

# EFFECT OF CALCIUM NITRATE, TRIETHANOLAMINE AND TRIISOPROPANOLAMINE ON COMPRESSIVE STRENGTH OF MORTARS

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## Abstract:

Chemical admixtures are used in concrete for various purposes such as water reducing, plasticizing, air entraining, bonding, viscosity modifying, colouring, corrosion inhibiting, permeability reducing, accelerating or retarding the initial setting time, and shrinkage reducing. The use of chemical admixtures in concrete helps to improve workability of fresh concrete and durability properties of hardened concrete as well as reducing the total cost of concrete production. In this study, three different types of chemical raw materials (calcium nitrate, triethanolamine-TEA and triisopropanolamine-TIPA) were used in the production of chemical admixtures, which were used in mortars with two different cement compositions. 7-day and 28-day compressive strengths of mortars were determined and it was found that TIPA has the greatest effect on increasing the compressive strength within these three chemicals.

**Keywords:** Accelerating admixture, antifreeze, chemical admixture

## Özet:

Betonda kimyasal katkıları; su azaltma, plastikleştirme, hava sürüklenme, bağlama, viskozite düzenleme, renklendirme, korozyon önleme, geçirimsizlik azaltma, priz hızlandırma ya da geciktirme, rötre azaltma gibi çeşitli amaçlarla kullanılır. Betonda kimyasal katkı kullanımı taze betonda işlenebilirliği arttırmaya, sertleşmiş betonda dayanıklılık özelliklerini iyileştirmeye ve beton üretiminde toplam maliyeti azaltmaya yardımcı olur. Bu çalışmada üç çeşit kimyasal katkı hammaddesi (kalsiyum nitrat, TEA ve TİPA) kullanılmış ve elde edilen katkıları ile iki farklı bileşimdeki çimento kullanılarak harç üretilmiştir. Harçların 7 ve 28 günlük basınç dayanımları belirlenmiş ve bu üç kimyasal arasında TİPA'nın basınç dayanımı arttırma üzerindeki etkisinin en fazla olduğu görülmüştür.

**Anahtar Kelimeler:** Priz hızlandırıcı, antifriz, kimyasal katkı

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## 1. INTRODUCTION

Due to hydration is an exothermic chemical reaction, temperature affects the rate of strength gaining of concrete. In cold weather, hydration gets slower, setting time increases and concrete strength gaining rate decreases. The ambient temperature has an important influence on concrete at early ages. To eliminate negative effects of low ambient temperatures, the adequate precautions must be taken and freezing of fresh concrete should be prevented. Using an accelerating admixture, which accelerates setting and/or hardening of concrete by accelerating the hydration of cement, is an alternative solution in cold weather concreting.

Cold weather is described in ACI 306 as “a period when for more than three successive days the average daily air temperature drops below 40 degrees Fahrenheit (4.4°C) and stays below 50 degrees Fahrenheit (10°C) for more than one-half of any 24 hour period”. In this period, concrete should be prevented from freezing until it gains a minimum compressive strength of 3.5 MPa [1].

In order to prevent freezing of concrete, accelerating and anti-freezing admixtures, which are added before or during mixing of concrete and decrease the freezing point of the composition, are used. Accelerating admixtures may have compounds of soluble inorganic salts (alkali and alkali earth salts of hydroxide, chloride, bromide, fluoride, nitrite, nitrate, carbonate, thiocyanate, sulphate, thiosulphate, perchlorate, silicate, aluminate) or organic salts (carboxylic and hydroxycarboxylic acids and their salts, and alkanolamines) [2].

Silicate minerals, cementitious materials, finely ground magnesium and calcium carbonates are used in accelerators as insoluble solid compounds in a limited range [3].

Calcium nitrate is a soluble inorganic chemical raw material used in accelerating admixtures with antifreeze characteristics. Although calcium chloride is a better accelerator, it has significant corrosion hazards in reinforced concrete structures and nitrates are used as an alternative of chloride-based accelerators. In recent studies, it has been found that calcium nitrate has an important effect on early age compressive strength; by accelerating setting and hardening of concrete, desired setting time, compressive strength and other properties can be achieved in cold weather and negative effects of internal freezing can be eliminated [4].

Triethanolamine (TEA,  $N(CH_2CH_2OH)_3$ ) is a soluble organic compound with compensating properties for the retarding effect of some plasticizers and is the most commonly known of

alkanolamines, which are used in accelerator blends or infrequently alone [2].

