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How Composite Materials Influence Sustainable Development

A. N. Emin[1]

Abstract: Sustainable development has become the most widely accepted concept. Sustainable development refers to the ability of society to develop economically and socially, meeting the requirements of current generations without compromising or risking the chances of future generations. In a broader sense, sustainable development refers to safeguarding the Earth's ability to support life in all its diversity. Especially in the last decade, it has become clear, in the light of climate change, that a more careful use of resources is needed and that all types of emissions must be minimized to reduce the impact of human development and to achieve the sustainable growth. A composite material is an ensemble of distinct materials, which has characteristics that the constituent materials do not have in part. The need to develop new materials and unconventional technologies was determined not only by economic and social reasons, but also by the fact that in the conditions of exponential development of production, there was a very strong crisis of sources of raw materials and energy, with increasing human aggression against the environment. The properties composites offer enable manufacturers to build sustainable attributes into projects or products that may increase energy efficiency, durability and the use of materials that lower environmental impact. The increasing demand for renewable energy, fuel-conserving transportation and greener buildings open a world of opportunity in the composites industry.

Keywords: composites; composites area of use; composites advantages; composites disadvantages; sustainable development

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1. Introduction

Composite materials have been present in the universe since ancient times, even if their existence was not realized then. Nature provides many examples of such materials. Natural composites exist in both animals and plants. Wood, for example, is made of long cellulose fibers (which is a polymer) that are held together by a much weaker substance called lignin. Cellulose is present in cotton, but if it were not for the lignin to bind it, it would be a much weaker structure. The two substances with low resistance - lignin and cellulose - together form a much stronger substance. Bones in the human body are also examples of composite materials. They are made of a hard but brittle material called hydroxyapatite (which is mainly calcium phosphate) and a soft, flexible material called collagen (which is a protein). On their own these components would not be useful in the skeleton, but the combination gives the bone the necessary properties to support the body.

[1] Doctoral School of Mathematics, Ovidius University of Constanta, Romania, Corresponding author: anamaria.leonte@365.univ-ovidius.ro.

The oldest composite materials used by man were straw and mud used in the form of building bricks. At the British Museum in London, a storage vessel from the Merovingian period, 900 BC, on the territory of Scotland, is made of a material made of fiberglass reinforced with a resin, which today would correspond to a composite. Natural composite materials (wood and bone) have been used by man since ancient times. Composite materials have been used to increase the performance of weapons. The Mongol bow consists of two distinct parts: the bone part, subjected to compression, and the wooden part, subjected to traction, the two parts being connected to each other by ox tendons. Damascus swords have a blade made of two materials: one part made of steel and one made of soft iron. The steel part strongly deformed and layered, with the orientation of the cuts and impurities according to the deformation direction, is cut in U, and the soft iron is introduced inside, thus making a material that resists very well to bending and shock. In the 19th century rods of ferrous material were used for masonry, thus laying the foundations of reinforced construction materials. The first fiberglass boat was made in 1942 and also at that time, this material was used in aeronautics but also for electrical components.

The concept of composite material (matrix + reinforcement) appeared in the early 1950's, with synthetic laminated materials. Fibrous composite materials were first used in relatively small quantities in the field of military aviation in the 1960’s and after 1970 began to be used in civil aviation. As early as 1980, composite materials were used by commercial aircraft manufacturers for a variety of aircraft elements such as wings, drifts and stabilizers. However, it was only in the last generations of aircraft that composite materials began to be used in the main structure. The Airbus A380 has wings made entirely of composite materials, which helps it save 17% more fuel than any other aircraft in the same category.

The need to develop new materials and unconventional technologies was determined not only by economic and social reasons, but also by the fact that in the conditions of exponential development of production, there was a very strong crisis of sources of raw materials and energy, with increasing human aggression against the environment. The evolution of the technology in the field of civil engineering has been and it still is possible at the same time with the emergence of new materials and technologies, with the promotion of superior structural systems and the ability to use complex methods of analysis and analytical calculation. Composite materials incorporate all the qualities mentioned above; they represent the future in the field of civil engineering. The concept of composite material allows the new one to be strictly directed towards the expected results, as well as the creation of materials with certain imposed properties, so that the technical parameters of an element are satisfied by the qualities of a special material created for it.

