# Strength Development in Fiber Enhanced Shells With and Without Polymer as a Function of Dry Time

Tom Branscomb, Director of Technology
Buntrock Industries, Inc.

## Abstract

Fiber enhanced slurries are successful in building shells with fewer dips because thicker individual dip layers are applied. Because of this, drying of these shells could be different than what is required for standard slurries.

The effect of dry time on Green and Hot/Wet shell strength was studied for Buntrock Industries fiber enhanced BI2010C fused silica slurries with and without polymer. Buntrock Industries TMM27 colloidal silica was used as the binder. Inter-dip dry times were 3,5, and 8 hours with final dry of 6,12, and 24 hours. All drying was performed at 40% R.H. with a fan.

The data show, that in this system, polymer increases Green MOR, but has a negative effect on Hot/Wet MOR. Green strength is relatively insensitive to inter dip dry time and somewhat sensitive to final dry time. Final drying in zero humidity significantly improves green strength.

## Introduction:

With more and more interest in organic fiber enhanced slurries, it is important to look at some of the process variables to see if they have more or less impact on these new slurries. One of the big advantages of a fiber enhanced slurry is that it deposits more slurry per dip and thus for a fixed number of dips, the fiber enhanced slurry will have greater thickness. Because of this greater thickness per dip, it is reasonable to assume that it may take longer to dry each dip. This paper investigates the time necessary to dry the Buntrock fiber enhanced slurry with and without polymer. Green (room temperature) and Hot/Wet (boiling water) MOR are used as a measure of dryness.

It was decided to use 40% Relative Humidity during drying because this is about average for the industry. Some shops are a little higher and some are lower. The dry time between backup dips was either 3,5,or 8 hours. Again, this is typical of the dry times used in the industry. Final dry was 6, 12, and 24 hours. A duplicate of the 8 hr / 12 hr dry sample was given an additional drying of 24 hrs. in a desiccator at 0% R.H. This perfectly dry sample was used to normalize all the MOR information for easy viewing. Absolute numbers in this case are not important. The relative numbers tell the story nicely.

It should be stated that these results might not represent what happens in other suppliers' fiber slurry, other polymer, or other binders. For example, we have some customers using straight Megasol binder with BI2010C and the results are very different.

## Experimental Procedure:

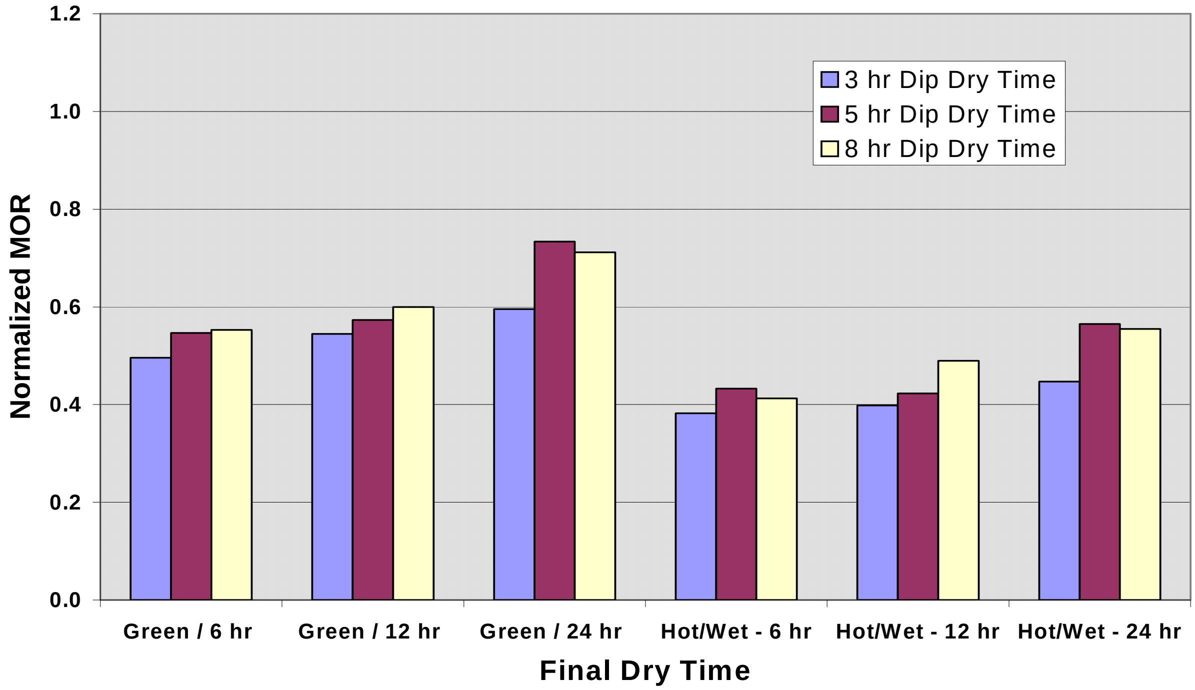
A prime dip consisting of Buntrock Industries TMM30 binder, QDA polymer, with zircon and fused silica flour was used as the first dip for all samples to be made. The backup slurry was made using TMM30 binder diluted to 27% $SiO_2$ and BI2010C flour. A second slurry was made exactly the same but with Dow460 Latex at a level of 10% of the colloidal silica binder. Viscosity on both backup dips was held at 12-13 seconds using the Buntrock Brass Cup. All second dips were stuccoed with 50x100 Fused Silica sand while backup dips were stuccoed with 30x50 Fused Silica Sand. All dip sequences were the same: 1 prime, 1 intermediate, 3 backups, and Seal dip. First and second dip stucco was applied by hand and backup stucco was applied by fluid bed. Drying was done in a controlled room at 40% RH, and 70 deg. F. Air movement was from an oscillating fan with 400 fpm peak velocity on the test strips. All dipping was done on an exact schedule according to the desired dry times.

