

Significance of Polymer Concrete and Mix Design Approach-Overview

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ABSTRACT: Polymer mortar possesses a unique combination of properties that depend upon the formulation. Mortar is a workable paste used to bind construction blocks together and fill the gaps between them. In this study the various polymer mortar mixture components and their effect on the properties are reviewed. The effect of resin content, aggregates, fillers was critically reviewed. Repair and restoration work of reinforced-concrete structures is increasing because of the deterioration of aging infrastructures and aggressive environmental condition worldwide. Polymer mortar by virtue of their high strength, excellent durability and easy processing has gained acceptance. The binder content in polymer mortar varies from five to fifteen percentages by weight of the mix. The aggregates are normally taken as inert materials dispersed throughout the polymer matrix. Ferro composites manufactured using polymer mortar are used for chemical storages, pipes, etc. A thin overlay of five mm can be applied on the top of the existing concrete and Ferro cement to improve its durability. Polymer mortar and concrete are related to new liquid resin such as polyester, epoxy as binding material with aggregates. The properties such as setting shrinkage, thermal properties, temperature dependence, lightweight are taken care in respect of lightweight, porous polymer mortar. In this paper the work in respect of polymer mortar so far analyzed is discussed in detail.

KEYWORDS: Composites, thermosetting, thermoplastic, filler, resin.

I. INTRODUCTION

Traditionally mechanical strength has been the major criterion in selection of building materials. Due to increasing chemical pollution, atmosphere has been added as aggressive environment. This has significantly contributed to building durability. Durability is the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environment and the properties desired. Concrete ingredients, their proportioning, interactions between them, placing and curing practices, and the service environment determine the ultimate durability and life of the concrete. Generally concrete gets attacked by chemicals which causes its deterioration. Concrete with compressive strength higher than 100MPa has been qualified as an exotic concrete. In reality, 80MPa to be the upper limit for practically available for Portland cement.

Polymer concrete, known also as resin concrete, is a constructional composite, a variation of concrete, in which traditional binder - cement, has been completely replaced with synthetic resins with a hardening agent and filler: mixture of sand-and-gravel and quartz powder. Binder of polymer concrete is crucial for improved strength in relation to ordinary concrete and particularly for chemical resistance. The weakest part of standard concrete - the hydraulic mineral binder was eliminated from polymer concrete. Polymer concrete is a part of concrete groups that uses polymers to supplement . The types include polymer-impregnated concrete, polymer concrete and polymer-Portland-cement concrete.

Polymers in concrete have been overseen by Committee 548 of the American Concrete Institute since 1971. In polymer concrete, thermosetting resins are used as the principal polymer component due to their high thermal stability and resistance to a wide variety of chemicals. Polymer concrete is also composed of aggregates that include silica, quartz, granite, limestone, and other high quality material. The aggregate must be of good quality, free of dust and other debris, and dry. Failure to fulfill these criteria can reduce the bond strength between the polymer

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binder and the aggregate. Polymer concrete may be used for new construction or repairing of old concrete. The adhesive properties of polymer concrete allow patching of both polymer and conventional cement-based concretes. The low permeability and corrosive resistance of polymer concrete allows it to be used in swimming pools, sewer structure applications, drainage channels, electrolytic cells for base metal recovery, and other structures that contain liquids or corrosive chemicals. It is specially suited to the construction and rehabilitation of manholes due to their ability to withstand toxic and corrosive sewer gases and bacteria commonly found in sewer systems. Unlike traditional concrete structures, polymer concrete requires no coating or welding of PVC-protected seams. It can also be used as a replacement for asphalt pavement, for higher durability and higher strength.

	Polymer concrete	M30 concrete
Compressive strength Rc [MPa]	80 - 110	30
Bending tensile strength Rg [MPa]	22 - 35	2 - 4
Splitting tensile strength Rr [MPa]	8 - 12	1.5 - 2
Abrasion resistance [cm]	0.1 – 0.2	0.6
Moisture absorption [mm]	0	4 - 8

Table 1. Comparison of properties of polymer concrete and traditional M30 class concrete

II. POLYMER

There are different types of commercial products available with a variety of formulations, some capable of hardening upto 105 MPa(15,000 psi) within a few minutes without thermal treatment. Epoxy resins are higher in cost but offer advantages such as adhesion to wet surfaces. Styrene monomer and methylmethacrylate (MMA) with benzoyl peroxide catalyst and an amine promoter are often used. Products with increased strength have been obtained by adding to the PC monomer system a silane coupling agent, which increases the interfacial bond between the polymer and aggregate.

