Chapter 22: Special Concrete and Concreting Methods – Polymer-Modified Concrete

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Introduction

Concrete, being the most widely used construction material, is constantly evolving to meet modern construction challenges such as durability, chemical resistance, quick setting, and high strength. One significant advancement in this direction is **Polymer-Modified Concrete (PMC)**. By integrating polymers into the concrete mix, we achieve a material that exhibits superior bonding strength, reduced permeability, enhanced durability, and excellent resistance to chemical attacks. This chapter discusses in detail the types, mechanisms, mix design, preparation methods, properties, advantages, and applications of polymer-modified concrete.

22.1 What is Polymer-Modified Concrete?

Polymer-Modified Concrete (PMC) is concrete that incorporates polymers, either in latex (liquid) or redispersible powder form, into the mix to enhance certain properties. These polymers form a co-matrix with hydrated cement that fills capillaries and micro-cracks, improving the physical and mechanical performance of the concrete.

Key Features:

- Improved bond strength with substrates
- Higher tensile and flexural strength
- Greater impermeability and chemical resistance
- Better adhesion to various surfaces
- Reduced shrinkage and cracking

22.2 Types of Polymers Used in Concrete

The performance of PMC largely depends on the type of polymer used. Common polymers include:

a. Styrene-Butadiene Rubber (SBR) Latex

- Enhances water resistance and flexibility
- Common in overlays and waterproofing applications

b. Acrylic Polymers (PMMA, PAE, etc.)

- High UV resistance
- Used in architectural finishes and precast panels

c. Epoxy Resins

- Excellent bonding properties
- Used in repair and restoration

d. Polyvinyl Acetate (PVA)

- Improves workability and bonding
- Commonly used in plasters

e. Vinyl Acetate-Ethylene (VAE)

- Improves freeze-thaw resistance
- Preferred for exterior applications

f. Redispersible Polymer Powders

- These are dry forms of polymers that re-disperse when mixed with water
- Used in dry-mix products like tile adhesives, repair mortars, etc.

22.3 Mechanism of Polymer Action

When polymer is added to concrete:

1. **Hydration of Cement:** The cement hydrates as usual, forming calcium silicate hydrate (C–S–H) gel.
2. **Polymer Co-matrix Formation:** As water evaporates, polymers coalesce and form a continuous film or co-matrix throughout the concrete.
3. **Pore Blocking:** This polymer film blocks pores and microcracks, enhancing impermeability.
4. **Interface Improvement:** It strengthens the transition zone between the cement paste and aggregates, improving bond strength.

This dual matrix—cementitious and polymeric—provides superior mechanical and durability characteristics.

22.4 Mix Design for Polymer-Modified Concrete

Mix design must account for the interaction between the cementitious and polymeric components. A general guideline:

Component	Typical Range
Cement	300 – 500 kg/m^3
Polymer (latex)	10 – 20% by wt. of cement
Water	Adjusted to maintain w/c ratio (0.35–0.5)
Fine Aggregates	600 – 800 kg/m^3
Coarse Aggregates	1000 – 1200 kg/m^3
Additives (e.g., silica fume, fly ash)	Optional depending on purpose

Important Considerations:

- Water-to-cement ratio must be carefully maintained.
- Overdosing polymer may retard setting and increase cost.
- Compatibility between polymer and other admixtures must be verified.

22.5 Properties of Polymer-Modified Concrete

Property	Performance Enhancement
Compressive Strength	Comparable or slightly improved
Flexural Strength	Significantly higher than normal concrete
Bond Strength	Highly improved
Water Permeability	Greatly reduced
Abrasion Resistance	Enhanced due to tough polymer matrix
Freeze-Thaw Resistance	Superior due to low porosity
Chemical Resistance	Excellent against acids, chlorides
Shrinkage and Cracking	Reduced due to flexible polymer matrix

22.6 Preparation and Placement Methods

a. Surface Preparation

- Surface must be clean, roughened, and saturated surface dry (SSD).
- Remove dust, grease, or laitance before placement.

b. Mixing

- Add polymer latex to mixing water.
- Mix aggregates and cement first, then add polymer water mix.
- Mixing should be done for at least 3–5 minutes for homogeneity.

c. Placing and Finishing

- Use conventional placing methods.
- Troweling and screeding should be done promptly.
- Finishing should be completed before polymer starts to set.

d. Curing

- Moist curing may not be necessary as polymer acts as a curing membrane.
- Air curing at ambient temperature is often recommended.
- For some polymers, protective coverings are advised for first 24–48 hours.

22.7 Applications of Polymer-Modified Concrete

1. Repair and Rehabilitation

- Used in patch repairs, overlays, and jacketing of structural elements.
- Excellent adhesion to old concrete ensures long-term durability.

2. Industrial Flooring

- High abrasion resistance and chemical tolerance make it ideal for factories, food processing plants, etc.

3. Waterproofing Structures

- Used in basements, water tanks, swimming pools, etc., due to its impermeable nature.

4. Architectural Finishes

- Acrylic-based PMC provides aesthetically superior finishes with color stability.

5. Bridge Deck Overlays

- Used in bridge decks exposed to de-icing salts and extreme weathering.

6. Marine and Coastal Construction

- Enhanced resistance to chlorides and sulfates makes it suitable for marine piers and jetties.

