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SPECIAL ISSUE

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According to a report put out by the United Nations last June, the world's population will grow from the current 7.7 billion to 9.7 billion by 2050. The same report forecasts a global population of 11 billion by 2100. For its part, the World Bank indicates that the urban population accounts for 55.27% of the global population and that by 2050, two out of three inhabitants will live in cities. To put it clearly, this means that 2.5 billion people will join the populations already inhabiting urban areas. The UN also says that there could be 43 megalopolises with more than ten million inhabitants in the world, compared to today's 31.

In other words, elected community representatives will face a colossal challenge. This concerns the habitat, transportation, networks, information, energy, waste management, etc. etc. The list could go on and on. In France, with regard to transportation, to take one example, the challenge is just as big even though the infrastructure is there and in relatively good condition. As the Xerfi Institute for sectoral studies informs us, 70% of employees in France mostly use their cars to go to work. At the same time, and for economic reasons, people are moving further and further away from the zones where they work. This only exacerbates the situation for already overburdened cities.
All these observations gave rise for the first time to the "Smart City" concept, in a challenge launched in a 2005 speech by Bill Clinton. We will not be able to sidestep these identified problems, so how can we approach and resolve them? What does this concept really mean? According to the French data protection authority CNIL, "This is a new concept for urban development. The idea is to improve the quality of life for city dwellers by making the city more adaptive and efficient with the help of new technologies that rely on an ecosystem of objects and services. The scope of this new mode of urban management includes the infrastructure (buildings, urban furniture, home automation, etc.), the networks (water, gas/electricity, telecoms), transportation (public transportation, smart roads and cars, car sharing, soft mobility), e-services and e-management". Other definitions using other words do exist, but the concept is there. One theoretician on the subject, Rudolf Giffinger, says that smart cities can be identified and classified according to five main aspects: a "smart" economy, "smart" mobility, a "smart" environment, a "smart" way of life, "smart" management and smart inhabitants.
What does this have to do with composite materials, you might ask? Quite simply, there is not a single one of the above-mentioned issues where composite materials do not already provide a practical solution. Whether you're talking about infrastructure, networks, or transportation, etc., composites are involved to varying degrees.

Smart cities in six points: a "smart" economy, "smart" mobility, a "smart" environment, a "smart" way of life, "smart" management and smart inhabitants.

This issue gives us the opportunity to show you some highly relevant solutions, and also to present some viewpoints from people involved in urban transformation for your consideration.
In this respect, the figures are dizzying. According to Grand View Research, an American business consulting firm, the global market for Smart Cities could reach $1,400 billion by 2020. For example, Angers, a city three hours west of Paris with a population of about 300,000 inhabitants, announced that it was replacing 4,800 old-generation street and traffic lights with new, modern LED lights equipped with various types of sensors. Happy reading!

"Composites are increasingly prevalent in the building sectors"

with

Christian Cremona,
Director, R&D Materials and Structures, BYCN Technical Director, Bridge and Materials Engineering, Bouygues Construction & Bouygues Travaux Publics

Introduced for the first time in 2005, the notion of smart cities gives greater substance to the quest for energy efficiency, smart habitats, smart networks and soft mobility in a sustainable urban environment. The "Smart City" market is a rapidly growing one. According to a report from Grand View Research, an American business consulting firm, this market will be worth $1,400 billion by 2020. Here, the Bouygues group, a major player in the field of construction and civil engineering, presents its vision and its solutions involving composites to address this 21st century challenge.

JEC Composites Magazine: How would you define the smart city concept at Bouygues? What kind of issues does it raise for a group such as yours?

Christian Cremona: An open approach to the mobility of goods and people was initiated in 2018 in collaboration with stakeholders and users with the objective of defining an ideal vision of smart mobility by 2030. Bouygues Construction analysed the supply and demand of this sector based on the habits and expectations of individuals. Local authorities, institutions, companies, start-ups, sociologists and real-estate professionals, among others, took part in the debate, sharing their own views and gauging their ideas against a sociological approach that included talks from experts and foresight workshops. The French Observatory of Emerging Uses in Cities (OUEV) conducted a poll of 4,000 people – representative of the French population and also including 3,000 European citizens – to assess how individuals perceive their city and to identify any new habits in urban mobility.

Five topics were chosen as a basis to investigate the future of cities. These topics can be seen as the key issues pervading the current debate on smart mobility for the future: 1. Mobility in suburban areas, 2. Importance of data for mobility services, 3. Emergence of autonomous vehicles, 4. Low-mobility solutions where city stakeholders can provide local services in and around built-up areas (accommodation, offices, etc.), and 5. Mobility of goods.

Evidently, mobility is a vast subject and has become one of the main concerns expressed by our customers with reference to smart cities.

The term "composite material" is very broad. How does Bouygues Construction define it?

C. C.: Composite materials are increasingly prevalent in the building and public works sectors. There is, however, some confusion among construction engineers who use the term "composite" to describe an assembly of materials with different properties: steel/concrete, wood/concrete, etc. We tend to forget that in other industries, it refers to materials comprising a reinforcement material and a matrix of thermoplastic or thermosetting materials. Composite materials are used in many applications, whether for structural work or interior/exterior finishings. When it comes to finishings, there is no denying that composites have invaded our homes, from floor to ceiling.

Yet composites are also a key component in the design of outdoor equipment; they will play a major role in the connected cities of tomorrow thanks to their low weight, strength and durability. This is particularly true for the deployment of 5G networks.

Composite materials will play a major role in the connected cities of tomorrow

Can you elaborate on some of your recent developments and applications in construction that use composite materials? Is the current trend set on improving existing systems or more so on implementing new materials?

Reinforcement using carbon laminates – Bouygues Construction

Self-sufficient building under construction in Grenobles, France, in which composites are used in the solar panels that generate energy

C. C.: There is still ample room for progress in structural materials, even if we are using composites in various fields: composite panels for façades, composite slabs for ceilings and walls, composite tiles for roofs, shutters and doors, etc. However, their higher cost can be a disincentive in a business model with margins that are already tight. Investment in this type of material can nonetheless help us sidestep issues such as sound pollution, weight, corrosion, etc. Corrosion is an issue that often takes centre stage in the design of structural components. In fact, one of the best examples worth citing is the use of composite materials to reinforce civil engineering works by means of adhesive-bonded carbon fibre reinforcements or fabrics. However, developing materials that are transparent to radio waves, for instance, remains largely overlooked even though the advent of 5G will undoubtedly bring this issue to the forefront in any smart city of the future.

How can composite materials be integrated into the smart cities of the future? What kind of advantages can they provide in smart transportation, communication and construction solutions?

C. C.: To build a smart city, we need to develop new construction practices. The public works sector initiated its digital revolution by adopting new digital tools (drones, virtual reality, digital mock-ups, etc.) to manage increasingly complex projects, while focusing more on the front- and back-end of structural life cycles. This also means we must review how we go about building, by using more prefabrication, modular and industrialised techniques. Composite materials are well suited to such techniques.
Thanks to their properties (sustainable, durable and lightweight), composites should be able to claim a fair share of the urban equipment market, which is set to play an increasingly important role in smart cities. Likewise, we need to take into account the increasing use of façade materials transparent to radio waves.

The population pressure in urban environments is intensifying across the globe, setting an unprecedented pace of construction and further densification of the urban fabric, infrastructures and services. How can composite materials contribute to the development of city centres?

C. C.: Being lightweight, corrosion-resistant and increasingly more recyclable, composite materials open the door to more diverse methods of construction (modular) that are not only sustainable but also suitable for urban regeneration projects and new structures. These materials also boast interesting properties for urban equipment in smart cities.

Is it more difficult to upgrade existing structures than to build new structures from scratch? Can composite materials simplify the transformation process for our cities?

C. C.: At the moment, composite materials are mainly used to reinforce structural work. By using composites, which are lighter, we can adapt infrastructures (for instance, adding pedestrian footbridges or cycle paths to bridges) or renovate façades when coupled with insulation materials. Last of all, composite materials are suitable for use with telecommunications equipment, PV panels, etc., which are also essential for smart cities.

How can composite materials gain the upper hand over more conventional materials?

C. C.: At this stage, it is difficult to say where the future of composites lies; the goal is to develop a broader range of materials suitable for different applications. The main issue for construction materials today is to reduce their carbon footprint without impacting their performance. Durability and strength are the key parameters for their use in equipment.

What limits and requirements have public partners defined with respect to employing composite materials in urban public spaces?

C. C.: The cost factor is still a considerable barrier, as is the carbon footprint.

Largely unknown by the general public because they are often "invisible", do you think composites will gain better visibility through their deployment in smart cities?

C. C.: These materials must not only be reusable and durable, but also capable of supporting the deployment of energy and telecommunication networks if their visibility is to be improved in smart cities.

Ten years ago, the use of composites in construction was following hot on the heels of that of transport in terms of volume. Do you think the development of smart cities will put your sector in pole position in the near future?

C. C.: Difficult to say. For this to happen, composite materials will have to be more sustainable. □

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Moving composites forward

Christian Cremona,
Director, R&D Materials and Structures, BYCN Technical Director, Bridge and Materials Engineering, Bouygues Construction & Bouygues Travaux Publics

En route to "massless energy" with structural power composites

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Airbus

Structural power composites are structural composites with the additional functionality of storing electrical energy. This paper provides an overview of the recent developments in structural batteries and structural supercapacitors, and an industrial perspective on the future challenges for their.

Lightweighting and energy storage are critical to transportation – composites have been at the forefront of the former for decades, their adoption providing significant reductions in system mass and hence emissions. However, a completely new solution to both lightweighting and energy storage is emerging: *structural power composites*. These are structural composites with the additional functionality of storing/delivering electrical energy. This should not be confused with multifunctional structures where conventional energy storage devices (e.g. batteries) are sandwiched within conventional composite laminates. In structural power composites, the constituents (fibres and matrices) synergistically and simultaneously undertake both structural and electrochemical roles. Polymeric composites provide compelling opportunities here – the laminated architecture and the use of carbon are common to both structural composites and energy storage devices. Melding of functions is a step change in how we use polymeric composites, going beyond the conventional monofunctional structural roles. This emerging field is presenting considerable technical challenges, but promises exciting opportunities in transportation. Central to this research is the SORCERER EU Clean Sky 2 project, in which Imperial College London, Chalmers, KTH and IMDEA, under the technical guidance of Airbus, are demonstrating structural power in aerospace components. This article provides a brief insight into this emerging field, and culminates with an industrial perspective on the potential impact of structural power composites.

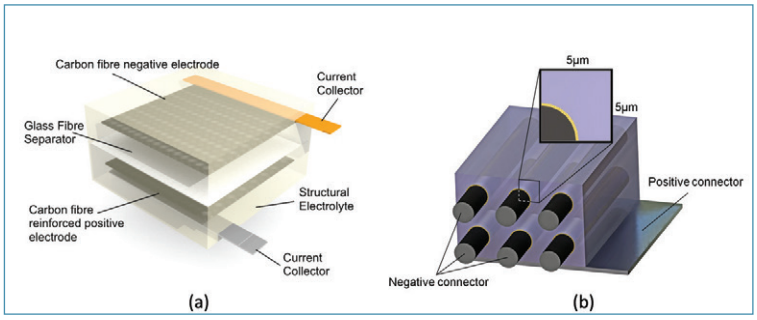

Fig. 1: (a) Concept of a laminated structural carbon fibre battery; (b) concept of a 3D structural carbon fibre micro-battery architecture

Structural batteries

A structural battery is a material that carries mechanical load while simultaneously providing electrical energy storage. By adopting a multidisciplinary approach, a novel Li-ion battery material was developed employing commercial carbon fibre grades as combined electrode and reinforcing elements, and solid polymer electrolytes as the matrix for simultaneous Li-ion transport and transfer of mechanical loads. These materials are anticipated to significantly reduce vehicle system weight and allow electrical energy storage in the structural load path of electrical vehicles in, for example, the body-in-white. Two architectures were conceived for making such structural battery materials: the laminated battery and the 3D micro-battery, as depicted in Figure 1.

A laminated structural battery is a concept that resembles a conventional fibre composite laminate (Figure 1a). Carbon fibres are used as a high-performance structural backbone and laid up in arbitrary angles in the following

En route to “massless energy” with structural power composites

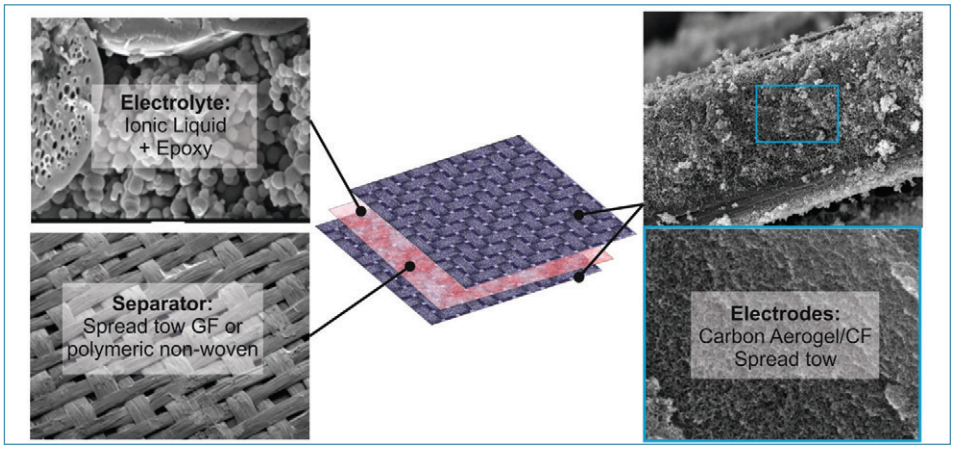

Fig. 2. Illustration of a structural supercapacitor

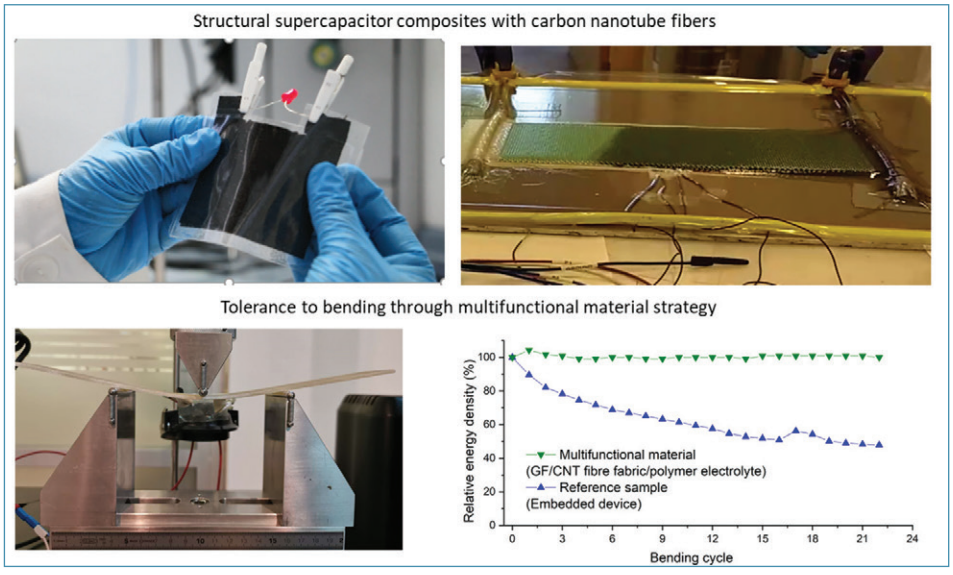

Fig. 3: Structural energy-storing composites based on macroscopic reinforcing fibres, high-capacitance fabrics of CNT fibres and polymer electrolytes. The multifunctional material approach leads to higher bending rigidity and fatigue tolerance

sequence: negative electrode/separator/positive electrode. On the negative side, the carbon fibres intercalate ions (here Li-ions) in just the same way as a state-of-the-art Li-ion battery electrode made from graphite [1]. The separator could be a thin glass fibre weave or veil. On the positive side, the carbon fibres are coated with an active battery material, e.g. $LiFePO_4$ [2]. The whole stack is then embedded in a matrix/electrolyte material, the structural battery electrolyte, to achieve mechanical load transfer and ionic conductivity [3]. The construction of laminated structural battery composites relies on access to a highly ion conductive, and reasonably stiff, solid polymer electrolyte (SPE). To mitigate the low conductivity of most SPEs, a 3D structural battery composite architecture was proposed [4], in which each individual carbon fibre is coated with a thin SPE in an electro-polymerisation process, resulting in a distance of less than 500 microns between the electrodes. In addition, the SPE coating electrically insulates the carbon fibre from the positive electrode, which is distributed in the matrix surrounding the coated fibres, as illustrated in Figure 1b. The 3D battery design is highly attractive, but efficient fabrication methods are lacking. To date, a structural battery consisting of approximately 1,000 fibres has been demonstrated, but new procedures are needed to make larger material volumes. In contrast, the laminated composite battery can be produced in large volumes. With the technologies developed in SORCERER, the partners expect to demonstrate a 28 V structural battery device with an energy density of 100 Wh/kg.

Structural supercapacitors

For applications in which energy delivery (i.e. power) and cyclability, rather than energy capacity, are required, an alternative to batteries are supercapacitors. These devices store energy through accumulation, rather than intercalation, of ions at the electrodes. Structural supercapacitors are assembled as shown in Figure 2: two high-surface-area electrodes that sandwich an ionically-conductive separator, all of which is infused with a structural electrolyte [5]. Imperial College London have developed Textreme spread-tow woven carbon fibre lamina which are infused with a high-surface-area carbon aerogel (CAG) [6], with woven glass or polymeric non-woven separators. The structural electrolyte is a blend of ionic liquid and structural epoxy, the microstructure of which can be tailored to provide either electrochemical or mechanically-dominated behaviour. The current devices have energy and power densities of 1.4 Wh/kg and 1.1 kW/kg, respectively (N.B. COTS supercapacitors are 4.7 Wh/kg and 4.1 kW/kg, respectively). Regarding mechanical properties, the elastic behaviour is comparable to that of conventional composites but the strength and toughness are inferior. In parallel with the device development, Imperial College London are focussing on formulating design methodologies for structural power, as well as developing numerical models for both electrochemical and mechanical prediction, with the aspiration of having a combined model in a single numerical code. This will permit modelling of any coupling behaviour between functions (i.e. how does mechanical

damage influence electrochemical performance?), provide a tool for parametric studies and, ultimately, support certification of structural power components.

A promising strategy for structural supercapacitors is to combine traditional reinforcing fibres with nanostructured fibres. With an electrical conductivity superior to that of carbon fibre (≈10^5 S/m) and roughly 1000x more specific surface area, unidirectional non-woven fabrics of carbon nanotube fibres (CNT) can simultaneously perform electric double-layer capacitive storage and current collector functions (Figure 3). Structural supercapacitors can be produced by integrating CNT fibre fabrics, a polymer electrolyte and a conventional fibre fabric, followed for example by vacuum bag resin infusion. To adjust the balance between structural and energy-storing functions, the electrochemical double-layer capacitor layer is pre-patterned using designs optimised via mechanical simulations of interlaminar properties. By monitoring the electrochemical properties during mechanical testing, complete tolerance against large deflections (Figure 3) is observed, with capacitance remaining stable after fatigue tests compared with a 50% reduction in performance for reference embedded devices (i.e. a multifunctional structure). The mechanical and electrochemical robustness of these composites is a consequence of the multifunctional material approach used, whereby materials and interfaces are designed to favour interfacial stress transfer and reduce interfacial electrical resistance.

Industrial outlook and closing remarks

Throughout the development of structural power materials, the SORCERER team cooperated with industry to produce demonstrators to pull through this technology. For example, the STORAGE project [7] developed a multifunctional boot lid for a Volvo S80, which contained four stacks of four structural composite supercapacitors (Figure 4a). In addition to providing electrical power, this led to a weight reduction from 13 kg (conventional boot lid) to 5.2 kg. In the current SORCERER project, the team is developing several demonstrators, including a multifunctional C-section fuselage beam that will replace an existing supercapacitor bank in the aircraft cabin (Figure 4b).

