as plastics made from fossil fuels. "Drop-in" bioplastics (like biopolyethylene) may be recycled with conventional plastics. Nevertheless, including biodegradable bioplastics into existing recycling processes may increase sorting costs and potentially lower both recyclate output and quality. Nonetheless, from a green perspective, both chemical and mechanical recycling is typically preferable to microbial degradation as an end-of-life disposal strategy for biodegradable bioplastics.

The notion of microbial degradation is not as simple as many assume; yet, degradability may provide an end-to-end application route, for instance in agricultural mulching. Given that the bioplastic's biochemical backbone structure greatly affects its susceptibility to microbial degradation, and that various bioplastics have varied structures, it is not safe to assume that any given biodegradable plastic in the ecosystem would quickly dissolve. It is also possible to make biodegradable polymers using fossil fuels. In 2018, bioplastics accounted for around 2% of total plastics production (more than 380 million tons). Although the production of bioplastics and fossil plastics both gradually expand, the former is becoming more dominant thanks to ongoing research, investment in bioplastics businesses, and more scrutiny of the latter.

Polysaccharide-Based Bio-plastics

Starch-Based Plastics

Packaging Peanuts from Bioplastics

Most bioplastics are made from thermoplastic starch, which accounts for around half of the bioplastics industry. At home, you may make a starch bioplastic film by gelatinizing starch and then solution casting. Because of its moisture-absorbing properties, pure starch is often used in the pharmaceutical industry to make medication capsules. Bioplastic made entirely of starch, however, is quite fragile. To facilitate thermoplastic processing, plasticizers such as glycol, sorbitol, and glycerol could be integrated to starch mixture. It is possible to change the features of resultant bio-plastics (i.e. "thermoplastic starch") by varying the proportions of these additions. Starch may be converted into bioplastic via the use of standard polymer processing techniques including compression molding, solution casting, extrusion, and injection molding. The amylose/amylopectin ratio has significant effects on the starch bioplastic's characteristics. In most cases, the mechanical qualities of high-amylose starch are better than those of low-amylose bio-plastics (or starch). Due to its greater melt viscosity, gelatinization temperature, high-amylose starch is less amenable to processing.

Common mixes of starch-based bioplastics include polylactic acid, polycaprolactone, and Ecoflex (Poly-butylene adipatecoterephthalate by Song, Zhang, Li, Wei, and Li [6]). The mixtures find usage in the industrial sector and are also biodegradable. The Roquette Company is not the only one to experiment with starch/polyolefin mixtures; there are others. While these mixes are not biodegradable, they do produce less greenhouse gas emissions than petroleum-based polymers used for the same purposes. Composting and biodegradable starch-based films are created when starch is combined with thermoplastic polyesters. Magazine wrapping and bubble films are two common examples of this kind of material used for packaging consumer items. Bakery bags and produce bags are common examples of film used in food packaging. This film is utilized in composting bags for selective garbage collection. Furthermore, films made from starch may be used as a substitute for paper. Several studies have shown that starch-based nanocomposites offer superior mechanical characteristics, thermal stability, gas barriers qualities, and water resistance.

Cellulose Plastics

Blister packaging produced from cellulose acetate, biopolymers. Celluloid is a kind of cellulose bioplastic that is derived from cellulose esters like cellulose acetate and nitrocellulose. By making a number of adjustments, cellulose may take on the properties of a thermoplastic. Cellulose acetate is one such material, although it is quite costly and is hence seldom used for packaging. Cellulosic fibers, which are less hydrophilic than starch, may be added to carbohydrates to boost their mechanical elements, moisture resistance, and gas permeability. By utilizing the process known as hot pressing, Plotnikova, Korchagin, and Popova [7] have created a brand-new eco-friendly plastic made from cellulose.

Other Polysaccharide-Based Plastics

To a lesser extent than cellulose acetate but similar to chitosan, alginate is another polysaccharide that lends itself well to plastic production. Chitosan is readily transformed into films by solution casting because to its solubility in mildly acidic environments. When it comes to film formation, chitosan shines. In addition, chitosan may be thermomechanically treated utilizing an internal batching mixer and compressive molder to create a plasticized form by adding a little quantity of acid. Because of its high viscosity during thermomechanical processing, chitosan mixes well with plasticizers, nanoparticles, and other biopolymers. Blended materials based on positively charged chitosan as well as other negatively charged polymers e.g., proteins, alginate, and micro-crystalline cellulose are difficult to produce under solution circumstances due to the electrostatic reaction that occurs between the two biopolymers, which often results in coacervates.

