International Journal of
AI ELECTRICAL CIVIL AND MECHANICAL ENGINEERING
Peer Reviewed, Referred & Indexed Journal
ISSN: 3070-0434 www.zesterapublications.com Original Research Paper

EXPERIMENTAL INVSTIGATION ON STRENGTH PROPERTIES AND SULPHATE RESISTANCE OF SELF-COMPACTING CONCRETE INCORPORATING SILICA FUME AND METAKAOLIN

Kirtikumar Vittal Yannam[1], Dr. Sudeep Biswas[2]

[1] PG Student, Department of Civil Engineering, Bharat Institute of Engineering and Technology, Hyderabad, India.
[2] Assistant Professor Department of Civil Engineering, Bharat Institute of Engineering and Technology, Hyderabad, India.

Abstract: Self-compacting concrete (SCC) may overcome obstacles and be poured without vibration. Due to its benefits, SCC has grown in popularity in Japan, Europe, and the US since 1988. SCC technology may reduce or eliminate concrete laying issues in tough situations. It also saves time and effort by reducing quality control test repetition. Faster and simpler construction and placement. Not vibrating reduces noise pollution. SCC increases concrete durability, particularly in components with reinforcing congestion or permeability faults. The compressive and splitting tensile strengths and sulfate resistance of silica fume and metakaolin self-compacting concrete will be examined in this research. Silica fume and metakaolin may substitute cement in 5%, 10%, and 15% amounts. Samples are tested for sulfate, cracking tensile strength, and compressive resistance. The seventh, 28th, and 56th days of life are tested. This experiment using silica fume and Metakolin self-compacting concrete passed all plastic stage tests. Hardened-stage compressive and splitting tensile strength testing was also good. The compressive strength increased 18–38% with Simica fume and 15–45% with metakaolin. By replacing cement with silica fume and metakaolin, SCC's sulfate resistance increased.

Keywords: Self-compacting concrete (SCC), Metakaolin self-compacting concrete, Compressive Resistance Silica fume

1. INTRODUCTION

Concrete buildings have been built without vibration. Subaqueous concrete is commonly placed using the Tremie process, which avoids vibration. Without vibration, mass and shaft concrete may be poured effectively. However, these specific instances are weaker and harder to uniformize. Current self-compacting concrete (SCC) utilization focuses on performance, reliability, and quality consistency. The concept of self-compacting concrete is not new. Self-compacting concrete initially used more cement paste. After that, superplasticizers were added to concrete. Minimizing combination segregation needed specialized and well-supervised placement processes For self-compactability to happen, the paste or mortar needs to be very flexible and keep the mortar and coarse aggregate from separating (Okamura et al., 2003). Self-compactability is a desirable property for mortars and pastes. This is essential in order to ensure that the concrete is able to flow through the area where the reinforcing bars are limited. When it comes to self-consolidating concrete (SCC), the term "homogeneity" refers to the capacity of the material to maintain its composition in a consistent manner and to

Received: 05-06-2026 | Accepted: 10-07-2026 | Published: 17-07-2026

prevent segregation throughout the operations of installation and transportation. The following methods are used to make self-compacting concrete (SCC) that has great flowability and doesn't separate:

This is because self-compacting concrete (SCC) has a significant number of extremely fine particles, which gives it an internal material structure that is akin to that of high-performance concrete. This is the reason why this is the case. There are a number of components that are similar to one another.

1.1 Need of study

For the last five years, SCC has been widely pushed across the Middle East, but most local communities have not adopted it with any momentum. Concerns over the lack of durability and consolidation in traditionally vibrated normal concrete have led to a widespread dissemination of information on self-consolidating concrete (SCC). There are many reasons why people are reluctant to take advantage of SCC's benefits.

- Lack of research or published data pertaining to locally produced SCC.
- The potential problems to produce SCC, if any, with local marginal aggregates and the harsh environmental conditions prevailing in the region.

2. Properties of Materials

As part of the experiment, the properties of self-compacting concrete made with and without silica fume and metakaolin, an extra cementing agent, are compared. The purpose of this comparison is to identify the variations between the two varieties of concrete. This comparison is done to determine the differences that exist between the two versions. The material that was utilized is the subject of a debate in this chapter, which you may find here. This chapter also includes a discussion of the basic research that was done on concrete samples when they were still plastic. Concrete samples were used in these tests. A brief synopsis of the mix design and the curing technique used throughout the procedure comes next. The next part contains a comprehensive overview of all the research that was conducted on the specimens.

