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Influence of Accelerators on cement replacement by large volumes of Fly ash to achieve early strength

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ABSTRACT: The chemical admixtures named as accelerators improve the early setting and strength of cementations products whereas theh Cement prepared with large volumes of Fly ash (Pozzolana) fetch the durability and better sustainability. Achieving High early strength as well as durability in cementations products is a tough and challenging job which provokes the idea of the addition of accelerators to cement prepared with large volumes of Fly ash (pozzolana). The present study investigated the early setting and strength enhancement of Ordinary Portland Cement (OPC) replacement with 30, 40 and 50% of Fly ash when mixed with the accelerating admixtures such as Calcium nitrate ($Ca(NO_3)_2$) and Calcium nitrate ($Ca(NO_3)_2$) combination with Triethanolamine ($C_6H_{15}NO_3$) at temperature of 25 ±5 ℃ and 58±5 % relative humidity.

In early ages, the maximum compressive strength was noted for 30 % Fly ash with 1% of $Ca(NO_3)_2$ in combinations with 0.05 % of $C_6H_{15}NO_3$ and the achieved percentages noted as 18.23% and 54.29% for 1 and 3 days. The microstructural property (SEM) was also determined for OPC replacement with 30% of Fly ash at 1 and 3 days for 1% of $Ca(NO_3)_2$ in combination with 0.05, 0.1, 0.15 and 0.2% of $C_6H_{15}NO_3$.

KEYWORDS: Accelerators, High early strength, Fly ash, Calcium nitrate ($Ca(NO_3)_2$), Triethanolamine ($C_6H_{15}NO_3$).

1 INTRODUCTION

Construction is an important sector that contributes greatly to the economic growth of a nation. Nowadays, the construction industry has a potent prominence on durability, better sustainability cementations products or concrete with high early strength to gratify the expected high early strength and to curtail the construction moment and also reducing construction costs. Achieving High early strength as well as durability and better sustainability in cementations products or concrete is a challenging job which provokes the idea of the addition of accelerators to cement replacement of Fly ash (pozzolana). The addition of accelerators and Fly ash (pozzolana) replacement cement in achieving the High early strength concrete is scarce in the literature. It would be a great contribution to the precast concrete industry if the High early strength concrete made with commercially available accelerators and high volume Fly ash (pozzolana).

Numerous chemical admixtures have been employed to obtain a satisfactory strength at an early age, the calcium chloride was most extensively utilized set accelerator, but the existence of chloride induces significant complications pertaining to corrosion of reinforcing bars implanted in concrete members, due to this reason construction standards regularly limit the usage of calcium chloride [1]. Accordingly, there is enthusiasm for the utilization of admixtures without chloride, for instance, Calcium nitrate ($Ca(NO_3)_2$), which can quicken response advancements. $Ca(NO_3)_2$ is fundamentally a set quickening agent [2-4], which is thought to restrain consumption by means of an anodic hindrance component, like Calcium nitrite ($Ca(NO_2)_2$) [5-7]

A review was presented by Dodson on non-chloride, non-corrosive set accelerating salts [8]. This study commenced in 1962. Dodson identified that the calcium formate ($Ca(CHO_2)_2$) can be practiced as a set accelerator [9] and the second accelerator to achieve requirements was calcium nitrate $Ca(NO_3)_2$, it was trademarked in 1969 [10]. Later on a comprehensive investigation, it was confirmed that the $Ca(NO_3)_2$ was also quite efficient corrosion preventive for metal implanted in concrete. The outcome of calcium nitrate supplements on the setting characteristics of cement and the steel corrosion has been deliberated by Justness [11-13]. In 2017 Kičaitė was investigated the accelerating impact of $Ca(NO_3)_2$ at dissimilar temperatures [14]. $Ca(NO_3)_2$ can also be used as an antifreeze admixture [15]. Oey, T et al. did study on influences of both $Ca(NO_3)_2$ and calcium chloride on Ordinary Portland cement (OPC) and blended OPCs, i.e., those containing Class F fly ash, slag, or fine limestone. The results indicate that $Ca(NO_3)_2$, on account of its chloride free composition is a very promising accelerator for use in concrete construction [16].

Triethanolamine ($C_6H_{15}NO_3$) can develop, retardation or set-acceleration, $C_6H_{15}NO_3$ is a dosage-sensitive admixture [1] depending upon the cement type and addition rate. The reaction between C_3A and gypsum gets accelerated and ettringite is converted into monosulfoalminate in the presence of $C_6H_{15}NO_3$ [17]. The reaction to the strength improvement in cement paste is also dependent on the amount of $C_6H_{15}NO_3$ [18-19].

The present study aimed to investigate the early setting and strength enhancement of Fly ash replacement with Cement and the addition of $Ca(NO_3)_2$ and $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$. In this view, tests were performed on samples from different mixes. Sixty-three (63) possible mixes were proposed with 30, 40 and 50% of Fly ash replacement of cement, $Ca(NO_3)_2$ (0.5, 1, 1.5 and 2% by weight of binder material) and $Ca(NO_3)_2$ (0.5, 1, 1.5 and 2% by weight of binder material) in combination of $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2 % by weight of binder material). Samples of these mixes were tested to assess their early age behavior of setting and compressive strength at various curing periods of 1, 3, 7 and 28 days. For curing of samples Acrylic resin-based curing compound was used.

2 MATERIALS AND EXPERIMENTAL METHODS

53 grade Ordinary Portland cement (OPC), Fly ash and faucet water were used for mixes performed well in the aggravation of setting and compressive strength at all ages.

Chemical compositions of OPC and Fly ash are shown in Table 1. The natural locally available Fine aggregate was used and the physical properties are shown in Table 2.

The characteristic properties of the accelerators used are shown in Table 3. The properties of curing compound used are shown in Table 4. For experimental exertion 63 possible mixes were investigated with different ratios of $Ca(NO_3)_2$, (0.5, 1, 1.5 and 2% of the weight of binder) and $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2% of the weight of binder), these mixes are listed in Table 5. The experimental work was done with cement paste to identify the setting property of mixes and cement strength property with mortar. The experimental results indicated that the $Ca(NO_3)_2$ in combinations of $C_6H_{15}NO_3$.

The Initial and Final setting times of the mixes were identified with the help of Vicat apparatus pertaining to IS 4031, 1988 [24-25]. The sizes of mortar cubes 70.5mm x 70.5mm x 70.5mm are cast and tested for compressive strength as per IS:10080-1982 [26] at the ages of 1, 3, 7 and 28 days.

The resulted early setting with high strength samples was contemplated by Scanning Electron Microscopy (SEM). Specimens for SEM investigation are taken close to the surface (0-1 mm profundity) of samples. SEM investigation is done at the amplification of 5000 x with vitality 30 Kev and a high determination of 3.8 nm. For this investigation, species of size 10 mm in solid shapes are cut with a saw shaper on 1 day and 3 days.

