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Effect of Calcium Sulpho-Aluminates on the strength of cement mortars

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ABSTRACT:

This study investigated the use of calcium sulfoaluminate (CSA) binders in mortars to improve the early strength development of ordinary Portland cement (OPC). An optimal CSA mixture was analysed to improve the early strength of OPC, and this mixture was investigated to illustrate the application of the resulting concrete mix.

Furthermore, mixture applicability was tested by mixing concrete and found, the optimal CSA substitution rate for achieving early strength was 17% of the total unit binder quantity, with CaO/SO3 and SO3/Al2O3 ratios of 1.9 and 1.25, respectively. Evidently, CSA in conjunction with Na2SO4 as an accelerator increased the early strength of concrete with OPC and ensured its constructability by employing additional retarders to manage the quick setting of concrete. Additionally, activating early hydration at low temperatures resulted in a compressive strength of 5 MPa/12 h or greater for the final concrete mixture.

Key words: Compression Strength, CSA, OPC

Introduction:

Concrete durability is a major issue in modern building. Cracks in monolithic and prefabricated constructions can significantly impact their longevity and security. Chemical shrinkage occurs when cement hydrates, while autogenous shrinkage occurs when the water/cement ratio is low, and drying shrinkage occurs when formed concrete is exposed to low humidity. Shrinkage fractures can occur due to temperature changes, structural design/manufacturing flaws, and reinforcing bar corrosion (wedge). The three most successful strategies to prevent drying shrinkage are to execute high-quality moisture care of the concrete structure, compensate for shrinkage using expanding mineral additives, and reduce shrinkage owing to Shrinkage Reducing Admixtures (SRA) based on glycols. The first option is the preferred one, but it is not always practicable in building. Expanding mineral additions are commonly used in concrete, mortar, dry mixes, and grouting. Expanding additives result from the production of ettringite (sulfoaluminate additives) or calcium hydroxide (CaO additives). Sulphoaluminate additions are safer for people than CaO-based compounds, are widely used globally. The usage of CSA-expanding chemicals dates back to the 1980s. Years of experience with these modifiers have revealed some downsides. They are only available in dry form and have a high dosage (about 10% by weight of cement).

Literature Review:

Byoungsun Park et.al (2021) investigated the phase composition of self-healing products of cementitious materials using supplementary cementitious materials – calcium sulfoaluminate and crystalline additives through X-ray diffraction (XRD) analysis and examined their morphology, ion concentration through scanning electron microscopy with energy dispersive spectroscopy(SEM_EDS). He found that when Ground granulated blast furnace slag, fly ash were used in the concrete along with calcium sulfoaluminate, the self-healing products contained [1]

Leyang Lv et.al., 2020, in this study, used calcium sulfoaluminate (CSA) cement as the matrix material to create quick hardening and high early strength engineered cementitious composites (ECC) and discovered that CSA cement with 2% Polycarboxylate-based superplasticizer (PSP), 1% ultra-high-molecular weight polyethylene (UHMWPE) fibre, and a cement to sand ratio of 0.5 performs best in terms of fluidity, flexural strength, and compressive strength. With his experimental results suggested that the CSA-ECC has good bonding strength to the concrete matrix. Compared with plain concrete members, both flexural and compressive strength of concrete members were significantly reinforced after 1, 3, and 28 days when CEA-ECC was applied as rapid repairing coating. [2]

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Jing Xu et.al., (2018) used calcium sulphoaluminate as a good protective carrier for ureolysis bacterial based self healing system in concrete, with a low alkali cementitious materials made of cement with 20% silica fume. He successfully enclosed bacterial spores inside the carriers. Although the encapsulation caused a loss of viability, they showed that the bacterial activity may be sustained for an extended period of time. In addition, the carrier material's compatibility with healing agents and the concrete matrix were optimized. The qualitative image analysis, capillary water absorption test, and mechanical performance were used to evaluate the crack healing efficiency achieved by combining low-alkali carrier with microbial CaCCO3 precipitation. They also looked into how to get self-healing cracks up to 417 um with practically complete crack closure in 28 days. They illustrated that when compared to plain mortar, the recovery ratio of compressive strength and water tightness increased to 130% from 50%. [3]

Tianwen Zheng , et.al., (2020) used low alkali sulpho-aluminate cement as a carrier to protect spores of bacteria from the high alkalinity environment and studied its effect on self healing efficiency of cracks by analysing repair ratio, recovery ratio of water permeability, repair ratio of anti-chloride ion penetration. He demonstrated that sulphoaluminate cement had an outstanding spore protection function, and that the inclusion of a microbial self-healing agent would have a minor influence on the early mechanical properties of cement-based materials, but might improve them later on. Furthermore, CaCO3 totally filled the cracks of the microbiological group with a width of 0.25 - 0.35 mm, and the area repair ratio, recovery ratio of water permeability, and repair ratio of anti-chloride ion penetration were 99.2%, 97%, and 63.2%, respectively. Meanwhile, the average healing depth of fissures was 2895 m, which had not previously been documented in research on self-healing cement-based materials. XRD and SEM equipped with an EDS were used to analyse the precipitates generated at the crack mouths of specimens. [4]

Danah Albuhairi et.al., (2022) provides an overview of current developments in Self-Healing Concrete (SHC) in addition to discussing potential opportunities and challenges for well-known healing systems. Along with future SHC projections and the identification of potential study requirements, trends are seen in the investigation of SHC's impact on the engineering characteristics of concrete were also discussed in this paper. [5]

Materials Used:

In the current study ordinary Portland cement 53 grade (OPC) was utilized for investigation. Physical and Mechanical properties of the cement utilized in the study are presented in the Table 1

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Table 1: Properties of cement

Sl.No	Description	Value
1	Standard Consistency	31.5%
2	Initial setting time	92
3	Final setting time	210
4	Specific gravity	3.15
5	7 days strength	34 MPa
6	14 days strength	45 MPa
7	28 days strength	54 MPa

Table 2 Properties of sand

Sl.No	Description	Value
1	Specific gravity	2.6
2	Grading Zone	Zone II
3	Fineness Modulus	2.66

Table 3: Sieve analysis of River sand

Sieve analysis of fine aggregates		
1000gms		
Seive size	Weight retained in gms	Cumulative % Passing
10 mm	2	99.89
4.75 mm	24	97.4
2.36 mm	34	93
1.18 mm	120	81
600µ	382	42.8
300µ	282	15.3
150µ	146	1
pan	10	0
Fineness Modulus 2.55		

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Table 3: Properties of the calcium sulpho aluminate

Chemical composition	Den g/cm^{3}sity	colour	Particle size mm	Initial setting time min	Final setting time min	Strength development hours
$C_4A_3\bar{S}$, or $4CaO \cdot 3Al_2O_3 \cdot SO_3$	2.80 to 2.90	Greyish white colour	10 to 20	20 to 60	60 to 120	24

Properties of the water

Portable water which is ordinary drinking water available in construction laboratory, was used for casting all specimens in this investigation. Water facilitates the even dispersion of cement, ensuring that every particle of aggregates thoroughly coated and mixed with other ingredients, it chemically reads with the cement promoting setting and hardening water also lubricates the mix and improves its compactness. It is free of impurities like oil and organic materials.

Table 5 – Water Content,

mg/l			
Soluble salts	SO4 $^{-2}$	cl^{-1}	Suspended particle
< 3000	< 2000	< 600	< 200

Experimental program:

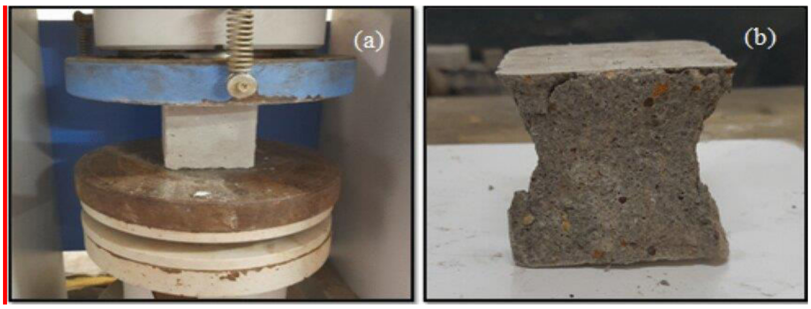

Fig1 (CSA image)

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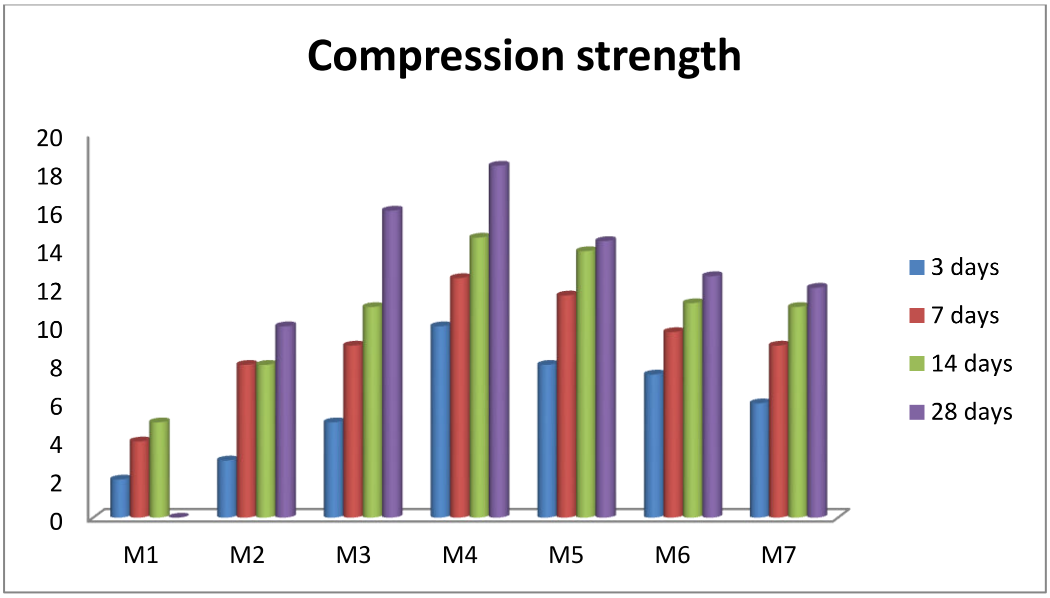
Fig 2 (mortar image for CSA with different combinations)



As compared to the control mix, the mix with 15% Calcium Sulphoaluminate cementitious material yields the highest strength.

Conclusion:

This study investigates the early strength development of concrete made using OPC and CSA cement blends after curing.

To test the setting time and initial compressive strength of mortar, the amount of CSA-containing OPC was adjusted. The optimal performance was found at 15% CSA.

The self-healing properties of these materials reduce the need for regular concrete instructions, resulting in a longer lifespan compared to traditional concrete.

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