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# **THE PERFORMATIVE POTENTIAL OF CERAMIC SYSTEMS FOR PREFABRICATED CONSTRUCTION**

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## **STATE OF THE U.S. ARCHITECTURAL CERAMICS INDUSTRY**

Since the heyday of architectural ceramics at the turn of the twentieth century and its subsequent decline through the modern period, numerous ceramics manufacturers throughout the country closed as a response to decreased demand, leaving a sparse number of large-scale architectural ceramics manufacturers in operation in the United States. These include Boston Valley Terracotta (BVT) in Buffalo, New York and Gladding McBean in Lincoln, California. Although these industries have evolved in terms of the type and scale of manufacturing, the high cost of retooling and low profit margins have hindered major technological advances, especially regarding the adoption of digital fabrication machines for mold making.

However, growing demands for off-the-shelf façade systems demonstrate a renewed interest in architectural ceramics and potential growth for the industry. US manufacturers who have lost jobs to international architectural ceramics manufacturers including industry giant NBK Ceramics, recognize the necessity to evolve. For example, BVT is investing in design and technology research and continues to develop new product lines, including rainscreen systems. Given increasing demand, it is hopeful that manufacturers in the US will expand product lines, which will decrease transportation costs to building fabrication sites.

## **DEVELOPMENTS IN CONSTRUCTABILITY AND MODULAR SYSTEMS**

Ceramics have been utilized on a surficial level throughout the modern era as an exterior and interior finish, and are usually wet-mounted. Two recent examples of large-scale ceramic surface projects include 3LHD's Zamet Sports and Cultural Complex Centre in Rijeka, Croatia, completed in 2008, which utilizes 51,000 tiles (custom designed and fabricated) on the horizontal and vertical exterior surfaces of the public project. Employing a similar grey color palette but a simpler geometry, tiles also envelope the Paraninfo de la Universidad del Pais Vasco in Bilbao, Spain, which was designed by Alvaro Siza and completed in 2010. These institutional projects take advantage of the durable, self-cleaning, low-maintenance aspects of ceramic. As a surface paver, the material is much more ecological than concrete or asphalt, and also reflects and diffuses sunlight.

Although pervasive, surface tiling is a limited utilization of ceramics, especially when investigating the potential of ceramics through the lens of prefabricated construction. As a moldable material, ceramic can do work through form and a growing number of manufacturers are developing off-the-shelf façade systems for solar shading and rainscreens. With improved manufacturing technologies and precision in fabrication, these systems are being manufactured as lightweight hollow-core, dry mounted systems, which can be disassembled and potentially re-used.



Figure 1. Sauerbruch & Hutton Architects, Museum Brandhorst Collection, (manufactured by NBK Ceramic), 2008<sup>1</sup>

Examples of large-scale modular screen systems include the colorful rainscreen designed by Sauerbruch & Hutton Architects and manufactured by German ceramics manufacturer NBK for the Museum Brandhorst Collection in 2008. In another example, large swaths of color distinguish Renzo Piano's Central Saint Giles Court, which was completed in London in 2010. The story-high, perforated panels perform as rain screens and provide solar shading. In both projects, ceramic is utilized for its durability, water-shedding capabilities and aesthetic performance achieved through the material's ability to be molded, texturized and colored, thereby defining the aesthetic character of the projects.

These off-the-shelf solar shading and rainscreen systems hold a number of benefits for offsite construction. Firstly, although not as lightweight as wood composite systems, the ceramic systems are more durable and light enough to be easily handled and assembled. Furthermore, clipping and bolting hardware enable dry mounting,

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which speeds up the construction process and facilitates replacement or reuse of modules throughout and after the life of the project.

### DEVELOPMENTS IN MANUFACTURING

As these pre-assembled systems become more popular and cost-effective, the industry is poised to expand into the realm of digital fabrication. Numerous contemporary architectural design practices are working at the cutting edge between analog and digital making, exploring the potentials of integrating craft, tooling and material sensibilities in the creation of new effects and experiences. Some of these designers include Enric Ruiz, who worked with Toni Cumella on a solar screen for the Villa Nurbs; the EcoCeramic research at the Center for Architecture Science and Ecology (CASE) in which Rhino, Ecotect and CNC-milled formwork were utilized to develop a structural facade; Jenny Sabin, who has taught design studios focused on 3d printed ceramic; Zoe Coombes and David Boira of Cmmnwlth who developed STL molds for ceramic objects; and Evan Douglas and Rhett Russo, who each held fellowships at the European Ceramic Work Centre (EKWC) where digital fabrication tools were utilized in the production of formwork. Although each of these designers is currently working at a small scale, the work demonstrates the potential for the use of digital fabrication machines to facilitate intricate, but highly precise ceramic object-multiples.