At the end of the final dry, the samples were ground, removed from the wax strips, and tested immediately. Both Green and Hot/Wet MOR were tested.

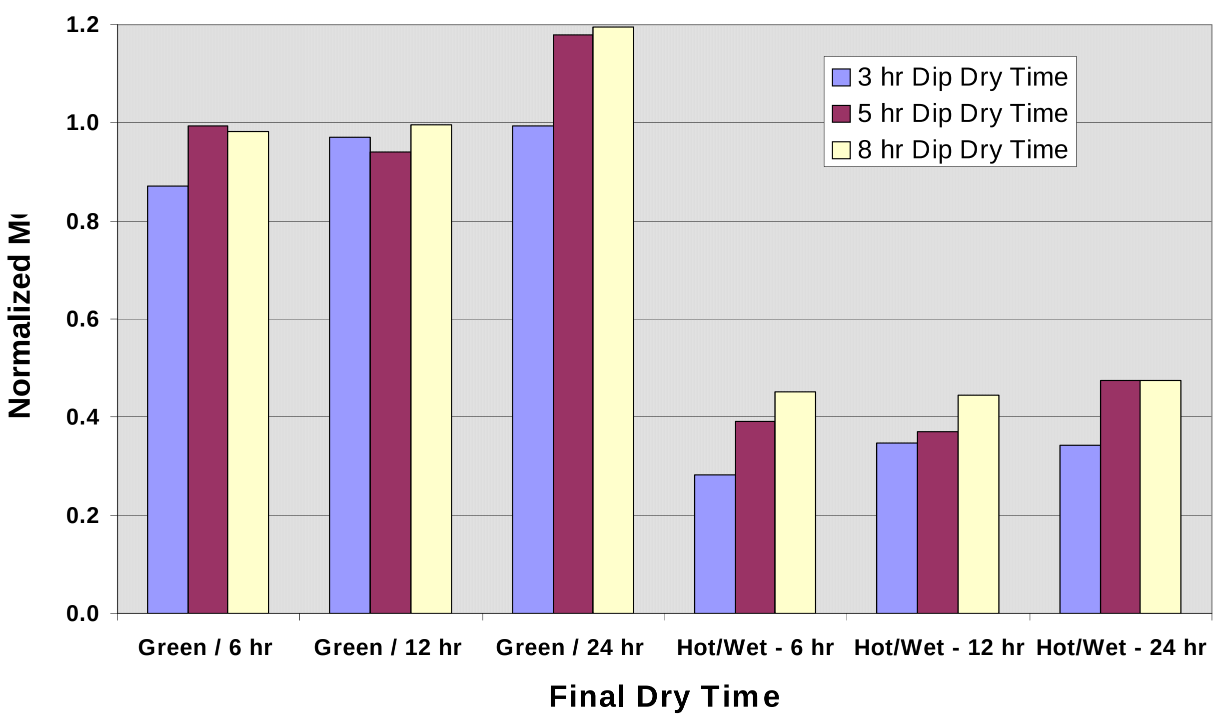
## Results:

The graphs below are plots of the Normalized Green and Hot/Wet MOR's at the indicated interdip and final dry time. The first graph is for backup not containing polymer and that for polymer second. As expected, Green MOR increases somewhat with increasing interdip dry time and final dry. This is true for both polymer and non-polymer slurries. Some improvement is seen in Green MOR in increasing from 3 to 5 hours interdip dry time. Not much increase in Green MOR is seen by increasing interdip dry time past 5 hours. Thorough drying between dips and a 24 hour final dry results in only about 75% of the desiccator dried sample Green MOR value. Roughly the same pattern is seen for the slurry containing polymer, with the exception that the Green MOR is at a higher level and the Hot/Wet MOR for the polymer slurry is slightly below that for a non-polymer fiber enhanced slurry. At first glance, it appears that adding polymer may be a good thing in that Green MOR is up and Hot/Wet MOR is only slightly lower.

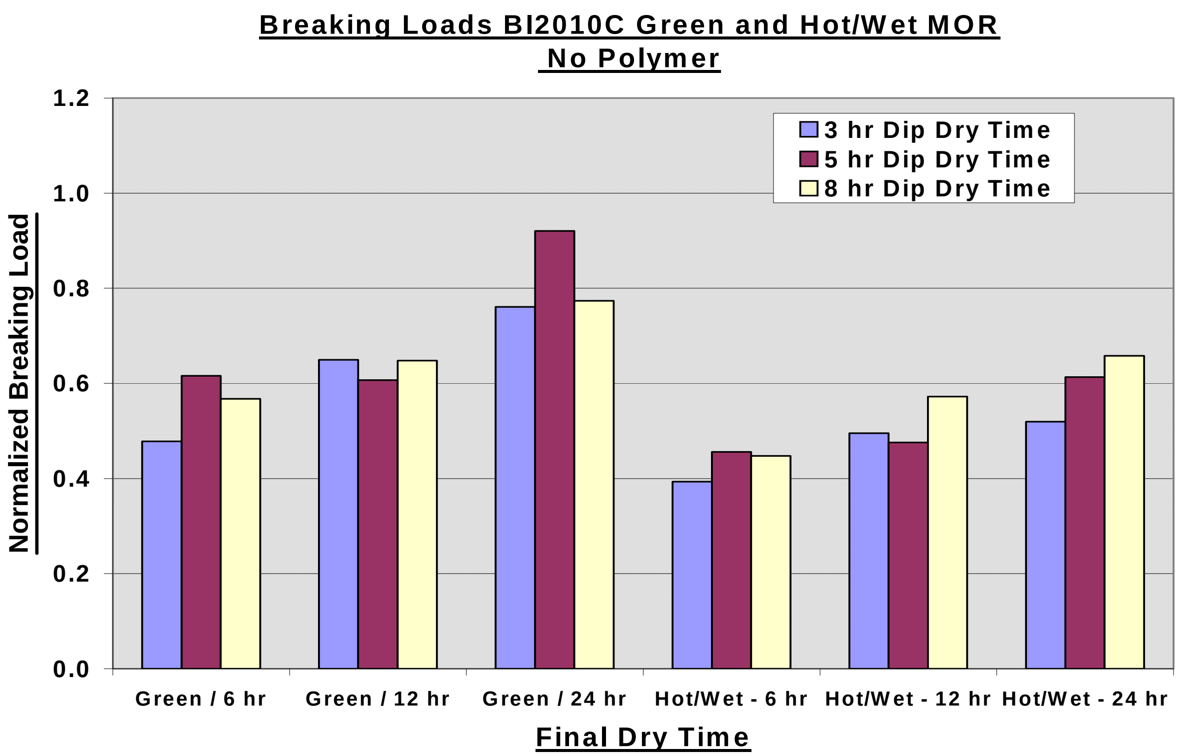
**Strength Development in Fiber Enhanced Backup**
**No Polymer**

