LOW CONCRETE STRENGTH?

TEN POTENTIAL CEMENT-RELATED CAUSES

Concrete Strength

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Low Concrete Strength?
Ten potential cement-related causes

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Introduction

This little e-book describes some possible causes of low strength in either concrete or mortar that are related to cement. It isn’t an exhaustive list, but it covers some of the more common causes.

For each potential cause, there is a short description followed by a brief discussion. In essence, this e-book is a checklist of some possibilities to consider when trying to resolve a strength issue. My intention is not to go into great detail - each potential problem is described in about one page - but rather to suggest ideas that may be applicable to a particular situation.

Cement is the main active constituent in concrete or mortar and is generally very reliable. On the odd occasion when things go wrong and strength does not develop as expected, rightly or wrongly the cement usually gets the blame. In my twenty-seven years working as an independent consultant in cementitious materials, low strengths are something that I’ve often been asked to investigate. At a rough guess, I would say that the cement has contributed directly to the problem maybe one time in three, although it may have only been one of several contributing factors.

Two out of three times, the problem was due to something else in the process that may have affected the cement, such as the addition of too much water, or too much admixture, or the concrete wasn’t mixed adequately, or it segregated.

These distinctions can be summarized as either intrinsic or extrinsic:

Intrinsic: the cement has some inherent characteristic or defect that gives rise to the problem.

Extrinsic: the cement itself is not the cause of the problem, the low strength is in some way related to how the cement was used, or to the effect on the cement of other materials in the mix.

Extrinsic problems are, broadly, within the control of the concrete producer or contractor while intrinsic problems are generally for the cement manufacturer to identify and resolve. However, the boundaries of these definitions may be blurred, for example where composite/blended cements are used. Both types of problem will be considered.

Of the ten factors discussed here that may cause a loss in concrete or mortar strength, two are very simple: insufficient cement and an excessive water-cement ratio. Although obvious, they are included because they are important and also very common.

Scope

The focus of this e-book is on fresh, or nearly fresh, concrete up to about three months old where the problem has a direct or indirect connection to the cement. Such defects are usually apparent within a few days or weeks and are generally highlighted by low strength results in cube or prism tests.

Obviously, other, non-cementitious, factors may affect strengths such as defects in mix design, aggregate or admixtures but these are outside the scope of this e-book. Additionally, older concrete may be affected by durability issues that affect strength, such as sulfate attack or alkali-silica reaction. These may well have a cement-related dimension - the alkali content of the cement, for example - but again, problems that tend to take months or years to appear are also outside the scope of this edition of the e-book.
Definition of cement

Until recently, “cement” usually meant Portland cement. Now, cements are often composite or blended cements, consisting of Portland cement and mineral additions, such as slag, fly ash or fine limestone. Used properly, these additions can produce concrete with enhanced properties while making use of waste or byproduct materials, but they may also make matters more complicated when things go wrong.

Good relationships help in solving problems

Most cement manufacturers have a good working relationship with their customers, especially the larger ones who buy most cement, and this can help greatly in ascertaining the cause of a problem. The cement manufacturer cannot possibly test his cement for the huge range of potential applications, processes, admixture combinations etc., and realistically cannot fund research into every customer problem in case the cement should be at fault.

A meaningful dialogue can often get to the heart of a problem. If the cement user just sees the cement as a commodity that either performs or doesn’t perform, and if the manufacturer is unsympathetic to any potential issue with his cement, this lack of communication just leads to a standoff:

_irate concrete producer:_ “Our two-day strengths have gone down 10% and the seven-day strengths are even worse. We’ve only used your cement and nothing has changed in our system, so it must be due to the cement.”

_Cement manufacturer_: “On the contrary, our cement is extensively tested and is compliant with all the requirements of the cement standard to which it is sold. We are not aware of any problem and you are the only customer who is complaining, so the problem must be due to something in your process.”

Either side, or both sides, could be right but they both have a commercial incentive to resolve the issue. Anything that aids a constructive and informed discussion is likely to be of benefit and I hope that this little e-book will make some small contribution.

These summaries of both extrinsic and intrinsic cement-related problems may widen the avenues for investigation when strength problems arise and lead to a quick indentification of the problem. I hope they will be helpful to both cement plant technical staff and to all those in the wider construction industry whose work involves concrete or mortar.

For a wider and very accessible introduction to cement production, hydration and cement chemistry in general, you may like to consider my “Understanding Cement”, available as a printed book and as an ebook.