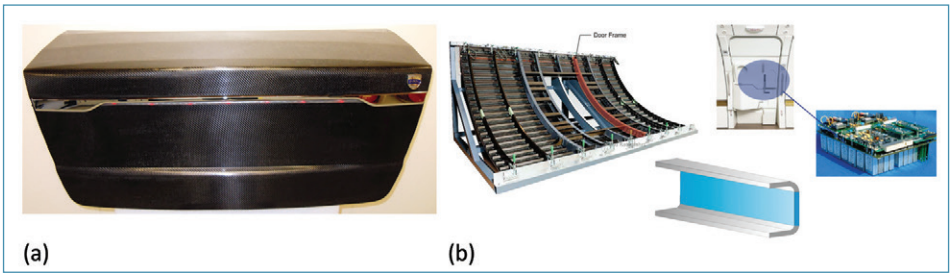

Fig. 4: a) Volvo S80 composite bootlid with four stacks of four structural supercapacitors within; b) fuselage C-beam multifunctional demonstrator replacing a supercapacitor bank

However, considerable hurdles still need to be overcome for structural power to be fully adopted by industry. Fundamental challenges include improved understanding of the interaction between electrical and mechanical behaviour, performance at temperature extremes and durability. Practical issues, such as accessibility, replaceability, sensing and battery management, will also have to be addressed. A particular challenge associated with aerospace is addressing the certification of structural power materials such that they are deemed airworthy. Ultimately, current developments of structural power composites represent the first steps in an exciting vision in which equipment, transportation and infrastructure will contain their own energy supply as their mechanically load-bearing structure. □

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References

[1] Kjell M.H., Jacques E., Zenkert D., Behm M. and Lindbergh G., "PAN-based carbon fibre electrodes for structural lithium-ion batteries", Journal of the Electrochemical Society, Vol. 158, No. 12, 2011, A1455-A1460

[2] Hagberg J., Maples H.A., Alvim K.S.P., Xu J., Johannisson W., Bismarck A., Zenkert D. and Lindbergh G., "Lithium iron phosphate coated carbon fiber electrodes for structural lithium ion batteries", Composites Science and Technology, Vol. 162, 2018, pp. 235-243

[3] Ihrner N., Johannisson W., Sieland F., Zenkert D. and Johansson, M., "Structural Lithium Ion Battery Electrolytes via Reaction Induced Phase-Separation", Journal of Materials Chemistry A, Vol. 5, 2017, pp. 25652-25659

[4] Asp L.E., Bismarck A., Carlson T., Lindbergh G., Leijonmarck S., Kjell M., "A structural battery half-cell, a structural battery and their manufacture", WO2014/033276 A1, 2014 (PCT, Patent No. 2893582, November 16th, 2016)

[5] Asp L.E., Greenhalgh E.S., "Structural Power Composites", Composites Science and Technology, Vol. 101, 2014, pp. 41-61

[6] Nguyen S., Anthony D., Qian H., Yue C., Singh A., Bismarck A., Shaffer M.S.P., Greenhalgh E.S., "Mechanical and physical performance of carbon aerogel reinforced carbon fibre hierarchical composites", Composites Science and Technology, Vol. 182, 2019, 107720

[7] https://cordis.europa.eu/project/rcn/93371/factsheet/en

An expanded role for pultruded composites in 5G cities

The construction market already presents a huge growth opportunity for the composite industry. But while many drivers for the increased use of composite materials in the built environment such as high strength, low weight and design freedom are well established, an emerging factor that will further favour their adoption is transparency to radio frequency (RF) signals.

Dr. Elmar Witten
Managing Director AVK – Federation of Reinforced Plastics and Secretary EPTA – European Pultrusion Technology Association

To realize the potential of the 5G next-generation mobile networks in future data-hungry smart cities, a dense network of 5G small cells will be needed. This will lead to increased demand for materials with enhanced RF transparency, bringing opportunities for pultruded composites in 5G radomes and base stations and new concepts such as smart lighting poles. Architects and urban planners will also need novel materials that deliver lower 5G signal loss over traditional construction materials to deliver reliable in-building 5G services.

Lot developments will support Industry 4.0 manufacturing concepts and smart factories

The future is smart

Rapid urbanization is a global megatrend, shaping the future of our world. More than half of the world's population already lives in urban areas and this is expected to rise to 70% by 2025, with the majority of the growth taking place in Africa and Asia. This accelerating urbanization will lead to the creation of more "megacities" of 10 million and more inhabitants. By 2030, there are expected to be at least 40 such megacities, with seven out of the top ten being in Asia. Managing this growth in a sustainable way will create huge challenges and require immense investments in infrastructure and services.

One focus for future investment is telecommunications. Future cities will be smarter, implementing digital and data-driven solutions to help them operate more efficiently and provide new services for residents and businesses. This will only be possible with an effective, reliable telecommunications network. According to the International Telecommunications Union (ITU), the United Nations agency for information and communication technologies, the number of connected devices on the internet is projected to reach 50 billion any time from 2025 onwards. A new digital infrastructure and fast, high-capacity networks will be essential to meet these ever-growing needs for data transmission.

5G technology, a driver for development

Operating at higher frequencies than current mobile net-

works, 5G is expected to enable faster data transmission rates of up to 10-20 gigabytes per second (GB/s) and greater capacity, allowing at least one million connected devices per square kilometre. Crucially, 5G also promises a greatly reduced response time or latency of a millisecond or less. This game-changing combination is expected to drive a whole new generation of applications and industrial advances. In addition to enhanced mobile broadband, 5G will be key to exploiting the vast potential of the Internet of Things (IoT), enabling the connection of potentially billions of devices and sensors for massive machine-to-machine communications to support new technologies, including artificial intelligence, robotics, automated factories and virtual reality. It will also allow ultra-reliable low-latency communications (URLLC) for mission critical applications requiring real-time control of devices, such as remote medical care, vehicle-to-infrastructure communications, and autonomous vehicles.

Trials for 5G technology have already commenced around the world. According to leading ICT provider Ericsson, volumes of mobile data traffic could increase by a factor of five by 2024 and 25% of that traffic will be carried by 5G networks.

Connected street furniture like bus stops and outdoor advertising will provide a platform for offering connectivity and digital services

RF transparency will drive choice of materials

By 2025, 5G services are expected to be widely available, but their widespread deployment in cities presents challenges.

While several radio frequency (RF) spectrum bands have been identified for 5G operations, the enabler for top-level 5G performance will be the high-frequency mmWave spectrum (also known as the millimetre wave or millimetre band). Technically, the term mmWave encompasses frequencies in the range of 30-300 gigahertz (GHz), but in the 5G world it is more frequently used to refer to bands above 24 GHz. The ITU has proposed a number of globally viable frequencies for 5G between 24 GHz and 86 GHz. While these high-frequency waves are capable of carrying much more data than current mobile networks operating in sub-6 GHz bands, they have shorter wavelengths (in the range of 1-10 millimetres) and travel over much shorter distances. Even without obstacles in their path, they may only travel a kilometre before fading out. In cities and other environments where network traffic is high, 5G technology will have to rely on "small cells". These low-power micro base stations (cell towers) transmit and receive signals locally, typically in a range from 10 metres to a few hundred metres.

Small cells are already widely used indoors and outdoors to address hot spots where extra capacity is needed, but mmWave technology will require many more antennas and a much denser network of base stations to provide the same coverage as current 4G networks in a particular area. The Small Cell Forum predicts that the total installed base of 5G or multimode small cells will reach 13.1 million by 2025, more than one-third of the total small cells in use.

Since 5G antennas and base stations are physically much smaller in size than those for 4G, to enable fast roll of 5G services and mitigate costs it is expected they will initially be "hidden in plain sight" on existing urban infrastructure and street furniture. This will create demand for antenna shrouds and radomes, base station enclosures and concealment solutions based on 5G-transparent materials such as composites.

A second challenge for 5G relates to the complex issue of signal loss within buildings. All RF signals lose strength as they travel through intervening materials (to an extent determined by the material and its thickness), but shorter wavelength signals are attenuated more rapidly than those with longer wavelengths. Millimetre-wave frequency 5G signals above 24 GHz have poor in-building penetration. Traditional building materials such as cement and brick attenuate and reflect these high-frequency signals, as do wood and glass to a lesser degree, and RF losses through metal are very high. The increased use of energy-efficient building materials such as spectrally selective glazing and metal-backed insulation as part of

ongoing "zero carbon" strategies is already exacerbating this problem. Novel materials offering improved 5G in-building signal penetration to traditional construction materials will therefore become more applicable.

Composite materials offer many properties that make them attractive construction materials for future cities, including high strength and stiffness, low weight, corrosion resistance, low maintenance requirements, thermal stability and design freedom. The need to ensure reliable 5G coverage in buildings and outside brings additional motivation for the integration of RF-transparent pultruded composites into urban design.

Pultrusion as a solution

Pultrusion offers the designer major freedom regarding the geometry, properties and design of the finished profile. Both solid and hollow profiles can be manufactured in simple and complex cross-sectional shapes, including tubes, rods, I-beams, T-, U- and Z-profiles. An immense variety of profile shapes is possible.

Since pultrusion allows for extremely high fibre loading and accurately controlled resin content, pultruded parts have excellent structural properties and are produced at a consistently high quality. A range of reinforcing fibres (and formats) can be used, including glass and carbon fibre, with a variety of thermoset-matrix resins such as polyester, epoxy and vinyl ester, as well as thermoplastics.

Almost any profile cross-section can be manufactured within the following parameters:

- maximum length: 12 m (determined by transportation limits);
- maximum width: 1350 mm/900 mm (depending on the flammability rating);
- wall thickness: from 1.5 mm to a maximum of 60 mm, and typically 3-3.5 mm;
- undercuts and different wall thicknesses are possible;
- radii between 0.5 mm and 2 mm are required.

Material	Specific weight (g/m^3)	Tensile strength (MPa)	Elastic modulus (GPa)	Thermal expansion coefficient (k^{-1})	Thermal conductivity (W/mK)
Wood	0.7	80	12	14×10^{-6}	0.1
Pultruded glass fibre composite*	1.8	240 (axial) 50 (transverse)	23 (axial) 7 (transverse)	11×10^{-6}	0.3
Aluminium	2.7	250	70	23×10^{-6}	170
Steel	7.8	400	210	12×10^{-6}	40

* According to EN 13 706

A number of standards have been developed covering the design, fabrication and installation of pultruded profiles. These include the Pre-Standard for Load & Resistance Factor Design (LRFD) of Pultruded Fibre Reinforced Polymer (FRP) Structures developed by the American Composites Manufacturers Association (ACMA) and the American Society of Civil Engineers (ASCE), and European Standard EN 13 706, which specifies minimum requirements for the quality, tolerances, strength, stiffness and surface of structural profiles. Other codes currently in use are the Eurocomp Design Guide and the CUR96 in the Netherlands. Work towards new European technical specifications for the design and verification of composite structures used in buildings, bridges and construction works is currently being conducted by Working Group WG4 "Fibre Reinforced Polymers" under the European Committee for Standardization (CEN) Technical Committee 250 (CEN/TC250).

The composite advantage

Pultruded glass-fibre composites offer a combination of properties not available with the traditional building materials of steel, aluminium and wood.

Low weight: Pultruded profiles are 80% lighter than steel and approximately 30% the weight of aluminium. They are therefore easily transported, handled and installed, resulting in lower costs. Complete structures can often be pre-assembled and shipped to the job site ready for fast installation.

High strength: Glass-fibre composites have excellent mechanical properties, delivering higher strength than steel and aluminium on a kg-for-kg basis. Composites are anisotropic materials, and pultruded profiles deliver their highest strength values in the lengthwise (axial) direction. Considerable design freedom can be gained by the capability of adding extra strength in highly stressed areas.

Parts consolidation: With composite materials, a designer is able to integrate various separate parts and functions into one profile and can create complicated shapes that are not possible with other materials. Single composite parts can replace complex assemblies of multiple parts that are produced with traditional materials such as wood, steel or aluminium.

Corrosion resistance: Glass-fibre composite is stable, inert and impervious to moisture and

a broad range of chemical elements. Pultruded products will not rot or rust and require minimal maintenance compared with traditional building materials.

Durability: Composite structures have a long life span. Many well-designed composite structures are still in use after 50 years of service. Coupled with their low maintenance requirements, this longevity is a key benefit.

Fire safety: Composite formulations have been developed to satisfy stringent fire safety regulations. Advances in resin and additive technologies continue to improve fire, smoke and toxicity (FST) performance of composite structures.

Thermal insulation: Glass-fibre composite has a low thermal conductivity. This is a significant advantage for applications where energy loss must be minimized, such as window and door systems and heating ducts.

Dimensional stability: Glass-fibre composite has a low coefficient of thermal expansion and pultruded profiles will not expand, shrink or warp.

High and low temperature capabilities: Glass-fibre profiles maintain excellent mechanical properties at elevated and very low temperatures (down to -50°C).

Electrical insulator: Glass-fibre profiles are electrically non-conductive and ideal for components in current carrying applications. This is a valuable safety benefit in utility poles, for example, where metal structures need to be earthed.

Excellent dielectric properties: Glass-fibre composite profiles are almost "invisible" to RF waves and have been used in telecommunications applications such as base stations and radomes for many years, where they offer minimal signal attenuation. Different fibres and resins can be combined to deliver a range of dielectric properties suitable for various end-use applications. Material advances continue to target lower dielectric constants and loss tangents to enable better performance with higher frequency signals.

Composite enablers for 5G cities

Pultruded composites are already used in the manufacture of energy-efficient windows and doors, facades and cladding, bridges and bridge reinforcements, street furniture and lighting, and rail and metro applications such as platforms and access structures. Composites also enable modular building concepts for the creation of affordable housing. The need for construction materials that offer low dielectric losses at mmWave frequencies will bring additional opportunities for pultruded composites in numerous areas.

The city-wide deployment of thousands of 5G small cells using existing infrastructure and street furniture such as light poles, traffic lights, bus shelters, advertising boards, walls and tops of buildings, and even below manholes, will create demand for 5G-transparent antenna shrouds and radomes, base station enclosures, and mounting/concealment solutions for city streets and public venues such as stadiums, parks, airports, train stations and hotels. Thousands of small cells will also be required along busy rail and road networks to provide future 5G coverage. Pultrusion is ideal for high-volume, cost-effective manufacturing of construction elements ranging from simple flat panels, posts, tubes and cylindrical antenna radomes/shrouds to more complex custom-designed structures.

In addition to minimizing 5G signal attenuation and interference, robust, durable composite structures offer easy-to-install, lightweight solutions with low maintenance requirements, and are proven to withstand the high-wear city environment and demanding weather conditions. Components can be manufactured in custom colours and finishes to blend in with their surroundings.

Pultruded profiles

An expanded role for pultruded composites in 5G cities

What second life for pultruded profiles?

At the end of their service life, pultruded profiles can be recycled through a grinding process and used as a filler in building materials such as concrete and asphalt, or reused in the pultrusion process as a filler in the matrix resin. An important advance in Europe involves the recycling of glass-fibre-based composite regrind through coprocessing in cement kilns. Highly cost effective, it helps to improve the ecological footprint of cement manufacturing and is compliant with the European Waste Framework Directive (WFD) 2008/98/EC. The composite regrind used for co-processing in cement kilns is both an alternative fuel and raw material (AFR). When combined with other feedstock materials into an input stream with consistent composition and caloric value, the inorganic fraction acts as valuable raw material, while the organic fraction acts as efficient fuel for the calcination process.

The LuxTurrim5G project

The LuxTurrim5G project on Smart City Digital Ecosystem Creation, driven by Nokia Bell Labs, is one initiative to develop pultruded composite light poles with integrated miniaturized 5G antennas and base stations. As well as providing energy-efficient lighting, the smart light poles will create a high-capacity 5G data transmission network, and incorporate sensors, information displays, cameras and other devices in order to trial a variety of services and business concepts. The composite pole hides the 5G equipment from view, protects it from the elements, vandalism and theft, and acts as a radome for the antennas.

The LuxTurrim5G project is also comparing 5G signal loss through composite building elements with the loss through conventional building materials and structures. Composite materials can deliver improved in-building mmWave signal penetration together with excellent thermal insulation. For example, a wall structure based on a composite sandwich panel comprising a foam core with composite skin layers and incorporating composite I beams and window frames could meet the requirements of energy-efficient buildings, while also enhancing in-building 5G signal reception. In addition, pultruded building elements such as window frames and doors, beams, panels and architectural facades are lightweight, durable and low maintenance, and offer part-reduction possibilities and low wall thicknesses for innovative design concepts.

One popular emerging platform for 5G small cells is light poles. The market for smart and connected lighting for commercial applications is forecast to reach US$21 billion (€19B) by 2022, growing at a compound annual growth rate of 21% from 2018, according to market research firm IHS Markit. Street and road lighting poles are perfect sites for 5G antennas and base stations, as they can be quickly installed for mass deployment.

Connected light poles or "smart poles" integrate energy-efficient LED lighting with interior space for 5G hardware and antennas from multiple OEMs into one pole, reducing visual clutter at street level. Designs are available to suit different cityscapes.

Other devices such as cameras, sensors and display screens can also be plugged in, turning the simple light pole into a multi-functional hub with the potential to generate revenue for municipalities. These metal-based poles require 5G-transparent radomes for the antennas positioned inside the top section of the pole.

Switching from metal poles to composite designs offers further benefits for infrastructure owners. While steel is currently the dominant material used to manufacture utility poles, authorities worldwide are increasingly adopting pultruded composite poles that are corrosion resistant and easier to install, and which offer a longer service life with lower lifecycle costs. Lightweight composite poles can often be carried by hand and installed without the need for heavy lifting equipment, making them quick to deploy with minimal disruption, especially in tight urban spaces with limited road access. Composite poles are also ideal for areas where corrosion is a key concern.

Opportunities for inventive businesses

5G will drive innovation and opportunities across all sectors, including materials. The new 5G urban environment is placing increasing demands on existing construction materials. When selecting materials for the next generation of city infrastructure, architects and planners must now consider compatibility with 5G mmWave signals in addition to performance, safety and sustainability requirements.

The increasing importance of RF-transparent materials for next-generation city infrastructure opens up a new market opportunity for the composite industry far beyond the scale of current construction applications. To seize this opportunity, all players in the composite supply chain need to be involved. Composite materials with tailored mechanical and dielectric

properties can deliver effective solutions for high-performance 5G applications. To minimize signal losses and increase network efficiency, 5G mmWave antenna radomes and base stations need novel RF materials. Smart lighting-pole networks will enable mobile operators to densify their networks without impacting the streetscape, while energy-efficient building systems with improved RF signal penetration present further opportunities for innovative designers, manufacturers and suppliers. By bringing together the benefits of lower 5G mmWave signal loss, cost-effective manufacturing and creative, multifunctional design, pultruded composites can earn a key role in the 5G-friendly infrastructure of future smart cities. □

More information:
www.pultruders.org

The humble street light is evolving into a platform for delivering smart city services.

3D printing and new materials are at the core of China's smarter cities

The urgent need to address the challenges of climate change and China's rapid urbanization involves both the private and public sectors. Projects are developed on the local scale but also planned nationally.

In December 2018, a 15m-long 3D-printed bridge made from composite materials was open to pedestrians in Taopu Park in Shanghai. The bridge benefited from 3D printing technology developed by the state-owned Shanghai Construction Group.

"*What is special about this bridge is its disruptive innovation in terms of materials and construction processes*", explains Chen Xiaoming, deputy chief engineer of Shanghai Construction Group, adding that the choice of materials was key.
After many comparisons and tests, the construction team finally selected a material with a certain proportion of glass fibre added in ASA (an engineering plastic), as well as anti-ageing materials, so that the bridge has high weather resistance and high impact strength. It can withstand long-term sun and rain, while meeting the requirements of 3D printing materials and building materials. The group ensured that the bridge's strength and durability are in line with national construction industry standards.

"*The bridge has a service life of up to 30 years. It can carry 250 kg per square metre, equivalent to a minimum of 4 adults per square metre passing by at the same time*", Chen Xiaoming says.

3D printing is not only a new way of building, but also a subversion of the traditional architectural model, says the Shanghai Construction Group in a press release. "*In the bridge 3D printing site, the printing robot left the scene clean and tidy, without dust or construction waste. In addition to the reduction of human costs and the promotion of green construction, the entire bridge printing process only took less than 40 days: intelligent construction has made a big leap ahead in terms of speed.*"

Fig. 1: The single-arch bridge structure was created using a 3D-printed concrete system developed by Professor Xu Weiguo's team (photo: Tsinghua University)

Reducing waste and human costs

Meanwhile, Shanghai also provided a frame to one of the world's longest 3D-printed concrete pedestrian bridges, which was completed a few weeks later. Designed by Professor Xu Weiguo from Tsinghua University (School of Architecture) - Zoina Land Joint Research Center for Digital Architecture, the 26.3m-long bridge was jointly built with the Shanghai Wisdom Bay Investment Management Company.

Inspired by the ancient Anji Bridge in Zhaoxian, China, the single-arch structure was created using a 3D-printed concrete system developed by Professor Xu Weiguo's team, integrating digital design, cost efficiency, smart technology, and architectural dynamism. Enclosing the 3.6m width, the bridge's handrails are shaped like flowing ribbons on the arch, creating a light movement across the Shanghai Wisdom Bay pond.

The bridge is constructed of 44 hollowed-out 3D-printed concrete units, while the handrails are divided into 68 units. The bridge's compo-

3D printing and new materials are at the core of China's smarter cities

nents were printed from composite materials containing polyethylene fibre concrete to match the structural performance of conventional materials.

The design process involved the construction of a 1:4 scale physical model of the bridge, built to demonstrate the scheme's viability and proving that the bridge could hold pedestrians crowding the entire surface. For the actual construction, concrete components for the bridge were printed by two robotic arms, over the course of 450 hours. The streamlined process is estimated to have produced savings of 33% when compared to a more conventional construction process – attributed mainly to the elimination of templates and reinforcing bars, according to information website ArchDaily.

Water management strategies

Facing rapid urbanization, China enthusiastically embraced the concept of "sponge cities", a reimagination of the urban environment where almost every raindrop is captured, controlled and reused.

The Chinese government has already chosen 16 pilot cities, including Wuhan, Chongqing and Xiamen, and allocated 400 to 600 million yuan to each of them for the implementation of innovative water management strategies that would gradually transform these cities into "sponge cities".

In June 2015, the Gui'an New Area, in Guizhou province, was approved by the state to become one of the 16 pilot areas for China's sponge city initiative, which aims to build natural systems in urban areas for mitigating rainwater runoff and replenish groundwater through the use of permeable surfaces and dedicated infrastructure.