Table 1 – Chemical compositions

Chemical compositions	OPC	Fly ash
Calcium oxide, Cao %	65.89	1.34
Aluminum oxide, Al_2O_3%	9.67	25.65
Silicon dioxide, SiO_2%	17.11	62.41
Manganese oxide, MnO %	0.022	0.031
Ferric oxide, Fe_2O_3%	2.23	3.46
Magnesium oxide, MgO %	1.15	2.59
Sodium oxide, Na_2O %	0.23	0.051
Potassium oxide, K_2O %	0.49	0.958
Loss of ignition %	0.83	3.76

Table 2 – Physical properties aggregates

Type	IS sieve	Zone	Fineness modulus	Specific gravity	Absorption
Fine aggregates	4.75mm	II of IS: 383-1978 [22]	2.60	2.69	0.96%

Table 3 – Accelerator characteristic

Main component	Chemical formula	Density	Molar mass(g/mol)	Melting point	Usage (cement* % mass ratio)
Calcium nitrate Triethanolamine	$Ca(NO_3)_2$ $C_6H_{15}NO_3$	1.896 g/cm^3 1.124 g mL^{-1}	236.15 149.19	42.7°C, 1042°F 21.60 °C, 70.88 °F	0.5-6 0.02-1

Table 4 – Properties of curing compound

Main component	Standards	Water loss after 72 hrs	Appearance	Viscosity	Reflectance
Acrylic resin	ASTM C309 - 99 & ASTM C156 - 99(a)	Not more than 0.35 Kg/m2	Translucent White	5 to 10 cps	More than 85% to that of MgO

Table 5 – Investigated mixes

Mix IDs	% of Fly ash replacement	% of Calcium nitrate	% of Triethanolamine
FA30CN0	30	0	0
FA30CN0.5	30	0.5	0
FA30CN1	30	1	0
FA30CN1.5	30	1.5	0
FA30CN2	30	2	0
FA30CN0.5-T0.05	30	0.5	0.05
FA30CN0.5-T0.1	30	0.5	0.1
FA30CN0.5-T0.15	30	0.5	0.15
FA30CN0.5-T0.2	30	0.5	0.2
FA30CN1-T0.05	30	1	0.05
FA30CN1-T0.1	30	1	0.1
FA30CN1-T0.15	30	1	0.15
FA30CN1-T0.2	30	1	0.2
FA30CN1.5-T0.05	30	1.5	0.05
FA30CN1.5-T0.1	30	1.5	0.1
FA30CN1.5-T0.15	30	1.5	0.15
FA30CN1.5-T0.2	30	1.5	0.2
FA30CN2-T0.05	30	2	0.05
FA30CN2-T0.1	30	2	0.1
FA30CN2-T0.15	30	2	0.15
FA30CN2-T0.2	30	2	0.2
FA40CN0	40	0	0
FA40CN0.5	40	0.5	0
FA40CN1	40	1	0
FA40CN1.5	40	1.5	0
FA40CN2	40	2	0
FA40CN0.5-T0.05	40	0.5	0.05
FA40CN0.5-T0.1	40	0.5	0.1
FA40CN0.5-T0.15	40	0.5	0.15
FA40CN0.5-T0.2	40	0.5	0.2
FA40CN1-T0.05	40	1	0.05
FA40CN1-T0.1	40	1	0.1
FA40CN1-T0.15	40	1	0.15
FA40CN1-T0.2	40	1	0.2
FA40CN1.5-T0.05	40	1.5	0.05
FA40CN1.5-T0.1	40	1.5	0.1
FA40CN1.5-T0.15	40	1.5	0.15
FA40CN1.5-T0.2	40	1.5	0.2
FA40CN2-T0.05	40	2	0.05
FA40CN2-T0.1	40	2	0.1
FA40CN2-T0.15	40	2	0.15
FA40CN2-T0.2	40	2	0.2
FA50CN0	50	0	0
FA50CN0.5	50	0.5	0

FA50CN1	50	1	0
FA50CN1.5	50	1.5	0
FA50CN2	50	2	0
FA50CN0.5-T0.05	50	0.5	0.05
FA50CN0.5-T0.1	50	0.5	0.1
FA50CN0.5-T0.15	50	0.5	0.15
FA50CN0.5-T0.2	50	0.5	0.2
FA50CN1-T0.05	50	1	0.05
FA50CN1-T0.1	50	1	0.1
FA50CN1-T0.15	50	1	0.15
FA50CN1-T0.2	50	1	0.2
FA50CN1.5-T0.05	50	1.5	0.05
FA50CN1.5-T0.1	50	1.5	0.1
FA50CN1.5-T0.15	50	1.5	0.15
FA50CN1.5-T0.2	50	1.5	0.2
FA50CN2-T0.05	50	2	0.05
FA50CN2-T0.1	50	2	0.1
FA50CN2-T0.15	50	2	0.15
FA50CN2-T0.2	50	2	0.2

3 RESULTS AND DISCUSSION

3.1 *Cement Paste tests*

3.1.1 *Normal Consistency*

The percentage of Normal consistency is used for calculating the water quantity for identifying the Initial & Final setting time. The result of standard consistency tests for OPC, 30%, 40% and 50% Fly ash replacement with cement are 34.21, 32.12, 30.26 and 28.78. It was observed by the results while the increment percentage level of Fly ash, the standard consistency was decreased.

3.1.2 *Initial & Final setting time of Cement prepared with 30% of Fly ash*

It is essential to know that cement or concrete sets neither too rapidly nor too slowly and it mainly depends on setting properties of concrete. It plays an important role in the field of concrete construction [27].

Fig 1&2 shows the Initial & Final setting times of 30% of Fly ash with different ratios of $Ca(NO_3)_2$ (0.5, 1, 1.5 and 2%) and $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2 %) by weight of OPC. As the quantity used of $Ca(NO_3)_2$ (0.5-2%) increases, both the Initial & Final setting times are the decreased. 2% of $Ca(NO_3)_2$ in combination with 0.05% $C_6H_{15}NO_3$ shows the early setting of Initial & Final setting times compare to other dosages.

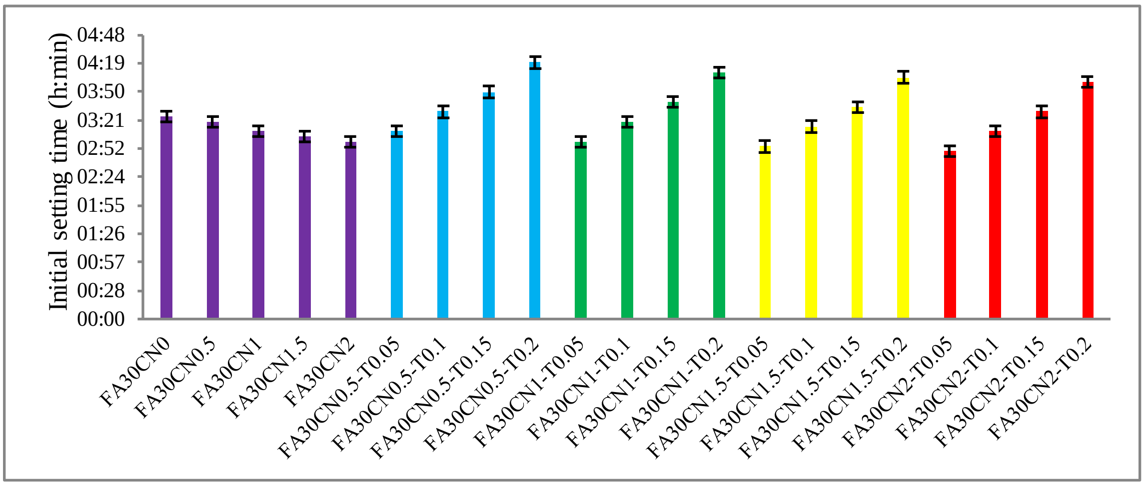


Figure 1 – Initial setting time of Cement prepared with 30% of Fly ash with $Ca(NO_3)_2$ and $Ca(NO_3)_2$ combination with $C_6H_{15}NO_3$

