Composites have evidently made significant incursions into many manufacturing sectors, frequently where their strength to weight advantages offered increased performance over other materials and methods. The drive to performance has nurtured an agile and innovative industry, and the rapidity of technical development has been quite remarkable. In the wake of such innovation a range of general manufacturing materials and methods has emerged, and these are consolidating their hold in many more general markets, the elegance of material-processing allowing economical as well as performance benefit - wind turbine blades as an example.

Evidently, though, production of boats or aircraft (where the goal was speed or weight) required a radical re-thinking of manufacturing processes, so it seems likely that a holistic revision of extant building-industry protocols will be required if there is to be real potential of composite buildings: it is unlikely that replacing components will prove competitive or beneficial.

What gives credence to such thinking is the sheer scale of projected building activity during the next few decades as global population increases to 11 billion - a likely doubling of buildings on Earth. This will be the largest manufacturing activity (by far) that humanity has ever engaged, and it raises profound questions about resources - both materials and energy - just to fabricate, let alone operate, such buildings. As sand, steel and aluminum face shortages of supply, and as fossil fuels are likely subject to increasing environmental limitation, so the need for radical lightweighting and low-energy-intensity material use at a scale of urban systems will become paramount. In this, only the hydrocarbon reserves seem really adequate to this civilizational-scale near-term challenge, so the race is on to devise lightweight composite building
technologies, largely for developing-world markets. These would ideally need to be economic, versatile, energy-efficient and recyclable; but also perceived as desirable housing by people in diverse cultures.

The building industry is facing a productivity and affordability crisis in developed and developing markets, largely due to its inability to embrace new material-processing: over the past 30 years the building industry has decreased in productivity, where the manufacturing sector has effectively doubled productivity. Evidently, buildings face particular technical challenges, especially fire retardancy, adaptability and longevity; but many of these issues have nascent solutions developed in other sectors. However, there is no Boeing or BMW in the building industry to take a decisive first step; and the thought-leaders (architects and engineers) are caught in a project-by-project procurement logic that doesn’t suit sustained research and development drives. As a consequence, there is a profound need for the polymer industries to initiate comprehensive building-focused research to devise a range of emphatically-beneficial composite buildings, materials and methods that offer versatile, economical, code-compliant solutions.

Implicit in a civilisational-scale composite-building vision, is that we seek to shift emphasis from burning hydrocarbon resources and instead deploy polymeric composites as an ubiquitous building material, sequestering carbon now at macro scale. The economic opportunity is vast, but so too is the potential environmental benefit, at what will be a critical period of unprecedented urban growth internationally.

The number of submissions received for the Innovation Awards program is proof that composite materials for construction have widespread applications. So, for its first edition, the Future of Composites in Construction will reward all these uses.

**GFRP for urban renewal challenge**

When faced with the challenge of restoring three existing buildings (old America’s Cup team base), the choice and use of composite materials became rapidly obvious because of their numerous advantages. Among other, the proximity of the sea required a highly durable and corrosion resistant material. Moreover, the ease of fabrication, production control and the rapid installation of finished components that is enabled by composite materials allowed the whole project to be completed in a mere year. The pultruded sunshade elements of the façades comprise two systems of slats designed to improve the energy efficiency of the building. Their spacing calculated to let the sun in during the winter but, at the same time, avoid it in summer. These slats benefit from the inherent thermal properties of GFRP when compared to aluminium allowing for the building’s very good energy efficiency.

**Company:** Owens Corning (France)  
**Partners:** Polymec SI (Spain), ERRE Arquitectura (Spain), Gazechim Composites Iberica, S.A. (Spain), Miraplas, S.L. (Spain), RTM Bey Consultant (Spain)
Highly integrated ductile reinforced carbon composite I-beam

This innovation is enabled by a novel continuous and direct weaving process, called Add-on Weaving, which offers great freedom in combining different fabric architectures in 3D, such as 0/90 and +/-45 weaves, with full mutual through-thickness interconnection between webs and flanges. This highly integrated fibre architecture at web/flange junctions arrests delamination and thereby promotes quasi-ductile structural response to bending.

Compared to traditional steel I-beams, the produced 3D-CFRP beams are 2-3 times stronger per weight and they absorb 2-3 times more energy than steel per weight.

Structural FRP composite panel with moulded Ultra-High Performance concrete finish

Ultra-High Performance Concrete (UHPC) provides an aesthetically pleasing, durable, fire resistant surface. But where most applications rely on UHPC as a structural shell, which can result in a heavy panel. Premier Composites have developed a solution where a relatively thin layer of UHPC can be utilized as an in-mould finish for FRP panels. This enables the use of UHPC on structural FRP sandwich panels.

Full-scale site testing of seismic retrofit

One of the main concerns of the Building sector worldwide is the aging of infrastructures. This threatens public safety and causes huge economic losses, therefore, finding efficient ways to repair buildings, bridges… will be a challenge for the future, especially in seismic areas.

To test the efficiency of its CRFP retrofitting solution, DowAksa, along with Istanbul Technical University, conducted a full-scale earthquake simulation. Using the same foundation and materials, two full-scale buildings were constructed using practices that were common for several decades in Turkish construction. The first building was retrofitted with CFRP, while the second one was not changed. During the test, the unchanged building collapsed while there was no strength loss or significant damage observation on the retrofitted one. And after the collapse of the reference building the push over loading continued until ten times higher lateral drift. Under this high lateral displacement, the retrofitted building stood upright.

Company: Premier Composite Technologies (United Arab Emirates)
Partner: Technische Universität Chemnitz (Germany)
This innovative process combines the lightweight and stability of structural sandwich FRP with the durability and fire resistance of UHPC. Enabling the making of large span panels with minimum finishing work, low maintenance and rapid installation on site.
Free-form structural FRP roof without moulds

This innovative solution concerns a composite that is forming the finished inner and outer surfaces as well as the primary structure of a roof. The composite roof replaced nearly all the supporting steelwork with a self-supporting very thick FRP/foam cored sandwich structure. The cores are produced from PET foam made from recycled water bottles, which are machined into complex forms and bonded together into very large subassemblies (the main structure is made in 26 pieces and is about 40m long). These are then laminated with structural FRP skins. In highly loaded areas the resulting sandwich structure is over 800mm thick and in addition to structural integrity provides very high levels of thermal insulation. The individual parts of the roof are assembled onsite without any mechanical fasteners to create a continuous shell structure and seamless visual appearance.