2.1 Cement

For the length of this job, cubes and cylinders were formed in all concrete mixes using J.K. cement, grade 43. The cement was colorless and without any apparent solid clumps. Its uniform tint was described as grayish with a little green undertone. To ascertain the cement's specific gravity, fineness, compressive strength, and beginning and final setting periods, a range of tests are carried out and evaluated. The trials discussed above may be viewed in Tables below.

Table 1: Properties of cement

International Journal of
AI ELECTRICAL CIVIL AND MECHANICAL ENGINEERING
Peer Reviewed, Referred & Indexed Journal
ISSN: 3070-0434 www.zesterapublications.com Original Research Paper

Test Conducted	Values Obtaine	Standard values
Initial Setting time	42 min	Not < 30 minutes
Final Setting time	310 min	Not > 600 minutes
Fineness	4.9 %	<10
Specific gravity	3.09	-

Days	Specimen	Compressive Strength (N/mm^2)	Average Compressive Strength
7	1	35.2	35.3
	2	36.1	
	3	34.7	
28	1	42.8	44.1
	2	44.1	
	3	45.3	

2.2 Fine Aggregates

Sand was obtained locally for the assignment, and it met the Indian Standard Specifications as stated in the 1970 book. To separate the larger particles from the sand, a 4.75-millimeter sieve was used. Several other tests are carried out and taken into consideration, such as bulk density, specific density, fineness modulus, water absorption, and sieve analysis. The obtained findings are shown in Tables 4.4 and 4.5, respectively. The fine aggregates were included in Grading Zone III.

Table 2: Physical Properties of fine aggregates

Characteristics	Value
Specific gravity	2.51
Bulk density	1.3
Fineness modulus	2.62
Water absorption	0.89

2.3 Coarse Aggregates

According to the International Standard (IS), "coarse aggregate" is defined as the material that is left behind after a sieve with a size of 4.75. Using crushed stone as coarse aggregate is one such use. The project's characteristics are

Received: 05-06-2026 | Accepted: 10-07-2026 | Published: 17-07-2026

used to determine the maximum size of the coarse aggregate. The coarse materials employed in this investigation had a maximum size of 10 millimeters and were readily accessible in the area. The procedure used in this investigation included cleaning the aggregates to get rid of dirt and dust, then drying them until they were surface dry. All of the aggregates were examined in compliance with the guidelines provided in IS 383-1970. Tables 4.6 and 4.7 provide the findings of many tests that were carried out on coarse aggregate.

Table 3: Physical Properties of Coarse Aggregates

Characteristics	Value
Type	Crushed
Specific Gravity	2.66
Total Water Absorption	0.56
Fineness Modulus	6.83

2.4 Magnasium Sulphate

The pulverized magnesium sulfate that was acquired came from Scientific Junction, which is situated in Patiala. It was made up of white. The material was mixed with water to create a solution with a concentration of 5%, and this was used for a sulfate resistance test.

2.5 Admixture

Conplast SP430, a water reduction admixture, was employed in this project. This particular mix satisfies the requirements stated in ASTM-C-494 type 'F', BS:5075 Part 3, and IS:9103:1979. During the batching process, Conplast SP 430, a commonly accessible additive, is added to the concrete. Conplast SP430 is not like other superplasticizers because it uses an aqueous solution of lignosulphonates, which is an organic polymer with long side chains. This technique significantly improves cement dispersion. Conplast SP430 is a brown liquid that spreads well over wet surfaces. The product has undergone extensive development to accomplish a significant 25% reduction in water content while retaining the required degree of workability. When the temperature is 30 degrees Celsius, the specific gravity ranges from 1.22 to 1.225.

2.6 Silica Fume

The addition of silica fume to the concrete mixture causes pozzolanic reactions to occur. An essential component of pozzolan is amorphous silica, which reacts with calcium hydroxide, a substance produced when calcium silicates hydrate. The end product of this reaction is calcium silicate hydrate, which has the chemical formula C-S-H (Mindess et al., 2003). When micro-silica is added to the concrete mixture, the matrix of micro-silica concrete often shows a noticeable increase in thickness (St. John, 1998). The minuscule particle size of microsilica might be the cause of the denseness effect. Applications for concrete that need a significant degree of imperviousness and great compressive strength use silica fume. The usual range for the appropriate dose of silica fume is five to ten percent by mass of the total cementitious material. Under some circumstances, the quantity of silica fume added to concrete raises the water consumption of the concrete proportionately. This state lasts until a plasticizer or water reducer is used. In certain low-density combinations, it is possible that the water requirement does not increase when the amount of silica fume is less than 5%.

