

The environmental impacts of calcium chloride addition to cement on reinforcing steel corrosion

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"This research is funded by the Deanship of Research and Graduate Studies in Zarqa University /Jordan - Zarqa"

Abstract

An alternative use of a specific type of cement for a particular purpose, usually we can change some properties of available cement by using the appropriate additions, with some negative side effects in some cases. In this research have been suggested values of calcium chloride(CaCl_2) additions for use in concrete admixtures as an agent factor in accelerating the process of cement setting, to clarify the extent of the negative impacts that could be induced, such as alkalinity decline of solution and the impact of the chemical composition of used cement on reinforcing steel. Chloride ion present in low alumina cement mortar was detected quickly, while it needed to increase calcium chloride content to double in moderate alumina cement mortar. The results showed that the depth of carbonation when samples of different composition and with various w/c ratio treated by stream was faster in low ammonia cement mortar from moderate ammonia and faster in mortar poor than in mortar rich, In addition, depth of carbonation increased when the calcium chloride content in cement was very small. Electrical potential of steel in cement mortar inversely proportional with increasing calcium chloride content and with increasing in water/cement ratio and increasing sand content in cement mortar medium ammonia. The lowest level of steel oxidation observed in mortar consisting of cement medium ammonia and the rate of corrosion increases when samples treated by stream in all cases.

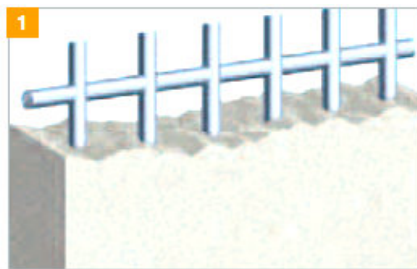
Keywords: Calcium Chloride, Oxidation, Reinforcement, Stream Treatment, Carbonation, Concrete admixtures, Electric potential

1. Introduction

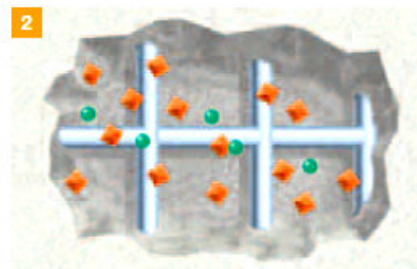
Concrete is a versatile building material used especially in civil engineering in combination with steel. However, concrete and steel are vulnerable to harmful substances that penetrate into the building material by means of moisture. This can result in costly concrete damage due to reinforcement corrosion. Concrete and reinforced concrete are building materials that have significantly changed construction over recent years. Their development provided architects, builders and engineers with building materials that, in addition to offering excellent mechanical and physical properties (such as compressive and flexural strength), could be shaped in new and unprecedented ways. It became possible to erect imposing structures such as bridges, towers and skyscrapers, as well as more intricate structures. Its cost-effectiveness and durability also make concrete a vital building material for the future. Concrete and reinforced concrete consist mainly of cement binder, sand aggregate and additives. In the case of reinforced concrete, the steel reinforcement improves the concrete's tensile strength. Water is also required for hardening the cement and attaining the desired processing consistency. One way of determining concrete quality is by the water/cement value, the ratio of mixing water to cement. Excess water results in an increased number of capillary pores in the cement and thus a loss in rigidity. Correct processing and mixing of the ingredients is necessary to ensure a building material with excellent weathering and aging resistance. Otherwise, serious damage impends after a relatively short time.

Fresh concrete is highly alkaline, which passivates the reinforcement steel 1. The greatest damage, which occurs, e.g., when the reinforcement steel corrodes, is caused by waterborne salts, particularly chloride ions. They are absorbed by the concrete, typically in the form of salt or seawater. This particularly affects highway structures, but also buildings in coastal regions. Ultimately, the salt transported into the concrete by water 2 causes the steel's passivating layer (protective layer) to dissolve. Under the influence of oxygen and moisture, the steel begins to rust and pitting corrosion starts to occur 3. Since the iron's corrosion process involves a drastic volume

expansion (bursting force) 4, the concrete layer above the reinforcement spalls 5, resulting in serious concrete damage 6.



1 The reinforcement steel undergoes passivation in alkaline milieu.



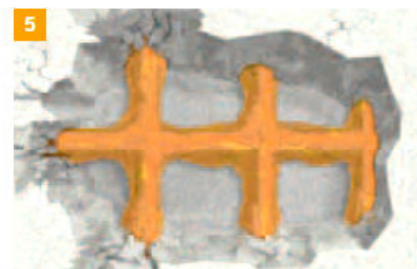
2 Dissolved salts, such as chlorides and acidic gases (e.g. CO₂), penetrate into the concrete and threaten the reinforcement.



