

CERAMIC TILE ON THE FOREFRONT OF ARCHITECTURE A 10 Year Retrospective



Richard P. Goldberg AIA, CSI, NCARB

Architect – Professional Consultants International, LLC (PROCON)

Richard P. Goldberg, AIA, CSI, NCARB is an Architect and President of Professional Consultants International, an international building design and construction consulting company. Mr. Goldberg is involved in all phases of a building project, from research and design development, to construction monitoring and forensic investigations.

Mr. Goldberg has over 32 years of architectural and construction industry experience.

He is an internationally recognized specialist in ceramic tile architecture, and he is responsible for design and specification of many significant tile façade cladding projects, including the 75 story Al Hamra Tower, Kuwait, the Brooklyn Children's Museum, New York City, USA and the Hilton Rainbow Tower, Honolulu, Hawaii, USA.

Over the past 10 years since my 2002 QUALICER presentation about the future of ceramics in architecture, many of the concepts and ideas presented at that time have come to fruition. In 2002, when the concept of sustainable architecture was in its infancy, I was convinced that ceramics were well positioned as a building material with the perfect balance of sustainable design and performance characteristics.

Now, in 2012, sustainability is the driving force in building design and materials, and ventilated tile building façade cladding systems have clearly demonstrated that sustainable architecture can be realized by offering reduced impact on material manufacturing and distribution, as well as significant efficiencies in technical performance, such as dissipation of and protection from wind, rain, sound, airborne contaminants and solar radiation.

Similarly, in 2002, computer analysis of complex composite material assemblies like adhered ceramics was not technically or economically practical. Now, 10 years later, computer hardware and software allow architects, engineers and product manufacturers to predict the behavior of non-linear composite wall systems (Figure 1) such as adhered and mechanically anchored ceramic tile building cladding systems with greater confidence and success.



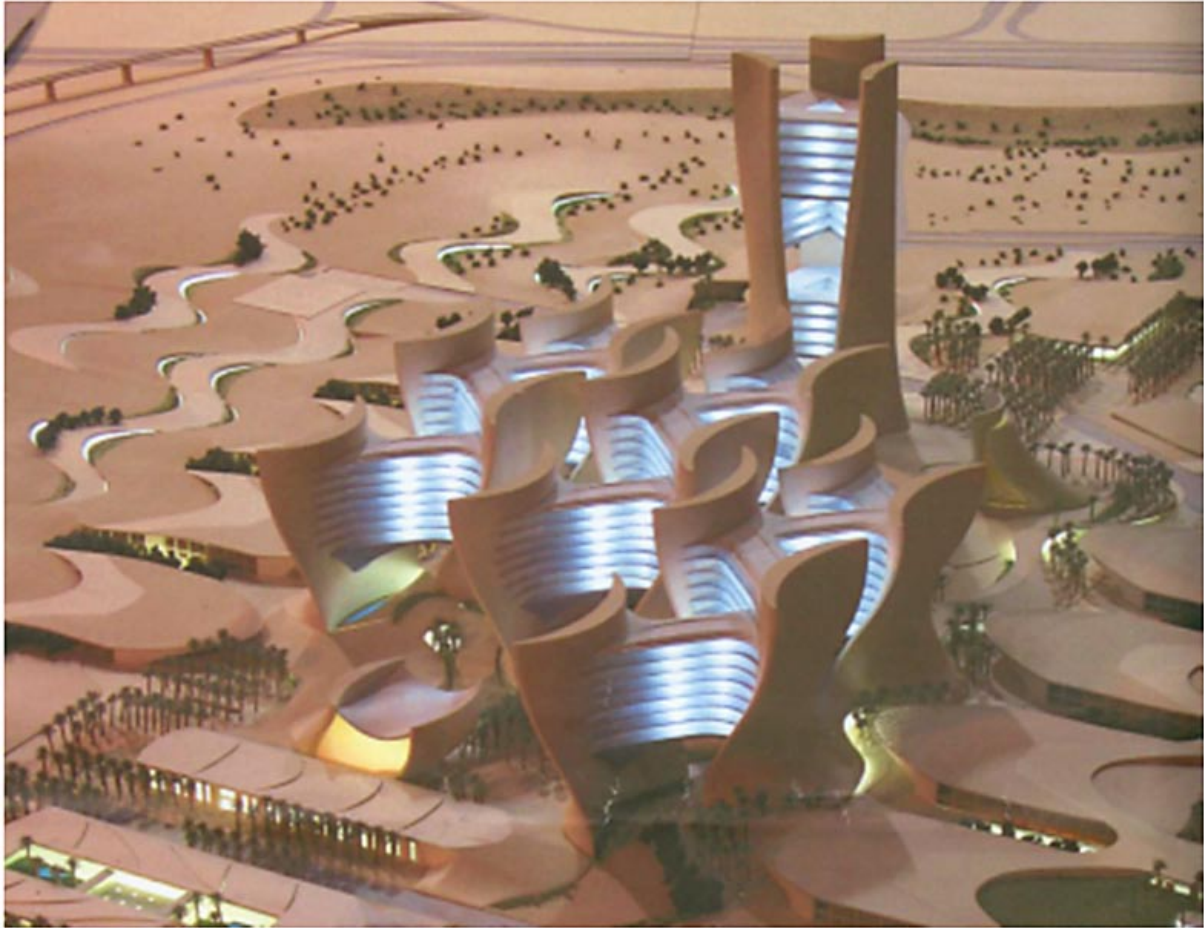
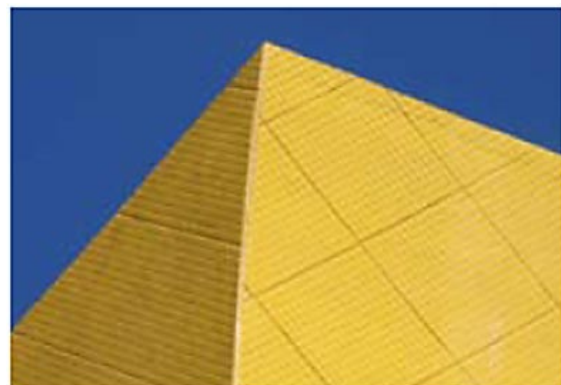


