Hot and Cold Weather Concreting

Weather conditions may greatly affect concrete quality. In this report the effect of cold and hot weather on concrete is discussed. Precautions, materials and tools that may eliminate the negative effects of weather are explained.

As an engineer who has worked in Kurdistan region, Iraq and abroad for many years I have encountered the problems arising from weather conditions; noting that Kurdistan in particular has cold winters and hot summers, this discussion becomes of great importance. I hope the material that I have collected here would be of great use for our engineers and construction practitioners.

What is Hot Weather?

Hot weather may be defined as any period of high temperature in which special precautions need to be taken to ensure proper handling, placing, finishing and curing of concrete. Hot weather problems are most frequently encountered in the summer, but the associated climatic factors of high winds and dry

air can occur at any time, especially in arid or tropical climates. Hot weather conditions can produce a rapid rater of evaporation of moisture from the surface of the concrete, and accelerated setting time, among other problems.1 Generally high relative humidity tends to reduce the effects of high temperature.

Why Consider Hot Weather?

It is important that hot weather be taken into account when planning concrete projects because of the potential effects on fresh and recently placed concrete. High temperatures alone cause increased water demand, which in turn will raise the water-cement ratio and yield lower potential strength. Higher temperatures tend to accelerate slump loss and can cause loss of entrained air. Temperature also has a major effect on the setting time of concrete; concrete placed under high temperatures will set quicker and can therefore require more rapid finishing. Concrete that is cured at high temperatures early will not be as strong at 28 days as the same concrete cured at more moderate (70°F) temperatures.

High temperatures, high wind velocity, and low relative humidity can affect fresh concrete in tow important ways; the high rate of evaporation may induce early plastic shrinkage or drying shrinkage cracking, and the evaporation rate can remove surface water necessary for hydration unless proper curing methods are employed. Thermal cracking may result from rapid drops in the temperature of the concrete, such as when concrete slabs or walls are placed on a hot day followed by a cool night. High temperature also accelerates cement hydration and contributes to the potential for cracking in massive concrete structures.

How to Concrete in Hot Weather

The key to successful hot weather concreting is (1) recognition of the factors that affect concrete and (2) planning to minimize their effects. Use proven, local recommendations for adjusting concrete proportions, such as use of water reducing, set retarding admixtures. Perhaps a moderate heat of hydration cement (ASTM Type II – moderate heat)2 or pozzolanic admixture (fly ash) can reduce the effects of high temperatures.

Advance timing and scheduling to avoid delays in delivery, placing and finishing is a must; trucks should be able to discharge immediately and adequate personnel should be available to place and handle the concrete. When possible, deliveries should be scheduled to avoid the hottest part of the day.

In the case of extreme temperature conditions or with mass concrete, the concrete temperature can be lowered by using chilled water or ice as part of the mixing water.3

Other measures such as sprinkling and shading the aggregate prior to mixing can be used to help lower the temperature of the concrete. If low humidity and high winds are predicted, then windbreaks, sunscreens or mist fogging may be needed to avoid plastic shrinkage cracking in slabs.

Follow These Rules for Hot Weather Concrete

Concrete mixture designs may include: set retarders and water reducers,4 the lowest practical cement factor. Modify mixtures as appropriate – retarders, moderate heat of hydration cement,2 Pozzolanic admixtures or other proven local solutions.5 Adequate manpower to quickly place, finish and cure the concrete.

Limit the addition of water at the job site – add water only on arrival at the job site to adjust the slump. Later additions should be avoided; in no instance should they exceed 2 or 2 ½ gallons per cubic yard. Never add water to concrete that is more than 1 ½ hours old.

Slabs on grade should not be placed on polyethylene sheeting – if a vapor barrier is required, then a bed of damp sand should be placed over it.

Finish as soon as the sheen has left the surface, start curing as soon as finishing is completed. Continue curing for at least 3 days: cover to prevent evaporation or use a liquid membrane curing compound, or cure slabs with water. (See pages 21-22). The addition of white pigment to membrane curing compounds will help by reflecting heat away from the concrete surface.

Moisten the subgrade, forms and reinforcement prior to placement. However, avoid standing water.

