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REVIEW ON HSC BY USING DIFFERENT METHODS OF MIX PROPORTIONING

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Abstract— Nowadays the most important building material is high-strength concrete because of its properties of being stronger, lasting longer, and having better operating conditions than normal concrete. The method used for mixing the HSC changes its properties. The objective of the project is to simplify and compare the different methods of mix proportioning of HSC by performing various trials. The analysis focuses on the water-cement ratio, aggregate size, types of admixture, superplasticizer, curing methods, and which property is responsible for enhancing strength, durability, and workability. The results will enhance the understanding of how the mixing method affects HSC's long-term performance and will assist in selecting the best mixing method for the project..

Keywords*— High strength concrete, mix proportioning, ACI method, IS method, water-cement ratio, aggregate size, admixtures, curing techniques*

I. INTRODUCTION

Concrete having more than 60 MPa is known as high-strength concrete. It is a modern material that is being used in new modern construction projects for stronger, longer-lasting, high-rise, long-span structures to make structural members small. HSC has many positive impacts, but the proper method of mix proportion is also very important. For high-strength concrete, the selection of supplementary cementitious material plays a very important role according to its properties[1]. To simplify the problems of mix proportioning of HSC, the study aims to methodically examine various mix proportioning techniques for M80-M90 grade HSC, also focusing on the fresh properties, strength, durability, and cost-effectiveness[5]. The aim is to create the flow diagram for selecting the most reliable and effective method for field projects. As HSC handles more stress and lower the cost of the project it can be used in wild range of things including high rise building, bridges, offshore structures, precast elements, and where durability and performance are mandatory[5,10,21,23].

When working on a project, it is essential to focus on the mix proportion of High-Strength Concrete (HSC). To achieve the desirable strength and properties like high strength, durability, and workability, a more carefully mixed design is needed[35]. It's all about the quantities of all materials of cement, aggregates, SCMs, admixtures, and water. The water-to-cement ratio plays a very crucial and important role in the strength and durability of the mix. Using extra cementitious materials (like silica fume and fly ash) and chemical admixtures (like superplasticizers) makes the process of figuring out the right mix even harder [23]. The size, shape, and grading of the aggregate, as well as the curing process, are also crucial in determining the mix design and the final performance of HSC [2].The main goal of this review is to compare different ways of mixing high-strength concrete.

The review looks at both empirical and performance-based methods to see how different methods affect the performance, durability, and sustainability of HSC This review will look at both academic and industrybased a pproaches. Thefirst type focuses on getting the best perfor mance while using the least amount of materials,while thes econd type focuses on making things easier to use and chea per. This comparison will help you choose the best ways to mix HSC for different construction projects [17].

II. RELATED WORK

There has been a lot of research on high-strength concrete (HSC), especially on how different mix proportions affect strength, durability, and sustainability. A lot of people employ empirical approaches like ACI 211.4R-93, DoE, and IS 10262. [17] found that ACI-based mixes tend to have slightly greater compressive strengths, but IS standards are more cautious, and durability is mostly the same across codes. Analytical methodologies, such as particle packing and optimization models [11], have demonstrated the capability to attain strengths exceeding 100 MPa while enhancing cement efficiency and sustainability; recent innovations even encompass machine learning applications for mix optimization [12]. Performance-based proportioning, as emphasized in ACI 363R (2010) and further elaborated [26], transitions the emphasis from prescriptive ratios to the attainment of specified performance objectives regarding strength and durability, thereby providing adaptability for contemporary infrastructure. The performance of high-strength concrete (HSC) has also improved a lot thanks to new admixtures and supplementary cementitious materials (SCMs) like silica fume, fly ash, and GGBS[8,13,18,36]. Studies have shown that HSC has higher tensile strength, lower permeability, and longer durability [10,13,23]. Also, sustainable methods like using recycled aggregates have been looked into, and they have been shown to work well with strengths of 70–80 MPa and only a small loss of workability [5,20,23,35]. Other combinations, such silica fume and high-volume Class C fly ash, showed great resistance to freeze-thaw and chloride penetration [1,2,8,14,22,,31,40]. These studies show a significant shift from old empirical methodologies to analytical and performance-based approaches. This is reinforced by the use of SCMs and recycled materials, which is in line with worldwide aims for high performance and sustainability in concrete technology.

