CHAPTER - 3

COMPOSITE MATERIALS AND THEIR STRUCTURAL APPLICATIONS
3.0 GENERAL

The role of development of materials in the evolution of civilization is so important that the civilizations have been known by the materials, which were used during the spread of time i.e. stone age, bronze age, iron age, concrete age and lately plastic age with the future prospective of smart materials. When the developed material in the particular application shows distress after its continuous use, then the situation demands improvement in the present material, development of a new material or to borrow the material being used in other area of application.

3.1 APPLICATIONS OF COMPOSITE MATERIALS

The infrastructure of a nation is composed of industrial and public works that support our daily activities. The infrastructure applications include buildings, bridges, sewage and water treatment facilities, off-shore structures and transportation systems. Most of the infrastructure has been built with steel or R.C.C. Steel is frequently exposed to accelerated corrosion leading to catastrophic failures and costly repairs.

Therefore there is a need to develop and use new long-lasting materials with attributes of corrosion resistance and high strength to weight ratio that can be mass produced at low cost to replace and complement conventional materials i.e. steel and concrete.

High strength fibre reinforced composites are increasingly challenging the supremacy of traditional materials in numerous applications in view of their combination of enticing properties, increasing availability and diminishing cost.

The applications of fibre reinforced composites have been divided into following categories:

i. Infrastructural Applications
ii. Electro-magnetic Applications
iii. Aerospace Applications
iv. Applications in Missiles, Space Hardware, Electricity and Electronics
v. Miscellaneous Applications
3.1.1 INFRASTRUCTURAL APPLICATIONS

Polymer Matrix Composites (PMCs) are a good candidate to fill many applications of composites in infrastructure. Polymer Matrix composites are divided into FRPs and advanced polymer composites.

FRPs are inexpensive as in case of polyester resins reinforced with continuous glass fibres. Many other low cost reinforced plastics such as sheet moulded compounds are not considered by structural engineers to be in this category due to their relatively low strength when compared to continuously reinforced composites. Advanced polymer composites have superior strength and stiffness but are much expensive than FRPs.

For the present studies, infrastructural applications including buildings and bridges have been discussed.

![Infrastructural Applications Diagram](image)

3.1.1.1 Building: Continuous fibre mats have been used in Austria as facades in high-rise building construction. The type of laminate lends itself well to produce economically large structural elements and large surfaced, thin walled structural systems such as domes, shells and stiffened roof components. In 1989, GE Plastics, Pittsfield, MA, unveiled a 'Living Environment' house using FRPs as innovative housing components and to test many FRP applications like roofing materials, moulded base boards for electrical and telecommunication purposes and radiant wall panels with integrated water, electricity and control services.

Innovations in terms of foam-core panel systems are being searched to reduce costs and improve earthquake resistance.
The extruded core marketed by Siteco of Italy has hollow sections spaced in such a way as to accommodate reinforced columns. The hollow foam core panels serve as a form to concrete at the time of construction.

A sandwich panel with fibre glass reinforced concrete facings and polystyrene extruded foam core is being successfully used for walls, partitions and floor panels. The polystyrene is extruded into cellular sections with holes designed to hold concrete reinforced with steel bars as in conventional construction, but eliminating the need for moulds since the holes in the core act as a permanent mould for concrete. The faces are made of fibre glass reinforced concrete. An acrylic emulsion additive in the concrete is said to inhibit the alkaline reaction between the concrete and glass and to improve bond between concrete and the core.

The reinforced concrete columns are joined by reinforced concrete beams poured during erection at the same time as the columns. Floor slabs with reinforcing elements are joined in the same fashion.

This system was ranked first in all nineteen classifications set up by the French Government to compare all types of construction building materials.

3.1.1.2 BRIDGES: Recent advances in the production and usage of high strength fibres have created a growing interest in their potential for advanced structures in the commercial sectors such as suspension and cable-stayed bridges. Composites are presenting unique opportunities to construction designers and engineers to project advanced structures such as long span bridges where design requirements can only be effectively met by materials possessing very high strength and stiffness.

McCormick, at University of Virginia, designed and tested a model of bridge deck containing deck slab, stringers and beam, of size 2.1 m x 4.9 m and 45.7 cms deep to monitor the structural behaviour, effect of weathering and user abuse. The decking system was made of concrete and stringers were composed of trussed webs, a solid flange plate forming a triangular shaped cross-section. All the components were made of glass reinforced polyester. Non-metallic fasteners were used in all of the connections.
The first reinforced plastic pedestrian bridge was designed by Yair Tene of North Potomac, MD and built in 1975 in Israel. The bridge of about 24 m span was cited by the Engineering News Records in 1976 as one of the ten most outstanding achievements in the field.