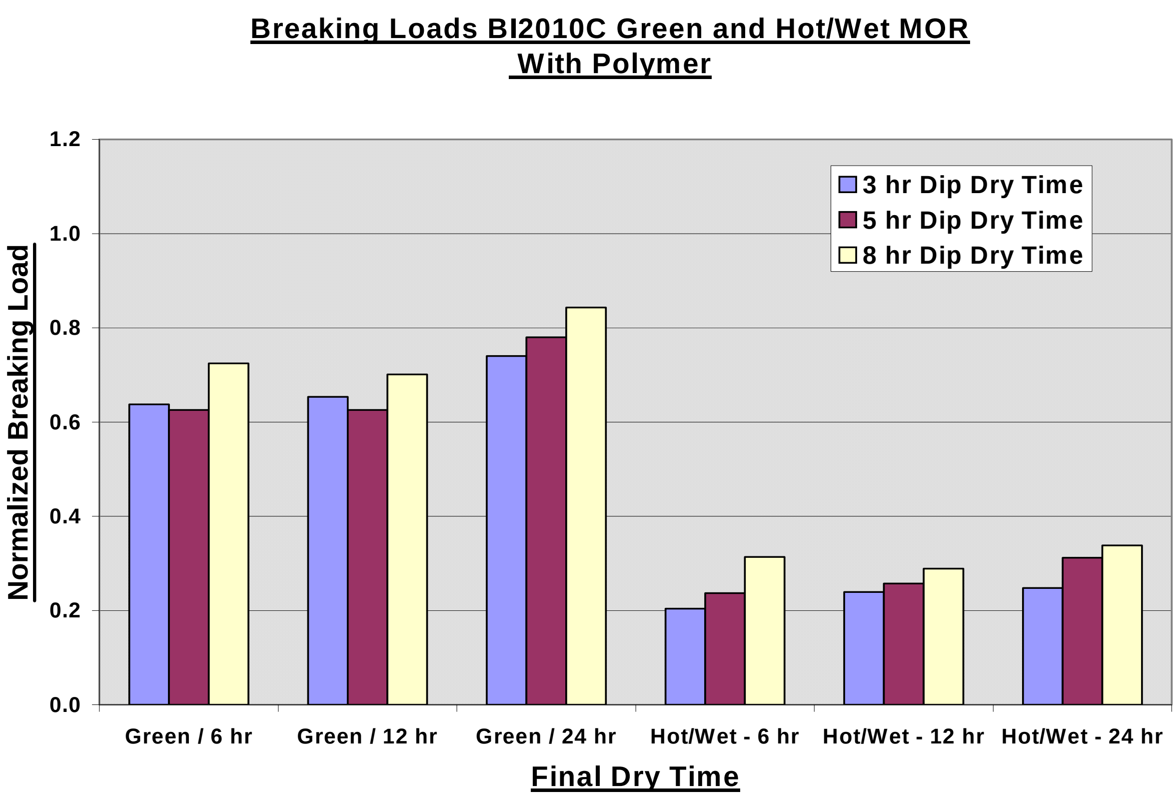



**Strength Development in Fiber Enhanced Backup**
**With Polymer**



However, MOR may not be the best measure of successfully getting molds through the autoclave without cracking. Take a look at the breaking loads of the MOR bars. This is the actual pounds load it took to break the ceramic strip with 5 dips and a seal.



In looking at breaking loads on samples with the same number of dips, a totally different picture is seen. The breaking loads for Green MOR are essentially equal for polymer and non-polymer containing backup slurries. So polymer doesn't buy and additional strength as far as breaking load is concerned. One could apply more dips to increase the Green breaking load, if desired. However, there is a large difference in the breaking loads for Hot/Wet MOR. The non-polymer shell has about double the breaking load independent of dry time. The reason for this difference is that the non-polymer shells are thicker with the same number of dips. The average shell thickness is given below.

| | Non-Polymer BI2010C Shell | Polymer BI2010C Shell |
|---|---|---|
| Average Thickness | 0.336" | 0.263" |

So, with polymer in the backup shell, the Hot/Wet MOR is lower and the shell is thinner compared to a fiber enhanced slurry without polymer. This is a recipe for dewax cracking.

## Conclusions:

1. With any shell system, it is important to look at both MOR and Breaking Load data to more fully understand shell strength issues.
2. Hot/Wet MOR may be an important metric for autoclave cracking.
3. Buntrock Fiber enhanced backup slurry Green MOR is fairly insensitive to interdip dry time. Polymer backup is less sensitive than non-polymer backup to dry time.
4. Longer interdip and final dry do slowly increase MOR and Breaking Load.
5. Polymer reduces shell thickness and lowers Hot/Wet MOR and Breaking Load.