

SOME ASPECTS CONCERNING MATERIALS AND THEIR IMPORTANCE IN THE ECO-DESIGN CONCEPT

AXINTE C.¹, CRISTEA I.², KOLIOPOULOS T. C.³

¹University of Bacau

²Technological Educational Institute of Athens

Abstract: In this paper certain properties of some common materials are presented. The aim is to show typical issues of these materials for a general understanding of what should be kept in mind when using them and setting targets for manufacturing environmental friendly products.

Keywords: eco-design, materials sources and applications

1. INTRODUCTION

All around the world, the assurance of raw materials requirement represents one of the conditions of economical development. Numerous natural resources are used for manufacturing of products and in the case of many products large amount of resources are used even during the usage phase. The increasing world population requires ever greater use of material and energy. The issue is further compounded by the fact that standard of living of most people is improving, which translates into a greater per capita use of materials and energy and also a greater rate of waste generation. However, use of raw materials is an irreversible process – once they have been used, they have gone. Accordingly, to minimize the consumption of resources as well as discharge of resources as waste it is essential to promote a design that facilitates resource saving, reuse and recycling and this are materialized by **ECO-DESIGN**.

Eco-design is the design of products with respect to their ecological effects. It considers the contribution of the product to environmental impact through all of its life cycle stages. The five life cycle stages of a product are shown in fig.1.

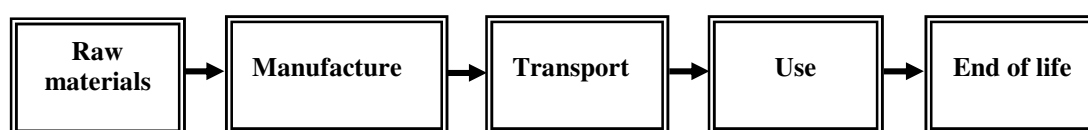


Fig. 1 The life cycle stages of a product

By applying Eco-design, resources are intelligently used and therefore benefit for all involved actors along the value creation chain is increased and, at the same time, environmental impacts are reduced. This should be achieved under social fair conditions.

To be able to produce any kind of products different materials are needed. By holding two products in our hands sometimes we think the heavier product is the better one. How comes that? Is it because we think the heavier product contains somehow 'better' materials by using for example metals instead of plastics? Is it because we think the product might have a longer lifetime then? Is it because plastics are considered as 'cheap' or somehow 'weak'?

Environmental considerations must start from the point where for example iron ore is extracted to produce steel or crude oil is extracted to produce plastics. Raw materials are processed to materials which can be used in products. If we want to go more into detail we should also take all energies needed for the extraction and the further processes of the raw materials into account. By going a level deeper into detail we should also consider for example the land transformation which occurs by extracting raw materials [1]. In this paper certain properties of some common materials are presented. The aim is to show typical issues of these materials for a general understanding of what should be kept in mind when using them and setting targets for manufacturing environmental friendly products.

2. RAW MATERIAS SOURCES

Materials can be classified depending upon their chemical composition, microstructure and properties into three main categories, respective: *metals* and *metals alloys*, *ceramic materials* and *organic polymers*. These three types of materials can be found in numerous combinations as *composite materials*, which combine in a synergetic manner the specific properties of their components.

2.1 Metals and alloys

Metals and alloys are obtained by processing the mineral ores extracted from the Earth's crust. Ore deposits are of many different types and occur in all geological environments but their economic viability depends on many factors as: grade (the amount of metals per ton of rock), size of the deposit (tonnage), easy access to infrastructure, current price for the commodity, etc. Searching for more ore deposits to meet the increasing demand has become more difficult with time and more complex techniques have been developed to locate them as easily accessible ore deposits close to the Earth's surface have already been exploited by humans in the past.

