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INDUSTRIALIZED PRODUCTION OF THIN RAINSCREEN CLADDING IN UHPC

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Abstract

This paper discusses the development of three ultra high performance concrete (UHPC) rainscreen façade projects with different designs. The first project describes a large-scale production of panels with both custom and flat finishing; the second project concerns both simple and three dimensional panels for application on the eyebrow section of the building. The third project utilizes a flat panel system with highly customized, textured patterns. Because it becomes very difficult to maintain finish color and consistency across each panel processed at an industrial scale, techniques for casting are discussed in the context of each of these three projects.

Résumé

Cet article porte sur le développement de 3 projets de bardage en Béton Fibré à Ultra hautes Performances (BFUP), de conceptions différentes. Le premier projet décrit une production à grande échelle de panneaux avec des panneaux de finition à la fois sur-mesure et plans, le deuxième projet nécessite à la fois des panneaux 2D et 3D pour application en linteau et allège. Le troisième projet utilise un système de panneau plan avec des motifs très personnalisés et texturés. Parce qu'il devient très difficile de maintenir la couleur et l'homogénéité entre chaque panneau produit à l'échelle industrielle, les techniques de coulage seront discutées dans le contexte particulier de chacun de ces projets.

1. INTRODUCTION

Ultra-High Performance Concrete (UHPC) offers a unique combination of superior performance characteristics including strength, durability and ductility, thereby facilitating the ability to design and construct innovative building facades in a vast range of aesthetics/ finishes/textures that were not previously achievable. The UHPC panels are thin, lightweight and easy to install (using standard attachment systems), Adapting to construction speeds. The surface finish exhibits extremely low porosity with high resistance to abrasion, impact and harsh environmental conditions, resulting in superior resiliency and a reduced need for maintenance.

In recent years, the design community has been moving away from the use of metal or synthetic cladding systems. Prior to development of the UHPC cladding system presented herein, the only commercially available rainscreen façade product with a "natural finish" was stone. Therefore, the development of industrially produced thin, flat UHPC panels was a natural progression towards the provision of a new cladding solution highly suitable for the many requirements and desires of modern architects or owners.

2. PROJECTS

2.1 Fulton State Hospital, Fulton, USA

The new Fulton State Hospital in Missouri will replace an aging mental hospital that originally opened in 1851. Slated for completion in 2018, this massive complex (Figure 1) will be situated across 22.25 hectare (roughly the size of 3 football fields) and provide state-of-the-art facilities designed for safer, modern patient treatments in the years ahead [1].

The project design called for a robust, solid surface rainscreen panel system to surround 11,612 square meters of its facade. The UHPC rainscreen solution was chosen, meeting the owner's and architect's requirements for high durability and finishing capabilities.

Figure 1: Artist's rendering of the new Fulton State Hospital. Aerial view from the southwest. (Credit: EYP | Parsons Brinckerhoff | Heery)

The factory in charge of precasting developed prototype panels in three different textures. One of the textures presents a series of grooves and shapes (Figure 2) that seem to change throughout the day capturing the sun and shadows, lending to a lightweight visual atop the tall courtyard walls. The panels appear to "dissolve" into the walls at the top, thereby creating the owner's desired perception of reduced height and overall size.

This project is very large and will require the mass production of thousands of panels. Therefore, an industrialized approach is necessary to meet the expected delivery schedules. Of course, it is also very important that the producer's automation process be very robust and reliable, with the capability to produce thousands of quality UHPC panels with few errors and a low rejection rate.

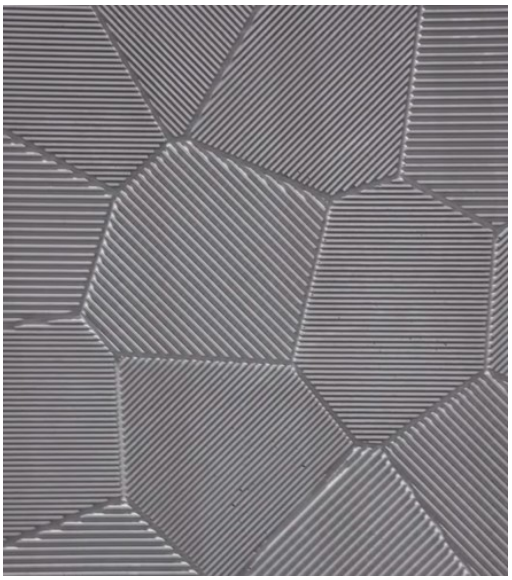

Figure 2: Grooved UHPC panel, pattern by EYP Panel, produced by Envel.

