Green engineering

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Key Concepts

- Green engineering practices provide environmental and economic benefits by reducing energy use, reducing waste, and maximizing the life spans of structures and products.
- Green engineering uses renewable and biodegradable materials (green materials) for products and infrastructure and promotes the reuse of these materials.
- In green manufacturing, products are designed for disassembly so components may be recycled or reused.

The technological approach to transform existing engineering disciplines and practices to those that promote sustainability of manufacturing processes, buildings, and infrastructure. The goal of sustainability in engineering is to develop and implement technologically and economically viable products, processes, and systems that meet the needs of humanity while protecting the environment (**Fig. 1**).

The following principles govern green engineering:

1. Use the least amount of energy to achieve any given task.
2. Generate as much energy as possible using renewable resources.
3. Generate the least amount of pollutants and by-products during energy generation.
4. Use renewable and biodegradable materials to a maximum extent for building structures and fabricating products.
5. Reduce waste during construction and fabrication.
6. Design structures and products to maximize their life spans and minimize maintenance.
7. Design for easy deconstruction and facilitate the reuse of components and materials from obsolete structures and products in new construction and fabrication.
8. Make the least impact on the environment.

Fig. 1 **Green roofs, also known as vegetated roofs or living roofs, at the U.S. Coast Guard Headquarters, Washington, DC. Engineered green roofs reduce stormwater runoff, reduce energy use through cooling effects, and provide urban habitats for plants, insects, and birds. Green roofs are also aesthetically pleasing and are expected to last about twice as long as conventional roofs. (Credit: U.S. General Services Administration)**

Engineers can readily apply green principles to the built environment. This term refers to surroundings—such as parks and buildings—that are human-made. The built environment uses the majority of the world's nonrenewable resources and much of its renewable material resources, and contributes significantly to pollution, habitat destruction, and other forms of environmental damage. As the developing world's economies continue to grow, resources are depleted even faster and exhausted sooner. Green engineering dictates that buildings and other built systems be compact, minimally intrusive of the natural environment, resilient, economical, and easily recyclable, and minimize the use of nonrenewable materials and nonrenewable energy. *See also:* ARCHITECTURAL ENGINEERING; BUILDINGS; CIVIL ENGINEERING; RESILIENT BUILDING DESIGN.

On the larger scale of civil-built infrastructure, green engineers are improving systems for integrated water use, such as the reuse of graywater—household water that has been used but does not contain feces—in irrigation and in heating and cooling systems. Best practices are being defined for graywater reuse, including storage and discharge. *See also:* WATER SUPPLY ENGINEERING; WASTEWATER REUSE.

Green materials

Concrete is a ubiquitous material in cities, covering sidewalks, bridges, viaducts, and more. Most forms of concrete seal the soil, making this material impenetrable by rainwater and preventing aeration of tree roots. Pervious concrete is an alternative green paving material. Many engineers consider pervious concrete to be a "best management" practice for capturing stormwater runoff and controlling non-point-source pollution. *See also:* CONCRETE; WATER POLLUTION.

An alternative to concrete is recycled tires. Sidewalk tiles made of rubber provide a surface that is more durable than traditional concrete sidewalks, because the ability of the rubber to flex prevents cracks caused by root growth. Compared to concrete, rubberized sidewalks also provide a softer surface for running and walking. *See also:* RUBBER; TIRE.

Reuse of old tires supports an important principle of sustainable construction: the use of renewable structural material. Bio-based materials are another example. These are industrial products—except food or feed—made from renewable agricultural and forestry feedstocks, such as wood, wood wastes and residues, grasses, crops, and crop by-products. Such eco-friendly biomaterials are easily recyclable, and biodegradability is easily triggered. Applications include natural fiber–reinforced composites, which could replace artificial fibers such as carbon and glass in various applications in the automotive industry. *See also:* BIODEGRADATION; POLYMER COMPOSITES; POLYMERS FROM RENEWABLE RESOURCES; RECYCLING TECHNOLOGY; RENEWABLE RESOURCES.

Timber is a truly renewable structural material, but major concerns with using timber revolve around fire resistance, low stiffness and strength, creep, and durability. Again, high-strength composite materials can overcome most of these deficiencies. For example, carbon fibers and inorganic polymers can effectively improve mechanical properties and fire resistance. **Figure 2** shows balsa wood with a coating of a polymer composite after fire exposure. *See also:* FOREST TIMBER RESOURCES.