Nick Winter
April 2014
The fast-start user friendly insight into cement production, cement hydration and cement and concrete chemistry

For more information, go to

www.understanding-cement.com
Images

Unless otherwise stated, the images are microscope images of polished sections, taken using either an optical (petrographic) microscope or scanning electron microscope.

The sections were prepared by embedding the sample (e.g.: clinker, concrete) in epoxy resin using vacuum impregnation. The hardened resin block was then ground flat and fresh resin applied to fill any remaining unfilled pores on the surface to be examined. Finally, the section was ground and polished using successively finer grades of diamond polishing compound.

Sections of clinker for examination using a petrographic microscope were etched using nital (nitric acid in alcohol) to differentiate the calcium silicates. Petrographic microscope images are in color.

Sections examined using the scanning electron microscope (SEM) had a thin coating of carbon applied to make the specimen surface conductive. SEM images are in black-and-white.
1 Insufficient Cement

Description

Insufficient cement in the mix is the first of two obvious causes of cement-related low strength. Cement content is typically measured in kg/m$^3$ or lb/yd$^3$.

Cause

In ready-mixed concrete, a low cement content could be due to various reasons, including a batching error at the concrete plant or a calculation error.

These factors may also apply to concrete products, but with concrete products there is often a different dynamic in that the actual cement content is irrelevant provided that the product performs as required. Since the cement is probably the most expensive component in the mix, the natural tendency is to use as little cement as possible.

However, if the cement content is reduced to the absolute minimum that gives satisfactory performance when the process is performing optimally, any slight variation in the process can cause problems. This might be a small change in the cement itself, or in the aggregate particle size distribution or shape, or slight deviation in mix proportions. Some degree of “excess cement” will often provide a cushion against these effects so that the product still performs adequately. If the cement content is cut to the absolute minimum, there is no margin for error.

If a concrete contains insufficient cement, strengths are likely to be lower than expected at all ages. The extent of the strength loss will evidently depend on the degree of the cement deficiency. Other aspects of concrete performance may also be adversely affected, such as permeability and durability.

If the cement content is less than that specified but the water content is correct for the specified cement content, it follows that the water/cement ratio in the concrete will be too high. This is likely to increase the permeability of the concrete and decrease its durability (see the section on water/cement ratio).
2 Excessive water-cement ratio

Description

A high ratio of water to cement in a concrete mix is the second of two obvious causes of poor strength in concrete. The ratio of water to cement is defined as (weight of water)/(weight of cement) and is often abbreviated to w/c. The w/c ratio has a strong influence on concrete strength; for a given mix, increasing the w/c ratio will decrease strengths at all ages, and decreasing the w/c ratio will increase strengths.

Cause

For a given cement content, a high w/c ratio is evidently due to adding too much water. The most common reason for a high w/c ratio is that additional water was added to the mix to improve workability.

As the w/c ratio increases, the porosity of the paste in the concrete increases. Since a porous paste is weaker than a dense paste, an increase in w/c ratio results in a decrease in strength at all ages. Additionally, the paste will be more permeable at higher w/c ratios compared with lower w/c ratios, increasing the rate at which material dissolved in water can penetrate the concrete surface. The possible effects of this are numerous, but the most significant and common are an increase in the rate of concrete carbonation, and an increase in susceptibility to chemical attack, particularly sulfate attack.

As concrete carbonates, it becomes less alkaline. Pore fluid in normal concrete has a pH of 13-14 but as carbonation progresses, the pH may reduce to perhaps pH 7 or 8. This allows steel reinforcement to corrode and the resulting expansion of the steel and oxide layer causes damage to the surrounding concrete. Many concrete structures have had to be demolished before the end of their useful life due to reinforcement corrosion, at great cost to the economy.

Sulfate attack occurs when sulfate salts dissolved in water penetrate the concrete and react with the cement hydration products. The concrete is weakened by a combination of expansive forces and a general loss of strength as the normal cement hydration products are decomposed to form sulfate salts.

High water-cement ratio: this is a polished section of a laboratory-produced cement paste viewed using a scanning electron microscope. The w/c ratio was 0.6. Black regions are pores within the paste that became filled with epoxy resin during specimen preparation. Bright features are residual unhydrated cement particles. In a series of mixes made using different w/c ratios, the porosity will increase with increasing w/c ratio and the strength will decrease.
3 Retardation due to contamination

Description

When the normal process of cement hydration is delayed, slowed or stopped entirely, the cement is said to be retarded. When retardation occurs the reactions between cement and water are inhibited, resulting in a cement paste that has much more unhydrated cement than it would otherwise contain. The paste is porous because of the deficiency in cement hydration product.

