Chapter 4: Chemical Admixtures

Introduction

Concrete is a widely used construction material due to its strength, durability, and adaptability. However, achieving the desired performance characteristics in different environments often requires modifications to its fresh and hardened properties. This is where **chemical admixtures** play a pivotal role.

Chemical admixtures are ingredients in concrete, other than Portland cement, water, and aggregates, that are added to the mix immediately before or during mixing. They enhance or modify the properties of concrete to improve workability, accelerate or retard setting time, reduce water content, increase strength, or impart other desirable properties.

Their use has become essential in modern concrete technology for achieving specific performance targets, reducing cost, and ensuring sustainability in construction practices.

4.1 Classification of Chemical Admixtures

Chemical admixtures are broadly classified based on their function in the concrete:

1. Water-reducing Admixtures (Plasticizers)

- **Purpose**: Reduce water content without affecting workability or increase workability without changing water content.
- **Types**:
  - **Normal water reducers**: Reduce water by up to 10%.
  - **High-range water reducers (Superplasticizers)**: Reduce water by 12–30%.
- **Examples**: Lignosulfonates, Polycarboxylate ethers (PCE), Sulfonated naphthalene formaldehyde (SNF), Sulfonated melamine formaldehyde (SMF).
- **Effects**:

   - Increased strength.
   - Improved workability and flow.
   - Reduced segregation and bleeding.

2. Retarding Admixtures

- **Purpose**: Delay the setting time of concrete to allow for longer transportation, placing, or to prevent cold joints.
- **Applications**: Hot weather concreting, mass concrete works, ready-mix concrete.
- **Common retarders**: Gypsum, sugar, lignosulfonates, tartaric acid.
- **Precaution**: Overuse may lead to excessive delay in setting and reduced early strength.

3. Accelerating Admixtures

- **Purpose**: Accelerate the setting and early strength development of concrete.
- **Types**:
   - **Set accelerators**: Reduce setting time.
   - **Hardening accelerators**: Increase rate of strength gain.
- **Applications**: Cold weather concreting, precast industry, repair works.
- **Common accelerators**: Calcium chloride (not used for reinforced concrete due to corrosion risk), calcium nitrate, triethanolamine.

4. Air-Entraining Admixtures

- **Purpose**: Introduce microscopic air bubbles into the concrete.
- **Benefits**:
   - Improved freeze-thaw resistance.
   - Enhanced workability.
   - Reduced bleeding and segregation.
- **Air-entrainers**: Natural wood resins, vinsol resin, synthetic detergents, fatty acid salts.
- **Typical air content**: 4–8% by volume of concrete.

5. **Superplasticizers (High Range Water Reducers)**

- **Function**: Significantly increase flow of concrete at low water-cement ratio.
- **Use cases**: Self-compacting concrete (SCC), high-performance concrete (HPC), pumped concrete.
- **Families**:
  - Polycarboxylate ethers (PCE): Modern, highly efficient.
  - Sulfonated melamine/formaldehyde and naphthalene-based products: Traditional superplasticizers.

6. **Shrinkage-reducing Admixtures (SRA)**

- **Purpose**: Minimize drying shrinkage and cracking.
- **Applications**: Slabs, bridge decks, industrial floors.
- **Mechanism**: Reduce surface tension of pore water.

7. **Corrosion-inhibiting Admixtures**

- **Purpose**: Protect reinforcement steel from corrosion, especially in chloride environments.
- **Examples**: Calcium nitrite, sodium benzoate, zinc phosphate.
- **Use**: Coastal structures, bridges, parking garages.

8. **Waterproofing Admixtures**

- **Purpose**: Reduce permeability of concrete.
- **Types**:
  - Pore-blocking type: Talc, silicates.
  - Water-repelling type: Stearates, fatty acids.
- **Application**: Basements, water tanks, tunnels.

9. **Bonding Admixtures**

- **Function**: Improve adhesion between old and new concrete layers.
- **Common types**: Latex emulsions (SBR, Acrylics), epoxy-based admixtures.

10. **Grouting and Pumping Aids**

- **Purpose**: Improve pumpability and reduce bleeding.
- **Use**: Tremie concreting, grout injection, underwater concreting.

4.2 Mechanism of Action

Chemical admixtures affect the hydration process and interaction between cement particles:

- **Water reducers** work by dispersing cement particles, reducing water demand.
- **Retarders** interfere with the formation of calcium silicate hydrates (C-S-H), delaying set.
- **Accelerators** promote rapid hydration, especially of C_3A and C_3S phases.
- **Air-entrainers** trap air during mixing due to surface-active agents forming stable bubbles.
- **Superplasticizers** neutralize surface charges, allowing cement grains to repel each other and disperse better.

4.3 Factors Influencing Admixture Performance

Several variables affect how admixtures behave in concrete:

- **Cement composition** (e.g., C_3A content).
- **Water-cement ratio**.
- **Temperature and humidity**.
- **Mixing time and method**.
- **Compatibility between admixture and cement**.
- **Dosage**: Under- or over-dosing may lead to poor performance or side effects like delayed setting or segregation.

4.4 Compatibility of Admixtures

Using more than one admixture requires checking for compatibility:

- **Examples of incompatibility**:
    - Retarder + superplasticizer may excessively delay set.
    - Air-entrainer + water reducer may alter air content unpredictably.
- **Testing**: Compatibility tests such as Marsh cone test, slump retention, and setting time are essential before site use.

4.5 IS Codes and Standards for Admixtures

- **IS 9103**: Specification for concrete admixtures.
- **ASTM C494**: Standard specification for chemical admixtures in concrete.
- **IS 456:2000**: Code of practice for plain and reinforced concrete (includes admixture guidance).
- **IS 2645**: For integral waterproofing admixtures.