Ferrous metals and alloys are iron-based materials that are used in a wide variety of industrial applications. They may have small amounts of other metals or other elements added, to give the required properties. From this category, **iron** is the second most abundant metal on Earth (5% of the Earth's crust) and is believed to be the tenth most abundant element in the universe. Astrophysical and seismic evidence indicate that iron is even more abundant in the interior of the Earth and has apparently combined with nickel to make up the bulk of the planet's core. Iron ore is primarily found as the oxides, notably hematite and magnetite and hydroxides as goethite and limonite. Small amounts are found as the carbonate siderite, the sulfides as pyrites and silicates as chamosite and greenalite. It is estimated that worldwide there are 800 billion tons of iron ore resources, containing more than 230 billion tons of iron. 96% of this amount is produced by only 15 countries, the largest iron ore producing nations being Ukraine, Russia, China, Australia, Brazil, Kazakhstan, USA, India, etc. [2]

The largest use of iron ores is to make *steel*. Due to their physic-mechanical, chemical and technological properties steels have a large applicability in many industries, being one of the most useful materials ever created. Recent developments in ferrous metallurgy have produced a growing range of microalloyed steels, also termed "HSLA" or "high-strength low alloy" steels, containing tiny additions to produce high strengths and often spectacular toughness at minimal cost. In figure 2 some statistics concerning the extraction of iron ores and production of steel in Romania are presented.

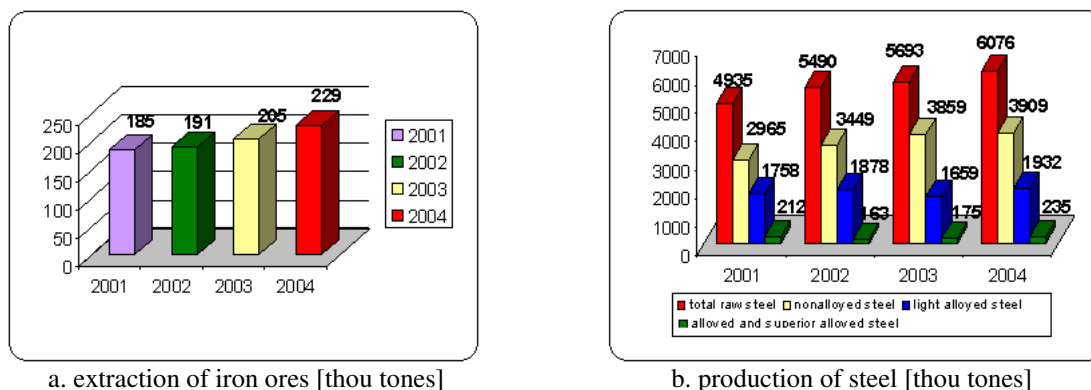


Fig. 2 Extraction and processing of iron ores [3]

Nonferrous metals and alloys

Aluminium is the most abundant metallic element, and the third most abundant of all elements in the Earth's crust, making up 8% of the crust by weight. Because aluminium metal reacts with water and air to form powdery oxides and hydroxides, aluminium metal is rarely found in nature in its elemental form. It has been found in volcanic mud and as tiny grains in highly unusual environments along with other elemental metals.

Many common minerals, including feldspars, contain aluminium, but extracting the metal from most minerals is very energy-intensive, and therefore expensive.

The main ore of aluminium is *bauxite*, the source of over 99% of metallic aluminium. About 85% of all the bauxite mined worldwide is used to produce alumina for refining into aluminium metal. Another 10% produces alumina which is used in chemical, abrasive, and refractory products. The remaining 5% of bauxite is used to make abrasives, refractory materials, and aluminium compounds. [4]

The primary aluminium production process is energy-intensive, but the industry has a long tradition of self-improvement regarding energy consumption and its environmental performance. For example, average energy consumption and subsequent emissions per tonne of production have fallen by 70% over the past hundred years. However, more than 55% of the world's primary aluminium is produced using hydro-electric power which is clean, non-polluting and renewable [5]. The largest producers of aluminium metal are Russia, China, the United States, and Canada, countries which have abundant hydroelectric power. More than 40 other countries also produce aluminium, including Norway, Iceland, Switzerland, Tajikistan, and New Zealand, which are small but mountainous, and have many rivers to provide hydroelectric power. Other areas of the world with access to abundant and cheap electricity, such as the Middle East, are also expanding their metal production capacities [4]. In fig. 3 some statistics concerning the production of alumina, aluminium and aluminium alloys in Romania are presented.