Table 4: Physical Properties of Silica Fume

Colour	Varies from white or pale-grey to a dark grey
Specific Gravity	It is generally equal to that amorphous silicon which is about 2.2. depending upon its chemical composition the specific gravity of silica fume particle can be as high as 2.4-2.55
Specific Surface Area	About 20000 m^2/kg approximately 10 times more than Portland cement
Particle Size	Mostly fine spheres with a mean diameter of .1 micron
Bulk Loose Density	230-300kg/m^3

2.7 Metakaolin

Certain kaolinite clays are burned under regulated conditions between 650 and 800 °C to generate metakaolin, a pozzolana. When temperatures are elevated to seven hundred to nine hundred degrees Celsius, kaolin is transformed into MK, and up to fourteen percent of its hydroxyl water is lost. This is the process of calcination, according to Caldarone et al. (1994). Stricter rules may apply to the manufacture of MK, which would improve quality control and ultimately result in a greater level of purity and pozzolanic reactivity (Kostuch et al., 1993). One of the secondary products of Portland cement's hydration process is calcium hydroxide (CH). The products of CH's reaction with the alumina and amorphous silica in MK are calcium hydro silicate (C-S-H) and calcium hydro aluminosilicate (C2ASH8), which are potentially gehlenite. The literature suggests that by optimizing the binder capillary porosity via the pozzolanic reaction between metakaolin (MK) and calcium hydroxide (CH), one can improve durability, including resistance to sulfate attack, chloride ingress, and alkali silica reaction, as well as mechanical characteristics, particularly during the early stages. The results of Zongin et al.

Tables 5: Chemical and physical properties of metakaolin

Constituents	Percent
CaO	0.78
SiO_2	52.68
Al_2O_3	36.34
Fe_2O_3	2.14
MgO	0.16
SO_3	-
K_2O	0.62
Na_2O	0.26
LOI	0.98
Specific Gravity	2.5
BET Fineness (m^2/kg)	12000

3.4 Mix Proportion

Table 6: Mix Proportion

Received: 05-06-2026 | Accepted: 10-07-2026 | Published: 17-07-2026

International Journal of
AI ELECTRICAL CIVIL AND MECHANICAL ENGINEERING
Peer Reviewed, Referred & Indexed Journal
ISSN: 3070-0434 www.zesterapublications.com Original Research Paper

Mixture ID	Cement kg/m³	MK kg/m³	SF Kg/m³	MK (%)	SF (%)	Sand kg/m³	C.A kg/m³	Water (kg/m³)	w/p	SP (kg/m³)	SP (%)
CM	550	0	0	0	0	910	590	265	.48	9.91	1.80
5%SF	522	-	28	-	5	910	590	265	.48	9.91	1.80
10%SF	495	-	55	-	10	910	590	265	.48	9.91	1.80
15%SF	467	-	83	-	15	910	590	265	.48	9.91	1.80
5%MK	522	28	-	5	-	910	590	265	.48	9.91	1.80
10%MK	495	55	-	10	-	910	590	265	.48	9.91	1.80
15%MK	467	83	-	15	-	910	590	265	.48	9.91	1.80

3 RESULTS AND DISCUSSIONS

The results of the control concrete as well as the concrete that was produced by substituting silica fume and metakolin for cement are investigated and reported in this section of the article. During the production of the control concrete, the use of cement was completely avoided. There are a number of metrics that are investigated, including the compressive strength, splitting tensile strength, and sulphate resistance of the material. Additionally, comparisons between the different blends are offered.

3.1 Fresh Concrete Properties

Slump flow, V-funnel, U-Box, and L-Box tests were performed on mixed concrete mixtures (SCC) that included varying concentrations of silica fume. The purpose of these tests was to investigate the impact that replacing cement with silica fume in varying proportions had on the characteristics of fresh concrete. Table 5.1 contains the findings on the fresh characteristics of all of the self-compacting silica fume concretes that were tested. A number of the qualities, including slump flow, V-funnel flow times, L-box, and U-box, are shown in the table. When it comes to slump flow, all of the SCCs demonstrated adequate slump flows in the region of 550–800 mm, which is a sign of good deformability.

