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SMART04

INTEGRATING INNOVATION IN ARCHITECTURE

Design, Methods and Technology for Progressive Practice and Research

Ajla Aksamija

WILEY

INTEGRATING INNOVATION IN ARCHITECTURE

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CONTENTS

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FOREWORD
TOWARDS A RESEARCH-BASED DESIGN PRACTICE

PHIL HARRISON

We are entering an age of serious design thinking.

The dominant modes of design over the last two centuries have been decoration, tectonics, theory, systematisation and intuition, among many others that have tended to be rooted in the past and the present. All have yielded beauty in various ways, and these foundational modes of thinking should and will remain part of modern practice, as designers embrace a richly layered approach to conceptualisation. But today, designers and their patrons are increasingly seeking proof that design will live up to expectations in the future. This yearning for predictability is pushing designers to balance their humanistic focus on what has been and what is, with a scientific rigour that attempts to establish what will be. This accelerating move towards fact-based predictive design thinking is revolutionising our creative process far beyond the limited aim of reducing risk, towards a new form of design practice that bristles with empirical discipline in balance with imagination.

Why? There are compelling economic, environmental and social reasons for this evolution. Economically, buildings simply cost more today than ever before, and building owners are demanding more from their capital investments. Environmentally, resource scarcity is similarly driving us all to do more with less. And socially, there is an increasing recognition that human performance and well-being are far more valuable than bricks and mortar. In all these, there is a growing awareness that design can answer these challenges. Design thinking is, in fact, the best answer to all these, because designers have the unique skill of using synthetic thinking to solve increasingly complex problems in simple and powerful ways.

But we have a problem. Modern design practice is not rooted in the kind of serious research-based thinking that is at the core of so many other innovative disciplines, such as medicine or engineering. To truly transform design practice to be stunningly innovative, we need to develop our own kind of intellectual rigour – a new type of design practice that is research-based and that is fundamentally conceived to yield breakthrough results.

This is an ambitious goal, and in my experience, this goal has been front of mind with many design educators and practitioners for at least the past decade. However, most have hesitated to move forward with meaningful action due to the uncertainty of the terrain of design research. What are the important research questions? How do we transform our profession, which is so rooted in history and intuition, and embrace a more scientific approach? How do we preserve what we love about the art of architecture with a new evidence-based approach; or, how do art and science mix for us?

How can the historically separate realms of the academy and the profession engage in research together?

Enter Ajla Aksamija and her book *Integrating Innovation in Architecture*. The following pages are at once a template, a primer and a call to action for serious research in architecture. The first step towards tackling any significant challenge is to simply understand it. The first three chapters of the book rigorously march through the various dimensions of architecture: materials, processes and technologies. Aksamija scans the global design market and reveals countless examples of innovative possibilities occurring all over the world. She succinctly explains each innovation and links each to relevant examples of their application, proving that these are not dreams but seriously useful and impactful innovations. This part of the book gives us the 'what', and anyone passionate about design should use the examples cited as an itinerary for their future travels. But Aksamija goes further in the second part of the book where she outlines the 'how' of research. I believe this part of the book is the most important, as it will provide practitioners with a prototype business strategy to develop their own research-based practice and the courage to do so.

Design practice is extremely difficult. Architects, interior designers, planners and landscape architects are historically less well compensated than other professional service providers. As such, our profession chronically skates on the edge of financial viability, even as the market grows increasingly demanding of our time and energy with more intense legal, regulatory, environmental and other pressures. In this predicament, it is understandably difficult for designers to find the energy to change their practices. Change is intimidating, but Aksamija's book helps break this down for us, and makes the prospect of change much less abstract. By explaining the 'what' and the 'how', she provides designers with an invaluable toolkit.

The key message of this book is action. The most important thing to do is to start something. By demystifying the challenge and breaking it down into smaller pieces, firms and design schools can find seeds of possibility and start incrementally. Aksamija's book title suggests that 'integrating' research into practice can be done as an evolution, not as a radical step. Our profession simply cannot afford to think about research in the manner of the pharmaceutical industry, for example. Instead, we can get there by reallocating current resources and establishing new degrees of rigour in our work. The evolution into research-based practice can be a subtle shift, but it needs to be a serious and purposeful one. Importantly, *diversity and transparency* will help our industry get further faster.

Here is what I mean by diversity: while Aksamija gives us a broad tableau of research possibilities, each designer, school and firm should craft their own research agendas that are more narrowly defined and have specific goals. Indeed, the possibilities are so broad and rich, there are virtually no limits to the work ahead

of us, and so a diversified approach to investigation is the right model for the design industry. This idea is the opposite of a singularly focused 'moon shot' mentality; it is a divide and conquer approach. We should pursue many smaller goals because there are so many important areas of inquiry, and tackling smaller research problems will be inherently more economically feasible for us.
But then we need to share what we learn. Diversity requires transparency. Unlike the pharmaceutical industry, we should not think about our research as a means to developing competitive advantage. Instead, we should take the leap of faith that sharing knowledge in a transparent approach will lead us to more innovation, more rapidly, and that this will ultimately make a stronger design industry in which we all can thrive.

But first, please read this excellent and important book, and please use it productively. I hope you enjoy it.

Phil Harrison, FAIA, LEED AP, is a Principal and Chief Executive Officer at Perkins+Will. He is responsible for the firm's strategic focus and business performance. He is directly involved with quality initiatives including design excellence, sustainability, research and technical delivery.