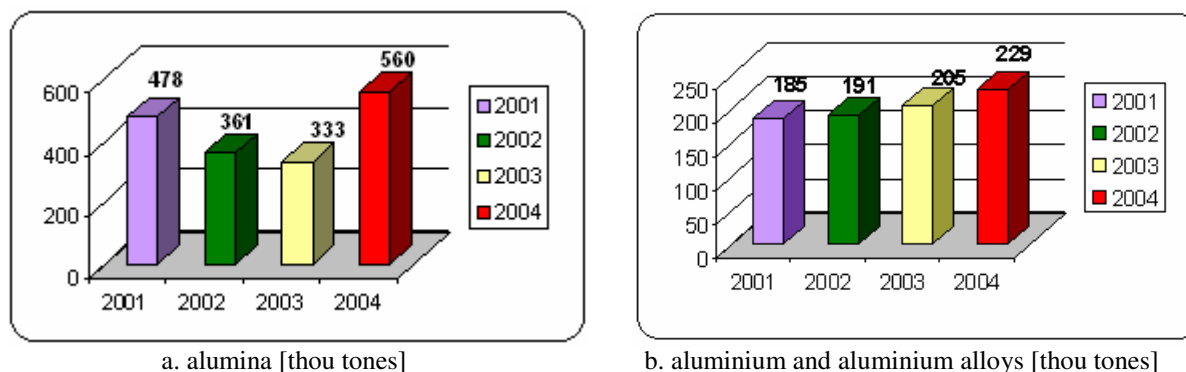


Fig. 3 Production of alumina respective aluminium and aluminium alloys [3]

Copper ore may be found in large deposits, relatively close to the surface. As a mineral, natural copper is relatively rare. Most copper in nature easily combines with a number of other elements and ions to form a wide variety of copper minerals and ores.

The high electrical conductivity of copper (overpassed only by the silver) determines that over 50% of the copper world production be used in electrotechnical field. Opposite, due to the bad workability, copper is not advantageous in mechanical structures.

The alloys of copper with tin (bronzes) and zinc (brasses) are widely used in industry (commercial tubing, electrical contacts, automotive and machine parts, decorative hardware). Brasses are one of the most used copper alloys. They are mixed in various quantities but one popular form contains 60% copper and 40% zinc. In fig. 4 some statistics concerning the production of copper in Romania are presented.

2.2 Ceramics and glasses

Ceramic materials are nonmetallic, inorganic compounds—primarily compounds of oxygen, but also compounds of carbon, nitrogen, boron, and silicon. Ceramics possess chemical, mechanical, physical, thermal, electrical, and magnetic properties that distinguish them from other materials, such as metals and plastics. Manufacturers customize the properties of ceramics by controlling the type and amount of the materials used to make them [6]. Industrial ceramics are produced from powders that have been tightly squeezed and then heated to high temperatures. Traditional ceramics, such as porcelain, tiles, and pottery, are formed from powders made from minerals such as clay, talc, silica, and feldspar. Most industrial ceramics, however, are formed from highly pure powders of specialty chemicals such as silicon carbide, alumina, and barium titanate. Ceramics are valued for their mechanical properties, including strength, durability, and hardness. Their electrical and magnetic properties make them valuable in electronic applications, where they are used as insulators, semiconductors, conductors, and magnets. Ceramics also have important uses in the aerospace, biomedical, construction, and nuclear industries.[6]

