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LA MARSEILLAISE TOWER

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Abstract

Marseilles' new high rise tower, *La Marseillaise*, is currently erected, surrounded by two concrete highways viaducts and nearby post-industrial harbors docksides. The tower is part of an urban piece composed of three other projects, architectural key players in the renewal of Marseilles waterfront skyline, within larger Euro-Mediterranean framework. The facades are composed of UHPC *(Ductal®)* prefabricated elements that participate in building's envelope (air and watertight sealing), in thermal insulation, in solar control (sun-shades and lateral partition grids inclusion), in the building maintenance (cantilevered outgrowth of a peripheral gangway), in fire partitioning (high-rise towers regulation), as well as in sustainability (resistance to salt spray due to Mediterranean Sea proximity). The building site being extremely constraining, facades erection has been highly simplified by the condensation of technical functions into monolithic and repetitive precast elements. UHPC made this multi-technical nature of the envelope come true thanks to its various inherent properties: leak-tightness, fire stability, ductility, durability, high mechanical performances in flexion and compression.

Résumé

C'est à proximité du port de Marseille, entre deux viaducs d'autoroute, que la *Tour La Marseillaise* est actuellement érigée. Elle s'insère dans une pièce urbaine composée de trois autres projets et participe au renouveau du skyline du front de mer dans le cadre d'Euro méditerranée. Les façades réalisées au moyen d'éléments préfabriqués en BFUP (*Ductal®)* participent au clos couvert du bâtiment (étanchéité), à l'isolation thermique (incorporation d'un isolant en face arrière), du contrôle d'apport solaire (inclusion de brise soleils ainsi que de grilles latérales de cloisonnement), à l'entretien du bâtiment (excroissance en porte-à-faux d'une passerelle périphérique), au cloisonnement feu (C+D réglementaire aux Immeubles Grande Hauteur), ainsi qu'à la durabilité (résistance aux brouillard salins et embruns de la Méditerranée voisine). L'univers chantier étant extrêmement contraignant, l'érection de la façade est facilitée par la condensation des fonctions techniques en une seule pièce monolithique, répétitive et pré-fabricable (en seize séries faiblement modulées). La pluri-technicité de l'enveloppe n'a été rendue possible que par l'emploi du BFUP dont les diverses propriétés (étanchéité, stabilité au feu, ductilité, durabilité, hautes performances mécaniques en flexion et compression) sont pleinement utilisées.

1. INTRODUCTION

The inner-city area's densification, the need for housing and the challenges of sustainable development are factors contributing to the rapid changes of our built environment. *Verticalization* is one of the possible paths for this movement.

The apparition of the modern tower is linked to the reconstruction of Chicago subsequently to the 1871 great fire. Initiated by an attempt to reduce rising land prices impact by increasing building heights, a quick, highly resistant and easy assembly method had to be found. Hence arose the now extremely popular new principle of structural metallic frame associated with a non-load bearing external skin (the famous curtain wall). Technical innovation has proven central to the birth the *'school of Chicago'*. As environmental impact of constructions becomes crucial nowadays, seventies' typical high rise towers design (highly energy consuming vertical glass boxes) need to be carefully reviewed. Space is left to a studied management of light and space. And it might strongly impact facade layouts.

The purpose of this paper is to detail how UHPC brought some tangible proposals to this interrogation. First, with a general project description (urban scale, programmatic approach, forces at stake), followed by a short overview of the architectural concepts, that, joined with some more specific design constraints *(section 4)* helped the notion of UHPC to emerge and to finally impose itself (Fig. 1). Although our initial intentions were to *'value engineer'* the facade as a clear standard case of economical effectiveness, it has to be admitted that the viability of this final UHPC choice is more linked to several concomitant factors (developed in *section 5),* amongst them *La Marseillaise's* iconic status has weighted heavily. And finally, to conclude, that Environmental Excellence standards expected were reached with some help of UHPC.

If *'Learning from Chicago'* was mainly structural, future tower concepts will probably involve innovations that will help astute answers for outer skin design to arise; for instance in its ability to absorb or combine the various technical layers required nowadays for durability purposes. In our opinion, *La Marseillaise* tower embodies this new paradigm.

