

POLYMER CONCRETE

Continuous research by concrete technologists to understand, improve and develop the properties of concrete has resulted in a new type of concrete known as, “Polymer Concrete”. It is referred time and again in the earlier chapters that the concrete is porous. The porosity is due to air-voids, water voids or due to the inherent porosity of gel structure itself. On account of the porosity, the strength of concrete is naturally reduced. It is conceived by many research workers that reduction of porosity results in increase of strength of concrete.

Therefore, process like vibration, pressure application spinning etc., have been practised mainly to reduce porosity. All these methods have been found to be helpful to a great extent, but none of these methods could really help to reduce the water voids and the inherent porosity of gel, which is estimated to be about 28%. The impregnation of monomer and subsequent polymerisation is the latest technique adopted to reduce the inherent porosity of the concrete, to improve the strength and other properties of concrete. The pioneering work for the development of polymer concrete was taken up by United States Bureau of Reclamation (USBR). The initial exploratory works carried out at the Brookhaven National Laboratory (BNL) in cooperation with USBR and US in Atomic Energy Commission (AEC) revealed great improvement in compressive strength, permeability, impact resistance and abrasion resistance. The development of concrete-polymer composite material is directed at producing a new material by combining the ancient technology of cement concrete with the modern technology of polymer chemistry.

Type of Polymer Concrete

Four types of polymer concrete materials are being developed presently. They are:

- (a) Polymer Impregnated Concrete (PIC).
- (b) Polymer Cement Concrete (PCC).
- (c) Polymer Concrete (PC).
- (d) Partially Impregnated and surface coated polymer concrete.

Polymer Impregnated Concrete (PIC)

Polymer impregnated concrete is one of the widely used polymer composite. It is nothing but a precast conventional concrete, cured and dried in oven, or by dielectric heating from which the air in the open cell is removed by vacuum. Then a low viscosity monomer is diffused through the open cell and polymerised by using radiation, application of heat or by chemical initiation.

Mainly the following types of monomer are used:

- (a) Methylmethacrylate (MMA),
- (b) Styrene,
- (c) Acrylonitrile,
- (d) *t*-butyl styrene,
- (e) Other thermoplastic monomers.

The amount of monomer that can be loaded into a concrete specimen is limited by the amount of water and air that has occupied the total void space. It is necessary to know the concentration of water and air void in the system to determine the rate of monomer penetration. However, the main research effort has been towards obtaining a maximum monomer loading in concrete by the removal of water and air from the concrete by vacuum or thermal drying, the latter being more practicable for water removal because of its rapidity.

Another parameter to consider is evacuation of the specimen prior to soaking in monomer. This eliminates the entrapment of air towards the centre of the specimen during soaking which might otherwise prevent total or maximum monomer loading. The application of pressure is another technique to reduce monomer loading time.

Polymer Cement Concrete (PCC)

Polymer cement concrete is made by mixing cement, aggregates, water and monomer. Such plastic mixture is cast in moulds, cured, dried and polymerised. The monomers that are used in PCC are:

- (a) Polyester-styrene.
- (b) Epoxy-styrene.
- (c) Furans.
- (d) Vinylidene Chloride.

However, the results obtained by the production of PCC in this way have been disappointing and have shown relatively modest improvement of strength and durability. In many cases, materials poorer than ordinary concrete are obtained. This behaviour is explained by the fact that organic materials (monomers) are incompatible with aqueous systems and sometimes interfere with the alkaline cement hydration process.

Recently Russian authors have reported the production of a superior Polymer cement concrete by the incorporation of furfuryl alcohol and aniline hydrochloride in the wet mix. This material is claimed to be specially dense and non-shrinking and to have high corrosion resistance, low permeability and high resistance to vibrations and axial extension.

Washington State University in cooperation with Bureau of Reclamation tested the incorporation of several monomers into wet concrete for preparing PCC for fabrication of distillation units for water disalination plants. However, it is reported that only epoxy resin produced a concrete that showed some superior characteristics over ordinary concrete.

Polymer Concrete (PC)

Polymer concrete is an aggregate bound with a polymer binder instead of Portland cement as in conventional concrete.

The main technique in producing PC is to minimise void volume in the aggregate mass so as to reduce the quantity of polymer needed for binding the aggregates. This is achieved by properly grading and mixing the aggregates to attain the maximum density and minimum void volume. The graded aggregates are prepacked and vibrated in a mould. Monomer is then diffused up through the aggregates and polymerisation is initiated by radiation or chemical means. A silane coupling agent is added to the monomer to improve the bond strength between the polymer and the aggregate. In case polyester resins are used no polymerisation is required.

