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Experimental Investigation of Compressive Strength of Self Compacting Concrete for Various Powder Content at Different Curing Regime

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Abstract: ***This study investigates the compressive strength of self-compacting concrete (SCC) with varying powder content under different curing regimes. The research focuses on M30 and M40 grades of SCC, with twenty-four mixes prepared for each grade. Fly ash, constituting 25% to 50% of the cement weight, was used as a mineral admixture. The SCC cubes were subjected to jute bag curing, water curing, and chemical curing and tested at 7, 28, and 56 days. Results indicate that higher powder content increases compressive strength, with chemical curing showing promise in waterscarce regions. This study highlights the ecological benefits of using fly ash in SCC and suggests optimal conditions for achieving maximum compressive strength. The obtained results were very promising and should be suggesting the use of chemical curing in the waterscarce areas.***

Keywords: Self-compacting concrete, compressive strength, curing regimes, powder content, fly ash

1. Introduction

Self-compacting concrete is a type of concrete that flows due to its own weight through the dense reinforcement and reaches every corner of the formwork and gets compressed without compaction. Now since vibration is not provided in it, the harmful effects caused by vibration are avoided and it is also very beneficial in terms of faster construction, the surface finish and durability. Therefore, Self-compacting concrete has proved its relevance in the economic perspective since its discovery in the early 1980s. SCC has demonstrated a strong balance between durability and deformation, which has been a key reason for its development. Various mixture composition procedures have been proposed for SCC, which includes the higher quantity of a mineral admixture and the quantity of superplasticizer and/or viscosity modifying agent that reduces the quantity of water. [1,2]

Many researchers have designed concrete mix using different designing methods viz rheology of paste method, particle packing method etc. In these designing methods, the main emphasis has been given to fresh concrete properties instead of concrete grade [3–6]. In this experimental study, design of the concrete mix is based on compressive strength method for M30 and M40 concrete grade. Depending upon the physical properties of the raw materials used for making concrete and as per Indian Standards and EFNARC guidelines, a SCC mix can be designed for each powder quantity for a particular grade of concrete [7,8]. Since Rajasthan province of India is a desert region having severe water scarcity, hence in this experimental work, the effect of variations in the quantity of each powder and different mineral admixtures on the compressive strength of concrete in different curing regimes has been studied.

This study is significant as it addresses the environmental and practical challenges in concrete construction, particularly in waterscarce regions. By optimizing the use of fly ash in SCC, the study contributes to sustainable construction practices while enhancing material performance. The purpose of this study is to evaluate the compressive strength of self-compacting concrete with varying powder content and under different curing regimes, with a focus on optimizing the use of fly ash as a replacement for cement in regions with water scarcity

2. Experimental Program

2.1 Materials

Ordinary Portland cement 43 grade conforming to IS 8112:1989 was used and its physical properties are shown in table - 1. Locally available river sand of zone - 1 as per IS 383, which has a fineness modulus of 2.29 was used. Locally available crushed angular aggregates stones with 12.5 mm maximum size were used. Properties of FAgg and CAgg are shown in table - 2 and gradation curve of FAgg is shown in fig - 1. Fly ash used as a mineral admixture whose specific gravity was found to be 2.04. A polycarboxylate based superplasticizer named melflux 2651 F complies to IS 9103 and specific gravity of it as 1.08 was used to achieve the appropriate workability of the concrete mixes.

Table 1: Physical properties of 43 grade OPC cement

Physical Properties	Requirement as per IS 8112	Results
Fineness (m^2/kg)	225 (minimum)	289
Soundness (Le Chatelier Method) (mm)	10 (maximum)	1
Initial setting time (minutes)	30 (minimum)	35
Final setting time (minutes)	600 (maximum)	378
Specific gravity	3.15	3.15

Table 2: Physical properties of fine and coarse aggregate

Physical Properties	FAgg	CAgg
Specific Gravity	2.58	2.63
Water absorption (%)	2.04	0.5
Dry Density (kg/m^3)	1500	1580

