Coventry University and
The University of Wisconsin Milwaukee Centre for By-products Utilization,
Second International Conference on Sustainable Construction Materials and Technologies
June 28 - June 30, 2010, Università Politecnica delle Marche, Ancona, Italy.
Main Proceedings ed. J Zachar, P Claisse, T R Naik, E Ganjian. ISBN 978-1-4507-1490-7
http://www.claisse.info/Proceedings.htm

Concrete: Timeless, Sustainable, and Beautiful

Harry P. Moats

President & COO, L. M. Scofield Company, 4155 Scofield Road, Douglasville, GA 30134. E-mail: <harry.moats@scofield.com>.

ABSTRACT

Sustainable. What does this word really mean? Webster defines sustainable as, "relating to or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged". Does concrete meet this definition? Yes, more than ever before. Concrete is one of the most "sustainable" building products around.

IN THE BEGINNING

As recently discovered, concrete has been around since the days of the pharaohs, approximately 3200 BC. A form of concrete has been found in the pyramids. Around 2000 years ago the Romans used concrete to build roads and aqueducts some of which are still standing today along with more well known structures like the Pantheon in Rome, Italy. The Pantheon is the oldest large-scale dome in Italy and is made of concrete panels. The height to

Figure 1. Concrete Dome of the Pantheon.

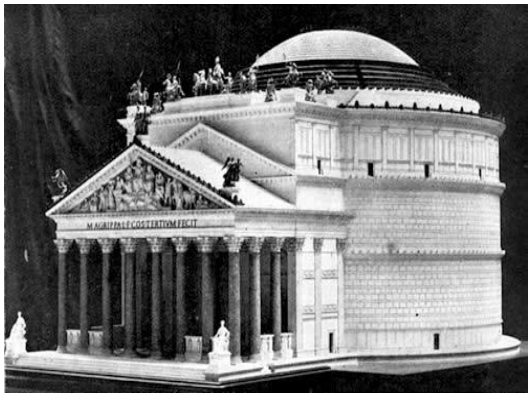

Figure 2. Model Rendering of the Pantheon.

the oculus and the diameter of the interior circle measure the same, 43.3 meters (142 ft.). The concrete dome weighs 4,535 metric tons (4,999 short tons). The thickness of the dome varies from 6.4 meters (21 ft.) at the base of the dome to 1.2 meters (3.9 ft.) around the oculus. From these early uses of concrete to the modern buildings of today concrete has passed the test of time.

Today more pounds of concrete are used than all other building materials combined. Except for some of today's chemical admixtures, concrete utilizes natural resources as its foundation.

These natural resources can be recycled and reused time and time again. Recycling concrete can result in considerable savings, as much as $ .25 per ton/mile, since it saves the cost of transporting concrete to the landfill, and eliminates the cost of disposal which is as high as $100 per ton. There are also no restrictions on the types of concrete that can be recycled. Machines today can crush more than 600 tons per hour or more. According to the U. S. Geological Survey, 7.3 million tons of concrete were recycled in the United States in 1996. So what is the value engineered benefits of recycling concrete? Recycled concrete can produce specific sized recycled aggregates at your location; avoid haul-off costs and landfill disposal fees and eliminate the expense of aggregate material imports and exports. Aggregates yield more volume by weight, up to 15% which increases jobsite efficiency and improved job costs. Recycling can minimize impact to community infrastructure by reducing import and export trucking. An additional benefit of utilizing recycled concrete is the potential qualification for LEED (Leadership in Energy and Environmental Design) points for the particular project. In fact, recycled concrete qualifies for both pre- and post-consumer LEED points. It also has been proven that recycled concrete can reduce shrinkage cracking and reduce initial set times, achieve higher 7 and 28 day strengths and can improve finishability.

