Standardized Testing Tolerances for Auger Pressure Grouted Piles Additive "Panacea"

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Panacea is an admixture for auger pressure grouted piles in deep foundation construction which was created by Berkel and Company Contractors, a design build corporation. The admixture is designed to increase workability time and increase water retention to avoid seepage into surrounding soils and allow for the insertion of reinforcing steel after the grout has been placed. The objective of this research was to correlate initial set times with internal temperatures over time for scheduling purposes. Multiple batches with varying amounts of the additive were observed. The research also served to create a standardized set of tolerances for various variables being tested on site for quality control including: temperature, flow, water retention, and viscosity. By implementing these standards and tolerances contractors will be able to better gauge material attributes and in doing so improve the scheduling of critical activities related to deep foundations.

Key Words: Panacea Product, Grout Admixture, Deep Foundations, Auger Cast Piles.

Introduction

Chemical additives for concrete and grout had been in research and development for the better part of a century until they became commercially used in the construction industry. There are now dozens of common admixtures that can be added to a batch at a concrete plant. The issue arises when a customer desires a product with specific characteristics that the batch plant cannot produce. This is rare for most customers, but common for specialty contractors; especially deep foundations in this case. This is the same story for Berkel and Company Contractors. Due to their need to have a workable grout for pile foundations so that they can place reinforcing steel after the grout is placed, and the complete lack of manufacturers to create this product; Berkel created their own additive which reaches all the performance requirements needed. Characteristics include: longer usable time, water retention for various environments, while still attaining a similar strength profile.

This paper aims at dispensing the multiple test results from the material testing of 6 separate batches of grout; each containing various amounts of the additive in question, with one control batch containing no additive for comparison. Variables being tested include: flow, set time, calorimetry, water retention, and compressive strength. The objective was to extrapolate a working range of tolerances based on these results and then create a method for the monitoring of these same variables for use in the field in the future. This research should act as a basis for future utilization for dispensing methods, mix design, and submittal procedures including Panacea.

Literature Review

Being that Panacea is a new product, the background literature review was minimal. However, grout additives with one or more similar characteristics have been widely documented. Panacea is mostly composed of three main types of additives: a hydration stabilizer, a defoamer, and superplasticizers. All of these admixtures are common on their own, but not together. Extended workability times can be expected from using Panacea due to its superplasticizer properties. Superplasticizers can quickly increase workability, but may lead to undesired results soon after. “Careful use of superplasticizers is very important because of its relatively short effect on concrete workability. Rapid slump loss which results in loss of workability will occur 45 minutes after the introduction of superplasticizers.” **(Neville, 1995).** This stiffening of the cement can create scheduling conflicts. If unexpected delays are encountered in transit, the effects of the superplasticizer may not last until the contractor is ready to place the load. Workers may then be unhappy with the slump, add water, and, consequently, reduce strengths. Which can lead to rejection of the concrete. This is why the addition of the additive on site has become so vital to the use of Panacea in the field. Advantages of adding superplasticizers onsite are that the contractor can see the effects, the inspector is assured that the superplasticizer is going in, and the contractor can add the superplasticizer when it will be most effective **(Fisher, 1994).**

In order to have repeatable results and understand typical testing processes, I also consulted ASTM standards C230, C403, C494, and C941. These standards guided the material testing and the methodology behind each test. These specifications instructed on the subjects of: flow table for use in tests of hydraulic cement, time of setting of concrete mixtures by penetration resistance, chemical admixtures for concrete, and water retentivity of grout mixtures for preplaced-aggregate concrete in the laboratory.

Methodology

The focus of the material testing centered around the batching of the grout with various amounts of the additive mixed in. See **table 1** for exact amounts of Panacea in each batch. Ready mix grout was trucked in and separated into 6 standing mixers. Then the Panacea additive was added based on percentage of total weight which would be added in the field on a per cubic yard basis **(Table 1)**. Mixing continued until the Flow Table testing equipment was ready for the initial flow test, and the Panacea had a chance to incorporate into the grout. Variables tested consisted of: flow, set time, calorimetry, water retention, and compressive strength; in that order, throughout the day.