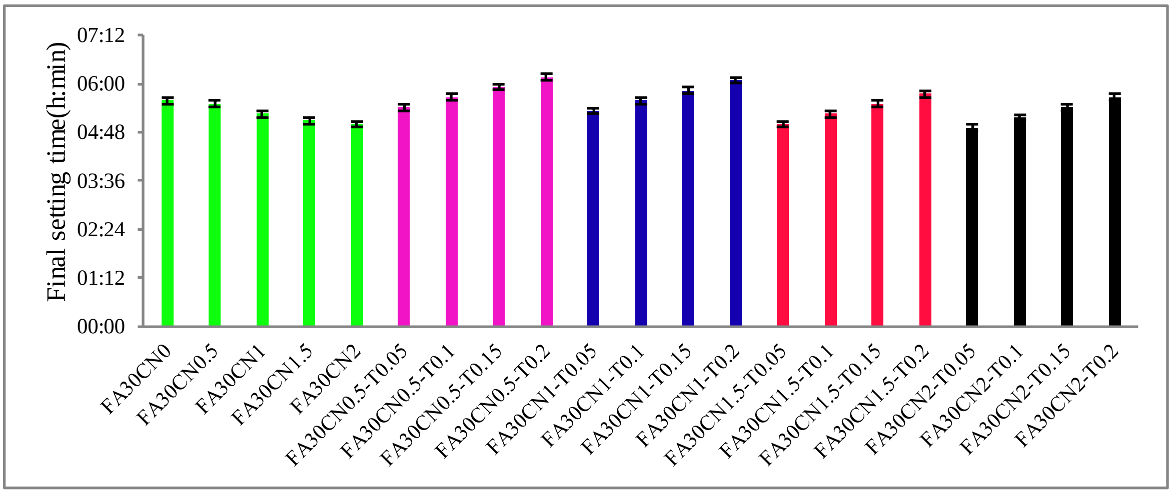


Figure 2 – Final setting time of Cement prepared with 30% of Fly ash with $Ca(NO_3)_2$ and $Ca(NO_3)_2$ combination with $C_6H_{15}NO_3$

3.1.3 *Initial & Final setting time of Cement prepared with 40% of Fly ash*

Fig 3&4 shows the Initial & Final setting times of Cement prepared with 40% of Fly ash with different ratios of $Ca(NO_3)_2$ (0.5, 1, 1.5 and 2%) and $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2 %) by weight of OPC.

As the quantity used of $Ca(NO_3)_2$ (0.5-2%) increases, both the Initial & Final setting times are reduced for 40% of Fly ash. 2% of $Ca(NO_3)_2$ in combinations with 0.05% $C_6H_{15}NO_3$ mix is shown the reduced Initial & Final setting times compare with other dosage levels.

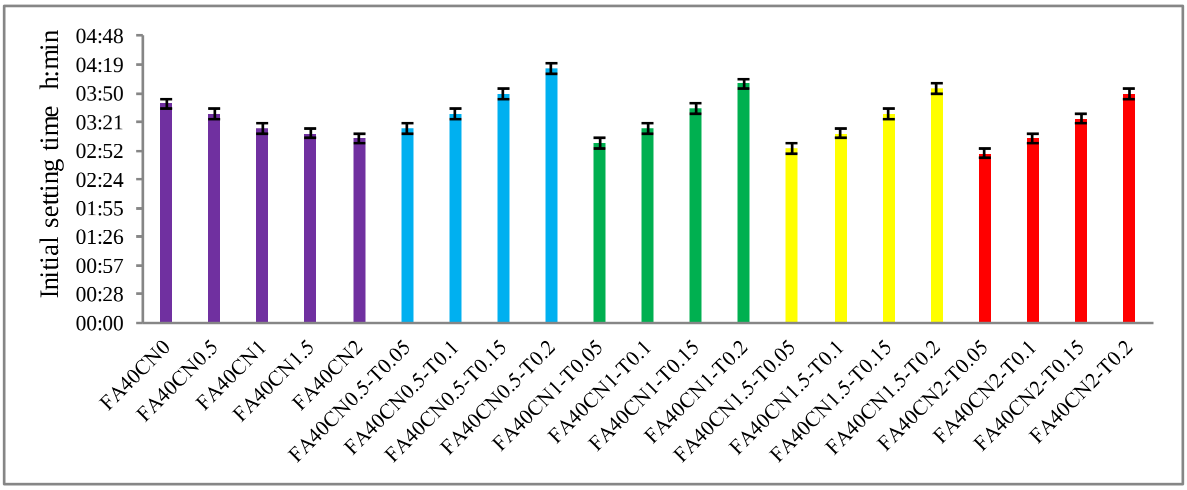


Figure 3 – Initial setting time of Cement prepared with 40% of Fly ash with $Ca(NO_3)_2$ and $Ca(NO_3)_2$ combination with $C_6H_{15}NO_3$

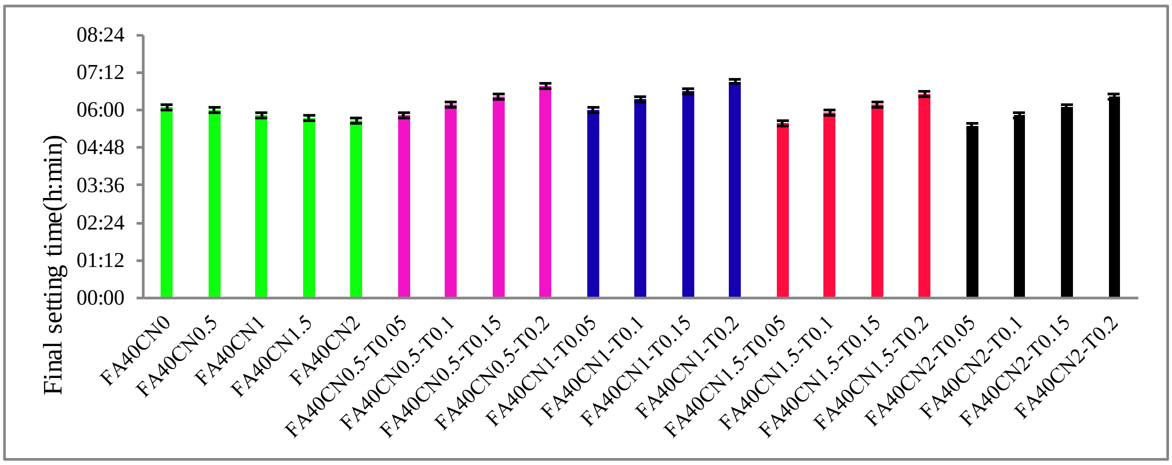


Figure 4 – Final setting time of Cement prepared with 40% of Fly ash with $Ca(NO_3)_2$ and $Ca(NO_3)_2$ combination with $C_6H_{15}NO_3$

3.1.4 *Initial & Final setting time of Cement prepared with 50% of Fly ash*

Fig 5&6 shows the Initial & Final setting times of 50% of Fly ash with different ratios of $Ca(NO_3)_2$ (0.5, 1, 1.5 and 2%) and $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2 %) by weight of OPC.