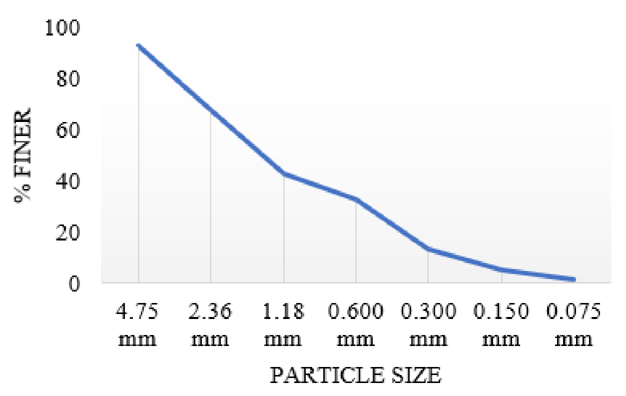

Figure 1: Gradation Curve for Fine Aggregate

2.2 Mixture proportions

A total of 48 concrete mixes were prepared of which 24 concrete mixes were prepared for every grade M30 and M40 SCC by compressive strength method based as per IS10262: 2019. Concrete mixes of M30 were prepared for 440, 470, 500, and 520 powder content while concrete mixes of M40 were produced for 470, 490, 520, and 550 powder content. Along with this, the proportion of fly ash used as a mineral admixture ranged from 25% to 50%. Table – 3 and Table – 4 show the mix proportions for M30 and M40 grade SCC.

2.3 Preparation and casting of the test specimens

Since the mixing method and mixing time greatly affect the properties of SCC, the mixing process was kept the same for all concrete mixtures and each mixing process lasted about 8 minutes. Firstly, all the ingredients used for making concrete were mixed in a dry condition for one minute, then after mixing was done for another 1 minute by adding superplasticizer along with 70% of the total amount of water, and finally 30% water was added, and then mixing is carried out for 5 minutes to get a uniform mix. For each SCC mix 27 cubes of $150\,mm \times 150\,mm \times 150\,mm$ were cast. Moreover, three types of curing regimes were adopted namely, jute bag curing, water immersion curing, and chemical curing. Thus, every grade of concrete consists of 648 cubes for testing.

Table 3: Mix proportion for one cubic meter M30 grade SCC

Sample name	Powder content	W/C ratio	Cement	Mineral admixture (Fly Ash)	C. AGG.	F. AGG.	SP (1% of weight of C+MA)	Water (Litres)
M30_25MA								
SCC 1	440	0.4313	296	99	673	1041	4	170
SCC 2	470		322	107	712	933	4.3	185
SCC 3	500		348	116	750	825	4.6	200
SCC 4	520		365	122	775	753	4.9	210
M30_30MA								
SCC 5	440	0.4313	276	118	664	1041	4	170
SCC 6	470		300	129	702	933	4.3	185
SCC 7	500		325	139	739	825	4.6	200
SCC 8	520		341	146	764	752	4.9	210
M30_35MA								
SCC 9	440	0.4313	256	138	655	1041	4	170
SCC 10	470		279	150	692	933	4.3	185
SCC 11	500		301	162	729	825	4.6	200
SCC 12	520		316	170	753	753	4.9	210
M30_40MA								
SCC 13	440	0.4313	236	157	646	1041	4	170
SCC 14	470		257	172	682	933	4.3	185
SCC 15	500		278	185	718	825	4.6	200
SCC 16	520		292	195	742	753	4.9	210
M30_45MA								
SCC 17	440	0.4313	217	177	637	1041	4	170
SCC 18	470		236	193	672	933	4.3	185
SCC 19	500		255	209	708	825	4.6	200
SCC 20	520		268	219	731	753	4.9	210
M30_50MA								
SCC 21	440	0.4313	197	197	628	1041	4	170
SCC 22	470		214	214	663	933	4.3	185
SCC 23	500		232	232	697	825	4.6	200
SCC 24	520		243	243	720	753	4.9	210

2.4 Compressive strength Test

The compressive strength test was conducted at the ages of 7, 28, and 56 days in accordance with IS 516. The specimens were loaded under gradually applied uniaxial compressive load up to failure by using hydraulic testing machine with a capacity of 2000 kN. Before the load is applied, it should be ensuring that the bearing surfaces of the testing machine shall be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression platens. The specimen shall be placed in such a manner that the load shall be applied to opposite sides of the cube as cast, that is, not to the top and bottom and the axis of the specimen shall be carefully aligned with the center of the thrust of the seated platens.