Figure 1: A UHPC precast element type A (left)
and a lateral partition grid also called 'waffles' (right)

2. PROJECT DESCRIPTION

2.1 Part of an urban piece & program distribution

Located on the *Arenc Docks* of Marseilles harbor and backing up CMA CGM tower, this new one hundred thirty meters high building offers thirty-five thousand square meters of offices spread over thirty levels. The tower is part of a larger urban piece *'Les Quais d'Arenc'* composed of four other buildings developed by Constructa, directly connected to the city center by newly built tramway (see *Section: Key Facts).*

The tower is divided into three main sections (lobby, nursery and restaurant; then two series of sixteen office floors. These sections are separated by landscape terraces. The main characteristic of *La Marseillaise* remains in its envelope: a pattern of cantilevered, louvered and colored UHPC shadings (Fig. 1). The two top floors of the tower will host the *World Trade Center (WTC) Marseille Provence*.

2.2 National, iconic and therefore highly political

Euroméditerranée is a development plan carried out by the French State: a national involvement embodied by Prime Minister Manuel Valls' visit of the *La Marseillaise* tower construction site in April 2017. The tower occupation rate clearly depicts this political voluntarism: seventy percent of *La Marseillaise* rental surface is quasi-public, occupied by *La Communauté urbaine MPM* and *Orange* (partially state owned companies). The remaining fifteen percent of gross area are left for private rent.

Being the flagship construction of the *Euroméditerranée* operation, this tertiary building of excellence needed a renowned architect signature. Marc Piétri (Constructa) chose Jean Nouvel (AJN) alongside with Xavier Huillard, (Vinci group) to carry out the project that has vocation to initiate a movement of attraction for international headquarters (re)implantations in the Phocean city.

2.3 Architectural concept

Jean Nouvel designed *La Marseillaise* tower as a *'mathematical frame punctuated by dashes of shadows and lights',* colored in pastel tones. To be understood: a self-supportive, colored, mineral and repetitive grid facade was desired.

From very conceptual stages, UHPC positively met the demand of a long lasting randomly colored monolithic facade element. *Blue* as the sky, *White* as the horizon and the clouds, *Red* as the ocher of bricks and roofs... the very patriotic colors of *La Marseillaise* are in fact reflecting the surrounding landscapes. The project, anchored in its immediate surroundings, is dramatically opposed to the generic glazed curtain wall tower offering no sense of scale nor generous shades. Playing both with the light and on a frame that will not always be read in the exact same way, *La Marseillaise* animates a visual movement while protecting inner spaces from direct sunlight. As a phenomenon of *Optical Art*, UHPC precast elements build a gigantic grid changing color shades according to the faces, the time of the day or the weather conditions. Because of UHPC fine cement matrix -no aggregates- and mainly because it remains a mineral material -opposed to shiny metal, aluminum or glazing-, UHPC strongly appealed architectural team for its very opalescence.

Through its innovative facade, *La Marseillaise* is becoming a visual icon of Marseille.

UHPC was the long lasting solution for durability criteria in order to resist to a highly aggressive exposure (sprayed salt due to sea closeness).

3. GENERAL DESIGN

After a year of foundation work, construction began at the beginning of January 2016 with the core of the tower cast above 83 piles sunk at 33 meters depth. For a total investment of one hundred eighty million euros -carried by CEPAC and Caisse des Dépôts- the construction is to remain below three thousand euro a square meter –floor area-. Construction costs necessitated tight control, made possible on the one hand thanks to the efficient construction techniques –self climbing formwork, repetitive precast facade- and on the other, quite simply because the local market would not afford higher rents.

The self-climbing formwork has been chosen to produce the simple and repetitive shapes of building's core (Fig. 2). This construction method did not require the use of an extra crane. It allowed independency from the erection of the external metallic frame and the facade curtain wall (assisted by two lifting jib cranes). The structure has been therefore continuously erected without scaffolding at a rate of one level every eleven days to the twelfth floor and one level every six days thereafter. Concomitantly, the dry construction method chosen for UHPC precast erection (integration of all the layers in the same monolithic element) has proven fast (Fig. 3).

Both the climbing formwork and a compact fully integrated facade complex allowed a full level to be produced per week in the optimal standard phase. Those techniques have proven essential to meet architect's design while balancing the delicate financial equation of the construction of such a tower.