Nevertheless, high-viscosity mechanochemical treatment may be used to create bulk chitosan blends, which may show significantly improved mechanical characteristics and hydrolytic stability. Casting films from alginate solutions is possible because alginate (often calcium alginate or sodium alginate) dissolves in water. Alginate may be thermomechanically treated into plasticized films by combining it with small quantities of water and plasticizers. Processing chitosan or alginate into films allows them to be flexible with the addition of plasticizers like glycerol.

Chitosan is an alternative biopolymer to synthetic plastics that has been researched for its potential as a packaging material. Chitin, the second most ubiquitous polysaccharide on the globe, is the source of chitosan, a polymer generated by deacetylating chitin and then purifying it. Chitosan is acquired from the inedible parts of marine animals. Food and packaging waste may be minimized if chitosan were used more often [8]. Biodegradable and inhibiting spoiling development, chitosan is composed of antibacterial activity and film forming characteristics. Biopolymers like chitosan may disintegrate in weeks, but it may take years for synthetic plastics to deteriorate. Modified atmospheric packaging is one kind of antimicrobial packaging that inhibits microbial activity and bacterial development. Instead of using non-biodegradable plastics, you may use chitosan as a replacement and reduce food waste.

Protein-Based Plastics

Several types of protein may be used to create bioplastics. Wheat gluten and casein, for instance, have useful characteristics as a raw ingredient from different bio-degradable polymers. The Soy protein is being researched as the possible bio-plastics material as well. For more than a century, soy proteins have been a key ingredient in making plastic. Soy-based plastic was used for the first Ford car's body panels, for instance. Plastics made from soy protein have a number of drawbacks, including their susceptibility to water and high price tag. Soy protein blends with several existing biodegradable polyesters increase water sensitivity and cost effectiveness.

IV. BIO ADMIXTURES

Several bio admixtures are now being used in conjunction with a wide variety of building supplies. Most bio admixtures are used in cement; one such bio admixture is lignosulfonate, which is derived from lignin, a wood natural polymer, and is used to improve the applicability of concrete and to create concrete with high compressive strength at a lower water/cement ratio. Foam concrete, which may be made, using "protein hydrates" produced from animal blood and hair, is used as a basis for roadways over unconsolidated soil and in prefabricated partition walls. Plasters also need an ingredient like "Cellulose ethers" to help them absorb and hold water. Paints, gypsum, varnishes, asphalt, foams, and grouts that include bio admixtures are also commonplace.

Vegetable oils, according to research in [9], may affect the strength and pore structure of mortars. Mortars may be treated with oils from rapeseeds, maize, linseeds, olives, soybeans, and peanuts to resist water for an extended period of time. Vegetable oils have been shown to aid in the formation of a pore structure that leads to a reduced degree of water saturation, thereby boosting durability. An additional additive that may serve as a concrete retarder is water hyacinth. It is a plant that thrives in water and has the capacity to spread and cover vast bodies of water, cutting out all sunlight and leading to oxygen shortage. It also tends to lengthen the time required for concrete to cure and make it less workable. Moreover, compressive strength was shown to grow with time.

Chemical admixtures serve a crucial role in the creation of long-lasting, normal concrete that is both environmentally friendly and functionally versatile, thanks to the enhancement of mechanical qualities. Plasticizers, waterproof additives, accelerators/retarders, air-entraining agents, shrinkage-reducing admixtures, and others like coloring agents, and corrosion inhibitors are all examples of useful chemical admixtures. Concrete's strength, resistance to frost, flow behavior and deicing salts sulphate, setting qualities, pumpability, and others are all influenced by chemical admixtures. Different Common kinds of chemical admixtures and their functions are listed in **Table 1** these admixtures are widely utilized in the creation of concrete with a very low water-cement ratio.

Table 1. Types of Admixtures

Types of chemical admixture	Functions
Super plasticizer	In order to get a high-strength, thick concrete while decreasing the amount of water needed for production by 15% to 20%.
Accelerator	The concrete sets faster and the forms may be removed sooner if this method is utilized, making it ideal for usage in cold climates.
Retarder	In high-temperature concreting environments, this method is recommended since it shortens the time it takes for the cement to cure.
Water reducing admixture	To reduce cement use while still meeting strength requirements, a low-water cement mix with a certain slump might be used.
Air entraining admixture	By adding tiny air bubbles that function as rollers to concrete, workability is increased, and the material is more resilient to freeze-thaw cycles. This is because the air bubbles act as a kind of padding for the expanding water that causes cracks in the material when it freezes and thaws.