Table 4: Mix proportion for one cubic meter M40 grade SCC

Sample name	Powder content	W/C ratio	Cement	Mineral admixture (Fly Ash)	C. AGG.	F. AGG.	SP (1% of weight of C+MA)	Water (Litres)
M40_25MA								
SCC 1	470	0.3522	319	106	735	1002	4.26	150
SCC 2	490		341	114	878	812	4.54	160
SCC 3	520		362	121	786	848	4.82	170
SCC 4	550		383	128	694	885	5.10	180
M40_30MA								
SCC 5	470	0.3522	298	128	726	1002	4.26	150
SCC 6	490		318	136	867	812	4.54	160
SCC 7	520		338	145	775	848	4.82	170
SCC 8	550		358	153	688	885	5.10	180
M40_35MA								
SCC 9	470	0.3522	277	149	716	1002	4.26	150
SCC 10	490		295	159	857	812	4.54	160
SCC 11	520		314	169	764	848	4.82	170
SCC 12	550		332	179	671	885	5.10	180
M40_40MA								
SCC 13	470	0.3522	256	170	706	1002	4.26	150
SCC 14	490		273	182	793	812	4.54	160
SCC 15	520		290	193	753	848	4.82	170
SCC 16	550		307	204	659	885	5.10	180
M40_45MA								
SCC 17	470	0.3522	234	192	697	1002	4.26	150
SCC 18	490		250	204	836	812	4.54	160
SCC 19	520		265	217	742	848	4.82	170
SCC 20	550		281	230	648	885	5.10	180
M40_50MA								
SCC 21	470	0.3522	213	213	687	1002	4.26	150
SCC 22	490		227	227	826	812	4.54	160
SCC 23	520		241	241	731	848	4.82	170
SCC 24	550		256	256	636	885	5.10	180

3. Results and Discussion

Figure - 2 to Figure - 4 showing the compressive strength test results of M30 grade SCC at the 7th, 28th, and 56th days respectively under different curing conditions. Similarly, Figure - 5 to Figure - 7 showing the compressive strength test results of M40 grade SCC at the 7th, 28th, and 56th days respectively under different curing conditions.

The results show that the compressive strength of SCC on the 7th, 28th, and 56th days is an increasing function with the increase in powder content. As observed, the compressive strength of all the samples increased with curing age, but those with higher fly ash content showed a greater percentage-wise increase in the compressive strength with time.

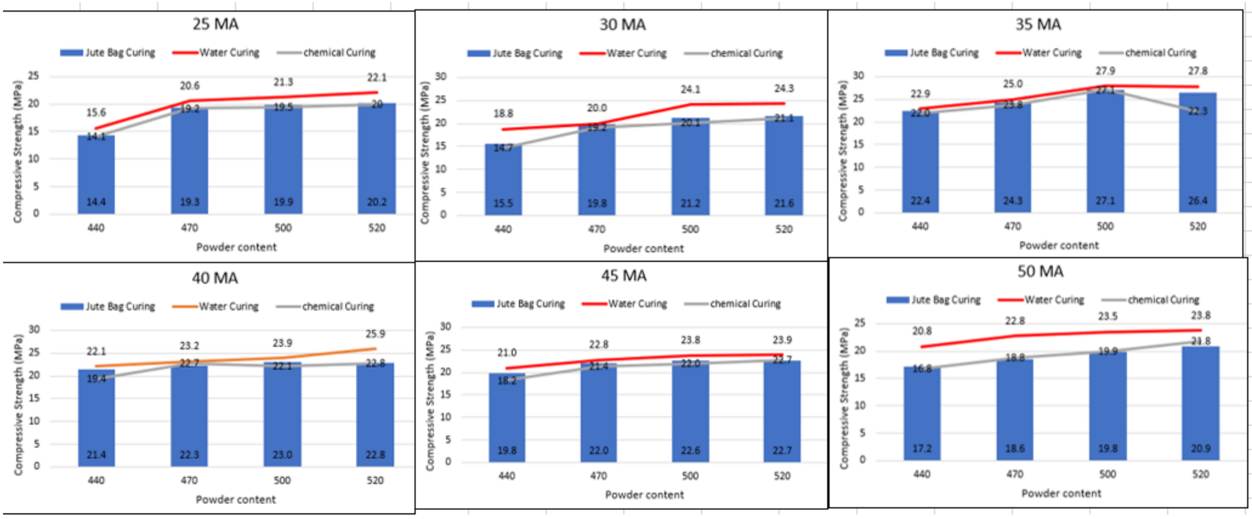

Figure 2: Compressive strength results of M30 SCC at 7 days for various curing regimes