The biggest advantages of the innovation are that the overall cost and build time were reduced, and that the lightweight, self-supporting nature of the roof enabled a significant reduction in supporting structure, providing a more open interior space.

SolarClover advanced solar panels

With growing consideration for low energy buildings, the integration of renewable energy sources becomes an important part of the Construction industry. This innovation consists in a thermoplastic honeycomb core and glass-reinforced thermoplastic skin composite that serves as a structure for a high efficiency solar panel.

The structure offers critical functionality like lightweight structure (30% less weight than state of the art solar panels), puncture resistance, thermal stability, fire and moisture resistance as well as recyclability. Moreover, as the innovative design eliminates the aluminium frames and glass front sheets, the composite structure utilizes an in-line production technology and uses less energy to produce, lowering the carbon footprint as well as the cost of the solar panel. Broadening the access to solar energy in emerging markets who have little to no access to electricity.
conferences

International JEC Conferences: knowledge and networking

ROOM B16

June 20th - 08:30am
Construction: A Segment Filled With Possibilities

With forecasts of the number of accommodation capacities doubling by 2050, the question of what materials will be used is becoming increasingly important, especially considering the environmental and weight constraints in this specific field.

8am Welcome Breakfast
8:15am Introduction

8:30am The Future of Building - the Growing Use of Composites in Construction and Architecture, Andrew Mafeld, Managing Director, Connectra

9:00am Towards a Systemic Architecture: Composites at the Conceptual and Practical Levels, Eric Davis, Lecturer, Department of Architecture Interior Architecture and Designed Objects, School of the Art Institute of Chicago

9:30am Structural Composite Shelters, Rich O’Meara, Owner/President, Core Composites

10am Networking break

10:30am Modular, Above the Ground, Composite Shelter, Uday Vaidya, Governor’s Chair in Advanced Composites Manufacturing Professor, Innovative Composite Solutions

11am Composites in Future Connected Cities, Mikko Lassila, Group Sales Development Manager and Product Business Owner, Exel Composites

11:30am A Composite Logic for a Tectonic Industry, Jefferson Ellinger, IA Associate Professor, UNC Charlotte (College of Arts + Architecture)

12pm Lunch Break

ROOM B16

June 20th - 01:30pm
Durability of Composite Materials in Construction

There are no structural reasons justifying the lack of composite materials use in architecture, but so far, architects have been reluctant to taking them into consideration. This session will develop how to take advantage of composite materials’ properties thanks to various case studies.

1:30pm Infrastructure - Next Frontier of Pultruded Composites, Mikhail Vorobiev, Global Product Manager - Infrastructure, Owens Corning

2pm Affordable Composites in Infrastructures, Martin Halpin, Innovation and Development Manager, Construction Composites

2:30pm Expectation of FRP for Infrastructure in Japan, Shinichi Miyazato, Researcher, Kanazawa Institute of Technology

3:10pm Networking break

2:45pm Large Scale Self-supporting CFRP Architectural Structures, Mark Hobbs, Head of Structural Engineering, Premier Composites Technologies

3:30-4:30pm On Ice, Fire and Carbon, and the Case for a Lightweight Ontology, Mark Goulthorpe, Professor and Architect, MIT
By nature, composite materials are inherently thermally resistant, which makes them a realistic and cost-effective option for buildings, where flame retardancy is a crucial challenge. However, the lack of inclusion of composite materials in the international building code have made their use difficult in the building and construction industry so far. Fire chemistry, different types of resins, and screening processes are among the subjects that will be addressed in this session.

There are no structural reasons justifying the lack of composite materials use in architecture, but so far, architects have been reluctant to taking them into consideration. Often, the full potential of composites remains untapped, and the issues that need to be addressed such as fire proofing, UV resistance, etc. constitute an obstacle to their generalization. This session will develop how to take advantage of composite materials’ properties thanks to various case studies.
The rigor of code-compliant requirements making it possible to use fiber-reinforced plastics in buildings is what has prevented these advanced materials from being adopted in a faster manner by the industry. This interactive session aims to present what has been done so far and what still needs to be set up.

**JUNE 22nd - 10am**

**Developing Building Codes and Guidelines: Is Standardization an Attainable Goal?**

**10am** • Building Official Acceptance of Composites in Concrete, Stephen Szoke, Professional Engineer, American Concrete Institute

**10:20am** • Evaluating the Performance of Composite Materials, Kevin Lambrych, Industry Manager - NA FR Laminating Resins and Gelcoats, Ashland Performance Materials

**10:40am** • Engineering Methods for FRP, Nicholas Dembsey, Professor, Worcester Polytechnic Institute

**11am - 12pm** • Interactive round-table discussion

**FREE ACCESS SESSION**

**JUNE 21st - 12:30pm**

**Connecting Technical Textiles and Composite Materials in the Building and Construction Fields**

**12:30pm** • T.R.C. (Textile Reinforced Cement) a New Generation of Composite Materials, Patrice Hamelin, Emeritus Professor, Ecole Nationale d’Ingenieurs de Saint Etienne (ENISE)

**12:50pm** • Experimental Study and Modelling of Composite Sandwich Renovation Panels, Matthias De Munch, Researcher, Vrije Universiteit Brussels

**01:10pm** • Evaluating Performance Properties of Thermal and Sound Insulation Products Developed from Waste Fibers for Over the Ceiling Insulation Application, Asis Patnaik, Senior Lecturer, Cape Peninsula University of Technology

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COMPOSITES VELOX EXPERTISE

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My interest in composites is part of a long-time concern with the technology of exterior envelopes. I approach them both technically and conceptually/theoretically. This personal obsession has endured through the past twenty years or so in practice here in Chicago, in a variety of firms and more recently in my own practice. As my personal practice evolved, I started teaching, at the SAIC, and found a natural fit with their technical courses, both graduate and undergraduate.

Over the past three academic years, while preparing for presenting these courses at the SAIC as well as a course on the History of Modern Architecture at the University of Chicago, I developed a point of view regarding the relationship between structure and enclosure. With increased emphasis on sustainable design and energy performance, it is my view that the two most prevalent idioms for exterior enclosures, at least in the US, have fundamental conceptual flaws. The industry has attempted to "tech" its way out of these problems but these efforts are both expensive and insufficient.