Most chemical admixtures used to alter the characteristics of polymer-based concrete are derived from petroleum and are thus nonrenewable. Production, shipping, storage, handling, applications in concrete, service life of concrete structure, regeneration of concrete following demolition, and disposal of construction debris and residues are all potential sources of pollution from chemical admixtures. **Fig 2** shows a simplified additive life cycle for concrete.

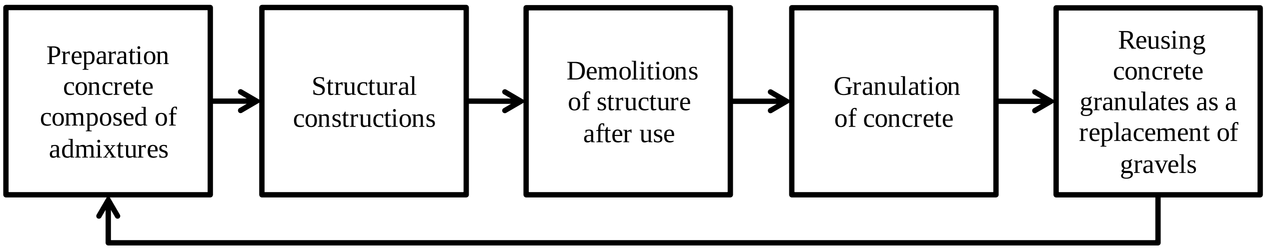

Fig 2. Life Cycle for Concrete

Superplasticizer is mostly comprised of water-soluble polymers, such as sulfonated condensate, melamine formaldehyde, naphthalene formaldehyde condensate and so on. They also release hazardous substances like formaldehyde, which is both a danger to the environment and to human health. Many compounds, including those with harmful effects on the environment, are used in plasticizers and superplasticizers.

V. BIO ASPHALT

It is possible to make bio-asphalt by substituting a bio-binder for petroleum asphalt or by altering the latter. Bio-asphalt may be made in one of three main methods, as shown by research by Lai et al. 10]. Three distinct replacement rates are plausible: (1) complete (100%) petroleum asphalt replacement with biobinders; (2) 10% petroleum asphalt modification of biobinders; and (3) 25 to 75% petroleum asphalt dilution with biobinders). Bio-oils, bio-asphalt, bio-oils, and biomass are all connected in some way, as indicated in **Fig 3**.