III. Difference between Normal and High Strength Concrete

Normal concrete is conventional structural concrete used in most buildings and civil engineering works. The characteristic compressive strength is typically from about 20–40 MPa (designations like M20, M25, M30, etc.).[2,3] The High-strength concrete (HSC) is a concrete designed to give substantially higher compressive strength. Practically HSC is often considered concrete with characteristic strengths above about 40–50 MPa. Ultra-high strength of HSC is much higher i.e. > 80–100 MPa.[2,3,5,9,23]

There is no stepwise difference between mix-proportioning methods for High-Strength Concrete (HSC) and Normal Concrete (NC) and the goal for both is the same i.e. to get required strength, workability and durability. The methodology for HSC is far more performance-driven, iterative, and sensitive. HSC mix design focuses on microstructure (low porosity, excellent particle packing and rheology) and therefore uses different inputs, tighter controls, more trials and often different test methods than ordinary mixes.[3,6,15,17]

Broad methodological differences (Design philosophy): Normal concrete frequently designed with prescriptive code methods (e.g., “nominal mixes” or code mix-design procedures) and single trial mix to confirm. But in case of HSC it is performance-based. Setting of a target strength and durability goals and then optimize materials and proportions by iterative lab trial mixes and testing is done.

VI. Mix-Proportioning Methods for NC and HSC

Though the Mix-proportioning methods for NC and HSC are same but are differs in practice. The steps of Mix-proportioning of IS 10262, DOE and ACI are tabulated below. [2,3,7,17,39]

TABLE 1: STEPS OF MIX PROPORTIONING OF DIFFERENT METHOD

VII. Mix-Proportioning Steps

Parameter	IS Method (IS 10262:2019 / IS 456:2000)	ACI Method (ACI 211.1 / ACI 211.4R)	DOE Method (UK Dept. of Environment, 1988)
Target Mean Strength	f_tm = f_ck + 1.65S OR f_tm = f_ck + X	f’cr = f’c + margin (std. deviation based)	f_m = f_ck + 1.64S (DOE charts)
Standard Deviation (S)	Typical 4–8 MPa	Typical 4–7 MPa	Typical 4–8 MPa
Air Content	0–2% (non-air entrained HSC)	0–2% (unless freeze-thaw exposure)	0–2% typical
Water Content	120–185 kg/m³ w/c = 0.25–0.35	120–190 kg/m³ w/cm = 0.20–0.35	120–190 kg/m³ w/c = 0.25–0.35
Cementitious Content	400–700 kg/m³ (cement + SCMs) Check IS 456 limits	400–800 kg/m³ (use SCMs, trial based)	400–700 kg/m³ (with SCM replacement)
Fine Aggregate (FA)	600–800 kg/m³ (balance volume method)	600–850 kg/m³ (absolute volume method)	From DOE tables; similar ranges
Coarse Aggregate (CA)	900–1100 kg/m³ (IS tables, size & sand zone based)	900–1200 kg/m³ (packing & absolute volume)	DOE ratios; ~900–1200 kg/m³
Permissible % of Admixtures	SP/HRWR: 0.3–2.0% of cement Silica fume: 5–12% GGBS: up to 50% Metakaolin: 5–15%	SP/HRWR: 0.2–2.5% Silica fume: 5–12% Fly ash: 25–40% Slag: up to 50%+	SP: 0.2–2.0% Silica fume: 5–12% Slag/Fly ash: 30–60%
Max Permissible Cement Content	Practical upper limit ~450–500 kg/m³ OPC Higher with SCMs but control shrinkage/heat	No strict max; practical 600–800 kg/m³ total binder (trial validated)	≤700 kg/m³ total binder; SCMs recommended to reduce OPC

In general the important design steps of all codes are

1. Select target characteristic strength (e.g., M20, M25).
2. Select maximum aggregate size and nominal mix proportions from code tables.
3. Choose w/c ratio to meet strength/durability (from code limits).
4. Estimate cement content and water content using charts.
5. Determine aggregate proportions by absolute volume method.
6. Make 1 or 2 trial mixes, check workability (slump), adjust admixture or water if needed.
7. Cast test specimens, confirm 7- and 28-day strengths.