Figure 1 – Finite Element computer modeling was used to predict performance of adhered ceramic tile façade on non-linear structural system for Qatar Petroleum (design by SOM Architects)

As a result, we are now starting to realize the true potential of applications for ceramics in architecture by establishing an identity as an industry that is market-oriented, and a supplier of “system-based” integrated solutions, and not just focused on providing a high quality ceramic tile building material without consideration of context.

In 2002, I offered the comparison that the ceramic tile industry was in a similar position then as the glass industry was in the early 20th century. Glass use in architecture was limited to small areas. This was due to its high cost, impossibility to produce in large sizes and the difficulty of installation. When the constraints of the production process and lack of integrated ancillary systems such as curtain wall frame were removed by modern technology, the use of glass surfaces became and remains fundamental in modern urban architecture. In a similar fashion, the ceramic tile industry is poised to repeat building history by removing previous production constraints, and developing “system-based” applications to take advantage of the tremendous production improvements and product innovations and solve common technical problems.

The challenge moving forward in addressing sustainability and taking advantage of the technological opportunities is to avoid letting the boundaries of our current knowledge of traditional architectural applications for ceramic tile limit our imagination of the possibilities for broader and more significant use in architecture (figure 2). We all know too well how certain ideas such as computer information modeling or social media, now with 800 million connected users (i.e. Google or Facebook), were unthinkable 10 years ago, yet those former far-reaching concepts now dominate and have forever changed our cultures and economies.



*Figure 2 – Bold forms and imaginative, colorful building façade design afforded by ceramic tile cladding - Brooklyn Children’s Museum New York City, USA
(design by Rafael Vinoly Architects / PROCON)*

1. CERAMIC TILE – ON THE FOREFRONT OF SUSTAINABLE ARCHITECTURE

Sustainability and environmental stewardship of building systems is a top priority with the current generation of architects and building engineers. Until recently, sustainability in architecture had been loosely regulated, with many dubious claims by product manufacturers. However, architects now demand more demonstrable scientific evidence about product sustainability, and more important, that product manufacturers are committed to a “holistic” approach in producing sustainable building products. Many manufacturers focus only on product attributes, such as recycled content, often without any consideration of related issues, such as corporate dedication to environmental innovations in product production, or management of life-cycle uses of their product.