Protect field test cylinders by shading and preventing evaporation. Field curing boxes with ice or refrigeration may be used to ensure required 60°– 80°F for cylinders.

Do not use accelerators!

References

ACI 305, “Hot Weather Concreting,” ACI Manual of Concrete Practice, Part 2. American Concrete Institute, P.O. Box 19150, Detroit, Michigan 48219.

ASTM C 150, “Standard Specification for Portland Cement,” American Society for Testing Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

“Cooling Ready Mixed Concrete,” NRMCA Publication No. 106.

ASTM C 494, “Chemical Admixtures for Concrete.”

ASTM C 618, “Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete.”

ASTM C 31, “Making and Curing Concrete Test Specimens in the Field.”

Hot Weather Concreting

Things to Consider about Hot Weather Concreting

When the temperature of freshly mixed concrete approaches approximately 25°C (77°F) adverse site conditions can impact the quality of concrete. Ambient temperatures above 32°C (90°F) and the lack of a protected environment for concrete placement and finishing (enclosed building) can contribute to difficulty in producing quality concrete.

The use of liquid nitrogen is one option to reduce concrete's temperature during hot-weather concreting. The precautions required to ensure a quality end product will vary depending on the actual conditions during concrete placement and the specific application for which the concrete will be used. In general, if the temperature at the time of concrete placement will exceed 25°C (77°F) a plan should be developed to negate the effects of high temperatures.

The precautions may include some or all of the following:

Moisten subgrade, steel reinforcement, and form work prior to concrete placement.

Erect temporary wind breaks to limit wind velocities and sunshades to reduce concrete surface temperatures.

Cool aggregates and mixing water added to the concrete mixture to reduce its initial temperature. The effect of hot cement on concrete temperature is only minimal.

Use a concrete consistency that allows rapid placement and consolidation.

Protect the concrete surface during placement with plastic sheeting or evaporation retarders to maintain the initial moisture in the concrete mixture.

Provide sufficient labor to minimize the time required to place and finish the concrete, as hot weather conditions substantially shorted the times to initial and final set.

Consider fogging the area above the concrete placement to raise the relative humidity and satisfy moisture demand of the ambient air.

Provide appropriate curing methods as soon as possible after the concrete finishing processes have been completed.

In extreme conditions consider adjusting the time of concrete placement to take advantage of cooler temperatures, such as early morning or night time placement.

With proper planning and execution concrete can be successfully placed and finished to produce high quality durable concrete at temperatures of 35°C (95°F) or more.

Setting Time

The effect of high ambient temperatures and high temperature concrete component materials have on the setting time of concrete mixtures is a topic of concern due to the reduced time in which concrete must be placed, consolidated and finished; increased potential for plastic shrinkage cracking, thermal cracking and cold joints; potential strength reduction due to high water demand and high curing temperatures; difficulty in controlling air content; and increased urgency for applying appropriate curing method at an early age.

As a general rule of thumb an increase of 11°C (20°F) will reduce the setting time of a concrete mixture by as much as 50%. As an example a concrete mixture that reaches final set in 3 hours at 16°C (60°F) may reach final set in as little 1 ½ hours at 27°C (80°F). As the concrete temperature increases the setting time is further reduced. The actual temperature of the concrete mixture as delivered is effected by the temperature of the materials used in the mixture, the cementitious content of the mixture, the temperature of the equipment used to batch and transport the concrete, and the ambient temperature and conditions at the project site. Concrete applications may be considered hot weather concrete at temperatures ranging from 25°C to 35°C (77°F to 95°F) depending on the specific application. Precautions should be planned in advance to counter the effects of high temperature well in advance of execution to counter these effects.

Precautions may include use of materials with a good performance history in high temperature conditions, cool concrete materials or concrete mixture, provide concrete consistency and placement equipment and crew for rapid placement, reduce time of transport, schedule placement to limit exposure to atmospheric conditions (night time placement or more favorable weather), plan to limit rapid moisture loss (sun screens, wind screens, misting or fogging), and consider the use of an evaporation retarder. Schedule a preconstruction meeting including all of the participants to discuss the plan to control the effects specific to the project and expected conditions.