INTRODUCTION

INNOVATION IN ARCHITECTURE (WHAT, WHY AND HOW)

Design professionals are currently faced with many challenges – rapid technological changes, the necessity to innovate and raise the bar in building performance, and a paradigm shift in architecture with the wider adoption of BIM-based design. There are a number of reasons why progressive practices must continuously invest in research and the implementation of advanced technologies, but the need to improve design processes and services is typically the overarching drive.

This book focuses on innovations in architecture, new materials and design methods, advances in computational design, innovations in building technologies and the integration of research with design. It also illustrates with case studies how these approaches have been implemented on actual architectural projects, and how design and technical innovations are used to improve building performance, as well as design practices in cutting-edge architectural and design firms. But first it is essential to discuss what innovation is, why it is necessary to innovate in architecture and how it relates to architectural design and practice.

WHAT IS INNOVATION?

The general definition of innovation is that it is the process of introducing changes to methods, services or products. These changes must be useful and meaningful, adding value to the established norms and contributing to our knowledge. Innovation and technological changes are complementary in nature, since innovation relies heavily on technological and scientific developments. For example, the diagram overleaf shows the use of the term 'innovation' in English language publications from the 1700s to today – it is evident that it coincides with major eras of technological developments, such as the Industrial Revolution and the Information Revolution. The last few decades have seen unprecedented social, technological and economic changes, and innovation is becoming critical to many fields including among others medicine, information technology, transport, engineering and design.

However, the concept of innovation in architectural design is not new – there are numerous examples throughout history where new ideas, design methods, materials and construction processes were introduced, resulting in new building typologies, design and construction methods. For example, the Romans introduced concrete and mastered the structural use of arches, resulting in monumental buildings and a style that significantly influenced

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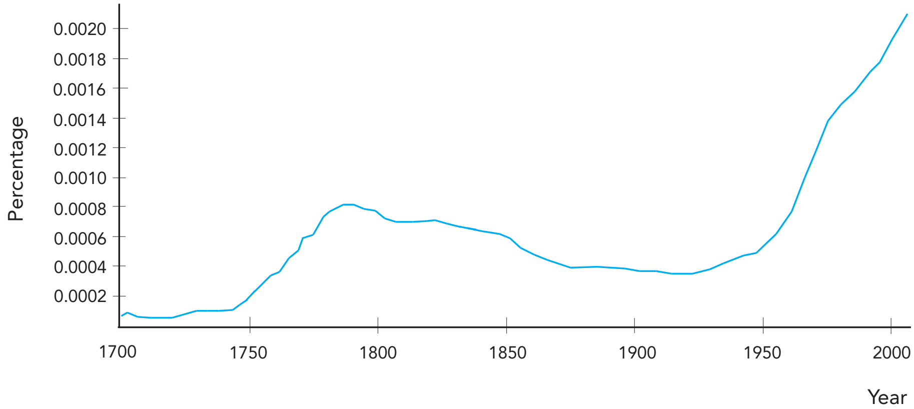
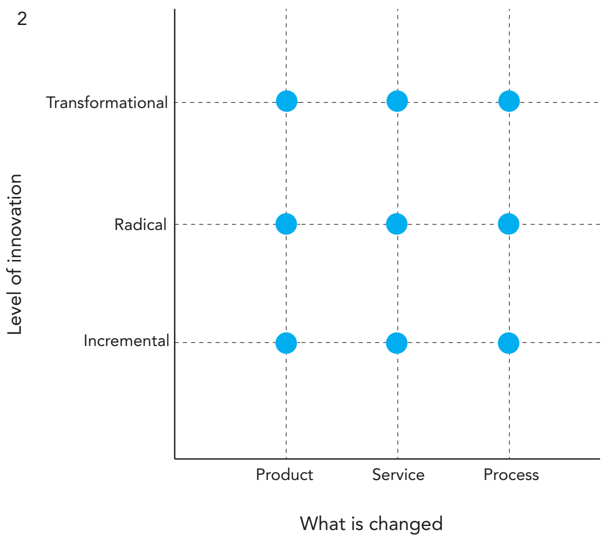


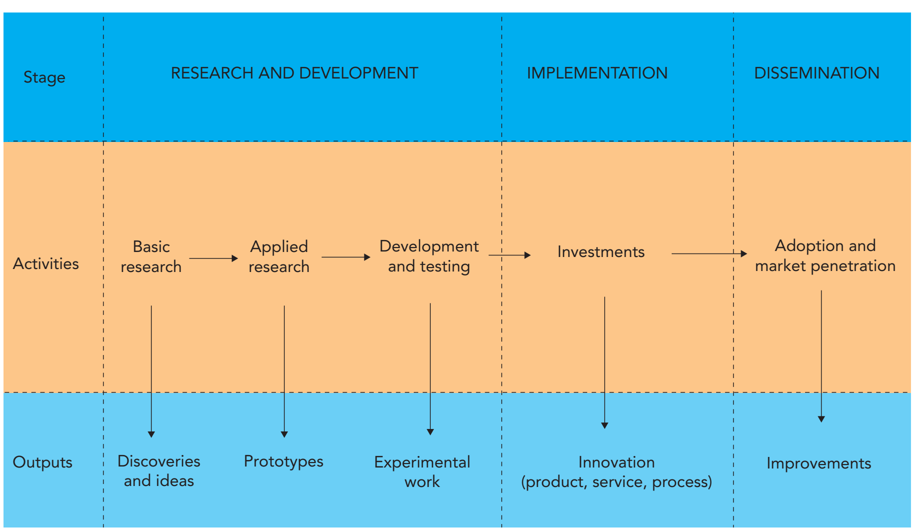
Percentage
0.0020
0.0018
0.0016
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
1700
1750
1800
1850
1900
1950
2000
Year

