IJCIET

INTERNATIONAL JOURNAL OF CIVIL ENGINEERING AND TECHNOLOGY

Journal ID: 6971-8185

IAEME Publication

Chennai, India

editor@iaeme.com/ iaemedu@gmail.com

https://iaeme.com/Home/journal/IJCIET

International Journal of Civil Engineering and Technology (IJCIET)
Volume 17, Issue 4, July-August 2026, pp. 98-112, Article ID: IJCIET_17_04_006
Available online at https://iaeme.com/Home/issue/IJCIET?Volume=17&Issue=4
ISSN Print: 0976-6308; ISSN Online: 0976-6316
Impact Factor (2026): 27.65 (Based on Google Scholar Citation)
Journal ID: 6971-8185; DOI: https://doi.org/10.34218/IJCIET_17_04_006

© **IAEME** Publication SCOPE DATABASE INDEXED

OPEN ACCESS

COMPARATIVE EVALUATION OF IS 10262:2019, ACI 211.4R, AND DOE MIX PROPORTIONING METHODS FOR HSC OF GRADES M70 AND M80 INCORPORATING TERNARY SUPPLEMENTARY CEMENTITIOUS MATERIALS

Darshana R. Sorte[1], Dr. Priyanka Pandey[2]

[1] Department of Civil Engineering, Sangam University, Bhilwara, Rajasthan, India.

[2] Department of Civil Engineering, Sangam University, Bhilwara, Rajasthan, India.

ABSTRACT

High strength concretes of the mixes M70 and M80 were studied through a comparative experimental study by adopting the most commonly used international mix proportioning methods, i.e., IS:10262:2019, ACI 211.4R, and the DOE method. In the mixes, ternary supplementary cementitious materials like Ground Granulated Blast Furnace Slag and Metakaolin, OPC 53-grade cement were used. The properties of the fresh and hardened concretes were tested at various ages, i.e., 7, 14, 28, and 90 days, according to the Indian Standards at the Government College of Engineering, Chandrapur, Maharashtra, concrete laboratory. The workability of the fresh concrete was tested by the slump cone test according to IS: 1199:1959, whereas the properties of the hardened concretes like compressive strength, split tensile strength, transverse strength, and density were tested respectively.

All these methods ensured the workability of the fresh concrete within the desired slump range of 275-300 mm. Regarding the compressive strength, it was observed that the maximum values were obtained by the ACI 211.4R code for both the grades of mixes.

It was observed that the DOE method was not capable of attaining the desired value of strength at any age for both the mixes of the desired grades. Another significant finding was in the split tensile and transverse strength testing. The IS 10262:2019 showed higher split tensile strength than the M70 and M80 mixes. It was surprising that the flexural strength of mixes M70 and M80 were same as per the DOE test results This suggests that the flexural strength and the compressive strength are not related.

Keywords: ACI 211.4R, Compressive Strength, DOE Method, Flexural Strength, GGBS, High Strength Concrete, IS 10262:2019, Metakaolin, Mix Proportioning, Split Tensile Strength, Supplementary Cementitious Materials

Cite this Article: Darshana R. Sorte, Priyanka Pandey. (2026). Comparative Evaluation of is 10262:2019, ACI 211.4R, and DOE Mix Proportioning Methods for HSC of Grades M70 and M80 Incorporating Ternary Supplementary Cementitious Materials. *International Journal of Civil Engineering and Technology (IJCIET)*, 17(4), 98-112.
DOI: https://doi.org/10.34218/IJCIET_17_04_006

I. INTRODUCTION

The mix proportioning methos for normal concrete and high strength concrete are similar, producing high strength concrete requires much stricter quality control and additional precautions because of its high-performance requirements. The core problem is no systematic three method comparison with ternary supplementary cementitious blends.

[1,2,3,4,5] Work is done only at lower grades or compared only two methods at a time. Due to this very limited body of work available at high grades and increasing the global demand for sustainable construction was the main motivation. The most important question was which method truly suits high grade with SCMs GGBS and Metakaolin.

