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Polymer-modified Concrete: World Experience and Potential for Bangladesh

M.A. Islam, M.M. Rahman and M. Ahmed

This paper describes the potential of using polymer-modified concrete (PMC) as a structural material. It reviews in brief the growth of the technology from ancient ages until date. First, a detailed survey of the literature reveals that, by varying the nature and concentration of polymer materials, concrete property can be varied across a wide range that makes polymer-modified concrete versatile in its applications. Then, the results of the initial tests conducted in the laboratory of the Housing and Building Research Institute, Dhaka (on the reproducibility of improving the mechanical strength of polymer-modified mortars/concretes as claimed in the literature) are reported. Finally, the use of PMC in Bangladesh in specific applications such as protecting constructions from floods, earthquakes, saline water and landslides at embankments is discussed.

Introduction

Among all the possible construction materials, concrete is the most widely used structural material in the world. Some of the reasons for this are its simplicity in preparation, the easy availability and low cost of its ingredients, and above all, the satisfactory properties of the structure. Concrete is strong in compression but weak in tension. It is a porous material. The pores in concrete result from the forming of concrete itself. Hardened concrete is a direct product of hydration, which is a reaction between water and cement particles. When the capillary water dries out it leaves interconnected pores. When the environmental conditions are favorable, these pores become the entry points for liquid water, water vapor, different gases and chemical substances that could be damaging to concrete. Some other flaws in the concrete also directly affect its performance. For example, because of weak adhesion to certain materials, decorating a concrete structure using such materials is temporary in nature; and because of high abrasion encountered on highways and runways, roughness of concrete surface deteriorates rapidly. Poor resistance to aggressive media and to salty water, as well as poor heat resistance and electric insulation, also limit its applications.

However, with the increasing demand being made on concrete technology to serve the needs of society, experts are responding positively by proposing new formulations using other materials. In this context, incorporating polymer materials into the concrete has, to some extent, contributed to this demand.

Polymers with different kinds of fillers are used as construction materials. They have good binding properties and good adhesion with aggregates. They have long-chain structure, which helps in developing long-range network structure of bonding. In contrast, cement materials provide short-range structure of bonding. As a result, polymer materials usually provide superior compressive, tensile and flexural strength to the concrete compared to Portland cement. Some polymer materials may selectively provide higher

tensile and flexural strength to the structure compared to compressive strength. In addition, they provide good adhesion to other materials as well as resistance to physical damage (abrasion, erosion, impact) and chemical attack.

Conventional concrete materials combined with polymers could yield composites with excellent mechanical and physical properties. Polymer materials with wide variations in properties could provide complex properties to polymer-modified concretes, and thus, present an opportunity to design structural materials with tailored properties.

Although basic application of polymer-modified concrete (PMC) started a few decades ago, researchers have been carrying out more intensive and systematic investigations in developing and applying this material since the 1940s. Developed countries such as the United States of America, Germany, the United Kingdom and Russia, and a developing country like India have long experience of using PMC.

In Bangladesh, polymer materials have been used sometimes as merely an admixture to construction materials. This is the first time (to the authors' knowledge), however, that the Housing and Building Research Institute (HBRI) in close cooperation with the Department of Chemical Engineering and Polymer Science, Shahjalal University of Science and Technology has come forward to start research on polymer-based concretes, and thus HBRI has become a pioneer in Bangladesh in this field of research. In the present paper: (1) the growth of polymer-modified concrete (PMC) technology is briefly outlined, (2) types, properties and the applications of different types of PMC worldwide are discussed, and (3) the prospects of using this structural material in Bangladesh are pointed out.

Growth of polymer modified concrete (PMC) technology and advancing research in the field

The idea of using organic polymer as construction material dates back thousands of years. There are signs that people in the early history of civilization combined natural polymer with inorganic materials to produce high strength and durable construction materials.[1] In the fourth millennium B.C, the clay brick wall of Babylonia was built using the natural polymer 'asphalt' in the mortar. Bituminous mortars in construction had been identified in the Indus valley cities of Mohenje-daro and Harappa around 3000 B.C and near the Tigris in 1300 B.C. Many natural polymers including albumen, blood, rice paste and others have been used in ancient mortars.[2] It is also believed that as early as in the second century B.C, glutinous rice paste lime mortar was used to build the Great Wall of China.[3]

Introduction of latex system in mortar and concrete

The use of the latex-hydraulic-cement system was introduced in the beginning of the 20th century. Cresson authored the first patent on paving materials with natural rubber latexes using cement as filler in the system.[4] One year later, Lefebure applied the modern idea of polymer latex-modified systems, and produced a latex-modified mortar and concrete using natural rubber latexes by a mixture-proportioning method.[5] Other researchers throughout the 1920s and 1930s followed the idea and developed different types of latex-modified mortars and concretes incorporating natural rubber latexes.

