Ministry of National Infrastructures,
Energy and Water Resources
www.energy.gov.il

US ISRAEL
Workshop on

Industrial Ecology in Multi-Scale Design and Construction of Sustainable Built Environments

Tel Aviv
March 9-11, 2014

PROCEEDINGS

Edited by: Rachel Becker

STANFORD ENGINEERING

National Building Research Institute
Faculty of Civil and Environmental Engineering
TECHNION

PROCEEDINGS

US-ISRAEL WORKSHOP

on

Industrial Ecology in Multi-Scale Design and Construction of Sustainable Built Environments

March 9-11, 2014, Tel Aviv, Israel

Edited: Rachel Becker

NATIONAL BUILDING RESEARCH INSTITUTE, TECHNION, HAIFA

Ministry of National Infrastructures,
Energy and Water Resources
www.energy.gov.il

The workshop was co-organized by:

USA

Professor Nabil F. Grace
Dean, College of Engineering
University Distinguished Professor
Director, Center for Innovative Materials Research (CIMR)
Lawrence Tech. University, Southfield, MI.

Assistant Professor Michael Lepech
Department of Civil and Environmental Engineering
Stanford University, Palo Alto, Ca.

ISRAEL

Associate Professor Rachel Becker
Associate Professor Mark Talesnick
Associate Professor Konstantin Kovler
National Building Research Institute (NBRI)
Department of Str. Eng. & Const. Management
Faculty of Civil & Environmental Engineering
Technion, Haifa.

The Workshop was co-sponsored by:

USA

National Science Foundation, USA
Dr. Sohi Rastegar, Director, Office of Emerging Frontiers in Research & Innovation (ENG/EFRI),
Dr. Bruce Hamilton, Deputy Division Director (Acting), Division of Chemical, Bioengineering, Environmental, and Transport Systems (ENG/CBET).

ISRAEL

Ministry of National Infrastructures, Energy and Water Resources, Israel
Dr. Shlomo Wald, Chief Scientist,
Eng. Eddie Bet-Hazavdi, Director of the Department of Energy Conservation & smart Cities,
Arch. Nathan Ohn-Bar, M.Arch.
Countenance Energy in Buildings.

Technion – Israel Institute of Technology
Prof. Daniel Ritel, Deputy Senior Vice President

TABLE OF CONTENTS

PREFACE

The design and construction of a built environment and civil infrastructure that is more environmentally, socially, and economically responsible over its full life cycle is increasingly desirable worldwide. Altogether these three design goals of improved environmental, social, and economic performance are commonly known as the "triple bottom line" of sustainability. As a critical set of systems that, on one hand, support our quality of life and enable global development and progress while, on the other hand, consume vast amounts of material resources and energy, it is essential that the built environment is designed according to these comprehensive, long term design goals for its own sustainability and the benefit of planet earth.

While the goals of such sustainable design are well intended, the creation and execution of built environment designs that are socially, environmentally, and economically sustainable is not functionally possible for current infrastructure designers, civil engineers, architects, or urban planners. This is due to a number of factors.

- There is a lack of reliable quantitative targets and metrics for sustainable design. There is a need for metrics that are built upon a scientifically-based design approach, as represented by the industrial ecology approach, and are translatable to everyday engineering practice.
- Probabilistic approaches, which are the hallmark of current civil engineering design theories around the world, have still not been applied to formalize the expectations of reliability-based design procedures that manage uncertainty in design, construction, use, and end of life management phases.
- Due to the absence of rigorous engineering design theories for sustainability, it remains challenging for advanced materials and methods of design to demonstrate their long-term sustainability benefits in contrast to their often higher initial economic cost. This slows their adoption among practitioners.
- The lack of systematic application of comprehensive industrial ecology tools and science-based ecological limit state functions spans throughout the early-stage design, planning, construction, and management of sustainable built environments. Such tools should be applied across scales (i.e. from material scale design to urban system design) to best achieve sustainable design outcomes.
- There are differences in priorities and approaches to sustainable engineering in developed and developing countries, and it is not clear whether similar metrics and tools can apply.

With the aim of elaborating on ways and tools to integrate industrial ecology within the multi-scale design and construction of built environments, this workshop was organized by the Center for Innovative Materials Research (CIMR) of Lawrence Tech University, the Civil and Environmental Engineering Department at Stanford University, and The National Building Research Institute (NBRI) of the Faculty of Civil and Environmental Engineering at the Technion – Israel Institute of Technology. It brings together researchers and practitioners to discuss topics on the methodology of industrial ecology for the built environment design, multi-scale design of sustainable urban systems, and engineering of sustainable building materials. The focus of deliberations is the possible implementation of the advanced tools in actual design and construction, addressing the different issues relevant to developed and developing countries. A major goal is to increase education and awareness of sustainable built environment issues both within and outside of academia.

Workshop Objectives

Main Objective:

This Workshop was organized to become a vehicle for promoting the use of science-based tools and the industrial ecology approach in setting sustainability targets and in the design and evaluation of the built environment that comprises materials, buildings, structures and urban systems.

Detailed specific objectives:

- ✓ To present methodologies for using industrial ecology tools when evaluating new materials, alternative structural designs, and innovative urban systems in view of a comprehensive set of environmental, social, and economic indicators for developing and developed countries
- ✓ To present case studies in which innovations have led to dramatic improvements in our built environment sustainability (measured through industrial ecology tools), and to show where these innovations are best leveraged
- ✓ To discuss the sustainability of advanced engineered materials, structures and urban systems based on investments and derived economic incentives
- ✓ To discuss how developed and developing countries differ in their approaches to sustainability, and to consider the challenge in applying advanced modelling and design tools to developing countries
- ✓ To craft a research agenda for the future in the use of quantitative sustainability assessment tools and industrial ecology principles in the design, fabrication, and implementation of innovative materials, structures, and urban systems
- ✓ To engage practitioners from both Israel and US in shaping future sustainability design practice, methods, and tools
- ✓ To introduce and educate a new cadre of graduate students and young researchers that will continue to explore these unique interactions throughout their academic careers

EXTENDED ABSTRACTS

Plenary Opening Session

SUSTAINABLE CONSTRUCTION WITH CEMENTITOUS MATERIALS AND CONCRETES

Arnon Bentur
Faculty of Civil and Environmental Engineering
National Building Research institute
Technion, Israel Institute of Technology
bentur@technion.ac.il

SUMMARY

In view of the expected increase in the global consumption of concretes in the coming decades there is a need the develop ways by which its characteristic environmental impact of concrete will be reduced by at least a factor of two. This can only be achieved by holistic integrated approach.

Keywords: environmental impact, concrete, cement, design

INTRODUCTION

The environmental and ecological requirements of the modern era have placed a special pressure on the cement and concrete industry to take drastic measures to reduce the energy and carbon foot prints of these materials. Although their specific foot print (embodied energy or carbon per kg or unit volume) is much smaller than other construction materials, such as steel, the absolute environmental burden is significantly high because of the huge consumption of these materials, as can be quantified in terms of the amounts of cement produced and the volume of concrete used.

THE CHALLENGE

The amount of concrete consumed globally is expected to be doubled within the next decades in order to meet the needs for housing and infrastructure. This implies that unless ways are developed to reduce the characteristic environmental impact of concrete by 50%, the overall environmental load of construction with concrete will keep increasing beyond the current level.

Of all of the concrete components, the Portland cement is the one which is of the highest footprint. Attempts have been made to reduce the embodied energy and carbon of cement by modifying the production process and incorporation of mineral additives. These have yielded considerable success, but they seem to be levelling off (Taylor et al. 2006). "Out of the box" strategies are needed to be developed in this area and this is quite difficult. Thus, the challenge for reducing the environmental foot print of concrete is so huge that it is unlikely to be met by a single strategy.

HOLISTIC - INTEGRATED APPROACH

A holistic approach combing several modes of action with synergy between them is required to achieve the target of 50% reduction in the concrete environmental foot print. Three strategies are outlined and discussed in this presentation:

(i) The "cement strategy" - Since the environmental impact of construction with concrete is largely due to the energy consumed and the CO_2 discharged in the cement production, the prevailing strategy so far has been based on developing technologies to reduce the energy consumed by improving the production processes and reducing the clinker content using blended cements. This seems to have levelled off (Taylor et al. 2006) and new scientific insights are required (Chatterjee 2011).

(ii) The "concrete strategy" – This strategy is based on modern concrete technology concepts applied to produce high performance concretes. These concepts can be used to provide means for achieving normal strength concretes with drastically reduced cement content (Dhir et al. 2004, Katz and Baum 2006, Wasserman et al. 2009).

(iii) The "environmentally driven design strategy" involves a more holistic approach, to be based on the overall design of a concrete structure to minimize its environmental impact. It can apply comprehensive models and design tools enabling to quantify the environmental impact based on life cycle assessment concepts, or modeling to calculate the impact of the structure in terms of energy and carbon footprints (Purnell 2011).

CONCLUSIONS

In order to achieve the goal of significant reduction in the environmental impact of construction with concrete there is a need to drum up numerous disciplines which are associated with concrete construction, spanning across cement production, concrete materials choice, mix design and overall design of the structure. Optimization within each field is required as well as integration across the disciplines. Current know-how and models of behavior can be used to provide the basis for the holistic approach outlined in this paper and thus, the implication is that considerable advance in this area can be made using current know-how.

REFERENCES

Chatterjee, A.K. (2011) Chemistry and engineering of the clinkerization process – incremental advances and lack of breakthroughs, Cement and Concrete Research, 41, 624-641

Dhir, R.K., McCarthy, M.J., Zhou, Z. and Tittle, P.A.J. (2004), Role of cement content in specifications for concrete durability: cement type influences, Structures and Buildings, 157 (SB2) 113-127

Katz, A. and Baum, H. (2006), Effect of high levels of fines content on concrete properties, ACI Materials Journal, 103(6) 474-482.

Purnell, P. (2011), Material nature versus structural nurture: the embodied carbon of fundamental structural elements, Environmental Science and Technology, 46(1) 454-461

Taylor, M., Tam, C. and Gielen, D. (2006), Energy efficiency and CO2 emissions from the global cement industry, paper for the IEA-WBCSD workshop: Energy efficiency and CO2 emission reduction potentials and policies in the cement industry, IEA, Paris, September 2006.

Wassermann, R., Katz, A. and Bentur, A. (2009), Minimum cement content requirements: a must or a myth? Materials and Structures, 42, 973-982

ON SUSTAINABLE MATERIALS AND STRUCTURAL ENGINEERING FOR THE 21st CENTURY

Lawrence C. Bank
Department of Civil Engineering, City College of New York, NY, USA
Corresponding Author: E-mail: lbank2@ccny.cuny.edu

SUMMARY

Materials and Structural Engineers are grappling with how to incorporate sustainability in both civil engineering curricula and in professional practice. This talk will discuss the past, present and future of these two closely related fields and examine how they could adapt to maintain their relevance in the next century.

Keywords: Civil Engineering, Education, Professional Practice, Sustainability.

INTRODUCTION

Within the field of Civil Engineering, those in the sub-fields of Structural Engineering and Structural/Construction Materials (e.g., concrete, steel, timber) have been the slowest to embrace and adopt the concepts of sustainability in the built environment Many structural and construction engineers have sat by with mounting frustration as Architects, Mechanical/Electrical/Plumbing (MEP) engineers, Environmental engineers and Urban Planners have defined "green" agendas for their disciplines and successfully embraced and marketed them. The reasons for this, which are perhaps understandable, can be traced to the way in which structural and construction engineers are educated and to the fact that it has been difficult to identify an appropriate vision for incorporating sustainability principles into the practice of structural and materials engineering in the built environment. In order to define the appropriate vision for the future of our profession, we need to understand how sustainability emerged from the environmental movement, where it currently is in terms of global development, and how we as structural and materials engineers can restructure and develop opportunities in this new sustainable world.