Finishing Concrete

Have you ever seen a sidewalk poured with new concrete and watched someone finish the concrete? You probably didn't pay a lot of attention but you noticed someone down on their hands and knees with a trowel moving around the concrete surface. Like everything else that is done by someone with experience, it looked easy. Guess what ? **It's not that easy unless you have done some homework .**
So consider this your first lesson. If you haven't done this before or only done it a few times you are likely to make two mistakes ;troweling too soon and troweling too much.

Both of these have the effect of pulling fines and water to the surface. This can lead to a weakened surface, tiny cracks and a white dusty surface. After thoroughly mixing the concrete pour it into the forms slightly overfilling them. Then take a straight board (a ٢x٤ piece of lumber works great as long as it isn't bowed) and simply level off the concrete. Using a board that is longer than your pour is wide and using a sawing motion work back and forth until the concrete is level. You really need someone on the other side to help with this part. This is called" screeding "if you are trying to learn new words with which to impress your friends. Then with a wooden trowel or magnesium float if you want to get fancy, smooth off the surface. This should only take a few minutes. Do not try to turn this into a masterpiece-leave that for art class. This step is simply to put a relatively smooth surface on the concrete. When you are done, go clean your mixer and tools and get something to drink. Keep an eye on the concrete. The first thing you will notice is that some bleed water will come to the surface. This is a good thing. Allow all of the water to disappear before you do anything else. This can take ٢٠ minutes or ٤ hours depending on the temperature, humidity and how hard the wind is blowing .
After the bleed water is all gone you can get out your steel finishing trowel and put on the final touches. You will notice the steel trowel is not perfectly flat. That is done so that when you trowel you will be more prone to lift the leading edge slightly avoiding digging into the concrete .
Even by following my outstanding instructions it is doubtful that your surface will look a pro did it. As I said in the beginning, using a trowel isn't all that easy. However, most of us are good with a broom. If your mother brought you up right, you've had lots of practice. Once you are finished with the trowel, simply take a soft broom and gently drag it across the surface. Always pull the broom (never push) and always go in the same direction. Just one pass should do the trick. I personally prefer a broom finish because it makes the surface slightly rougher. This is very helpful for those occasions when your sidewalk is wet. A hard troweled surface is very slick. Unless your brother-in-law is a really good lawyer, you don't want someone take a tumble on your property. Besides this way everyone will think you really knew what you doing and you won't have to tell them about the broom trick .
Don't stop reading yet or you will miss one very important point. You need to "cure" the concrete. If the concrete isn't kept moist for a few days it may crack. The problem is that the surface will dry out while the bottom is still wet causing tension which basically tears the concrete apart. There are several ways to cure concrete. The easiest is to simply spray it very lightly with a hose. You can cover it with a wet cloth such as burlap (don't let the burlap dry out). Or you can use chemical curing agents such as Sakrete Cure `N Seal. The question of how long to do this and how often is a tough one because it depends on temperature, humidity and air flow. The hotter and dryer and windier it is the more you will have to re apply water.

Placing Concrete in hot or cold weather

People who pour concrete for a living can work almost year round in most parts of the country. This is because either through trial and error or spending time reading a lot of technical journals they have figured out how to successfully place concrete even though it is sweltering hot or freezing cold. For almost everyone else I would recommend that you limit your concrete activities to more moderate weather. If it's so hot out that all you can think about is going for a swim I would suggest you get a cold beverage, turn up the AC and forget the concrete. If it's so cold that you need gloves, consider spending time in front of the fireplace with a good book.

If this doesn't quite give you specific enough guidelines, maybe we should define what moderate temperatures are? This is open for debate and involves other factors but in general if the air temperature is between ٥٠° F and ٩٠° F you should be safe. You can safely place concrete outside of these limits but you need to do a few things to make sure your job won't turn into a nightmare.

The air temperature by itself isn't the determining factor on whether you should pour concrete. The temperature of the air, the humidity level, and the wind speed, the temperatures of the surface where you are placing the concrete, the water and the dry concrete in the bag all play a huge part and must be taken into consideration. The air, wind and humidity are pretty much beyond your control but some of the others you can influence. It is important to remember that the temperature of the mixed material is as important as the air temperature.