So I undertook additional research and determined that the nexus for this relationship lies at the physical connection(s) between that which holds a building up and that which keeps out the elements. With only a few recent exceptions, the components that span this gap, which tie things together, are made from materials with high thermal conductivity. What is needed are components that are "as strong as steel" and yet do not serve as conduits through the thermal envelope for both heat and vapour/condensation.

That is what led me to composites. I have been aware of, and an advocate for, pultruded fibreglass for some time because of my work in the transportation sector. But my investigations during the past three years have broadened my awareness of the range of applications of composite materials, and the need for more research in their application in this critical area of the building industry. Also, as a native of Indianapolis, home to the Indy 500 car race, I have long been aware of the applications of composites in auto racing and their unique properties in an industry that requires both high strength and light weight.

I have presented this thesis over the past two semesters to my students.
in three courses, as illustrative of the conceptual and technical parameters they must consider when developing exterior wall designs. We are fortunate in Chicago to have examples not only of current construction, but also of some of the most important historical examples in the development of multi-storey buildings. My presentation to my students, and that which I will be sharing at the Symposium, includes a look at these earlier historical evolutions; a technical view that is not always well understood when these works are presented to students from an art historical perspective. Architecture students need the cultural/historical understanding but they also need the technical understanding, so they can judge what, if anything, can appropriately be applied from these important earlier works.

The SAIC is a unique venue in this consideration. The architecture programme is housed in one of the greatest masterpieces in architectural history, Louis Sullivan’s Carson Pirie Scott store. Our studios have direct views of other landmarks of “Chicago School” and early modern high-rise construction, such as Burnham’s Reliance Building and SOM’s Inland Steel Building – our students look across, not up, at these other landmarks. This makes for a unique setting for the teaching of technical systems. The students see and better understand the nature of the quandary that my research revolves around. The high degree of creativity in the SAIC programme means that the students do not simply clip an existing system onto the outsides of their designs, but rather they see the crafting of such enclosure systems as part of their artistic task.

That teaching, and the research in preparation for it, led me to be aware of the JEC symposia – first I found the one in Paris but then I was delighted to learn of the one here in Chicago. So I reached out and connected with JEC and I am very much looking forward to discussing this long-time obsession with people from the industry who know far more about the potential of this genre of materials than I do. In my mind, this is the future of the building industry, something that will become a regular part of the education and consideration of architects around the world.

More information: www.saic.edu
When did you start teaching composite materials at the IIT College of Architecture?

**Alphonso Peluso:** My students and I began working with composites in 2014. I was teaching a design studio titled “Design as a Performative Material Practice” and the focus was to design and build a full-scale temporary structure out of carbon fibre. The project was named the FIBERwave Pavilion, and it was quite well received. The project was written about in several architectural blogs including The Architect’s Newspaper. I should add that my students and I have only worked with carbon fibre.

What is the place of composite materials in the training programme?

**A.P.:** The topic is part of an ongoing elective seminar course that I teach each semester. Since the FIBERwave project, my students and I have completed a full-scale building facade panel made entirely out of carbon fibre called “carbonSKIN” and, last semester, they built a rolling sofa called “Rolling Vitruvius” for the annual SOFAexpo in Chicago.

What do your students look at these new materials, for which there is little experience in architecture?

**A.P.:** Initially, they view the material as very exotic. Typically, their go-to material is wood and acrylic and these materials are mostly used for making architectural models. So the fact that they will build something full scale out of this material that they have never worked with before is very exciting and intimidating at the same time. By making small-scale prototypes, they learn very quickly that working with carbon fibre requires a great deal of attention and craft.

What do you think is the main interest of using architectural composites but also the main obstacles?

**A.P.:** I think that currently the main interest is two things. The first is what do we do with it? Do we replace structural steel columns and beams with it? Do we make floors and ceilings out of it? Do we clad buildings with it? In these early stages of its use, the building industry does not know a whole lot about the material. The second is that the material is so lightweight and thin in relation to how strong it is. So what does that mean? Will this save money when building a building? Will it be easier to construct? How do we analyse the structure? As you can see, along with these interests comes a lot of questions. A few obstacles are fire safety, building codes and structural analysis. Once there are people dedicated to working on and solving these obstacles, the use of composites in architecture will grow at a fast pace.

More information: [http://arch.iit.edu/](http://arch.iit.edu/)

Without getting ahead of the presentation that he will give at the Future of Composites in Construction trade show 20-22 June in Chicago, we asked Alphonso Peluso, Studio Associate Professor of Architecture and Director of Design Communications at IIT Architecture Chicago, a few questions about his approach to composite materials and how they are integrated into architectural studies.

**“This material that starts out as cloth can be shaped to any form imaginable”**

**Interview**

**Alphonso Peluso,**

**Studio Associate Professor of Architecture**

**Director of Design Communications**

**IIT Architecture Chicago**

Focus

The College of Architecture’s programmes of study emphasize investigations in architectural and landscape architectural design and technology, while expanding the significance of these investigations through a rigorous application of critical thought and intellectual inquiry. The College draws strength from its unique traditions and circumstances, such as its Miesian legacy as a preeminent school of modernism, its location in Chicago with its profuse architectural heritage and devotion to enhanced landscapes, and the city’s present-day connections to progressively minded, global practitioners. The students, faculty, and alumni foster an academic environment that is intellectually stimulating, professionally challenging, committed to innovation, and international in scope.
The onion domes so characteristic of Orthodox architecture were absolutely required for the cathedral – representing Jesus Christ and the four Apostles Mark, Luke, John and Matthew. That was one of the instructions from the owner, the Russian Federation.

This new 4000-sq-metre Russian centre consists of the Saint Trinity Cathedral, an administrative centre, a school, and a cultural centre. Louis Lafargue, project director for the architecture firm Wilmotte & Associés tells us more about this extraordinary architectural adventure.

Combining tradition, harmony with the urban landscape, and a new creative design

Jean-Michel Wilmotte and his team started out by making sketches. “Onion domes are completely new shapes for us in France. They aren’t one of our building traditions,” said Louis Lafargue, project director in charge of the Orthodox centre, “so we did a lot of work on the profiles and on the models, using 3D printing with the building information model (BIM) that both architects and engineers use. We also exchanged a lot with our Russian colleagues, followed the instructions of Patriarch Kirill of Moscow, and explored many different shapes. We did a lot of travelling between Paris and Moscow. Using iteration, we arrived at this particular shape and these gilded volumes in this particular shade of gold that is more matte and paler than usual.” It was important not to compete with the nearby dome of the Invalides or the horses on the Alexandre III Bridge, shimmering in the classic traditional yellow gold seen in Paris, and which is achieved by gilding on lead or copper.