2



Level of innovation
Transformational
Radical
Incremental
Product
Service
Process
What is changed

3



Stage
RESEARCH AND DEVELOPMENT
IMPLEMENTATION
DISSEMINATION
Activities
Basic research
Applied research
Development and testing
Investments
Adoption and market penetration
Outputs
Discoveries and ideas
Prototypes
Experimental work
Innovation (product, service, process)
Improvements

future architectural styles and form. The Gothic architectural style was developed as a direct result of innovations in structural form – pointed arches, ribbed vaulting and flying buttresses provided new methods for spanning large areas in stone and for building taller. The introduction of reinforced concrete in the late 19th century revolutionised architectural design and engineering. Steel skeleton frames and advances in vertical transportation through the invention of elevators initiated the development of tall buildings, which was also influenced by particular economic conditions. High density and rising costs of urban land in major cities led to the development of tall buildings as a building type, where the building footprint and site were minimised, and the capabilities of steel structural systems were exploited to provide a design solution for maximising the building area and return on investment. Moreover, the second half of the 20th century provided unprecedented developments in materials, building technologies and systems, computational methods for design, fabrication methods and mass production, and construction processes. For example, advances in facade systems and glass, as well as developments in mechanical systems, introduced a new typology of commercial office buildings in the 1950s and 1960s, which became symbols of the International Style across the globe.

Although the concept of innovation within the context of architectural design is not new, the deliberate use of the word 'innovation' in architecture has become widely popular over the last 15 years. It is difficult to determine the specific cause – such as the development of a certain technology – that influenced the adoption of this term to describe contemporary design and practice. The key underlining standpoint of this book is that multiple reasons and causes, including new building technologies and materials, advancements in building systems, the wider adoption of computational design techniques, the adoption of BIM as a paradigm shift in design, collaboration and construction, new design practices (including research and development) and economic impacts have all contributed to embracing innovation as a key component in contemporary design.

Architectural design, in the context of contemporary innovation, relies on the decision-making process, where an idea is transformed into an outcome: either a tangible product (ie, building) or intangible service (ie, design process). Regardless of the type, innovation must be useful and meaningful, and must create added value by applying new ideas. The diagram, which shows the relationships between aspects that can be changed (product, service and process) and the level of innovation (incremental, radical and transformational), indicates different types and levels of innovation. Within architectural design, the product is the building, physical space, material or object; service is the way that we interact with clients, constituents and building occupants; and process is the design process that is applied to create a building, space or a system. Therefore, all of these three categories can be changed and improved, and the level of innovation can vary from incremental to transformational.

1 The use of the term 'innovation' in English-language publications from the 1700s to today.
Unprecedented social, technological and economic changes within the last few decades, such as the Information Revolution, have resulted in the growing significance of innovation in many different fields, including architectural design.

2 Relationships between the levels of innovation and what can be changed.
In the context of architectural design, the product is the building, physical space or object; service is the way that we interact with clients, constituents and building occupants; and process refers to the design process. Incremental innovation is a small change that affects certain projects. Radical innovation has an impact on larger contexts (such as the development of new software), while transformational innovation creates a paradigm shift in architectural design and the profession.

3 Three stages of the innovation process: research and development, implementation and dissemination.
The outputs of specific stages, such as research and development, influence and direct activities of subsequent stages.

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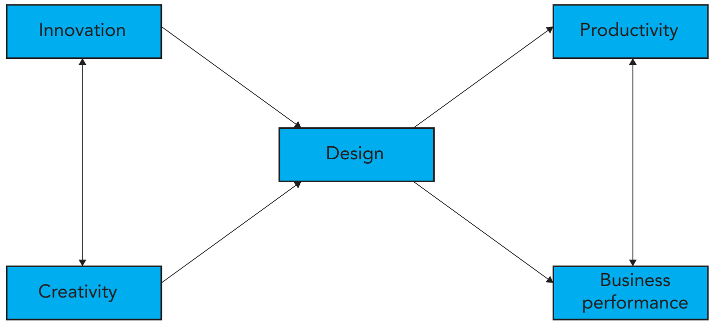

Incremental innovation is a small change that affects certain projects, such as the application of a novel material. Radical innovation has an impact on larger contexts, such as new computer software, or the improvement of a design process for a certain building type. Transformational innovation creates a paradigm shift in architectural design and the profession.

There are three stages that constitute the innovation process: research and development, commercialisation or implementation, and dissemination. During each stage, there are activities that require the input of knowledge, and the investment of time and resources. For example, research and development stages require basic research, applied research and development and testing. The outcomes include discoveries, new ideas, the development of new knowledge and the development of prototypes, testing and experimental work. The next stage constitutes implementation, and the last stage is dissemination and wider adoption. It is important to note that innovation is rarely a linear progression through the indicated stages, but rather specific outputs influence the activities of consequent stages.

WHY INNOVATE IN ARCHITECTURAL DESIGN?

An important question arises – why innovate in architectural design? What are the drivers for innovation in architectural design, and what is its value? Innovation helps organisations to progress and advance; it also affects efficiency, quality of work and improves design processes.