II. MATERIALS

All the materials used in this investigation were sourced locally and characterised as per the relevant Indian Standard specifications before the design of the mixes was carried out. A common raw material was used for all three methods of mix design to ensure that differences observed are due to the method of proportioning and not due to the raw materials. The following sections discuss the individual constituent materials, sources, and properties of the individual components.

TABLE 1. Primary Functions of Materials

Material	Primary Function	Contribution to HSC
53-Grade OPC	Main binder	Strength, hydration heat
GGBS	Latent hydraulic binder	Durability, long-term strength
Metakaolin	Reactive aluminosilicate	Early strength, improvement
Fine Aggregate	Filler matrix	Packing, rheology
Coarse Aggregate	Load-bearing skeleton	Strength, stiffness
PCE Admixture	Water reducer	Workability at low w/b
Water	Hydration medium	Enables binder chemical reactions

III. MIX DESIGN PARAMETERS FOR HIGH-STRENGTH CONCRETE (HSC)

IS (IS 10262:2019, IS 456:2000), ACI (ACI 211.1, ACI 211.4R), and DOE (UK Department of Environment) methods.

TABLE 2. Mix Design Procedure

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 (S from site or IS tables)	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

TABLE 3. Mix Design Proportions for M70 and M80

Parameter	**IS-M70**	**IS-M80**	**ACI-M70**	**ACI-M80**	**DOE-M70**	**DOE-M80**
w/c Ratio	0.28	024	0.25	0.22	0.35	0.32
Cement (kg/m^3)	330	360	350	375	280	310
GGBS (kg/m^3)	95	105	100	110	80	90
Metakaolin (kg/m^3)	60	65	65	70	50	55
Total Binder (kg/m^3)	485	530	515	555	410	455
Admixture (kg/m^3)	1.0	1.2	1.2	1.5	0.8	1.0
Slump (mm)	80	75	90	85	70	65

IV. BATCHING, MIXING, AND CASTING PROCEDURES

Batching

All the constituent materials were weighed using calibrated digital balances with an accuracy of ±0.1g for cementitious materials (cement, GGBS, metakaolin) and ±1g for aggregates. Aggregates were used in saturated surface dry (SSD) condition to avoid errors due to moisture absorbed or moisture present on the surfaces of the aggregates. Each batch was designed to produce a minimum volume to cast all the specimens required for the particular mix and curing age.

Mixing Sequence

A standard mixing procedure has been adopted for all mixes to achieve uniformity in the dispersion of SCM, especially metakaolin, which has a tendency to form agglomerates if directly introduced to wet mixes. The mixing procedure adopted is as follows:

(i) Dry mixing of aggregate for 60 seconds;

(ii) (ii) Addition of cement, GGBS, and metakaolin, and dry mixing for 120 seconds to achieve uniform dispersion of SCM;

(iii) (iii) Addition of 80% of mixing water and mixing for 60 seconds;

(iv) (iv) Gradual addition of superplasticizer, which has been dissolved in 20% of mixing water, and final mixing for 180 seconds to achieve a visually uniform, cohesive, and workable mix. All mixes have been prepared at laboratory ambient temperatures.

Fresh Concrete Testing

Immediately after completion of mixing, fresh concrete workability was determined by using the slump cone test according to IS 1199:1959. The cone is filled in three layers; each being compacted by 25 rodding strokes. Then, the cone is raised vertically, and the slump is determined by finding the difference between the height of the cone and the maximum point of the compacted mix. The target slump for all mixes is in the range of 275 to 300 mm, which is suitable for very workable HSC for use in congested reinforcement. Dosage adjustments for superplasticizer were done during trial mixing before final casting.

Specimen Preparation and Curing

Cube specimens of size 150 mm x 150 mm x 150 mm have been cast for IS and DOE method compressive strength and density test in accordance with IS: 516:2021. For the ACI method, specimens of size 150 mm diameter x 300 mm have been cast in accordance with ASTM C39. For the split tensile strength test, specimens of size 150 mm x 300 mm have been cast for all three methods in accordance with IS: 5816:1999. Beam specimens of 100 mm × 100 mm × 700 mm were used for transverse (flexural) strength tests in accordance with IS 516:2021 specifications. All specimens were compacted using a vibration table with a vibration duration of 2 seconds, filled in three layers, and finished level. The specimens were demoulded 24 hours after casting and immediately immersed in a portable water curing tank containing drinking water at ambient temperatures. The curing was done up to the respective ages for testing (7, 14, 28, and 90 days) in conformity with IS 516:2021 specifications.