3 The salts reach the steel and dissolve the protective layer. Pitting corrosion starts to occur.



4 The corrosion process results in a volume expansion and pressure build-up in the structure.



5 Crack formation and spalling of the concrete are the result.



6 The viewer sees the corrosion damages like that.

The frost action on fresh concrete in cold climate one of the most important and the main problem affecting the durability of concrete, it causes water freezing in concrete mix, that is leading to an increase in the total volume of concrete and reduces the water content available for chemical reactions and this in turn causes weakness in the required resistance and delay cohesion and solidification processes. The addition of calcium chloride to concrete mixes plays very important role to increase the rate of resistance, so it used when needed as accelerator when concrete casting in regions with low temperatures or in repair work with fast achievement nature, which increases the rate of heat emission during the first hours after the process mixing, and be more effective to increase the resistance of early-rich mixtures with low proportions of w/c content, because its effects depend to a certain degree on the chemical composition of cement since additions rates ranging among 0.5-3%. However, it's more likely that oxidation of steel due to presence of calcium chloride increase when using a high percentage of w/c ratios. In case of treated concrete with a stream there is a high probability of oxidation of steel, and there are risk of alkaline interaction in the presence of calcium chloride when the aggregates is subject to interaction, and its use is not recommended when the treatment temperature exceeds more than 60 C°.

Corrosion can be defined as the destruction or deterioration of materials due to reaction with its environment. Reinforced concrete is a versatile, economical and successful construction material. It can be molded to a variety of shapes and finishes. Usually it is durable and strong, performing well throughout its service life typically exceeds 50 years. Sometimes, it does not perform adequately as a result of poor design, poor construction, inadequate materials selection, a more severe environment than anticipated or a combination of these factors (John P. B.1997).

Reinforced concrete superstructures along the coast can corrode due to marine atmospheric exposure if not properly designed. Marine atmospheric can be defined as that atmosphere within 300m (1000 ft) of ocean or tidal water, tidal water: is anybody of surface water having a chloride content of 500ppm or greater (Corrosion Guidelines, 2003)]. The cost of repairing or replacing deteriorated structures has become a major liability for high way agencies, estimated to be more than \$20 billion and to be increasing at \$500 million per year that"s in united state (Paul Teng T.,2000).

Reinforcing steel embedded in concrete shows a high amount of resistance to corrosion because the cement paste in good quality concrete provides an alkaline environment with pH (12.5-13.5) that protects the steel from corrosion by passivating or protective ferric oxide film that forms on the surface steel bar when it is embedded in

concrete. This passive film is only a few nanometers thick and is stable in the highly alkaline concrete (pH approx. 11-13.5) (John P. B.1997). The protective action of the passive film is immune to mechanical damage of the steel surface, it can, however, be destroyed by carbonation of concrete or by the presence of chloride ions. The reinforcing steel is depassivated when the pH falls below 10 for any reason then the corrosion may occur (Paul Teng T.,2000). Then carbonation or chloride ions can penetrate through the concrete pores to the oxide layer on the rebar breaking down the passive layer and leaving the steel bar vulnerable against aggressive agents; in the presence of moisture and oxygen the corrosion will occur (Corrosion Guidelines,2003).

Most problems with corrosion of steel in concrete are not due to loss of steel but growth of the oxide that has a volume of about twice to six time that of the steel it replaces when fully dense (Bertolini, L. et al, 2004). When it becomes hydrated it swells even more and becomes porous. This means that the volume increases at the steel/concrete interface in two to several times. This leads to the cracking and spalling of the concrete cover that we observe as the usual consequence of corrosion of steel in concrete and the red/brown brittle, flaky rust on the bar and the rust stains seen at cracks in the concrete (John P. B.1997). The passivity provided by the alkaline conditions can be destroyed by the presence of chloride ions, even through a high level of alkalinity remains in the concrete. The chloride ion can locally depassivate the metal and promote active metal dissolution (Bertolini, L. et al, 2004).

Chloride reacts with the calcium aluminates (C3A) and calcium aluminoferrite (C4AF) in the concrete to form insoluble calcium chloroaluminates and calcium chloroferrites in which the chloride is bond in non-active form; however, the reaction is never complete and some active soluble chloride always remains in equilibrium in the aqueous phase in the concrete. At the low concentration levels of chloride in the aqueous phase, the rate of corrosion is very small, but higher concentration increases the risks of corrosion (Persson M, 2000). Thus the amount of chloride in the concrete and, in turn, the amount of free chloride in the aqueous phase (which is partly a function of cement content and also of the cement type) will influence the risk of corrosion. While the concrete remains in uncarbonated state the level of free chloride in the aqueous phase remains low (perhaps 10% of the total Cl). However, the influence of severe carbonation is to break down the hydrated cement phase and, in the case of chloroaluminates, the effect is to release chloride. Thus more free chloride is available in carbonated concrete than in uncarbonated materials (ACI Committee201 2R-92).

The level of chloride ions required to initiate corrosion in concrete corresponds to 0.1% soluble chloride ion by weight of cement. This is equivalent to between 0.6 -0.8 Kg of chloride per m³ of concrete (Bavarian B., 2000). There is a chloride threshold for corrosion given in terms of the chloride /hydroxyl ratio. When the chloride concentration exceeds 0.6 of the hydroxyl concentration, corrosion is observed. This approximates to a concentration of 0.4% chloride by weight of cement cast into concrete [(John P. B.1997), (Persson M, 2000)] see table 1 and 2.