8. Approve mix for production if tests meet requirements.

But the design steps of HSC differs philosophically and methodologically to achieve high and ultra high strength, more density and durability and overall performance.

1. Set performance targets: 28-day strength, durability requirements (permeability, chloride resistance), allowable shrinkage/creep limits.
2. Choose max aggregate size smaller (10–12 mm commonly) and select high-quality, well-graded aggregates.
3. Decide binder system: cement + one or more SCMs (e.g., silica fume for strength and pore refinement; GGBS for workability/durability).
4. Select an initial very low w/c value based on target strength and past experience.
5. Choose a suitable high-range water reducer (superplasticizer) and Viscosity Modifying Agent as needed.
6. Use particle packing principles (adjust fines, silica fume, microfillers) to minimize voids by calculating initial proportions.
7. Run multiple trial mixes varying binder content, fines, and admixture dosage. Measure fresh properties with appropriate rheology tests (V-funnel, flow table, L-box for SCC) rather than just slump.
8. Cast specimens and test for compressive strength, modulus, shrinkage, permeability, and bond at relevant ages. Evaluate early-age behavior (heat, shrinkage).
9. Iterate and optimize proportions until all targets are met. Document admixture doses and mixing/curing regimes.
10. Implement tight production QC (frequent sampling, admixture dosing checks, temperature control).

I. PRACTICAL CONSIDERATIONS FOR HSC

The extra care of various aspects should be taken to achieve the targeted high-strength concrete propereties.

1. Very low free water: superplasticizers must be well dispersed; improper dosing causes balling/segregation.
2. Silica fume and very fine fillers: increase water demand and can cause poor workability unless properly handled.
3. Early-age thermal & autogenous shrinkage: Can cause cracking — requires internal curing, shrinkage reducers, controlled temperatures or extended curing.
4. Strength is sensitive to small changes: In w/c, admixture dosage and raw material quality — hence tighter control and frequent testing.
5. Testing method changes: Slump alone is inadequate for very fluid or very stiff HSC; use rheology measures. [23,29,31,34]

II. ADDDITIVES USED IN HSC

The additives (mineral admixtures) like GGBS, Silica Fume, and Alccofine (AF) are used widely in high-strength and durable concrete.

1. Ground Granulated Blast Furnace Slag (GGBS): GGBS is the by-product of iron and steel industry (slag from blast furnaces), cooled rapidly by water to form a glassy powder. It is rich in amorphous silica and alumina.

Role in High-Strength Concrete: During the pozzolanic action of GGBS it reacts with calcium hydroxide (CH) produced during cement hydration forms additional C-S-H gel, which is main strength-giving compound in concrete. The Fineness of GGBS improves particle packing, reduces porosity and therefore increases strength. GGBS is also a thermal resistance material, it reduces heat of hydration which is useful in mass concrete and for gaining high-strength to concrete mixes.[14, 18, 36]

GGBS improves the long-term compressive strength, increases the durability i.e. resistance to sulfate attack, chloride ingress, alkali-silica reaction, Makes concrete dense & impermeable which is crucial for high-performance structures. Also it is a sustainable material which reduces clinker consumption and CO_2 emissions.

2. Silica Fume (Micro-silica): Silica Fume is a very fine (100x finer than cement), amorphous silica is a by-product from silicon or ferrosilicon alloy industry.

Silica Fumes plays considerable role in achieving High-Strength to Concrete. Its micro-filler effect fills extremely fine particles in voids between cement grains resulting drastically reduction in permeability. Due to its pozzolanic reaction it reacts quickly with CH to forms extra C-S-H gel, giving higher early strength. It also improves bond strength between paste and aggregate.

Silica Fume is a key ingredient for very high strength concrete (M70–M100). It increases the early-age strength useful in high-performance precast elements. It also enhances abrasion resistance (industrial floors, pavements) and resistance to chloride penetration which increases the durability ideally for bridges, coastal, and RCC structures exposed to salts. Silica Fume is effective in reducing the permeability again excellent for marine and aggressive environments.[1,4,8,16,27,31]

3. Alccofine (AF – 1203 grade): Alccofine is a ultra-fine, processed slag-based product from high glass content granulated slag. It is much finer than cement and GGBS (particle size < 5 micron).

