BRICKYARD magazine

By and for The Clemson Brick Forum and The National Brick Research Center | Volume 19 Number 2 | April 2020

CONTENTS

ON OUR COVER

•••

Brick relief sculpture at the Wentworth Courthouse in North Carolina. Artist Brad Spencer creates three-dimensional relief brick sculpture. Inspired by early examples of relief sculpture from ancient civilizations, like the Ishtar Gates of Babylon and Mayan ruins, Spencer and his wife have created brick art throughout the American South.

Chairman's Corner

...

Brad Cobbledick, Brampton Brick
Chairman, Executive Committee
National Brick Research Center

Well this is my last Chair's message! It has been an honour to serve the NBRC for the past two years in this capacity. I have learned a lot and I hope that I helped a little.

As I am writing this, we are in the darkest days of the COVID-19 pandemic. Never has our generation seen a global event such as this. Although finite in nature, the impact of the pandemic to the brick industry will be long lasting.

There are jurisdictions where brick plants cannot operate. This causes incredible financial uncertainty to those who have to stay at home. In the brick plants that are still in production, the continued vigilance in adhering to strict safety measures is required to keep our staff safe. The anxiety of those who continue to go into work is very high, taking a mental toll on them and their loved ones back home.

However, in times of extreme hardship and stress, there is opportunity. Opportunity to improve ourselves, our operations and our connection with others.

Personally, I am using this time to improve my mindfulness practice. I am focusing on those things I can control, such as my reaction to this pandemic, and trying to ignore things I cannot control, such as the reactions of others (hoarding of toilet paper comes to mind!). I am trying to help others with their struggles and learning to be more compassionate to their issues, and to have some self-compassion. After all, everyone is going through his or her own form of grief. No one is immune.

At Brampton Brick, we are using this time to improve our company through process review and updating key procedures, to solidify our Health and Safety program, and to double down on our efforts to implement better housekeeping practices. It is a unique moment to do those things we never have the opportunity to do in "normal" times.

This pandemic has also been a time to take the opportunity to strengthen our connection with others. It has forced us to use video networking programs to maintain the face contact we humans so dearly need. I can tell you that my wife's side of the family has taken advantage of this. They live in far-flung corners of the US and Canada and usually only get together for weddings and funerals. The last time they all got together was at my son's wedding 3 years ago. Now we chat every Sunday night on Google Hang Outs for two hours! I hope it lasts after this is all over.

In closing, I just want to say a special thank you to John and all the staff at the NBRC. My last few years as Chair have been very rewarding and working with this special team made it a lot easier! Stay safe and I look forward to seeing everyone again in person!

Brad Cobbledick, NBRC Chair

Important Updates from NBRC

•••

John Sanders
Director of the National Brick Research Center

2020 Summer Meeting

As many of you probably know, the joint NBRC and American Ceramic Society Structural Clay Products/Southwest Section Meeting that was scheduled for early June has been cancelled.

In place of this physical meeting, the National Brick Research Center will be holding an interactive virtual meeting. This event will include a short business meeting, as required by our bylaws, followed by an interactive review of our research. The virtual meeting is scheduled for Tuesday June 2nd from 2:00 to 4:00 PM Eastern.

Topics for the Research Review will include:

- Thermal Performance (Hotbox, Climate Modeling, and Solar Reflectance)
- Rheometer Evaluation of Extrusion Behavior
- ASTM Test Method Development (Improved IRA Test Method and Compressive Strength)
- Methods to control vanadium staining and improve fired color in higher iron buff clays

We intend to try a new format to make this meeting more interactive and engaging. We are currently researching platforms for this meeting and will send out an invitation and more information when it is available.

We wish you good health and hope that you can join us.

Limited Operations Continue Amid the COVID-19 Outbreak

At this time, The Bishop Materials Lab at the NBRC is continuing with essential research and testing functions. For everyone's safety, employee access has been limited by both Clemson University and State of South Carolina directives.

We will continue to maintain essential operations for as long as possible during this State of Emergency, and hope, like everyone else, that we can return to business as usual sooner rather than later.

If you have questions, please contact us: 864-656-1096 or *brick@clemson.edu.*

We wish you Safety and Continued Good Health!

LITTLE THINGS MEAN A LOT

Illite is a clay mineral that is commonly found in the Midwest. Illites typically have the largest particle size and lowest plasticity of any of the clay minerals. Illite is sometimes called a "micaceous clay mineral" due to its similarity to minerals in the mica group. While brick mixes with illite have lower plasticity than mixes based on the other clay minerals, they are typically easier to fire due to less chemically bound water and high levels of fluxes like potassium, magnesium and iron.

Like · Follow · Connect · Learn

/NBRCClemson @NBRCClemson bit.ly/NBRC-LinkedIn

brick@clemson.edu www.brickandtile.org

www.brickandtile.org/wikibrick

Just Down Brickyard Road

•••

Director's Column | John Sanders, Ph.D., P.E.

I have been fortunate to have some conversations recently that highlight my enthusiasm for the product that we make. I think that we all can take things for granted and sometimes focus on challenges more than an appreciation for what we have. This is the point of the whole "mindfulness" movement. One of these individuals is Garth Tayler who recently retired from Acme Brick. Garth has written a book about his experiences entitled ***Heavy Clay Business Breakthroughs*** which is available on Amazon. Garth's experience from South Africa to Denton Texas, highlights the universality of brick. Just about every country has some sort of brick production and in many cases this tradition goes back thousands of years. The universality of brick and its long history are a testament to its success. In other words, the product simply would not have endured this long if it did not perform well. Our job is to highlight these benefits and incrementally improve the product to add to the thousands of years of existing tradition.

For example, we have been studying vanadium staining recently. This is a consequence of consumer demand for lighter colored brick. Once I started doing research into the subject, I found publications going back to the 1920s. Despite all this time, there is still no definite understanding of the exact mechanism of vanadium staining. We know that it is more prevalent in high kaolin bodies, but there is significant disagreement in the literature as to why. Hopefully we have contributed to this understanding. In ongoing work, we are looking at how we can reduce vanadium staining through additives or modifications to the firing cycle. Being a ceramic engineer, I really enjoy this type of work.

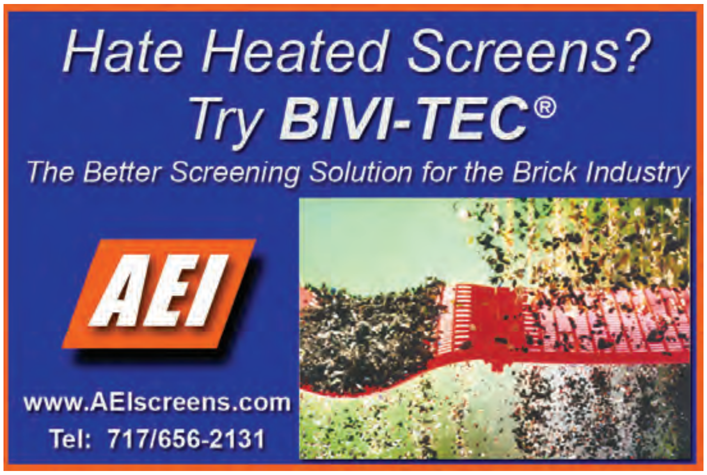
In other ongoing work at the NBRC, we are requesting input on additional wall systems, especially thin brick wall systems, that need to be evaluated in the hotbox. If you would like to make a suggestion, please contact us at the Center. We hope to have the next phase of this part of our research program ready soon. Nate Huygen is completing his dissertation for submission by the end of the year. He will give updates on his work at our June meeting. Nate has done a tremendous amount of work to help us understand the true thermal performance of brick veneer and to help us quantify this benefit.