“What to use to make these spectacular domes? Who would know how to do it? We ran through the whole spectrum of potential construction techniques. How could we cover these unusual domes? It wasn’t possible using standard techniques! We explored a lot and brain-stormed, then looked further into the automotive industry – there were some very innovative possibilities between sheet-metal work and prototyping, but at very small scales, and besides, the prices went over the budget. “In the team from Bouygues (general contractor for project management), one of the project managers had experience in the aviation industry. We started to talk about aircraft cockpits and, by association, we got to the subject of composite materials. Would
they make it possible to produce oversized construction materials that were of a single piece, without joints? Large, slender gilded volumes without marks?

“We knew that the Multiplast Company makes satellite antennas for military purposes, parabolas and boat hulls and, therefore, that they knew how to work with curves in their composite creations. It was also of interest that mechanical fastenings can be used with fibreglass.

“So we decided to work with this company, which is internationally reputed for its know-how in competitive multihull construction. The onion domes were fabricated in their facilities in Vannes (Brittany) by assembling huge golden petals on site.”

The world’s first Orthodox onion domes made of composites

Composite materials are in widespread use in the aerospace and marine industries, but seen more rarely in building and construction, so the use of this technology to make the cathedral’s domes is a world first. The target was a strong and very lightweight material that could meet the tolerance requirements and be used to produce oversized elements.

The technology’s twofold advantage is that it reduced the weight of the domes (the large dome, which would have weighed 42 metric tons if made in standard materials, weighs only eight metric tons) and enabled a shorter overall completion deadline, since the domes were prefabricated as the shell construction was taking place.

A nine-month fabrication process

Fabrication of the five domes started during June 2015 with the creation of the moulds, an individual one for each petal. The largest dome consists of eight lower petals, four upper ones, and an end cone to support the cross. The four smaller domes consist of three petals and an end cone. Three plies of glass fibre were laid up in each mould to make a petal. The fibre was then covered with a thermoplastic foam 50-mm thick, and then with three more glass-fibre plies. To mould the petals, vacuum infusion was used. In this process, epoxy resin is injected once the vacuum is installed. It diffuses throughout the fibres, and the laminate is then cured and released from the mould.

The domes’ impermeability had to be guaranteed for compliance with regulations, but the General Commission on natural and technological risks has established no code of practice for a roof made of glass-fibre-reinforced composite. As a consequence, to comply with the unified technical document (DTU) on roofing, it became necessary to ensure that the concrete domes underneath were leaktight, complicating matters.

In order to obtain insurance coverage for the monument, Wilmotte also had to file for an "ATEX" technique rating from the scientific and technical centre for the building industry CSTB, providing all the necessary evidence on this non-standard building technique. They made their case for the technical aspects of the project before the CSTB, including dome assembly, impermeability, weatherability, fire protection requirements, and the joint between dome and cross.

Focus

More progress needs to be made in legislation for the building and civil engineering industry with regard to the use of composite materials

Innovations are exceptional and therefore difficult to account for. The legislation on building and construction is very strict and does not provide for these “firsts” and “exploits” accomplished with composite materials. So, how to proceed?

In order to obtain insurance coverage for the monument, Wilmotte also had to file for an "ATEX" technique rating from the scientific and technical centre for the building industry CSTB, providing all the necessary evidence on this non-standard building technique. They made their case for the technical aspects of the project before the CSTB, including dome assembly, impermeability, weatherability, fire protection requirements, and the joint between dome and cross.
Between minimalism and baroque: a first in France’s construction sector

Each unmoulded petal was mechanically assembled to the others to check for fit, and then prepared for gilding with “Moon Gold”, an alloy of gold and palladium (similar to platinum). Multiple primer layers had to be applied to the fibreglass substrate to keep it separate from the 90,000 8x8 cm squares of gilding foil that were placed side by side on the surface by the journeymen from Ateliers Gohard – the same workshop that re-gilded the Statue of Liberty in New York and the dome of the Invalides. Nothing covers the foil, however.

Once dried, the gilded petals were reassembled, then disassembled once again and placed in frames for transport in wide-load vehicles. Multiplast took care of the handling operations – extremely difficult, as each petal had to be attached by its lower surface to avoid touching the upper gilded surface, which was absolutely forbidden!

When the petals were delivered to the worksite in Paris, they were assembled on the ground and crane-lifted to be mounted onto the concrete domes. The work operations had to be interrupted when the wind was stronger than 20 km/h (about 12.5 mph) to keep the lightweight composite domes from swaying too precariously. The self-supporting domes required no additional supporting metal structures. The end cones were installed last, along with the Russian-made crosses.

A symbol around the world

Despite a rather sensitive context, everything went quickly and serenely. The companies involved were highly motivated, and the interchanges with the head architect for Bâtiments de France and the Paris municipal administrative services were very fruitful.

In their exchanges with the workmen and journeymen, the architects emphasized the fact that they were working on a monument and not just on a building. A monument endures as a visible, recognizable symbol and should be flawless. Furthermore, in this case, the monument has a spiritual dimension. Religious ceremonies took place for the foundation ceremony and for the consecrations of the greater dome and the greater cross. The view of these onion domes from the top of the Eiffel tower is breathtaking. All the objectives in terms of the visibility, beauty, careful detail, simplicity of line and urban harmony that characterize the work of Wilmotte & Associés have been brilliantly achieved.

More information:
www.wilmotte.com

N°113 June 2017 / JEC COMPOSITES MAGAZINE
We live in a world of finite resources, and that is a fact! We now have to reinvent a growth and development approach that is compatible with ecosystem restoration.

From now on, any contemporary enterprise with an awareness of the real importance of preserving resources must commit to corporate social responsibility. Sustainable development consists of bringing together the best in social and technical advances to generate measurable sustainable progress for both humans and the planet. Insofar as the construction market produces about a fourth of global CO₂ emissions, it has a strong bearing on energy transition issues.