So where does the ceramic tile industry stand in the latest iteration of sustainable architecture ? It is good news that the ceramic tile industry is a leader in efforts to minimize the environmental impact of buildings, with programs such as the Green SquaredSM sustainability certification initiative developed by the Tile Council of North America TCNA under the auspices of the American National Standards Institute ANSI accredited ASC A108 standard committee process. Green SquaredSM is a comprehensive program that is the first “ceramic tile industry-specific” sustainability program that assesses ceramic tile and installation product manufacturers “holistically” in five categories (Figure 3). This program also provides an established certification agency, Scientific Certification Systems, to assist ceramic tile and ceramic tile installation product companies in the certification process, as well as assisting in gaining recognition with other established sustainable building systems programs, such as the U.S. Green Building Council (USGBC) LEED rating system. The Green SquaredSM initiative is especially important, as it will facilitate the ceramic tile industry’s compliance with specific requirements of the International Green Construction Code (IgCC), which has been recently approved by the International Code Council at final public hearings, and will be published in Spring 2012.

Assessment Categories

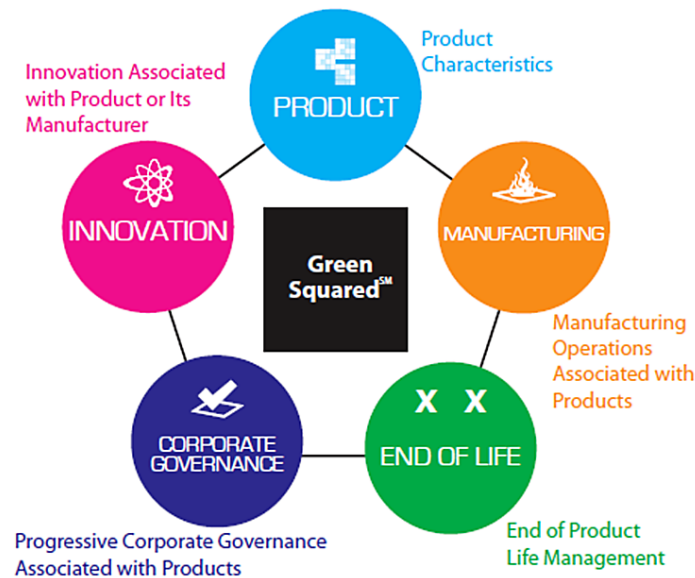


Figure 3 – Tile Council of North America Green SquaredSM certification categories "next generation" holistic approach to ceramic tile product sustainability

While the ISO 14000 series of International Standards and the EMAS European Eco-Management & Audit Scheme for environmental management of business are not ceramic tile industry-specific, these voluntary standards and certifications are well established and already provide a solid framework for continuous improvement and updating of environmental policy in the ceramic tile industry. The focus of these standards is the "Assessment of Environmental Impacts", which defines environmental attributes of products and related production activities, and their effects on the environment.

2. CERAMIC TILE PRODUCT INNOVATION

Product innovation is equally, if not more important to architects in assessing environmental impact of their building designs than physical product attributes (Figure 3). The tile industry has repeatedly demonstrated innovations which improve ceramic tile environmental impact, ranging from production of super large tile formats to 3 m in length and 3-5 mm thickness, to anti-microbial surfaces. Two of the most promising and exciting recent innovations have been the advanced development of back-ventilated ceramic tile building façade cladding systems (also known by the established construction term "curtain wall" systems), and research on integration of photovoltaic systems on ceramic tile panels¹ that can simultaneously produce energy and function seamlessly as a building component.