Construction works were first launched over an area of 19.55 square kilometres. The final plan is to make the entire 1,795km^2 area capable of absorbing and reusing rainwater in order to remedy urban flooding, save water resources and protect the local ecological system.

Fig. 2: The Yanweizhou Park project in Jinhua City, China, one of the 30 chinese cities as part of its «sponge city initiative.» (©Turenscape)

So far, 75 projects are underway to build roads, parks and water treatment facilities with permeable materials. The expected investment is about 6.9 billion yuan (US$1.05 billion), according to the Guizhou province's official data.

Meanwhile, the Area has installed 70 monitoring devices to collect operational data from the sponge city facilities, including rainfall utilization, water levels and river system data. The information platform will manage and analyze the monitored data to predict potential environmental hazards.

"*For the construction of Gui'an New Area's main road, New Era avenue, a variety of new processes and technologies were also designed*", Xu Dezhi, an engineer at Gui'an New District Development and Investment, explained to a local newspaper.
The rainwater inspection well is transformed into a composite overflow well, and the system and sponge facilities are effectively combined to ensure that the well cover meets the strength requirements, but also enhances the landscape effect. In addition, New Era avenue also uses composite materials and pebbles in a rainwater filtration pool.

Chinese eco-cities: will the utopia finally become a reality?

Beyond water management, on a national level, China's central authorities approved in 2017 a master plan for Xiong'an New Area, near Beijing, in central Hebei province, reiterating that its creation will carry "*lasting importance for the millennium to come.*"

As a testing ground for green urbanization, the government vowed that Xiong'an's population will not outgrow the existing resources to support it.
The city will be powered by "clean electricity", which in China does not exclude natural gas, according to specialized website Chinadialogue. However, at least half of the city's power is expected to come from renewable sources.

More specifically, Xiong'an will be the first test case of the Chinese leadership's ecological vision being applied to a mega-city, in which everything needs to be built from scratch in what was previously an economic backwater of Beijing.

Fig. 3: Rainwater management installation near Gui'an New Area's main road (photo: Gui'an New Area Wechat account)

Companies related to Xiong'an New Area include Hubei Huitian New Materials as well as Kuang-Chi Group, a new material manufacturing company based in Shenzhen, in South China's Guangdong province. The company signed a strategic cooperation agreement with Xiong'an New Area to promote the research and development of new materials and the integration of military and civilian life in the new area.

China has a long story of green cities experiments. The first Chinese eco-city, Yichun city in Jiangxi province, goes back as far as 1986. The projects that followed were locally-developed programmes with mixed results. According to Southern newspaper Nanfangzhoumo, they gave foreign companies the opportunity to carry out tests without being accountable. For nationally-driven Xiong'an, Chinese and foreign observers are more optimistic. Yet, according to Chinadialogue, the unique political support, as well as the subsequent resources and expertise it brought, may end up making Xiong'an an exceptional case that proves hard to reproduce elsewhere. □

More information:
www.scg.com.cn
www.arch.tsinghua.edu.cn
www.gaxq.gov.cn
www.xiongan.gov.cn

TRENDS **India**

Constructing highly populated smart cities in India

India has witnessed a considerable rise in its urban population. According to the World Bank, the urbanization in India was 34% in 2017, while a survey of the UN State of the World Population report states that urbanization in India will reach 40.76% by 2030. This means a predicted addition of approximately 220 million people to Indian cities, in slightly more than a decade. Just to set the context, the current population of Germany, France and Italy put together is about 210 million.

Amid such changes, the Government of India announced the Smart City Mission in July 2015. This mission aims to develop 100 smart cities, and rejuvenate 500 others. The Government approved a USD 14 billion budget towards this. However, the funding mechanism requires that each city create a Special Purpose Vehicle (SPV), headed by a full-time CEO. The central government will provide USD 144 million funding to the company, with a matching contribution of USD 72 million each. The company has to raise additional funds from the market as a debt or equity.

The Plan

The first 20 cities to be selected as "Lighthouse cities" will receive USD 29 million each from the central government on the year of selection, and USD 14 million for the next 3 years. The framework will then be extended to other cities. All the cities will be selected by a competition process. However, the first step itself – defining a smart city in an Indian context – was a major challenge. On the one hand is a population that is deprived of basic necessities, while on the other are truly modern citizens with advanced desires, with both residing in the same urban areas.

No. of cities selected 99	99
Cities that have formed SPV	92
Cities that appointed project consultant	69
Population affected	99 million
Town planners working on scheme	5500

Fig.1: Institutionalization status (as of 21 March 2018)

The official definition of a smart city is therefore kept open for interpretation and innovations. However, it broadly speaks about promoting mixed land use, giving a domestic identity to the city, creating walking localities, promoting a variety of transport options with last mile connectivity, making governance citizen friendly and cost effective, providing housing for all, preserving and developing open space, and developing smart solutions for disasters, resource utilization and cost effectiveness.

The aspirations of citizens with the smart city programme is huge. The authorities mostly have to focus on brownfield development of existing cities, while developing greenfield projects around the cities under a satellite concept.

Current state

The progress in the development of smart cities has yet to achieve its full momentum. During the past years, a lot of time has been spent in identifying smart cities, forming SPVs and appointing authorities. An overall snapshot

Constructing highly populated smart cities in India

of the institutionalization status of the smart city concept across India can be seen in Figure 1.

It is noteworthy that the 99 smart cities identified 5151 projects. Tenders have been issued for projects worth USD 6.9 billion. The execution of 220 projects worth USD 432 million has been completed, while 98 projects worth USD 830 million are being executed under a Public Private Partnership (PPP) model. A project-based snapshot is shown in Figure 2. Though the sheer number of projects undertaken is massive, the fund utilization indicates a slow momentum, as shown in Figure 3. The smart city initiative is also highly focused on affordable housing for deprived people. The government targets housing for all by 2022. Until 2016, at least 73 of all the proposed projects focused on affordable housing. By March 2018, the total value of affordable housing projects was USD 2.37 Bn.

Along with housing, the government strongly stressed clean water to all, sewerage connection to all and last mile connectivity. So much so that USD 6.9 Bn were sanctioned separately for a separate concept within the smart city scheme: the AMRUT scheme.

No. of projects proposed	5151
Estimated investment	USD 28.3Bn
Value of projects tendered	USD 6.9Bn
No. of projects completed	220 (4.2%)
Value of projects completed	USD 0.4Bn

Fig. 2: Execution status (as of 21 March 2018)

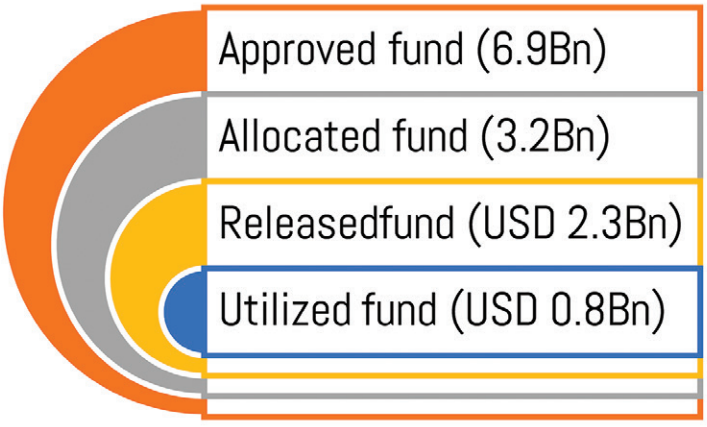


Fig. 3: Fund utilization

Technical advances

As is already evident, there is a plethora of small and large projects based on demography demands under the smart city mission. But some interesting technological successes are worth noting. Each city will have an integrated command and control centre (ICCC). For example, Pune has a USD 14 million ICCC, which integrates the management of various functions. The centre features a massive high-resolution display wall with multiple computer desktops facing it. This centre oversees nearly 200 Wi-Fi hotspots, over 80 environmental and flood sensors and 136 public address systems, among others. Transport, traffic and surveillance centres are also to be integrated. The city of Jabalpur addressed waste management as one of the core issues in smart cities. The city has taken up a project to introduce GPS-enabled solid waste collection trucks and RFID-tagged garbage bins. They are geo-fencing the landfills and installing heat sensors. To complement with affordable housing for all, a research team from the Indian Institute of Technology Madras (IITM) has taken construction to a whole new level. The team developed pre-fabricated panels made of waste gypsum reinforced with glass fibre. In fact, glass fibre-reinforced gypsum (GFRG) panels were originally designed for walls by Rapid Building Systems, Australia. The IITM research group extended the application of this product to the entire building system – including floors, roof and staircases. The team also collaborated in the indigenous development of an effective waterproofing material, which is essential to ensure the prolonged durability of GFRG panels, especially in the case of roofs and toilets. A one-of-its-kind demo building was constructed within a month using glass fibre-reinforced gypsum panels. GFRG technology also found its place in the guidance manual of Griha Council, a rating agency for affordable and sustainable housing. Below is an interview of two people closely associated with the mission.

Interview

Manish Bhatt,
General Manager (IT)
Vadodara Smart City Development Ltd

Fig. 4: The Vadodara ICCC

JEC Composites Magazine: Could you tell us about the Smart City Mission and your responsibilities within the programme?

Manish Bhatt.: The Smart City Mission is not only a brainchild of our Prime Minister, Mr. Narendra Modi, but also something very close to his heart for more than one aspect. Right from the definition stage, the government clearly informed all the civil servants associated with the programme that the developments under smart city missions must not cover the regular work of local municipal bodies. As per the central government, the smart city process is about translating the aspirations of hundreds of thousands urban dwellers by building the cities of tomorrow.

Like 99 other cities, Vadodara also qualified as a smart city, but in Phase II. An SPV – Vadodara Smart City Development Limited – was formed under the chairmanship of Shri S. K. Patel. The state government swiftly allocated two consultants for the effective utilization of the opportunity, one from PwC and the other from TATA Consultancy (TCE). I am part of the planning and execution team for all IT-related work in the projects under the smart city mission for Vadodara SPV. Vadodara now ranks no. 8 among 100 smart cities in India.

Could you take us through some of the projects under execution at Vadodara?

M.B.: Vadodara proposed 60 projects. About 30 of these will be executed under INR 1000 Cr. smart city funds, while a large chunk of the projects will be conducted under the public-private partnership (PPP) model and conversion from other schemes.

In fact, we had INR 25 Cr. sanctioned for city Wi-Fi. But after laying the infrastructure, we found that many private operators were interested. We converted the project to the PPP model, and also rent parts of poles for digital advertisement. We not only earned a surplus of approx. INR 23 Cr. but also ensured the project sustainability.

Like all smart cities, Vadodara also built an ICCC, inaugurated by the Prime Minister in October 2017. The ICCC is a huge building with a big wall screen and series of desktops in a room. It also involved putting up more than 950 cameras and laying approximately 250 km of cables throughout the city.

We also installed emergency call boxes, public address systems, variable data processing systems, smart traffic signals, geographic information systems (GIS), and GPS waste management and bus monitoring systems. All in all, we have about 74 layers of information in the ICCC (see Figure 4).

Vadodara also launched a very ambitious household water management project, by implementing a supervisory control and data acquisition (SCADA) system in the distribution chain. In Phase I, SCADA sensors were installed from the water sources in Ajwa and Mahi to the city water storage tank. During Phase II, these sensors will be extended to the last mile of residential society. This will not only automate valve operation, but also provide accurate information on the chlorination level, the pH level, water flow pressure and other monitoring and control data.

How is the progress of these projects monitored?

M.B.: The central government created an exclusive team for this purpose. During the approval stage, we had to propose lists and cost estimates for the project. After winning the Smart city contest, we have to send updates to the central government every week.

Every week, we have to update the information related to the projects in the TDR, tendering, execution and completion stages. We also have to update the delays and to provide revised plans. A representative of the centre is part of the SPV.

Constructing highly populated smart cities in India

Interview

Utpal Sharma,
Director
Institute of Architecture & Planning,
Nirma University

Aranya Housing

JEC Composites Magazine: What is your view on the Smart City Mission?

Utpal Sharma.: The Smart City Mission is definitely a good initiative, but I think it is slightly ahead of its time in India. India now needs to focus more on the availability of basic facilities to all. Most of the deprived portion of the urban population consists of people who have moved from villages in search of earnings, and not lifestyle. Therefore, the foundation of smart cities should be laid once we have provided adequate water supply, minimum housing, sewage connections, waste management, adequate roads and others.

How has technology changed Indian architecture over time?

U.S.: As Frank Lloyd Wright said, "If your architecture is imported, there is no civilization". Even during the colonial era, the Indian architecture has been improvised, rather than changed. The "Bangla" comes from Kolkata, "Otla" in Jaipur and so on. So, the central idea is that the availability of new technology rather allowed Indian architects to re-establish the style of the sub-continent with lesser constraints.

Historically, since we started doing construction, it has always been about increasing the span and having larger space. This is where technology comes in. The things that change the scene are concrete and glass fibre-reinforced concrete. Now we can have buildings of any shape. As Le Corbusier always suggested, build the frame structure first, and then do the filling. This entirely changed the way of designing and looking at things. With advanced concrete, we can fill the inner space with practically any material, even bamboo. This gives incredible freedom, even for interiors.

The new materials of building technology have also ushered in a completely new variety of industrial buildings. An example would be Mumbai's Chattrapati Shivaji Terminus Railway Station. A completely exposed steel structure.

With the new FRP materials, sections have become lighter and properties have improved for varying temperatures. Indian designs traditionally had a higher safety factor. This trend will also fade away with the advent of new materials.

Could you mention some of the landmark urban city development projects that took shape under your guidance?

U.S.: In my long tenure as a practicing architect and a professor, I had good opportunities to associate with certain key projects to re-define urban space.

The first one worth sharing is planning the megacity of Hyderabad. The city itself has a population of 9.7 million, making it the fourth most populated city of India. The idea here was still larger. The idea was to connect the circumscribing rural belt with the city for a planned expansion. In a way, it was also a greenfield development, which gave us good space for development. We integrated the rural scape with the mainland through a network of roads and other transit systems. The in-between lands were retained for small vegetable farms.

This design turned out to be the one with the highest urban agriculture and a municipality of connected towns with laid out public transport. This was possible because of the urban agriculture belt around the city. We also used the idea of limited buildings, with about 15% ground coverage. Today, it is looked upon as a sustainable town planning model for growing cities.

The second project is Bandra Kurla Complex (BKC) in Mumbai. BKC is a planned business district in Bandra, India. It was ideally located to break the monotony of business and residential settlements in Mumbai, which creates traffic mayhem at peak hours. 400,000 people are currently working in BKC. There

are two important achievements. First, as it was designed to be a fully air-conditioned facility, we oriented the building at the layout stage so that the longer sides face north and south. This reduces the AC load tremendously. Since this is done at the layout stage, the architects are bound to build plans accordingly. The second success was that we accommodated a lot of street vendors with planned spots in BKC. This initially met with huge opposition. But development does not mean depriving the existing ecosystem to form a new one. It rather means accommodating and benefiting the existing one and building the new one with it.

The third project is the Aranya housing scheme at Indore. It was housing for the poor, with an incremental housing approach. We used a cost-effective approach right from the town planning stage. Some innovative features were to build a clustered building, so that toilet manholes could be grouped together. From inspection to manhole, the design was such that 32 houses required only one manhole. We used a newer technology then, ferro-cement. In fact, we could cut down costs by 30% through the efficient use of a new-generation material and proper planning.

How good is the interconnection between industry, educational institutes and the government?

U.S.: I think it is scanty. During my tenure at CEPT University, I was part of many projects that intercoordinated educational institutes, industry and government. Some of these flagship projects were the Bus Rapid Transit System (BRTS), the Gandhi Ashram and the surrounding area, the Sabarmati riverfront and others.

I strongly feel India today is in a very high need of a platform to put forward ideas. Maybe starting with a platform like a World Urban Forum (WUF). A platform where educational institutes would propose a plethora of ideas. The best idea would be selected by private and public companies for scaled-down urban models. The winning concept would be financed and supported for municipal application.

Such initiatives will not only usher in new ideas, but also speed up the solution for growing urbanization needs in India. □

More information:
www.nirmauni.ac.in

Global smart cities will raise a market beyond $ 2 trillion by 2025

Smart cities are definitively a hot topic, although apparently different conceptions and definitions are applied according to the respective political framework and the cultural context. Fast-paced urbanization, high vehicle density, an obsolete infrastructure and high traffic-related emissions encumber the urban mobility ecosystem.

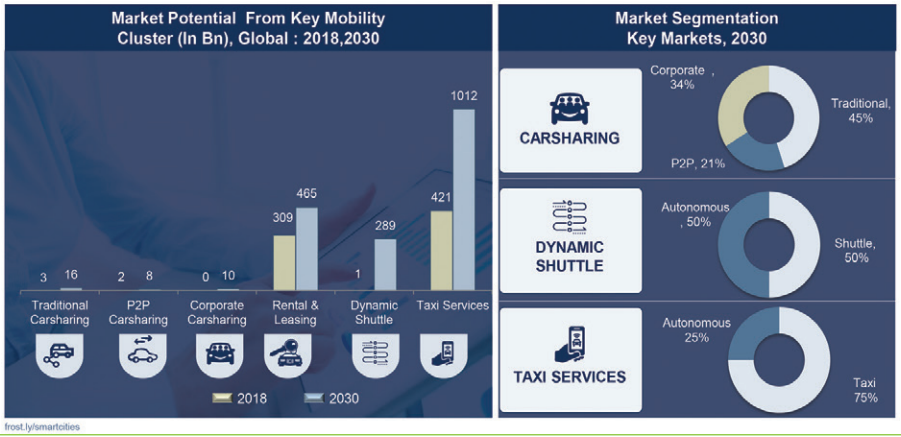
According to market research company Frost & Sullivan, 80% of the world population in industrialized countries will live in cities by 2050. In developing countries, estimations predict a 60% margin. Smart cities are anticipated to create huge business opportunities with a market value of over $ 2 trillion by 2025, says the study. The decisive technological cornerstones of smart cities of the future include artificial intelligence (AI), smart healthcare, robotics, smart transportation systems including advanced driver assistance systems (ADAS) and smart energy supplies.[1]
Due to recent engagements of the European Commission, Europe will most probably have the largest number of smart city project investments globally. By 2025, the Asia Pacific region will be the fastest growing region when it comes to smart energy. More than 50% of the smart cities in Asia will be found in China. However, a smart city can mean something different depending on the cultural and political context prevailing in countries such as China.

Global demand of passenger mobility is increasing copyright Frost & Sullivan

Future City © LAVA, Fraunhofer IAO

Global smart cities will raise a market beyond $ 2 trillion by 2025

Revenue from the taxi cluster alone expected to exceed $1 trillion in 2030



New mobility solutions market will grow to around $2tr market by 2030 © Frost & Sullivan

"An intelligent city is proactive in terms of creating added value for humans"

Smart city concepts in Europe are generally geared to enhance the quality of life of citizens. Sarwant Singh, managing partner at Frost & Sullivan, recently conducted a study called "*Future of Mobility in Smart Cities globally and Opportunities for the UK*".

London is certainly pioneering when it comes to new mobility solutions, with fleet sizes of 40,000 for ride-hailing, 3,355 for car sharing and 11,900 for bike sharing, just to mention the major ones. London is also one of the first cities with smart ticketing solutions, such as the oyster card that gives easy access to different types of public transportation.

Frost & Sullivan defined a smart city as one that has an active plan and projects in at least five of the eight following functional areas: energy, buildings, mobility, technology, infrastructure, healthcare, governance and citizens. These specific components define the "smartness" of a city.

In his book "*Smart Cities, smart mobility: Transforming the way we live and work*", Lukas Neckermann defines a smart city as follows: "*A smart city, in combination with smart mobility, offers residents, visitors and stakeholders a quality of life and an ease of experience that pre-emptively address their needs, desires and transport requirements [...]. The smartest of the cities are the ones that are willing to fight against a century of car-centricity, and for a refocusing on quality of life. An intelligent city is proactive in terms of creating added value for humans.*"[2]

- Smart city concepts in Europe reflect the cultural diversity.

The key focus is always a bit different according to the public needs and requirements.

Whereas in London the primary focus is on intelligent mobility and security, in Hamburg intelligent street lighting is a major topic, in Copenhagen and Barcelona traffic calming is an issue and in Oslo, smart, green transport solutions.

The Norwegian capital Oslo has been selected as the European Green Capital for 2019. The jury praised Oslo for granting its citizens an active role in the green transition.