22.8 Advantages of Polymer-Modified Concrete

- **Improved durability** under harsh environmental conditions
- **Excellent bonding** with substrates, ideal for repair works
- **Lower maintenance costs** over the structure's lifespan
- **Higher early strength**, allowing faster project turnaround
- **Flexibility** in formulation for different end-uses

22.9 Limitations of Polymer-Modified Concrete

- **Cost**: Polymers are expensive compared to traditional admixtures.
- **Storage Sensitivity**: Latex polymers are sensitive to temperature and may spoil.
- **Skill Requirement**: Requires trained personnel for mixing and placement.
- **Incompatibility Risk**: Some polymers may react adversely with cement or other admixtures if not properly selected.

22.10 Recent Advancements in Polymer Concrete Technology

- **Nanopolymer-modified concrete** for ultra-high strength applications
- **Self-healing PMC** using microencapsulated polymer agents
- **Recycled polymer waste** being used as eco-friendly concrete additives
- **Hybrid PMC Systems** combining fibers and polymers for enhanced performance in seismic zones.

22.11 Comparison with Other Special Concretes

It is important to compare Polymer-Modified Concrete (PMC) with other advanced or special concretes to understand its unique advantages and potential limitations.

Type of Concrete	Key Feature	Compared to PMC
High-Performance Concrete	High strength, low permeability	PMC offers better adhesion and flexibility
Fiber-Reinforced Concrete	Crack resistance via discrete fibers	PMC + fibers offer synergy in performance
Self-Compacting Concrete	Flows without vibration	PMC may require vibration unless modified
Lightweight Concrete	Reduced density	PMC typically does not reduce weight
Sulphur Concrete	Used in extreme chemical environments	PMC is more flexible in application
Geopolymer Concrete	Cement-free, eco-friendly	PMC is still cement-dependent

22.12 Durability Studies and Long-Term Performance

Several studies have shown that PMC outperforms conventional concrete in terms of durability over long-term exposure.

22.12.1 Chloride Penetration Resistance

- PMC reduces chloride ingress due to lower porosity.
- Extends lifespan of reinforced structures exposed to marine or de-icing conditions.

22.12.2 Carbonation Resistance

- Polymer content forms a continuous matrix that slows down CO_2 diffusion.
- Protects steel reinforcement from corrosion.

22.12.3 Sulfate Attack Resistance

- PMC performs better in sulfate-rich environments compared to normal OPC concrete.
- Polymers prevent sulfate ions from penetrating the concrete matrix.

22.13 Bond Strength with Existing Concrete and Steel

One of the most important properties of PMC is **its superior bond strength**, which is critical for:

- Structural retrofitting
- Overlay systems
- Composite structural members

22.13.1 Bond with Old Concrete

- Latex-modified concrete exhibits tensile bond strength >1.5 MPa.
- Surface preparation enhances bond effectiveness.

22.13.2 Bond with Reinforcement Steel

- Polymer-modified mortar shows improved grip due to better microstructure.
- Reduces risk of corrosion initiation by blocking moisture ingress.

22.14 Guidelines and Standards

Various international and national bodies have recognized and developed guidelines for the use of PMC:

22.14.1 ACI Guidelines

- ACI 548.3R – Guide for Polymer-Modified Concrete
- ACI 503R – Use of Epoxy Compounds

22.14.2 BIS Standards (India)

- IS 9112: Specification for polymer-modified bitumen emulsion
- IS 2645: Integral waterproofing compounds – relevant to PMC mix design

22.14.3 ASTM Standards

- ASTM C1059 – Latex agents for bond improvement

- ASTM C881 – Epoxy resins for structural use

22.15 Environmental Impact and Sustainability Aspects

While polymer addition can improve performance, sustainability must also be considered:

Positive Impacts:

- Increased durability reduces need for frequent repair
- Low permeability cuts down long-term maintenance and material use
- Less material usage due to thinner overlays or sections

Concerns:

- Some synthetic polymers are derived from petroleum-based sources
- Polymer disposal and microplastic leaching concerns
- Energy-intensive manufacturing of latexes

Solutions:

- Use of **bio-based polymers** (e.g., lignin, chitosan, natural latex)
- **Recycled plastics and waste polymer emulsions** as additives

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22.16 Case Studies and Field Applications

Case Study 1: Bridge Deck Overlay – USA

- **Material Used**: SBR-modified concrete
- **Result**: Increased lifespan by 20+ years with minimal maintenance

Case Study 2: Waterproofing of Rooftop Terraces – India

- **Material Used**: Acrylic polymer-modified mortar
- **Result**: Zero leakage for 10+ years despite monsoon exposure

Case Study 3: Repair of Industrial Floor in Chemical Plant – Germany

- **Material Used**: Epoxy-modified repair concrete
- **Result**: Resistance to acids and solvents, no spalling for over a decade

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22.17 Future Directions in PMC Research

Emerging research is focused on pushing the performance limits of PMC:

- **Self-sensing PMC**: Using conductive polymers for crack detection
- **Nano-polymer composites**: Addition of nanoclays or nanosilica for superior strength
- **3D printable PMC**: Development of printable, rapid-set mixes for prefabs
- **Photocatalytic PMC**: Capable of reducing urban air pollution (NOx degradation)