Table 1. *Grout Batching and Panacea Quantities*

Batch Number	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6
Amount Panacea (g)	0g (Control Batch)	21g	42g	63g	84g	105g
Panacea per Cubic Yard (lbs.)	0 lbs. (Control Batch)	1 lbs.	2 lbs.	3 lbs.	4 lbs.	5 lbs.

Flow Test

The water to cement ratio is often considered the most important factor in mix design due to the yielding strength, workability, and set time are directly related to the ratio. The flow test is done using the inverted cone method; by dropping a full inverted cone from a consistent height and then measuring the resulting diameter of the grout. The initial flow is done before any panacea is added to the other batches to ensure that they all have an appropriate water to cement ratio, and should measure approximately 22" across **(ASTM C230, 2014).** The test works by systematically measuring each batch every hour and a half; with the standing mixers mixing the batches independently in between inspections. Every batch that was tested was measured to a similar container with a unit weight within an acceptable range. After the test all remaining grout was collected and mixed back into the corresponding mixer.

Set Time

The initial set time for the grout samples is significant because it marks both the absolute end of the workability window, and the beginning stages of visible strengthening in the grout. Initial set for cement products is a factor of the penetration test. When it takes a contact pressure of 500psi to embed the needle to 1-inch depth we say the grout has reached initial set **(ASTM C403, 2016)**. Small containers that contained approximately 1/10 CF were filled with each batch and tested every hour until the equipment registered any sort of strength. Once the equipment got any reading whatsoever; the intervals for testing shrunk to every 15 minutes. The penetration testing equipment's range of measurements topped out at 200 pounds, with the PSI depending on the size of the head of the needle. We used an x20 needle head, so initial set was reached at 25 pounds. The samples continued to be tested every 15 minutes until they reached the upper limit of the equipment; not for initial set, but instead to create a better frame of reference for the continued strengthening of the grout. The results can be viewed in **figure 1**.

Calorimetry

Cementitious products' set time and internal temperature are directly related due to the chemical reaction of the cement which raises and lowers the temperature depending on the phase of reaction. In terms of workability and time, temperature can be a good indicator of when you can expect the mix to firm up, reach initial set and continue the hardening process. In order to record the temperature of the different batches; a sensor probe was inserted into cylinders which act as representative samples of the batches as a whole. The sensors then connect to a box which records the temperature every 15 minutes. The cylinders' information was taken for multiple days, but **figure 2** shows the relevant information over the time period when the same batches reached initial set and the common temperatures which were shared across batches set time. Temperature is a great indicator for scheduling purposes.

Water Retention

Water retention in the grout is key to the mix's consistency and the surrounding soil's ability to pull moisture out of the grout due to increased pressure from extreme depths. The apparatus for the test is a series of containers connected by rubber tubes to an air compressor in order to keep the samples under a constant pressure of 100 PSI. Graduated cylinder are placed below the sample containers with filters to keep solids inside **(ASTM C941, 2016).** These cylinders collect the water and measurements were taken every 5 minutes. The pressure was released for each batch once the samples expelled more than 30 mL; as this was the upper range of accuracy for the graduated cylinders. The amount of water retained can be seen as the inverse of the results in **figure 3**.

Strength

Cylinders were taken from the remaining mixers with a flow diameter large enough to satisfy initial flow requirements. The remaining batches were: 3, 4, 5, and 6. While these remaining batches are not representative of the entirety of the batches throughout the rest of the tests, they encompass the feasible range for the amount of Panacea that a contractor would actually use. The samples were then distributed to a third party consultant (Smith-Emery San Francisco) who then recorded the resulting concrete compression test results at the 7, 14, and eventually 28 day intervals. The outcomes of these tests can be seen in **figure 4.**

Results

The majority of the test results were similar to what was to be expected. The common characteristics in Panacea; the water retarder, hydration stabilizer, and superplasticizers, performed similarly to how they act independently in the same tests. Workability was greatly increased, and greater amounts of the additive resulted in extended set times and water retention. However, there were a few batches that produced unexpected outcomes.