Corrosion inhibitors technology has been used around since 1960, but has only been available to the construction industry for the past ten years. Corrosion inhibitors are chemical admixtures when added to concrete mix in very small concentration can be able to prevent or delay the corrosion that happens in reinforcement bars. Corrosion inhibitors are generally used as admixtures in concrete for construction, but they can also be used for repairs by being admixed into concrete for paths, sprayed or painted onto the surface of the concrete or applied by saturation treatment (Roberge P.R., 2005).

Table 1 Chloride concentration in reinforced concrete (Corrosion Guidelines,2003)

Cl⁻ concentration Kg/m³	Assumed condition
0 to 0.7	Passive (non- corroding)
0.9 to 1.8	Corrosion initiation
> 1.8	Active corrosion

Table 2 Chloride limits for new construction (ACI Committee 222 R -96).

Category	Chloride limit for new construction as a percentage of concrete mass	
	Acid –soluble ASTM C1152	Water –soluble ASTM C1218
Prestressed concrete	0.08	0.06
Reinforced concrete in wet condition	0.10	0.08
Reinforced concrete in dry condition	0.20	0.15

There is accomplished behavior for inhibitor molecules to penetrate the concrete through cracks and pores and then react with the cement and reinforcement steel to restore with successfully the passivating film to the steel and extend the useful life of the concrete structure (John P. B.1997). Corrosion inhibitors are organic or inorganic. Inorganic inhibitors like, potassium dichromate, zinc and lead chromate, sodium benzoate, calcium hypophosphite, and calcium nitrite and organic inhibitors like, sodium cinematic, ethanolamine (Bregman J.I.,1963).

In general, they are classified based on their protection mechanism that are added to a water source or other fluids or gases in small amounts to stop or delay corrosion of metals exposed to corrosive environment, they can protect by affecting the anodic reaction or the cathodic reaction or both reaction (mixed) [(John P. B.1997), (Fontana M.G.,1978)]. Inhibitors have been classified in many ways, including by composition, mechanism of action or form (Persson M, 2000). According to the mechanism of action inhibitors fall into several classes, passivation, precipitators, stream phase, cathodic, anodic, neutralizing and absorbents (Landroum R.J.,1989). Organic inhibitors are adsorbed layer formers, which strongly adsorb to the metal surface and interfere with the anodic and cathodic reaction in the area of adsorption. The chemical structure of the inhibitor molecule plays a significant role and often determines whether or not compounds will effectively inhibit a specific system in this study (Fontana M.G.,1978). They also may: Increase the anodic or cathodic polarization behavior; reduce the movement or diffusion of ions to the metallic surface, and; Increase the electrical resistance of the metallic surface (Kepler J.L.et al, 2000).

There are three major concerns regarding the use of corrosion inhibitors. The first one is the long-term stability and performance of the inhibitor. The second is the inhibitor's effect on corrosion propagation after corrosion initiation. The third is the inhibitor's effect on concrete's physical properties over the service life of the structure (Persson M, 2000). Berke N.S.,1989 studied the corrosion inhibiting properties of calcium nitrite ,and he states that calcium nitrite is successfully being used because it provides corrosion inhibition in the presence of chloride ; it is not detrimental to concrete properties ; and it is available in sufficient quantities for commercial use in concrete. Hope B.B. and Thompson S.V, 1995 found during an investigation on the effectiveness of corrosion inhibitors that, all samples of concrete containing NaCl which were soaked in saturated Ca (NO₂)₂ solutions undergo severe mortar deterioration. The mortar cracked and bulged without corrosion of reinforcing steel due to the use of corrosion inhibitors.

Limaye R.G.et al,2000 studied the ability of new generation of corrosion inhibitors (CPCI a Concrete–surface applied Penetrating Corrosion–Inhibitor), which is based on bipolar mechanism and which can penetrate even dense concrete by virtue of its stream pressure and affinity for the embedded steel in concrete. The inhibitor was used in both as an admixture in fresh concrete and as a coating on hardened concrete. Limaye R.G.et al, 2000 used two types of concrete mix ; weak and strong. The result was that the using of penetrating corrosion inhibitor as admixture to concrete did not impair any mechanical properties or physical properties like workability, water absorption, initial and final setting time and other properties did not show any change, also compressive strength and bond strength showed improvement at ambient temperature and even at higher temperature of 60°c . The corrosion rate that was measured with half cell potential has a reduction in both weak and strong concrete. However, this effect is more pronounced in weak concrete as compared to stronger concrete grades.

Stephen R.S., 2004 investigated the use of penetrating corrosion inhibitors to extend the life of existing reinforced concrete bridge decks. The idea of simply applying inhibitors to the concrete surface is appealing. It is critical that the inhibitor not only penetrates the concrete but also reaches the reinforcing steel in sufficient concentrations to inhibit corrosion. They used the vacuum to remove residual moisture from the concrete followed by the application of pressure to inject an inhibitor into the concrete. This technique reduces the corrosion rate by hindering the anodic reaction, the cathodic reaction, or both.