Table 7 : Fresh Concrete Properties

Mixture ID	Slump (mm)	V-funnel (seconds)	L-Box (H2/H1)	U-box(H1- H2)
CM	585	11	0.9	34
5% SF	610	11	0.9	34
10% SF	660	10	0.9	40
15% SF	685	8	0.9	35

3.2 Compressive Strength Test

Received: 05-06-2026 | Accepted: 10-07-2026 | Published: 17-07-2026

International Journal of
AI ELECTRICAL CIVIL AND MECHANICAL ENGINEERING
Peer Reviewed, Referred & Indexed Journal
ISSN: 3070-0434 www.zesterapublications.com Original Research Paper

Cube specimens measuring 150 mm on each side and 150 mm tall are being made so that the effect on compressive strength can be studied when different amounts of cement are used instead of silica fume. The cube specimens will be constructed with dimensions of 150 mm on each side. There are three levels of silica fume that are regarded as replacement levels: five percent, ten percent, and fifteen percent. When the specimens have been cured in water for seven days, twenty-eight days, and fifty-six days, the next step is to put them through a battery of tests.

Table 8: Compressive strength of SCC mixes

MIX	Compressive Strength (N/mm²)			Average Compressive Strength (N/mm²)		
	7 days	28 days	56 days	7 days	28 days	56 days
CM	20.7	28.4	31.7	20.6	29.5	31.7
	21.5	30.3	30.9			
	19.6	29.9	32.3			
5% SF	24.9	35.3	39.7	24.6	35.1	38.7
	25.7	34.1	38.9			
	24.4	35.9	37.5			
10% SF	28.1	39.6	44.2	27.2	39.7	43.5
	26.2	40.3	42.8			
	27.4	39.2	43.4			
15% SF	25.1	35.4	40.1	25.3	35.4	39.3
	24.1	36.1	38.8			
	26.8	34.9	39.0			
	21.5	30.3	30.9			

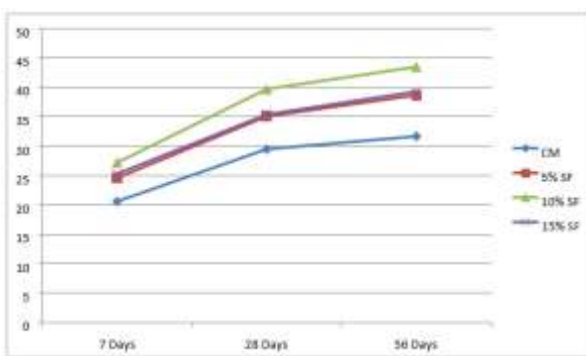

Figure 1: Compressive strength of SCC mixes

Table 9: Compressive strength of SCC mixes after immersion in $MgSo_4$ solution

International Journal of
AI ELECTRICAL CIVIL AND MECHANICAL ENGINEERING
Peer Reviewed, Referred & Indexed Journal
ISSN: 3070-0434 www.zesterapublications.com Original Research Paper

MIX	Compressive Strength (N/mm^2) (After 28 days curing)			Average Compressive Strength (N/mm^2) (After 28 days curing)		
	7 days	28 days	56 days	7 days	28 days	56 days
CM	29.6	32.3	33.6	29.1	31.2	33.3
	29.1	30.4	32.5			
	28.5	31.0	33.9			
5% SF	35.5	38.0	42.1	34.9	38.3	42.6
	34.8	39.3	43.3			
	34.3	37.6	42.7			
10% SF	39.6	43.1	46.6	39.4	43.2	45.8
	38.2	42.7	44.8			
	39.4	43.8	46.0			
15% SF	35.3	39.0	42.6	35.0	39.0	43.1
	35.7	38.7	43.8			
	34.2	39.4	43.0			

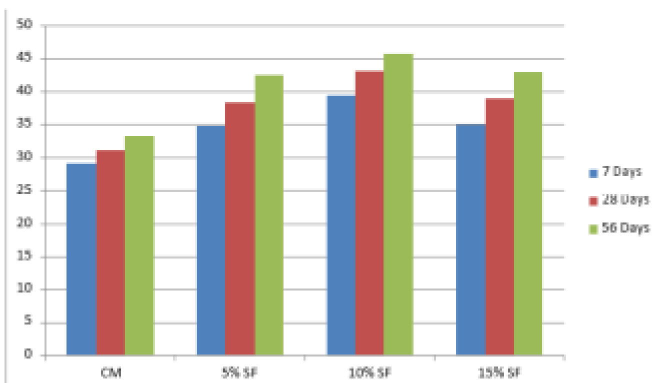

Figure 2: Compressive strength of SCC mixes after immersion in $MgSo_4$ solution

3.3 Splitting Tensile Strength Test

At seven, twenty-eight, and fifty-six days, split tensile strength tests were carried out. The results of the tests determined these ages. The results of the tests are shown in the table that may be seen below. In the short run as well as in the long term, the results of the tests demonstrated that substituting five to ten percent of the cement with silica fumet by weight leads to an increase in strength. This is something that can be seen on the table. If we increase the quantity of silica fume that is replaced, the strength of the replacement will continue to drop for an extended period of time. Concrete that includes 5% and 10% silica fume, respectively, exhibits an increase in splitting tensile strength that ranges from 20 to 40 percent at the age of 28 days in comparison to the control mix. This increase is seen in comparison to the control mix.