2.2 Kimmel Pavilion, New York University, USA

The Helen L. and Martin S. Kimmel Pavilion ("Kimmel Pavilion") is an 77,109 square meter addition on the main campus of New York University (NYU) Langone, on Manhattan's lower east side. The state-of-the-art medical center, set to open in 2018, is mostly conceived with glass, but the interstitial space between floors (where the floor slabs jut out) was designed to be covered with thin UHPC rainscreen cladding elements. These linear "eyebrows" that surround the facade on each level provide a visual break in the glass curtain wall [2]. UHPC cladding panels were chosen because of their light weight and high durability properties. To meet the project requirement for a natural finish, the panel color is simply "cement grey" (Figure 3).

Due to the panel's thin, light weight design, there would be no need for a larger crane on this project. In Manhattan, and on many projects with tight/constricted construction sites, the use of smaller cranes can contribute significantly towards budget reductions, as well as speed of construction and site safety. Each UHPC piece was cast as a C-shaped, 3D element. Besides the potential for large wind forces, these panels will also have to contend with the potential impact from window-washing baskets, which can create considerable, concentrated force. The UHPC material helped to make the 3D elements very robust and impact-resistant and the prototypes easily passed the required drop tests.

Figure 3: Full-size mock-up of the UHPC panel application for NYU's new Kimmel Pavilion

2.3 Lewis Farms Fire Station, Edmonton, Canada

For the main office building of the Lewis Farms Fire Station in Edmonton, Canada (Figure 4), a UHPC cladding panel solution was chosen for a very different reason (than the two projects previously discussed): high durability and high resistance to freeze-thaw. These are properties that almost all building façades in Edmonton, Canada require. Here, the buildings are frequently exposed to extremely harsh, freezing temperatures in the winter as well as some very hot temperatures during the summer. Typically, the environment is more brutal than most facades contend with in other parts of the world.

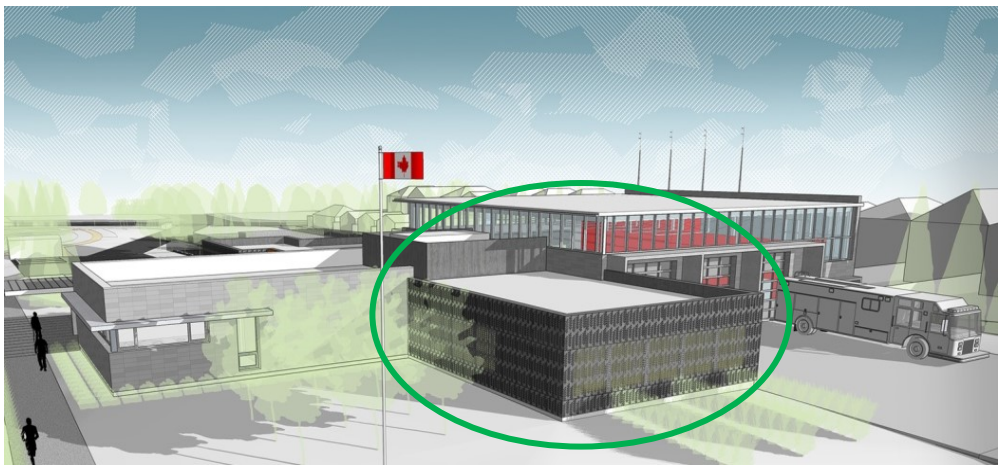

Figure 4: Lewis Farms Fire Station - Architect's rendering.
Credit: Arch|TB and Johnston Davidson Architecture + Planning Inc.

UHPC's density and extremely low porosity properties attributes to the material's low permeability characteristics. As such, water molecules are unable to penetrate its matrix, making the UHPC facade an ideal cladding solution for this particular location. The structure was also designed to meet the post disaster requirements of the Alberta Building Code, establishing the need for a robust, durable exterior facade that would provide superior resistance to impact, abrasion, chemical attack, fire and seismic activity [3].

Located in an estate neighbourhood, the project also had an art component. For custom design of the facade's textured panels (Figure 5), the Edmonton Arts Council conducted a "public art competition" in accordance with the City of Edmonton's policy, "Percent for Art", which designates of one percent of the budget "to provide and encourage art in public areas" [4].

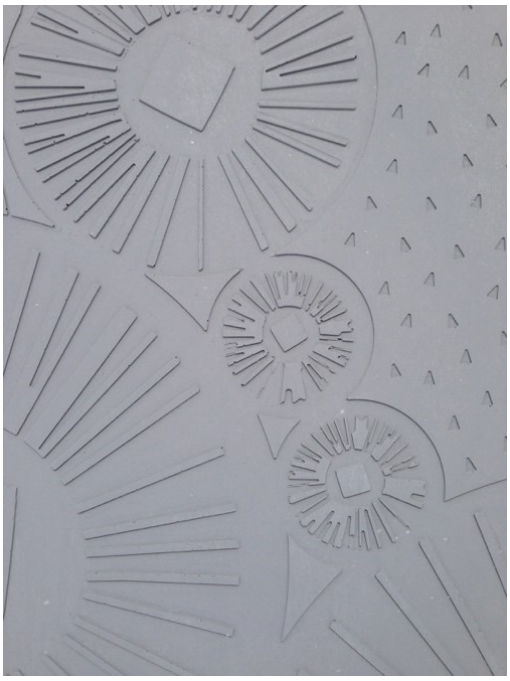

Figure 5: UHPC Panel Customized Texture

3. INDUSTRIALIZATION OF FLAT PANEL ELEMENTS

A robust production line/facility for the mass creation of UHPC flat panels requires determination and commitment by the person in charge of precasting; to carefully develop each segment in order to eliminate undesirable variabilities during the casting, curing and finishing processes. The following steps/procedures are highly recommended for the successful, industrialized production of UHPC panels.