V. TESTING PROGRAMME

A comprehensive testing programme was executed to characterise both fresh and hardened concrete properties at multiple ages. Three specimens were tested at each age for each property and mix, and the average of three values was reported. All testing was conducted at the concrete laboratory of Government College of Engineering, Chandrapur, Maharashtra, India.

VI. EXPERIMENTAL DESIGN AND QUALIT CONTROL

The experimental design adopted was of 3x2 full factorial design, where three design methods of mixing (IS, ACI, DOE) and two concrete mixes (M70, M80) were considered as the independent variables, and fresh concrete workability, compressive strength, density, split tensile strength, and transverse strength were considered as the dependent response variables. The same batch of raw materials was used, and the mixing sequence was kept the same to ensure minimum variability of the raw materials as well as the operator. The test machines were also kept calibrated before conducting the experiments.

VII. RESULT AND DISCUSSION

1. Fresh Concrete Workability — Slump Test

Workability of fresh concrete was evaluated by the slump cone test in accordance with IS 1199:1959. A target slump range of 275–300 mm was adopted for all mixes, consistent with the high workability requirements for placement of HSC in congested reinforcement zones. The measured slump values are presented in TABLE 4.

TABLE 4. Slump Test Results for M70 and M80 Grade Concrete

Grade	IS 10262:2019 (mm)	ACI 211.4R (mm)	DOE Method (mm)	Target Range (mm)
M70	293	300	287	275–300
M80	295	298	289	275–300

2. Hardened Concrete Properties — Compressive Strength-

Compressive strength was determined at 7, 28, and 90 days on 150 mm cube specimens (IS and DOE mixes) and 150 mm × 300 mm cylinders (ACI mixes), with cylinder results converted to cube-equivalent strength using the factor f_cube ≈ 1.17 × f_cylinder. Results for M70 and M80 grade concrete are presented in TABLE 5.

TABLE 4. Compressive Strength Results — M70 and M80 Grade Concrete (MPa)

	M70			M80		
METHODS/DAYS	**7 DAYS**	**28 DAYS**	**90 DAYS**	**7 DAYS**	**28 DAYS**	**90 DAYS**
IS 10262:2019	54.67	75.36	83.7	57.33	83.37	95.09
ACI	63.02	86.62	96.188	64.92	93.72	105.51
DOE	34.48	52.11	65.36	33.29	52.84	69.46