There is transparency given in litter and emission flows and who assumes the responsibility.[3] Neckermann also refers to the enormous costs due to traffic congestion ($ 305 billion in the US in 2017), that suggest a change to smart mobility. An average American spends 34 hours each year stuck in traffic, what a waste of time.[4]

"*Currently, most smart city models provide solutions in silos and are not interconnected. The future is moving towards integrated solutions that connect all verticals within a single platform. The Internet of things (IoT) is already paving the way to allow for such solutions,*" Vijay Narayanan, Visionary Innovation Senior Research Analyst at Frost & Sullivan states.[5]

Morgenstadt initiative: Government, industry, research and municipalities are working together for the city of the future

"*Appealing, connected, sustainable*", these are major features of the smart city of the future according to smart cities expert Alanus von Radecki. Alongside his role as head of the urban governance innovation team at Fraunhofer IAO, he is lead expert for the URBACT Network SmartImpact, advising various European cities such as Stockholm, Manchester, Eindhoven, Porto, Dublin and Zagreb, on how to adapt their governance systems to future requirements. There are a variety of projects within the framework of the Smart and Sustainable Cities (SCC) initiative of the Horizon 2020 European research programme, including Triangulum, Grow Smarter and Smarter Together. Von Radecki and Fraunhofer are involved in quite a few of them. "*Morgenstadt: City Insights*" is an initiative of the German Fraunhofer Society that develops solutions for the city of the future together with partners from industry and municipalities. With this innovation network, Fraunhofer is supporting the German government in its action plan for the Hightech Strategy 2020. Partnerships with frontrunning companies such as Bosch, OSRAM, DOW Chemicals, IKEA, SAP and others have been established so far and the network is growing steadily.[6]

Interview

Alanus von Radecki is head of the Competence Team Urban Governance Innovation at the Fraunhofer IAO and head of the Innovation Network "Morgenstadt: City Insights". In addition to his activities in project coordination and control, his work focuses on urban governance and on complexity and innovation research with a direct relationship to urban systems.
Further to his role at the Fraunhofer IAO, he advises cities and companies on the digital transformation of urban systems, for example in his role as lead expert at URBACT. Since 2017, he has also served as CIO of the Fraunhofer spin-off BABLE UG, a digital marketplace for smart city technologies.
© Fraunhofer IAO

JCM: Where do you see the biggest differences in the design and implementation of smart city concepts in Asia, the US and Europe?

Alanus von Radecki: In Europe, smart city concepts are strongly driven by the European Commission's initiative and European politics, therefore with a clear focus on Europe's political targets. Until now, significant investments have been made in the creation of new markets, sustainable urban development, CO_2 neutrality, smart buildings and smart energy concepts. Although new markets have been created, the innovation process is rather slow, since you always have to respect procurement laws. Administrations are involved and it is an ongoing private-public discussion. Particularly in Germany, we are rather slow and still lagging behind.
In China, on the other hand, the economic impulse is in my opinion much stronger than reflections on sustainability. Smart city concepts are pushed forward to be used for political ends. In the US, smart city concepts are mainly corporate driven. Sidewalk Labs, the urban innovation company of Google's parent company Alphabet, based in Toronto, is conceived as a new business model and has engaged a controversial debate in the US. It plans to invest $ 900 million in a high-tech district on Toronto's waterfront, kind of a testing platform for emerging technologies. People are concerned it may be mainly about collecting personal data and exploiting them commercially.

Where do you see the biggest barriers for the implementation of smart cities?

A.V.R.: We have high barriers in municipal administrations. They are not quick enough to change and adopt new processes, for example, to allow a broader participation of citizens. Further political courage is lacking to invest in new ideas such as reducing private traffic or parking in cities. Politicians avoid uncomfortable issues, since they want to be re-elected. Often, regulatory preconditions are missing to implement innovative processes. Existing regulations are no longer suitable with the new digital mindset. The energy systems of the future need to be self-sufficient. But at present, if you want to transfer energy from one house to another, network charges must be paid. This does not correspond to the innovative concept at all. Many sectors, such as buildings or traffic, still work with these regulatory systems of the past, and change takes time.

In your opinion, which are the existing smart cities that offer an extremely high quality of life?

A.V.R.: Quality of life is not a direct outcome of smart city concepts. It depends on a variety of aspects. For me, Copenhagen and Vienna are good examples for a high quality of living. They do have some of the smart city features, but there are other parameters that count when it comes to quality of life. 30% of the housing space in Vienna is dedicated to social housing, with the result that there are still affordable prices per square metre. Green zones and a cheap and well-organized local public transport system are a few concrete examples.

Against the background of your expertise, what is your personal plea to the parties involved?

A.V.R.: On a national level, we primarily have to address the topic of data sovereignty to avoid the emergence of a multitude of different data platforms that are not compatible in various cities. I would recommend that we create a national initiative related to the "digital city" topic geared to achieve a harmonization of standards and solve the data exchange issue. However, this initiative should go even further, inciting public funding that could trigger further private investments. We need a holistic approach and should take the so-called "packaging" system implemented on the European EU as a model. In Germany, we are still far from addressing issues this way. Topics and solutions related to smart city concepts need to be addressed, elaborated and structured on an abstract level, irrespective of existing providers in the market.
Municipalities could take these neutral proposals as a blueprint for their procurement and planning. Suppliers could then adapt their products accordingly.
It is a very complex market with diverse industries, standards and regulations involved.

Global smart cities will raise a market beyond $ 2 trillion by 2025

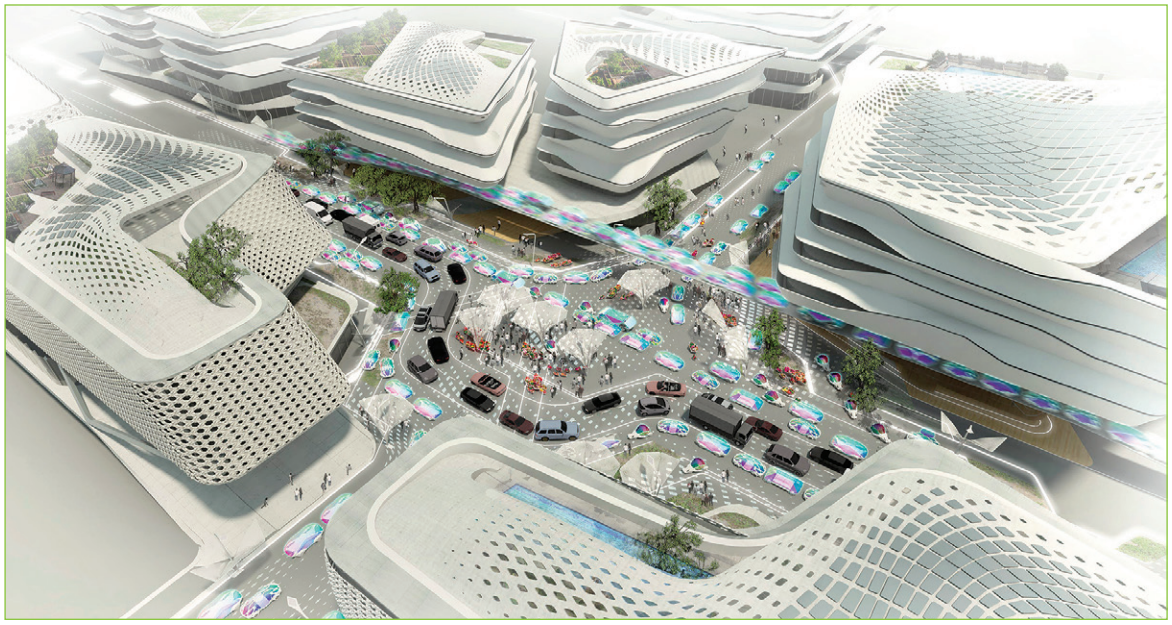


Fig. 2: Autonomous driving and the city of tomorrow (see Fraunhofer IAO's AFKOS study [7] © LAVA, Fraunhofer IAO

"Let's not take the Asian model as a blueprint"

The German government is fostering Smart City projects on a large scale. The IMPACT RheinMain project of the University of Applied Sciences Hochschule RheinMain in Wiesbaden/Rüsselsheim, Germany, is one of 29 projects in Germany that are part of the Innovative University initiative. The aim of IMPACT RheinMain as a strategic and interdisciplinary transfer project is to bring together all the parties involved - citizens, industry, government and public entities – so that they actively participate in the decision-making process, which is the purpose new technologies for smart cities should serve. The project focuses on three interdisciplinary cross-cutting topics: Smart Energy, Smart Home and Smart Mobility.

Interview

Prof. Dr. Thomas Heimer is chair in innovation & project management at the RheinMain University of Applied Sciences in Rüsselsheim since 2009 and is an honorary professor at the Frankfurt School of Finance and Management in Frankfurt am Main, Germany. Since 2018, he has been leading the IMPACT RheinMain project sponsored by the Federal Ministry of Education and Research. The project runs until the end of 2022.

JCM: How comes that the University for Applied Sciences RheinMain is engaging in a project related to smart cities?

Thomas Heimer: The assignment of a higher education institution is to conduct research in new fields. The development of smart city concepts is an exciting topic for every university, no matter which discipline, since smart cities will change living conditions in our societies fundamentally. Smart city concepts are the result of a previous societal negotiation process; based on which parameters you want to modify in relation to the respective social environment. We currently experience big differences. An example is the social scoring system in China, which is extremely controversial in Europe. A smart city concept can be conceived totally differently however, inviting to much more communicative spaces. In this context, I like to refer to the different ways of social interaction that existed in medieval times at the royal courts in France and England. Smart city concepts may be as different as those.

Songdo in South Korea has a 30% lower energy consumption than conventional cities. How do you assess the energy saving potential in a smart city?

T.H.: If energy saving is the main objective, there is of course an enormous potential. You can install decentralized energy systems that adjust themselves according to the wishes of the users. However, I feel bound to warn against taking the Asian model as a blueprint. It is tied to the Asian history and culture. The majority of the Chinese population endorses the social points system, whereas it would not be

feasible in European democracies. As Europeans, we have to be cautious not to take the wrong path when developing smart city concepts. Detailed monitoring may not be the major impact. We do not need to know what an individual person is doing; it is more about collecting data about flows and about optimizing processes. There is no contradiction between smart cities and the protection of personal privacy rights. Smart city concepts in Europe are quite diverse. For example, as far as intelligent imaging and image evaluation are concerned, London is by far the most advanced smart city. It has put the major focus on security. Valencia claims to be the first fully-integrated smart city in Spain with 45 different public services combined on a cloud platform. All the municipal services can be handled paperless via the online platform.

How would you define a smart city model for Europe?

T.H.: I would always define a smart city as an optimization of process flows in different societal application fields. These may be energy or traffic flows as well as social flows, for example the interaction between humans. Smart cities are no firm templates. They are the result of an active participation of the citizens and a preceding public-private discussion of what citizens really want and need. And this is exactly what the IMPACT project is channelling: inviting the public to participate in the entire innovation process. Smart city concepts can create digital village squares to comfort the growing number of single households. Mobility aspects and intelligent traffic regulation systems are highly relevant too, with intelligent parking management systems or intelligent information systems that indicate construction sites or accidents. Smart city concepts are far from substituting human intellectual intervention, they should on the contrary support and enhance human intellectual performance. This is the only way smart city concepts may find acceptance in democracies by not patronizing citizens.

Which timeline do you foresee for the implementation of smart city concepts worldwide?

T.H.: China is undeniably pioneering in smart city concepts, since they have the support of the world's leading technology partner Huawei. They know how to take advantage of a digital infrastructure to maintain their influence.

China is the frontrunner, followed by Europe in second place. As far as applications are concerned, we are lagging behind the US since we do not have the GAFAs (Google, Apple, Facebook, Amazon). However, we are taking the lead when it comes to a master plan of intelligent infrastructures. I would say countries like France, Germany, Benelux, Scandinavia and the Baltic Republics will be at the forefront in the future. □

References

[1] https://ww2.frost.com/news/press-releases/frost-sullivan-experts-announce-global-smart-cities-raise-market-over-2-trillion-2025/

[2] Lukas Neckermann: Smart Cities, Smart Mobility: Transforming the way we live and work, Troubador Publishing Ltd., 2017 and https://www.neckermann.net/thought-leadership/smart-cities-smart-mobility/

[3] https://www.theexplorer.no/stories/smart-cities2/smart-cities-in-norway-enhance-quality-of-life-and-reduce-emissions/ https://www.theexplorer.no/stories/public-sector/how-oslo-became-the-european-green-capital-2019/

[4] https://www.geotab.com/blog/what-is-smart-mobility/

[5] https://ww2.frost.com/news/press-releases/frost-sullivan-experts-announce-global-smart-cities-raise-market-over-2-trillion-2025/

[6] https://www.morgenstadt.de/en/solutions/solutions_for_companies/innovation_partnerships.html

[7] https://www.iao.fraunhofer.de/lang-en/press-and-media/latest-news/1427-mobility-plus-future-scenarios-for-autonomous-driving.html

Isa Hofmann,
Consultant, Industry

TRENDS **Italy**

The new frontiers of composite materials

Generally speaking, architecture and design are areas with great growth potential for composite materials. In fact, building & construction is one of the three industries, besides aeronautics and automotive, that have the potential to grow in the future. Composites allow designers great creative freedom and an alternative way to consider building design.

Construction is one of the sectors from which the composites industry expects important growth impulses for producers and processors of fibre-reinforced composites. Recently, there has been a growing interest in the use of composite materials in architecture and design – mainly carbon fibre for its structural and formal advantages – due to their high performance (high resistance in relation to weight) and the possibility of implementing complex geometries, offering the designer maximum creative freedom. Furthermore, the problem of energy saving puts these materials in pole position, as they allow the construction of lighter buildings requiring less energy.

Architecture and design in Italy

Stronger and lighter, this is the quest for better building design, exactly as it already happens in the aeronautical and automotive industries; but while these two sectors have registered a real boom in the use of composite materials over the years, the construction industry seems to live with suspicion over the use of composites in an alternative way compared to traditional materials such as reinforced concrete, wood and brick.

In Italy, the construction sector is extremely traditional and architecture schools still have a "romantic" vision of "natural" materials as an expression of creativity. Furthermore, until a few years ago, material technologies were considered a sector that belonged to engineers rather than architects. Not to mention that the legislation regarding the use of composite materials in building & construction is very fragmentary and inadequate. A good number of Italian companies have to wait at least two years to have their composite products certified; this is clearly discouraging.

One of the few examples of the use of composites in a large building is the Sheraton Malpensa Airport Hotel (2011) designed by Studio King Roselli in Rome. Its distinctive feature is the three-storey metal structure, covered with a glass fiber "skin" despite its considerable size: 420m in length, 64 in width and 21 meters high, showing a perfectly homogeneous surface with no obvious signs of joints even after nine years.

Sheraton Malpensa Airport Hotel (Milano) by Studio King Roselli, Roma (Courtesy of Studio King Roselli, Roma)

A long history

Composites have been used in the construction of buildings throughout history. The classic example of clay brick "reinforced" with straw or other materials is well known.

The new frontiers of composite materials

Today, when talking about composite materials, we mean those materials generally consisting of polyester or epoxy resins reinforced with glass or carbon fibres (GFRP, CFRP).
In Italy, the use of fibre-reinforced polymers (FRPs) in the building industry dates back to the 1960s, and it was certainly not for structural use as they were used by craftsmen to make decorative panels or architectural details that reproduced expensive materials such as ceramics, marble or wood, therefore hand made. In other sectors such as aeronautics and boat construction, composites were already used structurally. Over the years, even for the construction of buildings, methods have evolved and partly industrialized, allowing a much wider use and greater volume production. Advanced and faster production methods such as RTM and LRTM allowed the production of higher quality components with homogeneous finishes that, however, almost always used short fibres with poor structural properties.

Pultrusion technology

One of the production technologies that greatly contributed to the use of composites in construction is pultrusion, which uses long fibres for the serial production of linear composite sections, thus allowing the use of FRPs in the actual construction.
Higher volume fractions of fibres increase rigidity, reducing thermal movement in what used to be a family of intrinsically thermally resistant and electrically insulating materials. These properties are ideal for the construction of thermally-efficient houses that can help meet the challenge of reducing CO_2 emissions.
As stated by Professor Angelo De Tommaso of the School of Engineering at the University of Bologna: "*Buildings are potentially important applications for the pultrusion industry. Pultruded profiles are suitable for composite structures, forming the structural part that will be completed with moulded composite panels. The profiles are generally made of glass fibre composites with various types of resin matrices. The use of pultruded profiles in architecture is not as widespread as it should be due to aesthetic reasons as they are often considered as "cheap plastic". In Italy, there is a great potential for the pultrusion industry but the demand is still scarce. Professionals are poorly informed and receive very little training in the use of composites in their designs. I think that an action to spread the knowledge and appreciation of these materials among architects combined with professional training could be useful now that international norms have traced the essential lines for the use of composites*".

The TemporActive Pavilion, Politecnico di Milano.
Construction materials by Top Glass Industries. (Courtesy of Top Glass Industries)

Ultra-lightweight temporary building made of composite materials

Last June, on the occasion of the 6th Tensinet Symposium 2019 at the Politecnico di Milano, a very interesting architecture was built by Top Glass Industries using pultrusion. The TemporActive pavilion was an ultra-lightweight temporary building designed and built by university researchers. A bending-active hybrid structure was designed to support and shape a flexible translucent membrane. The structure was 7x12 m, with a height of about 3.5 m in the mid span, for a total weight of only 50 kg. The base structure and the upper curved part were built with TRIGLASS® profiles, a series of 75x150x8 mm "H" beams connected with angle profiles (45x112x3 mm) to create a primary and secondary warping. The entire structure was realized with pultruded composite materials except for the internal stainless steel cables. After the symposium, the structure was rebuilt and reused as a leisure facility for the students in the Politecnico campus.
According to the Composites Market Report 2018 of the Composites Germany trade association, pultruded profiles are mainly used for facades but also for the construction of bridges, window profiles and staircases, as well as reinforcement systems, especially in the construction/infrastructure sector, in addition to lightweight construction. The properties of these materials, such as corrosion resistance, low maintenance, the possibility of constructing according to the load, and non-conductivity of current and temperature, play a central role. According to the market report, current research activities focus on fibre-reinforced inserts for concrete construction methods (reinforcement, structur-

Lightweight structure designed to support a new roof after the earthquake of 2009 (S.Maria di Paganica Church, Aquila, Courtesy of Top Glass Industries)

al nets), for replacing steel reinforcements. The corrosion resistance of CFRP composites could save large amounts of concrete, as the minimum thicknesses required to prevent moisture penetration can be significantly reduced.

Today, recyclable formworks and insulating panels are available for the building industry. Last year, 35% of the fibreglass manufactured in Europe was produced for the construction industry. Also, according to the above-mentioned market research, construction/infrastructure is an important sector, in particular for continuous processes and pultrusion. The volume of fibreglass components produced this way increased by over 3.4% on average in 2018. The total production volume is now 151,000 tons.

This sector would seem a perfect framework for the large-scale use of composite materials but, at least in Italy, it is not for three main reasons: 1) the corresponding approvals and general standards are still lacking, so that many designers are still highly reluctant to choose these materials; 2) designers are not yet sufficiently aware of the properties of GRP compared to other building materials. Moreover, even young architects do not leave universities with an adequate preparation for using composites. Much can be done to increase consideration and preference for composites in the architect community; 3) the construction sector is notoriously very conservative all over the world, even more so in Italy where clients and builders are not very keen on using materials that are still considered "new" and unreliable. Carbon-reinforced composites (CC) play a much smaller role in the construction/infrastructure sector. With 7,740 tons, their market share is only about 5% out of a total of 154,700 tons. In terms of sales, their share is only 2%. Last year, the construction industry accounted for only USD 0.46 billion out of a total of USD 23.15 billion. According to the market report, CC applications in the construction sector are still not very consolidated. At the same time, the applications showing promise have very high mass throughput. Individual solutions would also have a significant impact on the global CC market.

Fibre-reinforced inserts for concrete structures

According to the market report, extensive research activities are currently focusing on fibre-reinforced inserts for concrete construction methods (e.g. reinforcement, carpets/structural nets), for example to replace steel reinforcements. At the same time, the corrosion resistance of CFRP composites could save large amounts of concrete, since the minimum wall thicknesses required to prevent moisture penetration can be significantly reduced. This would have a significant influence on CO_2 emissions in the construction sector. Furthermore, solutions for certification (e.g. fire protection) are currently the subject of in-depth discussions. The diversity of potential applications in construction offers great opportunities for fibre-reinforced composites. According to experts, the use of composites for bridges and roads offers many advantages. These materials are immune to both frost and salt damage and their weight is significantly lower. According to Carbon Composites, a composite bridge weighs about 40% of a steel bridge and less than 30% of a pre-stressed concrete bridge, and can be prefabricated in significantly larger sizes, transported and placed on site by a crane. Light construction already plays an important role in the construction sector. In the coming years, the use of composite materials in new projects is expected to increase, for example in the construction of facades. Fibreglass pipes and tanks are also very important for the construction of factories and pipelines, and they already represent a significant market.

The building & construction industry is notoriously risk averse and not very willing to innovate. This is true in many European countries and particularly in Italy. Furthermore, the lack of codes and standards for the use of FRPs is a serious problem. Very often, the designers and technicians who would like to use these materials do not have a complete picture of the new technologies and the relative legislation.

Development of FRP composites in building construction

In Italy, the many earthquakes unfortunately revealed serious shortcomings as regards the antiseismic qualities of buildings. Yet, composite materials and technologies

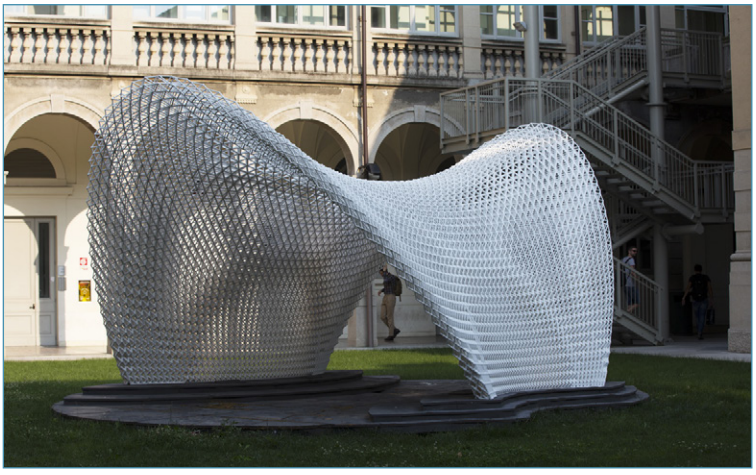
aimed at reducing the vulnerability of the architectural heritage have already shown to be very effective, for example in the reconstruction after the earthquake in Umbria. Their use, however, concerns a small percentage of the many possibilities offered by construction, while these materials offer many opportunities, from structural reinforcement to the renovation of historic buildings or bridges and roads. In an industry as conservative as construction, it is always difficult to get people to accept new technologies and materials. In Italy, people are so accustomed to traditional materials that getting them to accept innovative technologies is rather complicated.