TEA can accelerate or retard the reaction of cement depending upon its dosage; it accelerates  $C_3A$  hydration kinetics while retarding the hydration of  $C_3S$  [5]. Hewlett found out at dosages higher than 0.5 % by weight of cement, TEA leads to retardation of  $C_3S$  hydration; though at low dosages (0.1-0.5 %) it accelerates the hydration of  $C_3A$  [5]. TEA causes a decrease on compressive strength of concrete with ordinary Portland cement, but it behaves differently with blast furnace cements, as the rate of reaction of gypsum with slag, correspondingly hydration kinetics is accelerated in the presence of lime [6]. It has been concluded that TEA has no significant effect on early age compressive strength of mortars made with plain Portland cement, but it provides an increment on early strength of mortars made with fly ash/cement [7].

Chemical admixtures containing triisopropanolamine (TIPA) are used as setting and hardening accelerators. The strength development acquired with use of TIPA changes with the quantity of ferrite ( $C_4AF$ ) phase of clinker minerals [8]. The hardening accelerating performance of TIPA is greater than TEA [9]. Sandberg and Doncaster found out TIPA provides a strength improvement in both hydrated Portland cement paste and mortar, and the strength enhancement is not dependent on an interfacial transition zone mechanism [10].

In this research, examining and comparing the compatibility, effectiveness and contribution to strength development of calcium nitrate, TEA and TIPA have been aimed and experiments have been carried out with two different cement compositions.

## **2. EXPERIMENTAL STUDY**

In this experimental study, two different company Portland cement (CEM I 42.5 R) was used. The effects of calcium nitrate, TEA, and TIPA on compressive strength at the ages of 7 and 28 days were examined according to procedures described in TS EN 12390 [11]. Effects of combined use of calcium nitrate with TEA and TIPA were also discussed. Mortar mix design for TRACIM company cement and LIMAK company cement were shown in Table 1 and Table 2, respectively. Calcium nitrate was used at dosage 1 % by weight of cement, TEA 0.05 % and TIPA 0.05 %.

**Table 1.** Mortar mix design for TRACIM Company Cement.

Mixtures	Cement (g)	Water (g)	Natural Sand (g)	Crushed Sand (g)	Calcium Nitrate (g)	TEA (g)	TIPA (g)
TR*	450	225	675	675	0.000	0.000	0.000
TCN	450	225	675	675	4.500	0.000	0.000
TTEA	450	225	675	675	0.000	0.225	0.000
TTIPA	450	225	675	675	0.000	0.000	0.225
TCN+TEA	450	225	675	675	4.500	0.225	0.000
TCN+TIPA	450	225	675	675	4.500	0.000	0.225

\*R: Reference mixture.

**Table 2.** Mortar mix design for LIMAK Company Cement.

Mixtures	Cement (g)	Water (g)	Natural Sand (g)	Crushed Sand (g)	Calcium Nitrate (g)	TEA (g)	TIPA (g)
LR*	450	250	675	675	0.000	0.000	0.000
LCN	450	250	675	675	4.500	0.000	0.000
LTEA	450	250	675	675	0.000	0.225	0.000
LTIPA	450	250	675	675	0.000	0.000	0.225
LCN+TEA	450	250	675	675	4.500	0.225	0.000
LCN+TIPA	450	250	675	675	4.500	0.000	0.225

\*R: Reference mixture.

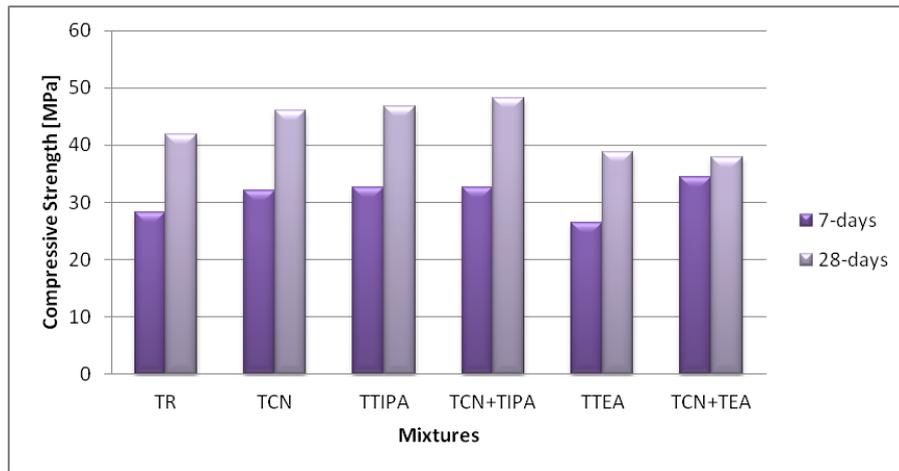
### 3. RESULTS AND DISCUSSION

The effect of accelerators on compressive strength of mortars prepared with TRACIM company cement at the ages of 7 and 28 days was shown in Table 3 and graphically shown in Figure 1.