As the quantity used of $Ca(NO_3)_2$ (0.5-2%) increases, both the Initial & Final setting times are the early setting. 2% of $Ca(NO_3)_2$ in combination with 0.05% $C_6H_{15}NO_3$ mix is shown the reduced Initial & Final setting times compare with other dosage levels.

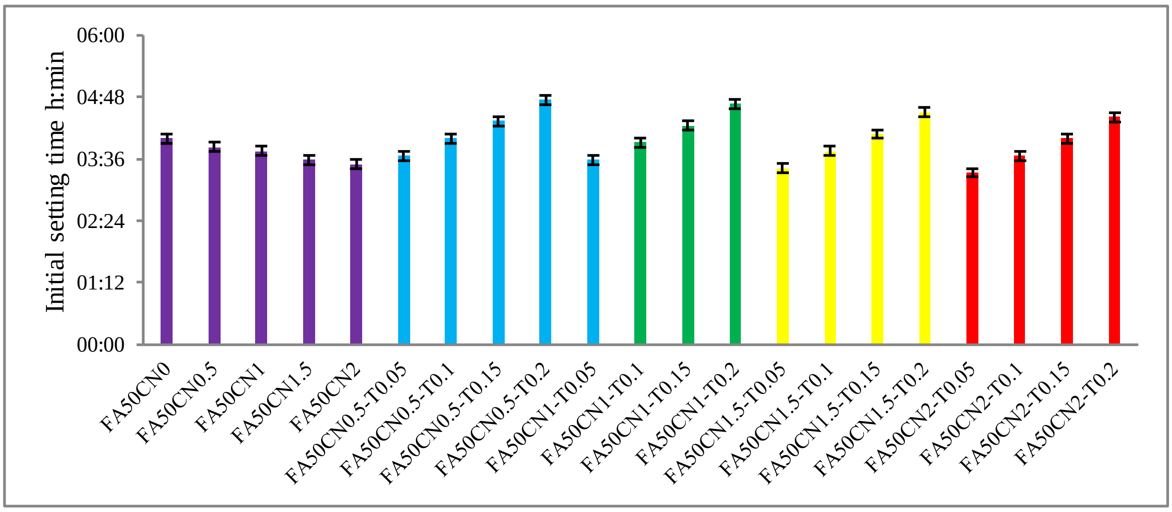


Figure 5 – Initial setting time of Cement prepared with 50% of Fly ash with $Ca(NO_3)_2$ and $Ca(NO_3)_2$ combination with $C_6H_{15}NO_3$

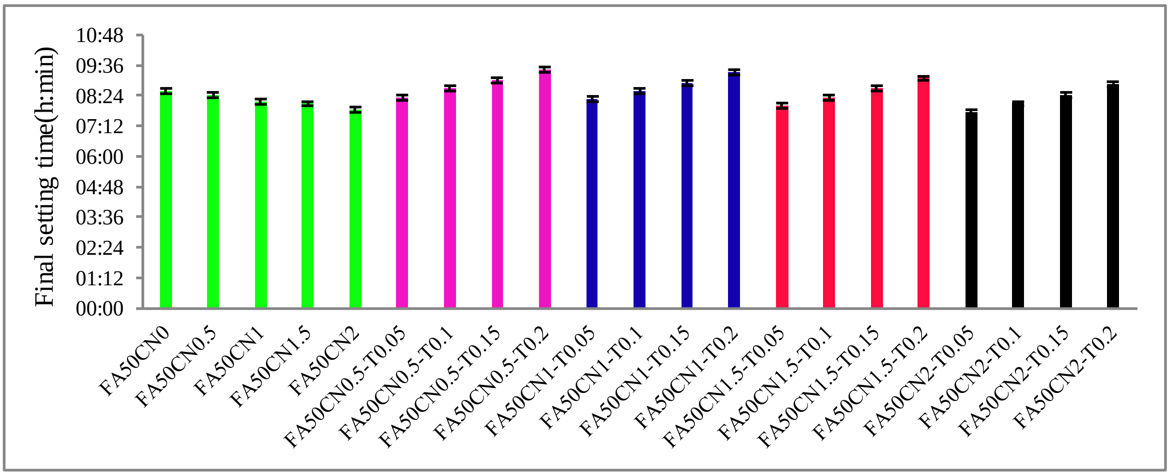


Figure 6 – Final setting time of Cement prepared with 50% of Fly ash with $Ca(NO_3)_2$ and $Ca(NO_3)_2$ combination with $C_6H_{15}NO_3$

As the quantity used of $Ca(NO_3)_2$ (0.5-2%) increases, both the Initial & Final setting times are reduced for Cement prepared with 30%, 40% and 50% of Fly ash when compare with conventional motor paste. The cement enhancement of strength designated by the Final setting time [28]. However, as Ca $(NO_3)_2$ lose its capability for set acceleration of approximately 2% (binder weight) [29]. Influence of Initial & Final setting time for different volumes of Fly ash with different ratios of $Ca(NO_3)_2$ (0.5, 1, 1.5 and 2%) and $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%) are evaluated in this study, from the experimental investigation it can be observed that $Ca(NO_3)_2$ accelerating behavior is improved with the addition of 0.05% of $C_6H_{15}NO_3$. An expansion rate of 0.02% to the type I Portland cement, $C_6H_{15}NO_3$ goes about as a set accelerator, at 0.25% as a mellow set retarder and at 0.5% a severe retarder and at 1% an exceptional accelerator [30-31]. The accelerating effect of $Ca(NO_3)_2$ (2%) with $C_6H_{15}NO_3$ (0.05%) was more in 30% Fly ash compare to 40% and 50%. However, after 0.05% of $C_6H_{15}NO_3$ the $Ca(NO_3)_2$ loses its acceleration ability and the Initial & Final setting time for 30%, 40%, and 50% are increased.

3.2 *Cement mortar tests*

3.2.1 *Compressive strength for Cement prepared with 30% of Fly ash*

Figure 7 (a) Shows the compressive strength of Cement prepared with 30% of Fly ash with different ratios of $Ca(NO_3)_2$ (0.5, 1, 1.5 and 2% of the weight of OPC).

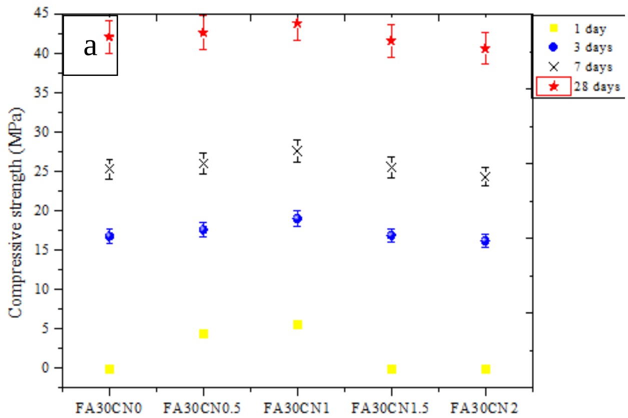
Up to 1% of $Ca(NO_3)_2$ the strength is increasing after this dosage the strength is slightly decreased. So the selective and effective dosage for $Ca(NO_3)_2$ is 1%.