2. Materials and Methods

In this research we used two types of cement, first Low Temperature Portland cement (LTPC), and the second Quick-setting Portland cement (QSPC) as shown in table 1, with addition 2% of gypsum to regulate setting time.

Tab3. The Percentage of chemical ingredients different types of cement

Types of cement	Percentage of chemical cement ingredients		
	Tri-calcium Silicate 3CaO.SiO ₂ (C3S)	Di-calcium Silicate 2CaO.SiO ₂ (C2S)	Tri-calcium aluminate 3CaO .Al ₂ O ₃ (C3A)
LTPC	21	57	3
QSPC	70	3	8

To reach the aims of research, samples were prepared in the form of cubes measuring 5*5*5 cm of cement mortar composed by 1:2 cement: sand (sand passing through a sieve 0.85 mm), so that no more than 10% of the weight of the sample passing through sieve 0.6 mm, as was the percentage of water: cement = 0.5, The other sample was composed of 1:3 cement: sand was reinforcing with steel bars 5 mm in diameter and the percentage of water: cement = 0.6 , with adding standard solution of calcium chloride at rates ranging from 0.5-3% of the weight of the cement.

Six similar samples were prepared for each experiment, half of the samples were treated in a private room immediately after casting by six hours under normal atmospheric pressure and temperature of 80 C° according to System 3 +3 +4 hours, and then the samples placed into private flames compartment with natural humidity and temperature 22 C°. The goal of procedure is to get early resistance facilitates handling of concrete production shortly after the casting process, templates can also be removed in less time than in the case follow the usual approach of wetlands treatment, which has economic benefits in the applied domain. The rest of the samples placed into hardening chamber immediately after casting samples templates.

Carbonation is the result of the dissolution of CO₂ in the concrete pore fluid and this reacts with calcium from calcium hydroxide and calcium silicate hydrate to form calcite (CaCO₃). Aragonite may form in hot conditions. Within a few hours, or a day or two at most, the surface of fresh concrete will have reacted with CO₂ from the air. Gradually, the process penetrates deeper into the concrete at a rate proportional to the square root of time. After a year or so it may typically have reached a depth of perhaps 1 mm for dense concrete of low permeability made with a low water/cement ratio, or up to 5 mm or more for more porous and permeable concrete made using a high water/cement ratio.

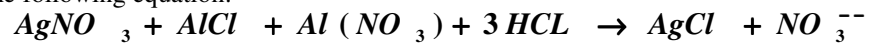
Carbonation depth is assessed using a solution of phenolphthalein indicator that appears pink in contact with alkaline concrete with pH values in excess of 9 and colourless at lower levels of pH. The test is most commonly carried out by spraying the indicator on freshly exposed surfaces of concrete broken from the structure or on split cores. Alternatively, the powder from drill holes can be sprayed or allowed to fall on indicator-impregnated paper.

The phenolphthalein indicator solution is applied to a fresh fracture surface of concrete. If the indicator turns purple, the pH is above 8.6. Where the solution remains colourless, the pH of the concrete is below 8.6, suggesting carbonation. A fully-carbonated paste has a pH of about 8.4. In practice, a pH of 8.6 may only give a faintly discernible slightly pink colour. A strong, immediate, colour change to purple suggests a pH that is rather higher, perhaps pH 9 or 10. Normal concrete pore solution is saturated with calcium hydroxide and also contains sodium and potassium hydroxide; the pH is typically 13-14. Concrete with a pore solution of pH 10-12 is less alkaline than sound concrete but would still produce a strong colour change with phenolphthalein indicator. It therefore follows that the indicator test is likely to underestimate the depth to which carbonation has occurred.

Detect chloride ion in concrete: After 180 days of keeping the samples were detected chloride ion using silver nitrate 1%, which is the first detector, where principle interaction depends according to the following equation when the mortar in the process of plasticity.



In case of hardened mortar was detected chloride ion using second detector silver nitrate and nitric acid ($AgNO_3 + HNO_3$), as this mixture reacts with both hydrated chlorides Aluminate ($AlCl_3$) and oxide chlorides Aluminate ($Al_2O_3, AlCl_3$) according to the following equation:



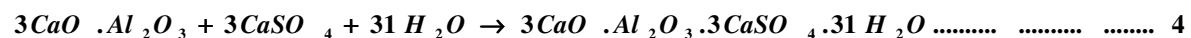
Measuring the intensity of rebar corrosion using the electrical potential difference method: in this method we measured electric potential difference using Electrochemical cell: one pole consists of silver wire immersed in a saturated solution of silver chloride and the other pole in a cement mortar cube which contains different ratios of (C3A) without being saturated or wet surface.

