SPECIALITY POLYMERS

MODULE III (balance)

Nano polymers

3.2.1 Nano materials & Structure

3.2.2 Nano material processing & applications

Nano materials & Structure

Polymers comprising particles at least one dimension in the nanosize range (1-100 nm)

This is a class of materials that have properties with significant commercial potential.

Polymer nanocomposites offer the possibility of developing new classes of materials with unique structure- property relationships. These nanostructure-property relationships are the frontier in nanocomposites.

Attractive features identified with nanocomposites are

Efficient reinforcement without loss of ductility and even improvement in impact strength

Excellent optical and altered electronic properties, heat stability, flame resistance, improved gas barrier properties, improved abrasion resistance, reduced shrinkage and residual stress.

Classification of nanomaterials

Three dimension

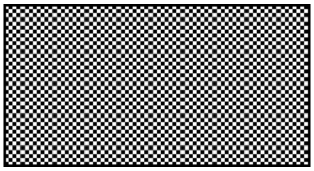
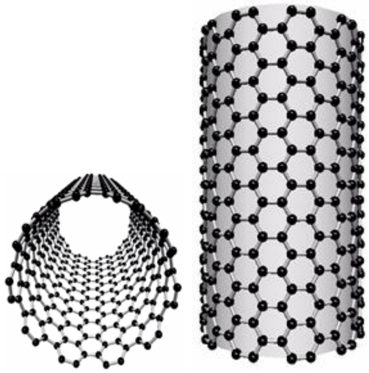
All the dimensions are in nanometer range eg. Nano silica

Two dimension

Two dimensions are in nanometer range,eg.wiskers or carbon nanotubes

Two dimension

One dimension is in the nanometer range, eg. Layered silicates or clays


Three dimension Two dimension Two dimension

Processing

Conventional processing (mixing, shapping , and curing if required) with apropreate quantity of nano materials and other aterials are followed . For better properties special technics such as **Intercalation and exfoliation are utilized . These are two m**ajour type of distribution of nano aterial in polyer chain

Applications

Automobile, aircraft and space, biomedical, composits etc are applications

MODULE IV

Understand Polymer concrete and polymer binders

Curriculum

4.1.1 Explain about polymer concrete
4.1.2 Explain the production, properties of polymer impregnated concrete ,ultra high modulus fibres
4.1.3 List out any four polymers used in bio-medical application, Explain their production and properties.
4.1.4 Explain the polymers used as rocket propellants. Give examples.
4.1.5 Explain the production of optical fibres used in telecommunication cables
4.1.6 Method of wave signal communication optical in fibre

Polymer Concrete

The polymers are used in the concrete due to the following reasons:
Polymers improve the strength and durability of hardened concrete
The chemical resistance and the impermeability of hardened concrete is increased
The flow properties of fresh concrete can be modified based on the required specifications
The bond characteristics between old and new concrete can be improved

Polymers that are used popularly

Urethanes: Urethanes are produced by the reaction of isocyanates with the polyols
Acrylics: These are esters of acrylic and methacrylic acids
Vinyl
Epoxies: These are type of synthetic fibers
SBR or Styrene Butadiene Resins: These are synthetic rubbers in the solution

Different ways

The different ways in which the polymer is introduced into the concrete (hardened concrete) will vary widely based on the commercial objective. The polymers can be employed in concrete in different ways. They are:

Polymer Impregnated Concrete (PIC)

Polymer-Modified Concrete (PMC)

Polymer Concrete (PC)

Polymer as Protective Coating

Polymer as Bonding Agent

Properties of Polymer Modified Concrete

The addition of polymers makes the concrete mix to become more workable. This can hence reduce the amount of water that is added to the concrete mix.

The crushing strength of the concrete is increased using the polymer in concrete. This is because the polymer reduces the water cement ratio which in turn increase the crushing strength.

The bond between the aggregate and the matrix is improved.

The polymer modification increases the flexural strength of the concrete.