Energy transition
These days, composite materials are already being used in certain building components. In terms of global carbon cost, composite materials are often more efficient than standard materials, and so they help to reduce the carbon footprint of buildings.

As a leader in building and construction, Bouygues is in the vanguard for innovation in its sector. For example, the Group develops both high-performance concretes that are of great interest to architects for complex engineering works, and environment-friendly “low-carbon” concretes. The leading source of greenhouse gas emissions in construction, excluding the operation of engineering works, comes from the materials used for shell construction (cement + steel).

Advantage 1: Low weight
In some cases, there are advantages to using composite materials in buildings. They are strong and durable, and they make it possible to use fewer raw materials for structural purposes. We have known for some time that the use of composites in all types of vehicles leads to significant savings in energy consumption, thanks to the weight savings compared to standard materials.

Advantage 2: the magic of strength
Thanks to composite materials, and in particular to their exceptional strength, we can now build structural components that could not be achieved using standard materials. The extraordinary thing about composites is their extremely high strength in combination with their low volume and low weight. The problem that remains is their manufacturing cost: in terms of overall costs, they are not often recommended by either architects or developers, but I remain confident. If you consider the case of photovoltaic panels, they were so expensive that they were considered a luxury, ten years ago. Nevertheless, solar power has still developed all over the world, prices have dropped, and now it is the cheapest energy worldwide in terms of euros/installed capacity, which is a good thing for the planet.

Due to the lower cost of solar panels, we can...
now build energy-positive buildings at a cost that is scarcely higher than the cost of a standard building ten years ago. This raises hopes that composite materials will follow the same path as solar panels, even if the production issues are quite different.

At Bouygues, as builders, we are in favour of having more composite materials integrated into structures, since that will enable the bold architectural ideas that are difficult to achieve with traditional construction methods.

Why are composites an advantage?
Because they are materials that age well – better than some types of wood that require protection, for example – and because they are extremely strong, it becomes possible to design buildings with fewer materials, and therefore which are cheaper to build.

The emblematic achievement in the current Parisian citiescape consists of the onion domes of the Russian Orthodox Spiritual and Cultural Centre. While Bouygues did not construct the domes, it did construct the building. In this case, composites turned out to provide the best quality/price ratio for the domes from the aesthetic and visual viewpoint, and also for the very low weight! This was a real first in construction, and it is something we need to continue to promote. It is through this type of emblematic construction that we will succeed in making the use of composites more widespread for more ordinary buildings. So major companies like Bouygues have a role to play in the potential development of composites in construction.

People are usually for progress but against change
Bouygues is an expert at crunching the numbers to find the right materials to use for the required strength and just the right quality to avoid wasting resources. Nevertheless, material engineers have their own ways: “People like progress, but they are against change,” jokes Fabrice Bonnifet. Many engineers, designers and architects have learned to work with concrete, and when they are handed a new “recipe”, it upsets their habits. Beyond cost concerns, the use of composite materials is still considered as disruptive with respect to their building methods, and the same thing can be observed with the use of wood, because it isn’t part of our culture.

However, all innovations start with a niche application, and if it is a good one, the system can be extended to become more widespread. Composite materials started with Formula One (the niche) before reaching run-of-the-mill cars.

It is time to accelerate the development of composites – providing the composite industry manages to achieve low-carbon production! Over the next ten to twenty years, whoever is not “low-carbon” in the construction industry will be out of the market. Life cycle analysis (LCA) will be a requisite for all materials.

LCA covers all characteristics of a material from cradle to tomb. If it turns out that all-carbon composite materials are better than the competing standard materials, there will be enormous prospects for progress. The LCA has to be good all through the life cycle – if it is good at one stage but deteriorates at another, the material will not be chosen. The standards for energy performance will keep getting stricter in the future, to build a better life for the benefit of all, and for the planet.

Conclusion
This paper introduced a novel global design strategy for composite structures. The goal of this strategy is to improve the design of a composite structure based on its specifications, while taking into account many specific features of these materials. The prototype version of this design tool showed very promising results and the development of an advanced version is underway. This advanced version will introduce new functionalities, such as taking into account damage initiation or failure prediction, or optimizing a structure with respect to cost/ process constraints. Ultimately, the tool would also be able to guide the designer in finding the optimum shape and process for the part, in order to, finally, fully exploit the potential of composite materials in aerospace structures.

More information:
www.bouygues.com

The Bouygues Group’s construction businesses – Bouygues Construction, Bouygues Immobilier (Bouygues Real Estate) and Colas – are present in some ninety countries (58% of their orders in 2016 came from abroad). The Group is one of the sector’s global leaders and has achieved positioning success in the long-term growth markets. At the global scale, population growth, urbanization and the new environmental requirements are generating significant needs for buildings, infrastructures and services. The Bouygues Group is addressing these major challenges through its strategy to make the city of tomorrow more sustainable and appealing, as substantiated by the many eco-neighbourhoods in France and abroad, positive-energy building projects, and also the WattWay photovoltaic road surface concept.
The façade was constructed by Affan, a market leader in steel and glass structures. In 2009, the company turned to advanced structural composites and decided to construct their new headquarters and production facility in Dubai, UAE, entirely out of composite materials.

**Spectacular façade design**
Affan’s amazing headquarters raised the interest of main contractors Belhasa Six Construct and Orascom Construction Industries joint venture, on the lookout for someone who could deliver a spectacular design of the Hub Zero façade. Affan was asked to make a proposal that would also include steel and glass façades for the office and entrance area, as well as the lobby with sliding doors.

The solution had to be cost-effective and the installation made efficiently and quickly as time was a determining factor. In addition, the façade had to be able to integrate more than 4000 LED panels.

**Composite cassettes for easy assembly**
The design was based around two-storey-high structural composite cassettes, ranging from 10m to 15m in a single element. The cassettes had more than 6000 individual decorative panels added, a design concept that brings varying depth and randomness to the façade. Finally, the LED panels were fixed to the cassettes. The units were designed to maximize the benefits of factory production and quality control. Pre-assembled in the factory, they were transported on trailers to the construction site, where they were swiftly put into place. This method allowed for a quick development from a simple block work structure to a fully finished façade. The entrance façade comprises structural glazing supported on structural glass fins with integrated break-out sliding doors from Boon Edam. Affan also designed all the structural supports for a 14m x 8m LED screen at the main entrance. The façade was completed in February 2016 and the centre opened to the public in August 2016.