3. Results and Discussion

Steam curing is a process for hardening concrete, cement, and mortar that involves exposure to warm steam. Materials subjected to this hardening technique tend to cure more uniformly and also much more quickly than those hardened via other processes. There are some disadvantages to this process that must be considered before deciding to use it for curing, and there may be certain applications where steam curing is not appropriate. In steam curing, objects to be cured are placed inside a chamber or room. Using a control panel, an operator can set the temperature and humidity level. Variations in pressure may also be possible, depending on the device. The heat and moisture penetrate the materials quickly to fully hydrate and harden them. Steam curing requires a fraction of the time involved with traditional curing and quickly strengthens the products so they can be used immediately. The alternative to steam curing is allowing products to cure naturally at ambient temperatures and humidity levels. Timing is important when using concrete, cement, and mortar, since cool, moist weather tends to provide the best cure. Dry, hot weather will cause weakness and cracking that may compromise the finished product and in some cases, the damage can be extensive enough that the product cannot be used. This is an especially important consideration when working outdoors, where controlling temperatures and humidity levels is not possible.

Chloride ion was detected in the cement mortar consisting of cement moderate Alumina in the event that the content of calcium chloride ($CaCl_2$) equal 3% of cement by weight using 1% silver nitrate ($AgNO_3$) reagent, While the chloride ion detected using the same detector in cement mortar low Alumina when calcium chloride content is 1.5% of the weight of the cement. After mortar steam curing chloride ion was detected only when the content of calcium chloride more than 2.5%, while in the hardened mortar chloride ion was detected using a second reagent in the case of calcium chloride content of 1% of the weight of cement.

Hydrated calcium aluminate chloride composed after being associated to existing gypsum in cement with tri-calcium aluminate to be hydrated sulfate calcium aluminate according to equation (4). The remainder of the tri-calcium aluminate are interacts with calcium chloride, according to equation (5), that is the amount of calcium chloride associated with aluminate determined by according to relation (6,7).



$$CaCl_2 = (C_3A \cdot \frac{P}{100} - CaSO_4 \cdot \frac{MCaSO_4}{MC_3A}) \cdot \frac{MCaCl_2}{MC_3A} \dots\dots\dots 6$$

$$CaCl_2 = 0.411 C_3A \cdot \frac{P}{100} - 0.207 CaSO_4 \dots\dots\dots 7$$

Where: P: The degree of hydration %C₃A, M: Molecular weight appropriate for correlation.

When P= 80%, and content of $CaSO_4= 2\%$, and the ratio $C_3A = 3\%$ and 8% the quantity of associated calcium chloride equal to 0.579%, 2.22 respectively. When comparing calculations data with the results of laboratory tests, in many cases, ions chloride are not detected knowing that mathematically according relation 6 no full association of chlorides calcium with CA3. The reason for this is due to negligence of the amount of chlorides calcium associated with aluminate iron Quartet calcium calculating. Since the resulting complexes of ion

chlorine association with ferrous hydroxide did not crash, therefore free ions are not produced again.

Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop (Fig. 12-1). Curing has a strong influence on the properties of hardened concrete; proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing and deicers.

When Portland cement is mixed with water, a chemical reaction called hydration takes place. The extent to which this reaction is completed influences the strength and durability of the concrete. Freshly mixed concrete normally contains more water than is required for hydration of the cement; however, excessive loss of water by evaporation can delay or prevent adequate hydration. The surface is particularly susceptible to insufficient hydration because it dries first. If temperatures are favorable, hydration is relatively rapid the first few days after concrete is placed; however, it is important for water to be retained in the concrete during this period, that is, for evaporation to be prevented or substantially reduced. With proper curing, concrete becomes stronger, more impermeable, and more resistant to stress, abrasion, and freezing and thawing. The improvement is rapid at early ages but continues more slowly thereafter for an indefinite period. Fig. 12-2 shows the strength gain of concrete with age for different moist curing periods and Fig. 12-3 shows the relative strength gain of concrete cured at different temperatures.