Nowadays, composite materials tend to increasingly replace classical materials in a wide variety of fields, from household items to components for spacecraft or nuclear power plants.

Sustainability is becoming an ever more compelling argument in the materials selection process. Fibre reinforced polymer composites are strong, lightweight and durable materials which are seeing increasing adoption in the transportation, construction, renewable energy and many other markets. Sustainability in their use phase is often a key driver for the selection of composites over traditional materials. Composite structures deliver a long service life combined with low maintenance requirements, and lightweight composites result in lower energy consumption throughout a product's life. But this is only part of the picture. To fully exploit the sustainability benefits of composite parts it is essential to consider the whole life cycle.

This paper is a presentation of the role of composite materials in sustainable development, including the classification of composites, the advantages, the areas in which they are used, the disadvantages and, obviously, the role of composites in sustainable development.

2. Composite Materials

2.1. Classification of Composite Materials

There are several variants of defining composites. The most comprehensive, best characterizing their nature is that given by P. Mallick. According to Mallick, “a composite material is a combination of two or more chemically different materials with an interface between them. The constituent materials maintain their separate identity (at least at the macroscopic level) in the composite, however their combination generates properties and characteristics different from those of the component materials in part. One of the materials is called a matrix and is defined as forming a continuous phase. The other main element is called reinforcement and is added to the matrix to improve or modify its properties. Reinforcement is the discontinuous phase, evenly distributed over the entire volume of the matrix.” Fibers are the element that give the assembly the characteristics of resistance to stress. Compared to the matrix, the effort that can be taken over is clearly superior, while the corresponding elongation is reduced. The matrix has a much higher elongation and breaking resilience, which ensures that the fibers break before the matrix gives way. However, it should be emphasized that the composite material is a unitary assembly, in which the two phases act together, as suggested by the stress-elongation curve for composite.

Broadly defined, a composite material is a set of distinct materials, which has characteristics that the constituent materials do not have in part.

Taken as a whole, the main categories of fiber-reinforced composites are the following:

1. Polymer matrix composites - usually thermosetting resins (epoxy, polyimide or polyester) or thermoplastics, reinforced with glass, carbon, boron or aramid (Kevlar) fibers, ceramic single crystals or, more recently, metal fibers. They are mainly used in applications involving relatively low working temperatures (reaching, exceptionally, for thermoplastics manufactured by injection, at a maximum level of 400 ° C).

2. Metal matrix composites - most often based on aluminum, magnesium, titanium or copper alloys, in which boron, carbon (graphite) or ceramic fibers (usually alumina or silicon carbide) are introduced. The working temperature (usually not more than 800 ° C) of such a composite is limited by the level of the softening or melting point which characterizes the matrix material. If the intended application involves high temperatures, then the use of nickel-based alloys or superalloys is recommended as a matrix. Their disadvantage is that they have high specific weights, leading to an increase in the mass of the final structure.

3. Composites with ceramic matrix - have been developed especially for applications with very high working temperatures (above 1000 ° C); the most used basic materials are silicon carbide (SiC), alumina (Al2O3) and glass, and the usual reinforcing fibers are also ceramic (usually in the form of very short staple fibers).

4. "Carbon-carbon" composites - with carbon or graphite matrix and reinforcement with fibers or graphite fiber fabrics; they are very expensive, but also incomparable with other materials due to their resistance to high temperatures (up to 3000 ° C), coupled with the low density and low coefficient of thermal expansion. The most common fiber-reinforced composites are carbon fiber, fiberglass and Kevlar.

Other classification criteria concern the state of aggregation of the matrix and the dispersed material, the configuration geometry of the complementary material, the mode of distribution of the complementary material, the way of making the contact surface or the size of the material complementary. Given the great diversity of materials it is obvious that there are many criteria for their classification and those mentioned above were just some of them.

2.2. Advantages of using composite materials

From a technical point of view, the notion of composite materials refers to materials that possess the following properties:

- are created artificially, by combining different components;
- represents a combination of at least two chemically distinct materials, between which there is a distinct separation surface;
- has properties that no component taken separately can have.