For the first time, in 1932, synthetic rubber (instead of natural rubber) latex was used for the latex-modified systems. In 1933, synthetic resin latexes (including polyvinyl acetate latexes) were used in the modified systems, and by the end of the 1930s the inventions clearly suggested that all types of polymers (natural or synthetic, elastomers or plastomers) could be used in polymer-modified concretes. In the 1940s, a few patents on latex-modified systems with synthetic latexes such as poly chloroprene rubber and polyacrylic ester latexes were granted. In addition, polyvinyl acetate modified mortar and concrete were actively developed for practical applications.[6]

Since the late 1940s, latex-modified mortars and concretes have been used in various applications such as bridges, paving, floorings, anti-corrosives, adhesives and deck coverings for ships. Stevens in 1948 and Griffiths in 1951 conducted feasibility studies on the applications of natural rubber modified systems. Their work succeeded in generating a strong interest on the use of synthetic latexes in the latex-modified systems.[7,8] Geist *et al.* conducted a detailed study on polyvinyl acetate modified mortar, and provided many valuable suggestions for further research and development of latex-modified systems.[9]

Ohama investigated the principle of latex modification and some typical properties of latex-modified mortars and concrete.[10] He found the latex modification improved the properties. The hardened latex-modified mortars and concretes developed good strength, adhesion, pore structure, impermeability, and durability (freeze-thaw

resistance, chloride penetration resistance, carbonation resistance, and weatherability). Bordeleau *et al*. made a comparative study of latex-modified concretes (LMC) and normal concretes subjected to freezing and thawing in the presence of a deicing salt and found that LMC had a better freeze-thaw resistance.[11] He concluded that the improvement in the properties depended on the quantity of styrene-butadiene rubber latex, the air-void spacing factor, and the water-cement ratio.

Incorporation of synthetic polymer in mortar and concrete

Many synthetic polymers were invented in the 1940s in response to the wartime demand for natural rubber. The use of new synthetic polymer materials gave a thrust to the development of PMC technology. Incorporation of the synthetic polymer in Portland cement mortar and concrete started in the 1950s.[12] Since then the use of PMC has been increasing with research being carried out all over the world during the last few decades on various aspects of PMC as a structural material.

Mandel and Said conducted research on the effect of an acrylic polymer on the mechanical properties of mortar and found that the mechanical properties of mortar and the adhesion between mortar and a steel fiber improved with the addition of an acrylic polymer into the system.[13] Kim *et al.* studied the properties of polyvinyl alcohol (PVA) modified mortar and concrete with up to 2 % polymer by weight based on cement and compared the structure and properties of polymer-modified mortar/concrete with those without polyvinyl alcohol.[14] The interfacial transition zone and fractured surface were examined with both polarizing optical microscopy and scanning electron microscopy. They concluded that poly vinyl alcohol modified mortar showed slower absorption of water as compared to the unmodified mortar, which was an indication of lower permeability of the polymer-modified mortar. Muthukumar and Mohan studied the mechanical properties and chemical resistance of Furan-based polymer concretes and concluded that they were cost-effective materials for construction in civil engineering applications.[15] Aggarwal *et al.* studied the properties of polymer-modified mortars using epoxy and acrylic emulsion, and found that these materials had superior strength properties and better resistance to the penetration of chloride ions and carbon dioxide than PMCs based on vinyl acetate, copolymers of vinyl acetate–ethylene, styrene–butadiene, styrene–acrylic, and acrylic-styrene-butadiene rubber emulsions.[16] Ohama *et al.* investigated the effect of the monomer ratio on the typical properties of polymer-modified mortars with styrene-butyl acrylate latexes.[17] They found that the properties (pore-size distribution, flexural and compressive strengths, water absorption, and drying shrinkage) were affected largely by both monomer ratio and polymer-cement ratio.