The polymer modified concrete consist of at least 3 % more amount of entrained air than the plain concrete. This additional amount of entrained air will reduce the modulus of elasticity of the concrete (PMC).

The polymer addition increases the setting time of concrete.

The resistance of the concrete against abrasion is increased using the polymer.

Freezing and thawing resistance of the concrete structure is improved by polymer modification.

The penetration of chlorine ions and other deleterious materials is restricted. The PMC gain higher resistance against such undesirable effects.

The PMC gains superior shear bond strength.

The ductility property of the polymer modified concrete is more compared with the conventional concrete.

These gain a superior tensile and flexural strength compared to the conventional concrete.

Polymer Impregnated Concrete

In the case of polymer impregnated concrete, the prepolymers or the low viscosity liquid monomers are partially or completely impregnated with the pore system of the hardened cement composite structure. After this procedure, the whole treated structure is allowed to polymerize.

The normal curing procedure of the hardened concrete results in the gain of a considerable amount of free water in its voids. These water-filled voids account for a significant amount of the total volume of the component. It ranges from 5% in the case of dense concrete and 15% in the case of gap-graded concrete.

In the case of polymer impregnated concrete, it is these voids (water filled pores) that must be filled with the chosen polymer. Hence the major factor that affects the monomer loading is the: moisture content in the hardened concrete and the air voids in the concrete.

Applications of Polymer Modified Concrete

The polymer modified concrete can be used in the repair and the rehabilitation of old damaged concrete.

The floor construction in frozen – food factories gains great application. This is because of the higher freeze and thaw resistance of PMCs.

For floor construction of factories were chances of the splitting of chemicals and oils more prone to happen.

For the preparation of steel bridge and ship decks surfaces.

For the concrete structure that is more subjected to large doses of de-icing salts.

For the cementing ceramic tiles to concrete.

Polymer Impregnated Concrete Manufacture

Operations involved in the impregnation process to develop polymer impregnated concrete are:

1. A well-designed cement concrete is made available. They must adequately moist cured and gain an optimum strength.

2. The moisture is removed by drying the concrete. The drying is carried out by heating the structural element to surface temperature of the order 120 to 150 degree Celsius. An air oven can be used to dry small specimens.

If the element has large surface, a thick blanket can be used, say, 10mm thick, to prevent from any thermal gradient. Another sophisticated application is the use of Infrared heaters.

For complete removal of moisture from the concrete, 6 to 8 hours of heating is required.

3. After the complete removal, the concrete surface is cooled to safe levels. This can go to a temperature of 35 degree Celsius. This temperature will avoid flammability.

4. The concrete is now taken to a vacuum sucker, where the whole air within the concrete structure is removed. The quantity of the monomer that is impregnated will decide the time and the degree of application of vacuum.

5. The concrete after adequate removal of air is dipped in a solution of monomer. It is soaked for a long time till the desired depth of penetration of monomer is obtained.

The soaking time is dependent on the viscosity of the monomer, the preparation of the specimen and the main characteristics of the concrete.

To reduce the time taken to acquire the desired penetration, it is preferred to use external pressure like air or nitrogen gas. This facilitates speedy penetration.

6. After the above procedure, the surface is covered with plastic sheet. This helps to prevent the evaporation of the monomer.

7. The thermal catalytic method of polymerization is carried out. This method involves the polymerization by heating the catalyzed monomer to the required temperature level. This will range from 60 degrees to 150 degree Celsius. The temperature range chosen depends on the type of monomer.

The heating can be carried out under the water or by low-pressure steam injection, or by means of infrared heaters or in an air oven. The heating decomposes the catalyst and hence initiate the polymerization reaction.

Once the monomer has penetrated the concrete, the polymerization can also be initiated using the ionization radiation such as the gamma rays. The polymers when fully polymerized or when they are cross-linked, they act as solids that occupy the voids into which they are impregnated.

8. The concrete structure is then allowed to cool.

The whole procedure from 1 to 8 can only be carried out in a precast factory. The Monomers like acrylate, styrene and the vinyl chlorides etc are used commonly for impregnating into concrete. Another widely used monomer is Methyl Methacrylate (MMA).