STRUCTURAL AND MATERIALS ENGINEERING TODAY

There are approximately 258,000 Civil Engineers, and 53,000 undergraduate students studying Civil Engineering in 233 ABET accredited programs in the US today (US Dept. of Labor; ABET). 12,300 graduated in 2012. 40,000 are structural engineers (Post, 2013) and if licensed, most structural and construction engineers practicing in the US have a license to practice Civil Engineering as a Professional Engineer (PE). A few states require an additional Structural Engineering (SE) license to practice structural engineering. There is considerable angst in the SE community regarding the future (SEI, 2013).

The structural engineering curriculum in the vast majority of schools consists of courses in engineering mechanics and linear structural analysis. These fundamental courses are taught using textbooks typically first published in the 1960s (or earlier) and are based on the theory of structures from the late 18th century to the early 20th century (Kurrer, 2008). There is usually only one course in CE materials. Design of steel and concrete structures is taught from textbooks from the 1950s and is AISC and ACI code based. The emphasis is on members in steel and concrete framed multistory buildings and short-span bridges. Other commonly used structural/construction materials may or may not be covered. There is some exposure to structural computer codes (SAP, RAM, etc.) but very little use of the design features of these codes. The MS degree typically covers more of the same except in somewhat greater detail (e.g., nonlinearly, seismic design, more classical mechanics) and perhaps with an independent study or thesis. The PhD is research based and typically deals with advanced topics of the same type (steel and concrete frames) in great depth and of little immediate, if any, value to the practicing engineer.

SUSTAINABILITY TODAY

In 1987, twenty-five years after Rachel Carson's, "Silent Spring," Sustainable Development, was defined by committee in the UN Brundtland Report "Our Common Future" as the now universally-known, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Less known is the latter part of the definition that "contains within it two key concepts: the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs." Since then sustainable development and sustainability science have proceeded along two distinct paths – one focused on the 2nd key concept (sometimes referred to as the "green agenda," - e.g., the Triple-Bottom-Line; People, Prosperity and the Planet (P3); LEED); and the other focused on the 1st key concept (sometimes referred to as the "brown agenda" (Williams, 1997) - i.e., population, pollution, public health, poverty, property rights). Today these two streams are expressed in the Intergovernmental Panel on Climate Change (IPCC) and the UN's Millennium Development Goals (MDG) activities.

SUSTAINABILITY IN STRUCTURAL AND MATERIALS ENGINEERING TODAY

In the US and the EU sustainability in Structural/Materials Engineering has focused primarily on the 2nd key concept and has worked toward the green agenda. On the materials side this has typically been focused on (1) Life-Cycle-Assessment (LCA) and specifically on the embodied energy (Cradle-to-Gate) of construction materials and products, (2) the decrease in GHGe emissions of construction materials (primarily cement whose production accounts for ~5% of global GHGe emissions), and (3) the use of recycled construction materials (primarily steel). On the structural side the focus has been on the optimization of framing systems in an attempt to use less material. Neither of these approaches is likely to contribute significantly to sustainable development. The embodied energy in materials in a building is a small fraction of the energy consumed over the building's lifetime, which in turn is only a small fraction of the commercial value of the property, and the income and health costs of the building occupants. The cost of the structural system in a building is perhaps 15% of the initial construction cost and optimization is unlikely to yield great sustainability benefits. In addition to this there has been significant consolidation in structural engineering consultancy firms in the last two decades leading to even less need for specialized structural engineers for what are now "routine" multistory building frames.

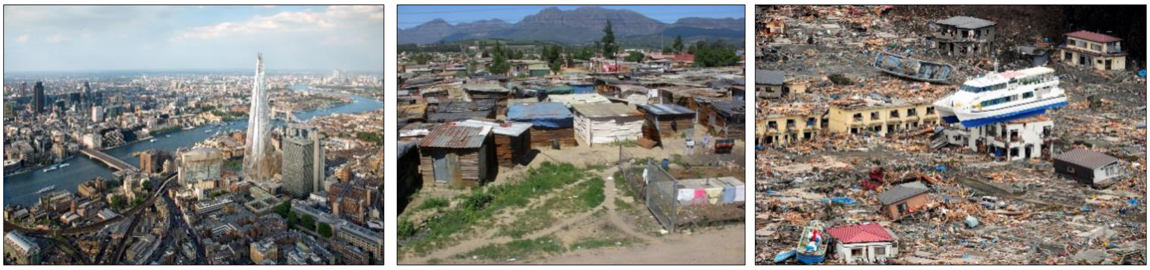


Fig. 1 – "Shards" –London, England; Cape Town, South Africa; Fukushima, Japan

A VISION FOR THE SUSTAINABLE FUTURE OF THE PROFESSION

One vision for a sustainable future for structural and materials engineering is to align our teaching, research and practice with the 1st key concept of sustainable development. To reorient our curricula to focus on the knowledge and skills needed to address the needs for safe and resilient infrastructure and housing for the 3 billion people living at the base-of-the-pyramid (BOP); earning less than 5 USD per day; many living in informal and illegal settlements (e.g., slums, squatter and displaced persons camps). The choice is vividly shown in Fig.1. Do we continue to teach our students to do what is well-known (i.e., designing "star" buildings in London) or do we teach them how to solve the problems of Cape Town and Fukushima (i.e., sub-standard housing and infrastructure and its resilience to socioeconomic or climatological events.) As materials and structural engineers we should all feel disgraced that we do not know how to provide meaningful input to solve these human catastrophes that are a direct function of the built environment. Such a focus will, of course, require a significant reprioritization and rethinking of every part of the curriculum. It will require courses in social sciences, environmental sciences, geography, world cultures and economics. However, it will bring back to the profession and especially to students of structural engineering a sense of mission and purpose, akin to those now studying environmental engineering and sustainability sciences of various types. It will make us relevant again.

REFERENCES

Post, N.M., (2013), "Four Groups Unite to Promote Structural-Engineer Licensing," ENR 05/15/2013.

Kurrer, K. (2008), "The History of the Theory of Structures: From Arch Analysis to Computational Mechanics," Ernst & Sohn, Berlin.

SEI (2013), "A Vision for the Future of Structural Engineering and Structural Engineers: A Case for Change," Task Committee Report, Structural Engineering Institute, ASCE, Reston, VA.

Williams, S.W. (1997) "The Brown Agenda: Urban Environmental Problems and Policies in the Developing World," Geography, 82, 1, 17-26.

1st Session: Sustainable Material Systems and Ecologies

Nabil Grace, Mena Bebawy: New generation of corrosion-free and long lasting CFRP prestressed concrete highway bridges

Konstantin Kovler: Low-contaminant construction materials in view of cost-benefit analysis

Shiho Kawashima, Pengkun Hou, Mohend Chaouche, Surendra Shah: Enhancing the fresh and hardened properties of concrete through the combined use of nanomaterials and supplementary cementitious materials

Amnon Katz: Recycled aggregate concrete – what else do we need to study?

NEW GENERATION OF CORROSION-FREE & LONG LASTING CFRP PRESTRESSED CONCRETE HIGHWAY BRIDGES

Nabil Grace, PhD, P.E. and Mena Bebawy, PhD
Lawrence Technological University, Southfield, MI 48075, USA
Corresponding Author: Nabil Grace, E-mail: ngrace@ltu.edu

SUMMARY

The use of CFRP materials as an alternative to steel reinforcement in precast prestressed concrete beams have been thoroughly evaluated through experimental and theoretical investigations. Results from these investigations have been deployed in the construction of multiple concrete bridges reinforced, prestressed, and post-tensioned with CFRP.

Keywords: Precast, Prestressed, CFRP, Highway bridges.

INTRODUCTION

In Michigan and other regions with harsh environmental conditions, the use of steel reinforcement in precast prestressed concrete elements poses an overwhelming corrosion and durability problem. Therefore, the use of carbon fiber reinforced polymer (CFRP) materials has been introduced as a non-corrosive alternative to steel. Numerous investigations have been conducted to evaluate the performance of CFRP materials as flexural and shear reinforcement. Half-scale Laboratory models for various beam configurations including box beams, AASHTO I beams, and decked bulb T beams have been constructed with CFRP reinforcement and tested to failure under flexural and shear loads. The results from the experimental investigations were evaluated theoretically and performance criteria have been established.

Motivated by the exceptional performance of CFRP and the results from experimental and theoretical investigations, Authorities in Michigan Department of Transportation (MDOT) have recently besought the deployment of CFRP in bridge construction. Over the last 13 years, four bridges have been constructed in Michigan with CFRP reinforcement; two bridges were fully reinforced and prestressed with CFRP reinforcement with no steel reinforcement, while the other two bridges were transversely post-tensioned with un-bonded transverse post-tensioning CFRP strands.

CFRP MATERIALS FOR PRESTRESSING AND POST-TENSIONING

CFRP materials are anisotropic materials with modulus of elasticity of nearly two thirds that of steel. They do not exhibit any yield plateau. Rather, they exhibit elastic performance to failure, which occurs at a stress level higher than the ultimate strength of steel strands. Therefore, the current investigation focuses on the performance of CFRP materials with respect to aspects such as: effective prestressing force, average prestress loss, ultimate load carrying capacity of beams with CFRP reinforcement, anchorage details, and shear load carrying capacity for members with CFRP stirrups.

Laboratory beams and bridge models with CFRP reinforcement

Three beam configurations with CFRP reinforcement have been evaluated experimentally: (1) side-by-side box beams, (2) AASHTO I-beams, and (3) decked bulb T beams. For each beam configuration, individual control beams as well as a complete bridge model have been constructed and tested to failure.

Control side-by-side box beams had a span of 9.44 m, width of 457 mm, and a total depth of 356 mm including a 76-mm thick cast-in-place deck slab. The bridge model was composed of seven side-by-side box beams connected together using a 76-mm.-thick deck slab, full-depth shear keys cast from non-shrink fast-setting grout, and five transverse post-tensioned diaphragms. Both the longitudinal and transverse reinforcement of the control beams and the bridge model were made of CFRP materials.

Control AASHTO I beam had a span of 12.5 m, a depth of 565 mm, and deck width of 500 mm. The bridge model was composed of five I beams with center to center spacing of 500 mm, which resulted in a total bridge deck width of 2.5 m. The beams were connected together with a 63-mm. deck slab and five transverse diaphragms.

Control decked bulb T beam (Grace et al 2013) had a span of 12.5 m, top flange width of 457 mm and a depth of 406 mm. The bridge model was composed of five decked bulb T beams connected together with shear key joints cast from ultra-high performance concrete and seven full-depth transverse diaphragms. The diaphragms were provided with ducts for possible transverse post-tensioning.

All control beams and bridge models were subjected to loading and unloading cycles and then loaded to failure under either flexural or shear loading setup. The age of the specimens on the test day ranged from 28 days to 18 months. Overall, the test results demonstrated that the performance of CFRP either as shear or flexural reinforcement is consistent and can be safely predicted using the appropriate theoretical approach.

Field deployment of CFRP in bridge construction

The first bridge in USA with CFRP reinforcement as the main reinforcement was Bridge Street Bridge, Southfield, MI. It was completed and opened for traffic in 2001. The bridge composed of three spans with average span length of 21 m. Each span consisted of four double T beams prestressed longitudinally with pre-tensioned CFRP strands and external un-bonded post-tensioning CFRP cables (Figure 1). The beams were connected transversely with a 76-mm thick reinforced deck slab and un-bonded CFRP transverse post-tensioning.

The second bridge with CFRP components was Pembroke Bridge over M-39 in Detroit, MI. This is a two-span side-by-side box beam bridge that was completed and opened for traffic in 2011. The beams in this bridge are transversely post-tensioned with un-bonded CFRP strands passing through six transverse diaphragms for each span. Formerly, this type of bridges used to be transversely post-tensioned with bonded steel strands, a technique that posed a restriction on maintenance and partial deck replacement (Grace et al 2012).