III. POLYMER AND POLYMER BASED MATERIALS AND COMPONENTS

Composition of plastics-Plastics are a wide group of organic material based on natural or artificial high molecular compounds(polymer) that can be readily molded by preheating and pressing and retain the shapes they are given .In composition ,plastics are complex substances. Their chief components are binder (polymer) ,filler(organic or mineral powders, fibers, threads, cloths, sheets),plasticizers (which improves mouldability), curing accelerators and dyes which are introduced to manufacture of coloured plastics. Classification of plastics is based on their physical and mechanical properties, structure and behavior with respect to heating. By physical and mechanical properties all plastics are subdivided into plastics and elastomers. There are rigid, semi-rigid and soft plastics. Rigid plastics are hard amorphous elastic materials with a high modulus of elasticity (greater than 1000MPa) and a small elongation at rupture; they retain their shape under exterior stresses applied at normal or moderately increased temperature. Semi-rigid plastics are hard elastic material of crystalline structure with a medium modulus of elasticity (greater than 400MPa),high ultimate persisting elongations ,the latter completely disappearing at crystal melting point. Soft plastics are soft and elastic materials with a low modulus of elasticity (not higher than 20MPa),high ultimate and small persisting elongation ,the latter slowly disappearing at room temperature. Elastomers are soft and elastic materials with a low modulus of elasticity (lower than 20MPa), which lend themselves to considerable deformation in tension ,this deformation disappearing rapidly at room temperature.

By structure of the polymer chain ,polymer are divided into carbon chain (composed only of carbon atoms) and heterogeneous chain (composed of carbon and oxygen ,nitrogen and other elements as well).By structure of plastics are divided into homogeneous and heterogeneous varieties. Structure of plastic is much affected by components other than

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polymers. This allows to sub classify plastics into no-filler, expanded, filler and composite varieties. No-filler plastics consist of a polymer, sometimes a dye ,a plasticizer and a stabilizer. Expanded plastics consist of the above materials of air or gas filled cells produced by gas forming or air entraining substances. Constructional plastic materials and items are mostly made from filler plastics composed of a polymer and filler. These are powder, fibrous and laminated fillers. Powder fillers are quartz powder, chalk, barite, talcum and organic substances (ground sawdust)-provide plastics with valuable properties (heat resistance, acid resistance etc) and also improves hardness, increase durability, reduce costs. Fibrous fillers-asbestos, wood and glass fibers are widely used in manufacture of plastics; they increase strength, reduce brittleness and enhance thermal resistance and impact strength of plastic. Laminated fillers are paper, cotton and fibers glass cloths, asbestos cardboard, wood veneer and others make plastics very strong. For instance, asbestos, cardboard provides not only a high mechanical strength but heat and acid resistance. Fillers are much cheaper than polymers. Therefore the greater the amount of filler, the cheaper is plastic. With respect to heating plastics are subdivided into thermoplastic and thermosetting varieties. Thermoplastic materials such as polyethylene, polyvinylchloride, polystyrene and others soften and become plastic when heated but harden again after cooling. These materials can be used to cast, draw and stamp various items. Their shortcomings are chiefly low mechanical strength and heat resistance. Thermosetting plastics change when heated into infusible and insoluble solid products and irreversibly lose their ability to soften. These materials possess high heat resistance and include aminoplasts and plastic based on polyester and epoxy resins.

IV. PROPERTIES OF POLYMER CONCRETE

Using resins instead of traditional binder helps in obtaining better properties such as high chemical resistance to many corrosive chemical substances or high mechanical strength. In case of ordinary concrete, the strength properties of cured cement paste is several times lower than the corresponding features of the mother rocks of the aggregate, and the adhesion of binder-and-aggregate is relatively small. The situation is different in case of resin concretes: the tensile strength of hardened resin binder is much higher, and the compressive strength is similar to the strength of the rocks from which the aggregate was obtained. The advantages of polymer concrete are particularly noticeable when comparing its individual properties to traditional concrete.

