The Perfect Mix Design

By Alan Sparkman

Is there such a thing as a Perfect Mix Design? If you are looking for one mix design 'recipe' that will work perfectly for every job and every application, the answer is definitely "NO". However, there is a right mix design for every job and every application, and with the right knowledge and good communication between a concrete contractor and his supplier, you can find The Perfect Mix Design for every one of your jobs. Continue >

There are some basic principles to concrete mix design and every contractor should be familiar with them. As you will see, there is a lot to learn about concrete mixes and you certainly won't learn it all in this article. If you want to learn more – and you should! - A great reference book for your library on this subject is 'Design and Control of Concrete Mixtures', published by the Portland Cement Association. Now in its 14th edition, this book is an accepted standard for mix design basics. Another good resource would be to attend Module One – Product Knowledge of the Concrete Sales Professional course from the National Ready Mixed Concrete Association. This is usually a 3-day class (with a test at the end!) but the classroom instruction and the interaction with other concrete professionals make it well worth consideration. (Visit NRMCA.org or trmca.org for schedules) Until you can read the book or attend a class, here are the very basic things you should know about concrete mix designs.

Photo courtesy of Portland Cement Association.

Water-Cement Ratio

The controlling factor for most of the desirable properties of concrete – things like strength, durability, shrinkage potential and permeability – is what's known as the water-cement (w/c) ratio. It really is as simple as it sounds. Just take the weight of water in a cubic yard and divide it by the weight of cement. Durable concrete mixes usually need a w/c ratio of .50 or less (lower is better). So, to translate, that would mean a mix with 500 lbs of cement shouldn't have more than 250 pounds of water or about 30 gallons.

So, one of the first things we have to decide on when designing a mix is the w/c ratio. Mixes with lower w/c ratios produce higher quality concrete and they will usually be better for the finisher in terms of set times, bleeding and other important characteristics, provided the mix also has sufficient workability for easy placement and consolidation. For specification work, this w/c ratio is usually determined by the service requirements or conditions for the concrete placement, and it is the first of many decisions that require the mix designer to balance a myriad of sometimes conflicting needs.

Cement and Other Powders

It is very common for today's mixes to have more than one type of 'powder' included – in addition to Portland cement many mixes will have fly ash (either Type F or Type C) or perhaps slag cement (the technical name for this would be ground granulated blast furnace slag). Some mixes might have all three 'powders'. For purposes of the water/cement ratio you total up all the powders and divide that weight by the weight of water in the mix.

The trend for the future seems to be toward greater use of the other powders. While there are several reasons for this, including better performance, two big reasons are the move toward building materials that are considered 'green' (US Green Building Council) and reduction of costs. The use of other powders gives the mix designer more tools in the quest to formulate mixes that meet varying performance requirements.

Photo courtesy of Portland Cement Association.

Both fly ash and slag produce mixes that are denser and often stronger than plain cement mixes, and mixes utilizing more than one powder are often more finisher-friendly in terms of placement and finishing characteristics. Of course, such mixes behave differently than plain cement mixes and generally have slower set times, especially in cold weather. Once again, the mix designer has to balance these factors as he or she moves through the mix design process.

Another trend that seems to be emerging is a move back to mixes with higher cementitious contents. There was a period of time when 'performance mix design' meant the cheapest possible mix that would meet the strength requirements for the job, often at the expense of other important mix characteristics such as durability or ease of placement. These lean mixes are rarely a bargain for anyone, so don't be talked into saving a few cents and then having to deal with a mix that won't perform well for you or for the owner. In many cases the best performance enhancer you can build into a mix is to add some more powder. And remember, when you add some more powder you can also add additional water without compromising the w/c ratio so this will often lead to a more workable mix that is easier to place and finish.

Aggregates

Another major factor that influences mixes is the type and amount of aggregate - sand and stone - that are included in the mix. The guiding principle of mix design is to pack as much aggregate into the mix as possible to make the mixes economical and to reduce the required paste volume (Paste is defined as the cement and other powders plus the water). The less paste (within reason) that a mix has, the less shrinkage potential it has (shrinkage is what causes most cracks in concrete) and the lower its overall cost.

Another aggregate principle is to use the largest possible coarse aggregate size – this also reduces the required paste volume and helps reduce shrinkage potential. As we have already noted, this principle of using the biggest and the most aggregate possible must be balanced against several other factors, but it is a ‘bedrock’ principle of mix design nonetheless.