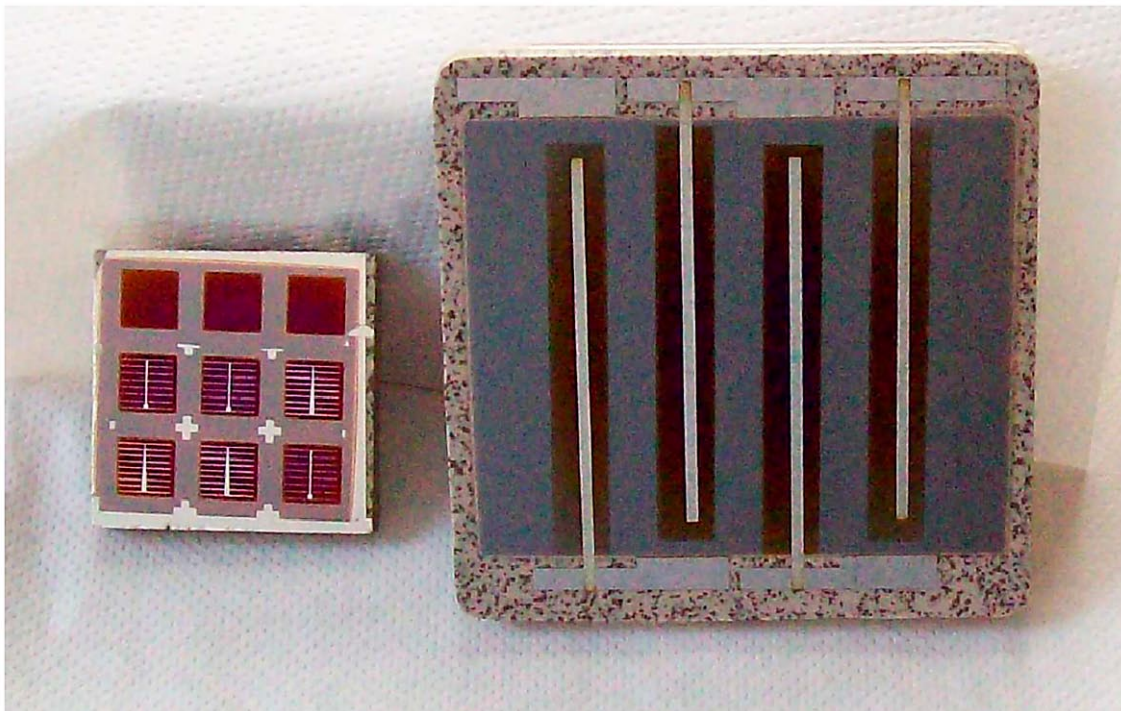


Figure 4 – Prototype of thin-film photovoltaic cell laminated to porcelain tile ¹

Researchers have succeeded in producing and testing prototypes of thin-film solar cells (figure 4) a few microns in thickness that can be deposited on ceramic tile panels using a low-temperature process (plasma-enhanced chemical-vapor deposition).

While the integration of solar cell films into roof shingles and other building components has already been accomplished, and perhaps even more advanced, what makes this innovation for ceramic tile so exciting is that the fabrication of ceramic tile and its application in modular, removable back-ventilated façade systems are perfectly suited to solve the problems with solar cell façade cladding integration that exist with other building materials. Modular construction of back-ventilated tile façade systems may solve problems of inter-connection, as well as access for repair and maintenance of solar cell ceramic panels.

Integration of solar cells within the body of ceramics still remains a far-reaching concept, but no less outrageous than the conception and refinement of the computer search engine. However, I would not hesitate to predict that soon, the tile industry will develop a method for firing photovoltaic systems directly into a ceramic tile body, utilizing existing concepts and technologies such as ink-jet printing and electrically conductive tile products. Similar research in progress may also offer potential for LED or low voltage lighting and fiber optics to be integrated into ceramic tile façade panels similar to systems already in use in the glass industry. The ability to electronically change colors of ceramic or glass tile as a design tool is not out of the question !



Figure 5 – Changing colors of ceramic or glass tile electronically could become a feasible design tool

Certainly, back-ventilated ceramic tile façade systems offer low environmental impact attributes that have been well documented:

- Durability – non-absorptive, non-toxic natural material that can incorporate re-cycled content
- Water control efficiency– dissipates and prevent water infiltration with external controls and access; minimize internal wall cavity issues such as mold and effects on indoor air quality
- Energy efficiency – dissipates of wind and solar heat for improved thermal performance and elimination of thermal bridges with external insulation, convection of air within the wall cavity, good thermal conductivity of tile
- Life-cycle efficiency - durability, fire-resistance, ease of maintenance with non-toxic cleaning solutions, ease of replacement / of both ceramic panels and internal wall components.
- Construction and post-occupancy efficiency - reduces construction time; efficiency of maintenance and replacement

So then what is the real innovation that the tile industry has to offer in the next generation of ventilated tile systems ? Again, it is embracing and marketing ventilated tile wall assemblies as an integrated system rather than just providing the tile and supporting framework (figure 6). This means that tile manufacturers must subscribe to the fundamental “cradle to grave” sustainability concept, and provide products and services ranging from design, engineering and testing guidelines and assistance, to proactive construction, maintenance and replacement / re-cycling guidelines. One only needs to study how the glass industry operates under the same paradigm.