Table 10: Splitting tensile strength of SCC mixes

International Journal of
AI ELECTRICAL CIVIL AND MECHANICAL ENGINEERING
Peer Reviewed, Referred & Indexed Journal
ISSN: 3070-0434 www.zesterapublications.com Original Research Paper

MIX	Splitting Tensile Strength (N/mm²)			Average Splitting Tensile Strength (N/mm²)		
	7 days	28 days	56 days	7 days	28 days	56 days
CM	1.4	1.9	2.1	1.4	2.0	2.2
	1.3	2.1	2.0			
	1.5	2.0	2.2			
5% SF	1.8	2.5	2.9	1.7	2.5	2.8
	1.7	2.65	2.8			
	1.6	2.45	2.7			
10% SF	2.0	2.85	3.2	2.0	2.75	3.0
	1.85	2.75	2.8			
	2.1	2.65	3.0			
15% SF	1.7	2.7	2.8	1.6	2.55	2.9
	1.6	2.6	3.0			
	1.5	2.4	2.9			

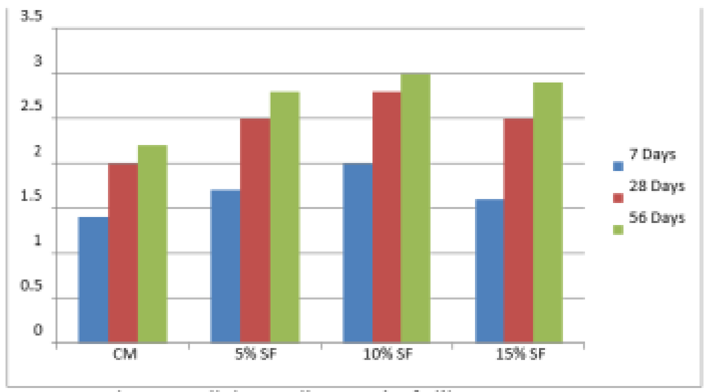

Figure 3: Splitting tensile strength of SCC mixes

4. CONCLUSIONS

- The findings of the study that came before this one show that it is possible to include silica fume and metakaolin in self-consolidating concrete (SCC) mixtures at a maximum concentration of fifteen percent. Every single one of the self-consolidating concrete (SCC) mixes has a slump flow that falls anywhere between 600 and 700 millimeters. The time required for the V-funnel interval is anywhere between four and ten seconds. The ratio of the L-box is more than 0.8, which indicates that the flowability is rather good. In addition, the U-box test demonstrates that there is a discernible variation in the height of the concrete between two compartments that ranges from 5 to 40 millimeters.
- Over the course of a week, the compressive strengths of the self-consolidating concrete (SCC) mixes were determined to be 24.6, 27.2, and 25.3 N/mm2, respectively, for silica fume replacement levels of 5%, 10%, and 15%. These values were determined by measuring the compressive strength of the mixtures. The specimen demonstrates strengths of 35.1, 39.7, and 35.4 N/mm2 in sequential order after it has reached the age of 28 days. The levels of acquired strength are specifically assessed at 38.7, 43.5, and 39.3 N/mm2 when the animal is 56 days old. When the material is seven days old, adding metakolin as an additional material in ratios of 5%, 10%, and 15% results in compressive strengths of 23.9, 28.6, and 30.3 N/mm2, respectively. When it comes to the measurement of

International Journal of
AI ELECTRICAL CIVIL AND MECHANICAL ENGINEERING
Peer Reviewed, Referred & Indexed Journal
ISSN: 3070-0434 www.zesterapublications.com Original Research Paper

strength, the values that were recorded at the age of 28 days are 34.8, 40.2, and 43.7 N/mm2, respectively. The strength that is reached at the age of 56 days is measured to be 37.8, 44.0, and 46.5 N/mm2, despite the fact that this observation has been made. When there is a higher concentration of metakaolin in a material, there is a commensurate increase in the compressive strength of the material. On the other hand, the compressive strength of silica fume displays an increasing trend until a replacement level of 10% is achieved, after which it suffers a considerable fall for the remainder of the experiment.