3.1 Quality Control of the UHPC Premix

The first step towards ensuring the successful production of UHPC flat panels is to remove any inconsistencies in the line, beginning with the UHPC premix. As a concrete material, UHPC is made of a combination of raw materials, with properties that can result in great variabilities. Quality control of the premix raw materials is a must because color consistency (in these

materials) is key to success. By blending each premix lot using the same colors (or as close as possible) from batch to batch over time, the finished panels will have the greatest chance to be more uniform in color (across multiple, different panels), whether cast on the same day or several days apart.

3.2 Automation

The second important step during the development of a consistent UHPC product line is to automate as many of the processes as possible, including batching, casting, curing and finishing. The process of handling the panels in the exact same way, and under the exact same external conditions is crucial in order to balance the natural fluctuation that the product presents, versus the many variables introduced by humans that can cause even greater differences.

3.3 Production Procedures

Temperature and humidity during the casting and curing process is a key variable that must be stabilized as much as possible. Proper mold isolation during curing will help to maintain good moisture levels in the UHPC matrix, as documented in the 2013 NPCA White Paper, "UHPC Guide to Manufacturing Architectural Precast UHPC Elements" [5]. The matrix of most UHPC elements is not fully hydrated and the loss of too much moisture during curing can be detrimental. In fact, steam curing could be a process that helps to fully hydrate the UHPC matrices, however careful testing, to determine how the steam may affect the surface finish should be conducted and reviewed first.

Final finishing of the flat panel surface should be timed, and not performed too early if a treatment like polishing is required. Alternatively, sandblasting or acid washing treatments must be done early for two reasons: (1) to reveal if the panel has any superficial cracking not visible in the upper-most layer and; (2) to determine precisely how much of the natural color variance on the panel will stand out. The “top cream” on a cast piece tends to hold the impression of the molded surface and removal of this surface can help to even out the overall finish.

3.4 Packaging and Shipping

Finally, packaging and shipping procedures are also very important because surface marring can occur through concentrated water exposure in a singular area of the panel. Also, if the panels are supported on the front face, it is important to only use bubble sheets. The use of foam or other padding in a condensed area can cause dark marks on the panels. Because of the continuous curing that concrete undergoes, a material placed in one area of the panel will cause a differential cure in that area.

4. PRODUCTION OF 3D UHPC ELEMENTS

Three-D facade elements made with UHPC can be cast in almost any shape. Custom elements can be added during production, allowing for the creation of unique flat panels and innovative building facades with enhanced design aesthetics. The use of 3D elements also allows for a larger portion of the facade surface to be completed at once; faster than conventional precast cladding systems that require installation of one panel at a time. 3D elements are more difficult to manufacture in an industrialized fashion. The molds require more

space in a plant and do not lend themselves easily to automated casting procedures, considering that more finesse is needed when dealing with the molds.

It is also necessary to consider the shrinkage of UHPC elements in 3D molds, and build in safeguards to prevent self-induced cracking of a young element that cannot support the load of the shrinking.

5. CONCLUSIONS

The projects presented demonstrate that the use of thin, UHPC rain screen/flat panel systems allows architects to design with a natural, durable material similar to stone but lighter in weight and easier to install. The panels are customizable by color, texture and/or pattern, contributing to a high level of design options for a range of building projects and budgets.

Across North America and around the world, fluctuating or harsh climates and other environmental factors (i.e., coastal conditions) are a significant concern for building owners, engineers and architects. The longevity and low maintenance of these panels contribute to the sustainability of the overall building and are therefore desirable. UHPC panels, blended with organic fibers during production, are extremely low in porosity, and therefore provide exceptional durability and ductility. Subsequently, UHPC rain screen systems provide excellent resistance to the elements, impact and/or chemical attack.

The Lewis Farms Fire Station was designed to meet provincial post disaster requirements. This is one of many UHPC facade projects with "disaster" requirements, such as "The Atrium", in Victoria, located in one of the most seismically active zones in Canada [6].

In addition to panel performance and improved freedom of design aesthetics, the budget/cost, project schedules and site safety are of high concern. Based on comparative studies [7]; when UHPC panels are cast in an automated, industrialized facility, the price point is better than facades made of stone and other high-end materials. As well, ease and speed of installation and reduced crane size can further contribute to overall project cost savings.

ACKNOWLEDGEMENTS

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