Figure 6 – Back-Ventilated Porcelain Tile Wall Cladding System- engineering and development of an integrated system including all accessories, waterproofing, insulation, flashing (courtesy Professional Consultants International)

3. INNOVATION FOR ARCHITECTURAL CLADDING APPLICATIONS – NEED FOR IMPROVEMENT

Since 2002, many of the QUALICER presentations within the “installation category” have continued to focus on pathologies in direct-adhered ceramic tile façade architectural cladding applications. While the advancement of back-ventilated tile cladding systems has been an alternative solution to the chronic problems experienced with direct-adhered ceramic tile cladding, it is unfortunate that 10 years later, the ceramic tile industry continues to attribute many of these problems to labor issues beyond their control, rather than focusing on innovations and solutions to these problems.

What are the opportunities and technical solutions that have been overlooked or ignored ? Certainly the most critical pathologies have been tile adhesion failure and water infiltration / deterioration of direct-adhered tile cladding assemblies, yet

there has been little progress or innovation in solving these problems, primarily because the industry has been focused on the ceramic product only, rather than the ceramic tile as part of a façade cladding system.

Two examples of solutions to direct-adhered ceramic tile building cladding pathologies are as follows:

- Computer modeling (Finite Element Analysis)
- Water drainage plane products

Computer modeling– QUALICER has historically been a forum for introducing cutting-edge research on computer modeling of adhered ceramic tile building façade cladding². Adhesion failure pathologies tend to be rooted in our inability to understand behavior and quantify forces / stresses that occur in non-linear, composite systems such as adhered ceramic tile cladding. The complexity of simultaneous and differential building movement from shrinkage (creep) of concrete, wind, thermal and seismic loading (figure 7) is simply beyond practical calculation. As a result, our industry has been “guessing” on which materials and methods are necessary to accommodate or isolate building movement from affecting the adhesion of architectural tile cladding.