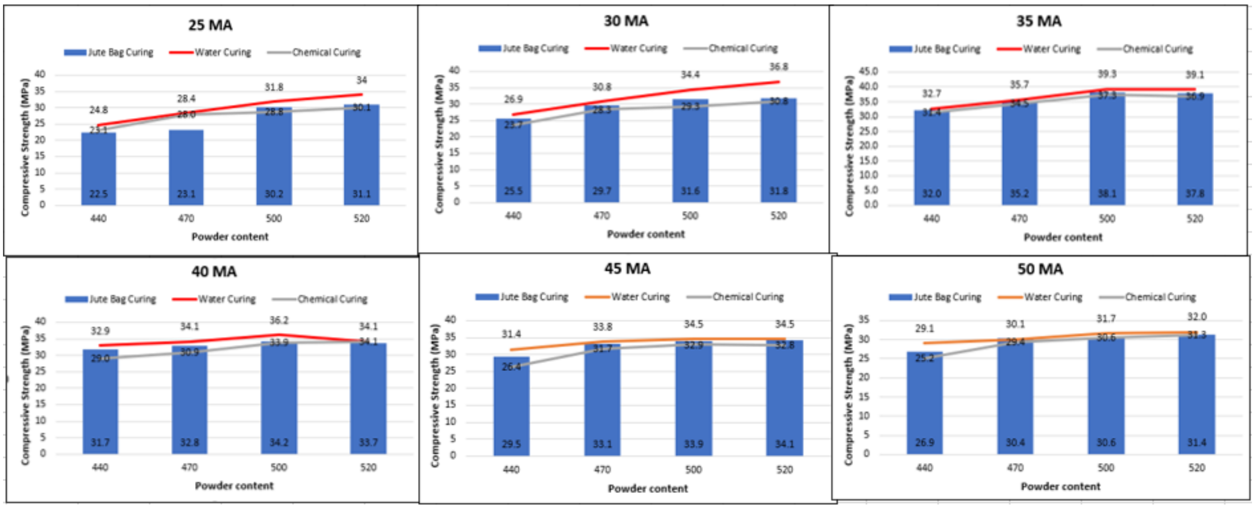

Figure 3: Compressive strength results of M30 SCC at 28 days for various curing regimes

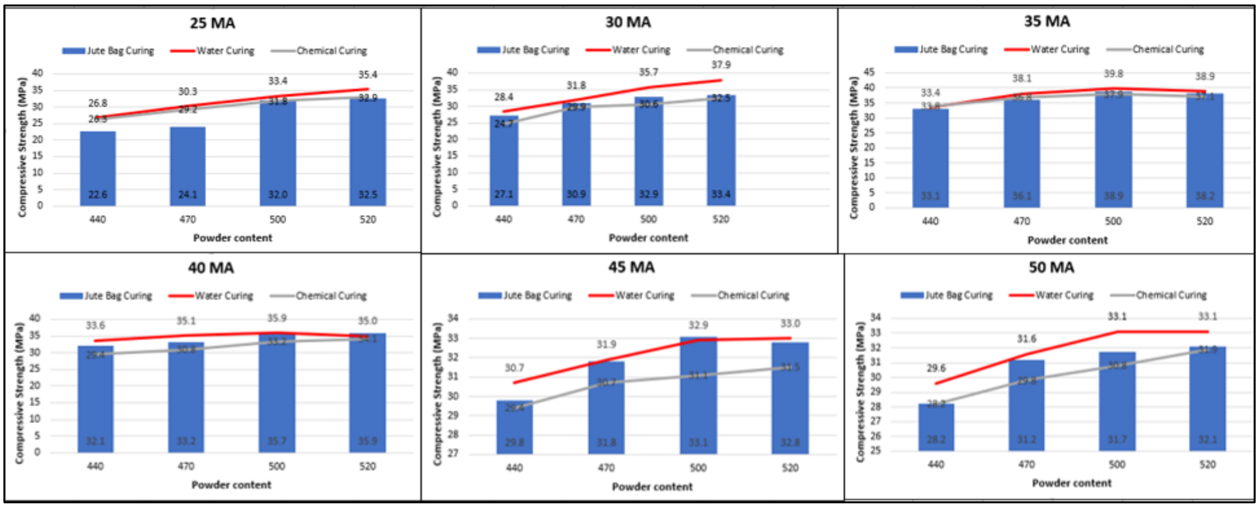

Figure 4: Compressive strength results of M30 SCC at 56 days for various curing regimes