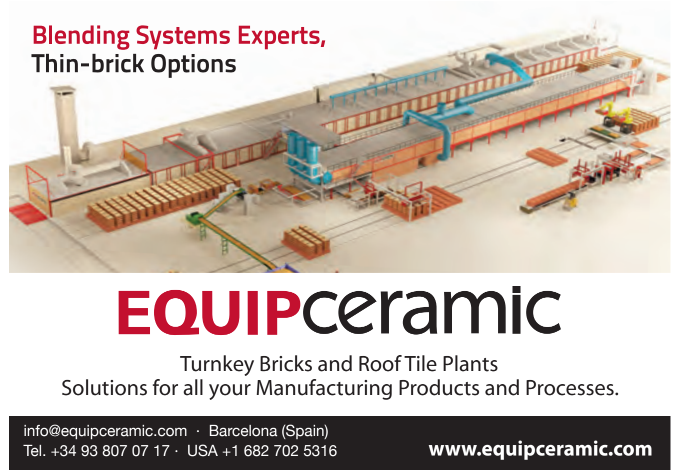
We also plan to continue with the missile impact work that we did last year. We would possibly like to include some fire testing aspect to this work as resistance to missile impact and fire resistance are two key features of our product that we need to emphasize along with the long service life of our product. In addition to these wall systems projects, we are collaborating with the ASTM subcommittee that is responsible for the C67 test methods to make some improvements in the areas of compressive strength, freezing and thawing, efflorescence, and initial rate of absorption.

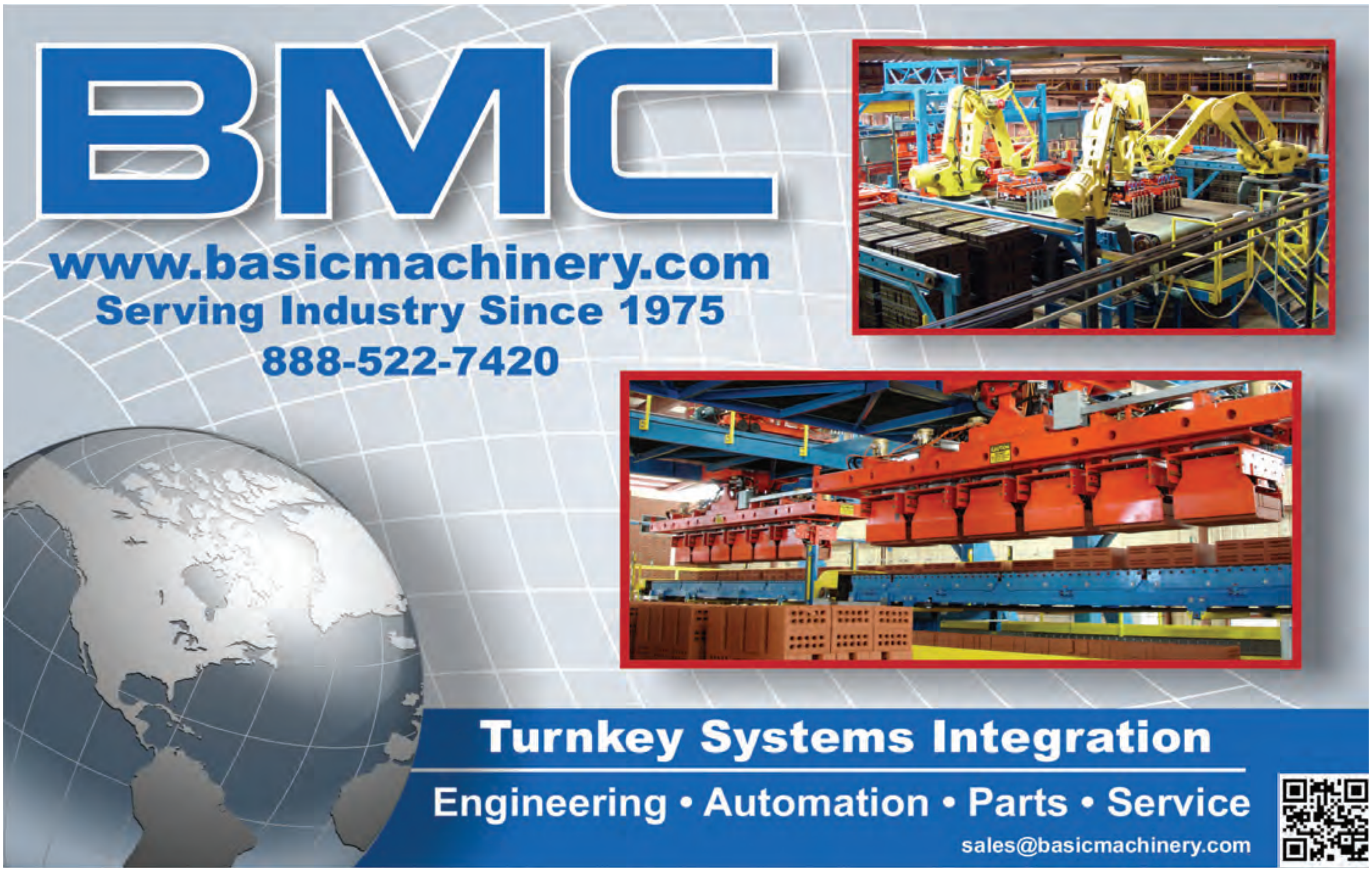
In this issue you will find Part 1 of our work on vanadium staining which adds to and extends the historical work on this subject. You will also find a discussion by Teddy Lentz, on solar reflectance and solar absorption which are current topics in the energy code and building science communities. Teddy is a new graduate student who is working on this subject for us so that we can be prepared for proposed code changes that may impact us. Some preliminary information for the 2020 Clemson Brick Forum and our virtual June meeting is also included. Finally, another retiree, Johnny Brown (formerly of General Shale) has contributed an article on brickmaking fundamentals. Thanks goes to Jim Frederic for helping with the editing on this article.