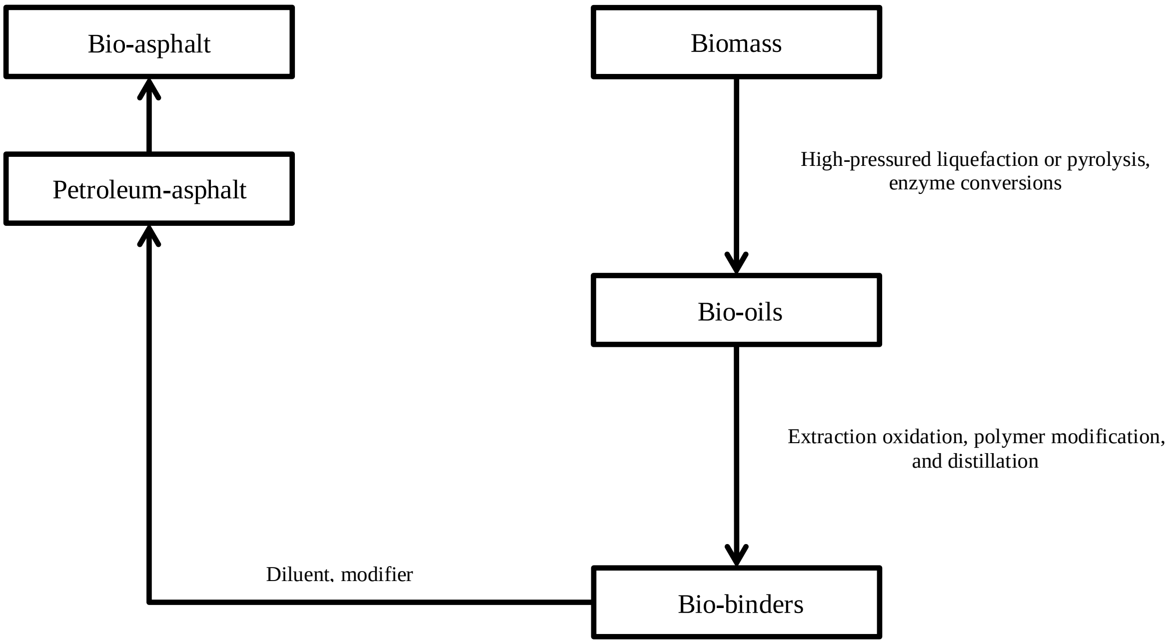

Fig 3. Biomass, Bio-Asphlt, Bio-Binders, and Bio-Oils Relationship

If petroleum asphalt is modified or combinied with bio-binder, we get bio-asphalt, which may lessen the dependence on petroleum asphalt and boost its efficiency. To make bio-asphalt, Robertson, Adiningtyas, Ebrahim, Scoles, Baranova, and Singh [11] combined virgin asphalt with a lignin-based bio-binder and sheared the resulting mixture at 110 °C for 6000 revolutions per minute for 30 minutes. Xi, Yu, Zhu, and Wang [12] combined petroleum asphalt with a bio-binder made from swine manure, then sheared the mixtures at a 1000 revolution rate per minute for thirty minutes at a temperature of 200 degrees Celsius. To produce bio-asphalt, Xie et al. [13] combined bio-binders created from waste oils with petroleum asphalts and sheared the combination using sheering machine operated at a high speed at 70 degrees Celsius for four thousand revolutions per minute for twenty to thirty minutes. Parameters used in the manufacture of bio-asphalts from distinct biomasses in the past few years are summarized in **Fig 4**.

Fig 4 demonstrates that the shear degree of the lignin-centric bio-asphalt is minimal compared to that of the swine manure-produced bio-asphalt. It also demonstrates that the temperature of shear of the waste oil-produced bio-asphalts is more compared to tha of the wood fiber-based bio-asphalt. It is recommended to prepare swine manure-produced bio-asphalt in the following way: The shear duration is normally 30 minutes long, the temperature of shear is typically between 120 °C and 140 °C, and the speed of shear is frequently between 1000 rpm and 3000 rpm. The following preparation method is also suggested for the varieties of bio-asphalt produced from wood fiber and waste oilts: The temperature of sheear is typically between 120 °C and 170 °C, and the rate of shear is usually between 400 and 5000 r/min. The shear length is often about 30 min. It is an asphalt alternative that may be made from resources other than petroleum that are sustainable. Some of the resources integrate molasses, vegetable oils, natural latex rubber, maize, rice, sugar, gum reins, and natural trees, and cellulose, lignin, peanut oil wastes, and dried sewarage effluents include canola oil wastes. In 2010, a researcher looked at the properties and applications of manure-produced bio-asphalt within the asphalt sector. The natural process of thermo-chemical liquefication was employed to turn grape manures into bioasphalts. Nonetheless, the fundamental residue was employed as the asphalt modifier. The leftover material was then combined with regular base binder at rates of 10%, 5% or 2% of the overall base-binder mass.

