EXPERIMENTAL STUDY ON SELF COMPACTING CONCRETE USING EXFOLIATED VERMICULITE AND MICRO SILICA FUME

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Abstract - *This experimental study investigates the influence of Exfoliated Vermiculite (EV) as a partial fine aggregate replacement and Micro Silica Fume (SF) as a partial cement replacement on the properties of Self-Compacting Concrete (SCC). With the construction industry increasingly demanding materials that combine high fluidity with structural durability, this study evaluates the optimal replacement levels to achieve a balance between workability and mechanical performance. The experimental program included four mix proportions (Control, 5% SF/10% EV, 10% SF/20% EV, and 15% SF/30% EV) tested for fresh properties (slump flow, V-funnel, L-box, U-box) and hardened properties (compressive and split tensile strength). Results indicate that the mix comprising 10% EV and 5% SF (Mix SCC2) serves as the optimum proportion, demonstrating superior mechanical strength compared to the control mix. Conversely, higher replacement levels led to a decline in structural performance due to increased porosity, confirming the viability of moderate EV and SF substitution in producing economical and durable SCC.*

Key Words: Self-Compacting Concrete (SCC), Exfoliated Vermiculite, Micro Silica Fume, Compressive Strength, Flexural Behavior, Deflection, M30 Grade, EFNARC.

1. INTRODUCTION

The present investigation has been aimed at to bring awareness amongst the practicing civil engineers regarding advantages of these new concrete mixes. the maximum compressive strength (both cube and cylinder) is noted for 10% replacement of cement with silica fume and the values are higher. Moreover with 10% of cement replaced by silica fume, the characteristic strength of higher grade of cement concrete namely M25 is achieved. concrete namely M25 is achieved. under its own weight. Historically, the primary challenge in concrete construction has been ensuring durability, which is directly dependent on uniform compaction a process often hindered by skilled labor shortages and mechanical vibration constraints.

To address these challenges, researchers are exploring the integration of mineral admixtures, such as Silica Fume (SF), and lightweight aggregates, such as Exfoliated Vermiculite (EV), to improve rheology and structural performance. Silica fume, a by-product from silicon alloy factories, possesses a large surface area that enhances the pozzolanic activity and cohesiveness of the concrete matrix. Similarly, EV offers potential advantages in thermal insulation and crack resistance, though its porous nature necessitates careful mix design. This study aims to optimize these materials in SCC, providing a methodology for producing concrete that minimizes reliance on traditional vibration while enhancing mechanical strength and sustainability.

1.1 VISCOSITY AGENT TYPE SELF –COMPACTING CONCRETE:

This type is proportioned to provide self-compaction by the use of viscosity modifying admixture to provide segregation resistance. Super plasticizers and air entraining admixtures and used for obtaining the desired deformability.

1.2 Need For SCC:

For several years, the problem of the durability of concrete structure has been a major problem posed to engineers. To make durable concrete structures, sufficient compaction is required. Compaction for conventional concrete is done by vibration can easily cause segregation .in conventional concrete, it is difficult to ensure uniform material quality and good density in heavily reinforced locations.

1.3 Materials Properties

Fig 1 Exfoliated vermiculite

Fig 2 Silica Fume

2. LITERATURE REVIEW

Jonna Mahesh (2020): Evaluated lightweight SCC incorporating exfoliated vermiculite (bulk density: 60{--}130 kg/m^3) as a partial aggregate replacement. The study revealed that while the cellular structure of vermiculite inherently lowers compression resistance, the concurrent integration of micro silica fume and optimized superplasticizer dosages successfully mitigates strength degradation while maintaining structural fluid properties.

Ahmed Tahwia (2020): Evaluated SCC performance by using silica fume as a partial cement substitute. The findings highlighted that an optimal binder replacement level of 15% to 16% refines the structural pore web, converting large continuous pores into discontinuous voids, which resulted in a 67% to 79% reduction in overall chloride ion penetration along with late-age strength enhancement.

Subramanian et al. (2018): Investigated the hybrid impact of micro and nano-silica matrices on self-consolidating designs utilizing Viscosity Modifying Admixtures (VMA). The research showed that a 15% cement replacement combined with calibrated chemical dosages yielded superior filling and passing abilities during fresh state evaluation, while boosting the final compressive and splitting tensile strength parameters by over 25%.

Praveer Singh (2016): Documented a comprehensive review analyzing micro silica fume inclusions across multiple experimental concrete groups. The structural meta-analysis concluded that replacing Portland cement with 5% to 15% industrial silica fume significantly scales up early strength values, whereas any dosage crossing the 20% limit triggers a steep decline in mechanical resistance due to water demand variations.