Especially on the part of builders who, always looking for solutions that reduce their final costs, fear that shifting to new materials will mean higher costs.

To set the record straight, we asked a few questions to some of the greatest Italian experts in composite construction.

According to Alfonso Maffezzoli, Professor of Materials Science and Technology at the University of Salento: "*In the last 25 years, carbon fibre composite materials have found an increasing use in civil structures. In Italy, their applications in new buildings are limited by the lack of regulation, even though preliminary regulatory documents have been published. Nowadays, they are mainly used in reinforcement and restoration, even though I also see a strong potential in new building elements such as facades, domes and complex shapes.*"

Maria Antonietta Aiello, engineer and Professor of Structural Engineering at the School of Engineering, University of Salento, adds: "*FRPs are used for the most different typologies and structural materials. Recently, composite materials were applied to metal and wood structures. The need to provide for the adjustment of structures not or poorly designed to withstand seismic events and the need to increase the bearing capacity of structural bridges and viaducts, due to the growing vehicular traffic, constitute a problem of primary importance*".



Politecnico di Milano. Fully 3-D printed pavilion with bio polymers that is a one-to-one architectural demonstrator of how a lattice structure could be 3-D printed. (Courtesy of Ingrid Poletti, PoliMi)

The most frequent uses of FRPs on existing reinforced concrete structures are: wrapping the exterior surface of elements subject to compressive or bending stress such as pillars, bridge pilings, chimneys, etc.; reinforcing load-bearing elements (beams, floors) through external plating; and reinforcing beam-column nodes in reinforced concrete frames.

Encircling wall structures with FRPs is a very important type of recovery/upgrading intervention on masonry structures.

Even though applications in new constructions are currently limited, the growing knowledge and the development of new materials, particularly cement-based composites and eco-friendly composites, along with the successes achieved in the applications of composite materials, point towards future growth.

The Dean of Composite Materials Engineering, Professor Angelo De Tommaso, affirms: "*We are still far from imagining large composite structures, but growth prospects are very good because everyone has come to understand that Italy is a country with high seismic risk, and therefore it is essential that the use of composite materials becomes widespread.*"

The future

The consequences of climate change are already visible in the changing weather patterns. In Europe, many unusual floods recently highlighted the dangers to which many constructions will be more and more exposed.

In other parts of the world, hurricanes and natural disasters, from tsunami to earthquakes, are severely hitting buildings. It is becoming clear that buildings must not only withstand the environmental impacts caused by climate change and natural disasters, but also reduce their impact on the environment by eliminating waste and CO_2 emissions in addition to improving energy savings.

A building material stands out for its ability to do both, but it is little known outside the sector that produces it. Stronger than steel, but only ¼ of its weight, composites are the first building material that is not affected by water or decay that damages natural materials. Composites offer a timely solution

to the biggest problem the world is currently facing: global warming.

Composites as an expression of creativity

Ingrid Paoletti, Associate Professor in Building Technology at Politecnico di Milano, thinks that: "*First of all, when we speak of innovation in architecture, we have to think that it is a very peculiar sector where the introduction of new products, materials and artefacts is slow due to the natural features of buildings, which are a capital good. This means that innovation is not always a priority requirement of this sector as in other sectors. Usually, innovation paths in architecture follow different strategies, and one of them is technology transfer. New technologies come from sectors with a higher degree of innovation, such as automotive, aerospace or navy. One of the most important boosts for innovation has been the introduction of computational techniques in design. The possibility to algorithmically anticipate the properties and performance of materials from the concept phase opens to the designer a wider scenario of possible techniques and creative solutions: this is where I see the most probable use of composites, not as a completely new material system, but more as a better known and understood technology.*

The creativity of designers can be boosted by new computational tools, which not only make it possible to embed digital information in the design but also widen the creative potential of production and fabrication, opening the process that is called mass customization.

Mass customization allows the production of single personalized pieces at the price of standard production due to the use of new tools and machines. Moreover, different material compositions – composites – can be "customized" to fulfil different needs in a single product.

In my opinion, designers, engineers and architects can thus couple material science with the advancement of digital fabrication techniques by performative-driven design, which means knowing better how matter works and also how composites work and producing innovative buildings and new tectonics. Hybrid material systems can meet different performance requirements of the ever-changing market.

An example at Politecnico di Milano is a pavilion fully 3D-printed with bio-polymers that is a one-to-one architectural demonstrator of how a lattice structure could be 3D printed. We made an unusual combination of components that could really express polymer printing techniques in lightweight structures and innovative tectonics. We computed and embedded the properties in the design, reaching a high level of novelty. We also thought of how to assemble and disassemble the structure during the lifecycle of the project. One option also considered the use of glass fibre as an envelope to prevent climatic conditions from weakening the structural properties.

More than forecasting, we should now use the word "back" casting, meaning setting the goal of which benefit we want to achieve, and then going back with a roadmap to it. We can put forward, for example, lightweight construction or disassembly or prefabricated sustainable components and how this paradigm can come into the design from the concept phase."

Industrial design

A world apart that deserves specific attention is the well-known Italian design. Since the 1950s, creativity in the field of industrial design developed together with the industrial boom of the last century, producing iconic objects, many of which have not been affected by the passage of time and still confirm their validity. Home appliances, cars, furniture, lamps and other objects form a complex landscape that constitutes Italian excellence. In this varied landscape, however, it is surprising that the interest in composite materials has been, and still is, very scarce.

One of the few iconic carbon pieces, the Katana floor lamp designed in 2007 by Valerio Cometti (V12 Design), thanks to its impressive

Katana Lamp (Courtesy of Valerio Cometti, V12 Design)

elegance, is still produced by the historic Venetian lighting brand Leucos as part of its Icone collection. Mr. Cometti explains: "*When I designed the Katana, I wanted to create a floor lamp that was both sculptural and graceful, I wanted to find a balance between a desire for expressiveness and a desire for refinement. Two rapid signs, which crossed each other in mid-air, identified the curved profile of the vertical and horizontal stems.*

It was one of those projects born with the name already from the first pencil mark: the famous Japanese samurai sword was the object that came to my mind while I elaborated the shape of the lamp. During the definition of the design, I realized that I wanted to find a particularly refined and "hidden" way of adjusting the inclination of the upper rod, or rather the one that holds the lighting body. Adjusting this inclination was necessary to be able to adjust the height of the light source, a very important feature in a floor lamp. I also didn't want to accept the compromise of a constant section, mandatory if I had adopted an extruded profile. I wanted the shape of the Katana lamp to be slender and dynamic, to be explored without haste. The sum of all these functional and aesthetic desires led me to think of carbon fibre, which brings the design freedom, the stiffness and above all the lightness needed to house a small counterweight in the rear part of the horizontal rod to adjust its inclination. In Katana, in fact, you just have to move the small counterweight a few centimetres to force the lamp's horizontal rod to find a new position, without having to resort to levers, fasteners or mechanisms that are not coherent with the purity of the project.

More than 12 years after the project, in addition to the aesthetic satisfaction that this lamp still offers me, I feel great satisfaction in being able to use carbon fibre for its intrinsic mechanical and physical characteristics, rejecting its superficial and sterile use as a "texture" only."

Valerio is an exception in a panorama of designers using "traditional" materials.

In fact, as he adds: "*As a mechanical engineer dedicated to creativity for the past twenty years, I admit to having a very close relationship with the materials and their characteristics. I cannot use them exclusively for their aesthetic value or as a "texture" applied to our projects. Together with my collaborators, I make a daily effort to identify the most suitable material and manufacturing process for each component of our projects.*

Having said that, I must admit that in my opinion, the balance of the relationship between Italian design and composite materials is not exciting. If we exclude the worlds of cycling and sports equipment in general, which are areas where we have excellent production realities in Italy, the presence of composites in Italian design is very limited. An esteemed colleague like Marc Sadler, a great expert in materials, has over the years designed successful lamps for Foscarini using composites in a satisfying and mature way. I can't, however, find many other examples...

Without any desire to make judgments, I think that this absence is attributable to a lack of education: designing with composites is very different from designing with solid wood, marble or glass. For years, I have seen carbon fibre composite objects where the material was used only for its own aesthetic value, for the evocative nature of the design.

Considering the lack of competence in composite materials of the average Italian designers, the intrinsic cost of composite manufacturing, the tendency to (drastically) reduce the industrial cost of a product, it is easy to understand how the intersection between parameters is not so good, giving little satisfaction to composite materials in the world of Italian design".

Conclusions

To conclude, composite materials certainly have a great future in the field of architecture and construction. With three quarters of the European population living in cities today, it is clear that urban centres are the great centres of development but also of risk in terms of air and water pollution, waste production and waste of recyclable raw materials. Suffice it to say that around 80% of CO_2 emissions come from urban areas. It is therefore from cities that the drive for innovation must start.

Reducing pollution and raw materials waste has now become an unavoidable goal. The designers of the cities of the future will have to know how to take advantage of all the tools available to respond to users' needs in the best possible way. Certifications will play a fundamental role in how real estate developers will look for innovative designs using new materials. Fibre-reinforced polymer materials (FRPs) with continuous fibres, thanks to the undeniable advantages deriving from their lightness and high mechanical characteristics, will find more and more consensus not only among structural engineers both for consolidation and seismic adaptation, but also among architects who, thanks to composites, will finally be able to achieve almost total creative freedom. □

Simonetta Pegorari,
Consultant,
Composites Industry

TRENDS **urbanization**

Street smarts: how composite materials are driving the smart city movement

The island-state city of Singapore is often hailed as the world's premier smart city. With a 99% connectivity rate, robo-taxis and a huge network of sensors providing a large pool of data for analysis, it is easy to see why the island is at the forefront of the smart city movement. But as urban areas across the globe get smarter, how will infrastructure support their progression? Here Robert Glass, Head of Marketing at leading composite technology company Exel Composites, explains how composite materials are helping to drive the smart city movement.

Robert Glass,
Head of Marketing
Exel Composites Oyj

Just 2% of people lived in cities around the world in 1800. By 2050, the United Nations predicts that 68% of the world's population will be urbanised. Escalating numbers of urban residents are already increasing the strain on public services, infrastructure and resources. Housing shortages, traffic congestion and overcrowded transport are all side effects of having too many people in one place. To tackle rising urban populations and provide enhanced standards of living, countries across the world are turning to technology.

On the rise

A smart city is an urban area that uses a variety of Internet of Things (IoT) sensors to collect data and use it to manage assets. This data is produced from our devices and infrastructure and is used to control assets such as traffic, transportation systems, water supply networks, waste management and community resources. As a "system of systems", value is given to a smart city by what it chooses to do with the technology, not just how much data the city has.

With data at the heart of the city, the possibilities to improve quality and efficiency are endless. If we think of our cities growing, they are going to need to get taller. Rising buildings will require highly efficient elevators in order to transport people to their homes and offices, as well as more precise co-ordination. A network of data and analysis systems could enable this precision by estimating our arrival and approach towards the elevator, identify who we are and, using predictive analysis, program the ideal and optimal elevator trips to respond to busy periods. For example, if a building "learns" that a worker arrives at 8:00am each day and works on floor 14, artificial intelligence could make sure the elevator is ready and waiting for the worker before he needs to push a button to call it.

The public transport system is another key element of smart cities. To optimise commutes, smart cities call upon sensors to accumulate and monitor large amounts of data on traffic and predict how busy underground trains are going to be to automatically adapt the number of vehicles in use at any given time. It is clear that a responsive data infrastructure will be as important as the electrical and water utility infrastructures in place today. To support this infrastructure, composites will play a key role in providing uninterrupted data flows.

Calling on composites

Composites offer great possibilities to enclose and protect data infrastructure, such as transmitters and other devices that facilitate radio frequencies. Unlike metals that block these signals, composites such as fibreglass are radio-transparent. This makes them the ideal material to allow a continuous data flow throughout a smart city that keeps its assets running without interruption.

With the implementation of 5G being another key driver in the smart city movement, the technology relies on an extensive network of small cells to transmit and receive signals. Composites can enable a fast roll out of 5G services with glass fibre profiles that are almost invisible to these frequency waves. Fibreglass antennas can be hidden in plain sight on existing infrastructure such as light poles and traffic lights, allowing cit-

Street smarts: How composite materials are driving the smart city movement

Light weight composite panels and stiffeners help improve vehicle energy efficiency.
©Bombardier

About Exel Composites

Exel Composites, a global technology company headquartered in Finland, is the world's largest manufacturer of pultruded and pull-wound composite solutions. The company's global manufacturing, R&D, and sales footprint serves customers across a broad range of industries and applications. With 60 years of composites experience and engineering expertise, Exel works closely with their customers to design and manufacture high-quality composite solutions using carbon fibre, fibreglass, and other high-performance materials. The company's composites help reduce weight, improve performance, and decrease total life cycle costs, all while helping increase energy efficiencies and supporting environmental sustainability.
Exel Composites employs approximately 650 innovative and customer-focused employees around the world and is listed on the Nasdaq Helsinki exchange.

ies to easily integrate the technology. Exel has been manufacturing radio-transparent outdoor structures for many years, and expects to see the lightweight, corrosion-resistant and radio-transparent qualities of composites help drive data around smart cities today and in the future.

Infrastructure presents a further barrier for short wave frequencies and could cause 5G to, quite literally, hit a wall. Due to its ultra-low latency, the availability of 5G could be dramatically reduced as its high frequency may struggle to penetrate buildings. With 80% of device use occurring inside buildings, this loss or reduction in availability significantly impacts the technology's uptake.

However, incorporating fibreglass components into buildings, such as in window and door frames, will help reduce signal attenuation into our houses and businesses.
In addition, because fibreglass is capable of withstanding strong UV rays, extreme temperatures and varying levels of humidity, composite components also provide smart city buildings with a durable material that reduces overall lifetime costs.

To optimise public transport, composites can provide a lightweight solution that helps to reduce the overall vehicle weight of buses and trams. They are used throughout vehicles, from fibreglass exterior panels to carbon fibre stiffeners and battery boxes. This helps save fuel, reduce pollution and lower the lifetime maintenance costs of vehicles.

Taking notice

The main hurdle that composites face is simple awareness. Many manufacturers may not be aware that composites are an alternative to the materials they are using today in buildings, infrastructure, transportation and telecommunication projects simply because it has not crossed their minds to explore new options.
Working alongside an experienced composites manufacturer, who can explain both the benefits of composite materials and their ability to produce smart city solutions using cost-efficient manufacturing processes, will help break down this barrier.

Smart cities are no longer a thing of the future. While Singapore is often considered as one of the first cities to benefit from increased data handling, the likes of Barcelona, Helsinki, Seattle and Milton Keynes are also positively altering the lives of millions of urban residents.
While data remains in the driving seat of the smart city movement, this information cannot flow freely without effective infrastructure.
Composite materials play an important and growing part in the success of a smart city, and their range of benefits create durable solutions that help manage assets efficiently. □

More information:
www.exelcomposites.com

A structural Eurocode for FRP structures

Over the past twenty years, several innovative solutions confirmed the usefulness of composite structures made of fibre-reinforced polymer or plastics (FRPs), both within and outside Europe.

Applications range from lock gates to entire bridges or bridge decks, both for pedestrian and vehicular traffic. Due to the steadily increasing market volumes and given the complexity of selecting from the materials available for FRP structures, it became necessary to develop a standardization document for the production of FRP structural elements as well as practical rules for the design and verification of structures intended for buildings and civil engineering works. The aim of this paper is to summarize and spread information about the activity already developed by CEN/TC 250, and to highlight the further procedures to be followed on the road towards a structural Eurocode for FRP structures.

L. Ascione,
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University of Salerno

Over the past twenty years, several innovative solutions confirmed the usefulness of composite structures made of fibre-reinforced polymer or plastics (FRPs), both within and outside Europe. The use of FRP profiles, shell structures and sandwich structures is particularly advantageous for applications in the civil engineering field. FRP bearing structures are therefore widely used in the construction of buildings for industrial or residential purposes. FRP usage is also increasingly widespread in civil engineering works. Applications range from lock gates to entire bridges or bridge decks, both for pedestrian and vehicular traffic (Figures 1 and 2).

Fig. 1: Lock gate at Werkendam (Spieringsluis, the Netherlands)

A structural Eurocode for FRP structures

Fig. 2: Pedestrian bridge at the golf club in Aberfeldy (Scotland)

Because of the steadily increasing market volumes and given the complexity of making a choice among the materials available for FRP structures, it became necessary to develop a standardization document for the production of FRP structural elements as well as practical rules for the design and verification of structures intended for buildings and civil engineering works.

In May 2010, the European Commission, DG Enterprise and Industry, issued the Programming Mandate M/466 EN to CEN concerning future work on the Structural Eurocodes. The purpose of the Mandate was to initiate the process of further developing the Eurocode system.

M/466 requested CEN to provide a standardisation programme covering:

- Development of new standards or new parts of existing standards, e.g. a new construction material and corresponding design methods or a new calculation procedure;
- Incorporation of new performance requirements and design methods to further harmonise the implementation of the existing standards.

The works of the future generation of Eurocodes will be carried out in several steps:

- Step 1: Preparation and publication of a Science and Policy Report, subject to agreement of CEN/TC250;
- Step 2: Following agreement of CEN/TC250, preparation and publication of CEN Technical Specifications (TS, previously known as ENV);
- Step 3: After a period for trial use and commenting, CEN/TC250 will decide whether the CEN Technical Specifications should be converted into Eurocode Parts.

The programme is scheduled to be completed by 2022. Within this Mandate, CEN/TC250 took the initiative to prepare a document addressing the purpose and justification for new European technical rules and associated standards for the design and verification of FRP composite structures. CEN/TC250 formed the CEN Working Group WG4 to develop the work items. It was motivated by the need to both ensure adequate reliability of the applications and promote a broader market for FRPs, ensuring the circulation of these materials between EU countries in accordance with well-defined standards. The author of this paper is the convenor of WG4. The broad interest in the development of a European-wide harmonized, acknowledged and coherent set of technical specifications or Eurocode parts for the design and verification of FRP composite structures is demonstrated by the impressive number of almost 50 highly motivated members bringing their specific expertise in CEN/TC250/WG4. The Association of the European Composites Industry (EuCIA) also participates in the activities and meetings of WG4.

Several countries contributed to the development of the currently available guidelines (1996-2010), especially those listed in the References.

After about three years of activity and many meetings, WG4 drafted a Scientific and Technical Report (2016) entitled Prospect for new guidance in the design of FRP. From January 2016 to July 2016, the Report was subjected to public inquiry by the EU National Standardizations Bodies. At the end of the inquiry, the Report was revised and resubmitted to CEN/TC 250 that, in July 2017, decided to start adapting it into a CEN Technical Specification (Step 2). The revised version of the Prospect was published by EuCIA and can be freely downloaded from EuCIA's website.

The Technical Specification will apply to the design of FRP constructions. It will comply with the principles and requirements for the safety and serviceability of structures provided in EN

1990-Basis of structural design. The operational rules for the basis of design, supplementary provisions for the determination of action effects, robustness requirement and guidance for material-oriented design of FRP constructions will be clearly given.
To achieve this goal, a project team of six members was entrusted by CEN/TC 250 to help WG4 on the road towards a structural Eurocode (Step 3).
The members were selected by public tender. The activities of Step 2 started at the end of July 2018 and should be completed by 2022.

Main features of the Prospect

The goal of the Prospect (Figure 3) is to stimulate the debate about future guidelines and rules for the structural analysis and design of fibre-reinforced polymers (FRPs) used in load-bearing structures, for buildings and civil engineering works.

The topics taken into account address FRP parts with a fibre volume fraction of at least 15%, i.e. the ratio of fibre volume to total volume.
The FRP composite has to be made of glass fibres (E-glass or R-glass), carbon fibres (HS, HT, IM or HM) or aramid fibres and a thermoset matrix based on unsaturated polyester, vinylester or epoxy resin.
The Prospect applies to FRP structures made of beams, laminated plates and shells or sandwich structures.
It does not include structures in which micro-cracks are not permissible, nor FRP-based reinforcing rods, cables or external reinforcements to existing structures.
The structural elements considered are produced using common manufacturing processes such as prepregging, pultrusion, compression moulding, resin transfer moulding, filament winding and hand lay-up.