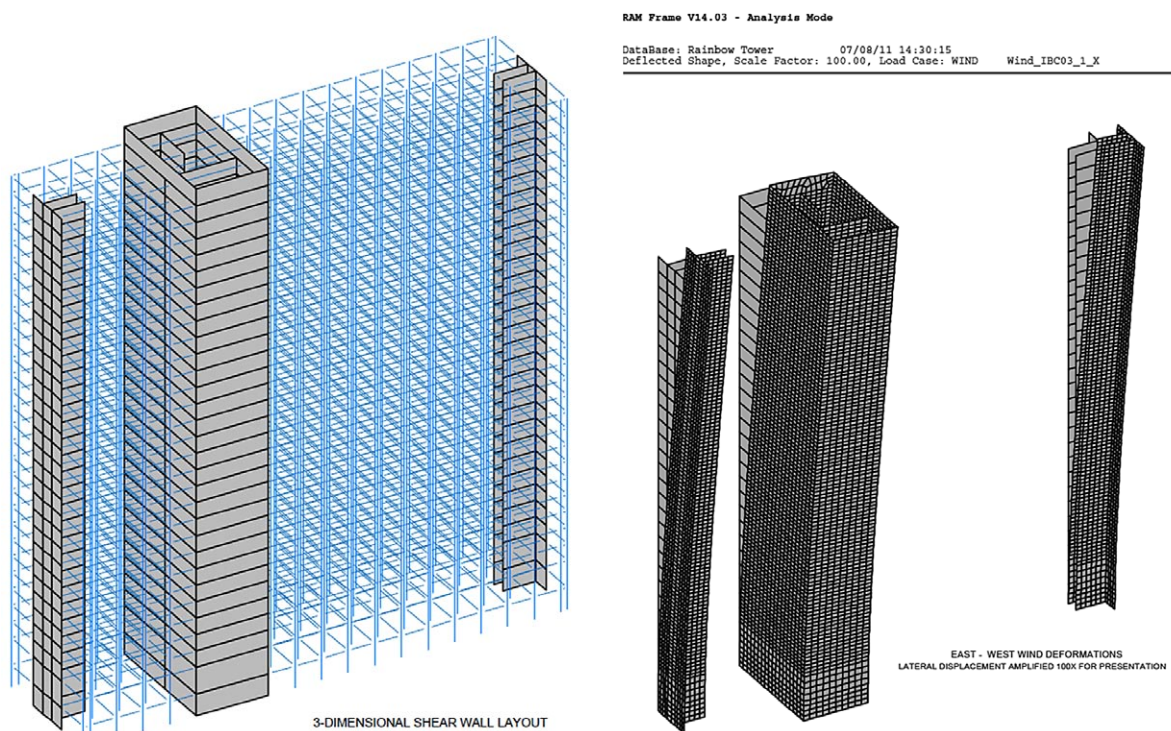


Figure 7 – Using computer modeling to analyze building structural movement and predict behavior of adhered porcelain tile façade cladding from lateral wind displacement on 30 story tower (engineering by Professional Consultants International)



Figure 8 – 30 Story tile façade prior to replacement

Shear Stress on Entire Facade

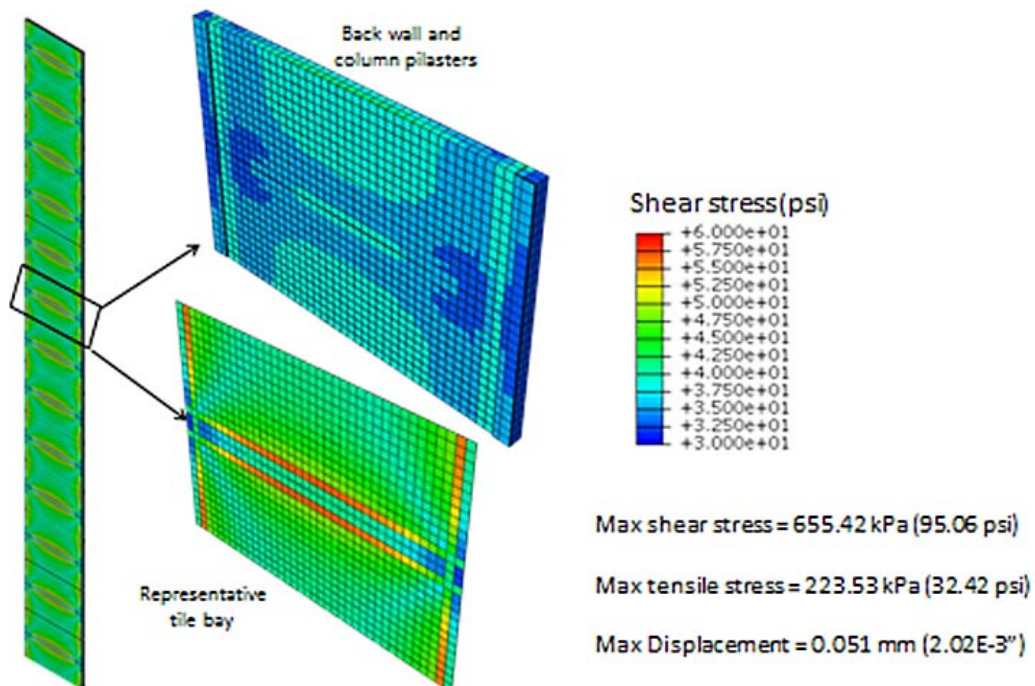


Figure 9 – Computer modeling using finite element analysis predicts shear stress caused by thermal changes; also provides information for architect's design of movement joints (engineering by Professional Consultants International)

Computer modeling is now an economically feasible design tool for most architects and engineers, and use of this engineering method should become a standard procedure and requirement in designing “structurally indeterminate” systems such as adhered ceramic tile architectural cladding (figure 8 & 9). Employing scientific design methods allows architects and engineers to quantify the location and extent of stress in the tile cladding assembly, and make informed, engineering decisions as to selection of tile adhesives, flexible membranes, and locations of movement joints in the same way a concrete structural system is designed and engineered.

While this resource should improve the outcome of adhered tile cladding applications, this innovation as well as other established scientific methods must be embraced by the ceramic tile industry as an integral requirement for design of such a system; anything less keeps the industry on the same path of chronic problems and negative architectural perception; the tile industry really needs to make courageous and bold decisions about system integration and engineering to move beyond the uncertainty most architects express when considering ceramic tile as an architectural cladding material.