Figure 2: Tower overall view (core and façade)

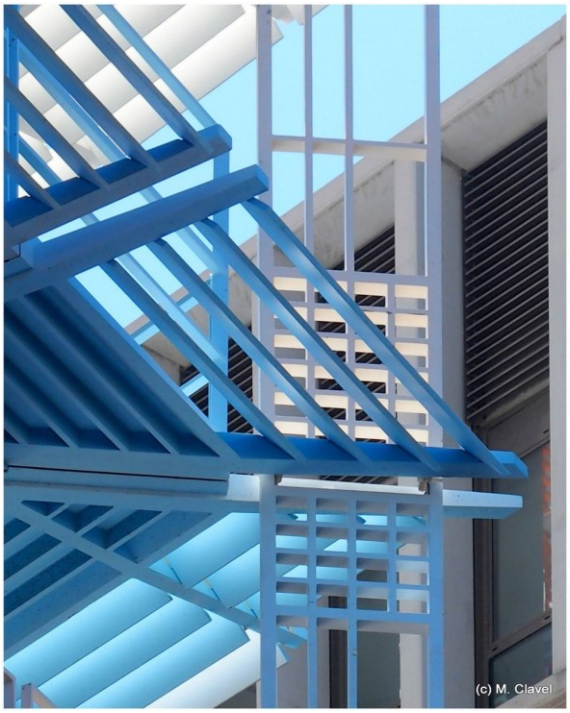

Figure 3: Construction detail (S&W angle)

4. THE CHOICE OF UHPC

Figure 4: Blue, White, Red and twenty seven shades
of Ultra High Performance Fiber Concrete

4.1 A panel of innovative concretes

On the one hand, high above usual standards concretes have been required for the in situ casting of the central core (mechanically and regarding viscosity). For instance, the last structural wall cast needed to withstand the self-climbing formwork weight twenty hours after cast, time for which the above wall could properly be cast itself.

On the other, facade envelope (Fig. 4) was required to be light-weighted while ensuring full air plus water tightness sealing, thermal insulation, while providing solar control and be used for building maintenance and for fire partitioning (high-rise towers regulation), as well as being long time lasting (resistance to salt spray due to Mediterranean sea proximity).

Ultra high-performance concrete has an exceptional strength and is easily workable, helped by the use of super-plasticizers. Very fluid, they ensure a good filling of the formworks and a complete coating of the reinforcements, even when the latest are very dense. These properties helped to reduce mold / unmold time laps, and allowed complex cast in enclosed molds with difficult access conditions.

UHPC used is Ductal in this project G2FMAF. Metallic Fibers and Poly Propylene fibers are used for fire resistance. Compressive strength is superior to 130 MPa; Flexural strength higher than 16 MPa and Young Modulus above 50,000 MPa.

4.2 A 'Sketched' grid

Savings allowed by construction methodologies and concrete innovations were transferred to the 16,000 square meters of facades for the sake of quality and image control. Nevertheless, complying with the specific architectural design while sticking to repetitive and cost effective precast elements remained necessary: simple mold variation combined together to recreate the wide tower grid was the key idea as represented on Figure 5.

The atypical facade grid is made up by three thousand five hundred UHPC sunscreen precast elements manufactured by *Méditerranée Préfabrication (Vinci group)*, in a factory unit specially built in Marignane. Alongside with glazing, UHPC precast elements constitute building's full enclosure. Helped by steel fibers of the G2FM *UHPC,* precast elements can be freed from part of its passive steels, with reducing coating thicknesses, and diminished structural thicknesses.

4.3 United Colors

Declined in a chromatic range of twenty-seven shades supposed to reflect the surrounding urban landscape, UHPC facade elements participate in the thermal comfort and aesthetics of the building (Fig. 4). A single precast panel could receive up to six colors, coated with two-component water-based coatings applied in two separate factories, one next to the tower, and the other close to Avignon.

From very conceptual stages, *UHPC* material positively answered the demand of a monolithic facade unit to be partially painted while allowing minerality of concrete to be felt. These colors have been tested on the UHPC on diverse prototypes placed on site.

4.4 Genealogy of projects

UHPC facade sets are assembled in preset order. An envelope of such a size (sixteen thousand square meters) is a world premiere even if premises of this design can be found in several *UHPC* projects such as the *Crèche Budin* and the *Campus EDF Saclay* –ECDM architects- for its ability to insure air & water tightness; but also *Casquettes Pharo* –Battesti architects- for the compact cantilevered outgrowth. In short, fifteen years of experience and numerous construction players are standing behind this ambitious design**.** At last, the city of Marseilles itself, and the MuCEM closeness might have played a particular magnetism on UHPC final choice.