4.6 Dosage and Addition Procedure

- **Dosage**:
  - Must be based on manufacturer's recommendation and trial mixes.
  - Usually expressed as a percentage by weight of cementitious materials (typically 0.2% to 2%).
- **Method of addition**:
  - Can be added directly to mixing water or introduced separately during batching.
  - Ensure uniform distribution through thorough mixing.

4.7 Effects on Properties of Concrete

Property	Effect of Admixtures
Workability	Increased by water reducers, superplasticizers
Setting time	Retarders delay; accelerators reduce
Strength	Water reducers and accelerators enhance early and final strength
Durability	Air-entrainers improve freeze-thaw resistance
Permeability	Reduced by waterproofing admixtures
Corrosion Resistance	Enhanced by corrosion inhibitors

4.8 Precautions in Use

- Ensure compatibility with cement and other admixtures.
- Conduct trial mixes for dosage optimization.
- Store admixtures properly to avoid degradation.
- Follow manufacturer's instructions and relevant IS codes.

4.9 Recent Developments in Chemical Admixtures

The concrete industry is witnessing rapid advancements in admixture technology aimed at sustainability, efficiency, and performance:

a) Polycarboxylate Ether (PCE)-Based Superplasticizers

- Third-generation superplasticizers.
- Provide excellent slump retention at very low water-cement ratios.
- Widely used in **self-compacting concrete (SCC)**, **high-performance concrete (HPC)**, and **ultra-high-performance concrete (UHPC)**.
- Environmentally friendly due to reduced cement usage.

b) Viscosity Modifying Admixtures (VMAs)

- Used in SCC to enhance cohesion and stability.
- Reduce segregation and bleeding without affecting flow.
- Important in underwater concreting and tremie applications.

c) Self-Healing Admixtures

- Release healing agents such as calcium carbonate or bacterial spores when cracks occur.
- Extend concrete durability and reduce maintenance.

d) Nano-Modified Admixtures

- Incorporate nano-silica or carbon nanotubes to improve microstructure and strength.
- Offer potential for crack resistance and superior durability.

e) Low-Carbon Admixtures

- Designed to reduce carbon footprint by reducing cement requirements and enhancing early strength.

4.10 Admixtures in Special Concretes

Admixtures are tailored to meet the requirements of specialized concretes used in advanced construction:

1. **Self-Compacting Concrete (SCC)**

- Requires:
    - High-range water reducers (PCE).
    - VMAs to prevent segregation.
    - Air-entrainers to improve flow and reduce resistance.

2. **High-Performance Concrete (HPC)**

- Uses combinations of:
    - Superplasticizers.
    - Shrinkage reducers.
    - Silica fume or mineral admixtures (covered in Chapter 5).
    - Corrosion inhibitors for reinforced concrete in marine environments.

3. **Shotcrete**

- Accelerating admixtures are critical to achieve fast setting.
- Plasticizers improve pumpability.

4. **Mass Concrete**

- Retarders used to control heat of hydration and avoid thermal cracking.
- SCMs (like fly ash or slag, discussed in Chapter 5) also aid temperature control.

4.11 Field Applications and Case Studies

a) **Bridge Construction in Coastal Zones**

- Use of corrosion-inhibiting admixtures (e.g., calcium nitrite) to protect rebar from chloride attack.
- Air-entraining agents enhance durability under salt exposure.

b) **Metro and Tunnel Projects**

- Superplasticizers reduce water content for high-strength, pumpable concrete.

- Waterproofing admixtures used in lining segments to prevent leakage.

c) **Cold Weather Concreting**

- Accelerators like triethanolamine used to achieve early strength despite low temperatures.
- Retarders avoided to prevent freezing before set.

d) **Hot Weather Concreting**

- Retarders extend setting time and help place and compact concrete before initial set.
- Air-entrainers reduce evaporation and improve finish.

4.12 Testing of Chemical Admixtures

Proper testing ensures safe and effective use of admixtures:

Test	Standard	Purpose
Setting Time	IS 4031 (Part 5) / ASTM C403	To assess delay or acceleration effects.
Slump Test	IS 1199 / ASTM C143	To evaluate workability.
Air Content	IS 1199 / ASTM C231	For air-entraining admixtures.
Compressive Strength	IS 516 / ASTM C39	To check strength enhancement or loss.
Compatibility	Marsh cone, mini-slump	To test with different cements.

4.13 Storage and Handling

- **Storage conditions**: Cool, dry place away from direct sunlight.
- **Shelf life**: Most admixtures have a shelf life of 6–12 months.
- **Packaging**: Available in liquid or powder form; packed in sealed drums, cans, or bags.
- **Mixing precautions**:

    - Stir well before use.
    - Avoid contamination between admixtures.
    - Use clean water and equipment.

4.14 Environmental and Safety Considerations

- Some admixtures may be **toxic** or **hazardous**, especially older types like **calcium chloride**.
- **Safety gear**: Gloves, goggles, and proper ventilation must be ensured during handling.
- **Eco-friendly alternatives**: Modern PCEs and bio-based admixtures are less harmful and more sustainable.
- **Disposal**: Follow local environmental laws; avoid releasing into drains or soil.

4.15 Limitations of Chemical Admixtures

While highly beneficial, admixtures also have limitations:

- **Cost**: Some admixtures significantly increase concrete cost.
- **Overdosing risk**: Can cause flash set, excessive retardation, or loss of strength.
- **Compatibility issues**: Require testing with local materials.
- **Misuse**: Blind use without understanding may lead to construction failures.