Composites offer many advantages:

- ❖ High strength and rigidity;
- ❖ Low weight;
- ❖ Energy saving during the production process;
- ❖ Increased durability, fatigue resistance and longer life;
- ❖ Impact resistance;
- ❖ Increased dimensional stability;
- ❖ Anisotropic properties;
- ❖ Good chemical properties, corrosion resistance;
- ❖ Fire resistant;
- ❖ High operating temperature;
- ❖ Extreme resistance in outdoor environments;
- ❖ Low maintenance requirements;
- ❖ Low thermal conductivity;
- ❖ Low thermal expansion or adapted to requirements;
- ❖ Adapted energy conductivity (for example, can be used to amplify or absorb vibrations);

- Transparency adapted to radio frequencies (transparency, reflection or absorption);
- Adapted electrical characteristics (insulation or conductivity);
- Adapted electromagnetic transparency;
- Custom features make composite products irreplaceable in telecommunications and stealth technologies;
- Flexibility of custom design and freedom of choice of shapes;
- Possibility to combine several materials and inserts;
- Relatively low energy consumption for the production of raw materials.

2.3. Main Areas of Use

The major market segments of composites are presented below. However, there are many other very important applications and new products that are released every year.

- Boats

Composites have opened a major gap in the traditional shipbuilding industry, offering features of high strength, safety, light weight, durability, reliability, corrosion resistance and low maintenance costs. The use of composites has expanded into the construction of hulls and ships, ribs, decks, deck superstructures, hatch covers, shafts, arms and countless other components.

- Cars

Composites offer the ideal alternative for replacing metal structures in car construction, by improving structural performance, safety, durability and machining processes. The use of composites offers high performance, lower costs, lower weight and compliance with environmental and safety regulations. They are widely used in the production of structural elements, body panels and many other components. The degree of their use depends on the options regarding the quality and price of the vehicle. In the automotive industry, Formula 1 cars are the most eloquent example of application, being made almost exclusively of composite materials.

- Heavy duty vehicles

Composite materials are widely used in the construction of heavy trucks, truck trailers, buses, trains and railcars. Some of the key features of composite materials in this market are: low weight, high strength, corrosion resistance and design flexibility. The benefits in turn include: fuel efficiency, dimensional stability, greater cargo/passenger capacity, corrosion resistance, lower maintenance costs and design flexibility. Composites are used in the manufacture of boxes, bodies and large panels for trailers/walls, floors, ceilings and interior elements in the railway field.

- Buildings/constructions

The structures made of certain composite materials have an excellent seismic resistance. The use of composite materials decreases inertia ("dead load") and weight, absorbs shock and vibration generated by earthquakes and other mechanical sources. Composites are widely used to build, restore and strengthen old structures that need to be rehabilitated, or to repair damage caused by seismic activity.

Other applications include domes, bridges, tunnels, poles, acrylic bathtubs and sinks, various types of composite panels, imitation natural stone, corrosion protection and water-repellent coating.

- Sports and recreation

Composite products are found in all outdoor sports, competitions and recreational activities, as they are compact, lightweight, impact resistant and aerodynamic. Traditional materials such as titanium, aluminum and steel are already obsolete and replaced with composite materials. Applications include surfboards, skis, kayaks, golf clubs, fishing rods, tennis rackets, hockey sticks, protective gear and bicycle frames.

- Wind power

In an effort to capture wind power and further reduce energy costs, wind turbine towers have become larger, as have rotor blades. Today's rotors are made exclusively of composites and incorporate some of the most advanced materials in order to withstand the severe stresses caused by gusts of wind.

- Corrosion resistant elements

Composite materials are ideal for meeting the demands of highly corrosive work environments. Among other things, they are used in the production of pipelines, tanks, bridges, power plants, electronic equipment, where there are harsh requirements for protection against highly corrosive chemicals, combined with exposure to heat, humidity and sunlight.

- Aeronautics and military applications

Aeronautical, space and military applications are the main uses of composite materials. A wide variety of cutting-edge products are used for the advantages conferred in extreme field-specific conditions. In general, the limits of the use of top composite materials are explored by those industries that have very large budgets for research and development.