Innovation in architectural design requires the application of new design strategies and new project delivery methods. New design tools, materials, building technologies and construction techniques contribute to making buildings more responsive to the environment and their occupants. Innovative methods for collaboration, such as BIM, provide new ways for integrating design and construction. Project delivery innovations blur the traditional roles in design and construction and have an impact on business performance. Seeking innovation in architectural design encourages creative thinking, which helps architectural firms to adapt to changing market conditions and inner dynamics, ultimately affecting productivity and business performance.

4 Relationships between innovation, design and business performance.
Innovation in architecture has an impact on creativity and design processes, which in turn influence the productivity and business performance of a firm.

5 Relationships between the innovation and operation of architectural firms.
Architectural firms that embrace innovation should maintain a balance between innovation and operation, allowing new ideas and new market demands to influence meaningful changes to operation.

Changing markets and economics dictate development and opportunities in the architectural and construction industries, and entrepreneurial firms are able to respond to these changes and adapt their practices.

Beyond the economic and competitive advantages, innovation in architectural design also influences the outcomes of the design process and the built environment, so instituting social impacts and human well-being. Energy-efficient, responsive buildings that adapt to environmental changes and occupants are an emerging category of buildings that have the potential to change our future. Therefore, the value lies not only in organisational improvements, economic benefits and enhancements for individual firms, but in the broader benefits for society.

HOW TO INNOVATE IN ARCHITECTURE?

Organisations typically classify their activities under two broad categories – operation and innovation. Operations include all activities that provide an existing service to clients, while innovation consists of all activities that change operations and are focused on the future needs of the organisation, market and clients, as well as technological developments. In some cases, tension between the operating activities and innovation may exist, since established operations will be affected. Innovative organisations embrace this challenge and maintain a balance, allowing the results of innovation to have an impact on operation. The diagram below shows how architectural firms and organisations that embrace innovation should function. Operation and innovation should be linked, allowing the results of innovation to influence changes in operation.

The size of a firm dictates its operation, mainly in terms of the selection of clients, specialisation in specific building typologies and markets, types of design projects, as well as activities and roles in the design process. Small firms tend to focus on specific building types, such as residential, hospitality or commercial buildings, where the employees tend to be involved in all stages of the project and different roles are blurred between design, project management and technical delivery. Large firms typically

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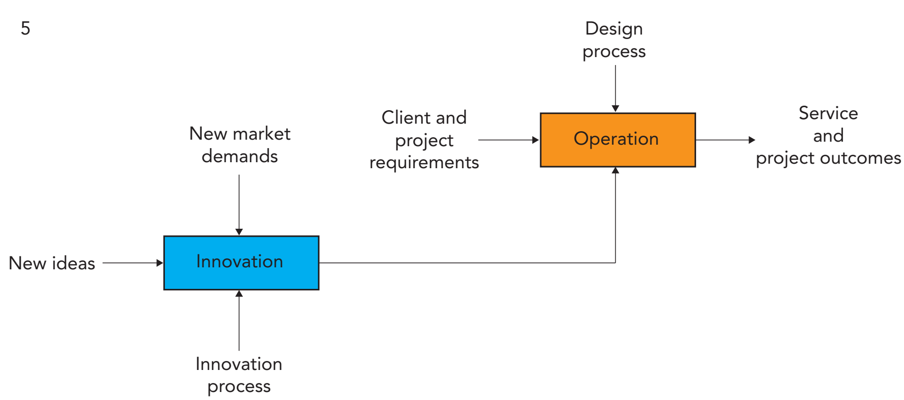

serve several market sectors and multiple building types, including healthcare, educational, academic, institutional, commercial and other building typologies. The roles of different employees are typically differentiated by the project stages, where design, project management and technical roles are distinguished and teams are organised by the market sector. However, innovative practices can be applied to any building type, and the firm's size is irrelevant in implementing innovative design approaches. New ideas, new market demands and innovative processes are applicable in all market sectors and drive innovation in all building types. The differences between small, medium and large firms in accepting and implementing innovation are mostly evident in the firms' operations. For example, larger firms may have more resources for research and development, where internal research teams are integrated with the design teams. Smaller firms may use different models for research, such as funding specific studies led by academic institutions or collaborating with research centres. Nevertheless, the size of the firm does not affect innovation, but rather its vision, motives and goals.

But, how to innovate in architecture? One of the most important aspects is that innovation requires integrated approaches, where design methods, technology and firm culture must coalesce to address issues and problems, and provide solutions that create value for the firm, client and society. Therefore, advanced materials and building technologies, design computation, innovative project delivery, BIM and construction techniques all play a role, as well as motives, the firm's organisation, research and development, and investments. An integrated model for innovation in architecture is shown in the following diagram overleaf, which demonstrates how these different factors influence innovation. The rest of this book discusses all of these factors in detail and provides guidelines for integrating innovation in architecture. Chapter 1 focuses on advances in materials: composite materials, responsive and smart materials, as well as energy-generating materials. Chapter 2 discusses innovations in computational design: tools and methods for successfully integrating computation with design and digital fabrication, the use of BIM for all stages of a building's life cycle, the use of simulations and performance-based analysis methods for environmental and structural investigations and processes for translating design to digital fabrication. Chapter 3 focuses on technological innovations: mainly innovative building technologies (facades, HVAC and lighting systems, and building automation); innovations in construction techniques (modular and prefabricated construction, automation of construction processes and robotics), as well as smart and responsive buildings. Chapter 4 presents guidelines for stimulating innovation in design practice: the integration of research and design, economic impacts and financial factors, innovations in project delivery and risk management in innovative design practices. Chapter 5 discusses specific case studies that illustrate methods for building-integrated innovations, including innovative materials and building technologies, responsive design, computational approaches, BIM and construction techniques. The concluding section of the