Today's concrete has more recyclable content than ever before with fly ash and slag being some of the more prominent. These materials are by-products and residuals of other processes and are great pozzolanic and supplementary cementitious materials. With the more sophisticated mixes that are available, less cement and more pozzolins can be utilized to achieve the same design strengths and improved durability as cement alone developed just a few short years ago. What else in our world is more sustainable in today's building materials than concrete?

As the industry has grown from the first uses of concrete to the broad uses today, the world sees a different material with many more uses than it ever has before. From the first major structures such as the Parthenon in Athens, Greece, to the first skyscraper in the United States, the Ingalls Building, a 15 story concrete structure built in 1904 in Cincinnati, Ohio, to the masterpieces of Frank Lloyd Wright, concrete has become a very important element of design, functionality, strength and beauty. Concrete has and will continue to become a more important and valuable building material. There is no other structural building material that is delivered to a jobsite in a semi-liquid state, mixed on site and then transformed into any number of shapes, sizes and colors right before your eyes, than concrete.

CONCRETE INNOVATORS

Frank Lloyd Wright was one of the very first architects to truly understand the limitless ability of concrete to not only meet structural needs, but at the same time meet aesthetic needs. He designed and built with concrete elements as the main focus of his structures. Wright designed more than 400 buildings and homes in his career, many of which utilized concrete as the central building element.

Following suit were many other up and coming architects and engineers that have reached notoriety over the years by utilizing concrete as the center post of their designs. The 20th Century was really the proving ground for the many uses of concrete in structures because of their true nature of sustainability, again growing from structural elements to more eye catching aspects of form and color. As the market has continued to grow and expand, manufacturers of concrete products continue to push the limits of chemistry, imagination, and durability that has now changed concrete from this drab gray sustainable building material to

a beautiful mix of color and texture that changes the outside appearance as well as the interior motif of all types of public and privately owned structures.

Figure 3. The Parthenon, Athens, Greece

Figure 4. The Ingalls Building Cincinnati, Ohio

Figure 5. The Guggenheim Museum, New York City (Frank Lloyd Wright, 1959)

THE HISTORY OF SUSTAINABILITY

So let's go back to the definition of "sustainable" and look at some of the areas where concrete has become the epitome of "sustainability".

As we move a little closer into the 19th and 20th centuries more uses and more diversification of concrete and concrete related products were developed. A little know fact is that Thomas Edison promoted the value of concrete in the building of concrete homes. Edison's plan for concrete homes didn't materialize as he was slightly ahead of his time. Thomas Edison believed concrete homes would revolutionize homebuilding. He built 11 concrete homes. Throughout the last years of the 19th century and even more so in the beginning of the 20th

century, concrete advancements in design, engineering methods and construction techniques made concrete the prime material of choice for building construction. Even ships and boats were built out of concrete. Some are still being built today.

On August 2, 1917, N.K. Fougner of Norway launched the first ocean-going concrete ship, an 84-foot long vessel named Namsenfjord. With the success of the ship, several more small concrete vessels were built.