4.5 Species and families of precast elements

The following description of *La Marseillaise* facades is to be read alongside with the sketch proposed on Figure 5 presenting a synthesis of precast elements families.

La Marseillaise presents two facade types according to its main orientations.

On the central part of Figure 5 is represented the tower facing us with its South and West facades. On the left side of the illustration (left of the tower) is the N&E facade unitary modulus that is to be repeated all the way up. This is the smallest grid constituent, the core sketch element mentioned in the architectural section. Composed of nine *UHPC* precast elements, it will be fully described later in the paper. N&E facade *UHPC* precast elements are part of buildings technical sealing to air and water tightness but also thermal insulation and fire resistance as is shown on detailed cross section.

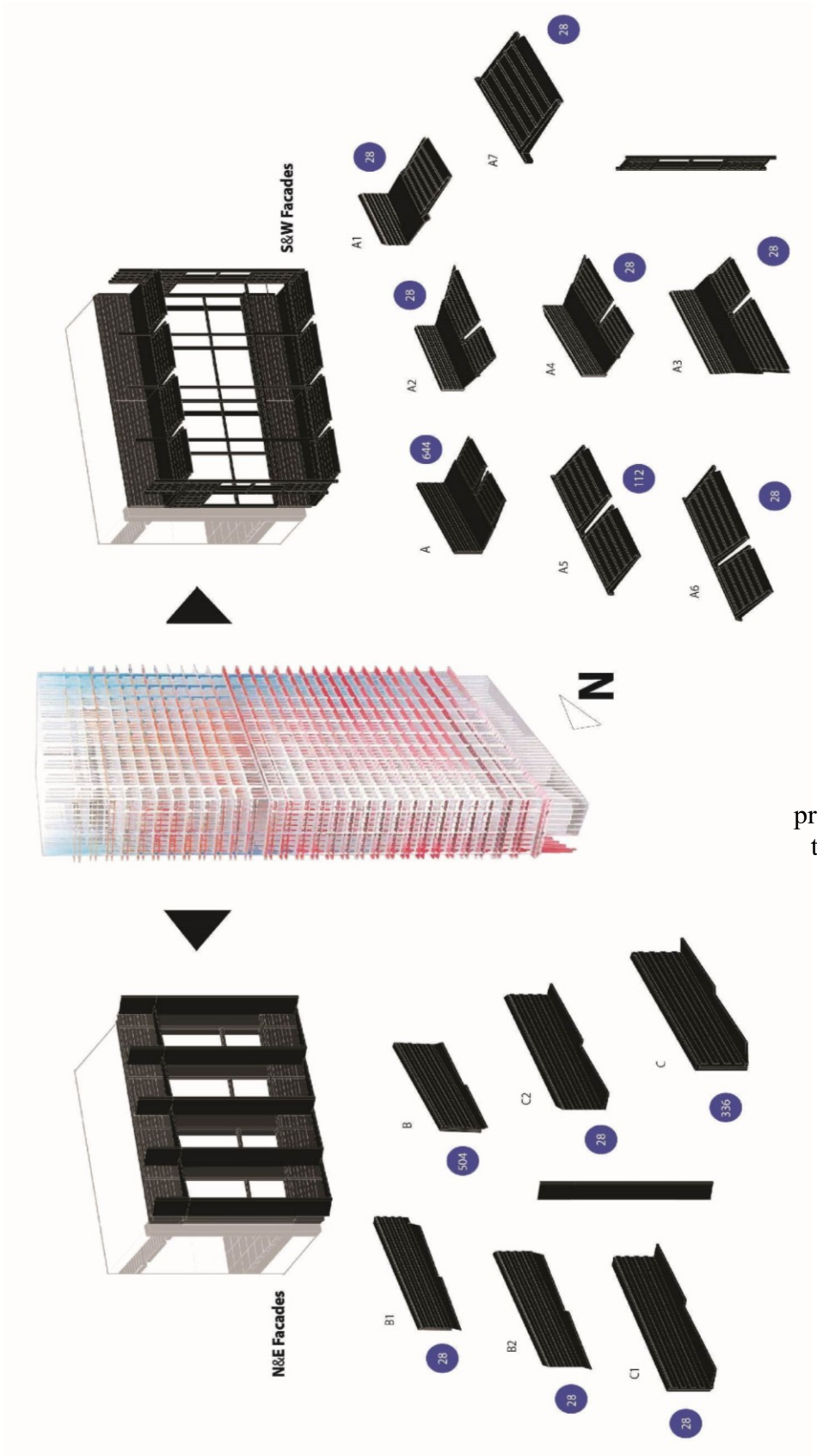

Figure 5:
Sixteen types of precast elements and three main families

S&W facade unitary modulus is logically presented on the right of the tower, top right corner of Figure 5. These facades are more complex (and more interesting technically and architecturally wise) as they are more exposed to Mediterranean sun and they consequently incorporate one extra technical layer to the ones of N&E Facades: solar control (Figs. 6-7).

Below the two unitary facade modulus are shown the repartition of the almost two thousand main *La Marseillaise UHPC* precast elements into sixteen element types and three four main families (A, B, C and vertical partitioning elements). Families are associated to a mold type that can be slightly modified to get the inner families variations (Fig. 6). For instance, A becomes A1 by dividing the mold in two equal parts. A2 and A4 are the necessary mutations of A in order to solve corner issue relative to adjacent facades; A5 and A6 were intended to duplicate the number of available shadings and the 'waffles', true unidentified organism are repetitively fixed perpendicularly to the facade. True unidentified because - interestingly enough- the vertical lateral partitioning system were intended to be made out of anodized aluminum but proved out in tender phase to be too expensive for the multi-colored applications wished and switched along the way in *UHPC* as more economical.

Similarly, B family members, the standard cladding UHPC precast set for North and East facades, are symmetrically opposed to family C ones and their respective descendance more adapted to solve corner issues (respectively B1, B2, C1 and C2).

In the blue chips (Fig. 5) are mentioned the number of individuals in each family.

644 A, 28 A1, 28 A2, 28 A3, 28 A4, 112 A5, 28 A6, 28 A7 = 924 S&W individuals

504 B, 28 B1, 28 B2, 280 C, 28 C1, 28 C2 = 896 N&E people

Beyond the gigantic geometrical game that might be intellectually recreating, the very essence of this exercise is to rationalize cast elements for production purpose and keep facade cost at an affordable rate while complying with architectural intentions. This later observation remains feeble without technical layer condensation, detailed now.