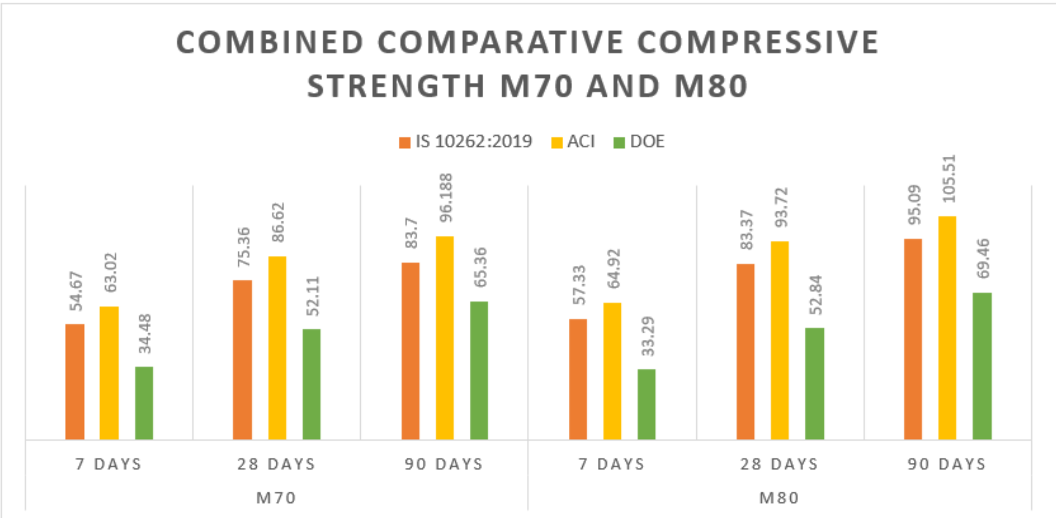

Fig.1 Combined Compressive Strength of M70 and M80 concrete

3. Hardened Concrete Density

Density was measured at fresh, 28-day, and 90-day stages on 150 mm cube specimens in accordance with IS 516:2021. Density evolution provides an indirect indicator of microstructural development, compaction quality, and pore refinement over the curing period. Results are presented in Tables 12 and 13 for M70 and M80 grades respectively.

TABLE 5. Density Results — M70 and M80 Grade Concrete (MPa)

	M70			**M80**		
METHODS/DAYS	**Fresh**	**28 days**	**90 days**	**Fresh**	**28 days**	**90 days**
IS 10262:2019	2376	2382	2401	2500	2436	2460
ACI	2342	2362	2378	2376	2416	2437
DOE	2428	2398	2409	2457	2454	2491

4. Split Tensile Strength

Split tensile strength tests were conducted on 150 mm × 300 mm cylindrical specimens at 7, 14, 28, and 90 days in accordance with IS 5816:1999. Results for M70 and M80 grades are presented in Tables 6.

TABLE 6. Split tensile Results — M70 and M80 Grade Concrete (MPa)

	M70			**M80**		
METHODS/DAYS	**7 DAYS**	**28 DAYS**	**90 DAYS**	**7 DAYS**	**28 DAYS**	**90 DAYS**
IS 10262:2019	5.14	6.05	6.40	5.30	6.39	6.82
ACI	4.09	4.80	5.06	4.20	5.05	5.37
DOE	4.01	4.68	4.92	4.09	4.82	5.17

5. Transverse (Flexural) Strength

Transverse (flexural) strength, also referred to as the modulus of rupture, was determined on 100 mm × 100 mm × 700 mm beam specimens under one-point central loading (span = 580 mm) at 7, 14, and 28 days in accordance with IS 516:2021. Results for both grades are presented in Table 7.

TABLE 7. Transverse Strength — M70 and M80 Grade Concrete (MPa)

Method / Grade	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
IS — M70	5.88	6.64	7.73
ACI — M70	5.56	6.98	7.22
DOE — M70	6.37	6.93	7.80
IS — M80	6.71	7.12	8.17
ACI — M80	5.79	7.19	7.43
DOE — M80	6.60	7.15	8.03

VIII. CONCLUSIONS AND RECOMMENDATIONS

The present research carried out a controlled comparative experimental study of the internationally recognized concrete mix proportioning methods IS 10262:2019, ACI 211.4R-08, and the DOE method for the production of high strength concrete of grade M70 and M80 with a binary supplementary cementitious material system of 40% GGBS and 10% metakaolin by total binder mass. The fresh and hardened concrete properties were systematically characterized at various ages (7, 14, 28, and 90 days) at the concrete laboratory of Government College of Engineering, Chandrapur, Maharashtra. From the experimental findings of the research study presented above, the following conclusions are drawn.

Conclusions

Fresh Concrete Workability

All three mix proportioning methods were able to produce fresh concrete within the desired range of slump (275 to 300 mm) when the dosage of polycarboxylate ether (PCE) superplasticizer admixture was optimized at the trial batching. For all the three mix proportioning methods, slump values of 293-300 mm for M70 and 289-298 mm for M80 were obtained. The highest workability was obtained by AC 211.4R and the lowest workability was obtained by the DOE method. IS 10262:2019 resulted in medium workability. Maximum water content was given by AC 211.4R, medium water content given by IS 10262:2019 and minimum water content given by DOE method. This shows that the change in workability is within ±5%, hence not a factor for differentiating the three methods. No segregation or bleeding of mix was seen.

Compressive Strength

ACI 211.4R-08 always yielded the highest compressive strengths for both M70 and M80 mixes at all test ages. At 28 days, ACI yielded 86.62 MPa, 23.7% above the design requirement, and 93.72 MPa, 17.2% above the design requirement, for M70 and M80 mixes, respectively.