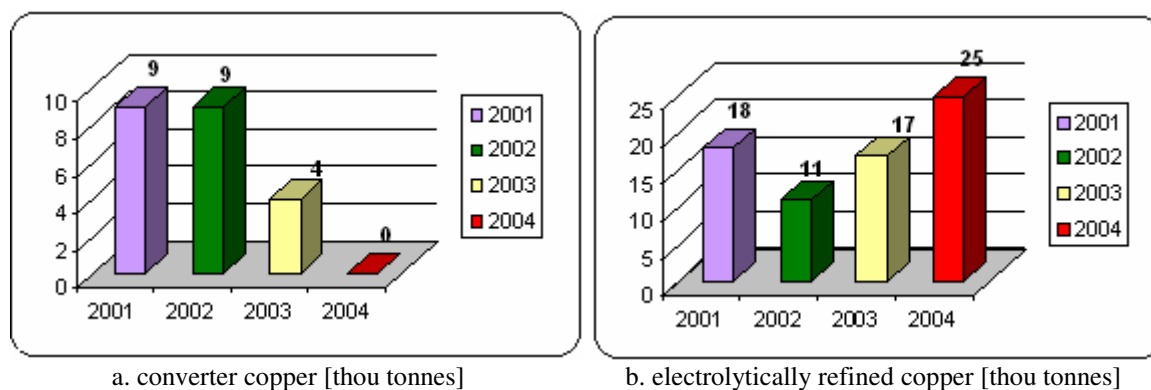


Fig. 4 Production of copper [3]

Glass is a uniform amorphous solid material. The basic ingredient of glass composition is silica (SiO_2). Common glass contains about 70-72 weight % of silicon dioxide. The major raw material is sand (or quartz sand) that contains almost 100% of crystalline silica in the form of quartz. There are other forms of silica which are either non-crystalline, or of a different crystalline form than quartz. These other forms include opal, chalcedony, flint and chert (non-crystalline), and cristobalite, tridymite, coesite, and stichovite (polymorphs of quartz, meaning that they have the same chemical composition (silica), but different crystalline forms).[4]

Examples of glasses range from the soda-lime silicate glass in soda bottles to the extremely high purity silica glass in optical fibers. Glass is sometimes created naturally from volcanic magma. This glass is called obsidian. In fig. 5 some statistics concerning the production of ceramic and glass products in Romania are presented.

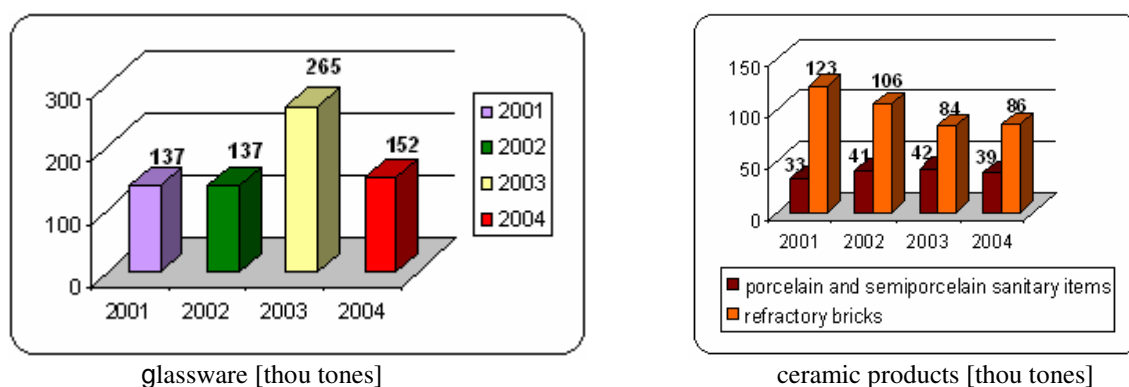


Fig. 5 Production of some glass and ceramics [3]