The third bridge with CFRP component was the M-50/US-127 Bridge over Norfolk Southern Rail Road (NSRR) in Jackson, MI. This bridge was opened for traffic in 2012. It is a three-span side-by-side box beam bridge that is also provided with un-bonded CFRP transverse post-tensioning strands to ensure the integrity of the bridge in the transverse direction.

The fourth bridge (Figure 1) with CFRP reinforcement was completed in 2013 and is carrying M-102 over Plum Creek in Southfield, MI. This 21-m-long simply supported bridge consists of 8 spread box beam supporting a 230-mm.-thick reinforced deck slab. Both the beams and the deck slab are completely reinforced with CFRP reinforcement. Each beam is prestressed with 37 CFRP strands with a diameter of 15.2 mm and is also provided with CFRP stirrups with a diameter of 15.2 mm.

Figure 1: Left: Bottom view of Bridge Street Bridge. Right: Construction of M-102 Bridge.

CONCLUSIONS

CFRP materials promote the construction of an infrastructure system with a long lifespan and minimum maintenance cost while satisfying the need for increased load carrying capacity and traffic safety.

REFERENCES

Grace, N., Ushijima, K., and Bebawy, M., 2013 “CFCC Decked Bulb T Beam Bridge System for Accelerated Bridge Construction,” fib symposium, Tel-Aviv, Israel, April, pp. 463-466.

Grace, N., Jensen, E., and Bebawy, M., 2012, “Optimal Transverse Post-tensioning Arrangement for Side-by-Side Box Beam Bridges,” PCI Journal, Vol. 57, No. 2, Spring, pp. 48-63.

LOW-CONTAMINANT CONSTRUCTION MATERIALS IN VIEW OF COST-BENEFIT ANALYSIS

Konstantin Kovler
National Building Research Institute – Faculty of Civil and Environmental Engineering, Technion – Israel Institute of Technology
E-mail: cvrkost@technion.ac.il

SUMMARY

In the last years international society became aware of the problem of the increasing production of industrial waste. Indeed, the construction industry uses large amounts of industrial by-products. The advantages of utilization of some of these by-products in construction are well-known, as well as numerous technological and environmental problems caused by an elevated content of chemical and radioactive contaminants and the need to purify the materials before their final uses.

Keywords: Building materials, contaminants, NORM, cost-benefit analysis

What are the optimum requirements for low-contaminant construction materials from the points of view of the customer, producer and of the society? In the last years international society became aware of the problem of the increasing production of industrial waste. Indeed, the construction industry uses large amounts of by-products from other industries. The advantages of utilization of coal fly ash, slag and some other industrial by-products in construction are well-known, as well as numerous technological and environmental problems caused by an elevated content of chemical and radioactive contaminants and the need to purify the materials (or dilute them) before their final uses in construction.

Let us consider, as an example, the situation around production and use of construction materials with enhanced levels of radioactive contaminants. The depletion of energy resources and raw materials demands introduction of sustainability in construction sector. In the development of new synthetic building materials the reuse of NORM (Naturally Occurring Radioactive Materials) residue streams becomes a necessity. NORM residues, such as coal fly ash produced in large quantities from coal burning, slags from steelworks and metal recycling industries, phosphogypsum – the by-product of the phosphate industry, and red mud of the aluminum processing industry, are investigated for various applications in construction materials. Fig. 1 uses the data available in RP-112 (1999) and shows typical effective specific activity concentrations of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in common building materials and industrial by-products used for building materials in the EU. Using NORM residues in the production of new types of synthetic building materials for buildings raises concerns among authorities, public and scientists on the potential gamma exposure from building materials to occupants and on indoor air quality related mainly to possible enhanced radon gas concentrations in living spaces of the buildings. Many NORM residues currently end up at landfills since so far no acceptable compromise is found between economical reuse options and health related legislation.

Coal fly ash is one of the most known examples of such industrial by-products. Its use in concrete is a well-recognized source of gamma exposure that is due to the presence of activity concentrations of ^{226}Ra, ^{232}Th and, to a lesser extent, ^{40}K, while its effect via radon exhalation is controversial, due to the low emanation coefficient from the ash (Kovler, 2012). Large quantities of coal fly ash are expelled from coal-fired thermal power plants and these may contain enhanced levels of radionuclides along with other toxic elements. More than 280 Mt of coal ash (fly ash and bottom ash combined) are produced annually. About 40 Mt of these are used in the production of bricks and cement (IAEA, 2003). Since most of the process residues further processed into building materials do not meet the required technical specifications, they are typically mixed with pristine raw materials. The net effect is a dilution of the NORM content relative to the process residues.

Because there is no threshold value for stochastic effects, the aim of radiological protection of the public is not to just keep within the dose limit, but to ensure that protection is optimized and the exposures are all kept as low as reasonably achievable (ALARA principle), economic and social factors being taken into account. ALARA concept provides that no level of radiation exposure is acceptable without justification. Restricting the use of certain building materials might have significant economical, environmental or social consequences, which should be assessed and considered when establishing binding regulations (RP-112, 1999).

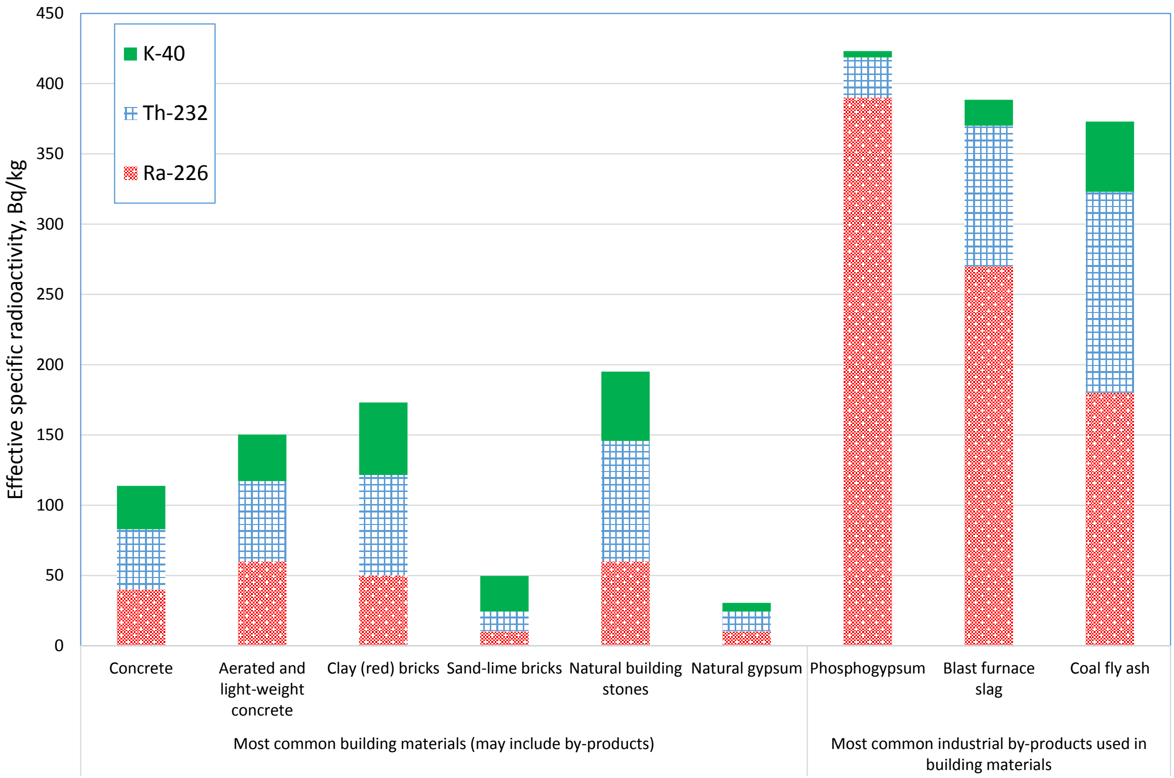


Figure 1. Typical effective specific activity concentrations of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in common building materials and industrial by-products used for building materials in the EU

The tendency to develop stricter environmental norms is observed in the last years in different countries. However, the trials to introduce too strict regulations fail without conducting an appropriate cost-benefit analysis. The stricter are the norms, the more expensive is their implementation. Moreover, cost-benefit analysis shows than in the countries with high GNP per capita the expenses for radiation mitigation are also high (Kovler, 2009).

On the other hand, cost-benefit analysis ignores several questions – such as who suffers as a result of environmental problems and, therefore, threatens to reinforce existing patterns of economic and social inequality (Heinzerling & Ackerman 2002). Poor countries, communities, and individuals are likely to express less “willingness to pay” to avoid environmental harms - simply because they have fewer resources. Moreover, the highly complex, resource-intensive, and expert-driven nature of this method makes it extremely difficult for the public to understand and participate in the process.

The paper makes an attempt to analyse consequences, pros and contras of the implementation of cost-benefit analysis in legislation, as well as an alternative solution - "information-based" regulation. The example of the latter one can be the Swan label (the official Nordic ecolabel, introduced by the Nordic Council of Ministers) demonstrating that a construction product is a sound environmental choice.

REFERENCES

Heinzerling, L.; Ackerman, F. (2002). *Pricing the priceless: Cost-benefit analysis of environmental protection.* Georgetown University.

IAEA. (2003). *Extent of Environmental Contamination by Naturally Occurring Radioactive Material (NORM) and Technological Options for Mitigation.* Vienna, Austria: International Atomic Energy Agency.

Kovler, K. (2009). Radiological constraints of using building materials and industrial by-products in construction. *Construction and Building Materials*, 23, 246-253.

Kovler, K. (2012). Does the utilization of coal fly ash in concrete construction present a radiation hazard? *Construction & Building Materials*, 26 (4), 158-166.

RP-112. (1999). *Radiological Protection Principles Concerning the Natural Radioactivity of Building Materials.* Luxembourg: European Commission.

ENHANCING THE FRESH AND HARDENED PROPERTIES OF CONCRETE THROUGH THE COMBINED USE OF NANOMATERIALS AND SUPPLEMENTARY CEMENTITIOUS MATERIALS

Shiho Kawashima[a], Pengkun Hou[b], Mohend Chaouche[c], and Surendra Shah[d]
[a]Columbia University, New York, New York, USA, [b]University of Jinan, Jinan, Shandong, China, [c]CNRS, Ecole Normale Superieure de Cachan, Cachan, France, [d]Northwestern University, Evanston, Illinois, USA,
Corresponding Author: Shiho Kawashima, E-mail: sk2294@columbia.edu

SUMMARY

This presents a summary of studies on the activation of fly ash and control of rheology through nanomodification. Through seeding effects and increased reactivity, nanosilica accelerates production of calcium hydroxide, which can help activate pozzolanic reaction of fly ash. Nanoclays can significantly increase the thixotropy of fresh fly ash-cement systems.

Keywords: Fly ash, nanosilica, nanoclay, cement rheology, nanomodification

INTRODUCTION

Given that cement production is high in carbon emissions and that concrete is so widely utilized in construction, it is necessary to make it a greener infrastructural material. This is possible through substantial replacement of cement with supplementary cementitious materials, such as fly ash. The positive effects of this approach are twofold. First, it reduces cement content of concrete, which will reduce its carbon footprint. Second, it utilizes a waste material, as fly ash is a coal combustion by-product, which must be stored in landfills and enclosures if unused. Although fly ash can introduce a number of beneficial properties to concrete, it has effects on the early-age properties that are undesirable from a constructability standpoint, namely lower rate of hydration, slowed setting, and low early-age compressive strength gain.