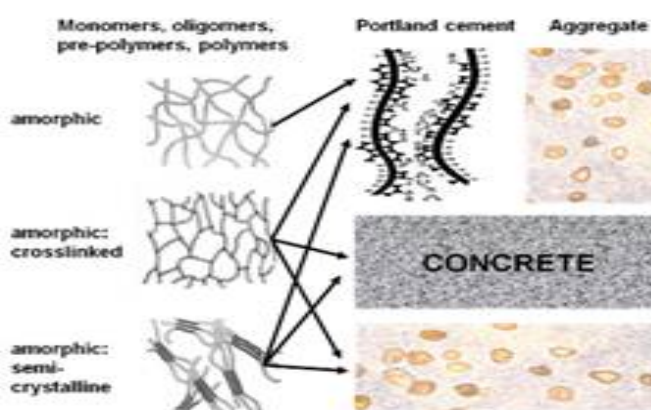


Fig 1 Cement-Polymer Composite

Due to its properties, polymer concrete is nowadays used in many applications such as production of prefabricated products for bridge drainage system (bridge edge beams, bridge kerbs, bridge drainage inlets, gutters), production of prefabricated products for linear drainage systems (channels, linear drainage channels, linear drainage silt boxes).production of industrial tanks, intended for electrolysis of non-ferrous metals, production of catch basins and channels to drain aggressive industrial wastewater, water meter chambers, sewage pump stations, production of storage

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tanks to store corrosive substances, e.g. acids, bases, execution of chemical resistant cladding as chemical resistant coats made of laminates or resin composites

Requirement	Unit	Required value
Compressive strength Rc	MPa	Not less than 90
Bending tensile strength Rg	MPa	Not less than 22
Splitting tensile strength Rr	MPa	Not less than 8
Apparent density of resin concrete	kg x m ⁻³	On average 2300
Poisson's coefficient	--	0.16 – 0.30

Table. 2. Physical properties of polymer concrete

V. MIX DESIGN APPROACH

The development of a mix design method for polymer concrete mixes with a principal focus on compressive strength. The method is based on the hypothesis that the overall strength of polymer concrete depends on the strength of the binder materials, the packing density of the aggregates in the mortar and the amount of binder. First, the strength of the binder was evaluated experimentally. Fly ash, calcium carbonate, ground granulated blast-furnace slag were used as the main ingredients in the production of the polymer concrete. Correlation between the packing density of the aggregates in the mortar and their influence on the binder demand and compressive strength are compared. Finally, a conceptual framework for a mix design approach with minimum polymer and maximum strength. In addition to describing the mortar mix design methodology in a rational way, it is hypothesized that the approach can also be extended to the development of a polymer concrete mix.

VI. POLYMER BASED BUILDING MATERIALS AND COMPONENTS

Polymer based building materials are sub divided into floor materials ; materials for interior finishing of walls ceilings and built-infurniture; materials for structural components; miscellaneous slender and tubular building items; synthetic glues and mastics; heat and sound insulating materials; roof, waterproofing and ceiling materials: sanitary equipment, pipeing and fittings: synthetic varnishes and paints. Present day polymer mortars are also developed according to their end useses especially for chemical resistance applications.

VII. DEVELOPMENT OF POLYMER MORTAR AND ITS COMPOSITES

1. M Neelamegam,VS Parameswaran and JK Dattatreya discussed the process technology and performance evaluation of glass fiber reinforced resin mortar products. GFRRM has very good mechanical and durability properties. Resistance of GFRRM to abrasion is higher than normal concrete/mortar. Resin mortar was prepared by resin and filler as one part fine aggregate four parts fiber was varied from 0 to 4% . GFRRM hollow columns with 2% glass fibre in filled with mortar can support additional axial load up to 25% and undergo less axial deformation compared with normal hollow columns. Bond strength for GFRRM pipe lin ears on concrete and steel pipes was around 1.1-1.3MPa.GFRRM pipes of 170mm diameter and 20mm thickness are able to sustain 300-400% higher load compared to unreinforced plain concrete pipes under the three edge bearing test.
2. M Neelamegam, Y.Ohama , K.Demura,S Suzuki and A.Shirai discussed about the polymer mortar composite matrices as candidate material for maintenance free high durable ferrocement. Ferrocement is used in much