Role in High-Strength Concrete: due to its High reactivity i.e. immediate pozzolanic activity which is faster than GGBS, Micro-filler effect and property to enhances flowability & workability of high-performance concrete (important for self-compacting concrete) it imparts a great role in HSC.

Alccofine substantially increases early & later compressive strength, improves pumpability & cohesiveness of concrete (SCC, HPC), provides very low permeability resulting into enhanced durability, reduces bleeding and segregation in concrete. It also makes mixes more economical compared to high % of silica fume even partial replacement is also possible.

The Combined Importance of GGBS, Silica Fume, and Alccofine in High-Strength Concrete when used strategically, these additives together is as follows,

1. Increase strength: Silica fume + Alccofine for early and ultimate strength.
2. Enhance durability: GGBS for chemical resistance + silica fume for impermeability.
3. Improve workability: Alccofine improves flow in dense reinforcement concreting.
4. Sustainability: GGBS and Alccofine reduce cement usage → lower CO_2 footprint.
5. Performance balance:

Silica fume = very high strength, but reduces workability (sticky mix).

Alccofine = improves workability, reduces need for extra water/plasticizer.

GGBS = improves long-term durability & strength.

In practice M60+ concrete mixes usually contain 5–10% silica fume, 8–12% Alccofine, and 30–50% GGBS (depending on design requirements). typical combinations are widely used in high-rise buildings, bridges, metro projects, marine structures, nuclear plants.[14, 18, 28, 30, 36]

TABLE 2.Comparative Table: GGBS vs Silica Fume vs Alccofine

Aspect	GGBS (Ground Granulated Blast Furnace Slag)	Silica Fume (Micro-silica)	Alccofine (AF-1203)
Source	By-product of iron & steel industry (blast furnace slag, rapidly cooled)	By-product of silicon/ferrosilicon alloy industry	Processed ultra-fine slag with high glass content
Particle Size	Finer than cement but coarser than silica fume (~350–450 m^2/kg Blaine fineness)	Extremely fine (100x finer than cement, ~15,000–25,000 m^2/kg)	Ultra-fine (particle size < 5 µm, ~12,000 m^2/kg)
Reactivity	Slow → contributes to *long-term strength*	Very reactive → contributes to *early and ultimate strength*	Highly reactive → contributes to *early & later strength*
Main Action	Pozzolanic + latent hydraulic	Pozzolanic + micro-filler effect	Micro-filler effect + rapid pozzolanic activity
Strength Contribution	Improves strength after 28 days (long-term gain)	Increases early-age & ultimate strength	Improves both early-age and long-term strength
Workability Effect	Improves workability (smooth, glassy particles)	Reduces workability (makes mix sticky)	Improves flowability & cohesiveness (ideal for SCC)
Durability	High resistance to sulfate attack, chloride ingress	Very low permeability, high chloride resistance	Very low permeability, dense matrix
Heat of Hydration	Low → reduces cracking in mass concrete	Slightly increases heat due to rapid reaction	Moderate → better control of shrinkage & cracking
Typical Dosage	30–50% replacement of cement	5–10% replacement	8–12% replacement
Applications	Mass concrete, bridges, foundations, marine works	High-strength concrete (M70+), precast, bridges, marine	High-performance concrete, SCC, high-rise, precast
Cost Factor	Economical (bulk use reduces cement)	Expensive (small % used)	Moderate (cheaper than silica fume, more than GGBS)
Special Feature	Sustainability (major cement replacement, eco-friendly)	Key for very high strength, abrasion resistance	Balances strength + workability + durability

III. CONCLUSION

HSC is gaining importance in modern construction. It plays vital role in construction of high-rise buildings, long-span bridges, metro & nuclear projects as they need stronger materials. HSC improves the Load-bearing capacity and allows slimmer sections, reduces dead load, and increases usable floor space. It also improves the durability of concrete which is very much needed in aggressive environments (marine, industrial, coastal) for longer service life. HSC improves the overall performance of structure. It is essential for earthquake resistance, high fatigue loads, abrasion resistance, and high traffic structures. Use of HSC may be economical as it can reduce quantity of concrete & reinforcement due to higher strength, lowering overall costs in mega projects.

High-strength concrete is the need of modern construction for strength, durability, economy, and sustainability. Its future lies in smart, green, and innovative infrastructure worldwide

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