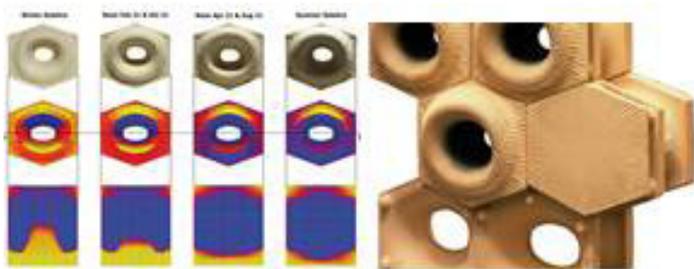


Figure 2: Center for Architecture, Science & Ecology (CASE), EcoCeramics, ongoing research<sup>2</sup>

Although this research is incredibly promising, on the whole, and especially in the US, the ceramics industry has only timidly dappled the realm of CNC form making. Because of the technical expertise required for digital fabrication and ceramics production, the most interesting design research is often achieved through cross-disciplinary partnerships. Taking the Villa Nurbs as a case study example, architect Enric Ruiz partnered with internationally known ceramist Toni Cumella in the design and fabrication of a solar screen for the southern façade of the residence. Ruiz and Cumella designed a module, which varies and repeats in order to create a textured gradient across the bulging form of the façade. Molds were fabricated from CNC milled foam, which enabled double curvature of the modules, aiding in their performance and system of assembly. The clay was mechanically rolled into thin sheets, cut as a 2d profile and then slumped over the formwork where the pieces were dried before

firing. Once kiln-dried (which enables the plasticizing process and generates hardness), the pieces were then painted by artist Frederic Amat and clipped onto a simple cable system that holds the pieces away from the building skin to facilitate airflow.



Figure 3: Enric Ruiz with Toni Cumella and Frederic Amat, Villa Nurbs, Empuriabrava, Spain, 20113

The potential of customization for prefabrication is incredible, and especially exciting when designed with site-specific environmental data integrated into designs through Building Information Modeling or parametric modelers. When using Grasshopper combined with Geco and Ecotect, for example, singular façade systems can be modified for different climate zones. Using the same module, horizontal depth and vertical aperture sizes can be manipulated to achieve the desired solar screening for specific climatic conditions. The modules can then be constructed utilizing a small set of digitally fabricated forms to generate multiples. This highlights another environmental benefit of the use of ceramic: once molds are made, there can be minimal material waste (except that which occurs through breakage during firing). Formwork can be selectively modified (through inserts or cuts) to create aesthetic variation and environmental performance without generating the material waste that would result from individualized forms.

The formal possibilities enabled through digital fabrication can be achieved through cross-disciplinary collaborations amongst designers, digital fabricators and ceramics manufacturers. Customized mold making and one-offs are often constrained by the costs of labor and tooling. Repeatability is essential for the bottom line, a concept that is paralleled on a larger scale in many prefabricated projects.

Despite the virtual absence of CNC mills and laser cutters in the ceramics industry, manufacturers have made a number of strides in tooling. Product lightness has been greatly enhanced through improvements to machines. High impact ram presses and rollers reduce air pockets, compacting the material to ever-thinner profiles. Large-scale extruders and kilns also enable manufacturers to create hollow-core louver and rainscreen elements 10' or longer, permitting lightness for handling and transport.

Two examples of ultrathin surface products include the large-format SlimmKer tiles, manufactured by Inalco in Spain and the 3mm

thick SlimTech, which is made by Lea Ceramiche in Milan. The lightweight material can be utilized as an interior finish and easily handled and transported. However, the benefits of using these products (as with all architectural material specification) must be balanced against transportation distance from the manufacturer to the fabrication site. Given the impact of weight in prefabricated assemblies, these and other lightweight products hold promise for use in offsite constructions.