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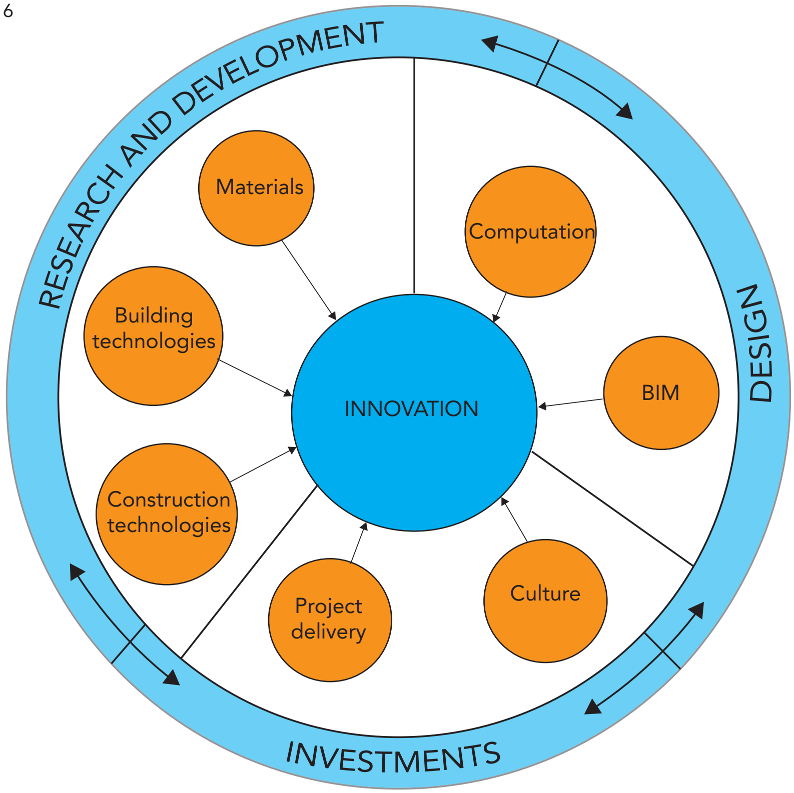

6 Model for integrating innovation in architecture.
Different factors – including advanced materials and building technologies, computational design, BIM, research and development innovations in project delivery and construction techniques – all play a role, besides the culture of the organisation.

book discusses future outlooks, and provides recommendations and steps that firms can take to integrate innovation into their operation and everyday activities.

We cannot exactly predict how cities will function in the future, how transport modes will work, or what types of new technologies will be discovered and developed. We cannot precisely predict how economic and societal changes will affect the human population in a long-term context, or how will our health be improved by new scientific discoveries and medical advances. But, we know that changes are imminent, and that architecture and the built environment will be affected. Contemporary practices that embrace technological, societal and economic changes, and establish innovation as a core value and design philosophy, are better equipped to face what the future will bring.

IMAGES

Opening image © James Steinkamp Photography; figures 1, 2, 3, 4, 5 and 6 © Ajla Aksamija

1 INNOVATIVE MATERIALS

Innovations in materials are influencing contemporary architectural practice. Today, the focus is primarily on new materials that exhibit enhanced properties. Therefore, advanced and composite materials, smart and responsive materials, and biologically inspired materials are gaining popularity in architectural design. Advanced materials are those that have enhanced properties (such as thermal performance, structural properties, durability and so on), and exhibit sensitivity to the environment in terms of production and use. Smart and responsive materials are those that exhibit properties that can be changed or altered, so that they act as sensors or actuators, responding to changes in the environment. These new emerging materials offer radical changes to the built environment in terms of energy usage, thermal behaviour, structural performance and aesthetics. This chapter provides an overview of emerging materials and discusses their use, performance, benefits and drawbacks.

Advances in physical sciences have led to a new understanding of changeable materials, particularly those compromising the acoustic, luminous and thermal environments of buildings. A smart structure can be defined as a non-biological physical structure that has a definite purpose, means and imperative to achieve that purpose, and a biological pattern of functioning. Smart materials are considered to be a subset, or components of smart structures, and act in such a way as to mimic the functioning of a biological or living organism and adapt to changing conditions in the environment. Smart materials can be classified into two general categories – materials that can sense and inherently respond to the changes in the environment, and materials that need control in a systematic manner in order to actuate based on a certain change. Different types of smart materials include piezoelectric, electrochromic, electrostrictive, magnetostrictive, electrorheological, shape-memory alloys and fibre-optic sensors. Piezoelectric materials exhibit significant material deformation in response to an applied electric field and produce dielectric polarisation in response to mechanical strains. Electrostrictive materials exhibit mechanical deformation when an electric field is applied. Magnetostrictive materials generate strains in response to an applied magnetic field. Electrorheological materials exhibit the 'ER response' or 'Winslow effect', which refers to a significant and reversible change in the