H. Premachandar (2016): Evaluated standard cement mortars by substituting fine aggregates with variable vermiculite intervals (5% to 30%). Utilizing a 1.5% dosage of Conplast SP430 superplasticizer, the experimental compression tests verified that a 10% substitution of fine sand with lightweight vermiculite generates optimal structural resistance and enhanced economy.

Pradesh (2016): Researched lightweight concrete configurations developed via expanded vermiculite aggregates, noting core density ranges between 750kg/m^3 and 2050 kg/m^3. The study demonstrated that incorporating up to 20% fly ash into lightweight vermiculite structures optimizes dead-load reductions and achieves substantial gains in structural load density.

M.R. Divya (2016): Investigated the eco-friendly and structural behavior of modified concrete matrix lines by evaluating high aggregate replacement thresholds (40%, 50%, and 60%). The report concluded that controlled vermiculite blending can enhance overall shrinkage limits, microstructural crack resistance, and fire enduring thresholds.

Alaa M. Rashad (2016): Conducted a microstructural overview of expanded vermiculite (EV), noting its ability to expand up to 30 times its volume under thermal treatment (650C-950C). The paper mapped out the physical attributes of EV, emphasizing its low thermal conductivity, lightweight chemical inertness, and exceptional thermal resistance within traditional cementitious matrices.

The present investigation has been aimed at to bring awareness amongst the practicing civil engineers regarding advantages of these new concrete mixes. the maximum compressive strength (both cube and cylinder) is noted for 10% replacement of cement with silica fume and the values are higher. Moreover with 10% of cement replaced by silica fume, the characteristic strength of higher grade of cement concrete namely M25 is achieved.

3. MIX DESIGN STIPULATIONS

The concrete mix design was developed targeting **M30 grade** Self-Compacting Concrete (SCC) in accordance with Indian Standard specifications. The material properties and design stipulations used for the mix proportioning are summarized.

Table -1: Material Properties and Design Stipulations

Parameter	**Value / Specification**
Grade Designation	M30
Characteristic Compressive Strength (28 days)	30 MPa

Parameter	Value / Specification
Cement Type	OPC 53 Grade (Specific Gravity: 3.14)
Fine Aggregate (Zone-II)	Specific Gravity: 2.65
Coarse Aggregate (Max Size: 12.5 mm)	Specific Gravity: 2.70
Target Mean Compressive Strength (f'_{ck})	38.25 MPa
Final Design Water/Binder (w/b) Ratio	0.41
Chemical Admixtures	Polycarboxylate

Table 2 Compressive Strength Test Values of concrete

Mix Ratio (EV & SF)	7 days Compressive Strength (N/ mm²)	14 days Compressive Strength (N/ mm²)	28 days Compressive Strength (N/ mm²)
0%	11.5	21.33	32
10%,5%	16	23.11	33
20%,10%	5.3	11.55	22
30%,15%	4	11.11	20

Table 3 Flexural Strength Test Values of concrete

Mix Ratio (EF & SF)	7 days Flexural Strength (N/ mm²)	14 days Flexural Strength (N/ mm²)	28 days Flexural Strength (N/ mm²)
0%	1.3	1.53	1.9
10%,5%	1.9	2.06	2.55
20%,10%	0.8	1.28	1.74
30%,15%	0.9	1.12	1.3

Table 4 Split tensile Strength Test Values of concrete

Mix Ratio (EF & SF)	7 days split tensile Strength (N/ mm²)	14 days split tensile Strength (N/ mm²)	28 days split tensile Strength (N/ mm²)
0%	4.52	7.35	13
10%,5%	5.09	8.48	15
20%,10%	3.39	5	8
30%,15%	2.26	3.3	7.3

3. CONCLUSIONS

Optimum Mix: The combination of 10% EV and 5% SF was identified as the optimal mix proportion, effectively enhancing the concrete matrix and outperforming the control mix. Higher replacement levels (20%–30% EV) led to increased porosity and strength reduction.

Mechanical Properties: At 28 days, the optimal mix achieved a compressive strength of 33 N/mm^2 up from 32{ N/mm^2, a split tensile strength of 15 N/mm^2(up from 13 N/mm^2, and a flexural strength of 2.55 N/mm^2 (up from 1.9N/mm^2).

Structural Ductility: Prism specimen trials validated the structural efficiency of the optimal mix, displaying an initial crack load of 16kN at 2.53mm deflection, and a high ultimate load-bearing capacity of 40.59kN at 12.32mm deflection, demonstrating excellent energy absorption capabilities.

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BIOGRAPHIES

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