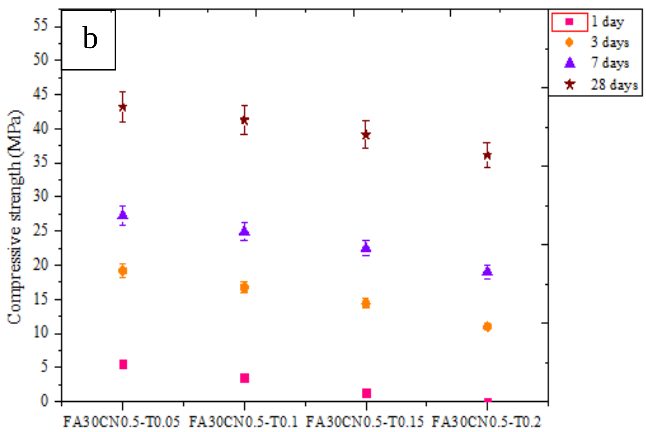
Figure 7 (b) shows the compressive strength of the Cement prepared with 30% of Fly ash with 0.5% of $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). The compressive strength is increased for FA30CN0.5-T0.05. The reduced compressive strength is observed with the increment dosage of $C_6H_{15}NO_3$.

Figure 7 (c) The Cement prepared with 30% of Fly ash compressive strength with 1% of $Ca(NO_3)_2$ in combinations with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). For 1% of $Ca(NO_3)_2$ in combination with 0.05 % of $C_6H_{15}NO_3$ is showing high compressive strength when compared with the dosages of 0.1, 0.15 and 0.2%. The reduced compressive strength is observed with the increment dosage of $C_6H_{15}NO_3$.

Figure 7 (d) shows the compressive strength of Cement prepared with 30% of Fly ash with 1.5% of $C_6H_{15}NO_3$ in combination with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). With the increment dosage of $C_6H_{15}NO_3$, the compressive strength is reducing. 0.05% of $C_6H_{15}NO_3$ is an effective dosage for 1.5% of $Ca(NO_3)_2$.

Figure 7 (e) shows the compressive strength of Cement prepared with 30% of Fly ash with 2% of $Ca(NO_3)_2$ in combinations with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). The compressive strength is increased for FA30CN2-T0.05. The reduced compressive strength is observed with the increment dosage of $C_6H_{15}NO_3$.





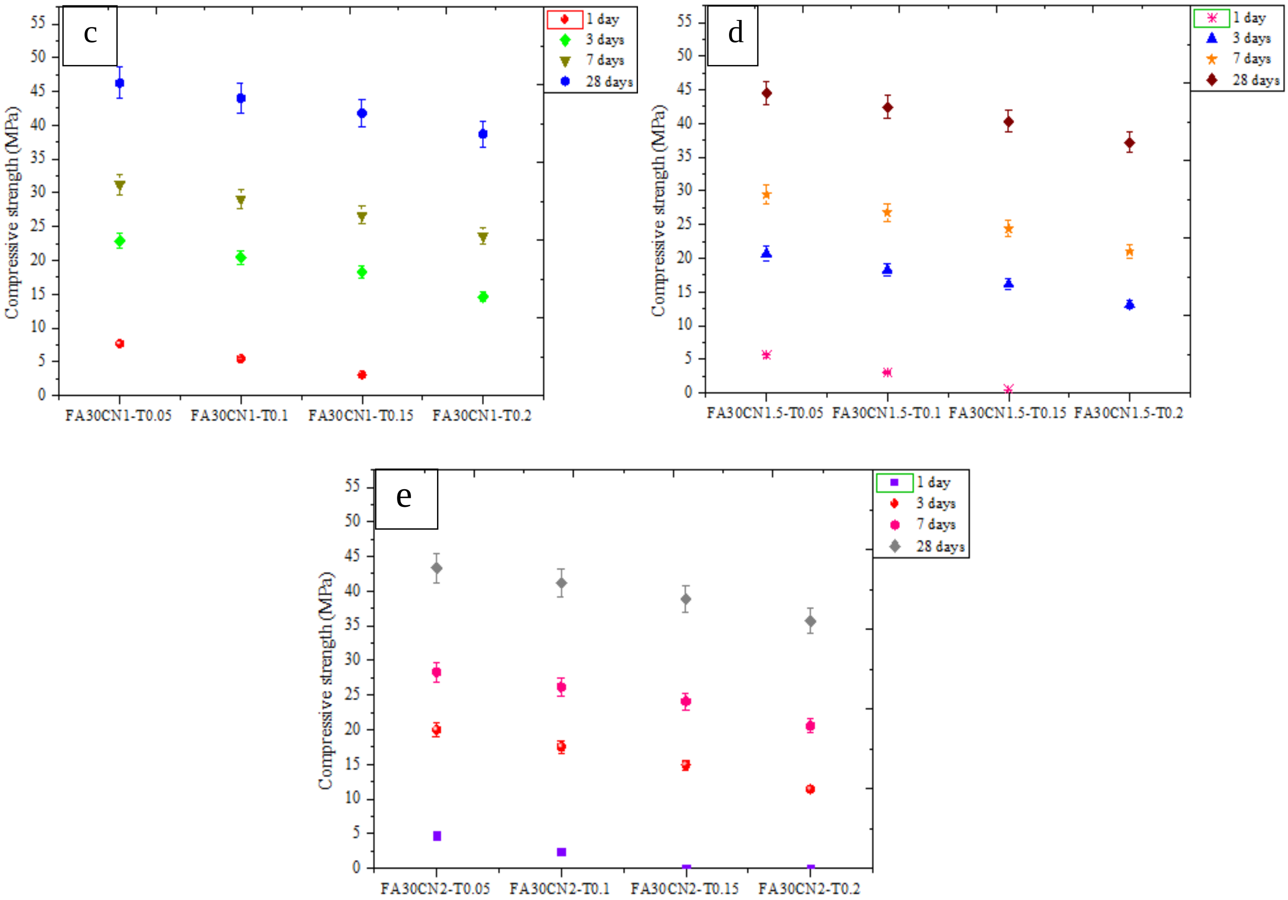


Figure 7 – Compressive strength of Cement prepared with 30% of Fly ash for $Ca(NO_3)_2$ (a) and $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (b, c, d, and e)

3.2.2 *Compressive strength for Cement prepared with 40% of Fly ash*

Figure 8 (f) Shows the compressive strength of Cement prepared with 40% of Fly ash with different ratios of $Ca(NO_3)_2$ (0.5, 1, 1.5 and 2% of the weight of OPC). Up to 1% of $Ca(NO_3)_2$, the strength is increasing after this dosage the strength is slightly decreased. So the selective and effective dosage for $Ca(NO_3)_2$ is 1%.