**Table 3.** 7 and 28-day compressive strengths of mortars produced with TRACIM company cement.

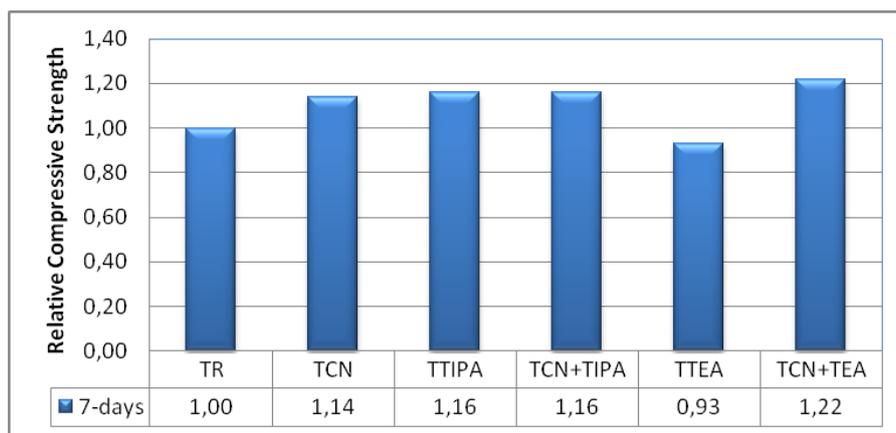
Mixtures	Compressive strengths at the ages of 7 and 28 days (MPa)	
	7 days	28 days
TR*	28.21	41.78
TCN	32.06	46.10
TTIPA	32.60	46.79
TCN+TIPA	32.64	48.30
TTEA	26.36	38.70
TCN+TEA	34.46	37.85

\*R: Reference mixture.

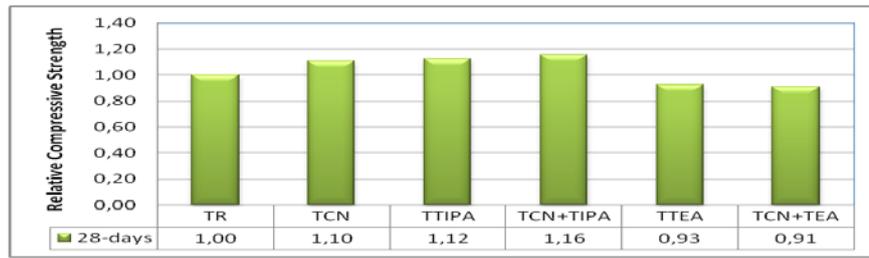


**Figure 1.** Effect of accelerators on compressive strength of mortars prepared with TRACIM company cement at the ages of 7 and 28 days.

Relative compressive strength of mortars with TRACIM company cement at the ages of 7 and 28 days were shown in Figure 2 and Figure 3, respectively. It has been observed that calcium nitrate provided 14 % increment of compressive strength at the age of 7-days, while TI-PA provided 16 %. Using TIPA alone or with calcium nitrate gave the same result from the point of 7-day compressive strength. TEA caused 7 % decrement on compressive strength, however, if it was used with calcium nitrate 22 % increment on 7-day compressive strength has been observed. At later ages, TEA caused a decrement on compressive strength of mortars prepared with ordinary Portland cement. It has been found that TIPA has a significant effect on early-age compressive strength of mortars.



**Figure 2.** Relative compressive strength of mortars with TRACIM company cement at the age of 7-days.



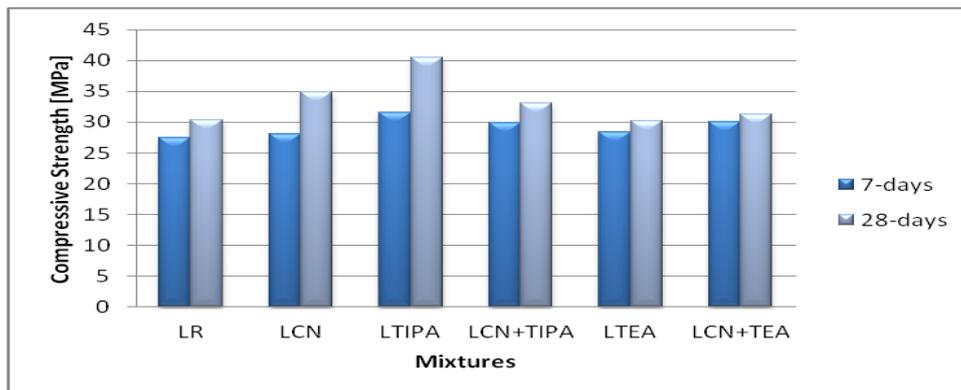
**Figure 3.** Relative compressive strength of mortars with TRACIM company cement at the age of 28-days.