Learn more about NBRC:

- *www.brickandtile.org*
- *www.facebook.com/NBRCClemson/*







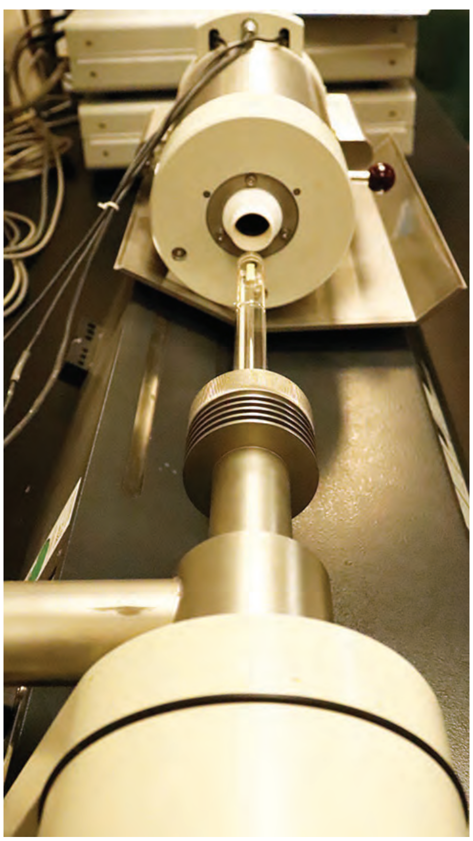
/NBRCClemson @NBRCClemson bit.ly/NBRC-LinkedIn

2020 Webinars: 3 - 4 PM Wednesdays

April 29	Extrusion, Moisture and Rheometry
June 24	Controlling Vanadium Staining
July 29	3D Printing Special Shapes from Clay or Shale
August 26	Extrusion, Additives and Rheometry
November 4	Capillary Absorption and IRA

Upcoming Events

June 2	NBRC Virtual Summer Meeting
June 30 – July 2	ASTM C15 Meeting, Boston, MA, USA
June 27 – July 1	2020 ASHRAE Annual Conference, Austin, TX, USA
August 3 – 6	NBRC Fall Short Course, Anderson, SC, USA
October 5	NBRC Advisory Board Fall Meeting, Anderson, SC, USA
October 6 – 7	66th Annual Clemson Brick Forum, Anderson, SC, USA
October 25 – 29	Thermal Performance Presentation, ACI Conference, Raleigh, NC, USA
December 8 – 10	ASTM C15 Meeting, Orlando, FL, USA
January 23 – 27	ASHRAE Conference, Chicago, IL, USA



In the Bishop Materials Lab: Cryogenic Dilatometry testing

The Bishop Materials Laboratory

The Bishop Laboratory is an ISO 17025 Accredited Laboratory. Our fields of testing include cement, concrete, aggregates, masonry, stones, bricks and tiles.

Analytical Methods

- Particle Size Distribution
- Loss on Ignition
- Chemistry (XRF)
- Pyrohydrolysis
- Soluble Salt Content
- Mineralogy (XRD)
- Crystalline Silica Content (XRD)
- Carbon & Sulfure Content (LECO)
- Dilatometry
- Thermal Gradient Firing
- Thermal Analysis (TG/DSC/FTIR)

Physical Properties

- AMSMV
- ASTM C67
- Concrete Masonry
- Dimension Stone
- Mortar for Unite Masonry
- Refractory

International Organization for Standardization ISO 17025 ACCREDITED LABORATORY

IAS ACCREDITED Testing Laboratory

CLEMSON BRICK FORUM

Time to start planning for the 66th Annual Clemson Brick Forum, October 6-7, 2020! We've got a brand new downloadable Sponsor & Vendor Registration Form and an informational packet with details on the hotels and more.

New this year:

- Attendee registrations will be made using the Attendify portal, available soon
- Vendor registrations may only be paid using a credit card
- All vendors must purchase a 10'x10' booth, even those sharing booth space with another vendor
- New Sponsorship opportunities like the coffee bar & charging station

Please contact Anne for the registration form or if you need any additional information: *ammcken@clemson.edu* or 864-656-1096.

LITTLE THINGS MEAN A LOT

Mica is a common accessory mineral in our raw materials and can have a wide range of chemistries. The most common mica phase is muscovite which is actually a parent mineral for kaolin. Muscovite mica has the following approximate chemical formula, $(Na,K)_2O.3Al_2O_3.6SiO_2.2H_2O$ where the ratio of sodium (Na) to potassium (K) can vary substantially. Other substitutions in the mineral are common including iron and magnesium. Mica is the most common source of fluxes in our raw materials. Micas tend to be platy like clays and generally fall into the silt sized particle range. Micas undergo a dehydroxylation just like clay minerals but the temperature for this decomposition can range over almost the entire preheat.

See all of our Little Things Mean A Lot posts in the Facebook Album: *bit.ly/NBRC-LTMAL*


...for clean air and
a better environment
Flue gas cleaning
for the future regulations
Complete DIFF and DLA installations.
Engineering, fabrication and installation.
Over 40 years with more than 600 installations around the world.
Ask us. We provide solutions.
HELLMICH
So that the air stays clean.
Hellmich GmbH & Co. KG · Holtkampweg 13
32278 Kirchlengern · Germany
Tel.: +49 (0) 5223 75770 · Fax: +49 (0) 5223 757730
info@hellmich.com · www.hellmich.com


Lhoist
Sorbacal® SPS
Hydrate for
BRICK MACT
Compliance
Dry Sorbent Injection (DSI) technology has proven to be a flexible, reliable solution to control acid gas emissions, including SO_2, HCl, and HF from brick and clay manufacturing plants.
The development of Sorbacal® SPS by Lhoist, an enhanced and more reactive hydrated lime product, offers an improved DSI solution for acid gas removal:
• High Surface Area
• High Pore Volume
• Optimal Particle Size
Lhoist North America makes it easy with on-site technical assistance from our highly experienced and knowledgeable technical team.
Sorbacal®
Contact our FGT Solution Experts:
1-800-365-6724 solution@lhoist.com
www.lhoist.us www.sorbacal.us
Sorbacal® is a registered trademark of Lhoist Recherche et Developpement S.A.


IS THIS AN
ORDINARY BRICK?
NOT IF
IT'S MADE
WITH
ADDITIVE-A®.
At Borregaard LignoTech, we're dedicated to quality—
both yours and ours.
When you use Additive-A,® you are using a product
manufactured to the highest quality standards.
Our quality management system is ISO 9001:2000 certified, and our technical specialists have been serving the clay technology industry for over 50 years. Contact us to optimize quality and reduce production costs in your plant today.
MORE THAN MEETS
THE EYE…ADDITIVE-A®
ADDITIVE-A®
CLAY CONDITIONERS
Additive-A®…
when quality
and performance
matter.
LignoTech USA • Tel: 715.355.3690
Fax: 715.355.3629
E-mail: ceramics@borregaard.com
www.lignotech.com
Borregaard
LignoTech

Process Control of Structural Clay Brick Products ...

by Johnny M. Brown
Brick Manufacturing Advisory Consulting (BMAC)

Quality facing / structural clay brick continues to be the preferred material for:

- Residential buildings
- Schools
- Churches
- Offices
- Corporate structures
- Cities
- Universities

Over the centuries, brick has been a building material of choice because of its beauty, durability, and continued low cost of operation, in addition to being almost fire-proof, sound-proof, and resistant to external penetrating damage. Builders and owners appreciate the continued payback and durability brick delivers.

For quality end products, the production process must be documented. The material available to the plant and the sizes of bricks required by the market may change, but manufacturers must adapt as required to continue the tradition of providing desirable and durable brick.

Mining and stockpiling procedures must be documented as necessary for the manufacture of clay brick. A geologist may sometimes be required to identify and estimate the available amounts of each deposit to be mined to complete the plant mix.

Good grinding and handling systems are readily available. Efficient blending, a retrievable ground storage system, and a supply system from ground storage to the mill room and extruder will result in a consistent product for the rest of the plant. The best retrieval systems are the mixing conveyors that mix from the top of the storage piles and from end-to-end of the accumulated storage. They then discharge on to a continuous collecting conveyor belt, providing the pug mill with material with water added to get the desired pugging consistency. It also feeds the de-airing chamber with thin shavings (produced at the discharge end) while feeding the extrusion auger at the bottom of the de-airing chamber. This continued flow forces the mixture through the die and shaper cap to form the desired green brick size. An observation port in the top of the de-airing chamber is provided to make sure the extruding auger is functioning as designed.