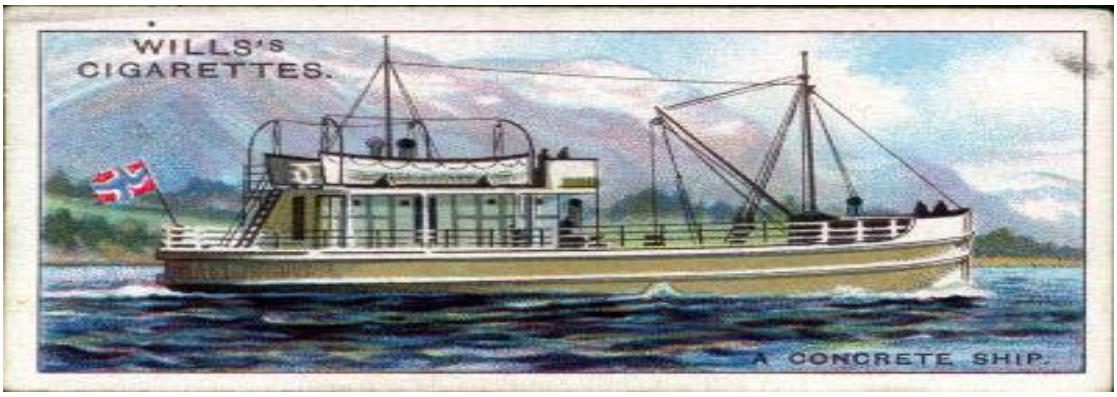

Figure 6. Picture of the Namsenfjord. Numerous small concrete boats were built in the U.K in the 1910's. One of these ships, the Violette, was built in 1917 and is currently used as a boating clubhouse on the Medway River in England. This makes her the oldest concrete ship still afloat.

So what changed? Why did we start moving more and more to the use of concrete in structures from foundations to architectural features on these buildings? The lack of natural materials, lack of skilled craftsmen, and the cost of both were starting to impact the building market drastically. Natural materials became more and more expensive as we trudged into the early years of the 20th Century and the old world craftsmanship, stone masons, stone cutters and true artisans started to dwindle and became fewer and fewer. This forced architects, designers and engineers to find less expensive methods of accomplishing the aesthetic features of their buildings. Concrete became the material of choice. Concrete was cheaper, more flexible to use, and it took workers with fewer skills to install this material. Of course, at this time the ability to color concrete, except for painting, which was not overly successful, had still not been developed. Around 1915 the first patent was issued for a coloring agent used to add color to the surface of concrete without painting it. This was an acid-based stain formulated from muriatic acid and heavy mineral salts that produced a limited selection of colors for the use of staining concrete surfaces both for interior and exterior use. This really set the trend for things to come. Concrete was starting to be seen as a building material that not only provided structural strength but flexibility in design to include color and textures never thought of before. This became the catalyst for manufacturers of these products to become aggressive in product development to meet the changing demands of the design community.

20TH CENTURY ADVANCEMENTS

Over the past 30 years, extreme advancements have been made in not only composition of concrete but also how concrete is transported, handled, treated, and finished. As these advancements have evolved so has the ability of concrete to fill a much larger role in building design and construction. A true palette of form and color has changed the way we look at

concrete. As concrete started making an impact on the design community the first thoughts were, how can we make concrete look more attractive and eye catching compared to the drab gray building material that it had become know as. So, color was added to change the appearance and texture. As previously noted stained concrete was the first coloring material utilized to make this visual change. This was just the beginning. Concrete started being recognized as a different form for expression of home and commercial applications alike. This form of color and texture started replacing natural and man made materials such as tile,