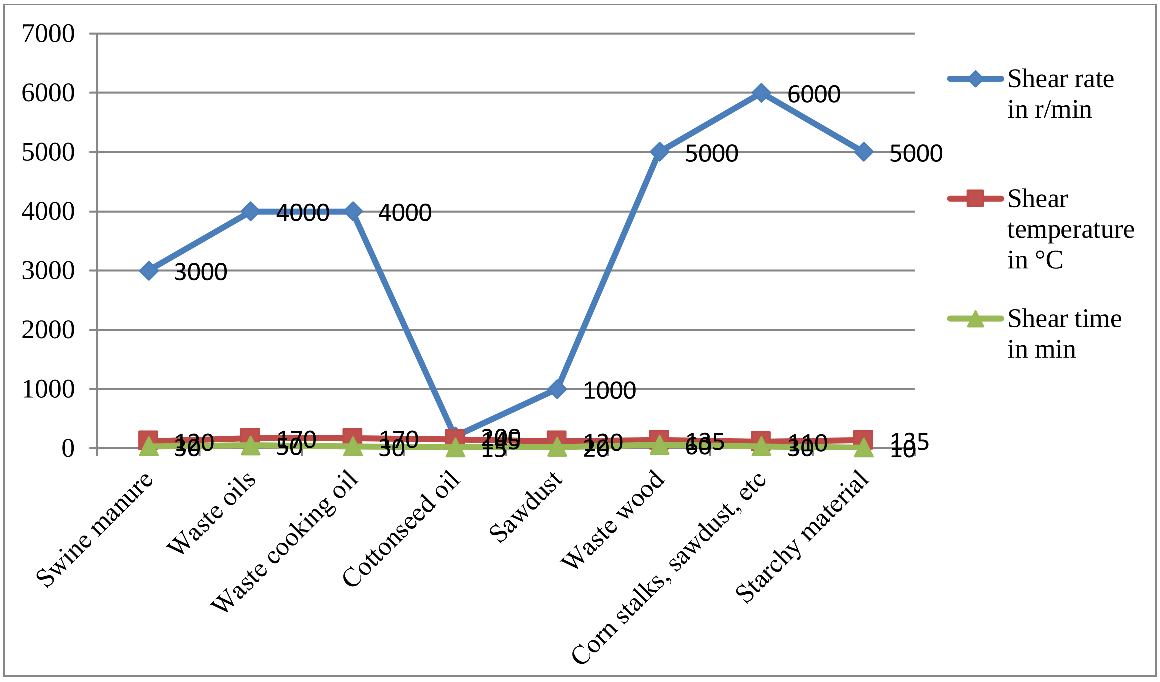

Fig 4. Bio-Asphalt Preparation Parameters

Based on the findings, integrating swine manure-produced bio-asphalt increased the reduced temperature element of the material but decreased its higher temperature resistance to rutting. Authors conducted a critical review to determine bow fractioned bioasphalt could be utilized in the lieu of outmoded asphalt. In the research, oak wood, switch grass, and maize stover were all exploited as biofuels. Biomass sources used in the production of bioasphalt were fractionated and pyrolyzed. To determine the electrostatic precipitates of biomass, they were integrated with asphalt binders at three distinct concentrations: 9%, 5%, and 3% by the mass of the complete binders. Combining bio-asphalt produced from biomass with these outmoded polymer-based asphalt binders was shown to have several advantages. The combined bioasphalt and conventional asphalt modifiers shared several chemical properties, according to the research. Afterwards, the scientist looks at how bioasphalt performs in engineering settings. In this experiment, it was combined with the basic binder at concentrations ranging from 0% to 30% by mass. The biomodified binder's rheological characteristics were investigated utilizing bending beam rheometer analysis, and dynamic shear rheometer.

Although the idea of using bioasphalt made from swine dung to improve the asphalt's resistance to rutting seems nice in theory, the initial test showed that the parameter of rutting was raised by its inclusion. After incorporating the bioasphalt, the binder's m-value dropped, as shown by the second test. Thus, bioasphalt mitigated the cold-resistant qualities. Our findings demonstrate that this particular bioasphalt may improve rutting qualities at the expense of poor thermal properties. The lower temperature binder elements as asphalt adapted with bioasphalt were investigated in a separate investigation. The swine manure used in the bioasphalt was liquefied using a thermochemical method. Conventional asphalt binder was mixed with bioasphalt at concentrations of 2%, 5%, and 10% by mass.

Low temperature binder characteristics were measured using a bending beam rheometer and an asphalt binder cracking apparatus. When the proportion of bioasphalt in the binder was raised, the experiments showed that the biomodified binder's lower cracking temperature dropped. Thus, the findings showed that an integration of conventional binder and bio-asphalt may improve the hot mixed asphalt's low-temperature characteristics. Every year, over 3 billion cooking oil gallons are collected from eateries e.g., fast food joints. Using a polymerization process, used cooking oil may be transformed into asphalt. Mixing the bioasphalt with regular asphalt and then testing its efficacy as a binder and in hot mixed asphalt was done.