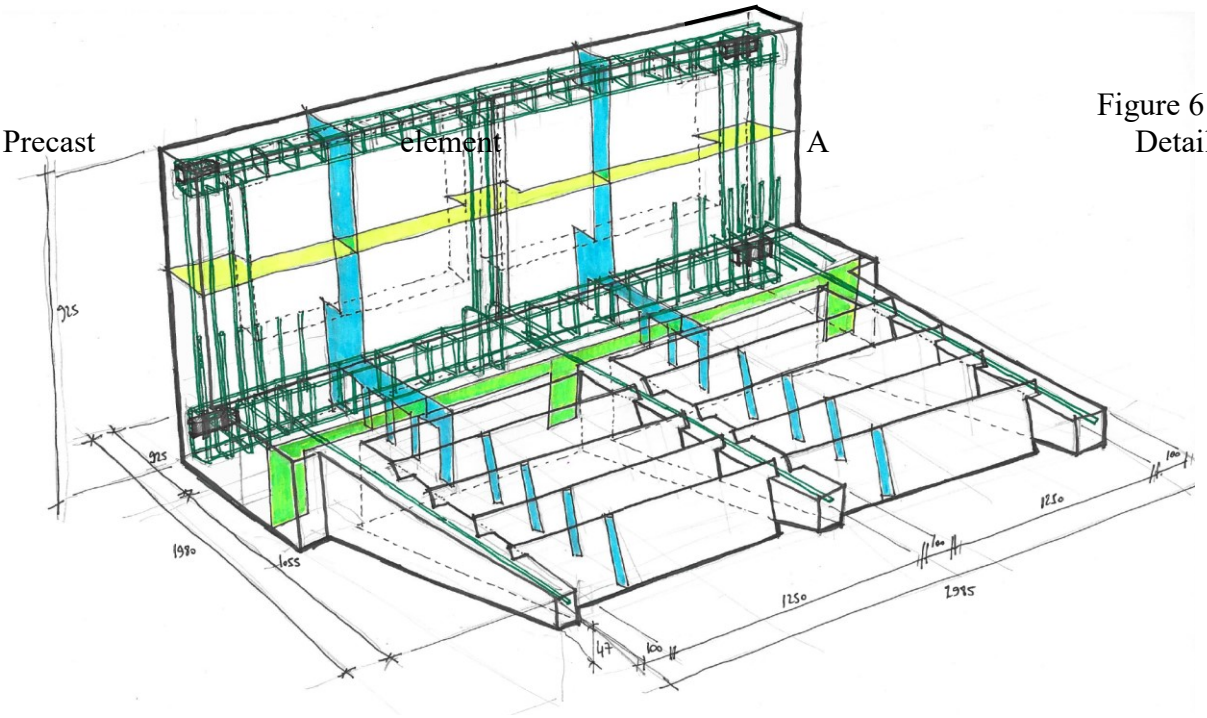

Figure 6: Precast element A Detail

4.6 A condensed envelope

UHPC precast elements, fixed to the tower steel supporting frame, are ensuring:

A. air and water tightness sealing with a thirty-five millimeter thick *UHPC* layer monolithically supported by ribs. Leak-tightness inherent property of *UHPC* is used here.

B. thermal insulation: sixty-five millimeters of polystyrene are embedded in *UHPC* shell to insure a first layer of the necessary thermal inertia. Other layers will be added later on precast element. UHPC being a concrete, its thermal inertia helps the system to better behave.

C. Solar control is insured by *UHPC* sun-shading and by the 'waffles' laterally fixed on elements as additional lattices. Flexion and ductility are used. No reinforcement was needed.

D. Building maintenance is insured first by the peripheral *UHPC* cantilevered gangway running along all the facades but also more commonly by a maintenance pod hung from the top. The supporting ribs (100 mm × 160 mm) are solicited in flexion, compression and shear.

E. Fire partitioning is insured by *UHPC* elements that have proven stable to fire and able to keep C+D > 120 mm.

And finally, UHPC high resistance to aggressive environment helped global building's durability.