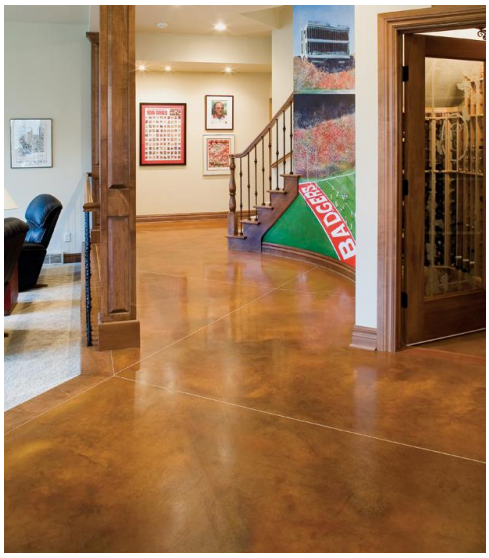

Figure 7. Acid Stain in Residence

Figure 8. Acid Stain in Retail Area

cut stone, granite, carpet, vinyl and other more costly materials. Each project became "one of a kind" because of the nature of stain and its unique and different reactivity to concrete from location to location and from project to project as seen in Figures 7 and 8. The benefit to the homeowner or business owner is the sustainability of the surface for wear, beauty, and uniqueness at a low cost of maintenance compared to conventional methods of floor coverings. This same concept applied to interior or exterior concrete. In the beginning the variation of colors were very limited so the next challenge was to find ways to add a wider array of colors which would allow for a more extensive use as an exposed aesthetic surface. The use of concrete as a finished or final surface in a building improves the air quality of the space. Concrete does not out-gas harmful or toxic substances into the air. The same cannot be said for other floor treatments. Indoor air quality is of specific importance and consideration for schools, public buildings and hospitals. These are areas where exposed concrete is being utilized more and more every day. Concrete is resistant to mold and fungus growth, does not trap dust, dirt or allergens, and acts as an air barrier limiting moisture migration.

Next came the development of integral color for concrete. With this invention, color selection expanded greatly. Today, thousands of colors are available to choose from: pastels, blacks, reds, blues, and everything in between. This development really opened up the market for the use of concrete to far greater potential than it had experienced to this point. Architects and designers were pushing the limits of their imagination to utilize concrete to enhance the beauty of their projects both indoors and outdoors. This has become extremely evident in many of the theme parks such as Disneyland and Disney World where concrete has been utilized, as not only a color enhanced walking surface, but also an element of form

where concrete rocks, waterfalls, and building facades have used concrete to replace expensive and hard to get natural materials. By doing so, concrete has saved many areas from being destroyed, disturbed or just plain ruined by having to remove these natural materials that once were the only materials available for such looks and effects. Not only did the use of concrete save our natural beauty in areas where these materials would have been removed, but also saved the cost of removing and transporting such materials from literally all over the world. Of course the durability of concrete is second to none compared to these natural materials. If you desire to change the color or form later there are many ways to accomplish this with today's materials without having to remove and replace the base concrete. With concrete you can recycle and reuse the materials and start the process all over again. What could be more sustainable?

Figure 9. Integral Colored Concrete Hotel pool deck.

Figure 10. Integral Colored Concrete New York City Street.

The next process that arose was that of imprinting or stamping concrete with a texture. This added another element that continued to raise the bar for the design community. Now concrete could take on a life of its own where concrete could replicate many more natural materials. A process was developed by which a surface applied cement-based colored material was broadcast onto the yet plastic concrete, then trowelled into the surface where it became integrated with the base concrete and then stamped with a defined and unique texture that was specific to the architect's or designer's needs. This unique material became known as color hardener to the architectural and decorative concrete industry. Not only did it color the surface but it also provided an extremely abrasion and wear resistant surface that could take a lot of abuse but still look natural and beautiful for many years with little maintenance. Some installations have been in place for more than 30 years and still look very appealing. The process of utilizing a color hardener, antiquing release material and a stamp tool or texture mat has been able to replicate natural materials from all over the world. This could take an old world look and place it into a new world design. The combination of texture and colors is almost limitless. How much more sustainable can concrete be than to replace natural materials with a durable, flexible and recyclable material at a lower cost and greater flexibility? Concrete is resistant to rot, corrosion and fire. Concrete provides thermal mass

for energy efficiency and concrete surfaces are easy to maintain, reducing maintenance costs. Whether in building infrastructure, vertical surfaces or decorative concrete, concrete exemplifies sustainability.