VI. BIO MEDIATED SOILS

There has been an unparalleled growth in both population and urban infrastructure. The American Society of Civil Engineers predicts a $1.6 trillion investment is required to keep up with the yearly 0.9% population growth in the United States. China and India in particular, have very high infrastructure needs. Countries like China, where approximately 10 million citizens migrate to urban environments per annum, struggle to keep up with the need for new infrastructure. Cities and areas with a long history that are hemmed in by geography or poor soil have it especially tough when population booms (e.g. Mumbai, Boston, Istanbul, New York, Taiwan, Los Angeles, Tokyo, Japan, and Holland). The availability of competent soils is a limiting factor in the capacity to repair and expand civil infrastructure to satisfy rising social demands.

At the same time, the life-sustaining environmental conditions are deteriorating and are expected to worsen more in the future. The anticipated sea level rise from global warming is a stark illustration of this point since it is directly related to CO_2 emission from fossil fuels combustion. Cement production is a major offender since cement is utilized in so many aspects of building, including ground improvement. Hence, it's obvious that soil-improving technologies ought to be long-lasting so that they can serve society. In a world where over US$6 billion is spent annually on soil improvement projects, it is clear that there is a pressing need for innovative, environmentally friendly approaches. Each year, over 40,000 soil improvement projects are carried out.

Soil improvement methods often include the use of man-made materials and/or mechanical energy, both of which need considerable energy for their manufacturing and/or installation. Epoxy, micro-fine cement, phenoplasts, acrylmide, polyurethane, and silicates are only some of the synthetic man-made compounds that are often injected into the pore spaces for binding solid particles. Methods such as chemical grouting, jetting, and permeation grouting are used to achieve this. All chemical grouts, with the exception of sodium silicate, are poisonous and/or harmful, bringing more public policy and opinion attention to these methods. Japan banned practically all chemical grouts in 1974 after five incidents of water poisoning were linked to acrylamide grout. In the United States, this had repercussions because of impending federal laws that would have required the removal of most items from shelves. It has recently been proposed to outlaw all synthetic man-made grouting materials in several nations.

In addition, existing grouting injection methods have poor "certainty of execution," or the capacity to provide the in-situ conditions called for by the engineering design. Although quality management during the process of construction is fundamental, tracking the pressure and volume of injection is normally all what is done instead of undertaking real-time measuring of the relevant transformations happening within the subsurface, irrespective of the fact that the grouting treatment approaches are only effectual up-to 1m to 2m from the point of injection. Uncertainty about the ultimate built state necessitates a cautious over-design, which drives up the price of the project and causes a greater amount of grout to be used than required.

The convergence of these elements calls for research into the development of novel, effective technologies for soil improvement and related, trustworthy monitoring strategies. There are now promising new avenues open for using biochemical mechanisms to mediate the enhancement of soil characteristics. Interdisciplinary studies at the intersection of fields like microbiology, geosciences, and civil engineering have made these possibilities possible. The topic is still in its infancy, therefore there will be decades of interesting study ahead if we are to put current concepts into reality and meet the demands of society.

Microbial accelerated carbonate deposition is a safe and inexpensive technology that harnesses native soil bacteria to speed up the cementation process on the spot. Sporosarcina pasteurii, a common alcaligenes soil bacterium, induces urea hydrolysis, which leads to the precipitation of calcite between soil particles. The findings demonstrate that soil shear strength, stiffness, and dilative tendencies have all increased as a consequence of microbially driven carbonate precipitation. Cone penetration tests and other in-situ methods may be able to determine whether or not huge areas of sand are improved by microbially induced carbonate precipitation. In addition to the loading settings (such as tri-axial pressure circumstances and unconstrained compression circumstances) studied in microbial driven bicarbonate precipitation experiments [14], soil elements may also be subjected to k0 stress circumstances when in situ methods are applied (e.g. located at the exact center of a massive foundation). Previous studies have examined traditional mechanically cemented sand under k0 circumstances.

VII. BIOMATERIALS AND SUSTAINABILITY

The Native American phrase, "We do not inherit the world from our ancestors; we borrow it from our offspring," captures the essence of sustainability. To ensure future generations may satisfy their own requirements without jeopardizing those of existing ones, sustainable infrastructure must be built. Progress in the chemical industry was a watershed moment in humankind's development. Our demands might be better met because of its help in optimizing synthetic procedures. On the other hand, it has poisoned the Earth to its very core. Using bio-based products, we can solve many of the issues plaguing our planet. During their lifetime, they are less harmful to the environment than their synthetic counterparts, producing less greenhouse gases and a far lower hazardous pollution load. Using biomaterials that can be recycled and maintained indefinitely is a major strategy for green sustainable building, as stated by Lee, Boubekri, and Park [15]. It places an emphasis on biomaterials and finishes that are derived from recycled or repurposed sources, such as food scraps or industrial offcuts [16]. Certain structural insulated panels are also made using bio-based materials.