At 90 days, ACI M80 mix yielded ultra-high-strength concrete above 100 MPa, i.e., 105.51 MPa, thus showing the inherent conservativism of the statistical strength margin of ACI 211.4R, coupled with the effectiveness of binary SCM.

IS 10262:2019 yielded compressive strengths well within the design requirements with moderate safety margins of 7.7% for M70 mix and 4.2% for M80 mix, respectively, at 28 days. At 90 days, the mixes yielded 83.70 MPa, 11.1% above the 28-day strength, and 95.09 MPa, 14.0% above the 28-day strength, confirming the contribution of GGBS to concrete strength, especially in the dense paste formed by low w/b ratio of IS mixes.

The results of the DOE method did not comply with the compressive strength requirements for M70 and M80 grades at all test ages. At an age of 28 days, the results of the DOE method were found to be only 52.11 MPa and 52.84 MPa for M70 and M80 grades, respectively, i.e., 25.6% and 34.0% below the targets. Even at an age of 90 days, the results of the DOE method were found to be only 65.36 MPa and 69.46 MPa, respectively, i.e., still below the targets. The increasing gap in the results of the DOE method at higher grades indicates that the empirical charts of the DOE method, developed for w/c ratios greater than 0.40 and standard British aggregates without mineral admixtures, cannot be used for M70 and M80 grades of HSC with binary SCM systems.

Hardened Concrete Density

All methods resulted in hardened concrete densities in the range 2,362-2,491 kg/m^3 at 90 days, as expected for the normal weight HSC. Density increased progressively for all methods from fresh to 28-day and then to 90-day measurements, thus confirming continued densification of the microstructure through continued GGBS hydration and metakaolin pozzolanic reaction beyond 28 days.

The DOE method resulted in the highest coarse aggregate content and fresh density, whereas the ACI method resulted in the lowest density for all ages. Most critically, however, the ACI method resulted in the highest compressive strength while also exhibiting the lowest density, thus confirming that density is not a reliable predictor of compressive strength in SCM-modified HSCs, in which paste quality and SCM reactivity are the critical determinants.

Split Tensile Strength

Significantly, there was a reversal of rank order of compressive strength with regard to split tensile performance. IS 10262:2019 always yielded the best split tensile strength, achieving 6.05 MPa (M70) and 6.39 MPa (M80) at 28 days, which were 26-27% higher than those of ACI, i.e., 4.80 MPa and 5.05 MPa, respectively. This is because IS 10262:2019 had the lowest w/b ratio of 0.24 for M70 and 0.21 for M80, thus yielding the densest paste matrix with finest ITZ, which is considered to have the maximum contribution to concrete tensile strength.

The reversal of rank order between ACI and IS with regard to split tensile strength, while ACI ranks first in compressive strength, shows that there is no single mix proportioning method that can optimize all the mechanical properties of HSC. The method to be used is dependent upon the governing structural performance requirement.

Transverse (Flexural) Strength and the DOE Paradox

The most counterintuitive finding of this study is that the DOE method, despite producing the lowest compressive strength at all ages and failing the HSC compressive targets, achieved transverse (flexural) strength values essentially equivalent to IS 10262:2019 — the highest-performing method in split tensile strength. At 28 days, DOE attained 7.80 MPa (M70) and 8.03 MPa (M80), compared to IS's 7.73 and 8.17 MPa. The difference of less than 1.7% between DOE and IS flexural strengths is within experimental variability.

This DOE paradox is mechanistically explained by the DOE method's substantially higher coarse aggregate content (1,254 kg/m³ for M70), which creates a dense aggregate skeleton that more effectively resists crack propagation under bending through aggregate crack-bridging and mechanical interlocking — mechanisms that are governed by aggregate content and surface texture rather than by paste compressive strength. This finding provides direct empirical evidence that compressive strength cannot be used as a universal proxy for flexural performance in HSC with binary SCM systems.