Fracture properties of PMC

Considering the importance of the fracture parameter of concrete, Vipulanandan and Dharmarajan analyzed the fracture parameters of epoxy-polymer concretes in 1989, and found that all fracture parameters of polymer concrete increased with an increase in the polymer content.[18] Sujjavanich and Lundy studied the strength and fracture properties of styrene-butadiene copolymer latex-modified concrete.[19] They observed that its development of strength, deformability, and fracture properties was different from conventional concrete. The test results, however, indicated a significant improvement over conventional concrete in reducing and bridging micro-cracks, especially in the pre-peak load region. The load deflection relationship was observed to be linear up to 93% of the peak load. Fracture toughness and deformability also increased significantly.

Performance of PMC under continuous stress and in aggressive media

Vipulanandian and Paul studied the performance of epoxy and polyester polymer concrete under various curing conditions, temperatures, and strain rates.[20] The influence of aggregate size and distribution on the mechanical properties of polymer concrete was investigated in the study. The results showed high durability of PMC. O'Connor and Saiidi carried out a comparative study on the basic engineering properties of polyester-styrene polymer concrete overlays and Portland cement concrete bridge decks.[21] The results of their study, however, indicated that, in extreme cases with wide temperature ranges and stiff bridge girders, polymer concrete overlays may be susceptible to cracking.

Solovjov *et al.* reported that furan resins were used widely in the Commonwealth of Independent States (some of the former *Soviet Republics*).[22] They were commonly used in aggressive environments and in construction-related industries. Swamy *et al.* studied the performance of concrete slabs coated with acrylic-based coating against chloride and atmospheric carbon dioxide attacks.[23] Their finding was that coated surfaces prevented chloride and carbonation penetration into concrete. They also pointed out that the coating maintained good adhesion with the substrate concrete even after long-term repetitive wetting and drying cycles.

Folic and Radonjanin reported achieving the highest effects of polymer modification on such properties as tensile strength, ductility, bond between reinforcement and concrete, and on the properties contributing to the durability of reinforcements in structures.[24] On the contrary, Silva and Silva pointed out that the effective use and reliability of polymeric mortars require that designers and builders have a better knowledge of the temporal evolution of their mechanical properties.[25] The study comprised of tests for accelerated aging to quantify property degradation. These authors noted that the degradation was high for epoxy mortar in the cases of temperature cycles and of salt fogging cycles, both for reduced ductility and bending strength. Cycles of dry-wet environment, at a fixed temperature, led to growing reductions of strength with time. Ultraviolet radiation caused superficial effects and negligible reduction of mechanical strength, but a decrease of stiffness was detected. It appears that not all authors achieved a durable positive effect of polymer modification on concrete. No doubt, further research in the field is needed for the proper choice of polymer and the method of preparing the composite for different applications. The ACI committee published a guide in 1993 for polymer concrete overlays providing an overview of thin (less than 25 mm. thick) polymer concrete (PC) overlay for concrete and steel substrates.[26] The guide emphasizes using PC in the transportation sector, specifically for bridge decks and parking garages. Surface preparation, application, evaluation, maintenance, and safety aspects are included. In the same year, the ACI committee presented a similar guide for the selection and use of structural adhesive with concrete. This guide provides the engineer, contractor and architect with a description of the various types of polymer adhesives (epoxy, polyester, acrylic, polyurethane, polysulfide, silicone, vinyl acetate, and styrene butadiene) most frequently used for the adhesive bonding of fresh concrete, bonding concrete to other materials, and the adhesive grouting of bolts and other inserts into concrete.[27] It emphasizes the factors that should be considered when selecting a structural adhesive, including its characteristics during installation and in service. The benefits and limitations of adhesive bonding are discussed.