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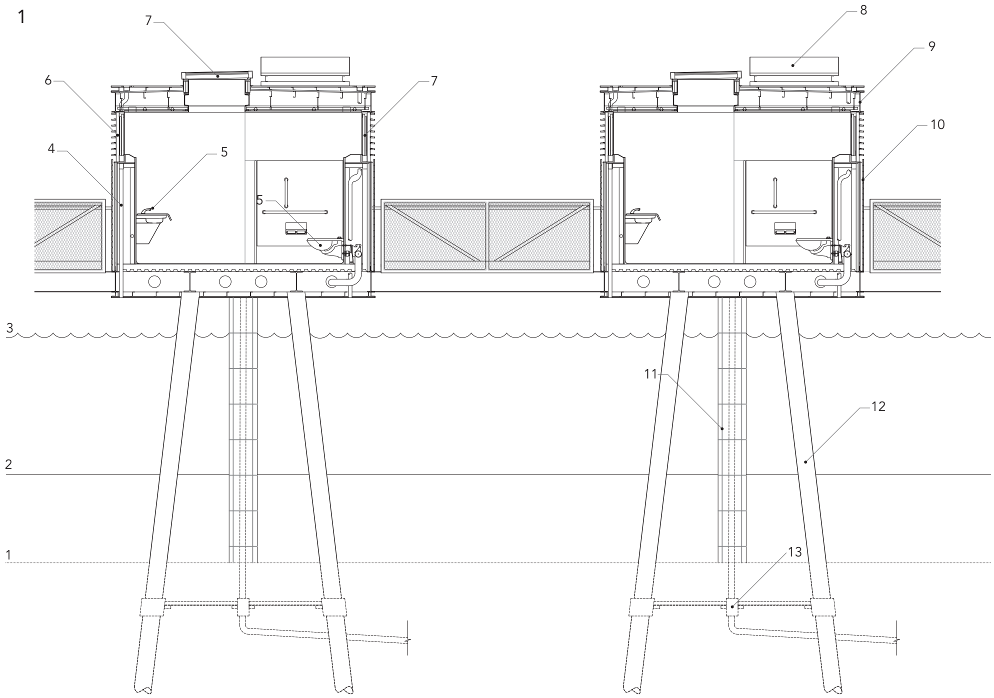
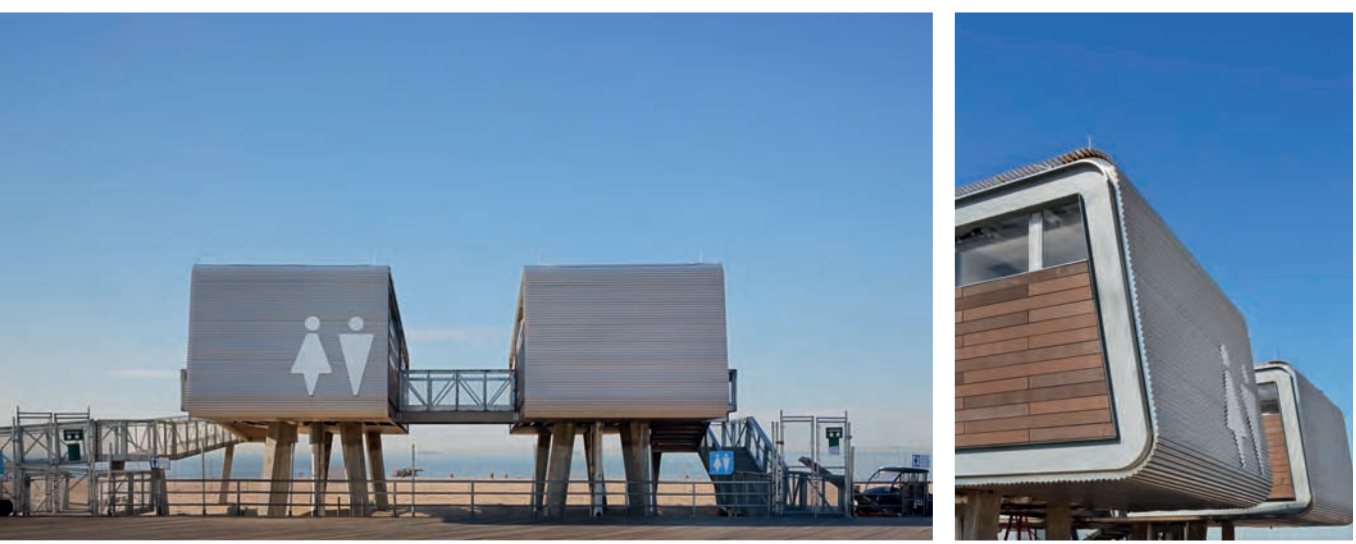


1 Garrison Architects, New York City Beach Restoration Modules, New York, USA, 2013.
The section shows building elements and systems. The modules are raised on concrete legs to withstand significant sea level rise.

1 Sand
2 Boardwalk
3 Advisory base flood elevation
4 Building envelope
5 Low flow plumbing fixtures
6 Operable windows
7 Skylights
8 Photovoltaics
9 Galvanised steel frame
10 Fibre-reinforced concrete cladding
11 Pre-stressed concrete pilings
12 Utility chase
13 Piping connectors

2



rheological behaviour of fluids subjected to an external applied electric field – low viscosity fluid converts into a solid substance. Shape-memory alloys are metal compounds that can sustain and recover large strains without undergoing plastic deformation under externally applied stress or thermal changes.

ADVANCES IN CONCRETE

Transforming the design and construction industries are new advances in concrete- and cement-based products. Among many new materials being used are superplasticising admixtures, high-strength mortars, self-compacting concrete and high-volume fly ash and slag concretes. A number of advances in new concrete technologies have been made in the past decade, including materials, recycling, mixture proportioning, durability and environmental quality. There are also diverse new methods and techniques in today's construction world, such as high-performance concrete (HPC) and fibre-reinforced concrete (FRC). Advanced composite materials have become popular in the construction industry for innovative building design solutions, including the strengthening and retrofitting of existing structures. The interface between different materials is a key issue of such design solutions, as the structural integrity relies on the bond between different materials. Knowledge about the durability of concrete/epoxy interfaces is becoming essential, as the use of these systems in applications such as fibre-reinforced plastic (FRP) strengthening and retrofitting of concrete structures is becoming increasingly popular.