Properties of Polymer Impregnated Concrete

1. The polymer concrete gains cube compressive strength more than 100N/mm2. This strength is irrespective of the strength of the conventional concrete.

2. The flexural strength of polymer impregnated concrete is usually about 15N/mm2. This is slightly higher than the highest strength plain concrete that is made from normal ingredients.

3. The elastic modulus lies in the range from 30 to 60N/mm2. This value is similar to the value that is obtained from high strength concrete (i.e. about 45N/mm2)

4. The polymer impregnated concrete possesses lesser creep and shrinkage problems due to a lesser number of pores.

5. The polymer impregnated concrete is highly resistant to acid attack, sulfate attack and chloride attack when compared with PCC.

Applications of Polymer Impregnated Concrete

1. Surface Impregnation of Bridge Decks: The bridge decks are allowed to undergo impregnation to avoid the intrusion of moisture, chemicals as well as chloride ions.

The bridge decks constructed in the areas of high salt water and moisture exposure can be protected by this method.

2. Repair of the structures: The damaged structures can be improved by the method of polymer impregnation. The life period of structures which cannot be reconstructed can be increased by this method.

This method hence helps in restoration as well as the preservation of the stone monuments.

3. Underwater and Marine Applications: The ability of Polymer impregnation help in improving the structural properties, resistance to water absorption, and impermeability properties of the concrete structure. This makes them be widely used in underwater construction and for marine structures.

The structures constructed in desalination plants and sea floor structures use this method of concrete construction. It has been observed that the partial impregnation of the concrete piles in the sea water reduces the corrosion of steel reinforcement by 24 times.

4. Application in Irrigation Structures: The use of conventional methods in the repair and rehabilitation of dams and other important hydraulic structures are found to be ineffective and imperfect.

These are later found to cause a large loss in the benefits that are obtained from the irrigation, power generation, flood control etc. But the method of impregnation work best.

The concrete from the severely damaged area is removed, patched and dried. This area is later treated by means of a polymer impregnation.

5. Structural Members: The polymer impregnated concrete have a great potential as a structural material. The PIC also shows remarkable improvements over the conventional concrete.

The internal cracks and voids are the basic factor behind all the issues in conventional concrete structure. As the polymer impregnation stops the root cause, it is best used in structural members.

Ultra high modulus fibres

Fiber-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers – each of which lend varying properties to the concrete. In addition, the character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities.

Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact–, abrasion–, and shatter–resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment–resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete.

GLAS FIBERS –

Glass fiber reinforced polymer (GFRP) has a very important role to play as reinforcement in concrete structures which is exposed to harsh environment conditions where traditional steel reinforcement could corrode. It was found that the unique physical properties of GFRP that made it suitable for applications where conventional steel would be unsuitable. Compressive strength, flexural strength and split tensile strength for these AR glass fibers are more as compared to other glass fibers.

Ultra high modulus fiber reinforced concrete

It stands for concretes with compressive strengths exceeding 150 MPa. The concrete composition includes a high cement content, mineral admixture (usually silica fume), steel fibers and a very low water/binder ratio ensured by the use of last generation superplasticizers. UHPFRC incorporates

very fine sands or quartz sands with granule size up to 1 mm. Besides the superior physical-mechanical

properties compared with ordinary concrete and even high strength concrete, Ultra high Ultra high modulus fiber reinforced concrete presents very good ductility and durability properties

major ultra high modus fibers

Carbon fiber

Aramid

Glass

Comparing the properties of all of the fibre types with each other, shows that they all have distinct advantages and disadvantages. This makes different fibre types more suitable for some applications than others. The following table provides a basic comparison between the main desirable features of generic fibre types. 'A' indicates a feature where the fibre scores well, and 'C' indicates a feature where the fibre is not so good.