The façade of Hub Zero, Dubai’s first immersive family entertainment park, lights up in an ever-changing pattern. An eye-catching landmark at Meraas’ City Walk, the centre offers a fully interactive gaming experience for young and old.

**Installed facade**
Complex shapes

The complex shapes that are part of Affan’s trademark, and that are evident in the Hub Zero building, can be achieved with composite materials, which is why the company has been a steady Diab customer for the past six years or more. A fire-retardant material – Divincell P60 – provided the base core for the façade structure, whereas Divincell PX300 was used for high-density inserts around the LED square panels where good screw retention was required. Wood was originally chosen for this application, but once Diab was able to demonstrate the excellent screw retention properties of the PX300 material, Affan decided to use it in the structure instead, ensuring good compatibility with the system and long service life.

Diab’s high-quality products are appreciated at Affan, but equally important is the customer relation and Diab’s support throughout the process. Affan’s team enjoy working with Diab, as they find them very responsive to their needs. They look for solutions from both a product and supply point of view.

More information:
www.diabgroup.com
http://affan-uae.com/home/hub-zero
From fibreboard to composite honeycomb cores for custom-built doors

This article is a case history on the use of a unique composite honeycomb core to replace fibreboard cores in high-end, custom-made residential wooden doors. The first application was an oversize door for a walk-in cooler in a residence, where the weight of the door was more than halved by the change in cores. This was very important since the cooler-facing side of the door was exposed to cool/dry conditions, while the exterior (exercise-room-facing) side of the door was exposed to warm/humid conditions, which could have caused dimensional stability issues.

Fenstür Windows and Doors, a manufacturer and direct retailer of high-end custom-built residential wooden doors and windows, has begun replacing fibreboard cores in its doors with a unique composite core produced by RhinoKore Composite Solutions (Armstrong, B.C., Canada). The composite cores offer a number of benefits, the most important of which is more than halving door weight, which eases handling and installation at the construction site, plus brings the carry-over benefits of mass decompounding, such as being able to use smaller and lighter hardware to hang the doors. Additionally, the new cores improve dimensional stability and thermal insulation (their R value is 3.15 to 3.19 per 2.5 centimetre thickness), and they also proved to be a drop-in replacement during the manufacturing process without the need to modify anything, including the adhesive.

The collaboration began at the recommendation of a local builder who was working on a residential construction project where Fenstür was asked to produce a custom interior door for a walk-in cooler. The homeowner, an avid hunter, wanted a cold room with a hidden door to hold game, food, and wine. The unique oversize door is designed to blend into the wall when closed, hence it features concealed hinges and a removable spindle that functions as a handle. The side of the door facing the inside of the cooler is finished in birch wood to match the cooler interior, while the outside (exercise-room-facing side) of the door is covered with hackwood to match the floors and walls in that room.

Temperature and humidity differences

The door was built before the exterior/exercise room was panelled with hackwood. The wood for that side of the door was brought to Fenstür’s shop and

A unique composite core was first used on a custom door for a large walk-in-cooler at the home of an avid hunter who wanted a cold room to store game, food, and wine. The custom-build door is designed to blend into the wall when closed.
The patented honeycomb core is made from nylon (polyamide) and polyester fibres. The fabric is fed into a custom-built “honeycomb” machine where it is quickly exposed to hot air (427°C), which heats and softens the fibres and allows them to be manipulated and formed easily. The fabric is then pressed into sheets of conjoined hexagonal cells (13 mm in diameter with 1.1 mm walls) and cooled. Next, the solidified honeycomb sheets (122 centimetres wide by 244 centimetres long by 152 mm thick) are removed and placed in a mould, where a two-part, closed-cell polyurethane foam is injected into all the cells and allowed to cure in a heated press. The finished core is then sliced to thicknesses ranging from 0.64 to 15.2 centimetres so that it can be bonded to facings of thermoplastic or thermoset composite, metal, wood, or even concrete. The honeycomb core has a very good stiffness and strength-to-weight ratio and helps improve the structural integrity – especially torsional rigidity – of any structure it is bonded to. It is dimensionally stable and provides very good compression and shear strength, as well as thermal and acoustic insulation. At any thickness, the core offers excellent impact strength (energy absorption/damage tolerance). And unlike fibreboard, it is impervious to water and will not trap moisture or rot. It is also much lower in density than fibreboard, which helps reduce part mass significantly.

**No changes in the production process**

The RhinoKore product was tried on the cooler door for a couple of reasons. The team had some weight issues with the overly large front door to this house, so they opted to use the lighter core for the cooler door, which was also oversize. The new core gave them added dimensional stability and resistance to warpage and cracking, which they felt was really important given the significant temperature and humidity differences on either side of the door. The cold/dry side of the door wants to shrink, while the warm/humid side is in a different dynamic equilibrium. And the fact that the core is insulated is a bonus, as it helps make the cooler and its door more energy efficient.

The Fenstür team built the door using the composite core and found that it was a drop-in replacement for the fibreboard they had previously used. Nothing had to be changed in the production process – even the adhesive (polyvinyl acetate (PVA, also known as white carpenter’s glue)) they had previously used to bond fibreboard to wood facings could be used with the honeycomb core. The final door consisted of a 1.9 centimetre-thick layer of backwood panelling on the outside, a 2.5 centimetre-thick composite core, and a 1.3 centimetre-thick layer of birch panelling on the inside. Once the new door was assembled, Fenstür’s carpenters and finishing specialists were amazed to see that it was less than half the weight it would have been with a fibreboard core. It also was quieter and took less effort to open and close. The team knew that that would not only make it less costly to ship to the worksite, but would make it easier for the local builder’s construction crew to hang and true the door. They also felt that door sag would not be an issue, since the hinges were not stressed thanks to the reduction in door weight.