Figure 8 (g) shows compressive strength of Cement prepared with 40% of Fly ash with 0.05% of $Ca(NO_3)_2$ in combinations with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). The compressive strength is increased for FA40CN0.5-T0.05. The reduced compressive strength is observed with the increment dosage of $C_6H_{15}NO_3$.

Figure 8 (h) shows the Cement prepared with 40% of Fly ash compressive strength with 1% of $Ca(NO_3)_2$ in combinations with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). For 1% of $Ca(NO_3)_2$ in combination with 0.05 % of $C_6H_{15}NO_3$ is showing high compressive strength when compared with the dosages of 0.1, 0.15 and 0.2%. The reduced compressive strength is observed with the increment dosage of $C_6H_{15}NO_3$.

Figure 8 (i) shows the compressive strength of Cement prepared with 40% of Fly ash with 1.5% of $Ca(NO_3)_2$ in combinations with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). With the increment dosage of $C_6H_{15}NO_3$, the compressive strength is reducing. 0.05% of $C_6H_{15}NO_3$ is an effective dosage for 1.5% of $Ca(NO_3)_2$.

Figure 8 (j) shows the compressive strength of the Cement prepared with 40% of Fly ash with 2% of $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). The compressive strength is increased for FA40CN2-T0.05. The reduced compressive strength is observed with the increment dosage of $C_6H_{15}NO_3$.

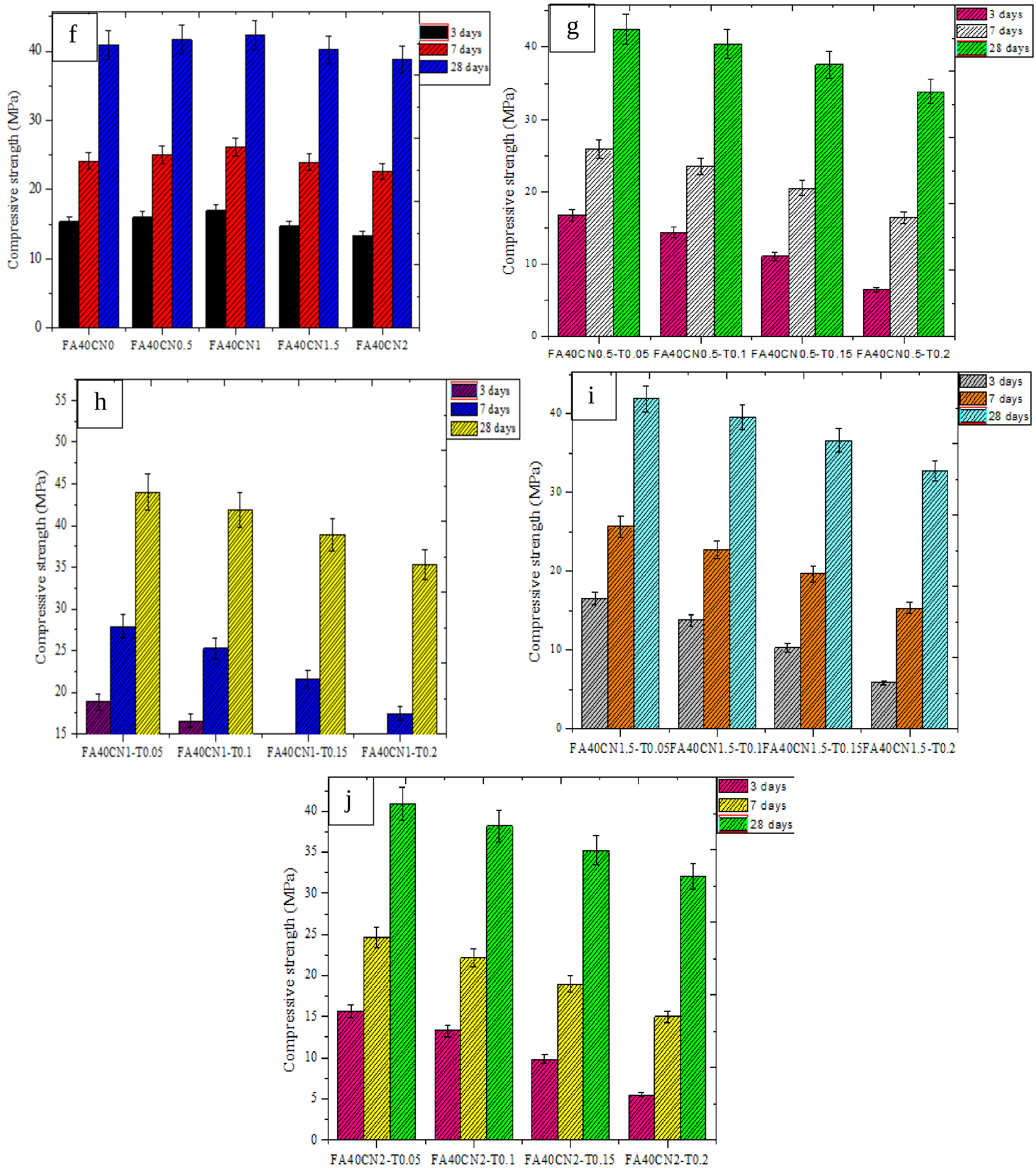


Figure 8 – Compressive strength of Cement prepared with 40% of Fly ash for $Ca(NO_3)_2$ (f) and $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (g, h, i and j)

3.2.3 *Compressive strength for Cement prepared with 50% of Fly ash*

Figure 9 (k) shown the compressive strength of Cement prepared with 50% of Fly ash with different ratios of $Ca(NO_3)_2$ (0.5, 1, 1.5 and 2% of the weight of OPC). Up to 1% of $Ca(NO_3)_2$, the strength is increasing after this dosage the strength is slightly decreased. So the selective and effective dosage of Ca $(NO_3)_2$ is 1%.

Figure 9 (l) shown compressive strength of Cement prepared with 50% of Fly ash with 0.05% of Ca $(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). The compressive strength is increased for FA50CN0.5-T0.05. The reduced compressive strength is observed with the increment dosage of $C_6H_{15}NO_3$.

Figure 9 (m) shows the compressive strength of the Cement prepared with 50% of Fly ash with 1% of $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). The compressive strength is increased for FA50CN1-T0.05. The reduced compressive strength is observed with the increment dosage of $C_6H_{15}NO_3$.

Figure 9 (n) shows the compressive strength of Cement prepared with 50% of Fly ash with 1.5% of

$Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). With the increment dosage of $C_6H_{15}NO_3$, the compressive strength is reducing. 0.05% of $C_6H_{15}NO_3$ is an effective dosage for 1.5% of $Ca(NO_3)_2$.

Figure 9 (o) The Cement prepared with 50% of Fly ash compressive strength with 2% of $Ca(NO_3)_2$ in combinations with $C_6H_{15}NO_3$ (0.05, 0.1, 0.15 and 0.2%). For 2% of $Ca(NO_3)_2$ in combination with 0.05 % of $C_6H_{15}NO_3$ is showing high compressive strength when compared with the dosages of 0.1, 0.15 and 0.2%. The reduced compressive strength is observed with the increment dosage of $C_6H_{15}NO_3$.

