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Engineering Materials and the Environment

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Abstract: Engineering materials react with a large number of environmental conditions. Such reactions affect their properties and in some cases mar the appearance. At times, these impair the materials properties making them unsuitable for their intended use or failing before the design life, such environmental conditions are said to be unfavorable or hostile, on the other hand the reactions improve the properties of the materials, such environment is described as being favorable. This study reviews literature on how some materials are affected by environmental conditions i.e., the atmospheric conditions, rainfall, temperature, humidity etc. The major classes reviewed are metals, organic materials (Polymer) and ceramic materials i.e., glass, concrete etc.

Key words: Materials, environment, metals, polymers, ceramic, corrosion

INTRODUCTION

Materials can be defined as solid substances such as timber, plastic, metals, ceramics, etc from which things can be made (Jackson and Ravinder, 1988). Engineering materials fall into three groups vis-à-vis metals, organic materials and ceramic materials (glass, bricks and concrete) (Gourd, 1982).

Materials environment can be defined as all the situations, events, people, etc that influence the performance of the material during its service life (Gourd, 1982). It may tend to be favorable or hostile to a particular material depending on its properties and behavior. This may include the atmospheric conditions, aqueous solutions, soils, acids, bases, inorganic solvents, molten salts, etc which the materials are exposed or subjected to. Hostile environments chemically attack the surface or alter the chemical composition and properties of the material; this derivative takes a variety of forms and may be different for the material types identified. In metals there is actual material loss either by dissolution (corrosion) or formation of non-metallic scale or film (oxidation). Polymers may dissolve when exposed to liquid solvent, thus taking a form of corrosion or they may absorb the solvent and swell. Also electromagnetic radiation and heat may cause alterations in their molecular structure. Ceramic materials are relatively resistant to deterioration, which usually occurs at elevated temperatures or in rather extreme environment, a process called corrosion.

In a nutshell, the understanding of the properties of engineering materials in relation to the environment is essential in both design and construction phases of engineering projects. Therefore, this study reviews the work of some authors and pointed out the need to be cautious when putting engineering materials into use.

METALS

Metals are widely employed in engineering. They are used as structural materials in civil engineering, for instance as structural steels where the design is based primarily on the yield stress or proof stress of steel and concrete reinforcement, the reinforcing steel must have adequate tensile properties and form a strong bond with the concrete since the concrete transmits load to the steel by shearing stresses. Generally , the unique properties are high stiffness and tensile strength, the ability to be formed into plates and sections, the ease of welding, electrical conductivity and metallic luster (Jackson and Ravinder, 1988).

Environmental stability of metals: The reaction between environment and metals often results in the process termed corrosion. Corrosion is often defined as destruction of metal by chemical or electrochemical action (Michael and David, 1994) this implies transfer of electrons. Rusting of iron and low-alloy steel, corrosion by liquid metals and fused salt do not fall within the above definition, thus a broader definition is put as the destruction of material by chemical, electrochemical, or metallurgical interaction between the environments (Michael and David, 1994). Corrosion may mar appearance under service conditions or it may reduce to a level at which failure will occur. It may be uniform, or it may concentrate along grain boundaries and other line of weakness. It may result in pits on the surface; the conditions conducive to corrosion (rusting) include moisture, oxygen, etc. The presence of moisture in the environment greatly affects corrosion as can the presence of chemically active pollutant. Iron rusts when the environment contain moisture, but not with oxygen or moisture alone, for instance iron nails neither rust if kept in a container with a dry air nor if in oxygen free environment e.g. boiled water, but in moist air they rust readily.

Aluminum is an example of metal that builds up a protective oxide layer, which is a very effective barrier against further oxidation. Man-made pollutants such as the oxides of carbon and sulphur produced in the combustion of fuel dissolve in water to give acids which readily attack metal and many other materials. Marine environment is also corrosive, due to high concentration of salts from the sea.