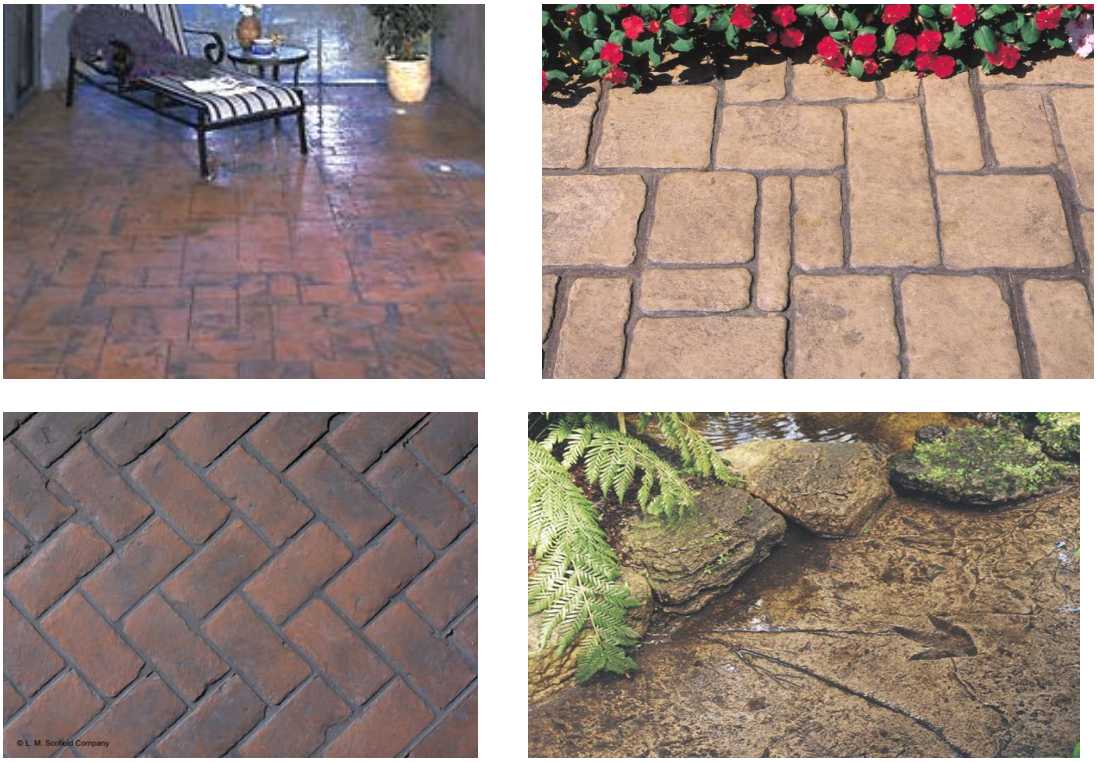

Figure 11. Examples of textured concrete surfaces, replicating stone, brick and even dirt with embedded leaves.

The market demand for a thin resurfacing material that could be placed in 3/16" or more thickness opened the door for a broad range of products that could be spray-applied and trowel applied to add color and texture to resurfacing concrete that was old, warn, damaged or just needed a face lift. The same stamping process stated above could be utilized with these thin toppings as long as the depth of texture did not exceed 75% of the depth of the material. This material can be stained or integrally colored. These materials have taken concrete chemistry to new levels by taking such a thin mass and handling issues such as shrinkage, cracking and delamination very effectively. The results are astonishing and give a finished product and appearance that pushes the imagination. This not only eliminates the need for the base concrete to be replaced, and makes it possible to change the appearance of existing concrete, not only once, but several times before having to replace the base concrete. These cement and polymer based materials are reasonably durable and are suitable for indoor and outdoor installations as noted in Figures 12 and 13.

With these thin topping materials, new and creative ways to color, texture and enhance the product has given the end user a very wide variety of choices in decorative and non-decorative finishes in both residential and commercial environments. Not only can you save time and cost associated with the installation of these products compared to replacing the concrete and starting over but you can get a durable surface that is light and heat reflective depending on the colors you select.

A derivative of these thin toppings are the micro toppings which go down extremely thin, approximately 2.54 centimeters (1/16") or less. These materials are used to resurface existing floors and to provide a new palette for color and design features at a low cost.

Figure 12. Thin Topping Material (3/16") Imprinted and Stained.

Figure 13. Ultra Thin Micro Topping with Waterbase Stain.