Since 2007, RhinoKore Composite Solutions (Armstrong, B.C., Canada) has produced a unique honeycomb core for sandwich-panel composites originally developed for the oil and gas exploration industry. The core is produced from a tough nylon/polyester fabric that is formed (under heat and pressure) into a series of conjoined hexagonal cells, which after cooling are filled with a two-part closed-cell polyurethane foam. The core can be bonded to a wide variety of materials ranging from thermoset and thermoplastic composite skins to metal, wood, or even concrete, forming a lightweight but stiff and strong sandwich structure that also provides good thermal and acoustic insulation as well as impact strength (damage tolerance). The core is impervious to water and will not trap moisture or rot like fibreboard cores can. While not as stiff as paper/phenolic cores, it is far more durable (impact resistant). And unlike balsa wood cores (a rainforest product with inconsistent properties and limited supplies), the honeycomb core is tougher and stiffer. To date, the core has been used for crane pads, rig mats, insulated water tanks, load floors on commercial buses and long-haul trucks, and now as door cores.
Significant weight reduction

The weight reduction is really significant. On a conventional 125 by 250 centimetre door that can weigh 181 to 227 kilograms with a fibreboard core, the weight can now be reduced to about 68 kilograms. This is a benefit to anyone who touches the door and is definitely going to make the installer’s job a lot more pleasant. Not only does it reduce the risk of ending up with a door that lists to one side once hung, but it also lowers the chance of a door getting dings and dents as it is moved around, and it reduces the risk of warping and cracking too. It gives everyone some added peace of mind.

Owing to a positive experience with the new core on the cooler door, the Fenstür team built several prototypes. Then, they offered the new core as an upgrade at no additional cost to the first few customers to see how well it would be received. To date, no one has turned them down. In November 2016, they had already sold four doors and had another nine doors on order using this core.

The only downside Fenstür has seen is that because the core makes doors significantly lighter and also provides sound damping, it eliminates the heavy clunk traditionally associated with a door closing and with someone knocking. They have even tried bonding 6.35 mm plywood between the core and the skins to solve the sound issue, but the door still stayed very quiet. Some customers do not like the change, but others could not care less.

Going forward, the company plans to offer the composite core as a premium upgrade for a modest cost increase and will begin experimenting to see if it can be used for windows as well. Access to the technology has made the management more confident in bidding on very large doors, which could open up a new market segment for them. They could say that now that they have access to this core, it has given them new bragging rights because it enables them to build oversize doors and still maintain dimensional stability without losing strength. In fact, they are gaining strength and they can now achieve something that previously was very challenging. This means they are now better equipped to address the creative projects architects and homeowners imagine. This makes it a win-win situation.

The new business with Fenstür Windows and Doors is a welcome addition to the RhinoKore Composite Solutions family. The foundation of this company was built on the principle of creating innovative solutions for specific needs. Their work with Fenstür is a perfect example of this principle in action.

More information:
www.fensturwindows.com
www.rhinokore.com
Over the years, the civil engineering sector has developed anti-seismic infrastructure to an increasing extent to ensure all works meet specific design requirements. Shellife Srl designed a new composite module to protect people in the event of extreme danger or the collapse of an entire structure.

Prototype construction
The intuitive user interface (see Figure) describes the construction of a protective module that can accommodate up to four people (2 adults and 2 children) per capsule and be used both in newly constructed or existing multi-storey buildings. This module is designed to protect the life of people during a seismic event (for example, the collapse of the structure) and keep them alive until the arrival of the rescue teams. The module can be inserted in a normal house (office or other room), without altering significantly the intended use, functionality and aesthetics, indeed becoming itself a piece of furniture.

The capsule structure was subjected to virtual tests (crash tests) in order to define the features required to protect the "guests" during the seismic event. Both dynamic simulations (CAE analysis applied to the entire capsule of the type used for the design of F1 pilot protective shells) and static simulations (applied to the panels in laboratory samples) were conducted, providing indications for an optimum configuration of the final mathematics of the protective capsule.

The module was built using the latest generation of composite materials, in collaboration with the Italian Carbopress/ACS Group. It is integrally made of carbon fibre or a sandwich material combining carbon fibre and other materials with high mechanical resistance to stress, in particular an 800 gsm carbon layer and a 770 gsm glass fibre layer.
Two types of processes were used for the construction of the capsule: press and autoclave moulding.

**How the prototype works**

Within the capsule, a pressurization and air exchange system is inserted on the upper part of the cell. This system will ensure the survival of the occupants until the arrival of the rescue team. It is supported by a plate placed at the top (ceiling) of the capsule and consists of a supply fan with full motor speed shifter and a washable filter and gravity shutter, a UPS, LED lamps inserted in the removable panel ceiling, an alarm siren with a detachment button, an outlet to constantly keep the emergency back-up batteries charged, and an air distribution system using an air duct and adjustable air outlets made of a completely fireproof material.

In the upper part, the capsule is provided with a ring to lift and move it during the event recovery phase. Double doors are provided with rubber seals having a high degree of mechanical absorption and particularly functional and resistant hinges so that they do not weaken the module. Finally, the capsule’s interior is equipped with “passive” personal protection systems, in particular safety belts and airbags in addition to a system that completely fills the inner surface of the shell with a material able to absorb any shocks.

The use of the capsule is not limited to earthquakes. It can be customized during industrial production for other types of catastrophic events such as tsunamis, tornadoes, floods, etc., by adapting not only the structural aspects but also its water resistance and extreme resistance to different conditions. The module can be customized and made compatible with the environment or interior design where it is placed, using different types of materials such as wood panels, mirrors, or various types of fabrics so that the capsule can be used as a piece of furniture (living room, etc.).

**Patent developments**

To date, there are no devices on the world market comparable to those provided by Shellife in terms of purpose. The life-saving module is intended to protect the life of individuals in cases considered extremely dangerous, for markets potentially global in nature. Just think of what is happening over the world in terms of seismic activity (Italy, Honduras, New Zealand, the Philippines, India, etc.).

Once placed on the market, these protective systems, along with other systems currently in the prototype and development phases, could change the way new buildings are constructed or how existing infrastructure is modified, the latter often not being able to protect people effectively. In fact, these systems have a single objective: to save lives, no matter how “capable” the property is to avoid the collapse. The lack of an existing market offer suggests a strong possibility for the massive adoption of these life-saving modules. In order to evaluate the investment opportunities, in particular for the current patented product, a market survey was scheduled as part of the short-term planning activities aimed at analysing the buying preferences for such products. The investigation will be geared toward targeted regions such as Japan, the USA, South America and Asia. Based on a Shellife prototype model created by the engineer Matteo Gatto, the patent owner is currently identifying the financial market and one or more investors in order to – through a joint venture or the use of investment funds – not only put the prototype into production but also develop skills and know-how for the design and prototyping of new systems to protect people in case of natural and environmental disasters (telluric events, tsunamis, landslides, tornadoes, etc.).