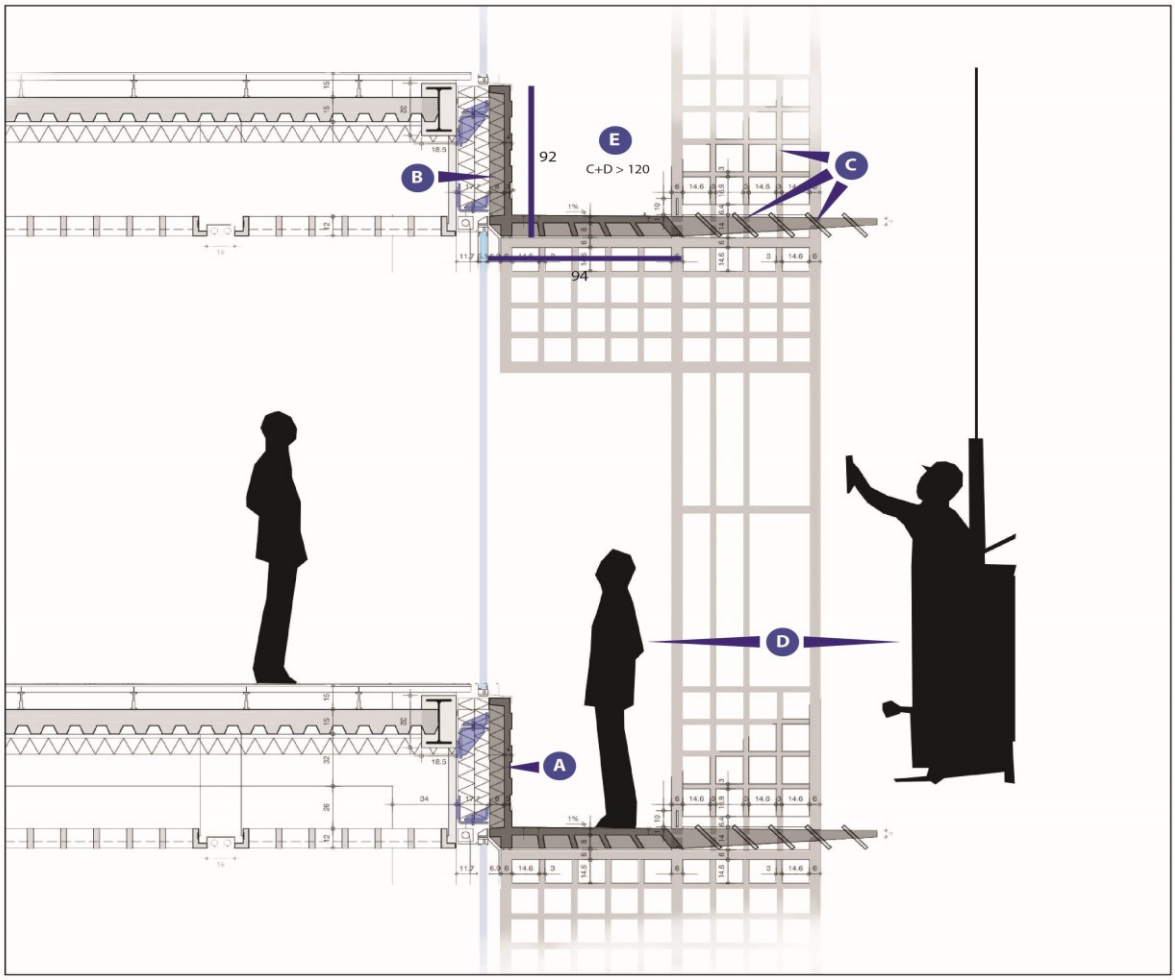

Figure 7: typical UHPC S&W facades cross section

5. ENVIRONNEMENTAL EXCELLENCE

La Marseillaise will be one of the most performing towers in France from an environmental point of view. It targets *LEED Gold* Certifications and *HQE Excellence*. Moreover, a marine geothermal loop will power the building and its connected dependences in heating and air conditioning. The use of UHPC for its facade components has contributed to achieve this level of excellence as described below.

A full *Environmental and Health Product Declaration* has been established in December 2015 for UHPC G2 FM AF precast facade elements. It has been realized according to norm NF EN 15804+A1 and its national complement XP 01-064/CN. The functional unit taken for this environmental analysis is a building element ensuring the function of maintenance passage, building envelope and sun-shade on 2,76 sqm of building's facade.

The facade element is precast in the workshop of *Méditerranée Prefabrication*. 0,41 m^3 of UHPC G2FM were necessary for its realization. 10 kg/m^3 of metal are used in reinforcement. The product is coated with a two-component water-based coating from *Guard Industries*. Concrete being a non-combustible material, the product under consideration does not present any special fire hazards. Properties described here are integrated in modelling.

5.1 Life cycle analysis

Modelling takes into account manufacturing in a first approach as the Premix Ductal G2 manufacturing in a dedicated preparation mixer; the production of raw materials: cement, additives, additives, aggregates, fibers (metallic and organic), stain; the transport of raw materials to the preparation workshop and premix at the prefabrication plant; the production of energy consumed at production sites; but also representation of construction stages with transport towards site construction and erection on building's frame.