The usage of wood and timber produced from certified forested areas where lumber extraction is accomplished using ecological techniques is also recommended as a sustainable approach. Synthetic waste disposal is an additional environmental issue. Our environment's current damaged state may be directly attributed to the widespread use of chemicals, which are very harmful. Biomaterials provide a workable answer because to their biodegradability. Hence, this decreases trash generation and, by extension, the disposal problem. For instance, there are two types of trash wood: clean trash wood and contaminated trash wood. Mulch made from clean trash may be utilized for gardening. It may also be used as a fuel for boilers and in a variety of manmade construction projects. The situation is different, however, with tainted wood. While lead paint may be found on wood salvaged from demolished buildings, it is often not acceptable for use in secondary construction. In addition, organic fertilizers and bio-methane for energy production may be produced from the decomposition of biomaterials.

One of the difficulties of the 21st century is finding ways to produce materials, chemicals, and fuels at industrial scale that are both cost-effective and ecologically friendly. Potential uses for bio-produced materials such as bio-degradable nanocomposites, and carbonaceous substances from natural resource are made obvious by a selection of bio nanomaterials schemes with an eye toward the future. The future of this field is on the production of controllable and well-defined nanostructures using inexpensive and alternate renewable antecedents (i.e., biomass and wastes). Relying on bio-degradable polymer synthetic approach or designated future use, it may be difficult to precisely regulate the characteristics of the synthetic biomaterials (such as precursor material complexity, the availability of contaminants, etc.).

Nitrogen and boron are two examples of heteroatoms that, when present, might boost an object's electrochemical performance. Electrodes in devices that store energy (battery packs, and fuel cells, among others) necessitate physical elements such as adaptability, transparency, conductivity, and tensile stability, all of which can be achieved through the creation of nano-materials or the occurrence of a different starting/substrate substance (e.g., graphitic carbon). Depending on their composition and porosity, these biomaterials may be used as CO_2 adsorbents or super-capacitor cells electrodes. In my opinion, the future of sustainable biomaterials for various applications hinges on a thorough understanding of the composition and structure of the starting materials (i.e., lignocellulosic fraction).

Another of potential interest is the investigation of whether or whether non-traditional, benign-by-design processes may achieve the same results as conventional approaches. Several of the conventional techniques were time-consuming and difficult to follow, and they often resulted in biomaterials that were morphologically, mechanically, or thermally unstable. Reproducibility, high porosity, controlled characteristics; stability, etc. are only some of the obstacles that must be overcome in order for biomaterials to be designed in a sustainable manner. However, the possibility of such benign by designing principles is well portrayed by the establishment of nano-materials and nano-composites from the polysaccharides e.g., exo-polysaccharides, starch, and alginic acides generated from natural resources, such as macro algae or tobacco. To meet the formidable problems of resource scarcity and energy needs for future generations, further research is now underway in this field, and future discoveries will be revealed in due time.

VIII. CONCLUSION

This article provides an introduction to the state-of-the-art biomaterials that may be used to build in a way that is both environmentally friendly and long-lasting. Among these components are asphalts, soils, admixtures, polymers, and concrete. When it comes to biomaterials, natural evolution is the only way to ensure that certain qualities are present that would otherwise be impossible. Growing interest in finding sustainable alternatives to traditional nonrenewable synthetic fibers like glass and carbon reinforced composites has prompted research into the design of biobased composite nano-materials for a variety of end-user applications. However, biocomposite materials are not without their own set of issues; they are not a perfect replacement due to their reduced thermal ignitability, stability, reduced electrical properties, and difficulty in extractions, machining, manufacturing, surface functionalization, production, categorisation, and so on. Many studies have been conducted recently to discourse the difficulties connected with long-term dependability, resilience, serviceability, and ecological manufacturing (based on the application of the circular economic strategy for bio-composites). To that end, this article provides a critical overview of current efforts associated with various elements of biocomposites.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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Ethics Approval and Consent to Participate

The research has consent for Ethical Approval and Consent to participate.

Competing Interests

There are no competing interests.

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