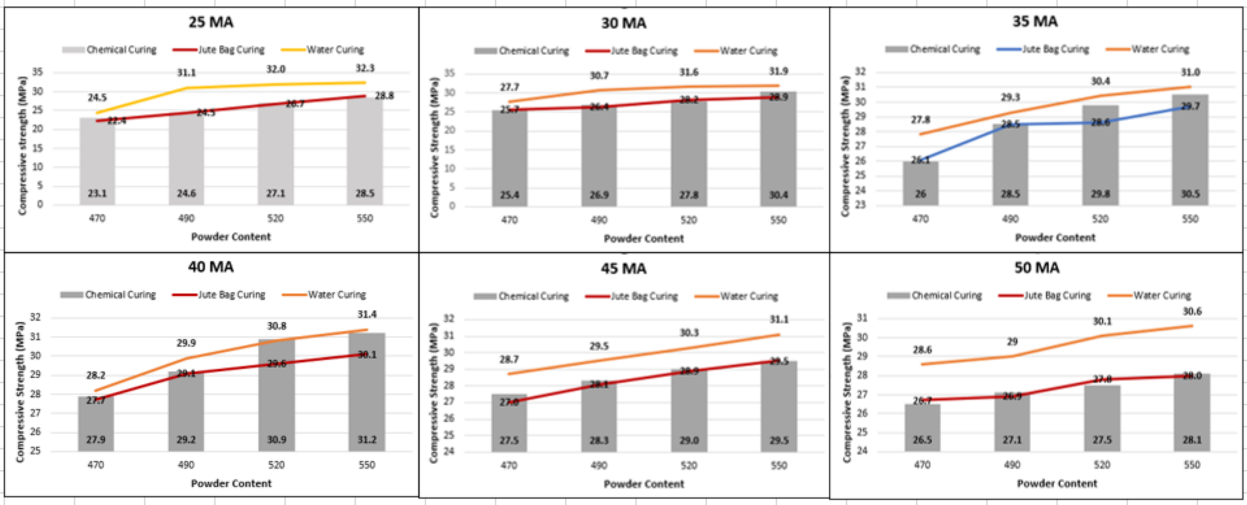

Figure 5: Compressive strength results of M40 SCC at 7 days for various curing regimes

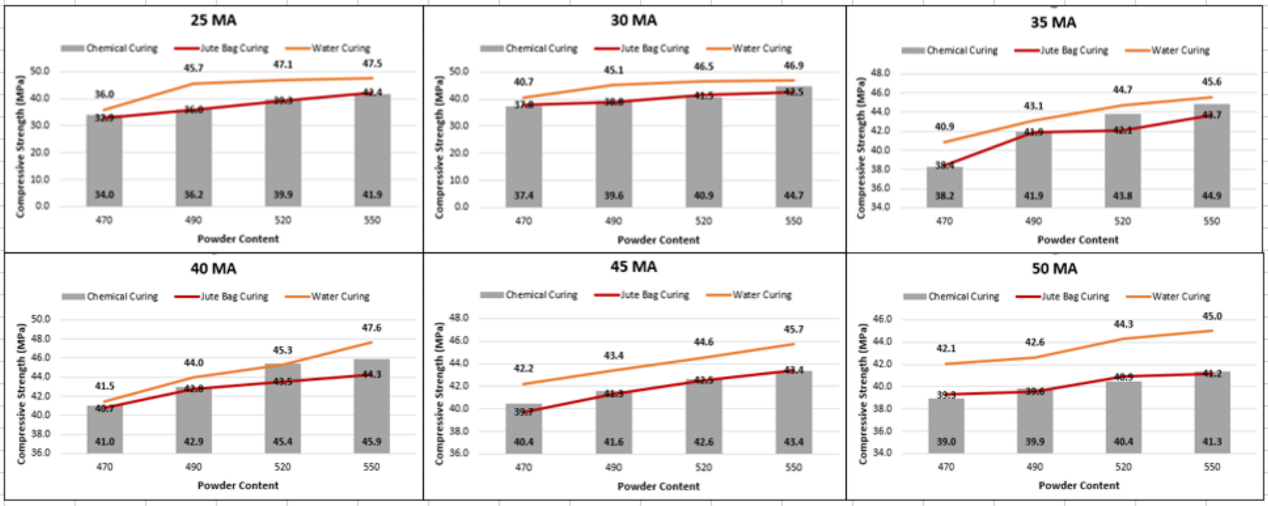

Figure 6: Compressive strength results of M40 SCC at 28 days for various curing regimes