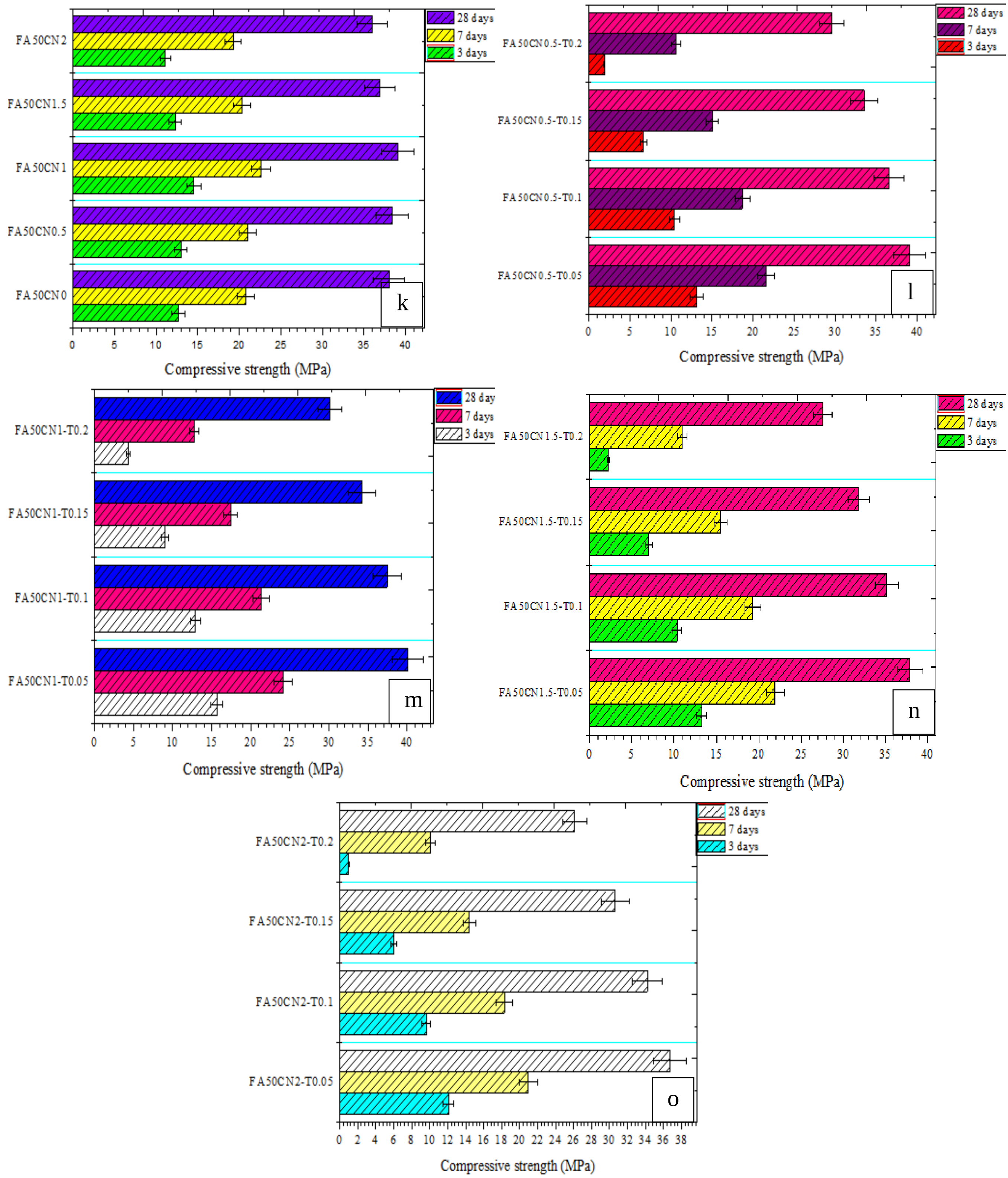


Figure 9 – Compressive strength of Cement prepared with 50% of Fly ash for $Ca(NO_3)_2$ (k) and $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ (l, m, n, and o)

In the case of the $Ca(NO_3)_2$ mixes, the compressive strength development response is extremely dosage responsive. For example, unforeseen decrement in compressive strength is noted at 1.5 and 2% dosages $Ca(NO_3)_2$ for 30%, 40% and 50% of Fly ash, respectively. Fascinatingly, the systems that demonstrate such reduction in most accelerated setting behavior. However, with a dosage level of 1%, $Ca(NO_3)_2$ strength is more compared to other dosages.

The use of $Ca(NO_3)_2$ in combinations with $C_6H_{15}NO_3$ resulted in their fusion effects. From the research of Ramachandran VS and Rixon R [30-31], the $C_6H_{15}NO_3$ dosage was selected (0.05, 0.1, 0.15 and 0.2% by the weight of the binder). 0.05% of $C_6H_{15}NO_3$ dosage was showing better setting and strength enhancing dosage for 30%, 40% and 50% of Fly ash, respectively. After 0.05% dosage remaining dosages are showing delay setting time and reduction in strength it means the dosages of 0.1, 0.15 and 0.2% by the weight of binder $C_6H_{15}NO_3$ is acting as a retarder. So the selective and effective dosage of $C_6H_{15}NO_3$ is 0.05%. S. Aggoun and M. Cheikh-Zouaoui the $C_6H_{15}NO_3$ observed together in the process of a hardening accelerator inconsiderate of the cement type used that the research evidently proven [32]. The addition of 0.05% $C_6H_{15}NO_3$ with 1% of $Ca(NO_3)_2$ shows that very effective accelerating and strength enhancing dosage.

3.3 *The microstructure analysis of Cement prepared with 30% of Fly ash Cement Paste tests*

The microstructure analysis (Scanning Electron Microscope) was performed for the High early strength achieved mixes for 1 and 3 days to observe early strength response, Fig 10-13 shows the result of Scanning Electron Microscope of FA30CN1-T0.05, FA30CN1-T0.1, FA30CN1-T0.15 and FA30CN1-T0.2 mixes respectively. In mix FA30CN1-T0.05 with 1% of $Ca(NO_3)_2$ in combination with 0.05 % of $C_6H_{15}NO_3$, huge of C–S–H gel is observed in 1 and 3 days. Mix FA30CN1-T0.1, $Ca(OH)_2$ is experiential at age of one day; C–S–H was extended after the age of 2 days. Microcracks are observed for mix FA30CN1-T0.15 and FA30CN1-T0.2; because of this microcrack, the compressive strength was reduced. Hence it is evident that hardening accelerator built up the creation of C-S-H by hydration and compressive strength be converted to more advanced by generating huge extent of C-S-H at the initial stage as the amount used of hardening accelerator development.