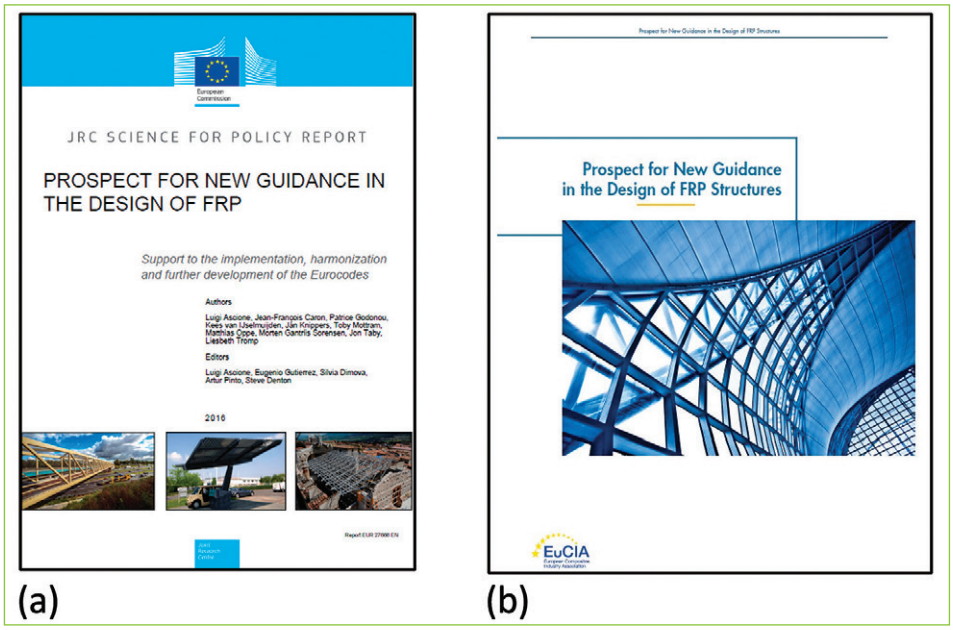

Fig. 3: (a) Cover of the Prospect; (b) Cover of the revised Prospect

Main features of the technical specification

As a result of the public inquiry, the main aspects developed to draw up the technical specification (TS) (Step 2) concern the Basis of Design and in particular, considering the values of the partial and conversion factors, sandwich structures and adhesively-bonded joints.

Moreover, the following elements will be processed in Step 2:

- a Background Document (BD) alongside the TS, by (i) adding further information whenever applicable/needed, and (ii) introducing and adequately citing all the references required to trace the source of the information used in the TS;
- Worked Examples, to be included in the BD, for typical design cases.

The TS will include the following clauses, according to the structure recommended by CEN:

- European Foreword
- Introduction
- 1. Scope
- 2. Normative References
- 3. Terms, definitions and symbols
- 4. Basis of Design
- 5. Materials
- 6. Durability
- 7. Structural Analysis
- 8. Ultimate Limit States
- 9. Serviceability Limit States
- 10. Fatigue
- 11. Joints and Connections (Bolted and Glued)
- 12. Detailing
- 13. Production, Installation and Maintenance

Conclusions

This paper summarized the ac-

tivities developed by CEN/TC 250 during the past years on the subject of full composite structures made of FRP.
Their goal was to:

- ensure adequate reliability of such structures,
- promote a broader market for FRPs, and
- ensure their circulation between EU countries in accordance with well-defined standards.

Furthermore, the additional activities planned by CEN/TC 250 to develop a structural Eurocode dedicated to these structures were also highlighted. □

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References

Prospect for new guidance in the design of FRP, JRC Science and Policy report, ISSN 1018-5593 (January 2016).

CUR 96, Fibre Reinforced Polymers in Civil Load Bearing Structures (Dutch Recommendation, 2003).

EUROCOMP, Structural Design of Polymer Composites (Design Code and Handbook, 1996).

BD90/05, Design of FRP Bridges and Highway Structures (The Highways Agency, Scottish Executive, Welsh Assembly Government, the Department for Regional Development Northern Ireland, May 2005).

DIBt, DIBt – Medienliste 40 für Behälter, Auffangvorrichtungen und Rohre aus Kunststoff, Berlin (In German, May 2005).

CNR-DT 205/2007, Guide for the Design and Construction of Structures made of Pultruded FRP Elements (Italian National Research Council, October 2008).

ACMA, Pre-Standard for Load and Resistance Factor Design of Pultruded Fiber Polymer Structures (American Composites Manufacturer Association, November 2010) under review by ASCE.

DIN 13121, Structural Polymer Components for Building and Construction (August 2010).

BÜV, Tragende Kunststoffbauteile im Bauwesen [TKB] – Richtlinie für Entwurf, Bemessung und Konstruktion (in German, 2014).

Owens Corning's vision of composites in construction

The construction sector has made steps to adopt fibre-reinforced polymer composites (FRPs) since the 1960s and have been successfully used in many applications. We had the great pleasure to interview Marcio Sandri and Nicolas Del Monaco from Owens Corning to have their thoughts about the use of composites in construction.

Interview

Marcio Sandri,
President of Composites
Nicolas Del Monaco,
VP, Nonwoven and Glass Reinforcements, Europe
Owens Corning

Owens Corning Nonwoven lines of products offer myriad performance advantages and superior finishes

JEC Composites Magazine: One of your four key focus market is building and construction, what are your main innovations in this sector?

Marcio Sandri: Owens Corning has four pillars in its strategy: building and construction, wind, automotive and regional growth across the globe. Within our building and construction pillar, we focus on three things: building capacity to support the growth of the market; supporting the innovation of new products so that our industry can succeed; and investing in increasing the adoption of composites. OC has invested in capacity across our business – in Gastonia, North Carolina; in Chambéry, France; and in Taloja, India as just a few examples.

Nicolas Del Monaco: If you look at the building and construction market, the trends are for buildings to be built faster and for much lighter structures ultimately to make the building more energy efficient. Our Nonwoven line of products apply across the building and constructor sector and answer that call for cleaner, greener, high performing solutions. Glass nonwoven solutions bring mechanical performance and act as a barrier, as well as bringing higher-end type of properties like aesthetics and acoustics. This year, OC has a big focus on the gypsum market, which will accelerate those types of benefits. Also, our higher-end ceiling tile business is one where we have a big bet for growth and we are bringing new products this year to the market to continue to improve the level of acoustics, visual and safety performance.

The construction market is beset with regulations currently. How is Owens Corning impacted by these regulations?

M.S.: Ensuring environmental and regulatory compliance is something we take very seriously, and we believe regulations can

Owens Corning's vision of composites in construction

Marcio Sandri and Nico Del Monaco discussing composite applications in the building and construction sector at JEC World 2019

support growth in composites. Mainly because it creates standards for customers and there is a standard that you play against to improve quality. Owens Corning works closely with customers, associations and government agencies to support regulations that guide the growth of the industry. So, yes regulations do impact our industry but in a positive way and we always try to work very closely with regulators.

What is Owens Corning's involvement in the composite rebar market?

N.D.M.: Long-term infrastructure solutions are desperately needed, and composites offer unique answers. Composite rebar is a market where OC has declared our ambition to grow. It is a market that hasn't been deeply penetrated yet, so we believe there is a big opportunity for us as a composite provider. In the last year, three key things have happened in the market and really gave us a lot of confidence in what we can achieve. First, the American Association of State Highway and Transportation Officials (AASHTO) has revised their guidelines towards how composite rebar can be used. Basically, it is going to be simpler for composite rebar to be used compared to steel as the previous guideline was very stringent on the use of composite rebar. The second is that we are working with the American Concrete Institute and later this year we expect to publish a paper which proves that over time – about 15 year later – composite rebar will show very little degradation compared to other materials. And finally, we are in the process of building an expanded capacity in North America and maybe in other places later. So, we believe that with these three things we will continue to grow the composite rebar market very quickly. We are also involved in many other projects now, such as the Anthony Wayne Trail Bride in Toledo, Ohio.

What is your point of view in the development of composites in construction?

M.S.: For composites to grow in construction, first we must see construction growing, and that is happening. The growth of construction around the globe is around 5 % which is a hefty number as people are increasingly able to realize their dream of buying a house. As well, people who already have a house want to have a nicer house with better aesthetics, better air quality and better weatherability because it is a big investment. Composites can provide products and applications that can help in every single aspect – in aesthetics, in air quality, in fire resistance and in durability. Our Nonwoven products offer superior performance. Ceilings with modern styling; flooring barriers that are more durable; and wall coverings that protect against moisture.

That's how composites will grow in this market and how composites will become more valuable for the construction industry. □

More information:
www.owenscorning.com

Scan
to discover !

"We always start with a blank sheet of paper"

No need to present the Hyperloop concept, that could make it possible to travel as fast as a plane but through a tube, either above or below ground. Among the companies involved in this quest, Hyperloop Transportation Technologies is very well positioned with an interesting business model and a clear view of materials. Here is an informal interview with Dirk Ahlborn, the company's CEO.

Interview

Dirk Ahlborn

CEO
Hyperloop transportation technologies

Fig. 1: Hyperloop Transportation Technologies' capsule

JEC Composites Magazine: Why did you opt for composite materials for your capsule (see Figure 1)?

Dirk Ahlborn: For a number of reasons, and weight is a very important one. There are many applications where composites have advantages over metals such as aluminium. For example, with composites we can have certain things embedded or weaved in. We are looking into composites not only for the capsule. We are conducting many developments in several other areas.

For the tubes?

D. A.: Maybe! We will be presenting something soon… Let's say that we are looking at how we can make them part of the overall production process.

What about Vibranium? It sounds like a "super hero material"? Really clever in terms of marketing…

D. A.: We were looking at names. My kids are super hero fans, so when I explained them that our goal is to keep people safe, and described all the advantages composites have, they told me "How about Vibranium, it is the strongest materi-

al on earth!" This is where the trade name of our smart composite comes from. This material has sensor capabilities. It is not Vibranium itself, the capsule is made in a way that we have two skins.

Who produced the capsule?

D. A.: We work with many different composite manufacturers. The capsule is now produced by a company called Carbures Artificiales.

If you win a huge contract in the Emirates or in China, can you localize the production there?

D. A.: Well, this is our goal. We are organized in a very lean way. We want to work with a network of partners, to control the intellectual property rights, and so the integration process. Our goal is not necessarily to manufacture composite parts. We are working with people who do this every day, who have the knowledge, who do this for a living and who are the best at it. This is not our job.

Do you have a TÜV certification?

D. A.: It is not a certification, but a safety guideline. TÜV will then handle the certification. Together, we created the first draft of the safety guideline that is now presented to the different governments. We also presented it to the European Commission, which is currently working on the basis of our guideline. But this is something that we do for the industry. We are working with the DoT in America to do the same thing.

About the tubes again... Usually the tricky thing is to join the tubes properly (Figure 2). How do you overcome this problem?

D. A.: Yes, it's true but I actually believe that composite materials have some advantages here. We have been looking into some specific technologies but the main thing for us is that we do not want to depend on one material. Let's say if we build the L.A.- San Francisco line, it will be the largest steel construction in the world. So, it is fine that there is a certain availability but you need to have flexibility. Based on the availability in each country, we will use different materials. So it is not always a cost issue or sometimes one is better than the others only under certain specific circumstances.

Fig. 2: Conveying the tubes

What about your rivals? Are you a step ahead or are they pushing you?

D. A.: There are two large players in this field: Hyperloop Transportation Technology, our company, and Virgin Hyperloop, which had a lot of trouble. They probably overcame most of the issues. It is a good thing to have a rival but they are very different from us, they are a typical American company. They raised and spent a lot of money. In our case, it is more about knowledge, IP. In our model, we actually use the money mostly for building. We used only 10% of what they used and this makes a big difference. Also because they need to refinance continuously. I can imagine that, in the last final round, probably most of it came from existing investors in order to keep the company running, which is a good thing. But this makes it very difficult. In our case, luckily, we are little bit more flexible, we are more like the cockroach. But this also enables to innovate a little bit more. Why should I manufacture tubes if there are people who do this all day long. It does not make sense. This is a little bit at our advantage.

Composite materials offer so many advantages and potential developments. And we are looking into many different new technologies as well, composites are still a very young market. The good thing is really that we always start with a blank sheet of paper. In aerospace, you have people with a preset mindset so when they introduce a composite material in an airplane, they don't call it a composite, but black aluminium. And they design it in a way that the parts are manufactured the same way as with aluminium. This is not the type of problems we have. We start from the beginning the way it should be done. This is a huge advantage. This is why we are also interested to hear from people who have this expertise. Maybe they have good ideas to do things better, more cost efficiently. □

More information:
www.hyperloop.global

Solar Tree: making the city more attractive

The Solar Tree is an innovative urban structure, an off-grid stationary power generator that provides shadow, clean energy, night lighting, connectivity and can be used for IoT commerce and Mobile Out of Home Advertising (MOOH).

Santos Venetia,
Director
Flying to the sun
De Queiroz Pilz Daniel,
Director
Cogumelo S.A.

The Solar Tree uses Arkema's Elium recyclable resin, which offers excellent structural characteristics and has a lower environmental impact. This resin is styrene-free, recyclable, thermoformable and enables the manufacture of lighter parts, making the tree easier to process, store and transport, while offering a high modulus, toughness and stiffness.

Manufacturing processes

The Solar Tree was developed using two types of manufacturing processes:

- *Pultrusion*: The stem is manufactured with pultruded profiles for a lightweight, bold design with high mechanical resistance to support the leaves, and precision of the rails where the LED strips are fitted.
- *Infusion moulding*: The tree's base and seat are made by infusion using Elium resin. Two moulds, one on each side of the leaf, are bonded by adhesives or by induction and secured to the stem's pultruded profiles. The stems are then connected to the pultruded profiles, which are also fixed by adhesives or by induction at the base of the tree bench, formed by two parts (base and seat cover). The new technology made it possible to innovate and to achieve a lightweight composite structure. The organic photovoltaic film (OPV) weighs 200g per m^2, is extremely light and can directly adhere to the leaves.

Modular design

In this project, the advantage of using composite materials was shape freedom. The Solar Tree has a bold, modular design, where a single leaf makes it possible to create different configurations. It is composed of six leaves, organized in two different heights. Sold separately or together, the client will be able to buy one or more leaves and even organize a forest and sell visual advertising space on the leaves.

Moreover, the use of composite materials reduces maintenance costs as the tree's fibreglass structure requires no maintenance. Any other type of material, in addition to design limitations, would generate high maintenance costs.

The use of composites increases the product's life, as it can withstand rain, wind and sun. The Solar Tree offers other advantages including high impact resistance and post-thermoformability due to the use of Elium resin. The tree is lightweight and can be easily transported and assembled. It is recyclable and offers new material assembly possibilities. Printed organic photovoltaic panels can be bonded directly onto the product.

The Solar Tree also has the social function of making people aware of sustainability. The use of composites also offers enhanced marketing opportunities as advertisement and publicity

Energy for Smart City

Solar Tree: making the city more attractive

Now with the indoor version using IoT , it is possible for the tree to colaborate with robots to provide service for customers inside shopping malls

photos and images can be projected on the leaves and bench.

First prototype

The first tree prototype was made of fibreglass, with a simple design using 3 m^2 of solar panels and offering four USB ports for charging devices. This prototype was tested and installed in the Santa Marta community in Rio de Janeiro under Shell's Make the Future programme. Following the initial tests, the design was changed and simplified, and a bold design was developed using a single solar leaf that can be composted and assembled in different ways. Using six leaves of the same size, it is possible to form a Solar Tree. The final prototype uses 4 m^2 of organic panels, thus increasing the production of renewable energy, a high-efficiency LED stripe, USB sockets, sensors and a Wi-Fi system. This last prototype was installed in Rio de Janeiro's biggest shopping mall, Rio Sul Mall, and was successfully tested for 12 months, exposed to winds and storms.

An application was developed for the tree. Through this application and the use of augmented reality, blockchain and QR codes on the tree, the customer can enter a virtual world that promotes sustainable products and solutions from associated stores and businesses.

State-of-the-art technology

The Solar Tree uses state-of-the-art technology and materials and benefits from a partnership between French and Brazilian companies:

- The organic photovoltaic films are produced by Industria Armor in Nantes (France). These extremely lightweight films weigh 200g/m^2 and are sustainable.
- The Elium recyclable resin developed by Arkema improves resistance and material use.
- A geolocation system (IoT) and sensors receive information on the percentage of solar energy captured (Sigfox technology).
- The tree will be manufactured in Brazil by Cogumelo and in France by PRS Composites. Cogumelo is a manufacturer of pultruded profiles, stairs, railings for floors, platforms, electric trays, lids and poles made of fibreglass. Its role was to turn the project into a composite reality.
- The tree can charge bicycles and electric cars.

Market potential and business model

The first target are countries with high sun exposure. In addition to Brazil, which has a large untapped demand for solar energy, the company is also prospecting to sell the product in other countries and regions such as the Caribbean, Florida, California, and Australia as well as Latin American and Mediterranean countries. The Solar Tree is a smart urban structure that caters to public lighting, advertising and out-of-home sales activities. It can be installed temporarily at fairs and/or events, and permanently in many places.

Other potential customers include Uber meeting points, beaches, shopping malls, supermarkets, hospitals, private universities, businesses, local or resident associations, clubs and bars. The tree can also be used as a charging station for electric cars and bicycles.

Market projections for technological advancements and commerce in 2020 are: 50 billion smart objects and 6 billion mobile phones resulting in an exponential e-commerce growth greater than 6.7 trillion dollars.

Based on the business model, earnings will be obtained through the sale of advertising via electronic media and advertising totems, a percentage of the goods sold, tree rentals and system maintenance.

The project was selected twice in the national StartOut programme of Apex/MDIC/Business France as one of the most innovative projects in Brazil, and represented Brazil in the Missions for France and Germany. It also won the Sesi Senai Innovation Award (2017) and the products were exhibited at the Museum of Tomorrow at the Interface Interlace 2017 exhibition. The company was selected for the Brazilian Innovation Programme Cycle 2018 and for the Innovativa Alto Impacto 2018. It recently won the 2018 Composite Excellence Award at FEIPLAR.

The company holds two patents for this product.

A sustainable project

We need to increase the use of renewable energy. Designing roofs that can support solar panels is a great challenge. These coverings must withstand the weight of the panels; resist the action of the sun, wind and rain; require low maintenance; have a long lifetime; be intelligent; use embedded technology; and be recyclable or compostable.

The Solar Tree is conceptually more advanced than existing products. It is a smart power station with connectivity (IoT) for a circular economy and for the production of renewable energy. The Solar Tree contributes to the population's awareness of sustainability, focusing on economic, social and environmental development. The project uses recyclable raw materials, state-of-the-art flexible solar panels made from polymers and nanotechnology eliminating the use of silicon, and a LED stripe with an 85% greater efficiency than traditional materials. These lamps consume 10 times less energy, last 10 to 15 times longer and do not emit UV radiation. This all results in cost savings and a drastic reduction of carbon emissions.

The composite parts made of Elium resin can be recycled after their end of life in two different ways. The first one involves grinding and compounding for use as a chopped fibre compounding resin and the second is a thermolysis process allowing the recovery of fibres and monomers by depolymerisation. The adopted business model is innovative and foresees a social impact. □

Main advantages

- Spreading information and creating awareness about sustainability and
- renewable energy generation;
- Use of recyclable resins, organic photovoltaic film, global IoT network, augmented reality and blockchain;
- Innovative sustainable design; focus on economic and social development;
- Smart furniture concept for smart cities;
- App with innovative IoT e-commerce for sales of sustainable products.

Smart furniture concept for smart cities

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An innovative system to build the city of today and tomorrow

The building & construction sector is in the forefront to take up two major challenges: providing decent housing for ever more inhabitants at affordable cost, and minimizing the environmental impact of such construction. The sector is the biggest greenhouse-gas emitter in France and the other developed countries. It is also consumes the most natural resources, both raw materials and primary energy. The idea behind Wall E+, an innovative building system for walls and façades, is to take advantage of the potential of composites in the building sector, which has so far ignored these materials.

Laurent Destouches,
CEO
Solutions Composites

The CompoHouse demonstration building was inaugurated in Mettray, France on 13 June of this year. Made of composite materials with high environmental performance, it is the result of an innovative brainstorming project on how to build differently by starting from zero to refocus specifications on the following key ideas:

- using truly industrial composite processing technologies like pultrusion;
- perfecting formulations that are specifically adapted to these constraints;
- opting for functional integration in designs;
- exploiting solar energy;
- minimizing the consumption of primary resources and reducing the carbon footprint.

The Wall E+ building system is currently the subject of an ATEx (Appréciation Technique d'Expérimentation) technical assessment. The Caerostris holding was created in late 2018 to enable the industrial development of this building system, which has just been successfully implemented at full scale with a demonstration building called CompoHouse.

The Wall E+ building system

Hollow blocks/profiles are used for the structural wall for residential home construction, and for self-supporting external insulation wall panelling that covers up to two upper stories for apartment buildings. These function fully as the building's envelope, integrating siding and active/inactive technical equipment like energy recovery systems, plant cover, etc. It is perfectly leak tight, so it can receive any type of insulating material.
The prefab modules are installed and joined together. The extremely thin joints between the panels help to considerably minimize the thermal bridge effect compared to standard wood, concrete, concrete-block and brick construction. The Wall E+ system is a breakthrough innovation that features GlassthermR, a formulation that was specifically developed for the product; high-productivity processing technology; integration of multiple functions (in particular energy recovery systems); and industrial prefabrication.

Pultrusion: These days, pultrusion is certainly the most promising technology for producing polymer-matrix composites in building & construction. It is the only continuous process, and it makes it possible to obtain profiles at lower prices than any other converting process.
Reinforcement contents of up to 70% guarantee exceptional mechanical properties. It is also easy

CompoHouse

to incorporate a high mineral filler content into certain resins, so you can obtain excellent fire-resistance properties (self-extinguishing products, non-toxic smoke, M1/F0/I0-type fire/smoke ratings). Also, by their very nature, these products are rotproof, and depending on the chosen formulation, they have exceptional resistance to all types of corrosion.