Cause

Cement hydration can be retarded, or stopped altogether, by a range of chemicals that may be present either by accident or design. Retarding chemicals may be organic or inorganic.

Where a retarding chemical is present by design, this usually means in the form of a retarding admixture incorporated into the mix. This may be to delay the setting process to allow concrete to be placed, perhaps because it has to be transported a long distance, or in special applications such as sprayed concrete. The effect of such admixtures is designed to be temporary and normal strength development can be expected subsequently. However, in some circumstances strength development may be delayed significantly, or final strengths may be lower than expected. This is unusual but where it occurs it may be because too much admixture was added. Excessive addition of a water-reducing plastizer may also result in retardation.

If the retarding chemical is present by accident, it could be anything that happened to get into the mix by some means and so may or may not be a compound normally used as a deliberate retarder. Its presence may remain unsuspected until it is found that concrete strengths are not developing normally. Often, the cement itself is initially blamed for the low strength and only after investigation is the true cause discovered (and maybe not even then). The classic organic retarder is sugar (sucrose); just 0.1% sugar by weight of cement will have a marked negative effect on cement hydration. Other organic compounds that retard cement hydration include calcium and sodium lignosulfonate, and hydroxycarboxylic acids such as tartaric or citric acid.

Inorganic retarders include compounds of lead or zinc, or those containing borates or phosphates. Lead or zinc compounds may occasionally be present as inclusions within material used as aggregate.

Retardation of cement hydration: the hydration of cement in this concrete has been severely retarded by the presence of zinc compounds in the aggregate. Bright region within the central aggregate particle contains a high level of zinc. Numerous cement grains are visible that have barely hydrated (examples labeled "c"). Dark features within the zinc-rich aggregate are silica (s). Other features are silica sand and limestone coarse aggregate (at bottom of image).
4 Error in proportions of Portland cement and supplementary cementing material (mineral addition)

Description

Cements containing mineral constituents as partial replacements for Portland cements are known as composite cements, blended cements or extended cements. The added mineral components (called mineral additions or supplementary cementing materials)) are reactive and contribute to the hydration process. Slag or flyash are most commonly used; other mineral additions include natural pozzolans and microsilica (silica fume).

The mineral additions are used partly because they are generally waste materials being put to advantageous use, partly because they represent some cost saving and partly because they produce concrete for particular applications that can be superior to concrete made from Portland cement alone. The mineral addition can be interground with the cement and gypsum at the cement plant, or blended with the cement at the concrete batching plant. In the USA the term “blended cement” is widely used for either process. In Europe, these cements are described as “interground” or “blended” respectively.

Although widely beneficial, the use of mineral additions means that the mix is more complex, with an additional component that has to be added in the correct proportions. Occasionally, things go wrong and too little or too much mineral addition is added. Using slag or flash as typical examples of mineral additions, the likelihood is that lower strengths than expected will be due to too much slag or flyash in the mix and too little Portland cement.

Cause

The usual cause is a batching error at the concrete plant. Incorrect additions to cements produced at cement plants are probably less common, although obviously no system is infallible.

A classic cause of batching error is where a silo has been filled with, for example, slag when it should have been filled with Portland cement. The concrete will then contain slag blended with more slag, with perhaps some Portland cement that was in the silo when it was filled.

Determining the quantities of the cementitious constituents in a hardened concrete made using a composite cement is more complex than for a hardened concrete made using Portland cement only.

For more on blended/composite cements see the Understanding Cement book/e-book, Chapter 7.

Portland cement and slag: this concrete contains the proportions of Portland cement (30%) and slag (70%) that were intended for this mix. Had the proportions of the cementitious materials been other than intended, the characteristics of the concrete would have been affected, eg: strength, permeability and sulfate resistance, and heat of hydration. In this image, most of the PC has hydrated but a few residual relict unhydrated clinker particles are visible (circled). Part-reacted slag particles are abundant (examples arrowed).
5 Agglomeration of microsilica/silica fume

Description

Silica fume (also known as micro silica) is a very fine powder (typically approximately 0.1µm) composed largely of silica. Silica fume is a highly reactive pozzolan and is used as a mineral addition/ supplementary cementitious material in concrete mixes to improve physical characteristics. These include high compressive strengths, reduced permeability, a reduction in the likelihood of alkali-silica reaction (asr) and a reduction in bleeding.