Plant personnel should run dry sieve analyses on the ground material and determine screen weights by percent using standard lab procedures. This will define the desired particle size distribution to be maintained for the best quality and the adjustments that might be needed in the future.

Wet sieve analyses should also be run on the ground material using standard procedures. Wet sieving separates the coarse fraction from the fine fraction. This information may be used in the future as a reference to suggest a rebalance of the mining plan as necessary to control IRA, absorptions, shrinkage, and compressive strength of the fired brick.

After extrusion, setting the green brick correctly on a level kiln car and conditioning the green brick in the pre-dryer become critical steps. The conditioning in the pre-dryer must be controlled 24/7! Monitoring pre-drying conditions on a daily basis is a necessity for making quality brick.

Brick extruded to die size should be measured, and the following information recorded:

- Wet and dry brick - average weight
- Wet and dry brick - average size
- Moisture content

Dry all sample bricks slowly to 200°F for 24 hours and save for reference.

Pre-drying will remove shrinkage water and the water in the pores. The shrinkage water is removed through the capillaries allowing hard particles to form the brick matrix. This action allows space to move the water and form the spaces between the hard particles that form the brick. Firing then forms the glass bond to produce the required matured properties necessary for the mason to lay the brick and to produce the desired tensile and compressive strength.

Dried samples should be fired in the plant kiln. Use

continued ⇒

these fired samples to determine shrinkage. Then use the rest of the dried samples for evaluation by differential thermal analysis. NBRC can run this DTA sample for your plant if necessary. Firing the dry DTA sample in the kiln in the temperature range from dryer temperature to soak temperature and cooling temperature will help define the necessary firing curve for the kiln as the product is exposed to different temperatures and heating rates.

The capillaries in the brick will shrink during firing as will the size of the brick itself. These changes define the porosity of the brick on completion of firing. The DTA data indicates the firing shrinkage that will occur as well as the effect of the silica. Silica has a transformation which requires a preheat holding zone at approximately 1100°F to minimize cracking the brick. Knowing the temperatures of the crown thermocouples and the heating rate of the bricks during firing are also helpful in maintaining the proper kiln curve.

It is very important to determine the C/B ratio for the fired brick in order to minimize F/T failure. ASTM testing will determine the C/B ratio (or absorptions for brick soaked for 24 hours in cold water divided by absorptions for brick soaked for five hours in boiling water). When wet bricks freeze, the water in the pores expands. If the expansion of the ice creates stresses greater than the strength of the brick, the brick will crack and F/T failure will occur.

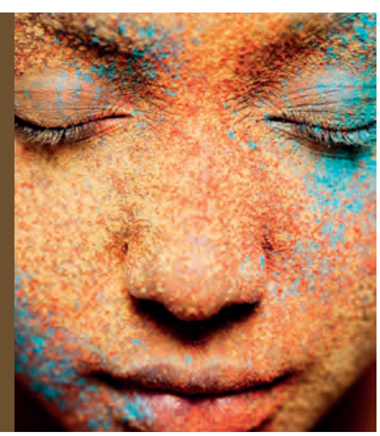
Compression testing is also run to determine brick strength for wall design. C/B testing at the plant and compression testing can eliminate uncertainty as to how the brick will perform at the job site.

continued on page 15 ⇒

LITTLE THINGS MEAN A LOT

Quartz is one of the most common minerals in the earth's crust and present as an accessory mineral in almost every brick mix. Quartz experiences a spontaneous change at 1063°F known as a crystalline inversion. This inversion results in an expansion on heating and a contraction on cooling. This sudden dimensional change can results in cracking on cooling that is sometimes called "dunting." Quartz contents up to about 25% are generally beneficial as they help reduce drying and firing shrinkage. Mixes with Quartz contents greater than 25% can be more sensitive to durting during cooling. The risk of dunting increases as the amount of quartz and the size of the quartz particles increase.

Fire Clay is a generic name for low iron, high kaolin clays that were originally used for lower duty refractories. Like all materials, fire clay usually contains some degree of quartz and may contain other alumina minerals such as lime gibbsite or boehmite. Fire clays are usually classified by their alumina (Al_2O_3) content with higher alumina contents being more temperature resistant. Fire clays are sometimes used for making buff or light colored brick but usually require a higher firing temperature than most other brick making materials.



Planning is underway for the 66th Annual Clemson Brick Forum. You can easily download & complete our Sponsorship & Vendor Registration form — updated with new information — by visiting the web page listed below. We look forward to seeing all of you in October!

Oct. 6-7

brickandtile.org/events/clemson-brick-forum

PROCESS CONTROL ... continued

Most brick manufacturers have procedures and manuals in place that cover variations in the process due to changes in production rates, and product types, as well as changes in ambient conditions. Particular care should also be taken to monitor wear of different components of the process. Wear can affect the efficiency of the equipment and efficiency can affect quality. A good example would be, if a blade on a recirculating fan on the pre-dryer is worn out, and it has lost the recirculating capacity it had when new. This changes the pre-dryer humidity, pressure, and air flow in that area/zone. The overall effect is that the drying curve is changed in the pre-dryer and drying defects can occur.

Most of the older facilities can be up graded to be more efficient. Some have oversized dryers and wasted space that can be modified. For example, the transfer car tracks can be enclosed to increase the size of the pre-dryer overall. This would also be a method to prevent loss of heat created during extrusion and setting. Also, available and new equipment such as the latest high velocity burners, efficient burner control systems, and computer kiln controls should be considered. These changes can save in fuel costs and even out the heat distribution in the kiln. As with all processes, if changes are made, we must be able to measure those changes so that the proper adjustments can be made.

If the quality of your products is not what it ought to be, the National Brick Research Center has the expertise, the equipment, and the personnel to diagnose the problem. Contact NBRC at 864-656-1096.