(If required add production and properties of above polymers studied in F & C)

Polymers used in bio-medical application

Macromolecular compound obtained from natural origin. Chemical nature - polysaccharides, protein and bacterial polyesters Flexibility; Resistance to biochemical attack; Good biocompatibility; Light weight; Available in a wide variety of compositions with adequate physical and mechanical properties and can be easily manufactured into products with the desired shape.

Classification Biomedical Polymers

1. Natural Polymers 2 Synthetic Polymers

. **Natural polymers, or polymers, derived from living creatures**, are of great interest in the biomaterials field. Properties of natural polymers: Biodegradable; Non-toxic/ non-inflammatory; Mechanically similar to the tissue to be replaced; Highly porous; Natural polymers .Encouraging of cell attachments and growth; Easy and cheap to manufacture Capable of attachment with other molecules (to potentially increase scaffold interaction with normal tissue).

Example of natural polymers ;- Collagen , Cellulose , Alginates , . Dextrans and Chitosan .

Collagen .

It is the main structural protein in the extracellular space in the various connective tissues in animal bodies. As the main component of connective tissue, it is the most abundant protein in mammals, making up from 25% to 35% of the whole-body protein content. Collagen consists of amino acids wound together to form triple-helices to form of elongated fibrils. It is mostly found in fibrous tissues such as tendons, ligaments and skin. Depending upon the degree of mineralization, collagen tissues may be rigid (bone), compliant (tendon), or have a gradient from rigid to compliant (cartilage) It Consist of three intertwined protein chains, helical structure . Collagen is .non-toxic, minimal immune response .Can be processed into a variety formats –Porous sponges, Gels, and Sheets .

Applications –Surgery, Drug delivery, Prosthetic implants and tissue-engineering of multiple organs . Derived from chitin, It present in hard exoskeletons of shellfish like shrimp and crab Chitosan desirable properties Minimal foreign body reaction ,Controllable mechanical biodegradation properties Applications .In the engineering of cartilage, nerve, and liver tissue, wound dressing and drug delivery devices Chitosan

Alginate A polysaccharide derived from brown seaweed . Can be processed easily in water . Non-toxic , Biodegradable , Controllable porosity • Forms a solid gel under mild processing conditions • Applications in Liver, nerve, heart, cartilage & tissue- engineering

Synthetic Polymers

Advantages of Synthetic Polymers, Ease of manufacturability ,process ability ,reasonable cost , The Required Properties , Biocompatibility , Sterilizability, Physical Property , Manufacturability

Applications: Medical disposable supplies, Prosthetic materials, Dental materials, implants, dressings, polymeric drug delivery, tissue engineering products

Example of Synthetic Polymers : (PTFE) Polytetrafluoroethylene ,Polyethylene, (PE) , Polypropylene, (PP) ,Poly (methyl methacrylate) PMMA – it is a Material used in maxillofacial prosthetic

(Study the production of all above)

Classifications

Biostable, Bioerodible, Water soluble ,

Polymers that are sufficiently biostable to allow their long term use in artificial organs blood pumps, blood vessel prostheses, heart valves, skeletal joints, kidney prostheses.

A polymer must fulfill certain critical requirements if it is to be used in an artificial organ. It must be physiologically inert .The polymer itself should be stable during many years of exposure to hydrolytic or oxidative conditions at body temperature Biostable Polymers

It must be strong and resistant to impact (when it is used as structural material to replace the bone). The polymer must be sufficiently stable chemically or thermally that it can be sterilized by chemicals or by heat.

Bioerodible materials . Polymers that are bioerodible materials that will serve a short term purpose in the body and then decompose to small molecules that can be metabolized or excreted, sometimes with the concurrent release of drug molecules. Mostly bioerodible polymers used as surgical sutures, tissue in growth materials, or controlled release of drug.

Water-soluble polymers (usually bioerodible) that form part of plasma or whole blood substitute solutions or which function as macromolecular drugs. Applications: Improvement in the behavior of pharmaceuticals. Used in synthetic blood substitutes as viscosity enhancers or as oxygen-transport macromolecules.