Silica fume is usually used in conjunction with superplasticizers to reduce the high water demand. Additions of up to 10%-15% by weight of cement are typical. To perform correctly, silica fume needs to be dispersed throughout the mix. However, occasionally it includes agglomerations of fine particles that do not disperse properly and remain as “clumps” of silica fume typically 50µm-100µm across, but sometimes up to 0.5mm or 1mm. Larger individual particles may also be present.

Cause

The cause of the initial agglomeration of the fine silica fume particles is probably electrostatic attraction. In bagged pre-mixed materials containing cement, aggregate and silica fume, the fine silica fume particles may adhere to the aggregate.

The cause of the low strength is primarily because the agglomerated particles are not combining with lime in the cement paste as expected to form additional strength-giving calcium silicate hydrate. In extreme cases, the agglomerations, if sufficiently large, can act as a reactive aggregate to form pockets of alkali-silica gel that potentially could cause expansive damage and further loss of strength.

If undispersed silica fume remains adhering to aggregate in bagged material, a thin layer of alkali-silica gel can sometimes be produced around the aggregate and consequently the bond between paste and aggregate will be poor, again leading to a loss of strength.

Clumps of gel in concrete: these clumps of gel (g) are due either to agglomerations of finer particles of silica gel, or to single larger particles. In composition, they are indistinguishable from gel produced by alkali-silica reaction. In this concrete, the gel has not caused any damage by expansion (the microcracking in the paste and within the gel is due to drying shrinkage in the SEM high vacuum). However, the gel clumps are undesirable as they contain silica that was intended to combine with lime to form calcium silicate hydrate.
6 Clinker composition: low Lime Saturation Factor (LSF)

Description

The Lime Saturation Factor (LSF) determines how closely the maximum possible alite content in the clinker is achieved. A value of 100% indicates that all the calcium silicate in the clinker is present as alite. With progressively lower LSF values, the belite content will increase and the alite content will decrease. The LSF can be applied to Portland cement clinker, and, with adjustments, to Portland cement.

Cause

Alite (impure tricalcium silicate, C3S) hydrates faster than belite (impure dicalcium silicate, C2S). Other things being equal (eg: cement fineness) a cement with a high alite content is therefore likely to give higher early strengths than a cement with a lower alite content and a higher belite content. A cement plant will have a target value for the LSF of the clinker; nevertheless, the LSF of the clinker as it comes out of the kiln is likely to fluctuate. In the cement mill (or clinker store) these fluctuations will tend to get averaged out to some extent in the final cement but occasionally the LSF of the cement supplied to the customer may be lower than what he/she is used to receiving.

The cement plant will have noticed the lower LSF of the cement and may take immediate corrective action, or perhaps wait for the early results of cube or mortar prism tests, which will take several days. The typical response of the cement plant will be to either adjust the clinker composition to increase the LSF again, or to grind the cement finer to make it react faster. Meanwhile the customer may also have noticed that early strengths are lower than normal. By the time the customer has eliminated other possibilities and decided the cement was the problem, the problem itself may well have been resolved by the cement plant.

As described above, a cement with a lower LSF than normal for cement from that source is likely to produce lower early strengths than usual. However, subsequent strength growth may be more pronounced than normal, because of the continued hydration of belite. Eventually, (eg: after 1-3 months) it may catch up again and even overtake the normal strength growth curve, although this will depend on the circumstances in which the cement is used.

For more on the lime saturation factor, and other formulae used in cement production, see www.understanding-cement.com, or the Understanding Cement book/e-book.
7 Overburned clinker

Description

Controlling kiln conditions for optimum cement characteristics is a delicate balance. The clinker has to be heated to a sufficiently high temperature, and maintained at that temperature for a sufficient length of time, to achieve good combination of the raw meal. However, if the clinker is burned too hot for too long, cement performance will suffer. Overburning of the clinker will produce cement that contains silicates that are less reactive than they otherwise might be and strengths are likely to be impaired.