MAIN BODY OF EXTENDED ABSTRACT

In order to facilitate the use of fly ash, it is necessary to develop strategies to produce fly ash-cement concrete that still exhibits properties comparable to cement concrete. Here, the approach of nanomodification is explored. The use of nanoparticles can introduce a number of beneficial effects due to their fine size and corresponding high specific surface area. This summary will highlight the results of studies on nanosilica and nano-sized attapulgite clays. The study on nanosilica focuses on the mechanisms underlying the effect of the pozzolanic nanoparticle on the long-term compressive strength gain of fly ash-cement mortars. The study on nano-sized clays shows that they significantly increase degree of thixotropy, demonstrating their potential to tailor the placement performance of fresh fly ash-cement systems.

Nanosilica

Numerous studies have demonstrated that nanosilica can accelerate rate of cement hydration through seeding effects and increased pozzolanic reactivity. However, the effect of nanosilica on later-age strength gain has not been thoroughly investigated. As part of an investigation by the authors, it was found that nanosilica enhanced early-age strength (at 7d), which is in agreement with most other studies, but led to a reduction in rate of strength gain over time (at 90 d). The mechanisms underlying the effect of nanosilica on the long-term strength gain of fly ash-cement systems will be discussed here through results of TGA and SEM-EDS (Hou et al 2012, Hou et al 2013a, Hou et al 2013b).

In a nanosilica-modified fly ash-cement system, both nanosilica and fly ash participate in pozzolanic reaction. Therefore, they are in direct competition with each other for CH. To observe this, the CH content over time of 40% fly ash-cement pastes with and without a 5% addition of colloidal nanosilica (CNS) were compared against that of plain cement paste. The results are shown in Figure 1. 40% replacement of cement with fly ash (40FA 0%CNS) resulted in a substantial decrease in CH due to the reduction in cement hydration that occurs in the system compared to the plain cement paste. The 40% fly ash-cement paste exhibited an increase in CH early on but was followed by a decrease by 56 d, which can be attributed to CH consumption by fly ash. With the addition of 5% CNS, the overall CH content decreased even further and there was no initial increase. This can be attributed to the CH consumption by the CNS, which occurs at a higher rate than fly ash due to its increased reactivity. This can partially explain the reduction in rate of strength gain of the CNS-modified fly ash-cement mortars – the higher rate of CH consumption by CNS left less CH for the fly ash to consume to sustain long-term strength gain that is typically characteristic of fly ash-cement systems.

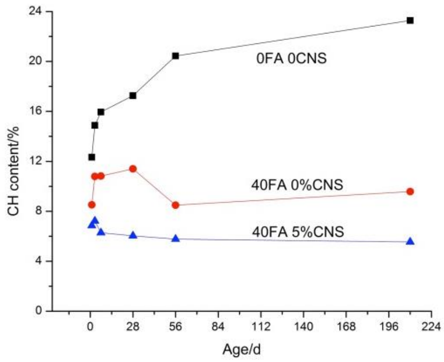


Figure 1: TGA results: CH content of plain cement paste (0FA 0CNS) and 40% fly ash-cement paste (40FA) with 0% and 5% CNS (Hou et al. 2013b)

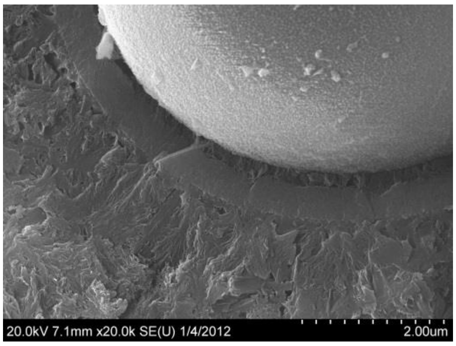


Figure 2: SEM images of 7 month old fly ash-cement samples with CNS (Hou et al. 2012).

Figure 2 presents SEM images of the microstructure of 7-month old fly ash-cement pastes with nanosilica. There was an apparent coating around the fly ash in the sample with CNS that was not present in the control paste. EDS results revealed an average Ca/Si ratio of 1.38, which was smaller than that of the adjacent C-S-H gel of 1.66. It has been reported that C-S-H gel with a low Ca/Si ratio is less permeable (Garrault and Nonat 2001). And in other work, nanosilica hydration gel has been observed to seal off C_3S particles from the pore solution and stop hydration (Thomas et al. 2009). Thus, it was deduced that the outer layer of compacted hydrates, which was formed by the pozzolanic reaction of nanosilica and CH, hindered ion diffusion and thus hindered fly ash hydration at later ages. This can, thereby, partially explain the reduction in rate of strength gain exhibited by the nanosilica-modified fly ash-cement mortars.

Attapugite clay

Fly ash can introduce beneficial effects to cement and concrete rheology, including segregation resistance and flowability. However, for select applications such as slipform paving, shotcrete, and reducing formwork pressure, further tailoring of the rheological properties is desired, namely enhanced degree of thixotropy – structural breakdown under shear and recovery at rest. For practical purposes, this is the balance between high flowability during casting and fresh-state stiffness upon placement. One set of results from a series of studies (Ferron et al. 2013, Tregger et al. 2010) will be discussed here on how highly purified, nano-sized attapulgite clays can help strike this balance in fly ash-cement systems (Kawashima et al. 2013, Kawashima et al. 2014). Ultimately this can lead to tailoring of the fresh-state properties to enable more low-energy construction processes, including reducing the need to apply vibration to consolidate and the amount of formwork needed.

The probe tack test is widely used to complement rheological characterization of soft polymer adhesives. Performed on a rotational rheometer with a parallel-plate setup, it measures normal force evolution at varying plate velocities. It can capture static cohesion strength at diminishingly low plate velocities and dynamic viscosity at high plate velocities. The results of the tack test for fresh pastes are shown in Figure 3. In both mixes with and without fly ash, the addition of nanoclay increases normal force throughout, indicating increase in both cohesion and viscous dissipation. Focusing on the combined effect of clay and fly ash, it appears that the clay can significantly increase cohesion while fly ash helps to maintain relatively low flow resistance. For instance, comparing the mixes with clay, both mixes exhibit comparable cohesion strength but fly ash effectively reduces peak force at higher velocities. These properties have good implications on thixotropy where high initial flowability during casting and high fresh state stiffness after placement are desired.

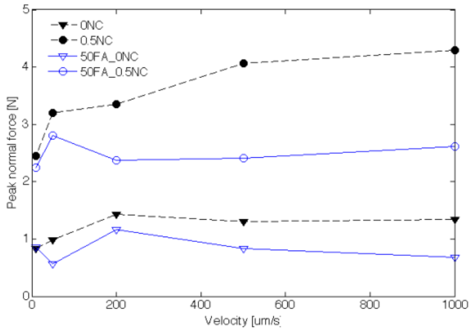


Figure 3: Normal force versus plate velocity of cement pastes with fly ash (FA) and nanoclay (NC) (Kawashima et al. 2014).

CONCLUSIONS

This was a summary that discussed two studies pertaining to the use of nanoparticles to facilitate the replacement of cement with fly ash. The mechanisms underlying the effect of nanosilica on fly-ash cement systems were investigated. Decrease in rate of strength gain over time was attributed to a) high rate of CH consumption by nanosilica leaving less CH for fly ash to react with at later ages and b) a compact coating that forms around fly ash particles and hinders their ability to participate in pozzolanic reaction. And the results of the tack test gave evidence that mix design with clay and fly ash can help balance flowability and fresh-state stiffness.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support from the Infrastructure Technology Institute at Northwestern University and Tennessee Valley Authority (TVA) and Oak Ridge Associated Universities (ORAU)(Award 105866).

REFERENCES

Ferron, R. D., S. Shah, E. Fuente and C. Negro (2013). "Aggregation and breakage kinetics of fresh cement paste." Cement and Concrete Research 50(0): 1-10.

Garrault, S. and A. Nonat (2001). "Hydrated Layer Formation on Tricalcium and Dicalcium Silicate Surfaces: Experimental Study and Numerical Simulations." Langmuir 17(26): 8131-8138.

Hou, P., K. Wang, J. Qian, S. Kawashima, D. Kong and S. P. Shah (2012). "Effects of colloidal nanoSiO2 on fly ash hydration." Cement and Concrete Composites **34**(10): 1095-1103.

Hou, P., S. Kawashima, D. Kong, D. Corr, J. Qian and S.P. Shah (2013a). "Modification effects of colloidal nanoSiO_2 on cement hydration and its gel property," Composites Part B: Engineering, 45(1): 440-448.

Hou, P., S. Kawashima, K. Wang, D.Corr, J. Qian and S.P. Shah (2013b). "Effects of colloidal nanosilica on rheological and mechanical properties of fly ash-cement mortar," Cement and Concrete Composites, 35(1): 12-22.

Kawashima, S., M. Chaouche, D. Corr and S.P. Shah (2014). "Influence of purified attapulgite clays on the adhesive properties of cement pastes as measured by the tack test," Cement and Concrete Composites, In Press.

Kawashima, S., M. Chaouche, D. Corr and S.P. Shah (2013). "Rate of thixotropic rebuilding of cement pastes modified with highly purified attapulgite clays," Cement and Concrete Research, 53(0): 112-118.

Thomas, J. J., H. M. Jennings and J. J. Chen (2009). "Influence of Nucleation Seeding on the Hydration Mechanisms of Tricalcium Silicate and Cement." The Journal of Physical Chemistry C 113(11): 4327-4334.

Tregger, N.A., M.E. Pakula, and S.P. Shah (2010). "Influence of clays on the rheology of cement pastes," Cement and Concrete Research, 40 (3), 2010, pp. 384-391.

RECYCLED AGGREGATE CONCRETE – WHAT ELSE DO WE NEED TO STUDY

Amnon Katz
National Building research Institute, Faculty of Civil and Environmental Engineering
Technion – Israel Institute of Technology
E-mail: akatz@Technion.ac.il

SUMMARY

Thousands of papers have been published in the past 20 years about the properties of recycled aggregate concrete but the way to implement it use in daily life seems still long. The reasons for lack of usage and the need for new direction of research are discussed in this paper.

Keywords: construction and demolition waste, recycled concrete, by-products.

CURRENT RESEARCH ON RECYCLED AGGREGATE CONCRETE

Construction and demolition waste (CDW) comprise a significant environmental burden in our society. In the developed countries, it is estimated at about 0.3-0.5 ton/capita/year leading to the accumulation of ~4 million tons/year in Israel or approx. 160 million tons/year in the US (update: 2009). Only 20-30% of the waste is recycled and the rest is directed to landfilling sites (official and non-official). Recycling of this waste attracts a global interest is serves as a source for intensive research worldwide.

Search in Google scholar for "recycled aggregates" yielded over 5000 publications through the year 2013, ~2700 publications in 2003 and about 1000 in 1993. This demonstrates the increased interest in this topic although the increased coverage of literature sources through the years should be remembered as well. Several RILEM state-of-the-art reports have been published through the years (Nixon 1977, Hansen 1986, Hansen 1992, Hendriks et al. 2005, and Vazques 2013), all of them covering significant amount of literature.

Checking the titles of these publications shows that the topics for research remained quite similar throughout the years e.g. properties of concrete with recycled aggregates (strength, durability, shrinkage etc.), structural properties of concrete elements with recycled aggregates, special recycled aggregates (non CDW). It is possible to say that the amount of knowledge accumulated until today regarding the use of CDW in concrete is tremendous. The actual use of CDW in the production of new concrete, though, is very limited, to say the least.

Hir otak a K A WA NO identified 10 parameters that are well agreed as barriers against reuse of CDW for the production of new concrete:

- Lack of suitable law
- Lack of codes, standards, specifications
- Cost
- Poor image
- Lack of experience
- Low quality
- Variation in quality
- Too many kinds of wastes
- Inefficient supply system
- Lack of proper information

Some of these parameters are inter-related. Lack of code, laws and proper information are all tied together; the information exists, laws also exist but the standards are not well defined yet. Cost depends on the cost of landfilling on the one hand, and the price of new aggregates, on the other hand. Both are dominated by governments. It seems that the most important parameters inhibiting wider use of recycled CDW for the production of new concrete are related to the quality of the recycled aggregates. The quality of recycled aggregates from CDW is lower than that of virgin aggregates. In addition, the standards for virgin aggregates set relatively high criteria that ensure high quality that cannot affect concrete properties, thus water to cement ratio becomes the only parameter dominating concrete properties. Lower quality of aggregates that varies from day to day inhibits extensive use of recycled aggregates. It is possible to overcome the problems of lower quality by properly adjusting the composition of the mix, mainly by somewhat lowering the water to cement ratio. This conclusion is well agreed by all the studies published on this topic. Yet, the adjustment should be done on a daily basis and preserving the structural properties is not obvious.