2.3 Plastics

Plastics are materials made up of large, organic molecules that can be formed into a variety of products. Plastics are moldable, synthetic materials derived mostly from fossil fuels, such as oil, coal, or natural gas. Plastics can be made hard as stone, strong as steel, transparent as glass, light as wood, and elastic as rubber. Plastics are also lightweight, waterproof, chemical resistant, and produced in almost any color. More than 50 families of plastics have been produced, and new types are currently under development. [7]

All plastics, whether made by addition or condensation polymerization, can be divided into two groups: thermoplastics and thermosetting plastics. These terms refer to the different ways these types of plastics respond to heat. Thermoplastics can be repeatedly softened by heating and hardened by cooling. Thermosetting plastics, on the other hand, harden permanently after being heated once; therefore these plastics can be made into durable and heat-resistant materials.

The most commonly manufactured thermoplastics are the following: Polyethylene (PE), Polyvinyl Chloride (PVC), Polypropylene, Polystyrene, Polyethylene Terephthalate (PET), Acrylonitrile Butadiene Styrene (ABS), Polymethyl Methacrylate (PMMA), Polyamide (PA), etc.

The most commonly manufactured thermosetting plastics are the following: Polyurethane, Phenols, Melamine-Formaldehyde and Urea-Formaldehyde, Unsaturated Polyesters, Epoxides (EP), etc. Plastics have a widely applicability. They are used extensively by many industries, including the automobile, aerospace, construction, packaging, electrical, health industries, etc. Therefore, plastics can be used in applications ranging from contact lenses to jet body components. In fig. 6 some statistics concerning the production of certain plastics in Romania are presented.

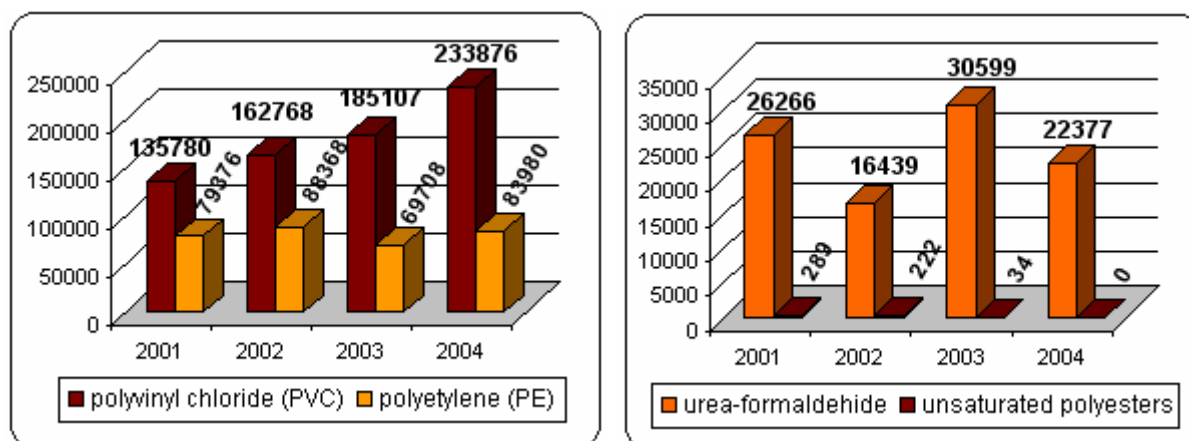


Fig. 6 Production of certain plastics in Romania [tonnes] [3]

2.4 Composites

Composite materials are formed by combining two or more materials that have quite different properties. The different materials work together to give the composite unique properties, but within the composite they do not dissolve or blend into each other. [8]