Fiber reinforced polymer (FRP) modification

Kshirsagar *et al.* studied the environmental aging of fiber-reinforced polymer-wrapped concrete cylinders, and investigated the effects of temperature, moisture, pH level, and freezing-and-thawing cycles on the mechanical properties of the material.[28] Hygrothermal swelling of the fiber-reinforced polymer wrap was observed for different aging conditions and that led to a reduction in the concrete confinement. De Lorenzis *et al.* studied the bond of fiber-reinforced polymer laminates to concrete materials[29]. The specimens for flexural test were prepared to address some of the factors expected to affect the bond, namely, bonded length, concrete strength, number of plies (stiffness), ply width, and, to a limited extent, surface preparation. The bond of fiber-reinforced polymer reinforcement to the concrete substrate is of critical importance for the effectiveness of the technique. The laminates are being successfully used worldwide for strengthening existing reinforced concrete structures.

Debaiky *et al.* discussed the use of carbon fiber-reinforced polymer (CFRP) wraps as a rehabilitation technique for corroded reinforced concrete columns.[30] These authors observed that the wraps significantly prevented corrosion activity when applied over the entire specimen. The application of the wraps before corrosion propagation prevented corrosion from taking place, while the application of the wraps after corrosion occurrence retarded the corrosion rate. Sett and Vipulanandan investigated the effect of adding glass and carbon fibers on the compressive and tensile behavior of polyester-polymer concrete and observed that fibers improved the properties of the polymer concrete system to varying degrees, depending on the type and amount of fibers.[31]

Polymer concrete based on recycled polymer

Rebeiz *et al.* investigated the mechanical properties of various polymer concrete systems using unsaturated polyester resins based on recycled polyethylene terephthalate (PET) plastic waste.[32] The recycled polyethylene terephthalate was mainly recovered from plastic beverage bottles collected after use. The author reported that resins using recycled polyethylene terephthalate offered the possibility of a low-cost source of materials for making useful polymer concrete products. Later on, these authors applied a similar idea to the preparation of polymer mortar (PM) using unsaturated polyester resins based on recycled polyethylene terephthalate and plastic waste.[33] The work of these authors could contribute to the development of polymer concrete/mortar technology and also to the solution of the environmental problem related to the management of waste and used plastic articles.

PMC in the Sub-continent: research and application

In both research and application of PMC, Bangladesh lags behind the developed world. To the authors' knowledge, so far polymers have seldom been used as

admixture, and PMC has never been used in application. The Housing and Building Research Institute (HBRI), Dhaka in close cooperation with the department of Chemical Engineering and Polymer Science (CEPS), Shahjalal University of Science and Technology, Sylhet is the pioneer in Bangladesh to initiate research in this field.

Excluding two papers, one presented in the 2nd *International Conference on Chemical Engineering 2008* at Bangladesh University of Engineering and Technology (BUET), Dhaka and the other presented in a seminar on *Eco-housing, Ferro-cement floating house and polymer in concrete 2009* at the Housing and Building Research Institute, Dhaka), this submission is the first article from a research group in Bangladesh.[34,35] Also, no local commercial firm is yet proposing to use PMC as a structural material.

In order to verify the degree of reproducibility of the literature data, some experiments were carried out in the laboratory of HBRI producing polymer cement mortar and polymer mortar. In polymer cement mortar, the cement-sand-polymer (epoxy resin) ratio was maintained at 1:2.75:0.28. The experiment was carried out at room temperature, and the water to cement ratio was maintained at 0.45. After 28 days, the ultimate compressive strength was found to be 48 MPa, which was about 2.8 times higher than that of normal conventional mortar prepared from a composition with cement-sand ratio of 1:2.75. In the case of polymer mortar, the polymer-sand ratio was maintained at 1:9. No cement was used as the binding element. After 28 days the ultimate compressive strength was found to be as high as 71 MPa. With cement-sand ratio of 1:9, no integrated material could be prepared. Obviously, epoxy resin is a better binder than cement. The first results obtained in the laboratory of HBRI are encouraging. Now well-designed experiments are being carried out to obtain improved performances.

PMC research in India started with a bit of delay compared to developed countries. Still, Indian researchers have made substantial progress. Some important research works in the field are outlined in the next paragraph.