NEW RESEARCH FIELDS NEEDED

The structural properties of concretes with the same strength grade but different sources of aggregates have been studied to much lesser extent. Many studies compare non-equivalent concretes, i.e. same mix composition but with different aggregates, namely, not having the same strength (for example, Arezoumandi et al. 2014). The different behavior is expected. An important question that remains open is whether the structural properties are different when the same strength is maintained. After all, concrete is characterized by its strength, not by the percentile of aggregate replaced.

Another important problem is the effect of varying properties on the reliability of the new concrete, both in concrete technology and design. Can we maintain the same safety factors in design as before? Should new quality assurance procedures be developed to ensure reliable concrete production that satisfies all the safety criteria we have today?

Advanced knowledge in the above fields can promote usage of recycled aggregates for high quality applications, reduce the environmental load of CDW and reduce extraction of virgin materials.

REFERENCES

Arezoumandi Mahdi, Smith Adam, Volz Jeffery S., Khayat Kamal H., (2014), "An experimental study on shear strength of reinforced concrete beams with 100% recycled concrete aggregate", *Construction and Building Materials*, Volume 53, Pages 612–620.

Israel ministry for environmental protection internet site http://www.sviva.gov.il/subjectsEnv/Waste/Types/ConstructionWaste/Pages/default.aspx, accessed January 30, 2014

EPA Buildings and their Impact on the Environment: A Statistical Summary, Revised April 22, 2009, http://www.epa.gov/greenbuilding/pubs/gbstats.pdf

Hir otak a K A WA NO, "The state of using by-products in concrete in japan and outline of JIS/TR on “recycled concrete using recycled aggregate”, Proceedings of the 1st *fib* congress. http://www.pwri.go.jp/eng/activity/pdf/reports/kawano01.pdf (accessed January 30, 2014).

Hansen T.C., (1986) "Recycled aggregates and recycled aggregate concrete second state-of-the-art report developments 1945–1985, Materials and Structures, Vol. 19, pp. 201-246.

Hansen T.C. (Ed.) (1992), "Recycling of demolished concrete and masonry", RILEM report #6, E&FN Spon publishers.

Hendriks Ch. F., Janssen G.M.T. and Vázquez E. (2006), "Use of Recycled Materials - Final Report of RILEM TC 198-URM", RILEM Report #30, RILEM Publicatins.

Nixon P.J. (1978), "Recycled concrete as an aggregate for concrete-a review", RILEM TC-37-DRC, Materials and structures, Vol. 11, pp. 371-378.

Vazquez E. (Ed.)(2013), "Progress of recycling in the built environment", RILEM TC 217-PRE report, Springer.

2nd Session: Innovative Materials for Sustainable Buildings

Oded Amir: On the prospects of applying structural optimization methodologies for achieving sustainable structural design

Bora Gencturk: A new framework for lifetime sustainability assessment of reinforced concrete structures in hazard prone regions

Erez Gal, Lior Nachum, Alva Peled: Sustainability aspects of textile reinforced concrete (TRC) structural components

Vikram Yadama: Natural fiber sandwich panels for building envelopes

Proceedings of the US-Israel Workshop on:
Industrial Ecology in Multi-Scale Design and Construction of Sustainable Built Environments
9-11 March 2014, Tel Aviv, ISRAEL

ON THE PROSPECTS OF APPLYING STRUCTURAL OPTIMIZATION METHODOLOGIES FOR ACHIEVING SUSTAINABLE STRUCTURAL DESIGN

Oded Amir
Faculty of Civil and Environmental Engineering, Technion – Israel Institute of Technology
Corresponding Author: Oded Amir, E-mail: odedamir@cv.technion.ac.il

SUMMARY

Structural optimization methodologies, particularly topology optimization, have been successfully applied for reducing weight of load-bearing structural components in the automotive and aircraft industries. Significant research efforts are directed towards extending the scope of application also to other engineering disciplines. Emerging applications driven by the goals of sustainable design are presented herein.

Keywords: Structural optimization, topology optimization, sustainable design

INTRODUCTION

In its basic form, the discipline of structural optimization deals with integrating structural analysis and structural design into a single process, aimed at finding the best possible assemblage of material for sustaining a given load. Traditionally, such optimal design procedures are divided into three categories according to the type of parameters to be considered as design variables. *Topology optimization* determines the structural layout. In skeletal structures such as trusses and frames, the optimal member connectivity is sought; in continuum structures such as plates, shells or walls, the distribution of material is optimized. *Shape optimization* determines the optimal form of a given topology, for example: node locations in skeletal structures or the contour of the boundaries in a continuum structure. Finally, *sizing optimization* determines geometrical parameters such as cross section sizes in skeletal structures or variable thicknesses of continuum structures.

This abstract focuses on the particular prospects of topology optimization as a novel computational tool that can be applied also for achieving sustainability objectives. Following intense research since its introduction (Bendsøe and Kikuchi 1988, Bendsøe 1989), the method is now considered an integral part of the design process of load-bearing structural components in the automotive and aircraft industries. Significant research effort has been invested over the past decade in further development of the method for utilization in other engineering fields. Some of the most exciting and promising examples are optimization of photonic crystal waveguides; microstructural design of materials with extreme properties; systematic design of phononic band-gap materials; and design of micro-actuators and micro-mechanisms.

TOPOLOGY OPTIMIZATION FOR SUSTAINABLE DESIGN

Up to date, design objectives related to sustainability have not been investigated extensively by researchers in the field of topology optimization, leaving much room for new ideas and insights. Several recent contributions are reviewed in the following, all involving novel computational procedures based on topology optimization.

Reducing weight of reinforced concrete members

Growing awareness for sustainable development calls for reducing the consumption of materials and resources used by the construction industry. Of particular importance is to minimize the consumption of concrete: in 2011, approximately 1.5 cubic meters of concrete were produced for every person on Earth (van Oss, 2012). Production of cement, the main ingredient in concrete mixtures, is responsible for roughly 5% of man-made carbon dioxide emissions annually (World Business Council for Sustainable Development, 2012). This motivates the search for design methodologies that facilitate weight reduction of concrete structures while maintaining the required stiffness.

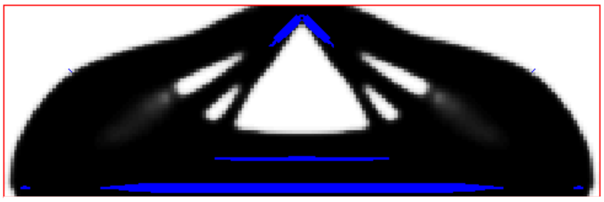


Figure 1: Optimized layout of a simply-supported reinforced concrete deep beam subject to a point load. Black = concrete; white = void; blue lines = rebars.

A computational framework for simulation-based topology optimization of reinforced concrete structures was proposed recently (Amir, 2013). Concrete was represented by a gradient-enhanced continuum damage model with strain-softening and reinforcement was modeled as elastic bars that are embedded into the concrete domain. Analytical adjoint sensitivity analysis was derived in complete consistency with respect to path-dependency and the nonlocal features of the model. The distribution of both concrete and reinforcement bars was optimized simultaneously. The objective was to minimize the volume of concrete subject to a compliance constraint as well as a constraint on the volumetric ratio of reinforcement. With respect to the load carried per unit weight, it was shown that the optimized designs perform 20% to 30% better than standard structures. The resulting designs outperformed those obtained by standard procedures based on linear elasticity, due to the consideration of the true material properties. A representative example is shown in Figure 1.

Improving thermal resistance of masonry blocks

The need to reduce the energy consumed for maintaining a comfortable indoor environment motivates the development of building envelopes with low thermal conductivity. This design objective gives rise to an emerging application of topology optimization, focusing on the layout of masonry blocks. Sousa et al (2011) proposed a single-leaf masonry wall (see Figure 2) obtained by coupling finite element simulations with an evolutionary algorithm. The suggested approach is essentially a sizing optimization, where several geometrical distances that define a staggered-type void distribution serve as design variables. More general layouts were obtained by Bruggi and Taliercio (2013), who suggested a continuum topology optimization procedure for determining the distribution of material and void within a masonry block. Their design objective was to minimize thermal transmittance while maintaining the required mechanical performance, see some examples in Figure 3.

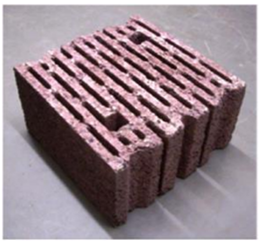


Figure 2: Optimized single-leaf masonry block (Sousa et al, 2011).

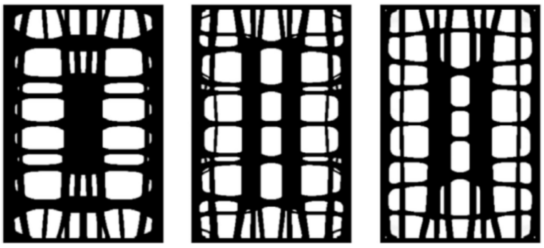


Figure 3: Various layouts of rectangular masonry bricks, minimizing thermal transmittance while constraining the in-plane and out-of-plane stiffness (Bruggi and Taliercio, 2013).

CONCLUSIONS

Structural optimization methodologies provide a very effective means of achieving novel designs with superior performance. Various goals of sustainable design, such as reducing material consumption and improving thermal insulation can be pursued. Fruitful research will most likely require collaboration between experts in several disciplines, such as construction materials, thermal performance, energy efficiency and structural optimization.

REFERENCES

Amir, O. "A topology optimization procedure for reinforced concrete". *Computers and Structures,* vol. 114, pp. 46-58, 2013.

Bendsøe, M. P. and Kikuchi, N. "Generating optimal topologies in structural design using a homogenization method". *Computer Methods in Applied Mechanics and Engineering,* vol. 71, pp. 197-224, 1988.

Bendsøe, M.P. "Optimal shape design as a material distribution problem". *Structural Optimization,* vol. 1, pp. 193-202, 1989.

Bruggi, M. and Taliercio, A. "Design of masonry blocks with enhanced thermomechanical performances by topology optimization". *Construction and Building Materials,* vol. 48, pp. 424-433, 2013

van Oss, H. G. "Mineral Commodity Summaries – Cement". *U.S. Geological Survey,* 2012.

Sousa, L. C., Castro, C. F., António, C. C. and Sousa, H. "Topology optimisation of masonry units from the thermal point of view using a genetic algorithm". *Construction and Building Materials,* vol. 25, pp. 2254-2262, 2011.

World Business Council for Sustainable Development. *The Cement Sustainability Initiative: executive brief*, 2012.

A NEW FRAMEWORK FOR LIFETIME SUSTAINABILITY ASSESSMENT OF REINFORCED CONCRETE STRUCTURES IN HAZARD PRONE REGIONS

Bora Gencturk
Assistant Professor, Civil and Environmental Engineering, University of Houston, Houston, TX 77204-4003
Corresponding Author: E-mail: bgencturk@uh.edu

SUMMARY

The objective of this short article is to highlight the main research needs towards establishing resiliency as a key component of sustainability with a special focus on reinforced concrete structures subjected to earthquakes. Brief findings from a recent study are included to reinforce the discussion.

Keywords: Reinforced concrete, sustainability, resiliency, life-cycle assessment performance-based earthquake engineering.