Most composites are made up of just two materials. One material (the *matrix* or *binder*) surrounds and binds together a cluster of fibres or fragments of a much stronger material (the *reinforcement*). For the matrix, many modern composites use thermosetting plastics (also called resins). The plastics are polymers because they are lightweight, inexpensive, and are easy to process and mould. Due to the use of plastics in the matrix, composites are commonly named "reinforced plastics". The matrix is sometimes a metal. Aluminum is common because it is lighter than most other metals. The glass fibres are the most common used reinforcement. The advanced composites use fine fibres of pure carbon that are much stronger than glass fibres but also more expensive to produce. Polymers are not only used for the matrix, they also make a good reinforcement material in composites (Kevlar for instance – a very strong polymer used in composites products that require lightweight and reliable

construction). By carefully choosing the reinforcement, the matrix, and the manufacturing process that brings them together, the composites properties can be tailored to meet the specific requirements for a particular purpose. The greatest advantage of composite materials is strength and stiffness combined with lightness. The composites also stand up well to heat and corrosion which makes them ideal for use in products that are exposed to extreme environments. Another advantage of composite materials is that they provide design flexibility - they can be moulded into complex shapes. The dark side of composites is usually the cost.

Some examples of composites materials include the automobile tires (carbon black particles in a matrix of polyisobutylene elastomeric polymer), concrete (cement and aggregate), fibreglass (fibres of glass in a matrix of plastic), mud bricks (mud and straw) etc. Composites exist also in nature. Wood is a natural composite and one of the most common materials used in the construction industry. In fig. 7 some statistics concerning the production of certain composites in Romania are presented.

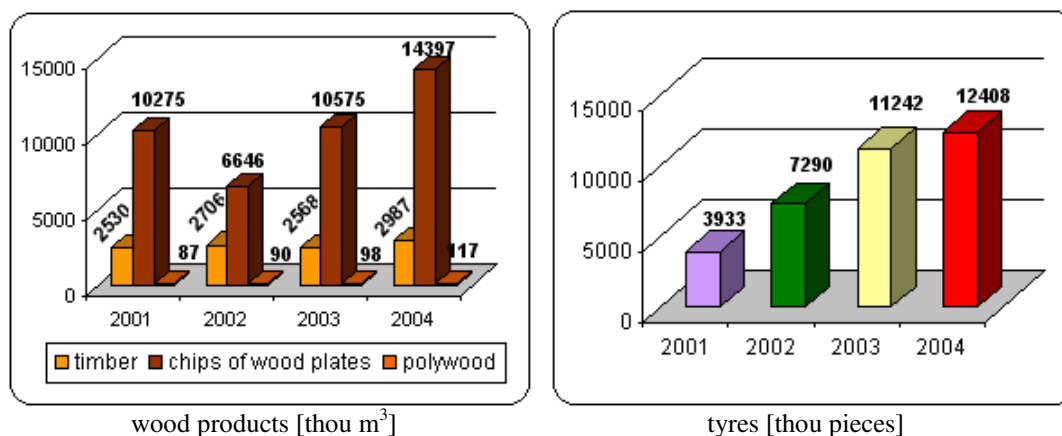


Fig. 7 Composite products [3]

3. CONCLUSIONS

All resources are limited because we live into a closed system, the Earth, and the problem is that our planet has the possibility to regenerate till a certain level. One rule of eco-design says that designers should use in their products less material and if possible, only coming from renewable sources.

Saving the raw materials is the main goal for designers and therefore the following possibilities should be taken into account when think to create a new product:

- reducing materials;
- saving the raw materials by adequate using and losses reduction;
- replacing the rare or expensive materials/ reducing the variety of materials;
- materials recycling by reusing or reprocessing materials, modules, assemblies or the whole product;
- reducing the number of components (simplicity).

REFERENCES

- [1] Eco-design – An innovative path towards sustainable development, 51388 - IC -1-2005-1- RO - ERASMUS – MODUC-4, *Embedding ECO-DESIGN into Product Development, Module 4*, Technical University of Wien (Wimmer W., Pamminger R.)
- [2] www.seabgems.com
- [3] Romanian National Statistic Institute, Statistical annual 2005 – the diagrams were obtained by processing data from the annual
- [4] www.mii.org - Mineral Information Institute
- [5] www.world-aluminium.org
- [6] www.encarta.msn.com
- [7] www.minsocam.org
- [8] www.science.org.au/nova