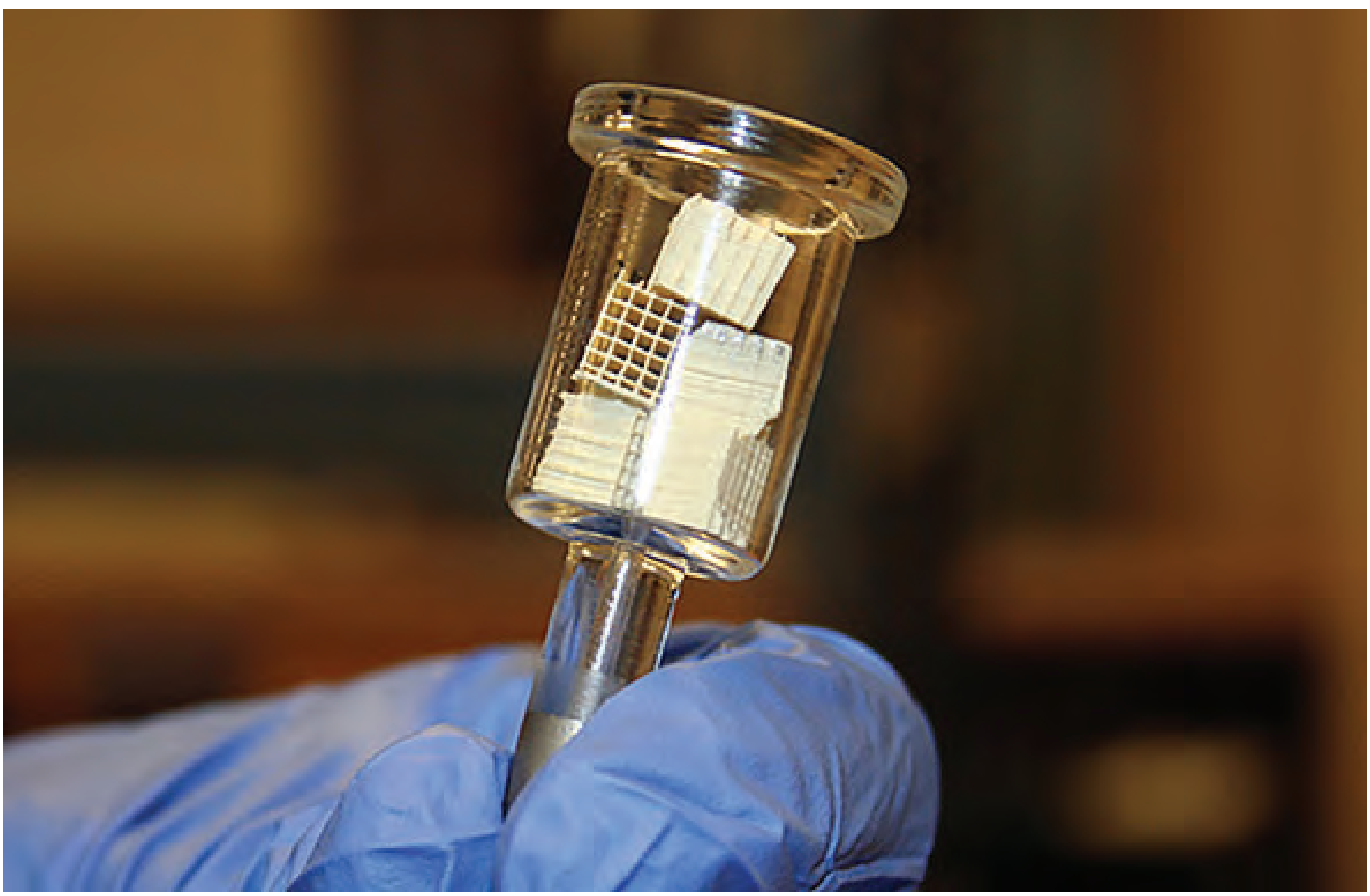
You can find a list of tests we conduct with sample size requirements here:
brickandtile.org/test-capabilities-sample-size/

Inside the Bishop Materials Laboratory: Fluxing
To prepare samples for chemical analysis by X-Ray fluorescence, we use this fluxer apparatus. We mix a prepared sample with a flux and fuse it into a glass disk for analysis. The crucibles are rotated over the flame to melt the sample and then the melt is automatically poured into a mold to make a sample that is ready to analyze. This type of preparation helps us account for matrix and particle size effects and gives us the most consistent results.

Follow us on Facebook!

facebook.com/NBRCClemson

- News & Updates
- RSVP to Events like Webinar, Short Course, the Annual Brick Forum and more
- Little Things Mean A Lot
- Event Photos



In the Bishop Materials Lab: Analystical testing of Mercury Porosimetry

Understanding Vanadium Staining Part 1

•••

by John Sanders, Director, National Brick Research Center

With the increasing popularity of light colored brick, reports of vanadium staining have been on the rise. Since we were getting more requests for help with vanadium staining, we decided to do some research on the issue. An example of the green vanadium staining is shown in Figure 1. It turns out that people have been dealing with this issue and publishing papers since the 1920s. The results and suggestions from all these publications are sometimes vague and contradictory so we decided to study the issue further. We selected two raw materials for this study. One is a high kaolin material and the other is a higher quartz and mica material. Both materials fire to a light color and tend to show vanadium staining.

Figure 1 – Example of Vanadium Staining

The important thing to remember about vanadium staining or efflorescence is that it is about more than just the brick. For the staining process to occur, there must be a source of the soluble species that causes the staining, vanadium in this case, along with the movement of water as shown in process diagram in Figure 2. The water movement generally occurs when the brick gets wet, usually from rain. As the water penetrates, the soluble material is dissolved and then as the brick dries, the soluble material is carried back to the surface where it is deposited as the water evaporates at the surface. People typically just focus on the salt part of this process and ignore the fact that you have to have a means of moving the salt to see the stain. The water movement part of the process will be important later in this discussion.

Surprisingly, after all this time and study, there is

Figure 2 – Efflorescence/Staining Cycle

still disagreement about what the vanadium staining compound actually contains. A number of compounds have been proposed over the years. This list includes: $KVO(SO_4)_2$, $(VO)_2(SO_4)_2$, $VOSO_4$, $VOCl_2$, $VOCl_3$, and KVO_3. Colors from green to yellow to orange have been reported and we have seen most of these in our lab during this study. Vanadium can actually have a number of oxidation states so the range of colors is not entirely surprising. The oxidation state associated with the green color is the most stable which probably explains why this is most common. We have had some stains that start out as orange but slowly change to yellow then green as they are exposed to air. Some closeup pictures from an optical microscope of a stain, showing the greenish/yellow color, is shown in Figure 3.

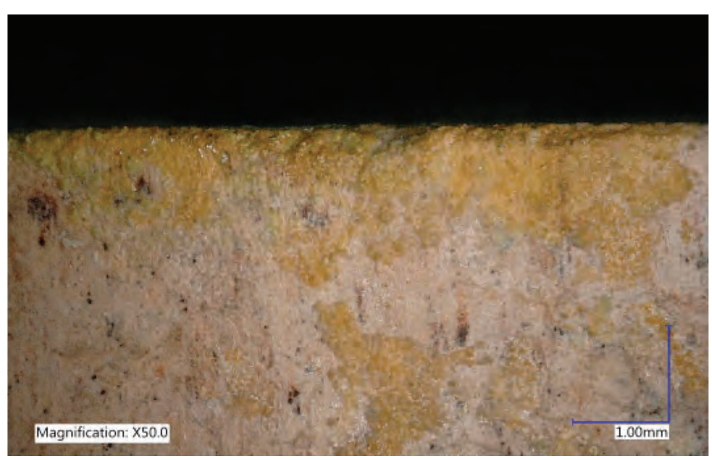


Figure 3 – Vanadium Stain on Surface

To better understand the staining mechanism and to be able to come up with a way to control the vanadium, we needed to know more about the composition of the stain. For example, if the vanadium stain is a sulfate salt as suggested previously, then we should see some correlation with the soluble sulfate content of the raw material. Further, if this is the case, reducing the soluble sulfate content would reduce vanadium staining. We did some surface chemical analysis using a scanning electron microscope, as shown in Figure 4, to try and understand the chemistry of the stain. We found higher vanadium in the stain, as you would expect, along with higher levels of potassium and sulfur. This would suggest that the stain is either a potassium vanadium sulfate or potassium vanadium oxide compound from the list of compounds that were reported previously. We will explore the nature of vanadium staining compound further with gradient firing results.