The design and selection of biomaterials depend on different properties – Host Response Biocompatibility , Biofunctionality , Functional Tissue Structure and Pathobiology , Toxicology, Appropriate Design and Manufacturability, Mechanical Properties of Biomedical polymers .

Polymers used as rocket propellants

Propellant is the chemical mixture burned to produce thrust in rockets . It consists of a fuel and an oxidizer. A fuel is a substance that burns when combined with oxygen producing gas for propulsion. An oxidizer is an agent that releases oxygen for combination with a fuel. The ratio of oxidizer to fuel is called the mixture ratio. Propellants are classified according to their state - liquid, solid, or hybrid.

The gauge for rating the efficiency of rocket propellants is specific impulse, stated in seconds. Specific impulse indicates how many pounds (or kilograms) of thrust are obtained by the consumption of one pound (or kilogram) of propellant in one second. Specific impulse is characteristic of the type of propellant, however, its exact value will vary to some extent with the operating conditions and design of the rocket engine.

Hydroxyl-terminated polybutadiene (HTPB)

$OH-\{-CH_2- CH= CH- CH_2-\}n- OH$

It is an oligomer of butadiene terminated at each end with a hydroxyl functional group.

HTPB is a solid rocket propellant. It binds the oxidizing agent and other ingredients into a solid but it remains as elastic mass. The cured polyurethane acts as a fuel in such mixtures. For example, HTPB is used in all 3/4 stages of the Japanese M-5 rocket satellite launchers and PSLV rocket developed by ISRO for satellite launches. "HTPB/AP/Al=12/68/20", which means, proportioned by mass, HTPB plus curative 12% (binder and fuel), ammonium perchlorate 68% (oxidizer), and aluminium powder 20% (fuel).

Similar propellants, often referred to as APCP (ammonium perchlorate composite propellant) are used in larger model rockets. A typical APCP produces 2–3 times the specific impulse of the black powder propellant used in most smaller rocket motors.

HTPB is also used as a hybrid rocket fuel. With N2O (nitrous oxide, or "laughing gas") as the oxidizer, it is used to power the Space Ship .

Optical fibre cable

It is a technology that uses glass (or plastic) threads (fibers) to transmit data. A fiber optic cable consists of a bundle of glass threads, each of which is capable of transmitting messages modulated onto light waves. Fiber optic cables have a much greater bandwidth than metal cables.

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. Optical fiber is used by many telecommunications companies to transmit telephone signals, Internet communication, and cable television signals.

How Fiber Optic Cables Work

Fiber optic cables carry communication signals using pulses of light generated by small lasers or light-emitting diodes (LEDs).

The cable consists of one or more strands of glass, each only slightly thicker than a human hair. The center of each strand is called the core, which provides the pathway for light to travel. The core is surrounded by a layer of glass called cladding that reflects light inward to avoid loss of signal and allow the light to pass through bends in the cable.

The two primary types of fiber cables are called *single mode* and *multi mode* fiber. Single mode fiber uses very thin glass strands and a laser to generate light while multi mode fibers use LEDs.

Single mode fiber networks often use *Wave Division Multiplexing (WDM)* techniques to increase the amount of data traffic that can be sent across the strand. WDM allows light at multiple different wavelengths to be combined (multiplexed) and later separated (de-multiplexed), effectively transmitting multiple communication streams via a single light pulse.

Advantages of Fiber Optic Cables

Fiber cables offer several advantages over traditional long-distance copper cabling.

- Fiber optics have a higher capacity. The amount of network bandwidth a fiber cable can carry easily exceeds that of a copper cable with similar thickness. Fiber cables rated at 10 Gbps, 40 Gbps and even 100 Gbps are standard.
- Since light can travel much longer distances down a fiber cable without losing its strength, it lessens the need for signal boosters.
- Fiber is less susceptible to interference. A traditional network cable requires special shielding to protect it from electromagnetic interference. While this shielding helps, it is not sufficient to prevent interference when many cables are strung together in close proximity to each other. The physical properties of glass and fiber cables avoid most of these issues.