Water drainage plane products – Water infiltration into and encapsulation behind direct adhered ceramic tile cladding has become a chronic problem, and the tile industry has made no progress in the past 10 years on a concerted effort to solve this problem. Adhered tile cladding is essentially a barrier-type system which is not waterproof. In many cases, the water infiltration results only in efflorescence deposits, and often does not affect the normal function of a tile cladding system. But experience has proven that efflorescence detracts from the fundamental beauty and design excitement of ceramic tile, and as a result, architects are often reluctant to use tile as an architectural cladding unless they are offered proven solutions to minimize or eliminate encapsulated water behind tile cladding (figure 10).

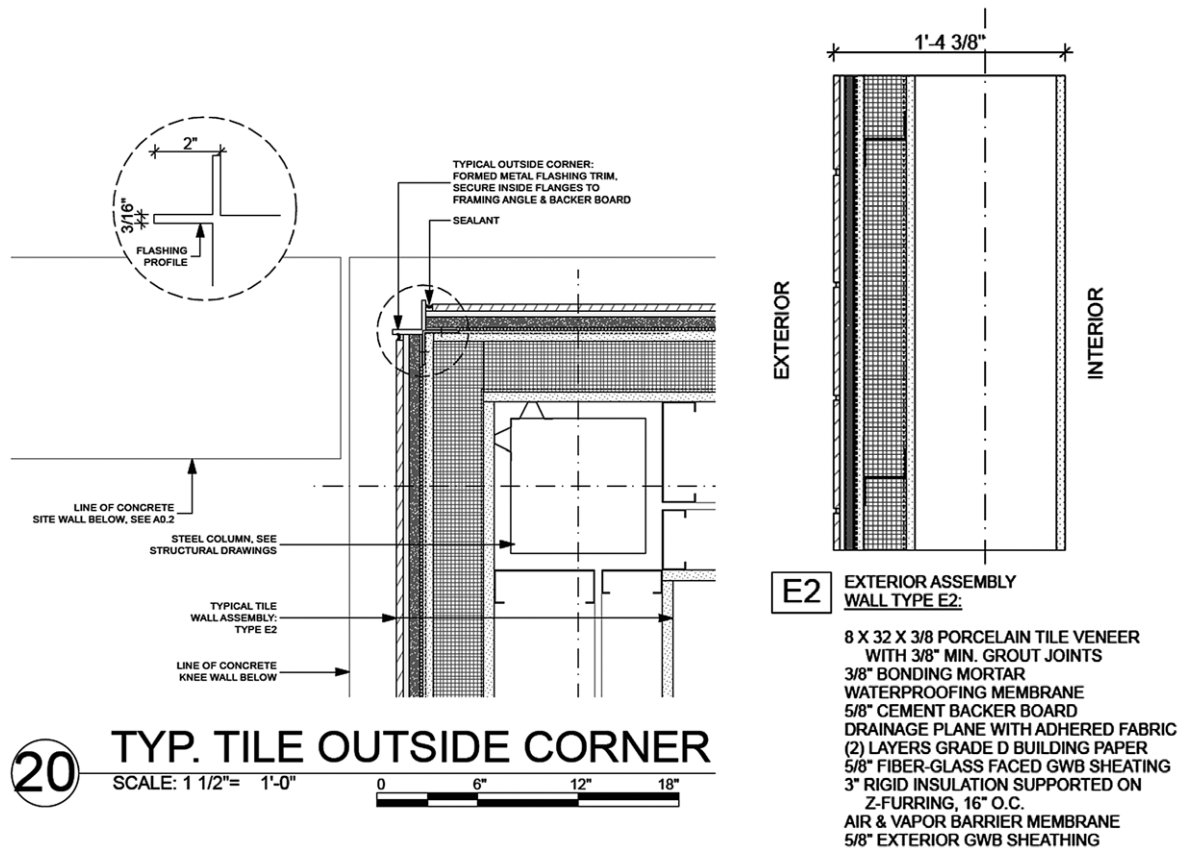


Figure 10 – Internal drainage plane behind ceramic tile cladding wall assembly can prevent efflorescence and damage in freezing climates.