Recycled materials are usually added to HPC, thereby reducing the need to dispose of them.[1] Some of the materials include fly ash (waste by-product from coal burning), ground-granulated blast-furnace slag and silica fume. But perhaps the biggest benefit of some of these other materials is the reduction in the need to use cement, also commonly referred to as Portland cement. The reduction in the production and use of cement has many beneficial aspects, including a decrease in the creation of carbon-dioxide emissions and energy consumption. In addition, fly ash and furnace slag have properties that improve the quality of the final concrete and the use of them is usually more cost-effective than cement.

Today's concrete technologies have produced new types of concrete that have lifespans measured in the hundreds of years rather than decades. When compared with standard concrete, new concretes have better corrosion resistance, equal or higher compressive and tensile strengths, higher fire resistance, and rapid curing and strength gain. In addition, the production and life cycle of these new concretes will reduce greenhouse gas emissions by as much as 90%.

Glass-fibre reinforced concrete (GFRC) is a new type of concrete with a much higher tensile and flexural (bending) strength than standard concrete.[2] This glass-fibre reinforced concrete is combined with pre-mixed dry components. It has higher density than standard concrete, and structural systems and building components need less material than conventional concrete for

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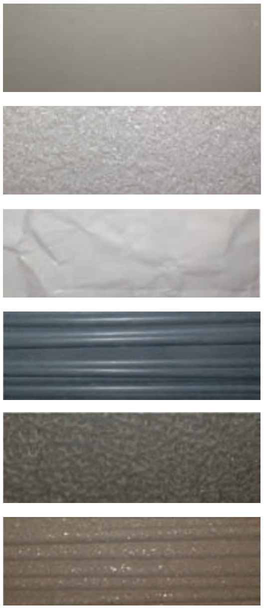
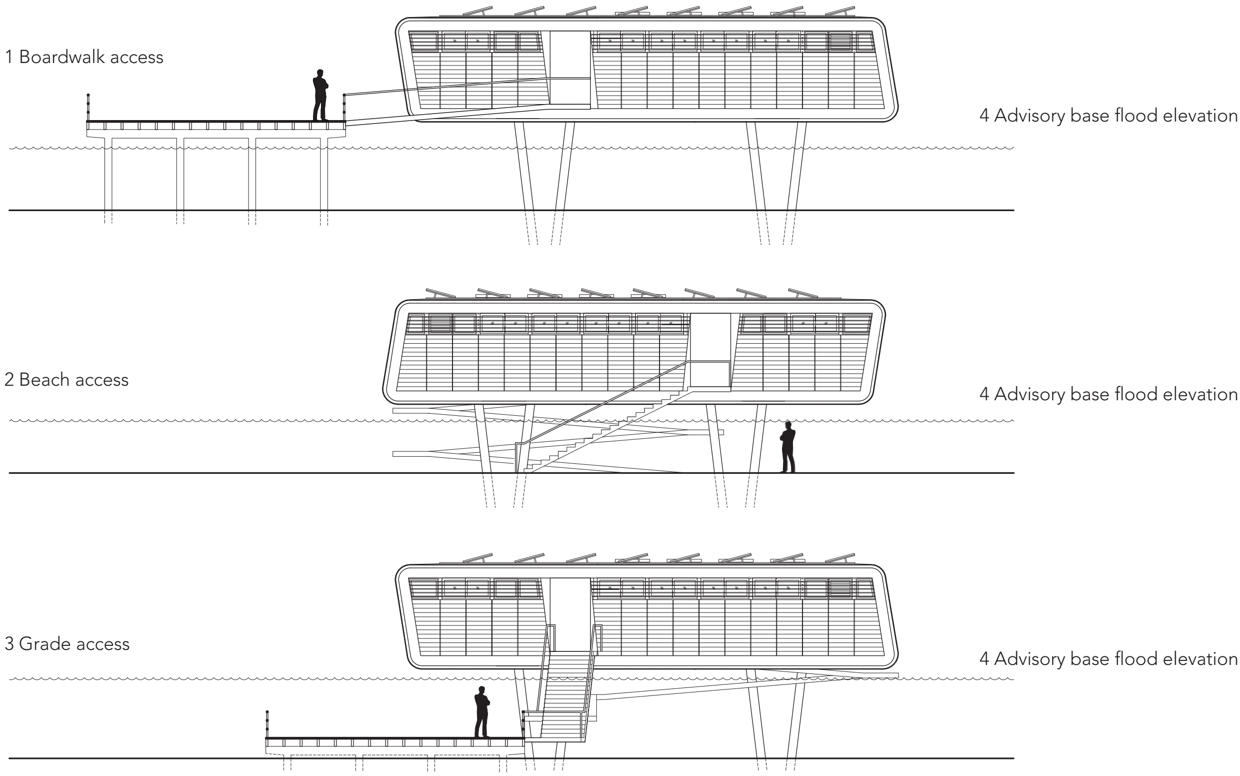


2 (opposite below and below) Garrison Architects, New York City Beach Restoration Modules, New York, USA, 2013.
The beach modules incorporate GFRC panels as facade cladding materials.

3 Surface, colour and finishing textures of GFRC concrete.
A variety of finishing techniques and colours are possible for GFRC concrete facade cladding, so facades can have interesting, dynamic patterns.