Both the strength testing and calorimetry revealed surprising results. Hypothetically the batches should reach similar, nearly identical, pounds per square inch strength at 7 and 14 day intervals. The breaks revealed that more Panacea in a mix will give a stronger output **(Figure 4)**. The temperature recordings showed that when adding a larger amount of Panacea can change the chemistry of the mix so much that initial set is actually reached nearly a full degree lower than the others which averaged a common 67.5°F **(Figure 2)**. Other than these few outliers, the bulk of the results help create a formwork for the tolerances that can be expected and planned for when incorporating Panacea into a project. By comparing the lab results with monitoring efforts in the field; contractors can better schedule and control quality on site. The two main variables: set time and temperature, are synthesized and can be visualized in **figure 5**. While neither result determines causation; the correlation gives a good range of values that act as a guide for determining ideal amounts of Panacea for mix design depending on desired performance.

Diminishing returns is the key result from the materials testing. Each test produced a “tipping point” where the difference in benefit for the variable being tested from batch to batch increased at a decreasing rate. The first 3 batches yield the greatest contrast from the batch before it even though they have the least amount of Panacea out of the samples. This is best seen in **figure 3** where the amount of water expelled creates a large disparity between batches 2 and 3. Whereas the last three batches are all close together in a small grouping even though the percentage of Panacea is much higher at that end. This differential is an indicator to the contractor that more is not always better. If the contractor can get by with less Panacea, then the result is a cost savings. By having this data, planners can find the absolute critical duration and compare it to the performance offered by the varied amounts found in batches 1-6.