INTRODUCTION

The importance of sustainable as an integral component of civil infrastructure construction and maintenance is now widely acknowledged. A prime example is the American Society of Civil Engineer's Policy Statement 517 (ASCE, 2009), which underlines the necessity of sustainable development to address the needs of human kind in the coming decades. When it comes to sustainability of new construction, the three key components are human safety, environmental impacts and financial considerations. However, we see that most commonly used sustainability assessment approaches, such as the Leadership in Energy and Environmental Design (LEED), do not give credit for improved structural performance, hence are incapable of addressing issues related to hazard resiliency. At the same time, for a structure located in a hazard prone region, sustainability carries little meaning if the structure does not show adequate resilience against extreme events. An outstanding example is the recent hurricane Sandy in the United States, which caused considerable damage in New England, including New York where there exist the largest number of "sustainable" buildings in the United States (Zolli, 2012). Previous studies incorporating the effects of natural hazards have only addressed individual components of a sustainability assessment, i.e. cost (e.g., Mitropoulou, Lagaros et al., 2011), environment (e.g., Arroyo, Teran-Gilmore et al., 2012) or society (e.g., Ang and Lee, 2001). Recently, Gencturk and Hossain (2014) have proposed a comprehensive life-cycle assessment framework which address all three components of sustainability. Although being applicable to all structural types and hazards, the details of the framework were developed for reinforced concrete (RC) buildings subjected to earthquakes. This framework is described in the following section.

SUSTAINABILITY ASSESSMENT OF STRUCTURES IN HAZARD PRONE REGIONS

The proposed process of lifetime sustainability assessment is shown in Figure 1. The performance-based earthquake engineering (PBEE) methodology, which consists of consecutive hazard, structural, damage and loss analysis, is adopted as the overarching structure for the framework. The location of the structure determines hazard modeling, which consists of the selection and scaling of earthquake ground motions. Based on the initial design of the structure, a simplified computer model is created and analyzed for conformance to design standards. If the initial model conforms to design standards, a more detailed computer model is created for inelastic dynamic analysis using the ground motions from the hazard modeling. This approach is implemented to eliminate the additional computational demand from inelastic analysis of the models that are not acceptable as design options. A damage assessment of the structure is performed to determine the number of deaths and injuries,

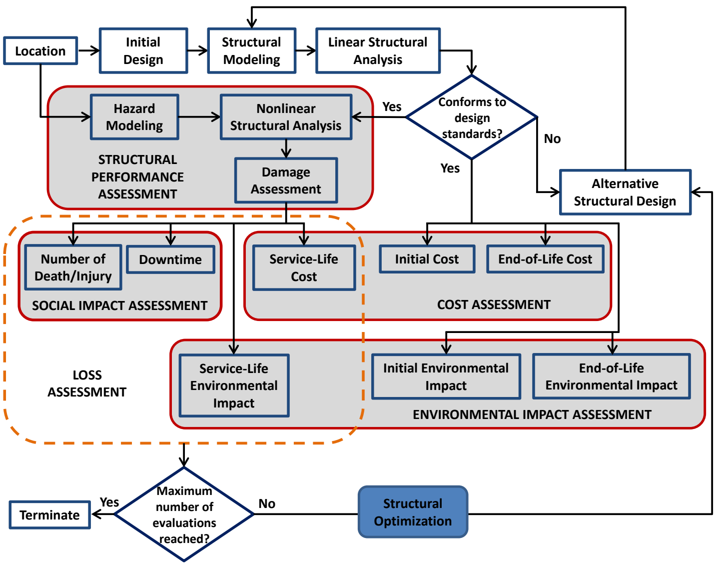


Figure 1: Proposed framework for lifetime sustainability assessment (Gencturk and Hossain, 2014)

and downtime (social impacts), service-life cost (repair cost of seismic damage), and service-life environmental impacts (resulting from the repair activities). At the same time for a given design, initial and end-of-life cost and environmental impacts are calculated. The service-life assessment of social, economic and environmental impacts constitute the loss assessment step according to PBEE methodology. Various sources of aleatory and epistemic uncertainty are accounted for in different steps of the evaluation.

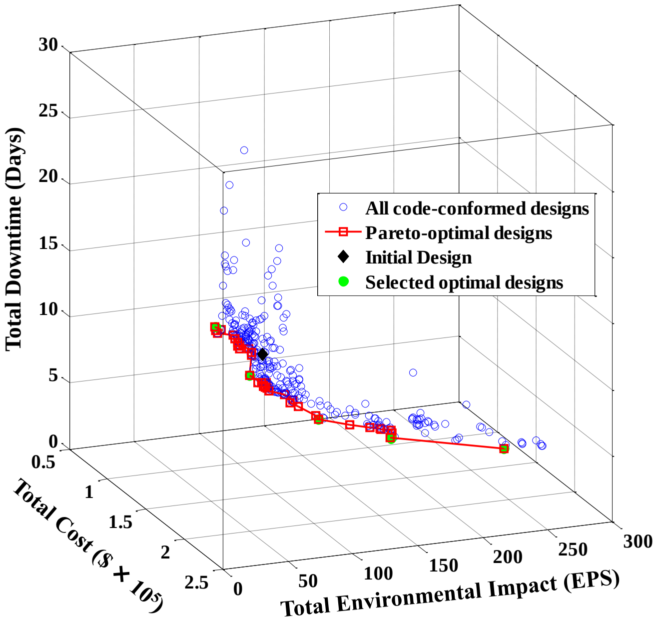


Figure 2: Sample results from multi-objective optimization for sustainability (Gencturk and Hossain, 2014)

This entire evaluation is placed inside a multi-objective optimization with total cost, and total environmental and total social impact being the three objective functions to be minimized subject to strength and serviceability constraints as per the governing design code provisions. The decision variables are selected as the cross-sectional dimensions of the structural elements as well as the reinforcement ratios. Figure 2 shows sample results of the multi-objective optimization in the solution space for a four story RC building where total downtime (in days), total cost (in $), and total environmental impact [in environmental performance score (EPS) according to Lippiatt (2007)] are used as the indicator for social impact, and economic and enviromental consequences, respectively.

CONCLUSIONS

Although a great momentum has been achieved in the last decade towards more sustainable construction, there is a clear lack of resiliency component in current approaches for sustainability assessment. Here, a framework for lifetime sustainability assessment has been briefly reviewed. This framework addresses all three essential components of sustainability: economy, human safety and environmental impacts for structures in hazard prone regions. Various challenges have been faced in developing this framework, which are identified here as the future research needs. Specifically, there is no uniformly accepted and comprehensive cost and environmental impact databases for reinforced concrete construction. There is significant variation in the definition of damage states by different researchers, which leads to significant uncertainty in loss assessment. In addition, information needed to quantify the uncertainty in repair cost, environmental impact and downtime for a given damage condition is not readily available. Further research is also needed to quantify the impacts of damage to nonstructural components.

REFERENCES

Ang, A. H. S. and Lee, J.-C. (2001). "Cost Optimal Design of R/C Buildings," Reliability Engineering & System Safety, 73(3), 233-238.

Arroyo, D., Teran-Gilmore, A. and Ordaz, M. (2012). "Seismic Loss Estimation Including Environmental Losses." *15th World Conference on Earthquake Engineering*, September 24-28, Lisbon, Portugal.

ASCE (2009). *Achieving the Vision for Civil Engineering in 2025: A Roadmap for the Profession*, American Society of Civil Engineers, Available from: http://www.asce.org/Content.aspx?id=8480, Accessed on July 12, 2013.

Gencturk, B. and Hossain, K. A. (2014). "Life Cycle Sustainability Assessment of RC Buildings in Seismic Regions Based on Cost, Environmental and Social Impacts," Structure and Infrastructure Engineering: Maintenance, Management, Life-cycle Design and Performance, under review.

Lippiatt, B. C. (2007). *BEESRG 4.0: Building for Environmental and Economic Sustainability Technical Manual and User Guide*, National Institute of Standards and Technology (NISTIR), Gaithersburg, MD.

Mitropoulou, C. C., Lagaros, N. D. and Papadrakakis, M. (2011). "Life-Cycle Cost Assessment of Optimally Designed Reinforced Concrete Buildings under Seismic Actions," Reliability Engineering & System Safety, 96(10), 1311-1331.

Zolli, A. (2012). *Learning to Bounce Back*, Available from: http://www.nytimes.com/2012/11/03/opinion/forget-sustainability-its-about-resilience.html?pagewanted=all, Accessed on December 1, 2012.

SUSTAINABILITY ASPECTS OF TEXTILE REINFORCED CONCRETE (TRC) STRUCTURAL COMPONENTS

Erez Gal, Lior Nachum and Alva Peled
Department of Structural Engineering, Ben-Gurion University of The Negev
Corresponding Author: Erez Gal, E-mail: erezgal@bgu.ac.il

SUMMARY

The purpose of this study is to examine the potential of reducing the embedded energy in reinforced concrete structures using Textile Reinforced Concrete (TRC). This type of reinforcement has the potential to allow a significant reduction of the structural component cross section and amount of reinforcing bars while keeping the constructional requirements. That is reduced the quantity of cement consumption and steel consumption in the production structure and thus significantly reduce the embedded energy in the structure.

Keywords: Textile Reinforced Concrete (TRC), Embedded Energy, Life Cycle Analysis (LCA), Cementitious Systems, Textile Reinforced Beams.

INTRODUCTION

The main component of the embedded energy in buildings depends on determining the structural system, namely the construction performance of a building. Today reinforced concrete is the main structural system used for construction in Israel. Findings show that Textile Reinforced Concrete (TRC) elements, compared with steel reinforced concrete elements, provides higher strength (Hegger, 2008), higher failure energy (Peled and Mubasher, 2007), improved durability (Lieboldt et al 2013) and better sustainability features. This enhancement features can be used to decrease the embedded energy in the structure.

Global industry cannot rely on energy derived from fuel combustion only; this understanding became more acute after the energy crisis in 1970. In recent years, more and more obvious negative consequences of environmental pollution due to the combustion of fuels have been established. Combustion of fuels produces atmospheric pollution in the form of CO_2 in charge of global weather changes. In recent years, the use of replacement fuels such as solar, wind and other renewable energy sources is increasing. However, even real combinations of alternative energy do not comply with the increasing amount of energy, in both, developing countries and developed countries. Therefore, there is great importance in more efficient use of existing energy to maintain the quality of our life. Energy utilizing to maintain the quality of life is defined by the ratio between the services received through energy and how we produce it. Optimization of thermal structure performance can be by exploited energy resources intelligently such as isolating and sealing the building, creating air channels, orienting the building according to the sun direction, etc. (e.g. see Huberman and Pearlmutter 2008, Huberman, 2006).

A large part of the total energy consumption is by developed modern society buildings, while residential and industrial account for - 40 % of total energy. This high percentage of the energy used in buildings takes into account the energy during use, i.e. the operation of energy and building maintenance such as heating, cooling and lighting. Energetic consumption related to buildings is growing substantially if taking into account the energy required to construct the building, which includes the energy needed for materials manufacture such as cement, aggregates, steel bars etc., the energy needed to transport the materials to the construction site, the energy needed to assemble the structural components, etc. Likewise energy consumption of the building must be considered also the processes of repair, demolition and recycling structure and materials (e.g. see Huberman and Pearlmutter 2008, Huberman, 2006).

It is common to divide the energy consumption for buildings to three categories: (1) The Embedded Energy (also refer as embodied energy)- the energy required for the pre-construction stage of the building i.e., materials manufacturing, transporting etc., (2) The Operational Energy - the energy required for the use stage of the building i.e., maintaining residence comfort at the building, heating, cooling, lighting etc., and (3) The Recycling Energy – the energy required at the post-use stage of the building i.e., demolition and/or recycling/reuse.