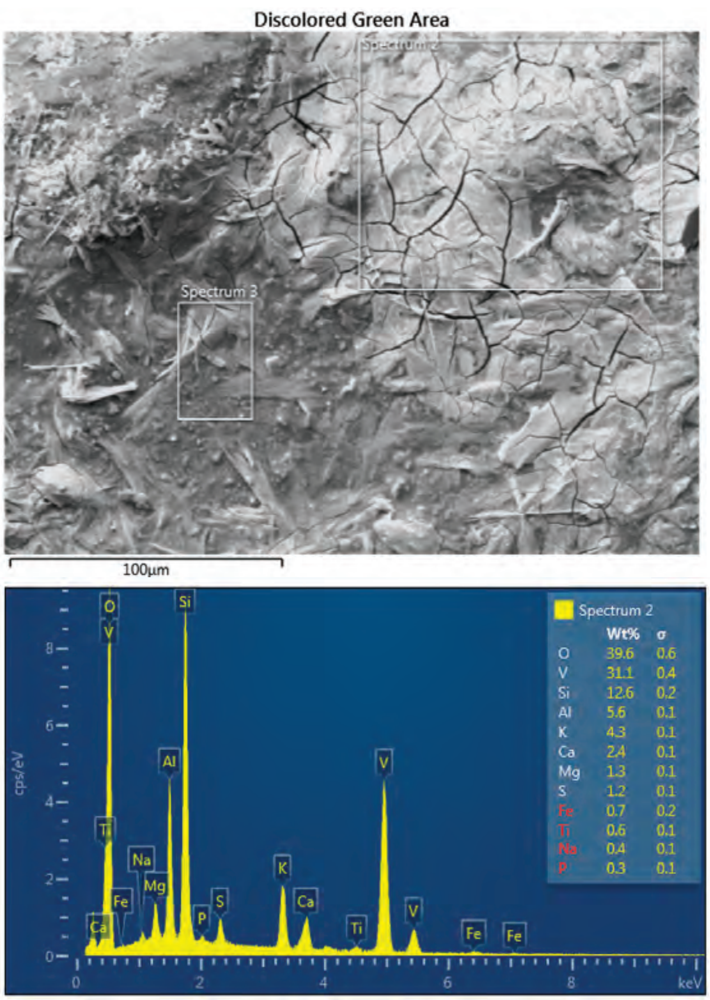


Figure 4 -SEM/EDS Analysis of Vanadium Stain

The next question that comes to mind is where does the vanadium come from? In short, the vanadium naturally substitutes for aluminum in the kaolin mineral at very low levels according to several sources. A similar thing happens with fluorine substituting for hydroxyl groups in the clay mineral as we have discussed with respect to fluorine emission and scrubbers. The interesting thing that we have found is that the vanadium is essentially not soluble in the raw material (since it is part of the crystal structure of the kaolin), but it becomes soluble after the clay mineral decomposes. During the soak when glass formation is taking place and the pores are sealing (reducing the absorption), the vanadium becomes progressively less soluble. There appears to be a range from about 1600° F to the early part of the soak where the vanadium is most soluble and most likely to cause staining.

Some soluble vanadium measurements, along with soluble salt measurements on some light colored brick mixes are shown in Table 1. We also measured the chemistry and mineralogy of these materials, and some key values are reported in Table 2. We did find a strong correlation between the amount of kaolin in the raw material and amount of soluble vanadium after heating along with the likelihood for vanadium staining. This seems to make sense since we know that the vanadium substitutes for alumina in the clay mineral and kaolin has a high alumina content. Generally speaking, the alumina (Al_2O_3) content in a raw material can be used as an indirect indication of how much clay mineral is present in the raw material. Some people express this as an alumina/silica ratio with higher numbers indicating a higher clay content and lower numbers indicating more quartz.

continued ⇒

UNDERSTANDING VANADIUM STAINING, PART 1 continued

Table 1 – Soluble Species in Test Materials

Sample	Soluble Vanadium (As Received Raw Material) (ppm)	Soluble Vanadium (After Firing to 1832° F) (%)	Soluble Potassium (As Received) (ppm)	Soluble Sulfate (As Received) (ppm)
High Kaolin	0.66	52.9	52.5	19.9
Medium Kaolin (balance quartz & muscovite)	0.80	27.3	104	209
Low Kaolin (balance quartz & muscovite)	0.77	21.5	110	144

Table 2 – Chemistry and Mineralogy of Test Materials

Sample	% Kaolin from XRD	% Al^2O^3 from XRF	Total Vanadium from XRF (%)	Total Sulfur (%)
High Kaolin	71.8	26.6	162.4	0.034
Medium Kaolin (balance quartz & muscovite)	34.4	22.7	156.8	0.514
Low Kaolin (balance quartz & muscovite)	9.8	20.3	140.0	0.154

Another aspect of vanadium staining that needs to be considered is the effect of firing. Presumably the vanadium becomes part of the glassy bonding phase at higher temperatures and become less soluble. This should mean that as we fire to higher temperatures, and lower water absorption, the vanadium staining should become less of a problem. There are two reasons that this should work. Firstly, the vanadium should dissolve into the glass which would render it insoluble and as the water absorption decreases, there are fewer pores to allow water to penetrate into the body and dissolve any remaining soluble vanadium. To study this, we used a gradient furnace to fire pellets made from the materials listed in Table 1 and 2. We then used the tray shown in Figure 5 to look for vanadium staining. This allowed us to see the relationship between firing temperature, water absorption and vanadium staining for two bodies. The separate compartments in the tray allowed us to keep each sample separate and not get cross contamination of the samples.

The results of the vanadium staining for the high kaolin body are shown in Table 3. For this material, there was visible vanadium staining, as indicated in the third column, until the cold-water absorption was approaching 9%. The high water absorptions for this material are very typical of very high kaolin mixes. We also looked at the soluble salt content as a function of temperature to see if there was a correlation. The high water absorptions for this material are very typical of

Figure 5 – Lab Tests for Vanadium Staining

very high mixes. We also looked at the soluble salts as a function of temperature to see if there was a correlation between these and the vanadium staining as discussed previously. soluble potassium, sulfate and chlorine, but did not find any relationship between vanadium staining and soluble salts for this material.

The gradient results for a blend of the lower kaolin materials is shown in Table 4. Since this material had more fluxes, the water absorptions were lower. For this material, you had to fire to less than 4.5% water absorption to eliminate the vanadium staining and again there was no evidence of a relationship between soluble salts and vanadium staining. There were several key takeaways from this study. The first is that the potential for vanadium staining is related to the

continued ⇒

Table 3 – Gradient Firing Results for High Kaolin Material

Firing Temperature (°F)	Cold Water Abs (%)	Observed Efflorescence (?)	Soluble Potassium (ppm)	Soluble Sulfate (ppm)	Soluble Chlorine (ppm)
1719	12.88	Yes	64.07	492.17	0.14
1764	12.45	Yes	46.50	95.39	0.18
1824	11.78	Yes	30.31	5.22	0.28
1889	10.79	Yes	27.81	2.30	0.21
1943	10.29	Yes	17.04	1.07	0.17
2005	9.13	No	7.87	0.34	0.14
2070	8.42	No	7.71	0.95	0.66
2110	8.04	No	4.59	1.53	0.20
2150	7.56	No	4.52	1.20	0.17

kaolin content where vanadium substitutes for alumina in the kaolin crystal structure at very low levels. The vanadium is not soluble in the raw material but becomes soluble after the material is fired hot enough to decompose the clay mineral. Unfortunately, high kaolin materials are more refractory than a typical brick mix and require higher temperatures to develop enough glassy phase and reduce water absorption enough to control vanadium staining. We did not find any relationship between soluble salt content and vanadium staining for these materials. With respect to strategies to control vanadium staining, we did find that there was a firing threshold for each material where we were able to eliminate the vanadium staining. The water absorption where we were able to eliminate vanadium staining was different for each material. The gradient test is a good way to find this absorption and use it in production as a guide.