Green manufacturing processes

Manufacturing and assembly processes are active areas of green engineering. The chemical process industry is developing methods for creating products necessary for daily life that do not cause collateral damage to the environment or society. For example, researchers are developing a green catalytic process for the treatment of industrial effluent. *See also:* INDUSTRIAL WASTEWATER TREATMENT.

Another example of green manufacturing is the disassembly of electronic components for reuse. For example, hot air can be used to melt solders and separate the components and base boards in waste printed circuit boards, providing a green method for both electronic component recovery and industrial exhaust heat reuse. *See also:* PRINTED CIRCUIT BOARD.

The concept of green manufacturing is influencing corporations and business leaders, many of whom seek greater corporate social responsibility. One driving force has been the development of systems analysis, the application of mathematical methods to the study of complex human physical systems. Systems analysis has evolved into the growing field of industrial ecology. *See also:* INDUSTRIAL ECOLOGY; SYSTEMS ANALYSIS.

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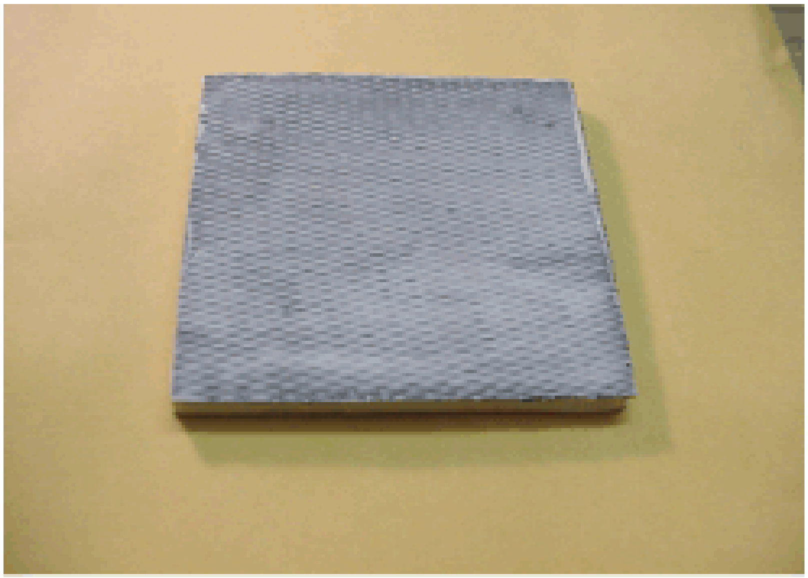
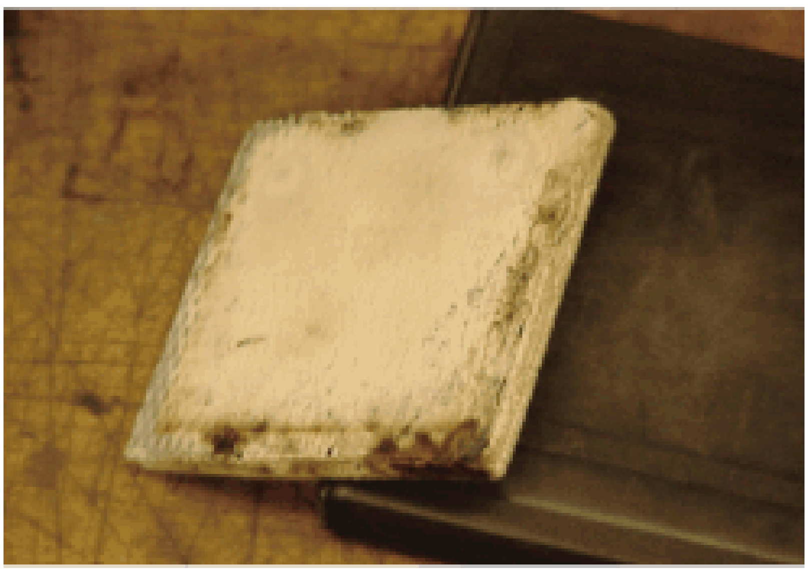


(a)



(b)

Fig. 2 Balsa wood with an inorganic polymer coating (a) before and (b) after high-temperature exposure.

Keywords

green engineering; green principles; green materials; green manufacturing

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