Neelamegam and Ohama conducted a series of tests on various types of polymer and resin mortar composites and observed the superior properties of polymer modified mortar (PMM) when compared to ordinary cement mortar.[36] Manjrekar discussed three categories of polymers in concrete, namely polymer-impregnated concrete (PIC), polymer concrete (PC) and PMC, and concluded that the latter was gaining popularity because of its ease of handling, economy and satisfactory results.[37] Seshadri and Ramanakumar discussed the practical applications of PMC using epoxy resin and other polymers and concluded that in recent years the use of polymers in concrete as a repairing material was expanding due to the increasing demands from the construction industry.[38] Jain conducted a study on the applications of polymer cement mortar and found that the adhesion of mortar and concrete to an old surface could be increased with the addition of a suitable polymer.[39] The use of polymer mortars for the rehabilitation of distressed reinforced concrete structures, for providing seamless flooring in large areas and for the construction of specialized jobs was also reported in the paper. Limaye and Kamat studied the effect of six types of polymers in cement mortar and found significant improvement in the energy absorption capacity of these polymer-modified systems.[40] Babu *et al.* studied the mechanical properties of lightweight expanded polystyrene concrete containing fly ash.[41]

Mailvaganam developed durable cement concrete using polymer latex.[42] This author described the specific mechanisms of degradation that a polymer-based material could be subjected to and the consequent defects. He also argued that to assure a predictable performance, the designer should have a good understanding of the properties of polymers, interaction with the environment in-service, and maintenance procedures. Gokhale reported two cases of using epoxy resins for structural corrections and connections.[43] This author reported that due to various unforeseen reasons, the provisions made in the design of a structure where epoxy was used for structural corrections and connections required major changes.

Several companies around the world are offering polymer-modified concrete items. In the sub-continent, such companies are few. Devcon Chemical Private Ltd. is specialized in the production and application of cement polymer composite coating (CPCC).[44] The Ironite Company of India Ltd. is producing polymer-based bonding agents and sealants for plaster, concrete and construction expansion joints.[45]

Properties and applications of PMC

Each type of polymer latex can and usually does impart specific properties to PMC when incorporated. As yet, there is no polymer latex to serve a universal purposes. Depending on the properties of the PMC to be achieved, the nature and quantity of the polymer composition should be chosen. Table 1 shows the general

characteristics and typical applications of some widely used polymer latex.[46]

The physical and mechanical properties of PMC are, in most cases, highly superior to those of the corresponding normal mortars and concretes. Table 2 summarizes the property variation factor *F* of the PMC product as compared to Portland cement concrete (defined as the ratio between the parameter of PMC and that of the conventional mortar or concrete prepared under identical conditions). The data in Table 2 are extracted from the literature.[46]

It should be noted that the polymer binder could not be identified and specified by a single common name (for example, Polyester). There are a large number of polymers under this title, and the binder as used in concrete technology is a composition consisting of some representative polymer. Notwithstanding the polymer type, Table 2 clearly indicates that the density of PMC does not differ appreciably from that of the corresponding conventional concretes. The water sorption, however, reduces substantially showing PMC's superiority to conventional concrete for aqueous media applications. The mechanical strength of PMC supersedes that of conventional concrete several-fold. The improvement in the mechanical strength undoubtedly suggests the replacement of conventional concrete by PMC, if economically acceptable.

Application: Status and potential

Polymer concrete is highly recommended in many fields of construction such as for building chemical plants, reservoirs and support structures. In the last few decades, the building industry has benefited from the availability of a wide range of facing materials that have influenced the design of facades. Polymer concrete panels are also used for making staircase steps. Polymer concrete and polymer plasters have long been used for covering standard cement floors. Rapid setting facilitates the use of polymer plaster for repairing road and other concrete surfaces.[47] Polymer concrete possesses high decorative and aesthetic qualities, resistance to acidic solutions and abrasion resistance. The use of PMC for major rehabilitation works has gained wide acceptance

Table 1. Widely used polymer latex with general characteristics and typical applications in concrete technology