**Denhouse**

At the moment, the start-up’s experimental research is concentrating on the development of an additional module called Denhouse, which will be an active seismic protection system for new homes right from the infrastructure planning stage and could be commonly deployed during standard architectural and operational phases.

In parallel, the start-up is developing a series of behavioural procedures that should be the subject of a technical legislative proposal transferring to the entire population (directly or indirectly affected) the knowledge of how to behave during seismic events, both at home and in places frequented by large numbers of people such as sports facilities, shopping centres or large industrial complexes.

Even Italian regulations should be properly adapted to promote prevention, in particular in regards to the correct behaviour and construction practices that, properly governed, can help provide tools for practical help especially during the event. To this end, meetings are currently being organized with the authorities in charge of developing the Italian technical standards currently under review following the recent earthquake.

In conclusion, the initiatives around this patent could allow a significant development of this sector, not really exploited today, especially considering the global relevance of these technologies and innovative services within certain catchment areas and markets.

More information: infomagat1@gmail.com
At 30, Timothée Boitouzet has been around the globe and seen many a school, university and laboratory. After his degree in architecture from French national school of architects ENSA in Versailles, he continued his architectural studies at Harvard, receiving instruction in biology at the same time. While these two disciplines in tandem might raise eyebrows in France, they are nothing out of the ordinary in the United States, where multidisciplinarity in studies is routine. But why, when you want to build houses, would you be interested in what is extremely tiny? “Because the approach is the same,” replies Mr. Boitouzet, unfazed, “a biologist does the same work as an architect, just at a different scale.” And therein lies the source of his charm and creativity: nothing impresses him and he succeeds at everything he does.

Influences and research, from East to West

During his architectural studies, Mr. Boitouzet first went to Japan, to the Kyoto Institute in the city of the same name, built all in wood. He worked for the well-known architectural agency, Saana, where international masterpieces like the Rolex Centre at the École Polytechnique Fédérale (EPFL) in Lausanne are designed, but where the teams only sleep three hours per night, from 5 to 8 a.m. “Working against the clock” may be usual for architect, but there, it is work non-stop. His interest in wood was born there, in the land of the rising sun. Wood is “the only building material that grows all by itself, is 100% renewable, and stores carbon instead of emitting it.” At the same time, his ecological awareness became sharper. “Over there, there are so many references to nature, an attention for detail, a sensitivity for aesthetics and what is ephemeral, and also a real fascination with substance, often made ambiguous, transparent.... glass, paper, marble”.

After obtaining his degree in architecture at the ENSA in Versailles, he was accepted at Harvard for a Master’s. There, he linked up with the laboratory of molecular biology and biochemistry and developed a partnership with the research scientists there. While he was in the United States, he soaked up an entrepreneurial culture in which research and business often coincide: “Americans appreciate the idea of transforming the world, and they push the development of R&D departments to the maximum.”

Polymerization

Ever since his stay in Japan, he had wanted to work with wood, so he developed his idea for an augmented wood. “I knew that it was my life’s project, to do my architectural work at the molecular scale.” He started to study wood as a material, and to remove the lignin from wood. (Lignin constitutes the structure itself, serving to hold the wood fibres together.) Observing that 60-90% of wood’s substance consists of air, he filled in the space left when the lignin was removed with a “stronger” material in the form...
thinking creatively about the dwelling and its different functions.”

Timothée Boitouzet chose his “primary” profession to address that social challenge, seeking to contribute sustainable solutions for the environmental issues of the twenty-first century and to meet the coming international regulations on building and construction.

Making the most of nature’s intelligence

All types of wood can be used to create augmented wood, but Mr. Boitouzet is more interested in the cheaper, more ordinary wood species like poplar or aspen. “You basically can’t do much with these, because they are too porous and fragile. In France, 50% of this type of wood is either not used, or used for heating purposes. The process is partially or entirely recyclable, depending on the type of infused constituents used, so it makes it possible to upgrade and transform wood of inferior composition into a wood with high added value.”

This bio-inspired hybrid material could breathe new innovation into the wood construction industry, which is still under-exploited in France. France has the second largest wood sock in Europe (2.4 billion cubic metres available), but uses it the least in the building industry because that is not part of its shared heritage. Developing the material and promoting the “made in France” label would therefore be synonymous with productive investment, innovation and competition, leading to the profitable use of these resources and to the revival of the wood industry.

More information:
http://woodoo.fr
Contact:
contact@woodoo.fr

Towards new sustainable building technologies

of a biobased monomer, i.e. a plastic of organic origin to solidify the wood. It also made the wood translucent. He says, “I woke up every two hours during the night for two whole years, to verify that the transformation of the wood was proceeding satisfactorily. It took me quite some time before achieving the desired result. Most of a research scientist’s work consists of failure. But I wound up managing to create a material that contains nature while serving human needs.”

The biobased monomer is integrated into the wood like a lattice, strongly reinforcing the atomic bonds between the fibres. Thanks to the cellulose, which is a crystalline substance, the wood lets light through and takes on an appearance similar to amber.

The circular economy: a virtuous cycle

Bionic wood is rotproof, waterproof, and more fire resistant, thanks to its higher density. It is also three times stiffer. As for the lignin that is removed, it is recycled as a biofuel using a methanization process, closing the loop.

“With standard wood, you can’t build very high, as stability becomes a problem above twelve stories. In future, it will be possible to build wooden towers using our super-wood! It meets the need for tomorrow’s cities to be vertical – it will be possible to reach up to 30 or even 40 stories for the buildings of the future. The projected carbon footprint is only half that of concrete, and 130 times less than that of steel,” says Mr. Boitouzet. For one who regrets the overly artistic aspect of the current architect’s profile, this is a good way to mingle economy and ecology. His aim is to return to the social role of the architect, who in the 1950s-60s worked to improve living conditions for his fellow individuals. “Architects had a real impact on town planning. They sought to improve the living conditions of the population by

This research was initiated in partnership with Harvard’s molecular biology and biochemistry department, MIT MediaLab, and the Cnam-ENSAM.

Timothée Boitouzet filed his patent and established his Woodoo startup in 2015. Six months later, he received the “European Innovator of the Year 2016” award from the MIT Technology Review, placing him in the spotlight.