The effect of accelerating chemicals on compressive strength of mortars prepared with LIMAK company cement at the ages of 7 and 28 days was given in Table 4 and graphically shown in the Figure 4.

**Table 4.** 7 and 28-day compressive strengths of mortars produced with LIMAK company cement.

Mixtures	Compressive strengths at the ages of 7 and 28 days (MPa)	
	7 days	28 days
LR*	27.44	30.31
LCN	28.11	34.94
LTIPA	31.57	40.47
LCN+TIPA	29.91	33.09
LTEA	28.37	30.27
LCN+TEA	30.11	31.33

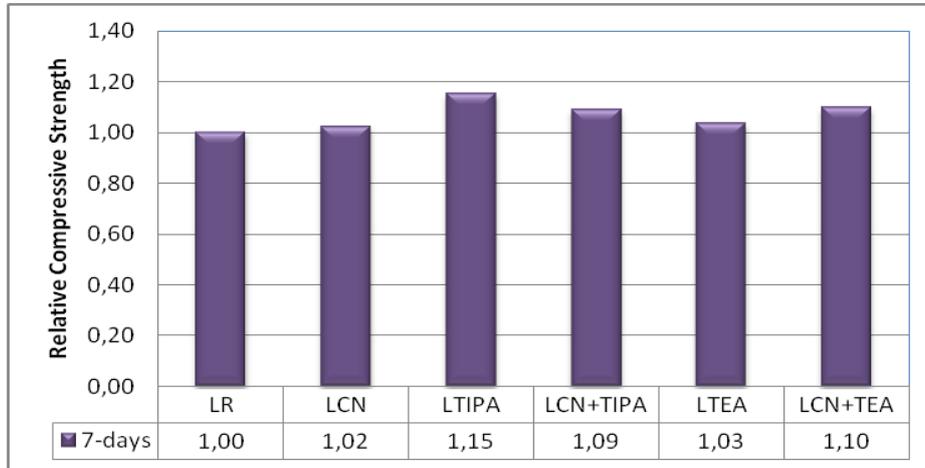
\*R: Reference mixture.



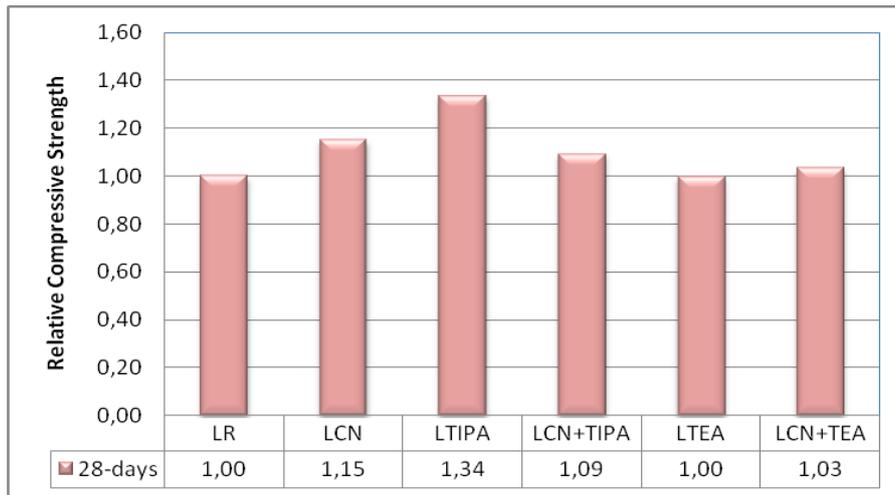
**Figure 4.** Effect of accelerators on compressive strength of mortars prepared with LIMAK company cement at the ages of 7 and 28 days.

Relative compressive strength of mortars with LIMAK company cement at the ages of 7 and 28 days were presented in Figure 5 and Figure 6, respectively. It has been observed that cement composition made the difference. In this case, TEA affected strength gaining positive-

ly at both early and later ages. Moreover, TIPA provided the highest increment on compressive strength.



**Figure 5.** Relative compressive strength of mortars with LIMAK company cement at the age of 7-days.



**Figure 6.** Relative compressive strength of mortars with LIMAK company cement at the age of 28-days.

#### 4. CONCLUSION

As a consequence, it has been found that TEA’s effect is dominant at later ages from the point of compressive strength of mortar made with ordinary Portland cement. In this experimental study, it has been observed that TIPA is effective on compressive strength at both earlier and

later ages. Besides, it has been resulted that TIPA has the greatest effect on increasing the compressive strength within these three chemicals. This is a beneficial outcome for companies producing accelerating admixtures.

## 5. SYMBOLS

CN: Calcium nitrate

TEA: Triethanolamine

TIPA: Triisopropanolamine

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