5.2 Indoor Air

The National Ready-to-Use Concrete Union (SNBPE) has asked the Scientific and Technical Center for the Construction Industry (CSTB) to test the volatile organic compounds (VOC) emissions of traditional vibrated concrete. The test reports of CSTB, SC13-047, and SC13-048 for BAP, establish the **A +** classification (very low emissions) for these concretes.

5.3 Radon and gamma radioactivity

In Europe, average concentrations of radioelements in commonly used concretes are 40 Bq/kg in radium, 30 Bq/kg in thorium and 400 Bq/kg in potassium. Emissions of radon gas from concrete material are much lower than natural emissions. On the contrary, in the case of natural radon emission from the ground, a concrete wall (vertical or horizontal) makes it possible to create a barrier to these emissions.

5.4 Acoustics

UHPC characteristics are involved in the creation of acoustic comfort conditions in the building. Thanks to its mass, concrete allows to considerably reduce the noise inside and outside a building. Besides the environmentally friendly impact of *UHPC* precast elements shown through the life cycle analysis, one of the major qualities of concrete material is its thermal inertia. It guarantees a low sensitivity to heating and cooling: in summer, the effects of sunlight on the material are therefore limited - appreciable quality in IGH where the extent

of the glazed surfaces brings a very high level of sunshine. Due to this high resistance to heating, a high rise building whose outer skin is made of concrete element will therefore be more comfortable and less demanding in air conditioning cooling systems. The qualities are the same in winter, where the concrete tends to conserve during the night the heat accumulated during the day. The result is significant energy savings and therefore reduced impact on global warming.