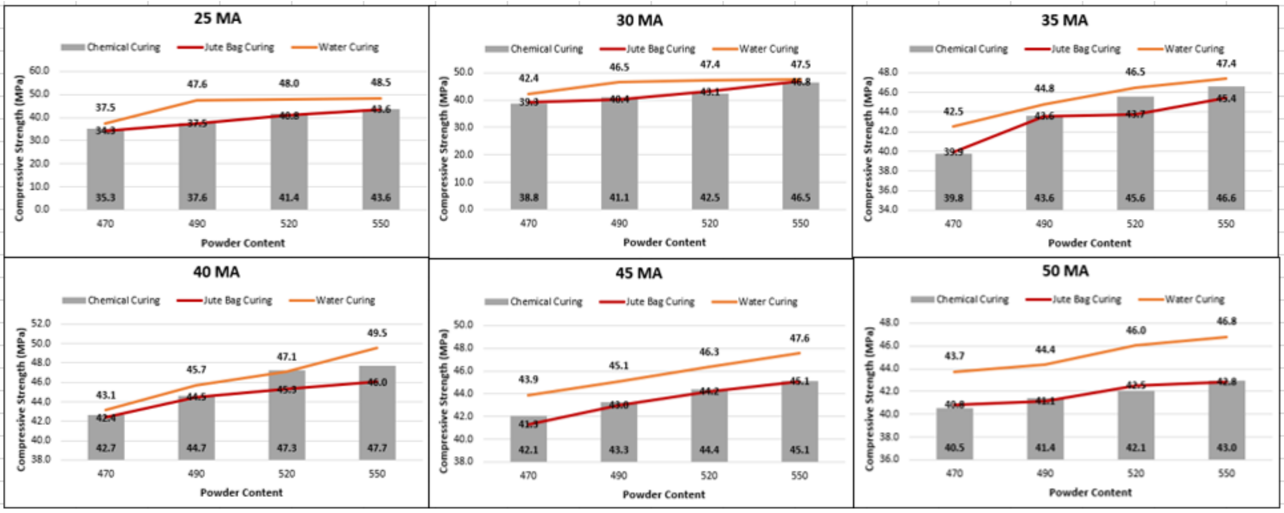

Figure 7: Compressive strength results of M40 SCC at 56 days for various curing regimes

In the case of M30 grade concrete, maximum compressive strength was achieved by replacing cement with fly ash up to 35% but a further increase in the fly ash content resulted in a decrease in compressive strength. But for M40 grade concrete, maximum compressive strength was achieved by replacing cement with fly ash up to 40% and decreased thereafter.

As per the observed results of the compressive strength for different methods of curing, the compressive strength achieved in chemical curing shall be 5% - 10% less than the compressive strength achieved in water curing.

4. Conclusions

This experimental investigation focuses on the effect of powder content on the compressive strength of SCC and the ecological benefits of the effective use of fly ash as pozzolanic material for replacement of the cement. From the results obtained in this study, the following conclusions can be drawn:

1) In the design of high-grade SCC, the observed results of compressive strength will be higher if the powder content is kept higher otherwise the compressive strength even will be less than the characteristic strength of the concrete.
2) As far as fly ash is concerned, its replacement with cement can be kept up to a maximum of 40%, after which the compressive strength of concrete decreases.
3) If the designed grade for a construction is M25, then increasing this grade i.e. making the grade of this construction M30 instead of M25 is an effective solution for chemical curing in the water-scarce areas.

This study demonstrates that increasing the powder content in SCC enhances compressive strength, particularly when fly ash is used as a partial replacement for cement. The results highlight the potential for chemical curing as a viable alternative in waterscarce regions. The findings contribute to the ongoing development of sustainable and durable concrete mixtures and suggest further research into optimizing curing techniques for different environmental conditions.

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