The purpose of this study was to examine the potential of reducing the embedded energy in reinforced concrete structural elements using TRC and exploit the ways to accomplish this goal. Textile reinforcement has the potential to allow a significant reduction of the element cross section and amount of reinforcing bars, while keeping the constructional requirements. Thus to reduce the amount of cement and steel consumption in the structure, i.e., reduces the embedded energy of the structure.

RESEARCH METHODOLOGY

This study deals with the potential to reduce the embedded energy in a structure by using TRC structural elements. To achieve this goal the research was carried out at three levels: A) Experimental –to obtain the tensile reinforcement stress-strain curve needed for the design process; B) Constructive Calculations – calculation of the TRC beam elements ultimate strength ; C) Embedded Energy Evaluation- calculations of embedded energy based on the amount of reinforcement and concrete consumption.

Experimental Study

Cement-based textile reinforcement sheets were prepared (300x300mm and thickness of 10mm) by the Pulltrusion method (Peled and Mubasher (2007) with different fabrics: carbon (100C), AR glass (100G), polypropylene (100P) and aramid (100A). The fabrics were passed through a slurry infiltration chamber and then pulled through a set of rollers to squeeze the paste between the fabric openings while removing excessive paste. The fabric-cement composite laminate sheets were then formed on a plate-shaped mandrel until reaching the required number of layers and sheet thickness. After 24 hours, the laminate sheets were demelded and cured for 28 days at room temperature and 100% relative humidity. Tension and bending tests were performed on the TRC reinforcing plates at a constant low speed of 0.5mm/min to obtain quasi-static loading. The experiments were conducted up to failure of the specimen in order to provide the stress-strain curve needed for the constructive calculation.

Constrictive Calculations and Energy Evaluation

The ultimate load of the textile reinforcement sheet was evaluated using the following equation (Hegger (2006)):

$$F_{ctu} = A_T \cdot f_T \cdot k_1 \cdot k_{0,\alpha} \cdot k_2$$

Where F_{ctu} is the ultimate load, A_T the textile cross section area, f_T the textile tensile stress (depending on the strain value) and k_1, $k_{0,\alpha}$, k_2 are parameters related to the textile fabric. To perform the TRC beams analysis and to perform a comparison with standard steel reinforced concrete beam a computer procedure was coded. These calculations were used to provide the amount of materials needed to retain the constructional requirements.

The evaluation of the embedded energy of the concrete and steel was based on Huberman (2008) and Huberman and Pearlmutter (2008) while evaluation of the embedded energy of the fabrics was based on average data appearing in the literature for various raw materials.

CONCLUSIONS

This work studied the potential to reduce the embedded energy in concrete structures by using TRC structural elements. To achieve this goal the research was carried out at three levels: Experimental, Constructive Calculations, and Embedded Energy Evaluation. Results for a simple case study will be presented

ACKNOWLEDGEMENTS

The author would like to acknowledge the Israel Ministry of Environmental Protection for their financial support in this research.

REFERENCES

Hegger J., Voss S. “Investigations on the bearing behaviour and application potential of textile reinforced concrete”, *Engineering Structures*, 30 (2008) 2050–2056.

Huberman N., (2006), *Life cycle energy costs of building materials: Alternatives for a desert environment*, Master thesis, Ben-Gurion University of the Negev, Sede-Boqer campus, Israel.

Huberman N., Pearlmutter D., "A life-cycle energy analysis of building materials in the Negev desert." *Energy and Buildings*, 40(5), 2008, 837-848.

Lieboldt M., Mechtcherine V. “Capillary transport of water through textile-reinforced concrete applied in repairing and/or strengthening cracked RC structures”, *Cement and Concrete Research* 52, (2013) DOI: 10.1016/j.cemconres.2013.05.012

Peled A., Mobasher B., "Tensile Behavior of Fabric Cement-Based Composites: Pultruded and Cast", *ASCE, J. of Materials in Civil Engineering*, 19 (4), 2007, pp. 340-348.

NATURAL FIBER SANDWICH PANELS FOR BUILDING ENVELOPES

Vikram Yadama, Chris Voth, Nathan White, and Arun Garg
Washington State University, Puget Sound Naval Shipyard, Stanley Consultants Inc., Washington State University
Corresponding Author: Vikram Yadama, E-mail: vyadama@wsu.edu

SUMMARY

Components of a building envelope influence its structural and hygrothermal performance and determine a buildings consumption of operational energy; alternative designs and materials that reduce a building's operational energy will meet our nation's goal of market-ready, net-zero buildings. This presentation discusses development of lignocellulosic sandwich panels for building envelopes.

Keywords: Wood-strand, Sandwich panel, Building envelope, Lignocellulosic, Wood composite

INTRODUCTION

Lightweight sandwich panels consisting of hollow cores have been utilized extensively in the aerospace, marine, wind energy, and transportation industries (Davies 2001). Traditionally, these cores have been manufactured using polymeric, metallic, or paper materials for high-end applications. However, natural fibers offer a renewable alternative source to produce hollow cores of sandwich panels that are multifunctional and can meet the performance needs for building construction applications. Decades of successful performance have shown that utilization of low value, small diameter timber to produce high-end structural components is commercially feasible. Changing resources and demand for reduced energy dependency have led to consideration of combining energy and structural performance codes for construction of sustainable buildings with low embodied energy materials and reduced operational energy (residential and commercial buildings account for almost 39% of the total U.S. energy consumption and 38% of U.S. carbon dioxide emissions) (US DOE 2008).

Development of laminated strand veneer (LSV) or thin wood-strand ply technology (Weight and Yadama 2008) was a natural progression towards developing thin-walled 3-D strand core and lightweight laminates (Voth and Yadama 2010, Yadama et al 2011). LSVs can yield strength and stiffness values that are 2 to 2.5 times greater than the parent material. These wood-strand sandwich panels with a thin walled 3-D core (Figure 1) show a promise for use in building envelopes. Research is focused on replacing typical construction products such as oriented strand board (OSB) as sheathing with the possibility of creating a thicker built-up panel geared toward panelized construction similar to cross-laminated timber (CLT) and structural insulated panels (SIPs). Drawbacks of SIPs are that expanded polystyrene foam cores can easily burn and are not environmentally preferred materials, and the walls are not breathable requiring mechanical ventilation system.

Figure 1: Wood-strand sandwich panel with 3-D core.

SANDWICH PANEL MANUFACTURING AND PROPERTIES

Thin strand-based preforms or mats that produce relatively thin-walled composite laminates are better suited for a 3D forming process that reaps the benefits of net shape design.

Mold Design and Sandwich Panel Fabrication

An Aluminum mold was designed for hot-pressing a preform of small-diameter timber strands into a thin-walled corrugated core with continuous ribs in the x-axis and segmented ribs in the y-axis (Figure 1). Sandwich panels have to be designed to overcome typical failures that include tensile failure of the faces, wrinkling failure of the faces due to compressive stresses, shear failure at the interface between the core and the face plies, crushing failure of the core, or buckling of the core due to compressive loads (Hunt 2004, Chang et al 2005, Carlsson et al 2001, Davies 2001). Based on these criteria, developing analytical model to design complex core geometry is not an easy task. A simplified design methodology based on beam theory (Hunt 2004, Voth and Yadama 2010, Yadama et al 2011) was implemented to engineer the core geometry and fabricate a small-scale core mold. Design equations included analysis of required rib width to resist shear at the interface of face plies and the core, core crushing, core buckling, and sandwich panel flexural failure. Thin wood-strand plies were tested and evaluated for tensile strength and Young's modulus, inputs for mold design.

3-D wood-strand cores were manufactured using Ponderosa pine strands bonded with phenol formaldehyde (PF) resin (8% by fiber weight) in matched-die assembly, and the sandwich panels were fabricated with thin plies of wood strands or LSV and 3-D strand cores. The cores and face plies were bonded using a modified diisocyanate (MDI) resin.

Properties of Plies and Sandwich Panels

Average strength and stiffness of thin strand plies in flexure were 100 MPa and 12.1 GPa and in tension were 31 Mpa and 9 Gpa (Yadama et al 2011). Average OSB flexure properties range between 20.7 to 34.5 MPa for flexure strength and 3.5 GPa to 7.0 GPa for stiffness. The sandwich panel density averaged 310 $kg.m^{-3}$. Compared to published values for 640 $kg.m^{-3}$ density 5-ply plywood and OSB panels (APA 2005), the sandwich panels' specific bending stiffness (normalized by density) was 71 % greater than the plywood and 88 % greater than the OSB. These sandwich panels can support a 40 psf live load and a 20 psf dead load without exceeding IBC deflection limits. Thermal conductivity and thermal resistance, R-values, of panels were analyzed using a heat flow meter and were found to have an R-value 7% greater than OSB once normalized by thickness. By incorporating a rigid foam insulation and radiant barrier into the voids created by the 3-D core, R-values were 147% and 45% greater than OSB (normalized by thickness). Aside from a significantly higher R-value, sandwich panels with foam yielded stiffer bending stiffness than OSB and the sandwich panel without foam.

CONCLUSIONS

This research has the potential to transform building envelope design by direct substitution for currently used sheathing or by customizing panel elements (walls, floors, and roof elements) for entire building envelope construction with performance enhancements. Compared to currently used OSB, which represents over 60% of the sheathing market, the thicker lightweight sandwich panel is significantly stiffer in bending with increased R-value while utilizing over 40% less material than OSB of equal thickness. Resin consumption, which accounts for approximately 30% of the production costs in a typical composite panel plant, is reduced significantly. Incorporation of foam insulation into the cavities of the sandwich panel further increases its flexural stiffness and thermal properties. Research is ongoing in developing an analytical model to understand the influence of factors critical in designing and deep thermoforming of hollow natural fiber core of a composite sandwich and performance evaluation of a purposely-designed sheathing component for use in wall systems of a building envelope.

REFERENCES

APA The Engineered Wood Association, Form No. TT-044A (2005)

Carlsson, L.A., Nordstrand, T., and Westerlind, B. (2001) *On the elastic stiffnesses of corrugated core sandwich.* Journal of Sandwich Structures and Materials 3:253-267

Chang, W-S, Ventsel, E., Krauthammer, T., and John, J. (2005). *Bending behavior of corrugated-core sandwich plates.* Composite Structures 70:81-89

Davies, J.M. (2001) *Lightweight sandwich construction*. Blackwell Ltd. p 370

Hunt, J.F. (2004) *3D engineered fiberboard : finite element analysis of a new building product*. In: 2004 International ANSYS Conference. Pittsburg, PA. 20 pp

U.S. Department of Energy (DOE), (2008) Buildings Energy Data Book. Prepared for the DOE Office of Energy Efficiency and Renewable Energy by D&R International, 2008

Voth, C. and Yadama, V. (2010) *Sustainable lightweight wood-strand panels for building construction*. In: Proceeding of the International Convention of Society of Wood Science and Technology and United Nations Economic Commission for Europe – Timber Committee. Geneva, Switzerland

Weight, S.W. and Yadama, V. (2008) *Manufacture of laminated strand veneer (LSV) composite. Part 1: Optimization and characterization of thin strand veneers*. Holzforschung 62(6):718-724

Yadama, V., Weight, S., and Voth, C. (2011) *Development of wood-strand composites for structural applications*. In: Proceedings of the Nineteenth International Conference on Processing and Fabrication of Advanced Materials Eds. Bhattacharyya, D. Auckland, New Zealand

3rd Session: Integrated Building Systems and Urban Environment

Mikhail V. Chester: Emergent behavior and infrastructure design for urban sustainability transitions

Abraham Yezioro: The Influence of various urban typologies on wind conditions in open urban spaces

Erin L. Gibbemeyer, Bhavik Bakshi: Seeking synergies between buildings and surrounding ecosystems for a sustainable built environment

Evyatar Erell, Yannai Kalman: Impact of increasing the height of Tel Aviv buildings on building heating and cooling loads

EMERGENT BEHAVIOR AND INFRASTRUCTURE DESIGN FOR URBAN SUSTAINABILITY TRANSITIONS

Mikhail V. Chester, Ph.D.
Assistant Professor | Civil, Environmental and Sustainable Engineering
Affiliate Faculty | School of Sustainability
Arizona State University mchester@asu.edu

SUMMARY

The sustainability of infrastructure should acknowledge i) the emergent behaviors that result from designs and ii) system interdependencies. Using transportation and land use systems, we explore how historical deployment of infrastructure has led to decreasing service quality and increasing impacts and how integrated infrastructure planning can lead to sustainable growth.