2.4. Disadvantages of Composite Materials

Composite materials have the following disadvantages:

• high cost for certain material processing;

• relatively immature manufacturing technology;

• limited operating experience;

• thermosetting composites cannot be easily reconverted into the raw material from which they were generated;

• most composites do not have ductility, they have a linear behavior until breaking;

• manufacturing methods become complex for fiber-reinforced systems (except pouring);

• in case of incineration of composite materials, their inorganic components cannot be reused, which is why incineration cannot be considered recycling; furthermore, the heat generated from incineration cannot be used for the purpose of reducing the amount of fuel needed;

• the recycling of plastics from composite materials is achieved in a relatively small percentage;

• fibers present in composite materials, generally cannot be recycled;

• the composite materials' flammability. Thus the organic components present in their structure burn, being combustible and the smoke from burning is toxic.

• although post-consumer products made of polymers pure is suitable for reprocessing, the situation is completely different in the case of composites having polymers in their structure;

• fibers absorb moisture, so Kevlar-reinforced composites are more sensitive than glass or carbon composites;

• due to the high resistance to cutting Kevlar-reinforced composites, special tools are required for cutting dry fabric and special drills for drilling hardened laminates.

3. Sustainable Development

Sustainable development can be defined as the practice of maintaining the productivity by replacing resources used with resources of equal or greater value without degrading or endangering natural biotic systems. Sustainable development binds together concern for the carrying capacity of natural systems with the social, political and economic challenges faced by humanity. Sustainability science is the study of the concepts of sustainable development and environmental science. There is an emphasis on the present generations' responsibility to regenerate, maintain and improve planetary resources for use by future generations.

Sustainable development is an organizing principle for meeting human development goals while simultaneously sustaining the ability of natural systems to provide the natural resources and ecosystem services on which the economy and society depend on. The desired result is a state of society where living conditions and resources are used to continue to meet human needs without undermining the integrity and stability of the natural system. Sustainability requires balance and consideration of economic, human and environmental factors in order to meet our needs today without compromising the resources available for future generations.

Six interdependent capacities are deemed to be necessary for the successful pursuit of sustainable development. These are the capacities to measure progress toward sustainable development: promote equity within and between generations; adapt to shocks and surprises; transform the system onto more sustainable development pathways; link knowledge with action for sustainability; devise governance arrangements that allow people to work together in exercising the other capacities.

4. Conclusions

At the European Composites Industry Association (EuCIA) seminar Lightweight, Durable and Sustainable Composites, Ben Drogt, consultant – composites, innovation & sustainability, at BiinC, emphasised this point. "Sustainability is about the complete life cycle of the product," he asserts. "The life cycle of a composite part has three phases: making the part, using the part, and end of use. And I use the 'term end of use' rather than 'end of life' since because of the durability of composite materials, very often the end of use of the part is not the end of life".

Composite materials through their importance contribute to the compliance and implementation of the principles of sustainable development.

For example, composites' light weight, high strength, cost and design flexibility provides a logical choice for longer wind turbine blades which produce more kilowatts (kW) per turbine. In environments where there is exposure to chemicals or saltwater, the corrosion resistance of composite materials prolongs the life of the end-use product and reduces risk of failure. Composite parts have superior strength to weight versus steel, and the energy used to manufacture steel or aluminium parts, even with recycling, can exceed the amount used to produce the same part with composite materials.

The properties composites offer enable manufacturers to build sustainable attributes into projects or products that may increase energy efficiency, durability and the use of materials that lower environmental impact. The increasing demand for renewable energy, fuel-conserving transportation and greener buildings open a world of opportunity in the composites industry.

The method used to assess or compare the environmental impact of the materials used to produce a particular component is a life cycle assessment, or LCA. The LCA measures environmental impacts for a number of different attributes rather than comparing a single attribute like recycled contents. A life cycle assessment considers the raw material production, product manufacturing, distribution, use phase, disposal phase and the impact of transportation. This begins with harvesting and extracting materials to make the product until its ultimate disposal.

Some of the common categories one should consider in a comprehensive LCA include:

- energy consumed, both renewable and non-renewable;
- global warming, greenhouse gases;
- acidification, soil and water;
- smog production;
- ozone depletion;
- excess nutrients to water bodies;
- eco- and human toxicology; and
- depletion of minerals and fossil fuels.

When assessing the impact of a product, its entire life cycle must be considered (ie. from its creation, starting from the choice of the material and the execution technology, until the moment when we get rid of it but it reaches the environment surrounding and it will affect it more or less).

It is necessary to design friendly and for recycling all products, but especially the packaging, that forms a large part of the post-consumer waste.

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