Cold Weather

If the air temperature is below ٣٢° F I would really advise that you wait until warmer weather or call a pro. Unless you want to erect a tent with a space heater or steal your spouse's electric blanket off the bed, this will only lead to trouble. If it is so cold out that the ground is frozen don't pour concrete under any circumstances. The biggest issue when pouring concrete when the air temperature is just above freezing is the night time temperatures that will follow. Concrete sets much slower in cold weather. It is critical (I'm going to repeat that- critical) that the concrete sets before it is exposed to freezing temperatures. The problem is that when water freezes it takes up more space in the ice phase than it does in the liquid phase. When all of the water that you used for mixing freezes, it expands, causing your concrete to crack. The key is doing what you can to make sure the concrete sets fast enough to prevent this.

The first thing that pros do in the winter is use hot water. If you use hot water and keep the dry product in a heated area of your house or garage until you are ready to use it this will greatly accelerate the set of the concrete. You can buy products designed to set quick such as Sakrete Fast Setting Concrete. It will not set as fast as the literature says it will if the air temp is anywhere near freezing but it will set much faster than normal concrete. You can also buy additives to accelerate the set. The only concern here is the

type of accelerator. If it contains calcium chloride and your concrete will contain rebar or metal wire mesh, the chlorides will attack it and produce rust. This will ultimately crack your concrete. When concrete sets it gives off heat. Not like frying an egg but there is a slightly exothermic reaction (a big word for a reaction that gives off heat-use it to impress your friends). You can use this to your advantage by covering the concrete (after it has stiffened) with a blanket. They sell blankets for this purpose so your kids won't have to sleep in the cold. You could also put up a tent or lean to and put a space heater inside.

Hot Weather

If the air temperature is above ٩٠° F you need to be careful. Of course what you are doing with the concrete also makes a difference. We will address that later. In addition if the wind is blowing hard and the humidity is low, even ٩٠° might be a problem. The issue with hot weather isn't really the heat. Neither the cement nor the aggregates have a problem with temperature. This isn't like a chocolate bar on the front seat of the car in July. The issue is that the top layer of concrete will dry much faster than the bottom layer. As concrete dries it shrinks. This means that the top will be shrinking while the bottom is stationary. At this point you get your own north/south civil war breaking out inside the slab. There will be casualties.

To avoid this aggression you need to keep the top and the bottom curing at the same rate. There are several things you can do before and during mixing and several things you can do after placement. Before mixing store the material in a cool place or at least avoid laying it in the hot direct sun. Then use the coldest water that you find. Ready mixed concrete companies actual use ice to replace all or most of the water to slow down the set. After you have placed the concrete and it has taken a set, you need to keep the slab moist. This can be done in several ways. You can spray the slab periodically with a hose, turn on a sprinkler with a fine mist, cover the slab with wet burlap or with chemicals designed to keep water from evaporating so quickly. In very high temperatures, very low humidity or high winds you may to do this for several days. Almost everything in this discussion on hot weather is directed at someone pouring a slab. If you are mixing up concrete and placing it in a hole to support a fence post of deck, hot weather normally isn't a problem. If the concrete is setting too fast to place in the hole, then using cold mixing water or ice will help.

Why do concrete slabs crack?

Concrete is one of the most long lasting, economical building materials ever devised by man. When placed properly and in the right application it will last a long, long time. However, (don't you just love it when a "however" follows an opening positive statement) nothing good lasts forever and concrete is no exception. It will crack; it is just

