

## QUALITY CONCRETE IN CONSTRUCTION OF DRY KILNS

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Last fall Mr. Kozlik called and asked me to prepare a talk for this meeting, and mentioned he had heard me speak before this same group some twenty years ago! As I recall, I didn't particularly enjoy that assignment. There is little satisfaction in telling people they are doing something wrong. I had visited some seventeen dry kilns in Oregon in various stages of disintegration, some only a few years old. In all cases the mode of failure was the same--steel corrosion.

Steel rusts; as it does it begins to lose strength, but more importantly, the rust occupies a much greater volume than the iron from which it came and this rust exerts expansion pressures exceeding the ability of even the strongest concrete to resist. The result is a cracking along the reinforcing steel, and if corrosion continues, concrete will spall away. Disintegration is progressive. If corrosion is not stopped and satisfactory repairs made, the disintegration will continue to collapse.

At that time, as I remember, I recommended the old standby in our industry--the rule of six, six sacks of cement, six gallons of water, six percent air, and six days cure. I further recommended a minimum of two inches cover over the steel. I also said that since the problem is associated with timber liquors and moisture penetrating the concrete cover and attacking the steel, there would be a definite advantage to consideration of precast, pre-stressed concrete roof panels as the prestressing of the concrete would tend to make it more moisture proof and close the shrinkage cracks. I was certain the precast concrete industry could and would have better quality control than the construction I had witnessed.

Then, I closed with some brash words to the effect that "you were abusing my beloved concrete by poor construction practices and if you did not choose to follow my advice the concrete would continue to have early failure, in which case I'd prefer you use some other material--such as wood or steel, and don't call me! However, if you would follow my advice I was certain of longer life for kilns so constructed."

Mr. Kozlik must have recalled those brash words for he said, "You laid it on the line; however over the past twenty years some of us have forgotten and we need to be reminded as we are having problems with our concrete kilns again."

Well, I'm flattered that anything I've said could be remembered a few days or weeks that would be great--but twenty years! So, I agreed to arrange to be in Reno for your meeting. I do thank you for the privilege of this platform, however it still is not too pleasant a task to stand here and tell you again we are not farming as well as we know how to farm! Concrete is a simple material with simple rules for successful use that should not be ignored.

Knowing this presentation was scheduled, I have spent some time selecting bits and pieces of reference material and have talked with some consulting engineers to your industry, asking the current state of the art and it appears the basic problem remains, steel rusts. The rule of six and cover will go a long way toward protecting the steel. However, let's dig a little deeper and see what we can do to improve kiln construction--20 years later.

There are four areas I want to touch on that I think will be of use:

1. Design. All too often it appears too little thought is given to the design of mill structures. It is as if it is only a cover to protect the equipment from the elements and can be cobbled together by anyone. Concrete kilns likewise seem to happen as a cover for engineered drying systems and perhaps retain or store some heat. Concrete has no problems with the temperature, while tests do indicate some reduction in strength at temperatures in the 500°F range. The much lower kiln temperatures give us no concern. However, the designer must recognize the thermal factors and know that concrete expands with heat. Concrete wants to expand about two thirds of an inch each 100 feet of length for each 100°F of temperature increase. Some kilns have not been designed to accommodate this movement as the temperature rises and falls. Consultation with your structural engineer should include a discussion of temperature ranges and cycles so that the structure can be designed to permit these movements or reinforced to accept the resultant stress.
2. Protect the steel. Good concrete ordinarily provides the ideal environment for reinforcing steel. Concrete's high alkalinity causes a thin, invisible, protective oxide film to form on the steel. The low permeability of good concrete minimizes penetration of water and air; for this reason reinforcing steel does not corrode at all in most concrete structures. At least two inches of cover of all steel is needed. Concrete cover of 2.5 inches is better. I say all steel as I'm reminded of one installation with two inches of cover provided by placing 2" metal chairs on the plywood forms, concrete cast, forms removed, and almost immediately rust formed on the metal chairs; this was the point of attack and start of disintegration. Masonry cubes should be used to chair the steel reinforcement off the forms.

One new item which should be considered is the use of fusion bonded epoxy coated rebars. Some state highway departments have been specifying these bars to prevent salt attack to the rebars in bridge decks. The National Bureau of Standards found that such coatings should be 0.005 to 0.009 inch thick for adequate protection against chloride attack and adequate flexibility during bending. Since the mode of failure for chloride attack to bridge members is similar to that of kilns, similar protection could be expected.

3. Improve Concrete. Here there is a temptation for a glib statement--that concrete needs no improvement; there is some honesty in such a statement as the concrete is not, in most cases, in difficulty, it's the steel in the concrete. What is needed is an improvement in the impermeability of the concrete.

Unfortunately, it is impossible to define impermeability in concrete in precise terms. Concrete has a pore structure and is different to metals. It is not vapor tight and water under pressure will pass slowly through it. The rate of flow through dense high quality concrete is extremely slow.

There is some indication that in addition to air entrainment other admixtures such as pozzolans and flyash added to the mixture may improve the placability of the concrete and also combine with the free lime in the mixture to make the resultant concrete more impermeable.

The rule of six is a minimum--six sacks or 570 pounds of cement per cubic yard; six gallons of water per sack or 36 gallons maximum water per cubic yard; six percent entrained air; and six days of moist curing before use in most locations would give a good grade of concrete.

4. Construction Practices. After the connection details have been carefully designed and the steel protected by epoxy coating or impermeable concrete, it appears that lack of ability to communicate these concerns to the construction crew can cause failures. I'm reminded of the steel chairs as a point of corrosion attack, of precast panels joined by weld plates exposed to attack, of rock pockets in the concrete due to improper mix design or poor vibration techniques, of over watered concrete to ease construction and also increase volume changes and thus a shrinkage crack (or natural joint) and another chance for the start of corrosion.

However, we can farm better than we have been. There are installations that have been properly designed and constructed that have provided a long and economical life. So remember the rule of six and give the steel adequate cover and just maybe I won't be invited to speak to you again in 20 years.