Aggregates make up about 75% of the weight of a cubic yard of concrete, accounting for around 3000 lbs in every yard of normal weight concrete. Because aggregates make up so much of the mix, they obviously have a major influence on all the properties of the concrete so it is important to pay close attention to the aggregates that go into any mix design. The two most important characteristics of aggregate are particle shape and gradation.

Depending on what area of the country you work in you may find that concrete mixes are primarily made from gravel with a naturally rounded particle shape or from a rock (like limestone or granite) that is mined and crushed, producing more angular particles. The same is true for the type of sand that will be used – sands can be either natural (pit or river sand) or manufactured from crushing mined rock such as limestone down to a sand size.

Gravel and natural sand make the most user-friendly mixes and generally have the lowest water demand. The rounded particle shape helps these mixes flow and move easier at a given w/c ratio and they are usually finisher-friendly and pump friendly. At the other end of the spectrum would be crushed stone and manufactured sand. Good quality concrete can be made with these materials, but they present a more difficult challenge for the mix designer in terms of making a mix that has a reasonable w/c ratio along with decent workability.

Photo courtesy of Portland Cement Association.

Especially important for mix workability is how the various size pieces of aggregate in both rock and sand are distributed. A well-graded aggregate will have a well-distributed range of particle sizes from large to small without having an overabundance of any one particle size. Well-graded aggregates usually have lower water demands and produce more workable mixes than aggregates that are more gap-graded. Gap-graded aggregates may have lots of one size particle and very few of another and this usually leads to mixes that are difficult to place and finish even if a lot of water is added.

Sometimes mix design problems are best solved by changing the aggregates in the mix, by modifying the ratio of coarse aggregate to fine aggregate used in the mix, or by changing the size of the coarse aggregate used in the mix. Local supply conditions and availability will determine how far you can go with these kinds of changes, but sometimes small changes can yield big results.

Admixtures

Admixtures are often the mix designer's best friend and they allow modern mix designs to be tailored to meet a large number of exacting performance demands while still maintaining high quality concrete. There are lots of different admixtures, but they generally fall into four categories:

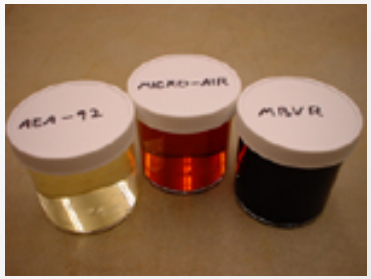

Photo courtesy of Portland Cement Association.

Air-Entrainment – these materials intentionally cause the formation of literally billions of microscopic bubbles in a cubic yard of concrete. Air entrainment is essential to produce long-lasting concrete in climates where concrete will be subjected to freeze-thaw cycles while in service. The air bubbles act as tiny pressure relief chambers when the water inside a piece of concrete freezes and expands by giving the expanding water someplace to go. A good target for the amount of air needed in a yard of concrete would be somewhere between 4% and 8% air by volume. Air entrainment is always specified as a range, not as a single number because many factors affect the amount of air that can be entrained in concrete (sort of like all those other factors that affect mix performance).

Its important to know that air-entrained concrete behaves differently than non-air-entrained concrete, especially with regard to bleeding (its reduced), segregation (also reduced) and the timing of finishing operations. Air-entrainment usually reduces the amount of water needed to provide a given level of workability because all those air bubbles act like miniature ball-bearings and allow the concrete to move more easily. Since air-entrained concrete bleeds more slowly, it is much easier to trap bleed water in the fresh concrete by performing finishing operations too soon – this will always lead to surface problems for the concrete later on. Also, higher air contents tend to make the concrete ‘sticky’ and hard to finish. Most finishers begin to notice this when the air content gets above 5% or 6%.

Water-Reducers – these chemicals act to reduce the amount of water needed to produce a given slump. They come in several varieties, from low-range to mid-range to high-range water reducers (often called supers or superplasticizers). Of all the admixtures available, water-reducers probably offer the most benefits to everyone involved in the mix design process. They allow engineers to get the strength they want, finishers to get the slump and/or workability they need, and owners to get high-quality concrete with a low w/c ratio. The key fact to remember is that water-reducers are the best way to alter slump and workability because they can do this job without requiring more water that will produce all those adverse effects we have mentioned. Best of all, most water-reducers are economical to use. When you need workability and ease of placement, use of the appropriate water-reducer will often be the solution you are searching for.