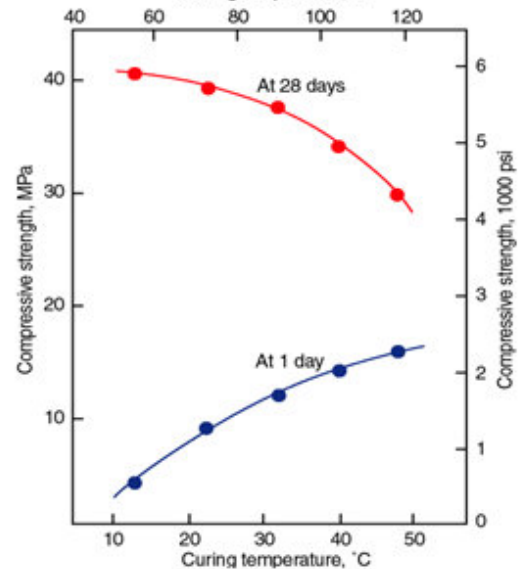
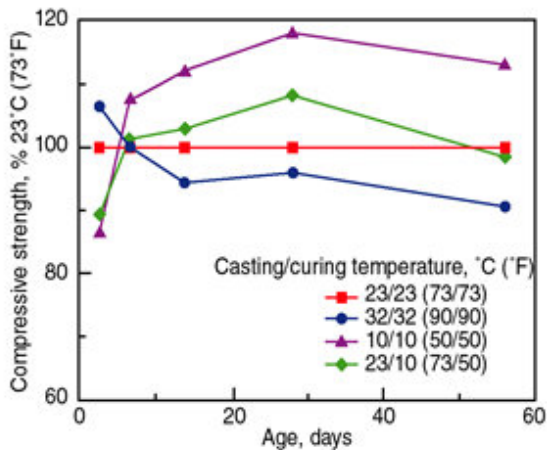
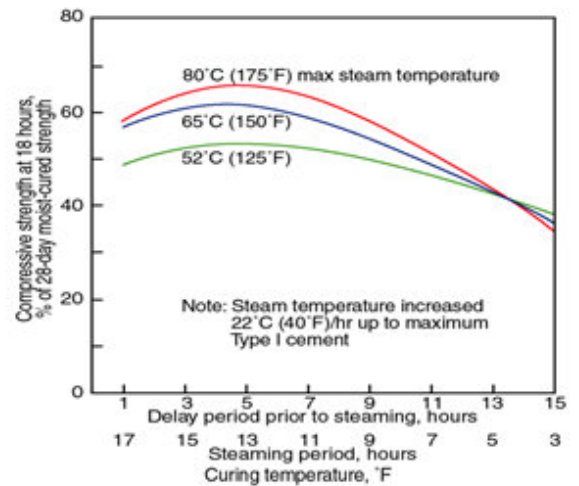
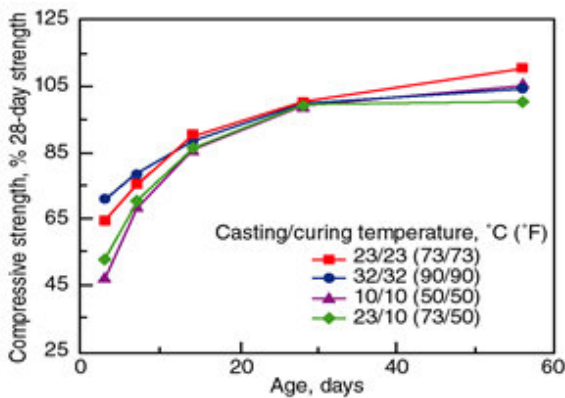
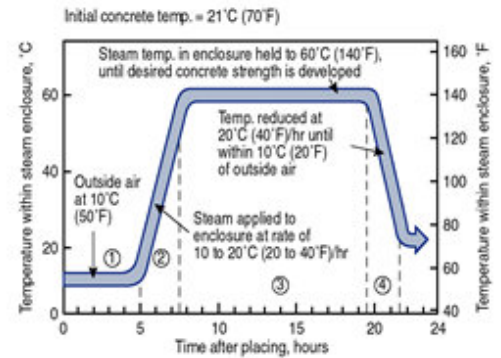
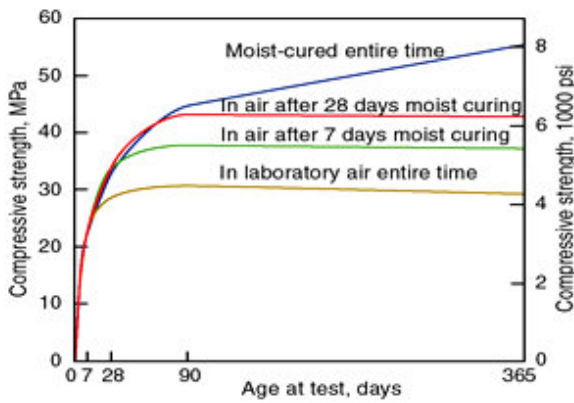
The most effective method for curing concrete depends on the materials used, method of construction, and the intended use of the hardened concrete. For most jobs, curing generally involves applying curing compounds, or covering the freshly placed and finished concrete with impermeable sheets or wet burlap. In some cases, such as in hot and cold weather, special care using other precautions is needed. Concrete mixtures with high cement contents and low water-cement ratios (less than 0.40) may require special curing needs. As cement hydrates (chemically combining with water) the internal relative humidity decreases causing the paste to self-desiccate (dry out) if no external water is provided. The paste can self-desiccate to a level where hydration stops. This may influence desired concrete properties, especially if the internal relative humidity drops below 80% within the first seven days. In view of this, membrane-forming curing compounds may not retain enough water in the concrete. Therefore, fogging and wet curing become necessary to maximize hydration (Copeland and Bragg 1955). Fogging during and after placing and finishing also helps minimize plastic cracking in concretes with very low water-cement ratios (especially around 0.30 or less).

When moist curing is interrupted, the development of strength continues for a short period and then stops after the concrete's internal relative humidity drops to about 80%. However, if moist curing is resumed, strength development will be reactivated, but the original potential strength may not be achieved. Although it can be done in a laboratory, it is difficult to re-saturate concrete in the field. Thus, it is best to moist-cure the concrete continuously from the time it is placed and finished until it has gained sufficient strength, impermeability, and durability. Loss of water will also cause the concrete to shrink, thus creating tensile stresses within the concrete. If these stresses develop before the concrete has attained adequate tensile strength, surface cracking can result. All exposed surfaces, including exposed edges and joints, must be protected against moisture evaporation.