6. CONCLUSION

Verticalization, as one of the possible well tested answers to cities densification, seems to be inevitable. But towers need to be rethought and move away from the energy consuming glass box typology.

La Marseillaise project might be announcing a future progress in this domain. In construction methodology first, with an efficient self-climbing concrete formwork forming the central core, allowing large and open floors thanks to a light metallic structure; but more specifically, with its innovative façade that truly mutates the classical curtain wall tower paradigms into some technically efficiently condensed outer skin. It is then now possible to insulate and seal buildings towards air and water with a thirty-five-millimeter-thick *UHPC* plate; to prevent fire running from one floor to the next one with this exact same plate (also used for building maintenance as a peripheral gangway); to shade with twenty millimeters thick louvers incorporated in the monolithic precast element; to insulate thermally and acoustically thanks to UHPC as an inert material backed by rock-wool. All these functions have been shaping a single monolithic *UHPC* precast element, easily installed.

To me, this very condensation of technical layers into single precast elements is key to the understanding of most successful UHPC designs such as *Tower La Marseillaise*, *Gare TGV de Montpellier* and *Campus EDF Saclay* all presented in this Symposium.

While the *UHPC* precasting method has helped to reduce the environmental footprint I would like to emphasize the fact that the association of a *UHPC* C+D system (preventing fire to jump from one floor) and a fire stable rock-wool embedded in a fire-inert cement material has proven safer than other cladding system (aluminum composite associated with polyethylene-like insulations for instance). This approach has shown adequate and wise while recent fire sinisters of *Grenfal Tower* in London (June 15th 2017) and *Address Downtown Hotel Tower* in Dubai (January 2nd, 2016) amongst other are hitting the head news.

In the very time lasting, resistivity and generosity of construction material resides the essence of Mediterranean constructions. Thanks to the innovations described in this paper, but also proceeding from kinetic art and references to the close by *Radiant City* of Le Corbusier, Jean Nouvel has defined with *Tour La Marseillaise* a new high rise building typology.

ACKNOWLEDGEMENTS

We would like to thank all the parties who have contributed to the project and made it possible to be completed in such a timely and efficient fashion, more particularly *Méditerranée Préfabrication, Guard Industries & Dumez Méditerranée.*

KEY FACTS

Tour La Marseillaise ID Card

- 135 meters high / 31 levels
- 39,560 sqm net developed area
- 35,000 sqm of offices / up to 3,000 workstations / 350 parking slots
- 18,800 cubic meter of concrete / 1,700 tons of steel
- 2,100 tons of UHPC (*UHPC)*
- 16,000 m² of glazed facades
- 3,500 UHPC solar shadings (*UHPC)*
- 26 color shades with dominants of blue, white and orange

Project key players

- Maître d'ouvrage : Constructa (developper)
- Maître d'œuvre : Ateliers Jean Nouvel
- Investors: CEPAC / Caisse des Dépôts
- Financial partners: Crédit Foncier / BPI France / La Banque Postale / CEGC / Socfim
- General Contractors: Dumez Méditerranée / Le travaux du Midi / GTM Sud

Construction works

- responsible of Design&Built team: Dumez Méditerranée
- contractors: GTM Sud / Travaux du Midi / Crudeli / SNEF / KONE
- UHPC (*UHPC)* precaster : Méditerranée Préfabrication / Colors : Guard Industrie
- design offices: Alto Ingénierie / ARCORA / SIDF / AEDIS / SERIUS / AVEL / GLI
- landscapes engineering: Tangram
- start of construction works: December 2014
- duration of construction works: 3 and a half years (December 2014 – end of First quarter 2018)

Occupation

- La Communauté urbaine MPM on 12 floors / 16,000 m²
- Orange on two floors / 2,200.00 m²
- Constructa on 27th floor / 1,400.00 m²
- La Caisse d'épargne Provence Alpes Corse on 28th floor / 1,400.00 m²
- The CCIMP and the World Trade Center of Marseille Provence will occupy the two very last floors (29th and 30th) / 2,300.00 m² to install a business center and the "Provence Business Sky Lounge", two spaces capable of hosting national and international clients.