a matter of when. Take a look at the sidewalk, the driveway, even the floor in stores where the concrete is not covered with tile. They have cracks.
Some of those cracks appeared within hours of pouring. Others took many years to develop. So, if we can put a man on the moon why can we make concrete that won't crack?
The answer to this is more complicated than I can deal with in this short blog. I also don't actually know the complete answer so I will just blame it on being too complicated. Seriously I do know some of the causes and even what you can do to avoid them. If you already have cracks, reading this article may be entertaining but it won't help your cracks. This blog is about avoiding cracks. Without further ado, cracks fall into one or more of several categories: ١) plastic shrinkage ٢) settlement ٣) drying shrinkage ٤)chemical ٥) corrosion and ٦) overload. Let's look at these one at a time and see what causes them. By knowing what causes cracks you can help avoid them. Keep in mind this in not a doctoral dissertation so I am going to oversimplify.
١) Plastic shrinkage cracks occur when water evaporates too quickly from the surface. This causes the top of the slab to dry more quickly than the bottom and they pull each apart. This is more likely to happen when it is hot, windy or there is low humidity. To avoid this use proper curing procedures. The key is to keep the surface moist. This can be done by placing wet burlap, mats or towels on the concrete. You can also put your sprinkler on the mist setting and let it run. There are also chemicals that can be applied that retard the water evaporation. The time to begin any of these processes is after the final trowel application and the concrete has stiffened to the point where a wet burlap bag would not leave an impression on the concrete. In very warm weather this may need to be continued for several days. It may seem silly to water new concrete the way you would new grass, but that is exactly what you need to do. Not to complicate things but it is possible on cool, overcast days that you don't need to do any of this.
٢) Settlement cracks occur when the ground under the concrete moves. This can be the result of poorly compacted soil, the wrong kind of soil (sand), water erosion or tree roots. If you have poorly compacted soil, dig it out and replace it with crushed stone before placing the concrete. If you have a situation where water drains across the sidewalk, backfill first with several inches of gravel. If I were a younger man I would go through the neighborhood and plant trees for free as long as they would let me plant them next to the sidewalk. Then when the trees grew and the roots took over I would come by and offer to replace the sidewalk-which would not be for free. If you plan to stay in your home for a while don't plant trees next to the sidewalk.
٣) Drying shrinkage occurs when a slab that is restrained is drying and shrinking. This usually does not occur on free floating slab. It is more of a problem when a slab is tied into another structure like a wall with rebar.
٤) There are two ways that chemical reactions can crack concrete. The first is because the concrete itself contains aggregates or cements that simply are not compatible. This isn't something you should be too concerned about because the manufacturer of the concrete should already know which of these is an issue in your area. The second one is very much under your control. A few years back my church built a beautiful new sanctuary. In front of the church is a large concrete apron that goes out to the street. I told them DO NOT PUT SALT on this slab for a few years. Use sand. So what did they do, they used salt. Guess what. It looks awful. They wanted to blame the contractor. I

told them the church did not have a “prayer” of winning that argument.
٥) Corrosion occurs when concrete that contains steel re-bar or steel wire mesh gets wet and comes in contact with oxygen. The only way this can happen is when small cracks develop in the concrete due to one of the reasons stated above and channel water into the crack. When water reaches the steel it begins to rust. Rust is expansive. As the steel rusts it pushes out and causes even more cracking. The prevention here is to make sure you treat all little cracks before they become big cracks. See my other blogs for fixing cracks.
٦) Concrete is designed to take a certain load. Most sidewalks and residential driveways are designed to take the weight of a car or small truck. If you should decide to back up a loaded tandem axle dump truck or an M-٦٠ tank (for you younger folks that’s what we had when I was in the ١st Armored Division a long time ago) on your driveway, don’t be surprised if it cracks.

It is important to know the way the pros avoid at least some types of cracks. They use control joints. Control joints are basically an acknowledgment that concrete will crack. The control joints can help to eliminate cracks or in a worse case scenario channel where the cracks will appear. Have you ever notice how your sidewalk or driveway has either dividers essentially making several slabs out of one big slab or it has cuts running through it every ٣ or ٤ feet? These are control joints. There is no set pattern for how often you need these. There are a lot of factors involved here. Maybe I will deal with that in a separate blog.

Finally, for those of you who this is too late for and you already have cracked pavement. I would not be doing my duty if I didn’t remind you that Sakrete has a full line of crack filling and concrete repair products that will help make your concrete cracks a problem of the past.