Figures

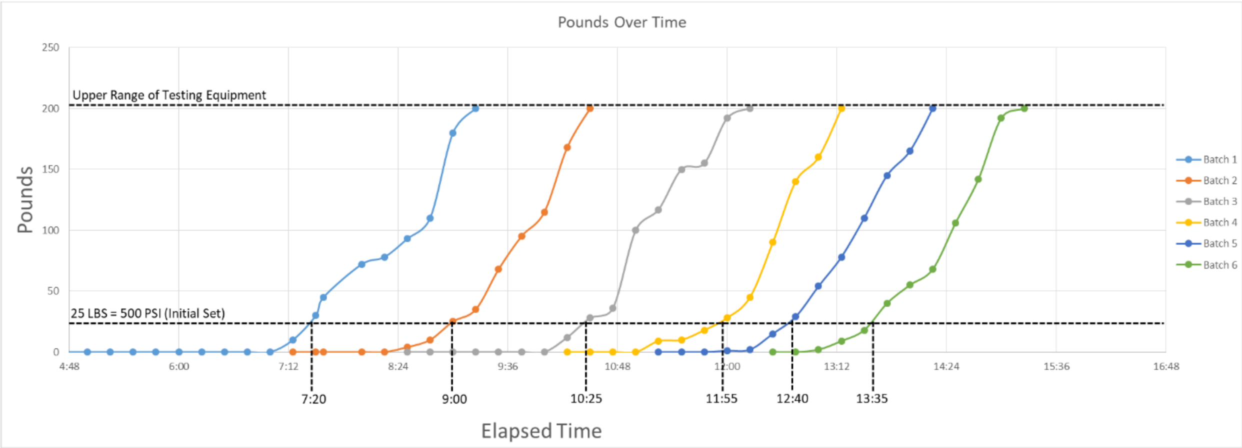

Figure 1. *Batch Strength and Relative Set Times*

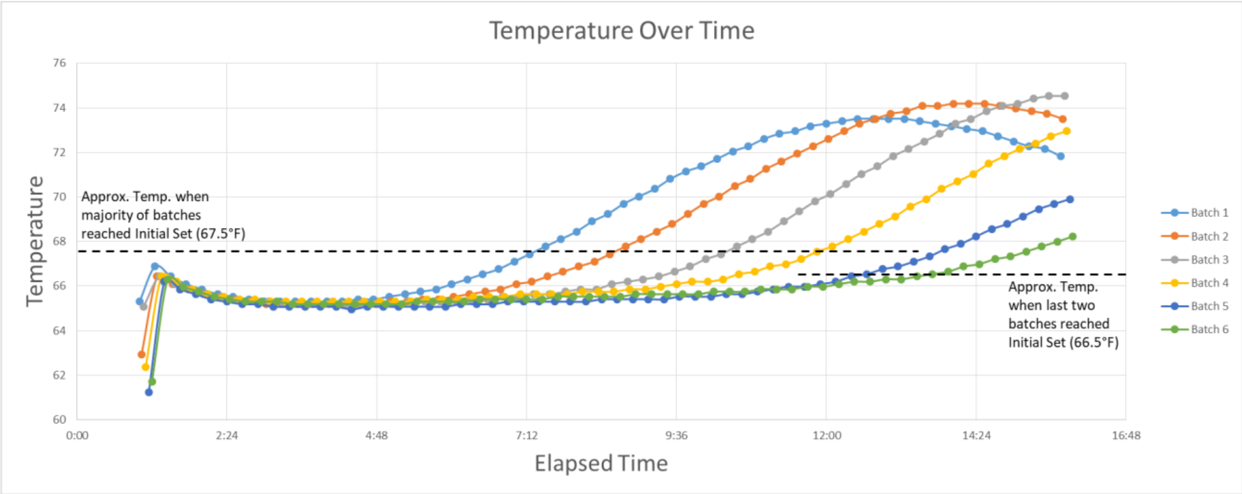

Figure 2. *Batch Temperature and Relative Set Times*

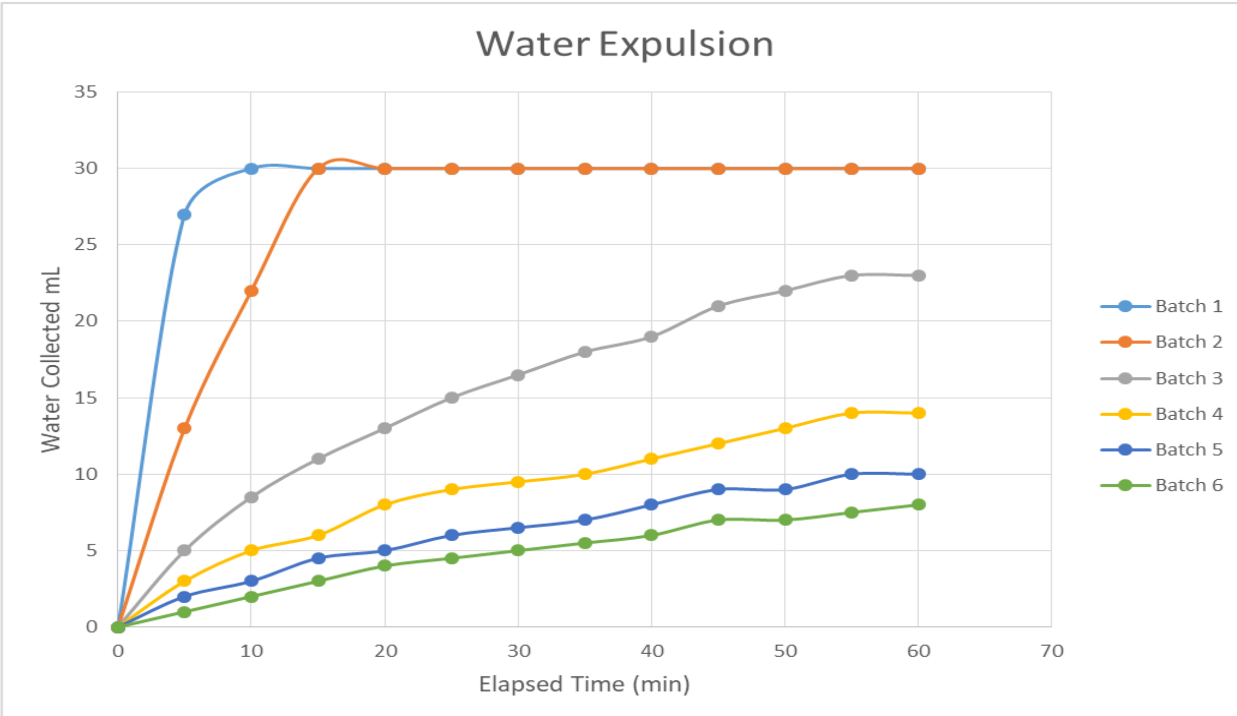

Figure 3. *Water Retention Relative to Panacea Quantity*

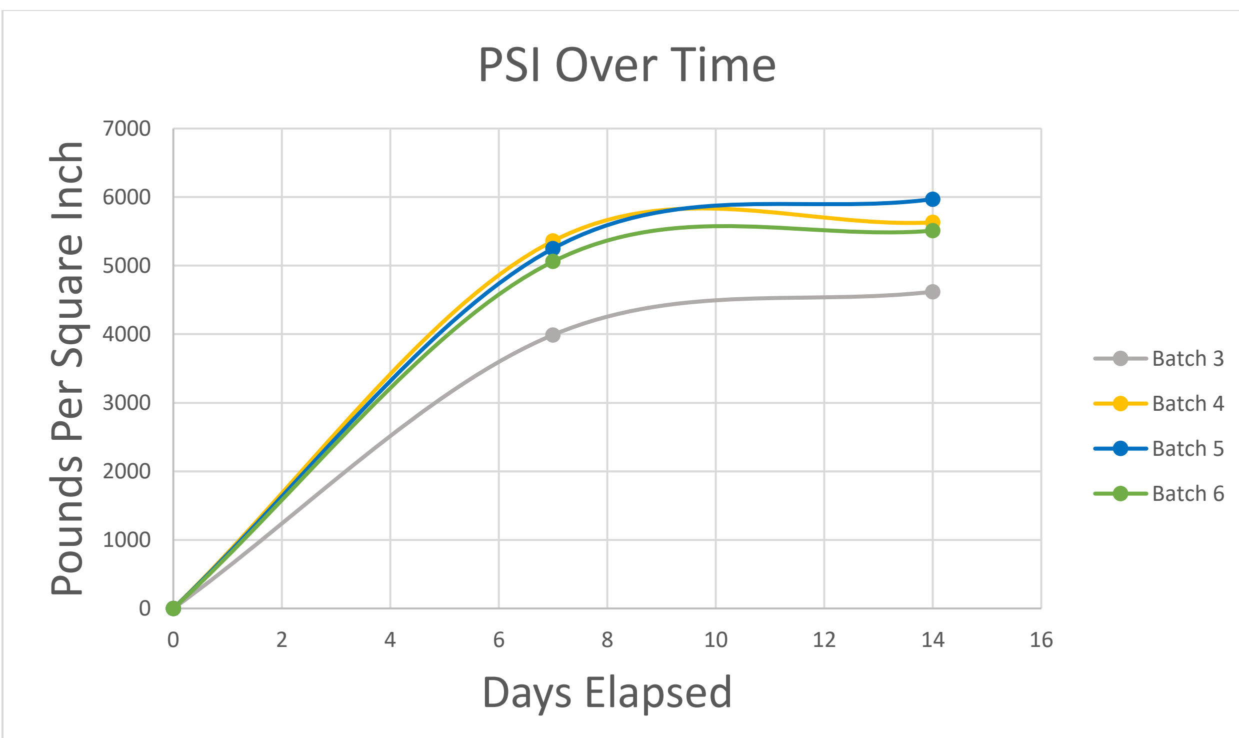

Figure 4. *Strength for Feasible Mix Designs*

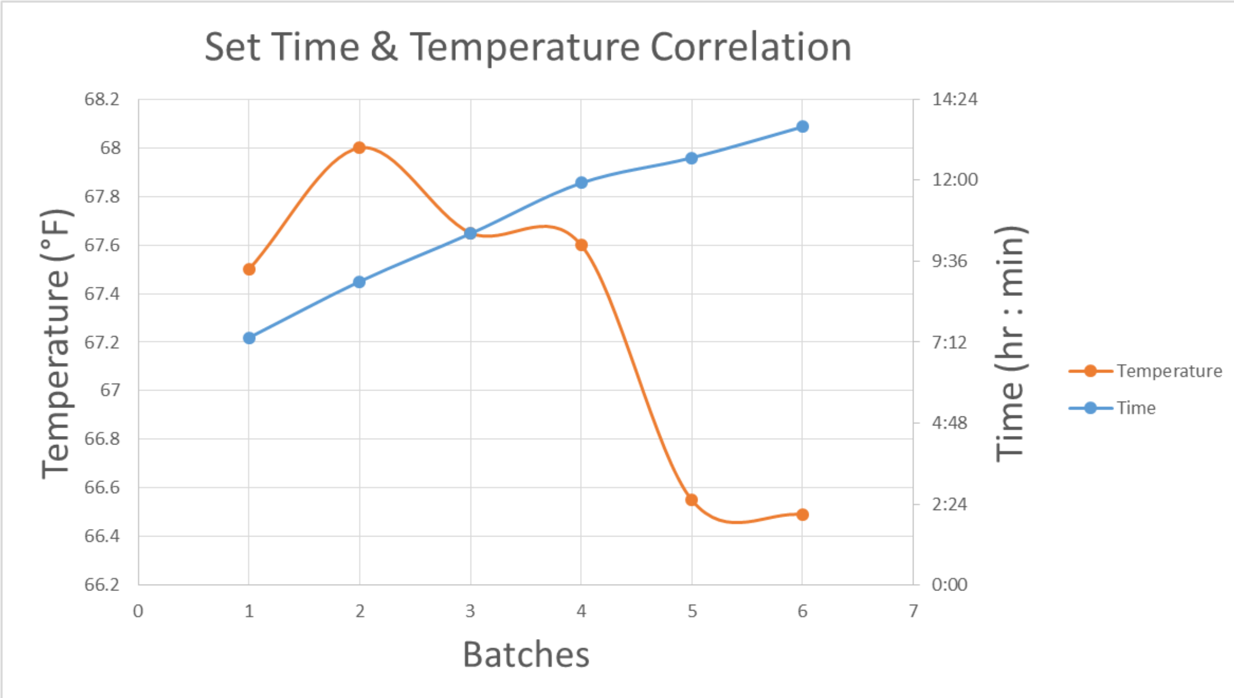

Figure 5. *Batch Set Time and Temperature Summary*

Discussions

While professional ASTM standards were consulted and every precaution was taken; possible sources of error and assumptions must be addressed. The clearest opportunity for error was in the calorimetry and temperature recording. The samples were stored in an uninsulated warehouse over the period of several days while the temperatures were being documented. The ambient temperature of the room and the surrounding areas could have easily influenced the final results and swayed the final operating initial set temperature. To help combat these extra variables, future research should consider a control container or room for a temperature controlled and insulated environment.

The results of this research are intended to provide a range of values with tolerances that can be used for future monitoring of the same variables, but onsite; not in a laboratory. These monitoring services might come in the form of temperature probes, or rotating vanes in concrete trucks to measure viscosity for workability. The key is to get the information and to then be able to correlate it back to these range of numbers to find which part of the curve you are on; this will greatly increase the ability of site personnel to schedule tasks and have a firmer understanding of real time setting properties of the grout.

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References

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