Type of binder	General characteristics	Typical applications
Poly (butadiene-styrene)	High elasticity, good adhesion, water proofing and high chemical resistance	Used in industrial floor toppings, repair and leveling of concrete, fixing bricks/tiles and water proof mortar
Poly (methyl methacrylate)	Low tendency to water absorption, high freeze-thaw resistance, high mechanical strength and outdoor durability	Used in the manufacture of stair units, facade plates, and sanitary products for curbstones
Polyester	Relatively high mechanical strength, satisfactory good adhesion to other materials, good chemical and freeze-thaw resistance, but have high-setting and post-setting shrinkage	Because of low cost, widely used in panels for public and commercial buildings, floor tiles, pipes, stairs, various pre-cast and cast-in applications in construction works
Epoxy	Strong adhesion to most building materials; low shrinkage, superior chemical resistance, good creep and fatigue resistance, and low water sorption	Due to relatively high cost mainly used in special applications including use in mortars for industrial flooring, skid-resistant overlays in highways, plastering of exterior walls and resurfacing of deteriorated structures
Furan-based polymer	High resistance to most aggressive media (strong acidic or basic aqueous media, polar organic liquids such as ketones, aromatic hydrocarbons and chlorinated compounds), and thermal shocks	Used for brick (e.g. carbon brick, red shale brick, etc.) floors and linings subjected to aggressive chemicals, elevated temperatures and thermal shocks.

Table 2. Property Factor *F* of PMC products as compared to conventional Portland cement concrete

Type of Binder	Density factor	Water sorption factor	Compressive strength factor	Tensile strength factor	Flexural strength factor	Modulus of elasticity factor
Poly (methyl methacrylate)	1.0-1.1	0.01-0.07	5-6	9-11	4-10	1.5-1.8
Polyester	1.0-1.1	0.06-0.12	4-4.5	5-7	2-20	1.0-1.5
Epoxy	1.0-1.1	0.004-0.1	4-4.5	5-7	2-25	1.0-1.5

in India. Manjrekar worked out model specifications for repair and restoration work of high rise buildings, bridges, large industrial premises, marine installations, heritage monuments and bomb-blast affected structures as a guide to clients and contractors.[48] PMC materials have the potential to be used in residential and other civil constructions. Structures made of conventional concrete have won the trust of the community. However, these structures are heavy and require heavy reinforcements for making cantilevers and walls. High-strength lightweight polymer concrete could be a solution in such applications. This is because, for the same density, the mechanical strength of PMC is several times higher than that of conventional concrete. The need for additional reinforcement of cantilever and walls might drop partially or completely. Because of weight reduction, assembly also becomes easier. Babu *et al.* developed lightweight expanded polystyrene (EPS) concretes using high volumes of fly ash (30 and 50 percent) and found that the densities ranged from 550 to 2200 kg/m^3. The compressive strengths of lightweight expanded polystyrene concretes containing fly ash showed a better strength gain rate even after 28 days than those containing ordinary Portland cement and silica fume.[41]

Polymer concrete has some exclusive properties that have some specific applications. As a sound insulating material, it is used for soundproof barriers on highways. In many countries, polymer concrete is being used for making feed troughs for use in piggeries and cattle farms.

The main reasons for using polymer concrete in such applications are its higher strength and lower weight compared to cement binders. It has high chemical resistance to the action of ammonia vapors common to all animal farms and the action of synthetic detergents used in removing pathogenic bacteria. Low water sorption and permeability make it an effective material for use in hydraulic structures as well.[47]

Using PMC in Bangladesh

Flooding causes huge damage to roads, bridges and local infrastructure in Bangladesh. Most of the roads in rural areas need yearly repairs that involved huge expenditure. In such works, normal/conventional mortar or concrete (in which Portland cement is used as the only binder in the structural material) is used. Everyone experienced in the art will admit that conventional cement-based structural material does not provide sufficient adhesion properties and resistance to corrosion, and thus fails to protect roads and infrastructure. Polymers can improve adhesion and resistance to corrosion, erosion and abrasion, and can reduce water sorption. So, the addition of small amounts of properly selected polymers to conventional cement-based structural material could protect the infrastructure in flood-affected areas, which in turn would save huge revenue every year. Landslides of embankments are another severe problem in Bangladesh. Thousands of acres of agricultural lands are being affected on both sides of the rivers. Polymer concrete could be an appropriate material to protect such types of embankments. Design engineers need different types of building materials in different construction works. Very often, lightweight high-strength concrete is very effective in the construction work of high-rise buildings incorporating some percentage of properly selected polymers and additives in the conventional concrete composition. Due to their high flexural strength and lightweight properties, PMCs would be effective and economically viable in the construction of high-rise buildings as well as in structures with specific requirements. For the same reasons, PMCs would also be effective against earthquakes.