An important reason for the development of this material is the advantage it offers over conventional concrete where the alkaline Portland cement on curing, forms internal voids. Water can be entrapped in these voids which on freezing can readily crack the concrete. Also the alkaline Portland cement is easily attacked by chemically aggressive materials which results in rapid deterioration, whereas polymers can be made compact with minimum voids and are hydrophobic and resistant to chemical attack. The strength obtained with PC can be as high as 140 MPa with a short curing period.

However, such polymer concretes tend to be brittle and it is reported that dispersion of fibre reinforcement would improve the toughness and tensile strength of the material. The use of fibrous polyester concrete (FPC) in the compressive region of reinforced concrete beams provides a high strength, ductile concrete at reasonable cost. Also polyester concretes are viscoelastic in nature and will fail under sustained compressive loading at stress levels greater than 50 per cent of the ultimate strength. Therefore, polyester concrete should be considered for structures with a high ratio of live load to dead load and for composite structures in which the polymer concrete may relax during long-term loading. Experiments conducted on FPC composite beams have indicated that they are performance effective when compared to reinforced concrete beam of equal steel reinforcement percentage. Such beams utilise steel in the region of high tensile stress, fibrous polyester concrete (FPC) with its favourable compressive behaviour, in the regions of high compressive stress and Portland cement concrete in the regions of relatively low flexural stress.

Application of Polymer Impregnated Concrete

Keeping in view the numerous beneficial properties of the PIC, it is found useful in a large number of applications, some of which have been listed and discussed below:

(a) refabricated Structural Elements: For solving the tremendous problem of Urban housing shortage, maintaining quality, economy and speed, builders had to fall back on prefabricated techniques of construction. At present due to the low strength of conventional concrete, the prefabricated sections are large and heavy, resulting in costly handling and erection. These reasons have prevented wide adoption of prefabrication in many countries.

At present, the technique of polymer impregnation is ideally suited for precast concrete. It will find unquestionable use in industrialization of building components. Owing to higher strength, much thinner and lighter sections could be used which enables easy handling and erection. They can be even used in high rise building without much difficulties.

(b) Prestressed Concrete: Further development in prestressed concrete is hindered by the inability to produce high strength concrete, compatible with the high tensile steel available for prestressing. Since PIC provides a high compressive strength of the order of 100 to 140 MPa, it will be possible to use it for larger spans and for heavier loads. Low creep properties of PIC will also make it a good material for prestressed concrete.

(c) Marine Works: Aggressive nature of sea water, abrasive and leaching action of waves and inherent porosity, impair the durability of conventional concrete in marine works. PIC, possessing high surface hardness, very low permeability and greatly increased resistance to chemical attack, is a suitable material for marine works.

(d) Desalination Plants: Desalination of sea water is being resorted to augment the shortage of surface and ground water in many countries. The material used in the construction of flash distillation vessels in such works has to withstand the corrosive effects of distilled water, brine and vapour at temperature upto 143°C. Carbon steel vessels which are currently in use are comparatively costly and deteriorate after prolonged use. Preliminary economic evaluation has indicated a savings in construction cost over that of conventional concrete by the use of PIC.

(e) Nuclear Power Plants: To cope up with the growing power requirements for industrial purposes, many countries are resorting to nuclear power generation.

The nuclear container vessel (pressure vessel) is a major element which is required to withstand high temperatures and provide shield against radiations. Another attendant problem of nuclear power generation is the containment of spent fuel rods which are radioactive over long period of

time to avoid radiation hazards. At present heavy weight concrete is being used for this purpose, which is not very effective. PIC having high impermeability coupled with high strength and marked durability provide an answer to these problems.

(f) Sewage Disposal Works: It is common experience that concrete sewer pipes deteriorate due to the attack of effluents and when buried in sulphate infested soils. Further, in the sewage treatment plant, concrete structures are subjected to severe attack from corrosive gases particularly in sludge digestion tanks. Polymer-impregnated concrete due to its high sulphate and acid resistance will prove to be a suitable material in these situations.

(g) Impregnation of Ferrocement Products: The ferrocement techniques of construction is being extensively used in the manufacture of boats, fishing trawlers, domestic water tanks, grain storage tanks, manhole cove, etc. Ferrocement products are generally thin (1 to 4 cms) and as such are liable to corrode. Application of polymer impregnation techniques should improve the functional efficiency of ferrocement products.

(h) Water Proofing of Structures: Seepage and leakage of water through roof and bathroom slabs, is a nagging problem and has not been fully overcome by the use of conventional water proofing methods. The use of polymer impregnated mortar should solve this problem.

(i) Industrial Applications: Concrete has been used for floor in tanneries. Chemical factories, dairy farms and in similar situations for withstanding the chemical attack, but performance has not been very satisfactory. The newly developed PIC will provide a permanent solution for durable flooring in such situations.