Corrosion of materials depends not only on materials and environment but also on internal structure of the material and nature of service. It is influenced by structural factors such as composition, residual stresses, voids and dissolved gases and environmental factors e.g. temperature, movement of corrodant, the presence of electrochemical couples, surface films and applied stresses. Corrosion of metals by chemical or electrochemical reaction with the environment occurs because metals are inherently unstable and tends to revert to a more stable form and energy is released to the atmosphere in the process. It is therefore, essential that metals are protected by coating, painting, galvanizing, etc, whenever they are to be used in hostile environment.

POLYMER

A polymer is a large molecule containing hundreds or thousands of atoms formed by combining one, two or occasionally more kinds of small molecules (monomers) into chain or network structures (Jackson and Ravinder, 1988). They are a group of carbon containing organic material which have macromolecular of this sort and are widely used throughout the industries and for engineering purposes. They have a wide spread of engineering properties very different from those of metals and ceramics and a distinct manufacturing and processing technology centered largely on moulding, extrusion and fibre forming operations. The polymers used in engineering are for most part wholly synthetic and are of much simpler structure. The only natural polymers of major engineering importance are timber and natural rubber. The relatively low elastic modulus and high permissible stains of many polymers frequently allow a softer approach to design and product manufacture. Its most prominent application is in pipe work and they play important supporting role like surface coatings, membranes, adhesive and jointing compound, roofing materials, cladding and thermal insulates.

Environmental stability of polymer: Unlike metals, polymers are relatively stable. They are largely unaffected by weak acids or alkalis, oils and greases, but may be dissolved by some organic solvents. When exposed, ultraviolet radiation can result in some deterioration. This may show itself as a loss of colour of the surface or its finish and there can also be a loss in strength. Hostile environment such as particulate matter, sulphur oxides and nitrogen oxides, both formed by the presence of sulphur and oxygen in the atmosphere, hydrocarbon and petrochemical oxidant such as ozone, atomic oxygen, singlet oxygen and peroxyacetylnitrate may cause serious corrosion of polymeric materials.

Corrosion of polymers by particulate matters: The particles in the air are of a variety of sizes, shapes and chemical composition, ranging from tiny, spherical metal particles from metallurgical film to huge porous conglomerate of sooty carbon, soil particles, fly ash etc. Particles larger than about 10 microns (sources from grinding, abrasion and flash from fuel combustion) settle on the surface of polymeric material, these particles are gathered as dust fall (Randy and Rabek, 1983). Dust falls play a fundamental role in the abrasive corrosion of polymer surfaces but it also decreases the photochemical processes (degradation, cross linking and oxidation processes) by scattering and absorption of harmful sun radiation.

Black smoke is a special kind of particulate material that covers polymer surfaces very tightly and it is difficult to remove. It may contain stable unpaired electrons(free radicals), which may play a specific role in photo stabilization of polymeric materials by scavenging free radicals formed from photolysis of polymer (Randy and Rabek, 1983).

Corrosion of polymer by sulphur oxides: In air, Sulphurdioxide (SO_2) reacts with oxygen, ammonia and other compounds, including the water vapour present in air, to form sulphuric acid mist, liquid drops of concentrated acid as well as various other sulphates. The acid aerosols attack polymer surfaces and cause lustrelessness to the surface (Randy and Rabek, 1983). "Filiform", an underfilm electrochemical corrosion (observed in polymer coated metal surfaces) takes place along with polymer damages as thread like pattern which forms under high humidity condition and is accelerated by the presence of sulphur dioxide and inhibited by carbon-dioxide (Randy and Rabek, 1983). Paper products produced from about 1750 on are embrittled by sulphur compounds converted to sulphuric acid which causes hydrolysis. Thus old books which are not stored in sealed cases undergo a gradual deterioration.

Photochemical degradation and biological defacement of polymers: The combined effect of moisture, oxygen, heat and ultraviolet light can result in photo-oxidation in the polymer surface. This ensures erosions and micro fracture of the polymer surface thus creating a microenvironment, which is conducive to moisture and dirt accumulation. Also, photo-oxidation leads to high concentration of a variety of carbonyl groups that cause the surface to be hydrophilic. This allows the polymer surface to swell and result in addition stress cracking. Chemical changes developed during polymer surface photo-oxidation and apparently precede biological defacement. In contrast, optimum light stabilization of polymeric materials can reasonably delay premature biological defacement. The controlling factor in defacement process is the disruption of surface integrity and the development of micro fractures and cracks which predispose accumulations of moisture and organic debris.