A driving force that helped propel concrete as a visual building material was the development of the large theme parks. Disneyland, Euro Disney, Tokyo Disney, Universal Studios, Sea World and others have brought a new use to what can be done with concrete as both a structural element and an inexpensive visual element. Theme parks became high traffic and exposure venues to show off what could be accomplished with concrete to replicate many different natural materials at a much lower cost to the owner. True natural materials such as marbles and other quarried materials are becoming more and more expensive to obtain and install. There are many areas of decorative concrete at Disneyland that were installed over 40 years ago that still have an attractive appearance and have passed the test of time for durability and sustainability. With this exposure to so much of the general public and also the design community, more and more architects and engineers have started designing with a more visual intent in mind as they not only pushed the limits of the imagination but also the limits of available products to meet these new design concepts. The industry, from material suppliers to ready-mix producers to the installers, have all contributed to the development of useful and sustainable products that are changing the world of concrete. As we move further into the 21St Century, cost, durability, sustainability and low cost of maintenance are the marching orders for architects, engineers, designers and interior decorators. What concrete has done and will continue to do is meet the needs of our ever changing world. Thanks to the efforts of cement and concrete suppliers, coloring product manufacturers, and admixture companies, concrete is more versatile today than ever. Also, in the 21st Century and beyond environmental concerns and issues will continue to drive the direction of building construction. Programs like LEED developed through the U. S. Green Building Council will help steer the future of concrete as an environmentally friendly, versatile and aesthetically pleasing building material. These products will help contribute to LEED points for their heat reflective characteristics and VOC (Volatile Organic Chemical) compliance and help create structures that are environmentally safe and energy conscious.

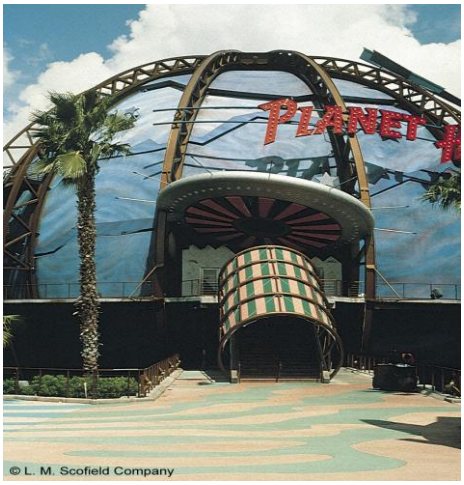

Figure 14. Planet Hollywood
Orlando, Florida

Figure 15. Theme Park Entry
Hershey, Pennsylvania

THE 21ST CENTURY AND BEYOND

"Green" is becoming the buzz word throughout not only the concrete industry but our entire planet as we look at the effect of years of use and abuse of our natural resources and environment. More and more architects, engineers and designers are embracing environmentally friendly designs as the general public is exposed to the concepts that Greenbuild embraces. ICF (insulated concrete forms), low VOC, low maintenance requirements, and energy saving systems are a primary focus of the design community and the general public. Concrete today can blend with the environment; it can be light and heat reflective, it can provide architectural features at a low cost and is long lasting, durable and sustainable. Concrete can replace many other non-environmentally friendly building materials and provide shape and color where before, less environmentally friendly materials were used. This is true not only for horizontal surfaces but also vertical surfaces as demonstrated in Figure 16 with this tilt wall project. The color and texture incorporated

Figure 16. Tilt Wall project utilizing concrete for color and texture.
Atlanta, Georgia. Headquarters, L. M. Scofield Company

into this structure is all concrete, no paints, coatings or other man made materials were used. This is the true definition of sustainability. This building has been in service now for over 18 years without any maintenance on the structure except for an occasional power washing and will still hold its color and character for many years to come.

New products like pervious concrete for exterior parking areas and roads is being developed to provide for an environmental alternative to asphalt. It is able to return surface water back to the ground quickly and efficiently without having to have detention or containment ponds. This product is gaining wide popularity and will become a large factor in the future design and development of residential and commercial projects. With this development comes an opportunity to take a more mundane concrete product like pervious and make something pleasing to the eye with the benefits of a truly environmentally friendly product. Figure 17 shows what can be done with pervious concrete by integrally coloring it and staining the top surface.