Cause

The usual cause of overburning of clinker is that the materials are not combining satisfactorily. The clinker free lime will be too high and the cement plant will respond by burning the clinker harder to try to get it to combine better. The most common reason for poor combination is that some of the raw meal, especially the silica, is too coarse, but there are many other potential causes. Silica particles coarser than about 45µm are unlikely to combine easily, whereas limestone up to about 100µm should combine without too much problem.

One effect of overburning on the clinker is that alite crystals tend to grow larger by merging with adjacent crystals and recrystallising to produce very large crystals. These large crystals are likely to be less reactive than small crystals as small crystals tend to have more defects in their structure and this enhances reactivity.

Hard-burned clinker: alite crystals (examples “a”) are brown in this etched section. Larger crystals are up to ~100µm in length, whereas smaller euhedral crystals (top left) are ~25µm. The larger crystals have grown by cannibalizing neighboring alite crystals during extended heating and have become distorted. The smaller crystals formed later in the burning zone. Beige regions (r) are epoxy resin in pores; yellow regions are ferrite and aluminate.
8 Reducing conditions in the cement kiln

**Description**

A cement kiln is essentially a long tube containing a flame and a somewhat restricted supply of air. In normal operating conditions, some degree of reduction is normal and some iron (III) will be reduced to iron (II) in the burning zone of the kiln. As the clinker cools, the iron (II) reoxidizes to iron (III).

Occasionally, a higher degree of reduction of the clinker can occur and this can have a significant effect on the clinker and on the cement made from it. This is what is normally meant by “reducing conditions” in the context of cement production, although this is a relative description since some degree of reduction is normal.

**Cause**

Reducing conditions can occur if there is insufficient oxygen in the kiln gas; this could be due to an insufficient air supply or to overburning. They can also occur if the raw feed contains carbonaceous material in the raw feed or if unburned fuel particles fall onto the clinker bed and become incorporated. Unburned fuel in the clinker can be a particular problem when waste materials are part of the fuel mix, for example, pieces of burnt plastic causing localized patches of reduced clinker. If these are sufficiently numerous, much of the clinker can be reduced.

The effect of reducing conditions on the clinker in the burning zone is that iron (III) is reduced to iron (II), which then substitutes for calcium in the clinker phases. Consequently, there is less liquid in the clinker and combination of lime and belite to produce alite becomes more difficult. Additionally, there is a loss of clinker sulfate as sulfur dioxide. As the clinker leaves the kiln and cools, it reoxidizes and some of the negative effects of reduction are offset, but much depends on the temperature at which reoxidation takes place. At high temperatures, the effects of reducing kiln conditions may be small, although still discernible microscopically. If the clinker reoxidizes at lower temperatures (below about 1300-1350 °C) cement made from the clinker is likely to be adversely affected.

Cement made from reduced clinker is likely to give lower strengths. Setting characteristics may alter as the cement will contain more aluminate phase (“C3A”) in total and the crystals will be larger.

While normal (gray) cement is generally adversely affected by reducing conditions in the kiln, in some circumstances reducing conditions are desirable. In particular, white cement is generally produced in a reducing atmosphere because any iron is then present as Fe(II) and the cement is whiter than if the iron were Fe(III). Since the quantity of iron in white cement is small, the adverse effects are minimal.

**Reducing conditions**: this nodule was sawn in half, revealing a yellowish core and normal, dark gray, outer shell. A thin yellow line is just visible at the interface between the yellow core and gray shell (arrowed). The normal dark gray color of clinker is due to the ferrite phase; in this nodule, the yellow color at the core is due to a relative lack of ferrite as much of the iron is Fe(II) in other phases substituting for calcium. The yellow line marks the approximate limit of reoxidation from the outside on cooling, with consequent ferrite formation as Fe(ii) converts to Fe(III). The iron in the ferrite has not fully re-oxidized, however, giving the pale color. In the gray shell, the iron has fully reoxidized, giving normal gray coloration. Note that a yellow or beige core does not necessarily indicate reducing conditions; large nodules produced under normal conditions may have lighter cores where the iron in the ferrite has not fully reoxidised, or the clinker may be underburned. Microscopic examination of this clinker showed that it was strongly reduced.
Understanding Cement
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9 Milling: coarse cement

Description

Coarse cement can be the cause of low concrete strength. It may seem obvious that finer cement will react more quickly, but it is important to emphasise the point. Often, when strengths are lower than expected, the chemistry of the cement is blamed and the cement examined from a compositional perspective. However, if the problem actually is that the cement is coarser than normal, no amount of chemical analysis will discover the real problem. When investigating low concrete strength the fineness of the cement, or preferably, the particle size distribution should be one of the first items on the list of potential causes to be investigated.