There are many hydraulic structures along the seashore in Bangladesh. Good maintenance of these structures is often essential, especially for those exposed to marine and industrial environments. Polymer-based concrete can play a very crucial role in this sector. Due to improved abrasion resistance properties, PMC is highly recommended in the construction of airport runways, railway station platform and chemical plants where normal concrete/mortars fail shortly after constructions due to high vibrations and rough heavy use. Frequent repairing is required for ensuring suitability of such facilities. Polymer concrete may be a suitable replacement for normal concrete in these fields due to its high abrasion resistance and its sound wave dissipation properties.

In carrying out the repair work of different structures, concrete/mortars need a minimum setting time and good properties of adhesion to old structures. Setting time could be tailored by varying the type and concentration of the polymer and hardener. Thus, PMC could be a successful candidate for use in concrete/mortar for repairing buildings and other concrete surfaces. In India, the use of polymer mortars has found its place in the rehabilitation of distressed reinforced concrete structures, in providing seamless flooring in large areas, and in the construction work of specialised jobs.[39]

The drainage system in Bangladesh is in a miserable condition. Even the capital city Dhaka cannot escape such blame. Due to its low water absorption properties, polymer concrete possesses an exceptionally high resistance to water permeability, and hence, the most popular use of polymer concrete could be in the drainage systems and canal networks of Bangladesh. These materials meet the current engineering requirements, and are produced and used in the United States of America, the United Kingdom, Germany, Russia, India and many other countries.

Difficulties in the proper choice of polymer composition and the remedy

There are many types of latex in the market but until now, only a few of them have been tested and proved to be suitable for use with hydraulic cements. Most of the tested latex is found to lack the required stability, i.e., they coagulate when mixed with cement.[6] This is not because suitable polymer materials are not available in the market. Polymer technology has undergone revolutionary developments in the past decades but if the polymer composition is wrongly chosen, the material fails to serve the purpose. Any material used inappropriately can give bad results, but the material itself is not responsible. The problem is that the people knowledgeable about polymers lack a background in building materials, and those experienced in building materials are ignorant about polymer technology. The Guide for the selection of polymers to be added to concrete materials as recommended by the ACI Committee should, by no means, be considered complete and perfect.[27] Engineers and researchers from the fields of both building and polymer materials should act in close cooperation with a view to make proper use of the choice that polymer materials offer, and thus to contribute to the development of PMC technology.

Conclusion

Polymer-modified concrete materials are a very promising group of new building materials. They possess remarkable potential due to a wide variety of interesting features, properties and applications. Such materials can respond to the many needs of current and future construction works. Structures in hostile environments, inaccessible for repair, or subject to impact, cyclic, or dynamic loading could benefit from PMC. Aging infrastructure can be repaired using PMC. Although polymer concrete might initially seem a bit more expensive when compared to conventional materials because of the monetary cost per unit weight, it will appear extremely feasible when judged on its low maintenance requirements, its durability and other parameters. This material has excellent potential for use in various fields in Bangladesh, and HBRI seems to be on the right path in initiating research into applications of PMC in our country.

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Md. Akhtarul Islam PhD holds a MSc Engineering degree (chemical engineering) and a PhD degree from The Higher Institute of Chemical Technology, Bourgas, Bulgaria. He is Professor and HOD, Department of Chemical Engineering and Polymer Science, Shahjalal University of Science and Technology (SUST), Bangladesh. His fields of research include membrane science and technology, water and wastewater treatment, structural material, polymer composites and renewable energy.

Md. Mostafizur Rahman received his BE (chemical engineering and polymer science) from Shahjalal University of Science and Technology, Bangladesh and is currently pursuing his PhD. He is presently a Research Engineer at Housing and Building Research Institute (HBRI), Bangladesh. His research interests include polymer modified concrete and composites materials.

Mainuddin Ahmed holds degrees in BSc (civil engineering) and MSc (civil engineering) from Bangladesh University of Engineering and Technology, Dhaka, Bangladesh. He is Director at HBRI, Bangladesh. His areas of interest include pre-stressed concrete technology, buckling behaviour of ferro-cement shell, spatial structure (large span), application of ferro-cement as appropriate technology in building industry and rehabilitation of old or damaged structures.