In the next part of this work, which is ongoing, we will look at how additives might help us reduce the potential for vanadium staining. Additives such as limestone, and marble dust have been described in the literature. Anything that promotes vitrification and helps us develop more glass at lower temperature should also help. Just like any additive, the particle size of the additive and the degree of mixing will influence how effective the additive is.

Table 4 – Gradient Firing Results for Low Kaolin Raw Material Blend

Firing Temperature (° F)	Cold Water Abs (%)	Observed Efflorescence (?)	Soluble Potassium (ppm)	Soluble Sulfate (ppm)	Soluble Chlorine (ppm)
1806	6.39	Yes	17.83	2.09	0.29
1841	5.76	Yes	21.07	2.56	0.38
1888	4.69	Yes	15.52	1.38	1.15
1938	4.31	No	13.40	1.11	0.89
1979	3.18	No	8.26	0.65	0.76
2031	2.71	No	6.94	0.52	0.29
2084	2.51	No	3.61	0.66	0.51
2115	2.23	No	3.67	1.67	0.46
2150	2.06	No	3.79	2.43	0.60

LITTLE THINGS MEAN A LOT

Kaolin or kaolinite is one of the most common clay minerals in the US and can exist in various states of purity. These can include china clays—which have very low iron contents and fire to a white color—in addition to clays with a higher iron content that might be used for making brick or tile. Kaolin is also the primary component in most fire clays. In the southeast, most shale contains some kaolin along with quartz and other accessory minerals. The chemical formula for kaolin is $Al_2O_3.2SiO_2.2H_2O$ and it tends to exist as very small platy particles. The chemically bound water is emitted during preheat in a process known scientifically as "dehydroxylation" or, to use an old-fashioned ceramic engineering term, "water smoking."

What is the Solar Reflective Index and Why Does it Matter in the Brick Industry?

•••

by Theodore Lentz, Graduate Research Assistant, Materials Science & Engineering

While the solar reflective index (SRI) of brick is not currently being considered within any building codes and regulations relevant to the United States climate zones; however, it is heavily reviewed and monitored for other building materials. Most notably in any materials used for roofing. Currently controls on the SRI are already being implemented in roof construction with regulations from LEED and the U.S. Green Building Council concerning 'cool roofs.' Cool roofs refer to roofs made with materials specifically designed to reflect more solar radiation to decrease the flow of heat to the interior of the house. The mechanisms for the heat transfer that drives SRI are the same between walls and roofs, just with a different magnitude, as walls encounter less solar radiation. It is understandable that there may be future regulations on the building envelope regarding SRI.

SRI is an indicator to how a material will react when under solar radiation. This indicator is in the form of a number on a scale where 0 represents a black surface with a low solar reflectance and 100 is a white surface with a high solar reflectance. These black and white surfaces have the same thermal emissivity and are considered standards. By relating the SRI of a sample to the SRI of these standards, the behavior of a sample under solar radiation can be predicted. However, to determine the SRI of a material both the solar reflectance and thermal emissivity are needed.

Solar reflectance can be directly described as the ratio of solar energy encountering a surface by the amount reflected by the surface. This means that the solar reflectance determines the amount of solar energy absorbed by a surface and converted into thermal energy. This thermal energy or heat is then imparted to the building envelop where it is transferred to the interior of the building. A high solar reflectance means that the material absorbs less solar radiation leading to less thermal energy entering the building.

The regulations for higher solar reflectance came from the development of urban heat islands. Urban heat islands are areas of localized heat, usually within cities or metropolitan areas, as compared to the surrounding areas[3]. This difference in temperature is due to different surfaces located in cities. Large cities have numerous roads and large buildings leading to a large amount of the cities surface area being concrete or asphalt, while the areas surrounding the city are coated in vegetation[3]. The vegetation converts the solar energy to sustenance for the plant life, but the solar energy encountering the surface of the buildings and roads is converted directly into thermal energy or heat[3]. Also, due to the thermal mass of ceramics the effect of urban heat islands can primarily be seen at night when this stored heat is released. The best way to decrease the effect of the urban heat islands was to increase the solar reflectance of the cities or increase the vegetation within the city as energy cannot be created or destroyed, so it must be reflected, absorbed, or converted.

A smaller component of SRI, compared to solar reflection, is thermal emissivity. The thermal emissivity of a material determines how well a material can passively cool with surrounding atmosphere. All objects above absolute zero, 0K, emit thermal energy. The magnitude of the emitted energy determines the direction of the heat flow[1]. So, since a building is above absolute zero it is constantly emitting thermal energy and the surrounding environment, also above absolute zero, is also emitting thermal energy. However, if the

contiunues on page 28

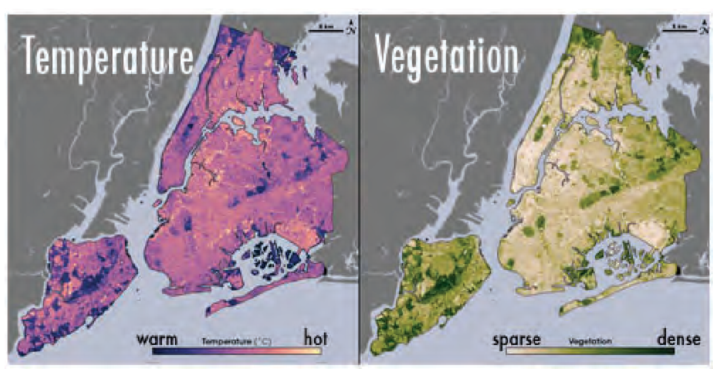


Figure I - Temperature effects from urban heat islands related to vegetation loss (UCAR, 2011)

wikibrick

WikiBrick is our exclusive brick-making encyclopedia, and it's only available to NBRC members.

Access technical articles, webinars and presentations just by logging in. You'll find all the content from our annual Brick Forums, past issues of Brickyard Magazine, and we've recently added a library of articles by Dr. Gil Robinson. Dr. Robinson founded the Center for Engineering Ceramic Manufacturing, now known as the National Brick Research Center.

To login, go to *brickandtile.org/wikibrick* and click Log In. If you haven't created your account simply click the link 'request one.' We'll approve your request as soon as we receive it!