Set-Accelerators – these chemicals speed up the chemical reaction of concrete and decrease the time required for concrete to reach initial set while speeding up the rate at which the concrete will gain strength. The most common application for these materials is for use in colder temperatures, but they can be used to advantage in other situations. Many accelerators are based on calcium chloride, but there are non-chloride accelerators available for jobs with limits on the calcium chloride (common in most reinforced concrete jobs).

Photo courtesy of Portland Cement Association.

Set-Retarders – these chemicals slow down, or even stop the hydration process. For hot-weather, long hauls, or jobs that require slow unloading they can maintain both the quality of the concrete and provide the necessary time for finishers to complete their work. Most retarders also provide water-reduction as well.

Many finishers resist the use of admixtures (or powders other than cement) because they fear the changes they might cause in the behavior of the concrete. While this is a valid concern, it is often carried to irrational extremes. With all of the factors that affect the way concrete behaves on a certain day it is simply not wise to ignore these tools that can help turn the tables back in your favor when it comes to controlling concrete's behavior. Used wisely, admixtures can solve many of the challenges you face each day and make your life much easier. Don't ignore these modern-day problem solvers on your next job!

Other Stuff You Might Want in Your Mix

These list would include fibers (a personal favorite for nearly any slab on grade application), integral colors, or some special purpose admixtures such as corrosion-inhibitors, viscosity-modifiers, internal vapor retarders and more. If you are not sure about what's available, discuss your particular situation with your ready mix partner. Today's concrete can be engineered to meet almost any requirement, no matter how far-out you might think it is. Again, the key is to communicate your needs to your supplier so they can help you design a solution tailored to your situation.

Final Thoughts

All the materials in a mix contribute to the properties that you deal with in the field. Set times, bleed rates, pumpability, workability, slump and ease of finishing are all pretty much determined at the ready mix plant. By understanding how the components in the mix interact you should be better equipped to diagnose problems with your mixes and to communicate with your ready mix supplier about what you need. A good ready mix producer will welcome your feedback and work diligently to meet your needs. If your supplier doesn't fit this description, it might be time to shop around.

You should know the basics about mixes, but it is probably best to leave the math and the exact proportions to your ready mix producer partner. Concentrate on communicating what you need the mix to do and let the ready mix producer suggest the most viable alternatives. You may be pleasantly surprised at what can be done to customize the concrete on your next job to your specific needs.

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The Concrete Sherpa is a team of people that represent the experience, teaching and learning of our team members and other industry leaders *on a mission to make life better for the concrete contractor*. We are an idea center striving to deliver thought provoking ideas based on “Concrete Advice for Business and Life” to stimulate you to reach new heights. As a user, you should remember to consider all information you receive, here at the Concrete Sherpa or elsewhere, not as a *cast in concrete* recommendation, but rather as an idea for you to consider and ponder.

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THE JOURNEY LEADING TO THE CONCRETE SHERPA PROJECT

The Concrete Sherpa Project (A Sherpa is a “guide”) was born at The Concrete Network in mid 2004. Here is how it happened:

The biggest surprise, or gift, since starting The Concrete Network in 1999 has been the concrete contractor friends from around the country we’ve made and witnessing the passion they have for what they do. These people include Dave Pettigrew, up in the San Francisco Bay Area, or the Verlennich brothers in Minnesota, or Bob Harris in Georgia, the list goes on and on. It’s quite inspiring.

We were once asked, “How are you so excited every day about concrete?” Well the answer is simple, it is impossible to not be excited about concrete when you have the job we do- interacting with hundreds of concrete contractors from every state in the country.

The thing we’ve learned about concrete contractors is that most are passionate *craftsmen*- they are often less passionate and experienced in the “office stuff”. Human nature channels us to do what we are most comfortable with; learning how to use a new saw-cutting tool is comfortable; learning and implementing a new estimating strategy, or job management tool, is not so comfortable.

Sherpa info

THE JOURNEY CONTINUES…

So Sherpa was born to provide FREE and easy to use information on topics many contractors are not too comfortable with.

- Concrete Sherpa is here to provide help to contractors who are often ‘Lone Rangers’ and don’t have anyone to get solid business advice from.
- Concrete Sherpa is here to provide help for contractors who have to work too hard and too many hours in their business, and one day realize they need to work *on their business, not in their business.*
- Have fun with Concrete Sherpa and go faster towards reaching success than you might have on your own.
- To skeptics who think something free can’t be valuable, or there must be a trick- visit Concrete Sherpa and decide for yourself.

We hope you make great use of the Concrete Sherpa and it helps you to become an awesome success for yourself, your family, your church, and your community.

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