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application such as tanks, irrigational structures marine structures but cement mortar used in ferrocement will not withstand high aggressive and temperature variation. Polymer mortar can be used on the ferrocement as a thin overlay to protect from attack. Polymer overlay can be of epoxy or polyester, polymer impregnated mortar, latex modified cement mortar on dried ferrocement surface. The mechanical properties of polymer – impregnated mortar matrix namely, compressive, splitting tensile, direct tensile and flexural strength are improved about 3 to 4 times over those of ordinary cement mortar matrix. In PIFC and FC flexural tests, the ultimate composite stresses are increased with increased main reinforcement percentages. The ductility and the number of cracks are slightly increased by increasing the main reinforcement percentage of PIFC and FC. The cracking composite stresses in flexural and direct tension of PIFC are improved 3 to 4 times over those of FC.

3. Y.S.Soh, H.S Park and Y.K.Jo studied on effect of filler on the mechanical properties of unsaturated polyester resin mortar. Fillers such as ground calcium carbonate, silica powder and fly ash were used as polymeric binders. The matrix was prepared using different filler contents and tested for compression, flexural, direct tension and splitting tensile strength. The results shows that the strength of matrix and mortar decreases with increasing filler content. Filler content 50% gives higher strength. The direct tensile and splitting strength of mortar with filler content 70% is about one-sixth and one-third for filler content 60%. So maximum filler content is limited to 60% for strength. Among the three fly ash gave the maximum compressive strength of 109.00 MPa.
4. R.S.Salunke studied the epoxy resin as a solution to structural repair and rehabilitation problems in civil engineering. The compressive strength of epoxy mortar was determined as 90N/mm^2 and tensile strength as 16N/mm^2 with flexural strength as 45N/mm^2 . Epoxy mortar was used for the repair of underwater structures, archaeological monuments etc. The bond between the old concrete and new epoxy mortar is very high.
5. T.Sundararajan and P.Ravikumar studies on the strength and other properties of materials using cashew nut shell liquid (CNSL) resin. The potential of CNSL resin as a binder in various forms of materials has been studied. CNSL based compressed earth block stabilises red soil and improves physical properties. Irrespective of the filler material water absorption is very less than conventional clay bricks. Increase in CNSL resin content even for a constant water-cement ratio for polymer – modified concrete as the excess of requirement to coat the fine aggregate in polymer reduces the compressive strength due to inadequate curing as oxidation is the process involved in room temperature curing. The compressive strength of CNSL based polymer mortar depends on the gradation of fine aggregate, type of microfiller, content of resin and microfillers and mix proportioning approach. Flyash can be used as a microfiller, whereas crusher dust can be used as both fine aggregate and microfiller in polymer mortar. Use of crusher dust as a microfiller reduces the requirement of CNSL resin for polymer mortar, even though there is no substantial variation in the compressive strength of polymer mortar based on the two microfillers.
6. M.Aamer Rafique examines about the flexural behaviour of polymer mortar permanent forms using methyl methacrylate solution of waste expanded polystyrene. The maximum deflection and flexural toughness of the (EPS-MMA) expanded polystyrene-methyl methacrylate based polymer modified permanent forms (PMPF) was twice larger than polymer impregnated mortar permanent forms (PIMPF) and flexural modulus of elasticity of PMPFs is almost half of that of the PIMPF. Ductility of PMPF is more for high load bearing capacity.

VIII. CONCLUSION

The development of polymer mortar is starting from the plastic and polymers. Plastic have high modulus of elasticity starting from soft, semi rigid and rigid plastic.

Plastics have lots of valuable physical and mechanical properties. Density is $10\text{--}2200\text{Kg/m}^3$. The plastics with powder and fibrous fillers have a compressive strength of $120\text{--}200\text{MPa}$ and a bending strength upto 200MPa . Tensile strength of plastics with sheet form fillers may be as high as 150MPa and that of fiberglass anisotropic material $480\text{--}950\text{MPa}$. The strength to bulk density ratio of plastic is very high.

Based on the above properties of plastic it is possible to develop polymer mortar nearer to physical and mechanical properties of plastics. The compressive strength of 109.0MPa , tensile strength of 16MPa , flexural

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strength of 45MPa are reported. This paper focuses on the development of new material based on polymer mortar in respect of construction industry.

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