Production: With pultrusion, all lengths of block can be made, extending up to a single storey or multiple stories high.

Fins: Straight or right-angled fins serve to insert and attach all types of elements (furniture, plasterboard, siding, plant cover, etc.) and reduce the number of elements (e.g. rails for plasterboard) that need to be attached to the wall to secure things.

Cover: The blocks ends are protected by an adhesive-bonded cover (air and water tightness).

Insulation: Two rows of joints seal off the profiles from each other. The profiles can be filled with any type of insulation (in bulk form, recycled materials, biosourced materials, etc.). The insulation encased within the block protects from any humidity, damaging materials, etc., and there are no metal inserts passing through (no thermal break created).

Different ways to architect façades

The strong point of Wall E+: The block concept relies partly on the very low thermal conductivity of the material (λ 0.3W/mK - 900 times less conductive than aluminium and 150 times less than steel) and its excellent mechanical performance. It is a thin, extremely strong envelope that has been designed. The fact that no thermal bridges in the structures can degrade the insulation's thermal performance is a real feat.

Compohouse: a miniature green-energy power plant

Beyond the Wall E+ building system, the CompoHouse goal is to use biomimicry to innovate sustainably, to understand and reproduce an ecosystem with all of its interactions, to use non-renewable resources responsibly, and to decrease our dependence on fossil energy sources.

Interview

JEC Composites Magazine: Can you tell us how this project came about?

Laurent Destouches: Standard techniques and materials have their limits when it comes to housing growing numbers of inhabitants at affordable prices, all while minimizing the buildings' impacts on the environment. These outdated methods lead to high cost and long delivery times, especially given the prospect of regulations that will require buildings to be energy positive and low carbon. Considering regulatory developments, in particular the future RT2020 on the construction of energy-positive buildings and on reducing carbon emissions (in France, the E+C- certification label), it seemed to us to be the right time to approach the building sector. From that angle, our R&D department spent some years focusing its efforts on understanding the needs and anticipating the technical and economic constraints with a "time to market" approach, on the topics of sustainable construction and energy performance. After filing other patents on building shells, we decided to thoroughly revisit the shell-construction issue by starting from an almost clean slate.

Which was the trigger for the undertaking, the concept or composites?

L. D.: TIt's difficult to separate the two: we can live all year long by exploiting the tremendous potential of these composite materials. The building sector has turned its nose up at them until now, while the aerospace, automotive, and other industrial sectors have already established them as

effective, mature solutions.
We are fascinated by construction, and also by composites, so it is very natural to associate the two. Just as we have done successfully in these other sectors, we started from scratch on the specifications in order to tackle this new market and to build differently by deploying the codes and best practices in the industry and the digital economy:

- lean management and lean design, and also building information modelling (BIM), of course;
- promoting functional integration in our profiles;
- working on all ecodesign strengths, aiming as a priority to minimize both the carbon footprint and the consumption of primary resources;
- making use of truly industrial processing technologies (pultrusion);
- industrializing the stages of construction to bring a maximum of VA back into the plant.

Do you think that composites could play a greater role in the modern city of the future, or smart city?

L. D.: "Smart" – isn't it above all the goal that best suits these materials, which are the result of human genius? Of course, these materials will be preferred solutions, for all that they offer in relation to the 21st-century building constraints. What current building material can claim to offer high mechanical properties, very low density, excellent thermal insulation properties, and resistance to all chemical and atmospheric attacks, all together?
"Smart" also applies to the idea that we will be able to build where no other material dares to go: in earthquake-prone areas, in places considered to be inaccessible (roofs) and also on water, underwater, in flood-prone areas, and more.
And in addition to these more extreme examples, composites help us build very rapidly and discreetly in cities, with ultra-lightweight prefab solutions that can be rapidly implemented without nuisances like noise, dust or vibrations for the surrounding neighbourhood. In this respect, we've just designed access-ramp systems for public-transport vehicles (bus, metro) that we can install in train stations in a single night without ever disturbing operation, whereas concrete would require nearly a month of highly invasive work that disrupts traffic.
Also smart: these different models for parking-lot photovoltaic chargers for electric vehicles (the latest "plug and play" model can be set up in a half-day), or our urban furniture and shelters that make the most of the properties of these materials, in particular the robustness.
"Smart" could also refer to the spire for the Notre Dame cathedral in Paris, which we propose to build from carbon to give artists free rein to their imaginations and allow light into the heart of religious buildings.
The city of tomorrow will not only need to accommodate the population explosion and promote the well-being, comfort and safety of its inhabitants, but also to be environment friendly. This isn't an easy proposition, but these performance materials, composites, will enable us to make progress on lower-energy solutions (both for machines along with their mobility infrastructure, and for the habitat), and will also have to prove to be "virtuous" in terms of their environmental impact. Material producers will also have to mobilize and help us demonstrate this aspect!

Will CompoHouse herald in the energy-saving, connected, clean building of tomorrow?

L. D.: Absolutely! Building with composites is not an end unto itself… What we are interested in is their potential for architecture and life. You are probably surprised by the demonstrator that you've discovered, for a lot of the other innovations – with no fewer than ten different solutions to use the energy of the sun, a major focus on reducing carbon emissions, and many other technical solutions. Another of our key ideas is to think of the building of tomorrow as a mini green-energy power plant. But Compohouse is much more than that – it is the expression of our desires: innovating to once again make humans and their ecosystem central to the act of building; the idea that architectural quality and the performance of the building's shell should prevail over the need for equipment that is too complex, expensive and fragile.
Globally, we also propose solutions for the future construction of sober, robust and durable buildings that are pleasant to live in, in which the main goal focuses on performance and user comfort.
And we also think about how to inhabit these buildings, so as to offer our customers much more than just a roof: a space that encourages living, expression, and freedom. For all that, the notion of connectivity and networking bulks large in our design work, so that it becomes possible to wire all the networks easily, rapidly and unobtrusively, and especially to adapt the building and its uses over its lifetime.

Do you think that this proposal will finally convince the players in the building industry, the architects, and also the certification bodies?

L. D.: That is the topic of the moment. And I will begin with the future owners – we have to convince them first. They are the ones who must help us lead their architects and builders to build with our solutions. We have to win over future customers using our strong arguments: extremely comfortable housing that is unostentatious and environment friendly, and rapidly implemented construction, with a focus on the architecture in the process.

Then there is the certification process, which is no simple matter. In this connection, it is astonishing – this world where for thousands of years and all by themselves, without much previous training or sophisticated means, humans have built both their own dwellings and splendid structures that still fill us with wonder… and the current period, which leads us to take infinite care in the act of building, where architects have to surround themselves with numerous experts, inspectors and insurers to address the fears and administrative constraints.

Creating, innovating and building with composites is our victory over the fear of leaving our children a planet in a much worse state than when our own parents turned it over to us.

What are your next projects in the field of construction?

There are many, but somewhat confidential.

The number of potential applications for composites in construction is absolutely gigantic.

Our work will still continue to focus on solutions that totally agree with our principle of building for a sustainable world.

Rooftop equipments : AZTEC© solar chimney, solar panel, green surface and water stockage

This building will have to be self-sufficient, and even become a miniature green-energy power plant.

CompoHouse stands out for its environmental performance in the broadest sense. The ecodesign approach minimizes the weight of the raw materials and includes a rigorous selection of building materials along with the rational use of composite-material properties. The sparing use of these synthetic materials but also of agricultural resources leads to a moderate use of energy and more broadly to a smaller, better-controlled environmental footprint.

Its design based on industrialization and short supply channels helps to minimize the environmental impact all through the life cycle: the grey energy is low for fabrication, assembly and partial or full disassembly. The system is entirely reusable according to the "cradle to cradle" approach.

The idea is to use the potential offered by renewable energies to best advantage in buildings. Wall E+ is the first wall to produce more energy than it consumes. To work towards purposive architecture, it is essential to take all flows into account, including the inflows (sunlight for energy/power and photosynthesis) and the outflows (electric power generated mainly from heat flows and in future, also from waste (bio-methanation is under study).

This is a "bioclimatic" and "politically modern" project that targets not only self-sustaining energy sources but also the collection of energy over the entire envelope for redistribution via a smart grid. Thanks to solutions for independent batteries or meters (consumption/production), it is now possible to consume the energy produced, i.e., to be self-sustaining. If more energy is produced than consumed, the surplus is distributed to the grid. If more is consumed than produced, the installation can be used to import power from the grid.

The large-scale use of solar energy

Wall E+, which has drawn attention and encouragement through all the awards received, is not CompoHouse's only innovation. The demo building has a surprising number of other ones, including various solutions for capturing solar energy, and a heavy focus on reducing carbon and other GHG emissions.

Solar house: The sun's radiation provides enough energy in 3/4 of an hour to supply the Earth with power for an entire year.

An innovative system to build the city of today and tomorrow

Influenced by the past and turned to the future, the demo building is a unique model for a solar house, using no fewer than six different integrated solar-energy recovery technologies.

Heat recovery: Solar energy can also be recovered directly as a source of heat. Solutions Composites teams have developed two products and integrated them into CompoHouse: Aztec®, a double-envelope thermal sensor system of the Trombe-wall type that heats the injected air, and a solar chimney that uses the heat column to cool the air inside.

Electricity-generating systems: The buildings of tomorrow must generate more electricity than they consume. Composite materials make it possible to have components that are both mechanically strong and lightweight. The demo building has sliding solar shutters, horizontal photovoltaic sunshades, solar panels, and solar collectors on the vertical sunshades.

Compo or Sun House: With almost 14 kWh/year of energy production on this building, CompoHouse will be able to provide an annual consumption (for a capture area of 130 m^2) equivalent to that of 2 ½ "BBC-effinergie" certified houses or eight "Passivhaus" houses. The CompoHouse is already a genuine miniature green-energy power plant for self-sufficient production. But connected to a smart grid system, it will lead straight to the energy revolution of the future, in the form of shared energy.

Aztec® solar chimney: The solar chimney is an illustration of bio-mimicry that exploits simple yet effective physical principles. We took inspiration from Navajo caves in the southwestern U.S. Here is the principle: Air is overheated in the upper part of the chimney (glass panels and dark surface) to create a temperature differential, and therefore pressure in the air column. The extractor at the top accelerates the stream of warm air to pull it up out of the room. In the winter, you close the insulating trap door.

Aztec® thermal sensor: This block serves as an air temperature sensor for double-envelope insulation walls of the Trombe-wall type. It was designed to update and harmoniously incorporate this ingenious process: concentrating solar radiation behind a glass wall to transform it into a flow of warm air. The heat produced is exploited, either by injecting it directly into the building, or by storing it within the building's own inertial masses to be used at night. The process introduces the idea of an architecturally integrated, active solar function at low investment cost.

"Low carbon" construction

The Wall E+ building system performs well environmentally all through its life cycle: the grey energy is low for fabrication, assembly and partial or full façade disassembly; the use of non-renewable resources is rational and controlled; and our dependence on fossil energy sources is minimized. Exploiting the inherent properties of composites and using these synthetic materials sparingly along with agricultural resources leads to rational energy use and more broadly, to a low, well-controlled carbon footprint. Wall E+ involves 40 kg of material per square meter, or 20 times less than a standard concrete building system.

Plant cover is still the easiest way to fix the carbon contained in the atmosphere by photosynthesis, an essential bioenergetic process for life on Earth that reduces carbon dioxide with the help of sunlight and transforms the carbon into glucose for plant growth, generating oxygen in the process. With green areas in cities shrinking more and more, rooftops and, especially, walls are replacing parks as urban "decarbonizers".
The Wall E+ block can accommodate plants at its surface with no risk of corrosion.

Green wall
Perforated wall e+ profiles for potential applications like:
- balconies
- noise barriers
- urban planning projects

Pre-planted boxes
- an immediately aesthetic façade
- easy installation and upkeep
- lower cost

Green wall
Two systems were designed for cladding a western-facing façade: one with independent boxes, including larger ones to provide a canopy, and one with honeycombed boxes in custom colours and sizes, for a successful architectural integration even before plant growth.

Water collection system
The habitat is also self-sufficient in water, with a roof design that reserves an area for rainwater storage (for plant watering and utilities).
Note that the architectural design of compohouse eliminates any unsightly rainwater pipes.

Green balustrade
- safety
- anti-pollution

AZTEC© solar Wall E+ (at left), and green balcony

Self-watering flower box
A flower box made of composites has a water collector, with automatic watering activated by solar panel.

Green roof
Besides storing CO_2, a plant-covered roof makes it possible to contribute to the development of biodiversity, reinforce the thermal inertia for greater comfort in summer, mitigate noise via the plant cover, reduce the flow of rainwater, and increase the roof's life span.

Architectural treatment of façades

Taking on bold environmental goals should not be done to the detriment of the architectural quality of buildings. While Wall E+ fulfils the complete building envelope function, it is also an innovative façade process that makes it possible to integrate all types of siding materials and a large number of fittings (active façade cladding, balconies, pergolas, green walls, etc.).

Architectural quality: The system applies "blocks" of simple design and shape as far up as several stories. The blocks are easy to lay out on an architectural plan: the system requires only a "Lego"-type grid layout for the façade. The system's very low weight enables architects to consider the most difficult of configurations, e.g. adding stories without overloading the existing structure. Wall E+ proposes treating the building façade as a whole: structure, finishing and fixtures, opaque parts and parts with windows. Joinery frames are integrated (subframe profiles, windowsills, doorsills, roller blind frames, etc.).

Composite joinery: The first installation in France of glass-fibre composite windows and doors features narrow frames that guarantee high mechanical performance along with optimum daylight. Other advantages are excellent thermal performance without need for thermal bridge breakers, and modern aesthetics.

Double glazing is used on the southern façade to bring in sunlight during winter, yet provide thermal insulation as well. Active protection will be added in the form of a solar canopy and shutters.
On the other hand, triple laminated glazing is used for the western façade to give priority to thermal protection (including in summer), sound insulation performance, and impact strength. The solar protection system will be reinforced by the installation of swivelling vertical blinds.
A double-envelope test window will be installed on the southern façade in partnership with the Ridoret group. The window functions as insulating glazing, solar sensor, and heat exchanger.

Skylights: The mechanical and thermal performance of the blocks makes it possible to create very simple skylights to bring light into the building in "strategic" places. Thanks to triple glazing, the relatively inexpensive system (compared with other products on the market) turns out to be very effective from the thermal point of view, with no thermal bridge.

Exterior structures

The same philosophy was applied to the exterior structures, which were given special attention.

Green balcony and railing: These Wall E+ blocks illustrate what could become a green balcony. They can be directly filled with a substrate, and they serve a twofold function: balcony safety and plant cover. A self-sustaining flower box will be added to the system.

Equipped with a solar panel on its southern wall and with a water tank and micro-pump in the bottom part, it will water itself on command from a moisture sensor.

Terrace & MIP facilities: The innovative CompoWalk system, developed initially to raise the platforms in SNCF train stations for easier access by mobility-impaired persons (MIP), was used to create the terrace and entrances. Thanks to the system's mechanical performance, the terrace boards can support 500 kg (per unit) between two joist supports 1.2 m apart. It can be rapidly installed, with no visible screws. The boards are up to 12 meters long with no joints, for a sleek design.

Bioclimatic pergola: A bioclimatic pergola on the balcony will provide natural shade to protect openings with southern exposure. A system of swivelling slats at roof level filters the sun's rays for sunlight in winter and shade in summer, and also collects rainwater.

Solar and green balustrades: There are two concepts to ensure balcony safety. One is an Aztec® photovoltaic glass balustrade, the other is for plant-covered balustrades, with composite boxes specifically designed for the twofold purpose.

An innovative modular beam

This variable inertia beam can vary from 400 to 1200 mm in height. Due to the anisotropic properties of the pultruded profiles (different according to the axes), this geometry is especially well adapted to composites from the mechanical point of view. The sole plates are assembled to the cores by structural adhesive bonding (epoxy). The beam can be spliced to adjust its length for each project. Used in footbridge and highway-bridge applications, it is the most highly performing beam on the global market. In CompoHouse, it supports the load of the entire roof.

There are a number of other potential building applications, like beams for corrosive environments (swimming pools, water treatment facilities, the maritime environment, chemical industries, etc.); and new builds or renovation of spaces that require long spans, high mechanical properties coupled with thermal properties, and an industrial "look".

A pre-bent version of the beam or a beam with variable-area core is perfectly feasible using this technology, so this is a truly innovative product that can adapt to many different applications.
In Compohouse, the beam supports six metric tons over a 13-meter span, and the tie beam supports that are hidden in the walls were made using the same technology.

Smart networks

As a miniature green-energy power plant, CompoHouse collects energy over its entire envelope and redistributes it. It is also a comfortable house, and its use should be able to change over time. All of this requires a carefully thought-out, forward-looking network architecture. The Wall E+ block was designed with an intrinsically "developable" building in mind. It makes the process of wiring all of the house networks extremely easy, along the vertical and horizontal axes – simple, fast wiring (including factory-made prewiring) and adjustable space between the block and the interior finishing, with room enough to fit all the networks (electric, computer, and also fluid networks, including air).

The main advantages include simpler operations (design and implementation), lower cost, functional integration and aesthetics, as well as flexibility and "developability".

Interior structures

Composite elements for glass walls and roofs: This system is based on pultruded profiles and has already been used for the shelters on Brittany's regional railway network and for the lookout post at Fort Boyard. There are interior and exterior applications: partition walls, verandas, garden hothouses, etc.
The system can be customized for colours and variants.

Wall E+ for interiors: The system facilitates the assembly of all types

Innovative modular 14m lenght composite beam

of facings directly on the profile and the integration of elements that are fixed directly on walls, and also affords considerable flexibility for the passage of network wiring along both axes.

Staircase/mezzanine/footbridge: In the present case, the staircase was custom designed in the CompoHouse.
Wall E "Sound", the sound wall: An audio-video system is fully integrated into the blocks for a sleek design and space saving. The loudspeakers are insulated and adapted specifically for this utilization. The hi-fi system (amplifier) and the TV are integrated directly into the wall, which is covered in fabric for an attractive look.

Lighting: Wall and ceiling lights are custom designed and manufactured. The light architecture will be another advantage of this process, as the power connections can be done very unobtrusively. ◻

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Composite staircase and customized « glass wall »

From floor to roof, inside and outside, composite solutions shape the city

Construction pioneered composite materials, combining straw and mud to form bricks. Today, the world of construction continues to find inspiration from composite materials, innovating around four main drivers: sustainability, safety, lightness and ease of use. These targets can be achieved with smart reinforcements such as laid scrim carriers. Laid scrim technology consists in laying glass, carbon or polyester filament yarns in an open mesh construction, where they are chemically bonded; a veil film or mat can be added. The result is a high-performance scrim with optimum yarn protection. Chomarat is a forerunner in this technology and developed a specific range for building materials.

Raphaël Pleynet,
Composites & Construction Business director
Claudio Colombi,
Construction Market Manager
Chomarat

This paper introduces several applications developed by global construction leaders, from the floor to the top of the building.

These case stories illustrate the evolution of composites in construction and infrastructure, using laid scrim as a reinforcement for different matrices such as resin, bitumen, cement or concrete.

Increasing road lifetime: cost savings and environmental benefits

Road traffic constantly increased over the last 50 years, resulting in the development of new infrastructure and a heightened concentration of traffic on existing roads, thus accelerating their wear.

Throughout the world, public authorities are in search of solutions to increase the life of infrastructure and to reduce maintenance costs.

Different solutions and approaches can be implemented to achieve these targets.

High-performance solution to extend road lifetime

Monitoring roads for 20 years, it was proved that a specific composite made of glass fibres and a latex resin enables road engineers to reduce the asphalt thickness by around 50%, depending on the issue to solve. Environmental studies also showed that this product can lower greenhouse gas emissions and energy consumption by 50% during road maintenance.

A unique solution for crack issues

The Roadtex™ & Cidex range is the fruit of a close collaboration between Chomarat and 6D Solutions. Over the past 30 years, Chomarat developed a unique 0 and 90° glass fibre assembly technique. A specific treatment protects glass during processing and throughout the lifetime of the works, helping improve the reinforcement's tensile modulus.

These innovative products are used to solve many crack issues every day, including on airport tarmacs and highways.

> **This specificity allows 6D Solutions to design and commercialize a range of reinforcements unique on the market.**
>
> Daniel Doligez, Director of 6D Solutions

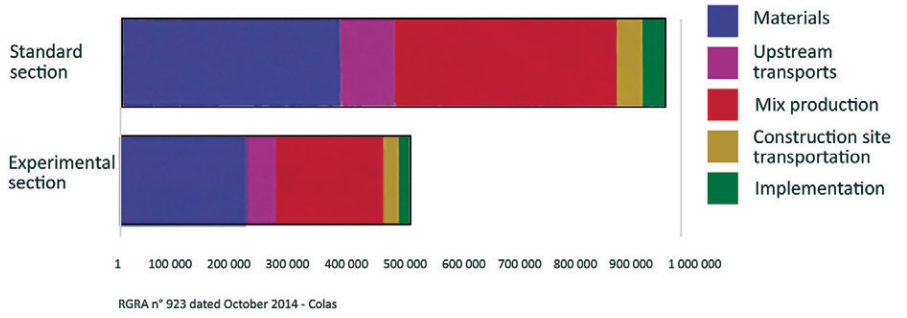
Waterproof, anti-crack bitumen membrane

According to statistical studies conducted in Italy, 20% of all reported accidents can be attributed to the quality of road pavements. Improving users' safety means improving maintenance.