Ternary SCM System Performance

The binary GGBS–metakaolin system performed effectively in combination with all three proportioning methods to produce concrete with distinct strength development profiles. The 7-to-28-day compressive strength ratios (IS: 72.5%, ACI: 72.8%) exceed the typical 60–65% expected from OPC-only mixes, confirming that metakaolin's rapid pozzolanic reaction provides meaningful early-age strength acceleration in M70–M80 HSC. The continued 28-to-90-day strength gains of 11–14% (IS and ACI) confirm GGBS's sustained long-term hydration contribution. The complementary chronology of these two SCMs validates the design rationale for their combined use in a single ternary system.

IX. RECOMMENDATIONS FOR FUTURE RESEARCH

The following directions for future research are suggested based on the findings and limitations of this study:

R1. Investigation of DOE method modification protocols — specifically recalibration of w/c–strength charts for Indian SCMs and aggregates — to develop a modified DOE framework suitable for HSC with mineral admixtures in Indian practice.

R2. Optimisation of GGBS and metakaolin replacement levels within each proportioning method (e.g., 20%, 30%, 40% GGBS combined with 5%, 10%, 15% MK) to identify the combination that maximises each method's compressive, tensile, and flexural performance.

R3. Comprehensive durability characterisation — chloride diffusion coefficient, rapid chloride permeability test (RCPT), carbonation depth, and acid resistance — for all six mixes to provide a complete performance profile for infrastructure engineering applications.

R4. Microstructural analysis using scanning electron microscopy (SEM) and X-ray diffraction (XRD) to quantify ITZ quality, C-S-H morphology, and CH consumption for each method's paste, providing mechanistic confirmation of the strength and density trends observed in this study.

R5. Extension of the comparative study to ternary SCM systems (OPC + GGBS + MK + silica fume or fly ash) for M80–M100 grades, and investigation of the interaction between SCM combination and mix design method at ultra-high-strength levels.

In conclusion, this study establishes that ACI 211.4R-08 and IS 10262:2019 are both technically viable methods for M70–M80 HSC production with binary GGBS–metakaolin systems, each excelling in different performance dimensions. ACI 211.4R maximises compressive strength and is preferred for compression-governed elements, while IS 10262:2019 provides superior tensile performance and is recommended for general HSC structural practice in India. The DOE method, without modification, is unsuitable for M70–M80 HSC with binary mineral admixtures and should not be employed for this application without recalibration of its core empirical relationships. The complementary GGBS–metakaolin SCM system successfully delivers early-age strength acceleration and long-term microstructural densification in all viable method-grade combinations, confirming its efficacy as a binary binder for Indian HSC practice.

REFERENCES

[1] ACI Committee 363. (2010). Report on High-Strength Concrete (ACI 363R-10). American Concrete Institute, Farmington Hills, MI.

[2] ACI Committee 211. (2008). Guide for Selecting Proportions for High-Strength Concrete Using Portland Cement and Other Cementitious Materials (ACI 211.4R-08). American Concrete Institute, Farmington Hills, MI.

[3] Department of the Environment. (1988). Design of Normal Concrete Mixes (2nd ed.). Building Research Establishment, HMSO, London, UK.

[4] Bureau of Indian Standards. (2019). IS 10262:2019 – Concrete Mix Proportioning – Guidelines (2nd Revision). BIS, New Delhi.

[5] Bureau of Indian Standards. (1987). IS 12269:1987 – Specification for 53 Grade Ordinary Portland Cement. BIS, New Delhi.

[6] Bureau of Indian Standards. (1970). IS 383:1970 – Specification for Coarse and Fine Aggregates from Natural Sources for Concrete. BIS, New Delhi.

[7] Bureau of Indian Standards. (1963). IS 2386:1963 (Parts I–VIII) – Methods of Test for Aggregates for Concrete. BIS, New Delhi.

[8] Bureau of Indian Standards. (1987). IS 12089:1987 – Specification for Granulated Slag for Manufacture of Portland Slag Cement. BIS, New Delhi.

[9] Bureau of Indian Standards. (2000). IS 456:2000 – Plain and Reinforced Concrete – Code of Practice (4th Revision). BIS, New Delhi.

[10] Bureau of Indian Standards. (1999). IS 5816:1999 – Method of Test for Splitting Tensile Strength of Concrete. BIS, New Delhi.