Hydration proceeds at a much slower rate when the concrete temperature is low. Temperatures below 10°C (50°F) are unfavorable for the development of early strength; below 4°C (40°F) the development of early strength is greatly retarded; and at or below freezing temperatures, down to -10°C (14°F), little or no strength develops.

Steam curing is advantageous where early strength gain in concrete is important or where additional heat is required to accomplish hydration, as in cold weather. Two methods of steam curing are used: live steam at atmospheric pressure (for enclosed cast-in-place structures and large precast concrete units) and high-pressure steam in autoclaves (for small manufactured units). Only live steam at atmospheric pressure will be discussed here. A typical steam-curing cycle consists of (1) an initial delay prior to steaming, (2) a period for increasing the temperature, (3) a period for holding the maximum temperature constant, and (4) a period for decreasing the temperature. A typical atmospheric steam-curing cycle is shown in Fig. 12-9. Steam curing at atmospheric pressure is generally done in an enclosure to minimize moisture and heat losses. Tarpaulins are frequently used to form the enclosure. Application of steam to the enclosure should be delayed until initial set occurs or delayed at least 3 hours after final placement of concrete to allow for some hardening of the concrete. However, a 3- to 5-hour delay period prior to steaming will achieve maximum early strength, as shown in Fig. 12-10. Steam temperature in the enclosure should be kept at about 60°C (140°F) until the desired concrete strength has developed. Strength will not increase significantly if the maximum steam temperature is raised from 60°C to 70°C (140°F to 160°F). Steam-curing temperatures above 70°C (160°F) should be avoided; they are uneconomical and may result in damage. It is recommended that the internal temperature of concrete not exceed

70°C (160°F) to avoid heat induced delayed expansion and undue reduction in ultimate strength. Use of concrete temperatures above 70°C (160°F) should be demonstrated to be safe by test or historic field data. Concrete temperatures are commonly monitored at the exposed ends of the concrete element. Monitoring air temperatures alone is not sufficient because the heat of hydration may cause the internal temperature of the concrete to exceed 70°C (160°F). Besides early strength gain, there are other advantages of curing concrete at temperatures of around 60°C (140°F); for example, there is reduced drying shrinkage and creep as compared to concrete cured at 23°C (73°F) for 28 days (Klieger 1960 and Tepponen and Eriksson 1987). Excessive rates of heating and cooling should be avoided to prevent damaging volume changes. Temperatures in the enclosure surrounding the concrete should not be increased or decreased more than 22°C to 33°C (40°F to 60°F) per hour depending on the size and shape of the concrete element. The curing temperature in the enclosure should be held until the concrete has reached the desired strength. The time required will depend on the concrete mixture and steam temperature in the enclosure (ACI Committee 517 1992).



Carbonization resulting from interaction of carbon dioxide with hydrated contents of cement in the presence of moisture. The results showed, as indicated in Tables 4-5, that the depth of carbonation in mortar with installation 1:2 Cement-Sand and $w/c = 0.5$ and normal circumstances conditions, whether cement mortar composed of low-temperature or quick setting was close. But when curing the same cement mortar with the same composition carbonation was faster and greater for first type than the quick setting cement. In cement mortar low temperature with 1:3 Cement-Sand and $w/c = 0.6$, the carbonation was faster and greater than cement mortar 1:2 Cement-Sand and $w/c = 0.5$. From tables 4-5 we mentioned that all cement admixtures consisting of low alumina the

carbonation depth inversely proportional to the increase in the content of calcium chloride.

From one hand line with carbonation resistance to loads increase and permeability increased. The reason that the free water from the carbonization process helps in the process of rehydration and calcium carbonate also reduces the voids in the cement paste. But from other hand carbonation with the presence of calcium chloride working together to remove the protective oxide layer of rebar and thus exposed to corrosion.

The results showed, as indicated in Tables 6-7, that measurement of electrical potential on iron depends on content of alumina in cement, reaching the highest value of in cement mortar moderate alumina, in the case that calcium chloride is bound to with a significant degree. It was also observed that the electric potential of iron less in mortar cement moderate alumina with increasing of the content of calcium chloride standard solution. It was found that the electric potential of iron in the moderate alumina and cement consisting of 1:2 cement- sand and W: C ratio =0.5 is greater than the same cement composed of 1:3 Cement-Sand and w/c = 0.6.

The results confirmed that the corrosion of iron bars in cement mortar little alumina and low-temperature occurs whether steam has been processed or not at all various cases of the content of standard solution of calcium chloride. The lowest level of iron corrosion was in the moderate alumina cement mortar, consisting of 1:2 cement- sand and W: C ratio =0.5 and hardened in normal conditions of moisture content, and Where the corrosion of iron in the mortar with a calcium chloride content of 3%, when more than calcium chloride content of 2.5% corrosion of iron begins with mortar in steam treatment cement. When iron bars was detected in Cement little alumina were all surfaces covered with a layer of rust, both were chloride ion detected in the process of plasticity or not, as the area of corroded surfaces in the mortar medium alumina was lower than in Cement little alumina and this is directly linked to the deficiency of chloride ion concentration.