Cause

In general, the finer the particle size of any material, the faster it is likely to react because it has a larger surface area. One of the options available to a cement plant if strengths start to decline is to grind the cement more finely. (Of course, this will have other effect too, such as increasing the water demand.)

The rate of strength growth of concrete or mortar made from Portland cement will depend in large part on the hydraulic reactivity of the cement. The overall hydraulic reactivity of the cement may be divided into two components: the cement itself (i.e.: the proportions and intrinsic reactivity of the clinker minerals) and the fineness of the cement. The intrinsic reactivity of the clinker minerals in Portland cement depends on kiln conditions and clinker composition. The overall reactivity will depend on both the intrinsic reactivity and how finely the clinker is ground in the cement mill.

Expanding this further, the rate of strength growth will be affected by both the intrinsic reactivity of the main strength-producing clinker phases, alite and belite, and also by the proportions of minor phases that affect the alkalinity of the pore fluid, principally alkali sulfates. An increase in pore fluid alkalinity will promote faster reaction of the alite and belite; finer grinding will increase the proportion of clinker alkali sulfate released from pores in the clinker particles into the pore fluid.

The rate at which the aluminate phase reacts is also important, as this affects how quickly sulfate ions are incorporated into solid phases such as ettringite, with a resulting increase in pore fluid alkalinity due to the formation of hydroxyl ions. Again, finer grinding will expose more aluminate phase to the pore fluid and increase the total rate of aluminate reaction. Cement fineness is typically expressed as a surface area, eg: 400m²/kg. However, an assessment of the particle size distribution (psd) of the cement is often more informative than the single surface area number.

As well as affecting the rate of early strength growth, cement fineness may influence the ultimate strength. Coarse cement grains may never react fully, even at high water-cement ratios, because a dense surface layer of hydration product forms that prevents the clinker minerals reacting with water.

Cumulative frequency diagram of particle size of two cements: the proportion of fines below ~7µm is similar but the cement represented by the blue line has a higher proportion of coarser particles.
10 Milling: false set and water addition

Description

A false set occurs in cement when sulfate salts crystallize and connect the cement particles together. This results in the concrete or mortar becoming stiffer, and in more severe cases, the mix may become a solid mass in less than a minute.

Cause

The cause of false set is typically an excess of hemihydrate (calcium sulfate hemihydrate, CaSO$_4$·½H$_2$O, also known as plaster of Paris) or soluble anhydrite (gamma anhydrite). Gamma anhydrite is almost pure calcium sulfate (CaSO$_4$) but contains a little residual water.

“Gypsum” added to cement at the mill to control set is typically a mixture of gypsum and natural anhydrite (beta anhydrite). Natural anhydrite is less reactive than gypsum and supplies sulfate to the hydrating cement at a slower rate.

However, gypsum is often dehydrated in the cement mill, and some, or most, of it converted to hemihydrate by the heat in the mill. If the mill temperature is sufficiently high, further dehydration to gamma anhydrite may occur.

When water is added, hemihydrate quickly rehydrates to form gypsum and it is generally the formation of these gypsum crystals that produce a false set in concrete.

Gamma anhydrite can also cause false set. Although it is less reactive as large crystals, when ground to cement fineness it too can rehydrate rapidly to form gypsum. The production of gamma anhydrite from gypsum requires a temperature of about 250 °C or more, much higher than a normal mill temperature, (~105 °C-115 °C). However, the transient temperature as the steel grinding media crash together is likely to be higher, instantaneously raising the temperature of the gypsum sufficiently to cause dehydration.

In cements high in soluble potassium sulphate, false set can also be caused by syngenite formation. Syngenite is potassium calcium sulfate hydrate (K$_2$Ca(SO$_4$)$_2$·H$_2$O).

When false set occurs, workability can usually be restored by continued mixing. It is generally thought that subsequent strengths will not be affected. However, that may not always be the case; in some instances it may be that false set, even when mixed through, can result in lower strengths. Speculatively, this may be because the paste microstructure has developed differently from normal due to the rapid formation of gypsum.

Concrete is generally produced to a fixed slump and where false-set occurs, especially if the mix has only a slight tendency to false set that may not be recognised, the addition of more water to the mix to restore workability will result in a loss of concrete strength.
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AND
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