Another novel application of FRPs in bridges is to provide a hollow enclosure system to protect the structure steelwork from corrosion. The enclosure system developed in England has unique inter-locking panels which form the structural floor. The enclosure system was found to have minimum weight, an estimated life of at least 30 years, good fire resistance, good long-term appearance and low life cycle costs.

A carbon-epoxy cable developed by Tokyo Rope Co. and Toho Rayon Inc., both of Japan, has found applications as a Post-tensioning device for bridges. BASF, who markets the product in Europe, is using the cable and metallic die-cast / wedge connectors to partially post-tension a bridge in its Ludwig- shafen chemical plant in Germany.

In Japan the Shinmiyabashii Bridge was built in 1988 and uses Rope's carbon cables in pre-fabricated pre-stressed concrete beams. In this case, a disposable anchorage system is used only temporarily at the factory until the concrete cures. Then the bond between concrete and the cable transfers all the load and anchorage can be removed.

### 3.1.2 ELECTRO-MAGNETIC APPLICATIONS

The electro-magnetic properties of FRPs have motivated the use of FRPs over the years despite the lack of design experience, standards and material data bases.

Imaging equipment used at hospitals has to be mounted on magnetically inert environment to avoid the distortion of the electro-magnetic field around the equipment that would otherwise affect the quality of imaging process.

Therefore, ferro-magnetic materials such as mild steel used as reinforcement for concrete can not be used to support this kind of equipment.

No ferro-magnetic materials can be present in the vicinity of communication equipment which may pose restrictions on the kind of materials used to reinforce concrete over large areas of airport pavement and buildings.
Glass fibre reinforced composite building systems made of FRP components and connectors are being used in civil engineering construction primarily because of their non-magnetic and non-corrosive properties.

All-weather, electro-magnetically compatible testing facilities have been built for various computer manufacturers and laboratories.

The construction of enclosures on the top of St. Luke's Episcopal Hospital in Houston, TX, to house radio antennas is an excellent example in terms of advancing state-of-the-art construction with FRP shapes.

Fibre glass cables were used in the rehabilitation of the Mairie d'Ivry Metro station in Paris, France where non-magnetic nature of the cable played an important role in the selection of this cable instead of high stress steel cables.

3.1.3 AEROSPACE APPLICATIONS

Getting the main advantage from the outstanding weight-saving opportunities of composites, the aerospace industry had soon discovered the potential. Various structural components of a modern passenger aircraft are already made from such a material. The importance of weight reduction in this case becomes obvious if one considers that the structural contribution to the total mass amounts to about 40% whereas the pay-load is around only 20%, rest 40% by engines and other equipment. A modest structural mass reduction of 10% would allow to increase the pay-load already by 20% or keeping the pay-load constant would save a considerable amount of fuel.

3.1.4 APPLICATIONS IN MISSILES, SPACE HARDWARE, ELECTRICITY AND ELECTRONICS

3.1.4.1 MISSILES: Composites have demonstrated the wide range of characteristics necessary to satisfy the operational requirements of missiles. High stiffness and strength and minimum weight are the major reasons for the use of graphite composite for critical structural members in missile systems.
3.1.4.2 SPACE HARDWARE : Composites reinforced with graphite and kevlar fibres have high specific strength and modulus and low co-efficient of thermal expansion, making them particularly attractive for space vehicles. Composites have become the basic material for spacecraft antennas.

3.1.4.3 ELECTRICITY AND ELECTRONICS : Demands for improved performance and for lighter weight products have led to increased use of composites in electrical and electronics applications.

3.1.5 MISCELLANEOUS APPLICATIONS

The corrosion resistance of the vinylester resins used in structural shapes makes FRP, the material of choice for auxiliary structures in chemical plants.

Handrail systems, platforms, ladders and ladder cage assemblies are some examples of successful applications of FRP in corrosive environments.

Replacement of steel components by FRP in major structures such as roof of the caustic chlorine chamber is common in chemical plants today.

Resistance to saline water corrosion and light weight makes FRP advantageous for offshore construction and applications in the area of water and effluent treatment.

3.2 CONCLUSIONS

Composite materials are being used in civil engineering construction industry to replace conventional materials like steel and concrete.