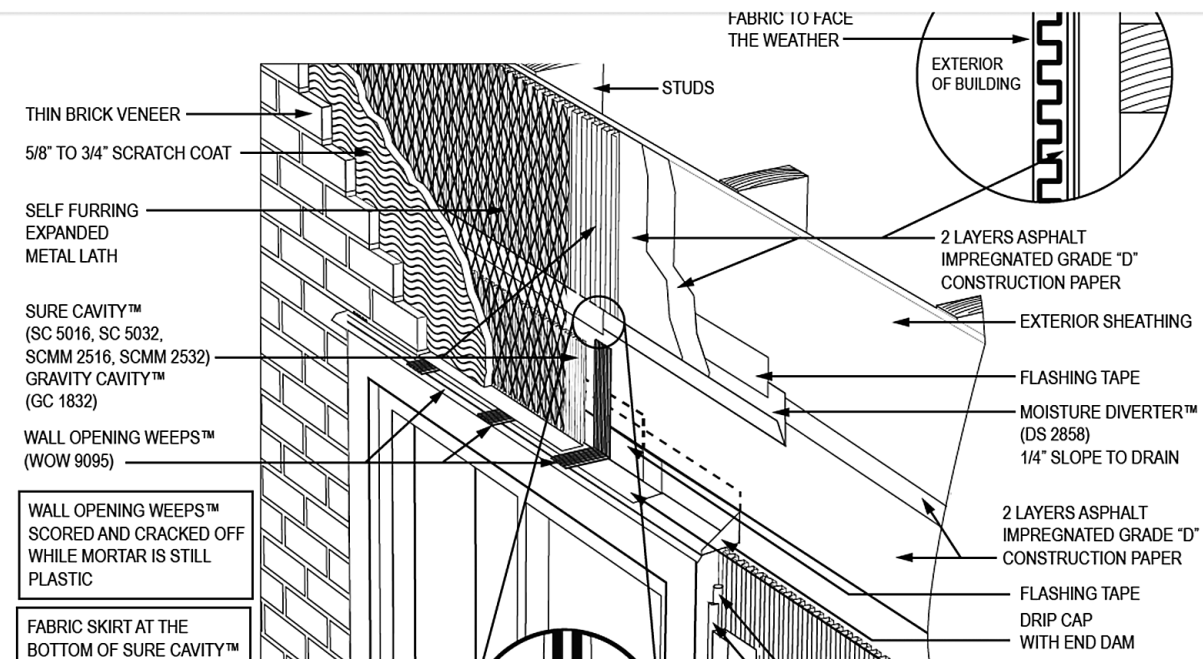


Figure 11 – Direct-adhered tile cladding details incorporating an internal water drainage plane, integrated with weeps and flashing

Water infiltration behind tile cladding that results in internal water leaks, tile cracking and adhesion failure in freezing climates also remains a chronic problem, yet there has been little progress on embracing existing solutions or innovation of new solutions. Most architects will not consider tile as an architectural cladding in freezing climates, despite the fact that when constructed with appropriate climatic consideration, these systems are functional, durable and beautiful.

First and foremost, the future success of direct-adhered architectural ceramic tile cladding will rely on recognizing that water infiltration behind tile cladding is inevitable, and that tile and tile installation products must be designed to incorporate a water-resistant drainage plane and integral waterproof membrane. Fortunately, there are many types of proven drainage products already in use with other types of barrier-type exterior wall systems, such as cement stucco and exterior insulation finish systems (EIFS) (figure 10 & 11). Water drainage planes can also solve problems of isolating building movement, as well as facilitate proper integration and function of movement joints.

4. THE FUTURE OF CERAMIC TILE IN ARCHITECTURE

Given both the promising innovations and disappointing progress solving certain technical issues over the past 10 years, ceramic tile remains well positioned to become one of the most important sustainable architectural materials in the 21st century...truly the perfect blend of art and science in the minds of most architects and engineers. If the tile industry can continue its legacy of product innovation, resolve urgent technical issues for architects and end-users, and adapt to the changing architectural paradigm of building materials as integrated systems and not individual products, I am confident that my 2022 QUALICER presentation will proclaim ceramic tile cladding systems as one of the most significant developments in sustainable architecture in the past 10 years !

REFERENCES

- [1] Iencinella, D.; Centurioni, E., "Effective integration of photovoltaics into the built environment". Institute for Microelectronics and Microsystems (CNR-IMM) , Bologna, Italy 2009
- [2] ABREU, M.; LEITAO, V; LUCAS, C " Modeling the Behavior of Ceramic Tile Coverings", QUALICER 2004, Castellon, Spain
- [3] BOWMAN, R; BANKS,P, "The Crucial Need for Computer Modeling of Tiling Systems:", QUALICER 1996, Castellon, Spain