LITTLE THINGS MEAN A LOT

Montmorillonite is another clay mineral found extensively in the states that border the Gulf of Mexico. It is characterized by a very small particle size and very high plasticity. Bentonite is a commercial clay that is mostly made up of the montmorillonite clay mineral. Montmorillonite is known to absorb moisture from the air and swell considerably as it absorbs moisture. Bentonite is sometimes intentionally added to low plasticity materials to improve extrusion behavior. High levels of fluxes like magnesium and sodium in montmorillonite result in lower firing temperatures than most kaolins.

building emits more energy that the surrounding environment, heat will flow from the building and it will experience passive cooling. This emittance is in the longwave infrared region using radiative heat transfer, and some materials are better at emitting within this region than others. This is because the thermal emissivity of all materials is related to a theoretical perfect black body with an emissivity of 1. This means that if a material is absorptive in the longwave infrared region it will have a higher thermal emissivity. So, ceramics commonly have a high thermal emissivity while metals commonly have a low thermal emissivity. When comparing thermal emittance to SRI there is a direct relationship, meaning the higher the thermal emittance of the material the higher the SRI.

The surrounding environment that the building losses heat to is both the nearby landscape and the skybox above the building. The nearby surrounding landscape is likely to be close to the same temperature as the building itself, leading to very little heat transfer. The sky above or around the building is transparent within the longwave infrared region[2]. There is also a large temperature difference as the average skybox temperature is 0° with the zenith being much colder than the horizon as the atmosphere is thicker towards the horizon[2]. So, the sky acts as a large thermal heat sink for the buildings and cities for passive cooling that can only be fully utilized by materials with higher thermal emissivity and solar reflectance[2].

While the SRI of brick is not currently included in any building regulations, the SRI of manufactured brick should be monitored. The high solar absorbance commonly seen in brick paired with its high thermal emissivity and thermal mass contributes to the urban heat island effect. By increasing the solar reflectance of brick, the contribution to the urban heat island can be decreased while also decreasing energy usage of the building. The National Brick Research Center is currently developing alternative methods to accurately and precisely measure solar reflectance and thermal emissivity. As well as develop methods and techniques to control and modify the solar reflectance and thermal emissivity of manufactured brick to optimize their SRI.

1. Holladay, Martin, and Martin Holladay. "Night Sky Radiation." *GreenBuildingAdvisor*, 11 July 2019, www.greenbuildingadvisor.com/article/night-sky-radiation.
2. Hossain, Md. Muntasir, and Min Gu. "Radiative Cooling: Principles, Progress, and Potentials." *Advanced Science*, vol. 3, no. 7, Apr. 2016, p. 1500360., doi:10.1002/advs.201500360.
3. UCAR. "Urban Heat Islands." *UCAR Center for Science Education*, 2011, scied.ucar.edu/longcontent/urban-heat-islands.

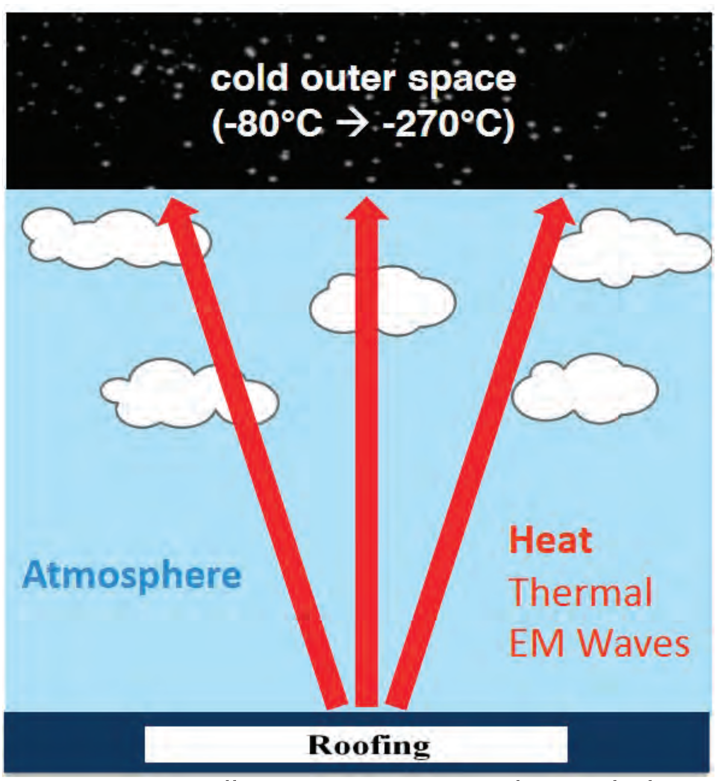


Figure 2 - Image illustrating passive cooling with the skybox (Holladay, 2019)

Staff Directory

Topic	Contact	Phone	Email
Technical Questions	John Sanders Mike Walker	864.656.0604 864.656.7358	jpsand@clemson.edu mdw8@clemson.edu
Raw Materials or Analytical Testing	**John Sanders Mike Walker**	**864.656.0604 864.656.7358**	**jpsand@clemson.edu mdw8@clemson.edu**
ASTM Testing	Mike Walker	864.656.7358	mdw8@clemson.edu
Meetings, Membership, General Questions	**Anne Jenkins**	**864.656.1096**	**ammcken@clemson.edu**
Dues, Invoicing, Accounting & The Brick Forum	Jessica Wagner Gary Parker	864.656.1104 864.’656.1473	roches2@clemson.edu parkerg@clemson.edu
Brickyard Magazine, The Brick Forum	**John Sanders Anne Jenkins**	**864.656.0604 864.656.1096**	**jpsand@clemson.edu ammcken@clemson.edu**
Webinars - Technical Problems	Anne Jenkins	864.656.1096	ammcken@clemson.edu
Webinars - Content	**Randi Sims**	**864.656.1094**	**rsims@clemson.edu**

/NBRCClemson @NBRCClemson bit.ly/NBRC-LinkedIn

LITTLE THINGS MEAN A LOT

Accessory Minerals are minerals present in brick mixes other than the clay minerals. The most common accessory minerals in brick mixes are quartz, mica, and feldspars. Less common accessory minerals are pyrite, marcasite, siderite, goethite, limestone, dolomite and gypsum. Accessory minerals can serve beneficial purposes like quartz which helps to limit shrinkage during drying firing while also causing other problems such as scumming or efflorescence with gypsum. The amount and type of accessory minerals depend on the local geology from where the raw material was extracted.

More at: *bit.ly/NBRC-LTMAL*

Thanks to our King Size Brick Forum Sponsors

To our Queen Size Brick Forum Sponsors

Bedeschi | Bongianni Macchine S.P.A. | Danser | De Boer Machines Nederland BV | Direxa Engineering, LLC | E.H. Wright Company | Halbert Mill Company | Hellmich | KELLER HCW GmbH | Lhoist North America LignoTech USA | Magneco/Metrel Inc. | The Manufacturers Equipment Company (MECO) | Midwestern Industries, Inc. | MoistTech Corporation Niokem, Inc. | Rockett, Inc. | Samuel Packaging Systems | STAR Engineering Inc. | Venator

And to our Modular Brick Forum Sponsors

Aggregates Equipment, Inc. | Capaccioli | DuBose Strapping | Ceratec | E. Dillon and Company Equipceramic, S.A. FLSmidth | Interstate Paper Supply Company (IPSCO) | KIMPE SAS Leiremetal McHale & Associates | McLanahan Corporation Orton Ceramic Foundation Polychem Corporation | Silike | TMI-USA, Inc. | Vitreus GmbH | Zschimmer & Schwarz