[11] Bureau of Indian Standards. (2021). IS 516:2021 – Hardened Concrete – Methods of Test (2nd Revision). BIS, New Delhi.

[12] Bureau of Indian Standards. (1959). IS 1199:1959 – Methods of Sampling and Analysis of Concrete. BIS, New Delhi.

[13] Bureau of Indian Standards. (2016). IS 4031:2016 – Methods of Physical Tests for Hydraulic Cement. BIS, New Delhi.

[14] Wani, S., Muntazari, T. H., & Rafique, N. (2020). Study on concrete proportioning methods: A qualitative and economical perspective. International Journal of Engineering Research & Technology (IJERT), 9(5), 614–620.

[15] Ejiogu, I. K., Mamza, P. A., Nkeonye, P. O., & Yaro, A. S. (2022). Comparative study of concrete mix design methods for normal concrete production. Nigerian Journal of Technology, 41(2), 214–222. https://doi.org/10.4314/njt.v41i2.5

[16] Singh, P., & Verma, A. (2017). A comparative study of concrete mix design using IS, ACI and DOE methods. International Journal of Civil Engineering and Technology, 8(4), 1332–1338.

[17] Santhosh, K. G. (2017). Study on comparison of concrete mix design by IS, ACI and BS methods. International Research Journal of Engineering and Technology (IRJET), 4(7), 1449–1453.

[18] Chhachhia, P. (2021). A comparative study of different mix design methods of concrete. International Journal of Innovative Research in Technology, 8(2), 247–251.

[19] Maldonado, N., & Helene, P. (2002). Mix proportioning of high strength concrete: A comparative study. In Proceedings of the 6th International Symposium on Utilization of High Strength/High Performance Concrete, Leipzig, Germany, pp. 891–902.

[20] Barwal, V. (2019). Comparative study of IS and DOE mix design methods for M50 concrete with microsilica. International Journal of Engineering Research & Technology, 8(10), 421–425.

[21] Hassaballa, A. E. (2024). Compressive strength of concrete with crushed and uncrushed coarse aggregate designed by ACI and DOE methods. Journal of Engineering Research and Reports, 26(4), 45–56.

[22] Karri, G., Rama, J. S. M., & Pannirselvam, N. (2015). Strength and durability properties of high performance concrete using GGBS. International Journal of Engineering Research, 4(8), 386–389.

[23] Sharma, R., & Khan, R. A. (2016). Sustainable use of copper slag in self-compacting concrete containing supplementary cementitious materials. Journal of Cleaner Production, 151, 179–192. https://doi.org/10.1016/j.jclepro.2017.03.031

[24] Elavarasan, R., Rajkumar, P. R. K., & Srinivasagan, N. (2014). Study on strength properties of high performance concrete with ground granulated blast furnace slag. International Journal of Civil Engineering and Technology, 5(4), 175–182.

[25] Swaminathen, A. N., & Ravi, R. (2017). Mechanical properties of metakaolin and rice husk ash based high performance concrete. IOP Conference Series: Materials Science and Engineering, 263, 032002.

[26] Gowram, V., Raju, P. M., & Rao, C. B. K. (2021). Experimental study on M60 high strength concrete with metakaolin and natural zeolite. Materials Today: Proceedings, 46(9), 4296–4302.

[27] Tiwari, A., Dubey, R., & Chandak, R. (2022). Ternary blend of metakaolin, GGBS and silica fume in high strength concrete. Construction and Building Materials, 326, 126831. https://doi.org/10.1016/j.conbuildmat.2022.126831

[28] Tiwari, P., Sharma, P., Sharma, N., Verma, M., & Rohitash. (2020). Experimental investigation on metakaolin GGBS-based concrete with recycled coarse aggregate.

Materials Today: Proceedings, 27(2), 1520–1527. https://doi.org/10.1016/j.matpr.2020.03.200

[29] Shruthi, M., Reddy, V. S., & Rao, M. V. S. (2023). Mechanical properties of self-compacting concrete with binary and ternary blend of metakaolin and GGBS. Construction and Building Materials, 368, 130499.