Tab.4. Carbonation Depth in cement mortar contain different % C3A and conditions

W:C ratio	Cement: Sand ratio	Stiffness Conditions	CaCl ₂	Carbonation Depth (Xmm) in cement mortar contain % C3A	
				LTPC C3A=3%	QSPC C3A=8%
				0.5	1:2
			1	2-3	4-5
			1.5	2-3	3-5
			2	1-2	1-3
			2.5	0.5-1	1-3
			3	0-1	1-2
0.5	1:2	Stream Curing	0.5	3-10	1-3
			1	1-3	1-1.5
			1.5	1-3	0.5-1
			2	1-2	0.5-1
			2.5	0.5-1	0-1
			3	0-1	0-0.5

Tab.5. Carbonation Depth in cement mortar contain different % C3A and conditions

W:C ratio	Cement: Sand ratio	Stiffness Conditions	CaCl ₂	Carbonation Depth (Xmm) in cement mortar contain % C3A	
				LTPC C3A=3%	QSPC C3A=8%
				0.6	1:3
1	15-30	1.5-3			
1.5	7-10	2-5			
2	5-12	2-5			
2.5	5-7	2-5			
3	3-4	2-5			
0.6	1:3	Stream Curing	0.5	4-18	2-3
			1	4-20	1-5
			1.5	2-13	2-3
			2	2-10	1-2
			2.5	2-10	1-2
			3	2-10	1-2

Tab.6 Rebar electrical potential for LTPC and QSPC with W:C ratio = 0.5

W:C ratio	Sand: Cement ratio	Stiffness Conditions	CaCl ₂	Rebar electrical potential (mv), Oxidation Surface (F %) in cement mortar according to % C3A			
				LTPC C3A=3%		QSPC C3A=8%	
				mv	F %	mv	F %
0.5	1:2	Natural Moisture	0.5	185	100	112	0
			1	270	100	95	0
			1.5	232	100	43	0
			2	240	100	51	0
			2.5	260	100	21	0
			3	260	100	20	0
0.5	1:2	Stream Curing	0.5	199	100	120	0
			1	280	100	58	0
			1.5	270	100	44	0
			2	280	100	44	0
			2.5	290	100	-2	3
			3	280	100	-1	2

Tab.7 Rebar electrical potential for LTPC and QSPC with W: C ratio = 0.6

W:C ratio	Sand: Cement ratio	Stiffness Conditions	CaCl ₂	Rebar electrical potential difference (mv), Oxidation Surface (F %) in cement mortar according to % C3A			
				LTPC C3A=3%		QSPC C3A=8%	
				mv	F %	mv	F %
				0.6	1:3	Natural Moisture	0.5
1	185	100	40				20
1.5	136	100	21				15
2	126	100	25				15
2.5	120	100	6				10
3	116	100	7				10
0.6	1:3	Stream Curing	0.5	19	100	7	0
			1	71	100	35	0
			1.5	277	100	6	7
			2	300	100	24	15
			2.5	280	100	26	15
			3	277	100	27	15

4. Conclusions

Steam curing concrete features: Provide time where gaining concrete the resistance in a very short time. Increase the value of compressive strength of the concrete. Reduce shrinkage in concrete (volumetric changes). Increase the resistance concrete to Chemicals (sulfate salts, sodium, and magnesium). The calcium chloride additives for concrete has many beneficial effects on some of the properties of fresh and hardened concrete and the following is an explanation of the effect of calcium chloride on the concrete: primary and final setting: It noted a decline in time of uncertainty primary and resistance as well as its impact on the cohesion between the iron and concrete at normal temperatures and low when you add calcium chloride for concrete mix by 2% by weight of cement. Early resistance: Earns calcium chloride concrete early resistance without reducing the final resistance this is an important feature for many reasons, including: Reduce time of decoding wrenches to half. Lead speed wrenches decoder to the early use of the building. Protection from the effects of cold weather and wet: affected by the rate of increase of temperature resistance of concrete where the resistance is required when the maximum temperature of 37.7 m and a distinct change in the resistance if the temperature dropped. The benefit of calcium chloride as making concrete, as if in mild weather and this interest is due to the increased heat generated by the interaction and stability with the use of calcium chloride in normal temperatures lead to get the resistance required at half time but it was noted that the percentage increase in the be greater resistance to low temperatures for example, at a temperature of 21.1 degrees Celsius get concrete treated with calcium chloride to resist in one day, equivalent to earnings of untreated concrete in three days. It should be noted that the calcium chloride is not considered a viable freeze Therefore prevention procedures should be followed in extremely cold climates for a period of 7-3 days. The additional benefits of calcium chloride: Increases the final resistance of the concrete in addition to increasing resistance early experiments has shown an increase of 9% in the three-year period. Increase the workability of concrete with retention by fresh water to cement (w /c), and Access to high-density concrete. Increase the resistance of the concrete surface corrosion and the use of calcium chloride resulting resistance are similar to those that we get from processing by wet burlap for three days. Reduces moisture loss during mixing and helps to facilitate the process of mixing with water.

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