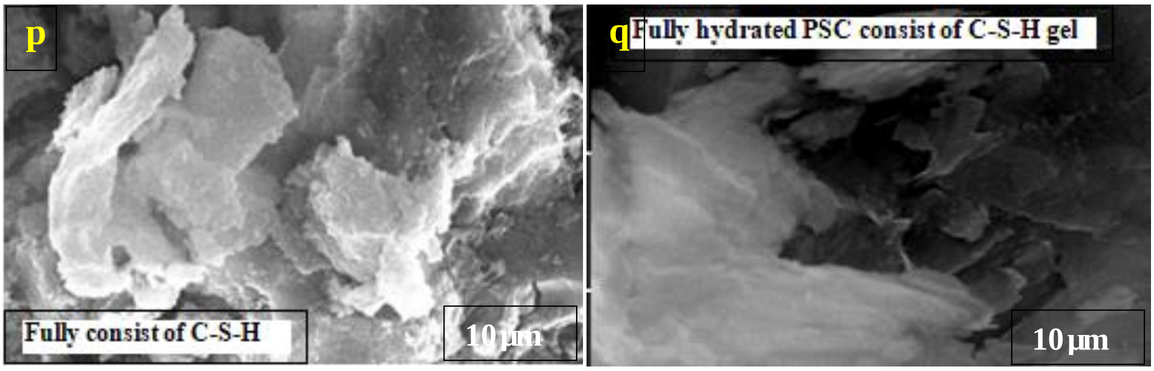


Figure 10 – SEM analysis of FA30CN1-T0.05 for 1 day (p) and 3 days (q)

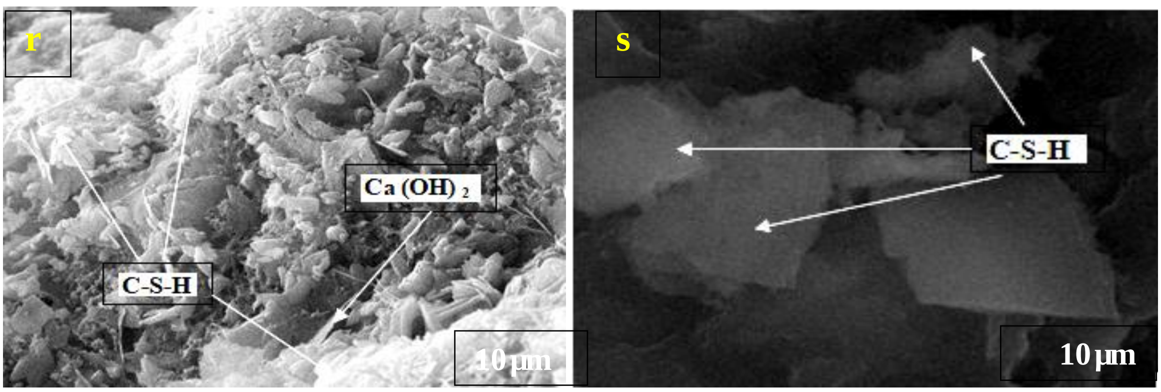


Figure 11 – SEM analysis of FA30CN1-T0.1 for 1 day(r) and 3 days(s)

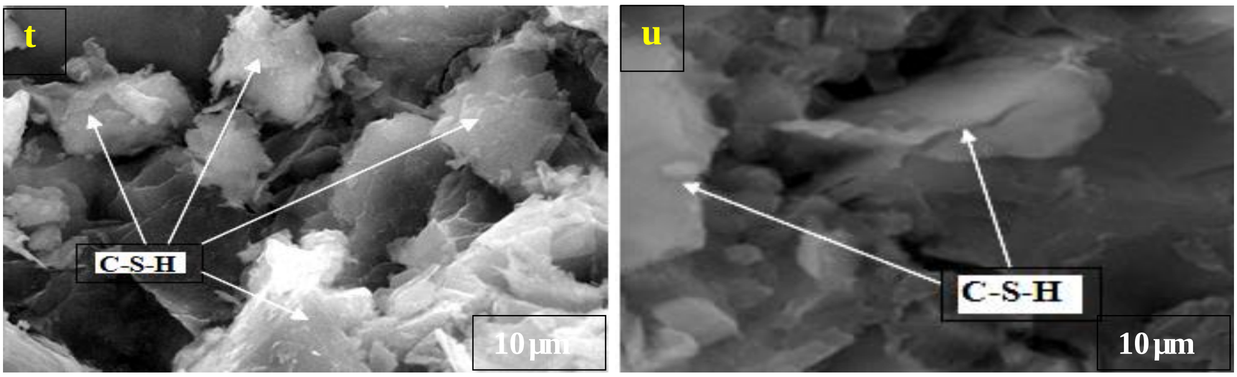


Figure 12 – SEM analysis of FA30CN1-T0.15 for 1 day (t) and 3 days (u)

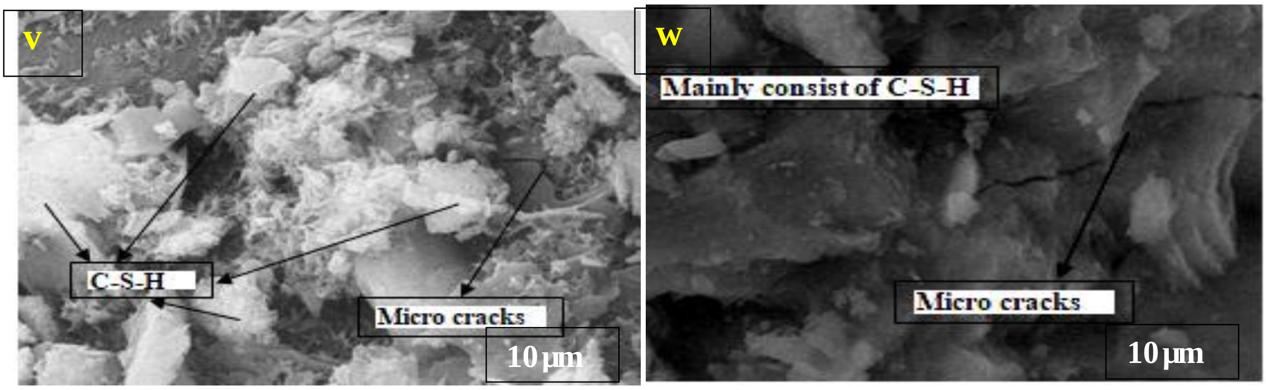


Figure 13 – SEM analysis of FA30CN1-T0.2 for 1 day (v) and 3 days (w)

4 CONCLUSIONS

Tests have been carried out on different types of cement paste and mortar specimens to investigate the effect of using two accelerating admixtures such as Calcium nitrate ($Ca(NO_3)_2$) and triethanolamine ($C_6H_{15}NO_3$), on the early setting and hardening process of different types of cement. In view of the admixture rates added, the main results show that:

1. The normal consistency is decreased with the increased volume of Fly ash.
2. Regardless of the Fly ash percentages used, both $Ca(NO_3)_2$ and $Ca(NO_3)_2$ in combination with $C_6H_{15}NO_3$ performed well as an early setting and hardening at all ages but the combination of $Ca(NO_3)_2$ and $C_6H_{15}NO_3$ show better high early setting and compressive strength.
3. The addition of 0.05% $C_6H_{15}NO_3$ with 1% of $Ca(NO_3)_2$ shows that very effective accelerating and strength enhancing dosage.
4. The maximum compressive strength was noted for 30 % Fly ash with 1% of $Ca(NO_3)_2$ in combinations with 0.05 % of $C_6H_{15}NO_3$ and the achieved percentages noted as 18.23% and 54.29% for 1 and 3 days.

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