## DEVELOPMENTS IN COMPOSITES AND MATERIALS RESEARCH

Equally as exciting as a renewed interest in ceramic façade systems, there is also great potential for ceramic to do work on a molecular level, an area of research that will dramatically transform the building industry. Material engineers have focused on the use of additives to improve ceramic strength, toughness and environmental performance. Perhaps the most transformative areas of research focus on the use of polymer additives, which are also revolutionizing the concrete industry. Similar to the concrete product Ductal, the addition of polymer additives into ceramic make it possible to create thinner, lighter ceramic structural elements. These new miracle clays originate in laboratories focused on developing lighter military armor using ultradurable, lab-formulated ceramic coatings<sup>4</sup>. According to a Technology Review of a *Science* magazine report, “The polymer permits the brick-like layers to slide over one another when stressed, making the material resistant to fractures... [T]he ceramics created at Berkeley have as much strength and toughness as aluminum alloys.”<sup>5</sup> By reevaluating this research within the context of the building industry, researchers are recognizing that improved strength and toughness permits a broader range of uses for ceramic, not only for fireproof coatings but also in creating ceramic structural modules.

Another method of improving ceramic tensile strength involves fiber additives. Similar to Glass Fiber Reinforced Concrete (GFRC), when added to clay mixtures before firing, the glass improves the plasticizing process and increases strength. While researching structural integrity of ceramics at CASE, glass fibers were utilized in the EcoCeramic modules. According to Jason Vollen and Dale Clifford, “The addition of glass fiber composite reinforcement significantly increased both the tensile and compressive strength of the clay body...tensile strength increased by approximately 100 percent and compression strength by approximately 300 percent.”<sup>6</sup> Although these additives may affect the recyclability of the ceramic, the environmental impact and lifecycle assessment needs to be weighed against concrete, which is the source of 5% of worldwide CO<sub>2</sub> emissions.

Other researchers are investigating clay additives as a means of harnessing the ability of the earthen material to filter air and water. In one example, Chicago-based manufacturer Stonepeak Ceramics has utilized a titanium dioxide coating for tiles that collects air pollutants. “According to closed-chamber Tile Council of North America tests, the company’s additive reduces smog by 70 percent.”<sup>7</sup> Biofilters, bioscrubbers and membrane bioreactors have

been used to remove odor at waste treatment plants for decades<sup>8</sup>. Numerous labs are investigating the use of microbial scrubbers on building facades for pollution mitigation, which may be incentivized through environmental ratings systems.

Water filtration through ceramics is a largely untapped area of research within the architectural context. Potters for Peace, Reservoir Studio and scientists at Penn State have developed ceramic drinking water filtration systems in developing countries. Potters add a burnout material (i.e. sawdust) to clay and water in a 2:3:2 ratio, and for its antibiotic properties, 300 milliliters of a 3.2% colloidal silver solution. The sawdust incinerates during the firing process leaving tiny porous pockets throughout the clay body. The ceramic vessel is placed within another container and as water seeps through the ceramic, particulates are captured. Remaining microbials are filtered by the colloidal silver, which was commonly used as a natural antibiotic until the 1940s, and is considered to be an effective means of filtering drinking water by the World Health Organization. The pots can be used to create drinking water for a family for up to five years.

In a similar vein, but on a larger, architectural-type scale, researchers at Kochi University in Japan have documented the successful filtration of water bodies using composite ceramic membranes and balls<sup>9</sup>. In their tests, along with various additives, ceramic proved to be an effective filter for microbes, viruses, heavy and toxic metals, concluding that ceramic “plays a significant role in providing a promisingly clean and hazard-free aquatic environment at a low cost without any negative feedback.”<sup>10</sup> Ceramic composites as air and water filters hold tremendous potential for architects and architectural materials manufacturers seeking to maximize the ecological performance of building structures.

## CONCLUSION

The architectural ceramics industry will continue to expand and evolve, especially in the realm of environmental performance and constructability. Recent advances in the constructability of systems, manufacturing processes and material performance are poised to transform the building industry. Continued research and specification of these systems are essential.

Kilns are of particular interest when scrutinizing environmental impact of ceramic products for energy expenditure and emissions. A few of the reported “eco-friendly” kilns in production include the Hybrid Hoffman Kiln, which blocks greenhouse gas emissions and recycles heat during the drying process. Another, the ECCD, uses magnetic currents to generate thermal energy thereby eliminating CO<sub>2</sub> emissions. From the website, “...the drum generates heat on its own so no noise or dust is released into the environment... Since this unit uses eddy current to generate heat, maintenance is virtually non-existent.”<sup>11</sup>

As with many manufacturing industries, the ceramics industry has been slow to transform. An increased market demand will drive

technological advances in prefabricated ceramic assemblies. Integrated design development through collaborations amongst architects, ceramists and manufacturers is essential to proliferation of skills and sensibilities.

### ENDNOTES

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