The chemical changes which accompany photo-oxidation apparently predispose the polymer to attack by microorganisms. Physical changes which accompany severe photo-oxidation provide perfect environment for debris accumulation to support active growth of organisms.

Radiation degradation of polymers: Radiation covers a wide range of frequencies from radio to gamma rays. The frequencies of radiation that are most harmful to polymeric systems are those from the blue parts of the visible spectrum and near ultraviolet (Randy and Rabek, 1983).

CERAMICS

Ceramic materials are inorganic, non-metallic materials which consist of metallic and non-metallic elements bonded together primarily by ionic and/or covalent bonds (William, 1990). Their chemical composition varies considerably from simple compounds to mixtures of many complex faces bounded together. The wide ranges of materials that fall within this classification include materials that are composed of clay minerals, cement and glass. They are typically insulative to the passage of electricity and heat and more resistant to high temperature and harsh environment than metals and polymers (Michael and David, 1994). Ceramics may not be as tough as metals but their resistance to corrosion, wear, decay and corruption is unsurpassed. They are hard and brittle solids (Charles, 1986) as seen in diamond, concrete, etc.

Environmental stability of ceramics: Ceramics are relatively stable when exposed to the atmosphere, though the presence of sulphur-dioxide in the atmosphere and its subsequent change to sulphuric acid can result in deterioration of ceramics, thus building materials such as stone and brick can be severely damaged by exposure to industrial atmosphere in which sulphur-dioxide is present. Most ceramics are corroded much less than metals when exposed to aqueous media, they are resistant to oxidation at moderate temperature, although many are unstable in oxygen (atmosphere) at higher temperature. Ceramics in contrast to metals are generally resistant to deterioration, while they are immune to electrochemical corrosion; they are not impervious in all situations.

Many ceramics are slowly dissolved at high temperatures by molten salts or molten metals. Carbon and graphite have good resistance to alkalis and many acids (other than oxidizing acids like nitric, concentrated sulphuric acid). Corrosion resistance in glass is more commonly known as chemical durability. It is well known that some glasses provide superior containers for hot water, fruit juices and weak chemicals of many kinds. Glass made entirely of silica and soda is soluble in water while borosilicate are extremely resistant (Michael and David, 1994) it is a highly complex process involving penetration of glass by water, followed by decomposition of the complex silicate mixture to give substances entirely different from those originally present. Concrete is a multiphase ceramic, which is exposed to atmospheric weathering and to chemicals in manufacturing and sanitary installations. Concrete can deteriorate from external attack or from internal reactions. Concrete must be impermeable to reactive solution to resist external attack.

CONCLUSION

This study has identified that hostile environment affect materials properties. Because the cost of deterioration of materials and in particular failure of engineering structures due to the unfavourable environment is high, it is important to avoid the conditions stimulating them, in cases where the conditions cannot be avoided, the materials should be protected by using a cost effective method for that particular situation.

REFERENCES

Charles O. Smith, 1986. The Science of Engineering Materials, 3rd Edn.

Gourd, L.M., 1982. An Introduction to Engineering Materials, Edward Arnold Publishers, London.

Jackson, N. and K. Ravinder, 1988. Civil Engineering Materials, 4th Edn. Macmillan Education. Ltd., London.

Michael F. Ashby and David R.H. Jones, 1994. Engineering Materials II , Pergamon.

Randy, B. and J.F. Rabek, 1983. Environmental Corrosion of Polymers; Causes and Main Reactions. The Effect of Hostile Environments on coatings and plastic, Stockholm, Sweden.

William F. Smith, 1990. Principle of Material Science and Engineering, 2nd Edn. Mc-GRAW-Hill International Editions, New York.