Topic 13 CONCRETE WITH TAILORED PROPERTIES

High Performance Concrete (HPC)

High-performance concretes are made with carefully selected high-quality ingredients and optimized mixture designs; these are batched, mixed, placed, compacted and cured to the highest industry standards. Plasticizers are usually used to make these concretes fluid and workable.

Features of High-Performance Concrete

• Compressive strength > 80 MPa ,even up to 800 MPa

• High-performance concrete is quite brittle but the introduction of fibers and can improve ductility.

• Water binder ratio (0.25-0.35), therefore very little free water

• Densified cement paste, Low bleeding and plastic shrinkage and Discontinuous pores So it is highly durable.

• Stronger transition zone at the interface between cement paste and aggregate.

Material used in HPC

Materials Used in High-Performance Concrete

Material	Primary contribution/Desired property
Retarders	Control setting
Accelerators	Accelerate setting
Corrosion inhibitors	Control steel corrosion
Water reducers	Reduce cement and water content
Shrinkage reducers	Reduce shrinkage
ASR inhibitors	Control alkali-silica activity
Optimally graded aggr.	Improve workability/reduce paste
Polymer/latex modifiers	Durability

Characteristics High Performance Concrete

• High strength

• High early strength

• High modulus of elasticity

• High abrasion resistance
• High durability and long life in severe environments
• Low permeability and diffusion
• Resistance to chemical attack
• High resistance to frost and deicer scaling damage
• Toughness and impact resistance
• Volume stability
• Ease of placement
• Compaction without segregation
• Inhibition of bacterial and mold growth

Applications of HPC in Civil Engineering Constructions

• High Rise Structures
• Bridges
• Highway Pavements
• Hydropower Structures
• Miscellaneous Applications (Steel fibers can be added to high-performance concrete to improve mechanical properties such as dynamic and static tensile strength, energy abrasion and toughness, and fatigue resistance.)

Advantages of HPC

• Ease of placement and consolidation without influencing strength.
• Reduce the size of structural members which lead to the increase of usable area. Consequently, concrete volume is cut.
• The size of structural members like beams and columns are reduced since smaller sections are enough to carry high loads.
• Reduction in the thickness of floor slabs and supporting beam sections which are a major component of the weight and cost of the majority of structures.
• The reduction in smaller structural members such as beams, columns, and slabs lead to the decline in self-weight and super-imposed dead load. As a result, smaller foundation size is needed which reduce the cost significantly.
• Higher seismic resistance compares with conventional concrete.
• High abrasion resistance

• Formwork area and its cost are reduced.

• Shoring and stripping time is decreased because of high early strength gain of high performance concrete.

Advantages of HPC

• Construction of high rise buildings with the accompanying savings in real estate costs in congested areas.

• Longer spans and fewer beams for the same magnitude of loading. That is why the use of high performance concrete in bridge construction is inevitable.

• Reduced axial shortening of compression supporting members.

• Number of supports and hence foundations are reduced due to the ability of high performance concrete to span for longer distances.

• Increase life span of the structure in severe environments

• Superior long-term service performance under static, dynamic and fatigue loading.

• Low creep and shrinkage.

• Greater stiffness as a result of a higher modulus.

• High resistance to freezing and thawing, chemical attack, significantly improve long-term durability, and crack propagation.

• Reduced maintenance and repairs.

• Smaller depreciation as a fixed cost.

Differences Between High-Strength and High-Performance Concrete

High-strength concrete is defined based on its compressive strength (55MPa or higher) at a given age whereas high-performance concrete is defined based on performance criteria namely: high durability, high strength, and high workability.

The use of high-performance concrete has overcome many problems observed in conventional concrete like less durability, weaker transition zone (aggregate-cement interface), low resistance to chemical attack and difficulty in repair and retrofitting works.

High strength concrete has been used in the construction of many structures to decrease the size of members, reduce dead load, and decline cost and construction materials.

Items	High-Performance Concrete	High-Strength Concrete
Definition	High-performance concrete is defined as concrete meeting special combinations of	High strength concrete is defined as concrete that has

	performance and uniformity requirements that cannot always be achieved routinely when using conventional constituents and normal mixing, placing and curing practices, as per ACI Code.	compressive of 55 MPa or greater.
Types	Chemical resistant concrete, early drying concrete, ultra-water resistant concrete, heat resistant concrete, and impact and abrasion resistant concrete.	High-Strength Concrete (50 – 100 MPa), ultra-High Strength Concrete (100 – 150 MPa), especial Concrete (> 150 MPa)
Strength criteria	High strength, modulus of elastic, low creep and shrinkage	It has high strength but does not necessarily possess superior characteristic as high-performance concrete
Durability criteria	Resist scaling, freezing and thawing, chloride and carbonation, and prohibit bacterial and mold growth	Durability of high strength is commonly improved by adding pozzolanic materials
Ductility	Low ductility but can be improved by adding steel fibers	It is brittle
Compositions	Cement, fine aggregate, coarse aggregate, water, mineral admixtures; fine filler and/or pozzolanic supplementary cementation materials, chemical admixtures; plasticizers, superplasticizers, retarders, air-entraining agents)	Cement, fine and coarse aggregate; fine aggregates with higher fineness modulus of around 3 is recommended, water, water reducing admixtures
Degree of quality control requirements	It is sensitive to changes in constituent material properties, hence great degree of quality control is required for the successful production of high-performance concrete.	High quality control is needed in order to maintain the special properties desired.
Production of concrete	High-performance concrete is produced by careful selection of raw materials such chemical admixtures and appropriate mix	High-strength concrete is achieved at low water to cement ratio which is obtained by

	design to achieve the desired performance objectives.	adding water reducing plasticizer or high range water reducing plasticizer. It is also essential to select a high-quality Portland cement, and optimize aggregates, then optimize the combination of materials by varying the proportions of cement, water, aggregates, and admixtures.
Placement and compaction	Easy to pour and can be compacted without segregation.	Placement would not be easy unless superplasticizer is used
Advantages	Already Mentioned in slide.	Reduce maintenance and repair, decline size of members and cost of formworks, allow longer spans in bridge and hence decrease number of vertical supports, and permits construction of thinner slabs.
Disadvantages	Need extensive quality control, costly, need special constituents, and need to be manufactured and placed careful.	Low resistance to fire i.e. damage at high temperature, and need great expertise in selection of constituents.
Applications	Already Mentioned in slide.	High rise buildings, bridges with long spans, and high load carrying buildings built on weak soil.