Bonding to Existing Concrete

Fact: ***Fresh wet concrete does not normally bond well to existing dry concrete.*** Do you remember elementary school where one of the subjects on which you were graded was “plays well with others”? Concrete would have gotten an F. There is nothing in basic portland cement that will act as a bonding agent. Portland cement concrete works well in mass and provides great compressive strength but not bond.
Concrete is marvelous stuff but in time it will deteriorate. When it does you either have to patch it or replace it. Assuming that it is structurally sound the least expensive alternative is to patch it. However patching it requires some attention to detail or your patch will not last. So that you don’t waste too much time or money we should probably discuss what “structurally sound” means. If your sidewalk has either heaved or dropped at almost every joint, repairing it will not provide a long term solution. The slabs are likely still moving. If your slab has so much sand and gravel on the surface that despite

sweeping and sweeping and squirting and squirting it just keeps coming back, don't waste your time on repairs. If you have multiple cracks that run so deep that they appear to run through the slab, a repair would only be temporary. The solution to all of these problems involves a jack hammer and bags of one of the Sakrete concretes. Since this discussion is on the best way to bond concrete we will assume that your slab is good.

There are a variety of Sakrete concrete repair products available to fix concrete that has begun to deteriorate. However without good surface preparation, none of them are going to perform satisfactorily. All loose sand, gravel, dirt, leaves etc. must be removed. This can typically be done with a garden hose and a good nozzle. Tough areas may require a pressure washer or mechanical abrasion. The two toughest areas to cover are those with oil and tree sap. Both of these will work their way down into the concrete. Simply washing the surface isn't sufficient. If the stains do not run too deep you can chip away the concrete using a hammer and chisel. Don't forget the goggles (not just glasses) as this process will throw concrete all over the place. Also keep your thumb out of the way. If the spots are too large or too deep for this to be practical you may need a sealer to cover the stains before patching.

There are two basic methods for bonding a portland cement based product to existing concrete; ١) chemically and ٢) mechanically.

Let's discuss the mechanical approach first since it is really used in both approaches. The most effective way to ensure a really good bond is with a scratch coat. This is simply a very wet coat made up by mixing the repair product with water. Mix up a small amount of the repair material to a soupy consistency. You don't need to measure the water-just turn the stuff into slop. Then, using a gloved hand or a rag, smear the material onto the area to be patched. Just think finger painting from kindergarten. The technique is about the same. Apply pressure to ensure that as much as possible is shoved into the nocks and crannies. You only need a thin coat. ***It is not necessary for this scratch coat to dry. By the time you get the repair material mixed it will be ready.*** Then mix up additional repair material to the proper consistency and apply over this thin scratch coat.

The chemical approach involved mixing up a liquid bonding agent that helps bond new concrete products to old. Products like Sakrete Top n Bond and Sakrete Flo-Coat already contain polymers that greatly improve the bond of portland cement and should **NEVER** be used with a liquid bonding agent. I know in America bigger is better but it just ain't so with these products. Other products like Sakrete Sand Mix and Sakrete Fast Set Cement Patcher benefit from the use of a liquid chemical bonding agent such as Sakrete Bonder/Fortifier. When you use a liquid bonding agent, paint the bonder onto the existing concrete and allow it to dry until it is tacky. This usually takes only a few minutes. Then apply the repair material. Just as in the process described above, after the bonder has become tacky apply a scratch coat and then apply the repair material. The most effective way to ensure that the bonding agent gets into the existing concrete is to apply it directly using a brush or rag. It can be sprayed if you happen to have a sprayer. Although the directions say that you can use it as part of the mix water, direct application works better.

If you are doing a large area and a scratch coat isn't practical you will need to spray the surface with water before you apply the repair material. On a warm day the existing concrete surface will be hot enough to suck the water our of the repair material. In addition some concretes are quite porous and will also rob water from your repair material. If too much water is lost into the old concrete there will not be enough water to hydrate all of the cement particles and a lower strength material will be the result.
There are some substances that concrete simply will not bond to. Paint, oil, glue from old flooring tiles are just a few. You must mechanically remove these materials if you want the job to last.
Once the job is complete you can do a quick check to see if the bond was successful. Wait at least ٢٤ hours and then tap "gently" on the patch using a hammer or some other dull object and listen for a hollow echoing sound. If you just get a dull thud then the material has bonded well. If you get a hollow sound, the material has not bonded and will crack in time. Which means it is back to the beginning of today's topic. *Here is hoping your concrete work comes across as a dull thud (not like some of my party guests) rather than a hollow endeavor.*