[30] Reddy, M. A., & Nirmala, G. (2018). Experimental study on quaternary blended high performance concrete with fly ash, silica fume, GGBS and high reactivity metakaolin. International Journal of Civil Engineering and Technology, 9(8), 613–622.

[31] Kumar, B. N. S., Giridhar, C. V., & Rao, T. D. G. (2019). Performance evaluation of GGBS-metakaolin based geopolymer concrete. International Journal of Recent Technology and Engineering, 8(3), 3124–3128.

[32] Kumar, R., & Ramesh, V. (2017). Mechanical and durability properties of geopolymer concrete with GGBS and metakaolin. International Journal of Civil Engineering and Technology, 8(9), 1084–1093.

[33] Mehta, P. K., & Monteiro, P. J. M. (2014). Concrete: Microstructure, Properties, and Materials (4th ed.). McGraw-Hill Education, New York, NY.

[34] Neville, A. M. (2011). Properties of Concrete (5th ed.). Pearson Education Ltd., Harlow, UK.

[35] ASTM International. (2021). ASTM C39/C39M-21 – Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. ASTM International, West Conshohocken, PA.

[36] Rashid, M. A., Mansur, M. A., & Paramasivam, P. (2002). Correlations between mechanical properties of high-strength concrete. Journal of Materials in Civil Engineering, ASCE, 14(3), 230–238. https://doi.org/10.1061/(ASCE)0899-1561(2002)14:3(230)

[37] Atis, C. D., Bilim, C., Celik, O., & Karahan, O. (2005). Influence of activator on the strength and drying shrinkage of alkali-activated slag mortar. Construction and Building Materials, 19(9), 671–676. https://doi.org/10.1016/j.conbuildmat.2005.02.010

[38] Khatib, J. M., & Hibbert, J. J. (2005). Selected engineering properties of concrete incorporating slag and metakaolin. Construction and Building Materials, 19(6), 460–472. https://doi.org/10.1016/j.conbuildmat.2004.07.017

[39] Sabir, B. B., Wild, S., & Bai, J. (2001). Metakaolin and calcined clays as pozzolans for concrete: a review. Cement and Concrete Composites, 23(6), 441–454. https://doi.org/10.1016/S0958-9465(00)00092-5

[40] Lothenbach, B., Scrivener, K., & Hooton, R. D. (2011). Supplementary cementitious materials. Cement and Concrete Research, 41(12), 1244–1256. https://doi.org/10.1016/j.cemconres.2010.12.001

[41] Siddique, R., & Klaus, J. (2009). Influence of metakaolin on the properties of mortar and concrete: A review. Applied Clay Science, 43(3–4), 392–400. https://doi.org/10.1016/j.clay.2008.11.007

[42] Boehm, A. B., Alappat, B., & Mahesh, N. (2020). A review on metakaolin as partial replacement of cement. Journal of Civil Engineering Research, 10(1), 1–8.

[43] Aiqin, W., Chengzhi, Z., & Ningsheng, Z. (1999). The theoretic analysis of the influence of particle size distribution of cement system on the property of cement paste. Cement and Concrete Research, 29(11), 1721–1726. https://doi.org/10.1016/S0008-8846(99)00159-2

[44] Scrivener, K. L., John, V. M., & Gartner, E. M. (2018). Eco-efficient cements: Potential economically viable solutions for a low-CO2 cement-based materials industry. Cement and Concrete Research, 114, 2–26. https://doi.org/10.1016/j.cemconres.2018.03.015

Citation: Darshana R. Sorte, Priyanka Pandey. (2026). Comparative Evaluation of is 10262:2019, ACI 211.4R, and DOE Mix Proportioning Methods for HSC of Grades M70 and M80 Incorporating Ternary Supplementary Cementitious Materials. International Journal of Civil Engineering and Technology (IJCIET), 17(4), 98-112.

Abstract Link: https://iaeme.com/Home/article_id/IJCIET_17_04_006

Article Link: https://iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_17_ISSUE_4/IJCIET_17_04_006.pdf

Copyright: © 2026 Authors. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Creative Commons license: Creative Commons license: CC BY 4.0

✉ **editor@iaeme.com**