Self Compacting Concrete (SCC)

Self-compacting concrete (SCC), also referred to as self-consolidating concrete, is able to flow and consolidate under its own weight. At the same time, it is cohesive enough to fill spaces of almost any size and shape without segregation or bleeding. This makes SCC particularly useful wherever placing is difficult, such as in heavily reinforced concrete members or in complicated formwork.

SCC has to have a low yield value to ensure high flowability; a low water content ensures high viscosity, so the coarse aggregate can float in the mortar without segregating. To achieve a balance between deformability and stability, the total content of particles finer than the 150 μm (No. 100) sieve has to be high, usually about 520 to 560 kg/m3 (880 to 950 lb/yd3).

- Strength and durability of well-designed SCC are almost similar to conventional concrete. Without proper curing, SCC tends to have higher plastic shrinkage cracking than conventional concrete. High-range water reducers based on polycarboxylate ethers are typically used to plasticize the mixture.
- This type of concrete is ideal to be used in such applications like drilled shafts, columns, earth retaining systems, areas with high concentration of rebar and pipes/conduits etc.
- Since SCC is characterized by special fresh concrete properties, many new tests have been developed to measure flowability, viscosity, blocking tendency, selfleveling, and stability of the mixture.
- The production of SCC is more expensive than regular concrete and it is difficult to keep SCC in the desired consistency over a long period of time. However, construction time is shorter and production of SCC is environmentally friendly (no noise, no vibration). Furthermore, SCC produces a good surface finish. These advantages make SCC particularly interesting for use in precasting plants.

Benefits of Self Compacting Concrete

- Improved constructability.
- Labor reduction.
- Bond to reinforcing steel.
- Improved structural Integrity.
- Accelerates project schedules.
- Reduces skilled labor.

• Flows into complex forms.

• Reduces equipment wear.

• Minimizes voids on highly reinforced areas.

• Produces superior surface finishes.

• Superior strength and durability.

• Allows for easier pumping procedure.

• Fast placement without vibration or mechanical consolidation.

• Lowering noise levels produced by mechanical vibrators.

• Produces a uniform surface.

• Allows for innovative architectural features.

• It is recommended for deep sections or long-span applications.

• Produces a wider variety of placement techniques.

Tests and Properties of Self Compacting Concrete The requirements of the self-compacting concrete are achieved by the properties in its fresh state. The three main properties of SCC are:

• Filling Ability: This property of the concrete is the ability to flow under its own weight without any vibration provided intentionally. (Tests: Slump flow test, T50 cm Slump flow, Orimet, V-funnel Test)

• Passing Ability: This property is the ability of the concrete to maintain its homogeneity. (Test: L-Box Test, J-ring test, U-Box Test, Fill-Box Test)

• Segregation resistance: This is the resistance of the concrete not to undergo segregation when it flows during the self-compaction process. (Test: V-funnel test at T5 minutes, GTM Screen Stability Tests)

Properties of Hardened Self Compacting Concrete

• Compressive strength

• Tensile strength

• Bond strength (assessed by Pullout test)

• Modulus of elasticity

• Freeze/thaw resistance

• Shrinkage and creep

• Some aspects of durability

• Structural performance

SCC Mix Design Requirements

• High Volume of Paste

• High Volume of Fines (<80μm)

• High Dosage of Superplasticizers

• Use of Viscosity Modifying Agent

• Less Coarse Aggregate

• Addition of Admixtures

Self-Compacting Concrete Special Considerations

Self-compacting concrete can have benefits and will shorten your construction time. However, special attention should be focused on:

• A full capacity mixer of self-compacting concrete might not be feasible due to potential spillage along the road, producing environmental and contamination hazards.

• Formwork should be designed to withstand the fluid concrete pressure that will be higher than regular concrete.

• Self-Consolidating Concrete may have to be placed in lifts in taller elements.

• Production of SCC requires more experience and care than the conventional vibrated concrete.

Advantages of Self Compacting Concrete

• The permeability of the concrete structure is decreased. • SCC enables freedom in designing concrete structures.

• The SCC construction is faster.

• The problems associated with vibration is eliminated.

• The concrete is placed with ease, which results in large cost saving.

• The quality of the construction is increase.

• The durability and reliability of the concrete structure is high compared to normal concrete structures.

• Noise from vibration is reduced. This also reduce the hand arm vibration syndrome issues.

Disadvantages of Self Compacting Concrete

• There is no globally accepted test standard to undergo SCC mix design.

• The cost of construction is costlier than the conventional concrete construction.

• The use of designed mix will require more trial batches and lab tests.

• The measurement and monitoring must be more precise.

• The material selection for SCC is more stringent.

Applications of Self Compacting Concrete

• Construction of structures with complicated reinforcement.

• SCC is used for repairs, restoration and renewal construction.

• Highly stable and durable retaining walls are constructed with the help of SCC.

• SCC is employed in the construction of raft and pile foundations.