Figure 17. Pervious Concrete, integrally colored with stain applied to the surface to create an effect symbolic of two rivers converging. Minneapolis, Minnesota

Concrete reflects more heat than all other widely used exterior paving products such as asphalt. Testing done through thermal imaging proves that exposed surfaces of concrete versus asphalt are considerably cooler and have much less heat sink characteristics. Today and in the future, more and more products used for exterior hardscapes are and will be rated utilizing the SRI (Solar Reflective Index) adopted by LEED and the Green Building Council to reduce the heat island affect that is becoming an ever increasing concern. The concrete industry has done well to embrace these standards by incorporating them in their product development. We will see more of this as technology improves and chemistry is developed to meet this new demand. Products such as integral color and dry shake color hardeners that have patented SRI improving characteristics are now available which will give the engineers the ability to utilize colors that would not typically be able to be used because of their heat absorbing characteristics. Now these products and colors are more heat and light reflective. Another attribute is that they are also somewhat self cleaning or restoring allowing the surface to maintain its reflective attributes longer with little maintenance. This is another true measure of sustainability. The current threshold to meet LEED requirements is a minimum SRI of 29. Asphalt has a SRI of 0.10. Dark colors of concrete today can be manufactured to provide an SRI of 35 to 39. As the colors graduate from dark to light so does the SRI where some of the lighter colors can give an SRI rating of over 75. These materials are manufactured from very specialized pigments and ingredients that are colorfast and UV

stable. This technology will continue to grow and expand as the industry works hard to find new and better ways to meet the needs of a visual society but also an environmentally concerned society.

The grind and polish segment of the concrete industry is also making great strides in making concrete more attractive, durable, and sustainable through their unique process of restoring, grinding, staining and polishing on concrete surfaces that are many years old to brand new installations. This process has allowed other floor coatings and coverings that are less environmentally suited to be eliminated or replaced by exposed concrete. These surfaces are very durable, easy to clean and maintain without harsh chemicals. The products and equipment utilized in this process are environmentally sound. An example of these results is noted in Figure 18 and 19.

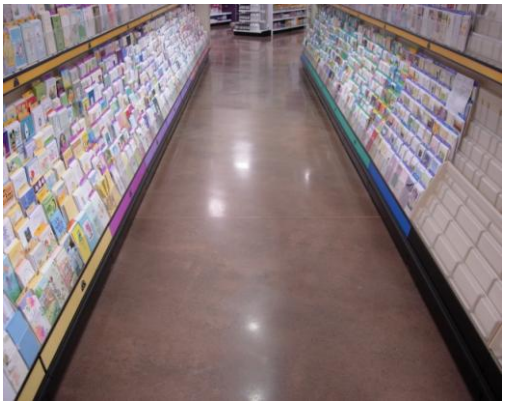

Figure 18. Retail Store
Ottumwa, Iowa

Figure 19. Commercial Warehouse
Waterburg, Vermont

WHAT IS NEXT?

The possibilities are limitless and as long as engineers, architects and designers are willing to push the expanse of their imaginations there will be industry leaders who will meet and exceed these demands. As we continue to learn more about a building material that has been around for centuries, we have only scratched the surface of what concrete can and will be used for in the years to come. New emerging markets will continue to evolve as today and tomorrow's technology continues to expand beyond our comprehension. As we look to areas of the world that have extreme conditions such as heat and cold, severe weather, a shifting earth, concrete will be developed to meet and exceed the need for strength, durability and sustainability. The world in which we live is finally grasping the concept that we have to conserve our natural resources and make better use of them. Concrete is going to play a very important role in our conservation measures. We are looking to the future to even build on other planets, probably sooner than we think and what will that concrete look like, how will it perform and how sustainable will it be, time will tell.

As demonstrated, concrete is durable, long lasting, flexible, structural and beautiful. This is a true testament to what "sustainability" is all about, past, present and future.