- The splitting tensile strength changed between 1.7 and 2.0 N/mm2 when silica fume was present, between 2.5 and 2.75 N/mm2 when there was no fume, and between 2.8 and 3.0 N/mm2 when there was fume at 7, 28, and 56 days. These values were observed at the corresponding times. Metakaolin was included in the self-compacting concrete (SCC) mixes, which led to splitting tensile strengths that ranged from 1.6 to 2.2 N/mm2, 2.35 to 3.0 N/mm2, and 2.55 to 3.3 N/mm2 after 7, 28, and 56 days, respectively. These values were measured at the end of the experiment. There were three different time periods at which the values were measured: seven, twenty-eight, and fifty-six, respectively.
- When silica fume and metakaolin are used instead of cement, the concrete is better able to withstand sulfate attack. When the loss in compressive strength is evaluated, it is seen that the strength drops by 1.7%, 1.7%, and 0.8% for replacement levels of 5%, 10%, and 15% of silica fume, respectively. This is according to the results of the evaluation. On the other hand, when metakolin is taken into consideration, the drop in strength amounts to 0.8%, 0.7%, and 0.6% at replacement levels of 5%, 10%, and 15%, respectively.

REFERENCES

[1] Aitcin, P.,C., (1999). “High performance concrete. London: E & FN Spoon.”

[2] Anagnostopoulos, N.S., Georgiadis, A.S., And Sideris, K.K., (2007). “Carbonation of self compacting concretes produced with different materials.” In: Proceedings of 5th international RILEM symposium on self-compacting concrete. Ghent; pp. 721–727.

[3] Bassuoni, M.,T., And Nehdi, M.,L., (2007). “Resistance of self consolidating concrete to sulphuric acid attack with consecutive pH reduction.” Cement and concrete research, Vol. 37, pp.

[4] Boukendakdji, O., Kadri, E.,H., And Kenai, S., (2011). “Effect of granulated blast furnance slag and superplasticizer on fresh properties and compressive strength of self compacting concrete.” Cement and concrete composites, In press.

[5] BS 1881, (1970). “Method for Testing of Hardened Concrete for other than Strength”; Part 5. Bui, V.K., Montgomery, D., Hinczak, I., and Turner, K., (2002). "Rapid testing method for

[6] Hassan, A.A., Lachemi, M., and Hossain, M.A., (2012). “Effect of metakaolin and silica fume on the durability of self-consolidating concrete.” Cement and concrete composites, Vol. 34, pp. 801-

[7] IS: 3812, (2003). “Indian standard on pulverised fuel ash – specification. (Part 2). For use as admixture in cement mortar and concrete.” Bureau of Indian Standards, New Delhi (India).

[8] Lachemi, M., Hossain, K.M.A., Lambros, V., Nkinamubanzi, P.C., And Bouzoubaa, N., (2004). "Performance of new viscosity modifying admixtures in enhancing the rheological properties of cement paste", Cement and Concrete Research, Vol. 34, pp. 185-193.

[9] Lee, S.T., Moon, H.Y., Hootona, R.D., And Kim, J.P., (2005). “Effect of solution concentrations and replacement levels of metakaolin on the resistance of mortars exposed to magnesium sulfate solutions.” Cement and Concrete research; Vol. 35, pp. 1314–1323

[10] Nanthagopalan, P., And Santhanam, M., (2011). “Fresh and hardened properties of self- compacting concrete produced with manufactured sand.” Cement and concrete composites, Elsevier Ltd., Vol. 33, pp.

Received: 05-06-2026 | Accepted: 10-07-2026 | Published: 17-07-2026

International Journal of
AI ELECTRICAL CIVIL AND MECHANICAL ENGINEERING
Peer Reviewed, Referred & Indexed Journal
ISSN: 3070-0434 www.zesterapublications.com Original Research Paper

353-358.

[11] Naik, T. R., And Singh, S., (1997). "Influence of fly ash on setting and hardening haracteristics of concrete systems." Materials Journal, Vol. 94, pp.355-360.

[12] Nehdi, M., Pardhan, M., And Koshowski, S., (2004). "Durability of self-consolidating concrete incorporating

Received: 05-06-2026 | Accepted: 10-07-2026 | Published: 17-07-2026