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4 Garrison Architects, New York City Beach Restoration Modules, New York, USA, 2013.
Elevations show facade treatment and indicate 500 year flood level.

5 Photocatalysis process for self-cleaning concrete.
The self-cleaning photocatalysis process for concrete consists of two steps: in the first step, UV light triggers an oxidation process on the titanium dioxide-coated surface, breaking down dirt and polluting substances; in the second (hydrophilic) stage, rain washes particles off the concrete surface.

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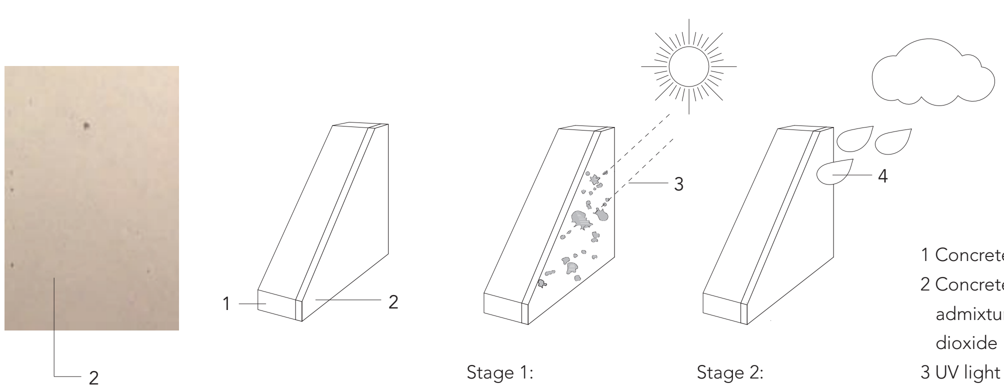
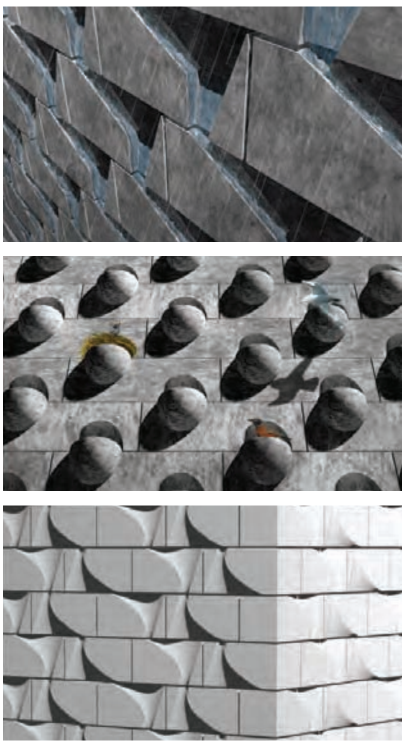


1 Concrete
2 Concrete with photocatalytic admixture containing titanium dioxide
3 UV light
4 Rain

structural stability. This high density gives GFRC concrete other properties, such as extremely high resistance to corrosion from chemicals. The higher strength also eliminates the need for steel rebars in structural designs. GFRC, or a variation with metallic fibres and/or superplasticisers, can be used to build extremely thin structural elements. Overall, structures built with GFRC will have much greater lifespans and require less maintenance. Special surface effects can be created with aggregates and a variety of finishing techniques. New York City's Beach Restoration Modules, designed by Garrison Architects, incorporate GFRC panels. These factory-assembled modules were designed following the devastating Hurricane Sandy that destroyed the coastline of New York City. The modules are mounted on concrete legs, raising the modules above the 500 year flood level, as shown in the sections and elevations. The modules, designed to withstand the next major ocean storm, rely on photovoltaics and a solar water-heating system.

Other advances include translucent concrete, which is created by adding optical fibres to the concrete admixtures. This is changing the perception of concrete as a primarily opaque mass. Applications to date have been mainly for interior and decorative use, partitions, and so on. Self-consolidating concrete is a special concrete mix that eliminates the need for mechanical consolidation and yields a smooth surface finish.[3] Insulated concrete form (ICF) walls are gaining popularity in the residential building sector. They consist of rigid thermal insulation that acts as a formwork and stays in place as a permanent substrate after concrete is poured. Since these systems are modular the benefits include rapid construction, improved thermal performance and energy savings.

6



Another low-tech innovation in concrete is the new concrete masonry unit (CMU) with varying surface geometry, as seen in the pictures opposite, which can be used to create an interesting pattern, form and facade geometry. The manufacturing process uses forms to create projections and voids within the exterior surface of the CMU, which when arranged in a typical wall can create a varied and dynamic facade.

New types of admixtures are also advancing properties of concrete. For example, a polymeric admixture that integrally waterproofs concrete is available and eliminates the need for external membranes. It also protects against corrosion of steel rebar reinforcement, and makes recycling easier after demolition. Self-repairing cement has been developed, which expands the longevity of concrete by reducing porosity. Additives that contain titanium dioxide can create self-cleaning effects, and cement with titanium dioxide (photocatalyst) is available for self-cleaning concrete. Photocatalysts are compounds that use the ultraviolet bands of sunlight to facilitate a chemical reaction. When exposed to sunlight, the titanium oxide triggers a strong oxidation process that converts noxious organic and inorganic substances into harmless compounds. The self-cleaning process involves two stages, as seen in the diagram on page 24. In the photocatalytic

6 Variable surfaces of CMU blocks.
Innovative manufacturing processes result in CMU blocks with assorted patterns, which can be used to create dynamic facade patterns.