Repair works involve closing roads, resulting in traffic issues and direct economic and environmental

Glass fibre grid installed on road

From floor to roof, inside and outside, composite solutions shape the city



Total energy consumed for 4000m² of pavement - RD 624 Castelnaudary
Monitored from 1998 to 2003

costs. Extending the service life of pavement is thus the objective of road providers.

Polyglass, a leading European manufacturer of waterproofing membranes based in Italy, developed Polystrada SA, an innovative composite membrane specifically designed for road pavement that improves road performance and lifetime.

Suitable both for new and renovated roads, this membrane is a stress-absorbing membrane interlayer (SAMI) that avoids the mechanical stresses generated by the interfaces between the different road layers.

Polystrada SA is a cold self-adhesive bitumen membrane comprising an elastomeric bituminous compound reinforced with a glass fibre composite. The special elastomeric bitumen partially melts during the application of hot asphalt, thus improving adhesion and filling micro-cracks. It also protects the reinforcement from damages during installation and the compression of layers.

Chomarat's dedicated laid scrim reinforcement provides the necessary mechanical performance (tensile strength and dimensional stability). It contributes to the absorption and distribution of local stress to extend road lifetime.

Simonetta Rossi,Product Management & Operational Marketing at Polyglass SpA

The special self-adhesive technology used for Polystrada SA membranes ensures good adhesion to the substrate, avoiding the need to use large amounts of hot bitumen to embed the geotextile, and brings cost and time savings. Several tests were conducted to demonstrate the benefits of using reinforcements.
The properties of the Polystrada SA reinforcing membranes drastically reduced the onset of cracks due to fatigue (repeated application of dynamic vehicle loads) and reflective cracking (existing cracks in the underlying structure reflecting to the surface following surface repairs).

A correct use of reinforcing systems can improve safety and comfort on the road, reduce maintenance, lower energy consumption and lower environmental costs with a favourable global environmental impact.

Trenchless pipe rehabilitation: a clean and durable process

In collaboration with RELINEEUROPE, a leading manufacturer of liners for trenchless pipe rehabilitation (CIPP), Chomarat developed and patented the Rovicut™ stretchable woven reinforcement for pipe rehabilitation.

Optimised CIPP liner

Cured-in-place-pipe (CIPP) is a well-established pipe rehabilitation method whereby pipes can be repaired without opening a trench, creating noise, pollution and dirt, or disrupting traffic flow. It is a reliable, economic and long-lasting solution.

Benefitting from an excellent design and material composition, the Alphaliner CIPP liner (GRP hose liner) provides special benefits and was optimised for a long service life and durability.

The primary contributory factor here is the particularly thick wearing course made from high-grade resin.

This means that the Alphaliner CIPP liner is not only significantly more resistant to aggressive substances in the sewage, but also well-equipped against abrasion and damage from flushing processes.

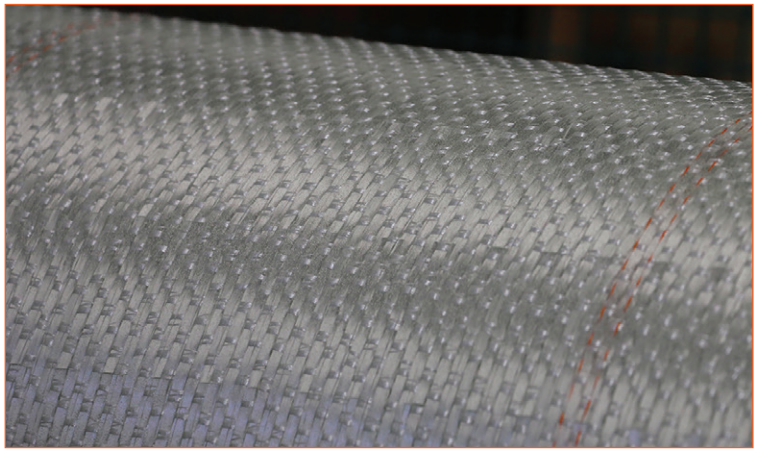
Stretchable fabric

Rovicut™ was developed in response to a special request from RELINEEUROPE, who was looking for a fabric with elongation properties. Chomarat designed a

Rovicut™ was specially designed for RELINEEUROPE's Alphaliner1800H range for large-diameter pipes.

Bettina Durupt, Assistant of the Executive Management Board RELINE EUROPE

UV lamp curing a large diameter pipe



Rovicut - Stretchable woven fabric

glass fibre fabric with warp threads cut at regular intervals, thus offering guaranteed performance in the 0° and 90° directions, with the cuts providing elongation.

Due to its elongation properties, it easily takes the shape of worn pipes, providing good mechanical characteristics without adding excess thickness to the liner. Optimizing the liner's thickness reduces weight, resulting in easier and quicker handling and installation in terms of UV curing, and leading to attractive cost savings.

Pipe rehabilitation stages

During the pipe rehabilitation process, Rovicut™ is first impregnated with resin, rolled onto a tube of the desired diameter, and film wrapped. The pipes are inspected and then cleaned. Finally, the liner is installed in the pipes, cured with UV lamps, and verified by a final camera inspection.

The installation is described in: *https://youtu.be/y7Spl4zf0qw*

A bituminous composite for acoustic insulation

Soukaro Confort is a process for thin acoustic insulation that was developed by BMI-Siplast to handle impact noise. The insulation is installed directly underneath tiling, with excellent results in terms of acoustic and mechanical performance for a reduced thickness.

A thin multi-layer system

Soukaro Confort consists of a bitumen sheet that is reinforced on the upper surface with a multilayer reinforcement (scrim/nonwoven) produced by Chomarat and on the lower surface with a polyester that provides resilience.

> **The Chomarat reinforcement makes it easier for the glue to adhere and improves crush resistance.**
>
> Samuel Heckenroth, Product Development Manager - Sound Deadening-BMI Siplast

Its nonwoven part helps to reduce noise, and the glass-fibre scrim provides mechanical properties like good tensile strength and high dimensional stability. The whole system is extremely thin at 20-25 mm, including the tiling.

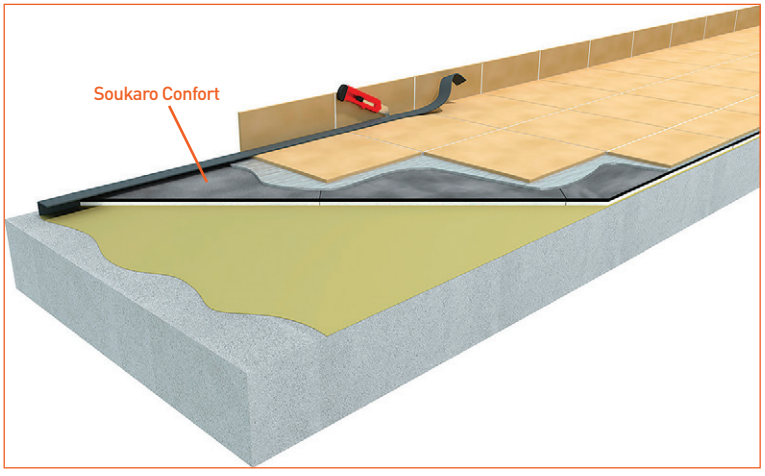
High acoustic and mechanical performance recognized by Avis Technique

From an acoustic viewpoint, the new underlayment achieves excellent results for impact noise: the reduction of impact noise is assessed at ΔLw = 18dB. As for its mechanical performance, it is optimum, as Soukaro Confort passed the falling-ball, crush, peel, and creep tests with flying colours. All of these aspects of its performance were validated by an "Avis Technique" (technical rating) from the French scientific and technical centre for the building industry, CSTB.

All this makes Soukaro Confort a thin, durable, easily installed, and high-performing acoustic underlayment that also complies with the acoustic regulations for apartment buildings.

Universal Alloy light press plant

Manufacturing buildings are almost exclusively utilitarian. Though many were constructed with precast concrete during the last half-century, most designers



Soukaro confort laying pattern

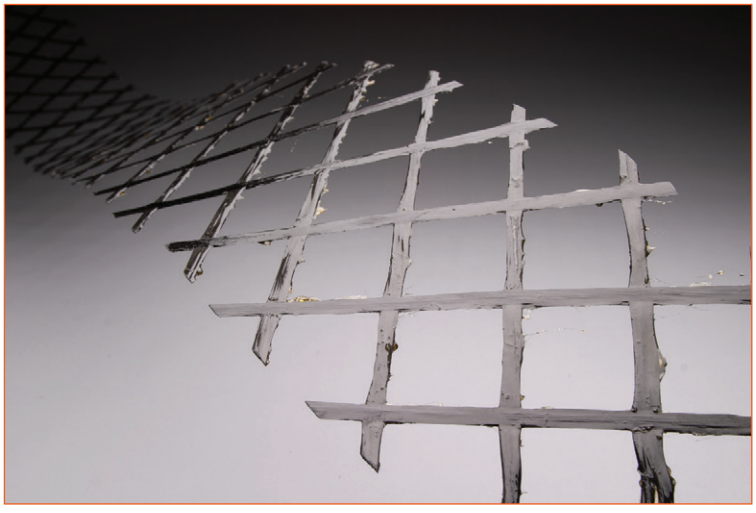
are not given the budget to take advantage of this material's unique properties to add enhanced architectural details. The Universal Alloy light press plant, completed by Choate Construction Company, is an exception – with virtually no added cost.

A 10,251 m^2 manufacturing facility in Ball Ground, Georgia, USA, this project features an exterior façade with load-bearing CarbonCast high-performance insulated wall panels from AltusGroup precasters. Due to the use of C-GRID® carbon fibre grid as a shear connector between the inner and outer wythes of concrete, CarbonCast high-performance insulated wall panels deliver an exterior wall panel with full composite action and continuous insulation. The panels have painted vertical accent stripes that align with sawtooth tops. This creates a 3D illusion that the panels project in and out like an accordion, making for an eye-catching façade.

This project used CarbonCast panels that are typically 25 cm thick, 3.65 m wide and 13.45 m tall. The tallest panel is 14.25 m tall and the heaviest panel weighs 23.36 metric tons. Both wythes of the insulated panels are prestressed to give them beam strength and load-bearing capacity. They span from foundation to roof structure without requiring wind bracing. There are 144 pieces and erection took fifteen working days.

The insulated wall panels have a 7.6 cm face wythe backed up by 7.6 cm of expanded polystyrene breadboard (EPS) with a 10 cm back wythe of concrete for an R-value of R-12. The door and window openings have a solid zone surrounding the openings to facilitate attachment of the frames. The solid zones represent only about 10% of the surface area, leaving a net R-value of R-11, still about 50% over the code requirement for this climate zone.

Universal alloy light press plant



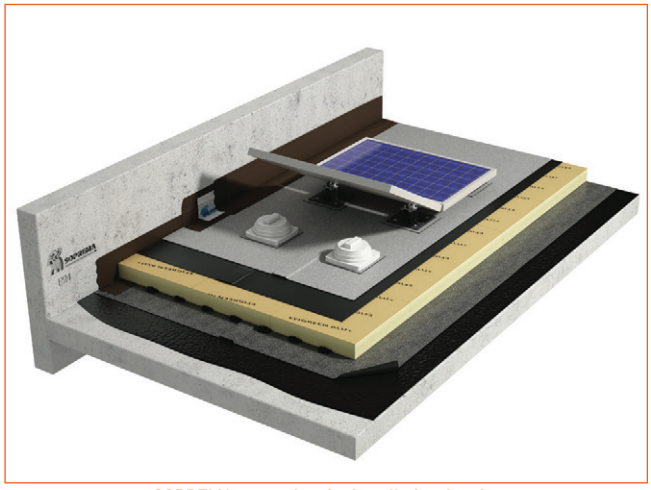
C-GRID® - Carbon Epoxy grid

C-GRID® is a high-performance reinforcement produced by Chomarat, made by bonding ultra-high-strength carbon tow with epoxy resin.

High-stability vapour barriers meeting new insulation constraints

The RT 2012 French thermal regulations for buildings require significantly thicker insulation in order to improve energy consumption efficiency, for cost and environmental reasons. The thicker insulation increases constraints on the vapour barrier, a crucial function of the roof system to avoid moisture transfer into the insulation.

In winter, the temperature difference between heated indoor areas and exterior weather conditions creates a vapour gradient that seeps through roof layers and can result in condensation, causing damage under the ceiling and thermal resistance loss. When moisture penetrates in thermal insulation, it can condensate in liquid form and create thermal bridges



SOPREMA vapour barrier installation drawing

Reflective membranes on roof

inside the insulation, thus making the building colder. If the water freezes, the thermal insulation can be damaged with a loss of efficiency. This process is not reversible, as permanent damage will occur when the temperature rises again.

Vapour barrier layers are mandatory in many countries and part of flat roof systems on many buildings. When vapour penetrates roof materials, it causes considerable damage, including steel corrosion, microorganism growth and a loss of insulation effectiveness. The vapour barrier has to be placed between the support and the thermal insulation material. Typical applications include metallic corrugated roofs and wooden decks.

> **Soprema developed a patented self-adhesive bitumen membrane that provides waterproofing functions as well as a vapour barrier with high dimensional stability.**
>
> Rémi Perrin, R&D Director, SOPREMA

SOPRAVAP® STICK ALU S16 is composed of different layers:

- SBS modified bitumen for a solid membrane;
- A special Chomarat composite glass laid scrim with an aluminium foil reinforcement providing mechanical properties and vapour barrier properties;
- A self-adhesive bottom face for easy and fast application;
- A sanded top layer for correct unwinding of rolls and good adhesion of the top layers.

In a typical commercial building or home, vapour barriers can improve energy efficiency and comfort, while preventing moisture and dampness problems.

Reflective roofs: cooler and smarter solutions

While temperatures are increasing worldwide, waterproofing membranes can be used for other purposes than simply waterproofing. A roof with passive cooling keeps the room temperature lower. A cooler room requires less air conditioning to ensure the comfort of the occupants, resulting in lower energy consumption and reduced CO_2 production. Derbigum, a Belgian waterproofing manufacturer, developed the Derbibrite NT© membrane, characterized by an innovative, smooth and white surfacing. The white acrylic topcoat provides optimum reflection of sun rays, up to 81% with SRI 100. A reflective roof contributes to energy savings and reduced CO_2 emissions. Thermal insulation is improved, and the air conditioners set up on the roof are more efficient due to the lower temperature around them. With less warming up on the roof, the waterproofing is more durable, with an extended lifetime. Derbibrite NT© benefits from a technology that makes it pH-neutral, thus allowing the collection of rainwater. Besides an aesthetic finish, the membrane offers high mechanical properties and fire resistance.

> **These characteristics result from an innovative design: a modified copolymer-bitumen recipe, with an acrylic reflective coating on top of a glass/polyester reinforcement, called ROTAFLEX™ NEO, developed by Chomarat**
>
> Says Patrick Cogneau, Derbigum Technical and R&D director

The Derbibrite NT©, as other Derbigum membranes, is fully recyclable into raw materials for new membranes. This waterproofing membrane can be used for both new construction and renovation. □

More information:
https://chomarat.com

Ishikawa Jyushi explores new design possibilities

Ishikawa Jyushi Kogyo (Kaga City, Ishikawa Prefecture), a plastics moulding company, will sell furniture made of carbon fibre starting from 2020. For example, the legs and backs of the chair, where the utmost strength is required, are made of a carbon fibre composite material using a plastic moulding process. Thus, the advantages of carbon fibre – lighter and stronger than metal – enhance the design and functionality of the furniture. Five years from now, the company aims to achieve total sales of over USD925,000 from this new business.

Tsutomu Ishikawa,
Senior Managing Director
Ishikawa Jyushi Kogyo

Carbon fibre composites are materials with increased strength in which carbon fibre is mixed with resin. Compared with iron, carbon fibre is one quarter of its weight and ten times stronger. As it can strengthen while lowering weight, it is often used in auto parts or aircraft bodies. However, it is rarely applied for daily use furniture. For the production step, Ishikawa Jyushi uses composite materials from Komatsu Matere or Suncorona Oda (Osaka City), who are handling all kinds of developments using carbon fibre. For the moulding process, a chip-like composite material is melt at high temperatures of 150 to 200°C and then placed into a dedicated mould.

Then, the composite material is hardened by lowering the temperature and pressure. During the processing step, the company uses waterjets for cutting at ultra-high pressure. In cooperation with Kanazawa Institute of Technology, Ishikawa Jyushi developed a mould with a high degree of sealing that can maintain internal pressure.

By controlling the pressure accurately, they can adjust the polish that appears on the surface.

Design potential

The material is used for the legs or backs of chairs and tables, where carbon fibre's strength and lightness advantages are best revealed.

With the collaboration of Secca, a design company in Kanazawa, the legs are made thinner and the contact surface (with the table or seat) is narrowed.

Ishikawa Jyushi has already manufactured chair and table prototypes.

With improvements, the products will be ready to be exhibited at the Resin Show in Japan in December this year. In 2020, the company plans to exhibit at JEC World, the largest composite materials exhibition, which will be held in Paris.

Fig.1: Firmly support concrete block with CFRTP bolts and plates

Fig.2: Enhance overall chair design with minimal leg thickness

Ishikawa Jyushi explores new design possibilities

Fig.3: Express new design by narrowing chair's legs thanks to the carbon fiber's strength

The estimated price for the table is USD3700 to 4600 or more. The company mainly targets the high-end market through wholesale furniture stores and will focus on hotel furniture and raise a business worth USD926,000 to 1,850,000.

A growing market

According to the survey company, Fuji Keizai Group (Central Tokyo), the market for carbon fibre composite materials is expected to be 2.6 times bigger in 2030 compared to 2017, at USD33,132 million. Apart from the growing trend in automotive or aerospace applications, Fuji Keizai analyses that the demand has also been increasing in construction and civil engineering due to stricter regulations resulting from ageing infrastructure and seismic reinforcements.

Last year, Ishikawa Jyushi started developing bolts – especially for bridge construction – made with carbon fibre, thus looking for potential demands in industrial applications. However, implementation in infrastructure takes time due to safety verifications and control, and the company rather decided to aim for early monetization in the carbon fibre business as furniture is relatively easy to introduce.

With their main products based on high-strength synthetic resin, the company achieved total sales of USD15.7 million in the fiscal year ended September 2018.

Although there is a headwind against the plastics industry due to rising environmental concerns, the executive management keeps pushing this new business through functionality or design. Due to the high strength of the resin mixed with carbon fibre, a longer life expectancy of the material could help reduce waste. □

More information:
www.ishikawajyushi.net/

Composites in smart cities

We hear about the smart city everywhere. Ecological, connected, adapted to strong urban development: this city of the future is full of promise. The smart city market is estimated at $ 1.5 trillion worldwide in 2020. The average annual growth rate of this market should be 13.6% between 2014 and 2020 What are the axes that need development to achieve this kind of city?

Building a city that is adapted to the needs of the present but preserves resources for the future has given rise to the concept of smart city. This covers several areas of development: for example, building more energy-efficient buildings or isolating them during renovations increases overall energy performance.

Other attributes are specific to smart cities: optimizing waste management, developing ecological means of transport such as electric vehicles, public lighting or telecommunication networks that will allow innovative services to be offered in real time to connected users.

The world's first biocomposite bridge at Eindhoven University of Technology © archello

Energy-efficient and transportable house ©Ecocapsule Holding

Infrastructure

Composite materials are used for repairing, and thus securing, structures (bridges, tunnels, etc.). They can also be used when it comes to adapting existing structures to the changing needs of their managers or to new regulations. Initially, their use was reserved to mitigate a possible lack of reinforcement in the reinforced concrete structures. They are now often used to increase the amount of passive reinforcement of prestressed concrete structures.

Energy efficient buildings

In addition to offering significant design freedom, composite materials make it possible to design green buildings through the insulating properties of these materials and the ability to integrate features such as solar panels.

Designed by Tomas Zacek and Sona Pohlova of the Slovak studio Nice and Wise, the figure 2 illustrates a light, intelligent and

Hyundai Nexo the latest fuel cell vehicle ©Hyundai

Bus Safra Businova, electric bus using a fuel cell ©SAFRA

autonomous micro-house (with solar and wind energy) buit with composites. Indoor surface of 8 m^2 for two people with ovoid shape that maximizes the collection of rainwater and dew, then filtered to make it drinkable. Transportable everywhere, in all climates, without leaving any traces.

Electric vehicles

One of the smart city's challenges is mobility: it is estimated that this market will experience strong annual growth by 2020 (15.2%) (Source: "Smart Cities Market Expected To Reach USD 1,422.57 Billion by 2020", Grand View Research, Avril 2016). The advantages of the use of electric vehicles are undeniable: silent and clean, they do not emit CO_2. For authorities seeking to reduce pollution in cities, it is a major asset. But to seduce more users, three challenges remain to be overcome: the improvement of battery life and charging time, the densification of the network of terminals and a more accessible purchase price.

Conclusion

To achieve the smart cities that we imagine, many axes need to be developped, starting from our infrastructure. Composite materials can benefit the development of our cities in so many ways, especially in construction where the penetration of composites is still quite small. ◻

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www.jeccomposites.com

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