Keywords: infrastructure interdependencies, behavior, life cycle assessment.

INTRODUCTION

The growth of cities is largely associated with the dominant technologies of the time and over the past two centuries these technologies have relied on fossil-based energy sources (Cardwell 1972). From automobile travel to long-distance water conveyance to air conditioning, urban infrastructure in newer cities and developing cities is built upon the notion that low cost energy resources and natural resources will continue. As we become increasingly aware of the constraints on these resources, a pressing need emerges for reimagining how cities should grow. Gone are the days when engineers and planners could deploy civil systems without considering the sustainability impacts of their choices and how these systems result in impacts to both the people that use them and the natural environment. As such, new frameworks are needed for understanding the role of engineered systems in affecting emergent behaviors, and how these behaviors produce impacts. Using Southwestern United States cities as case studies, we explore the relationship between infrastructure design and the sustainability of emergent behaviors in cities, and how the redesign of infrastructure in neighborhoods can reduce environmental impacts.

INFRASTRUCTURE DESIGN FOR URBAN SUSTAINABILITY

Cities in the Southwestern United States grew predominantly in the second half of the twentieth century with decreasing costs of fossil energy, increasingly affordable personal vehicle travel, and zoning of land that favored lower efficiency low density detached homes and a separation of residential and non-residential activities. Cities like Phoenix, Los Angeles, and San Diego grew rapidly during this time period with up to tripling of populations in 20 year time periods. This growth was enabled by the rapid deployment of infrastructure that by the end of the twentieth century had produced urban environments that were exceptionally dependent on the extensive import of energy and raw materials. In particular, during this time, transportation systems grew to be increasingly strained with increasing congestion, decreasing mobility, and the financing for routine rehabilitation becoming increasingly unavailable. In Los Angeles, the roadway network was deployed largely between 1930 and 1970 and enabled the increasing use of personal automobile travel that has produced unacceptable levels of congestion (currently, 94% of peak travel occurs in congestion) (Fraser and Chester 2013).

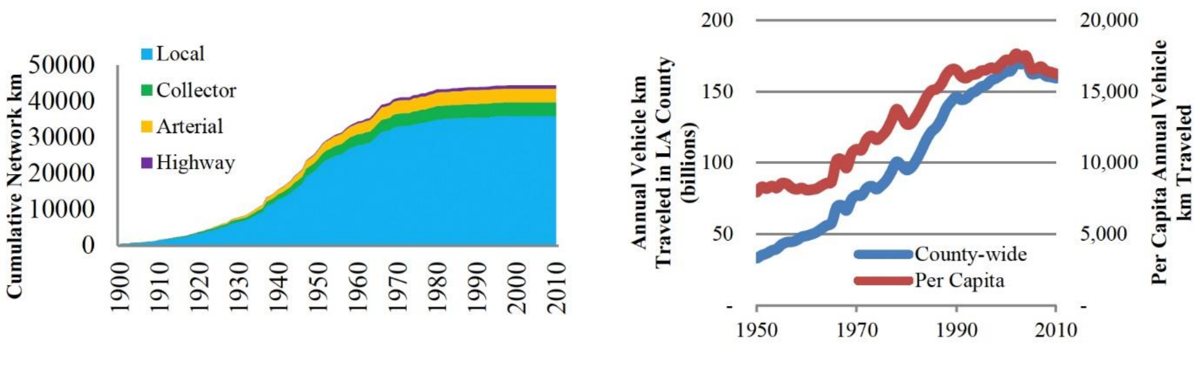


Figure 1: Deployment of the Los Angeles Roadway Network (left) and resulting vehicle travel (right) (Fraser and Chester 2013).

By the end of the twentieth century the network was physically constrained from expanding which contributed to a suppression of personal vehicle travel. This suppression manifests not only in a peaking of automobile travel but also shows in increasing congestion across the city. It is clear that new models are needed for twenty-first century infrastructure to reduce the direct impacts of infrastructure impacts as well as the behaviors these infrastructure enable. In Southwest United States cities it is clear that the investment in roadway infrastructure does not lead to increased mobility.

New strategies are needed for reimagining the deployment and upgrade of sustainable infrastructure. Given the outcomes in Los Angeles, several analyses have been developed of the potential for environmental improvements from upgrading of infrastructure around high-capacity transit in the urban core. Both Phoenix and Los Angeles have recently (in the past 5 years) deployed new light rail lines to selectively service the core urban areas. Yet this transit service has not been deployed with coordinated upgrades to the existing building infrastructure. Through several research projects, we redesign neighborhoods around light rail service selectively deploying new mixed use (residential and commercial) structures as well as adaptive reuse of existing structures. We then evaluate the energy and air emissions benefits of these infrastructure upgrades. We find that i) the marginal costs associated with the upgrading of infrastructure in the urban core leads to marginal benefits up to 100 times greater, and ii) that the benefits are found in the interconnected transportation and land use systems (i.e., benefits accrue across both systems) (Figure 2).

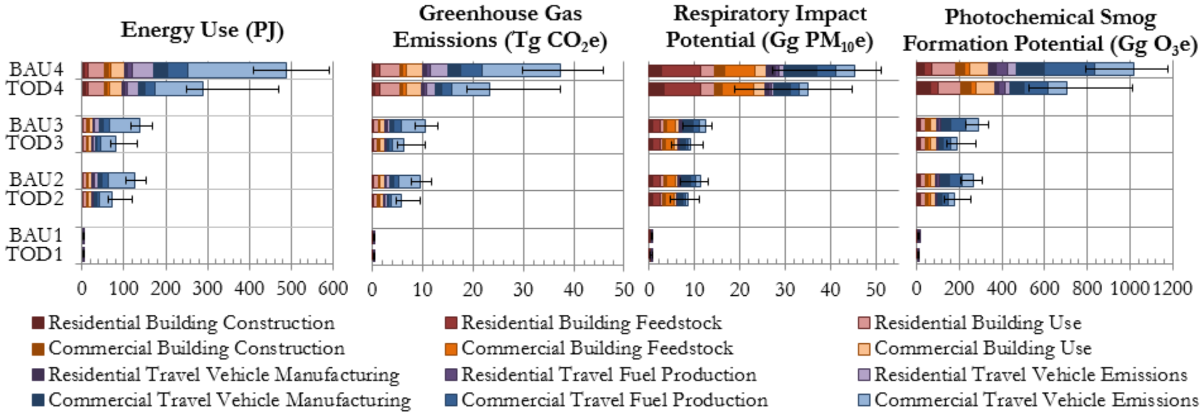


Figure 2: Life-cycle benefits of transit-oriented development (TOD) over business-as-usual (BAU) infrastructure deployment near light rail in phoenix (Kimball et al. 2013, Chester et al. 2013).

CONCLUSIONS

Efforts to improve the sustainability of engineered infrastructure systems should acknowledge the role that such systems have on emergent behaviors as well as interdependencies with other systems. How people interact with large civil systems is a give and take between the activities that they desire and the infrastructure that facilitates services. While buildings by themselves are core infrastructure systems whose sustainability can be improved, it is also important to recognize that they can be more or less effectively integrated with other infrastructure leading to either increasing or decreasing sustainability outcomes.

REFERENCES

Cardwell, D., 1972, Turning Points in Western Technology, Science History Publications, New York City, New York, ISBN 0-88202-004-8.

Chester, M., Nahlik, M., Fraser, A., Kimball, M., and Garikapati, V., 2013, Integrating Life-cycle Environmental and Economic Assessment with Transportation and Land Use Planning, Environmental Science & Technology, 47(21), pp.12020-12028, doi: 10.1021/es402985g.

Fraser, A. and Chester, M., 2013, Life-cycle Greenhouse Gas Emissions and Costs of the Deployment of the Los Angeles Roadway Network, Arizona State University Report No. SSEBE-CESEM-2013-WPS-001.

Kimball, M., Chester, M., Gino, C., and Reyna, J., 2013, Transit-oriented Development Infill in Phoenix Can Reduce Future Transportation and Land Use Life-Cycle Environmental Impacts, Journal of Planning, Education, and Research, 33(4), pp.395-410, doi:10.1177/0739456X13507485.

THE INFLUENCE OF VARIOUS URBAN TYPOLOGIES ON WIND CONDITIONS IN OPEN URBAN SPACES

Abraham Yezioro, Vladimir Lovchakov
Faculty of Architecture and Town Planning. Technion - Israel Institute of Technology
Corresponding Author: Abraham Yezioro, E-mail: ayez@ar.technion.ac.il

SUMMARY

A methodology for systematic analysis of the effects of geometrical parameters of different typologies on the wind climate in open spaces between buildings will be presented. The results of the study can function as a tool that enables designers to estimate the suggested plans already in its early design stages.

Keywords: Open Spaces, Urban Typologies, Thermal Comfort, CFD.

INTRODUCTION

Open public spaces are a vital component in a built urban environment that encourage public life in the city. Achieving comfortable conditions will strengthen their use fitting them to different outdoor activities. Wind affects the comfort conditions and determines the ability to use open spaces. Different urban typologies influence the local wind regime and create pleasant/unpleasant wind conditions in the pedestrian level around the buildings.

A system developed for systematic analysis of the effects of geometrical parameters of different typologies on the wind climate in open spaces between buildings will be presented. This system enables, on the basis of qualitative-quantitative analysis, to develop recommendations and determine the recommended outdoor activities for people; activities that can take place in open areas of the examined urban typologies in respect to human thermal comfort. The results of the study can function as a tool that enables designers to estimate the suggested plans already in its early design stages.

The advantages of the suggested system are the graphical, easy to use, recommendations and guidelines. They enable the designer with general knowledge to make quick decisions and apply the correct principles for open public spaces in respect to exposing or avoiding them to the wind.

MAIN BODY OF EXTENDED ABSTRACT

Quality open spaces consist one of the measures of urban life. Taking into consideration aspects of microclimate and the comfort of the environment in these areas, such as gardens and parks, squares and streets is an essential part of urban planning.

This study examines the effects of different urban typologies on wind regime expected in open areas between buildings. A method for analyzing these effects and give advices and general guidelines for sensible planning in open public areas in accordance to wind comfort standards was developed. The effects of different urban typologies with plain geometry were examined. The evaluation of the anticipated wind climate in open areas of these typologies is based on the CFD (Computational Fluid Dynamics) simulations.

The study focuses on examining the wind climate in Tel-Aviv, during the summer at the time of intensive pedestrian activities. The weighted summer speed in the common direction was chosen as the wind condition for performing the urban typologies examinations.

The literature study showed that up until now the subject of this study wasn't researched systematically, and this study is the first to deal with it parametrically (Blocken and Carmeliet 2004, BRE, 1994, Capeluto et al 2003, Ferriera et al 2002, Penwarden and Wise 1975). The sources of information on which the study is based were reviewed based on the following subjects: estimation of wind climate via wind tunnels and CFD models (Bruse 1999, ENVI-met 2014, Murakami et al 1999); human thermal comfort and safety (Arens et al 1980, Olgyay 1963); evaluation of the climate and design with awareness to the Israeli climate.

The study focuses in the assessment of simple schematic urban typologies, in different proportions and in a different heights (Figure 1, left and center). Three basic proportions were studied, 1:1, 1:2 and 2:1. Moreover, the surrounding buildings change height, from 15 to 60 every 15 mts. Hence various configurations of those urban typologies were assessed.

A method for systematic assessment and analysis of the results for the different typologies was developed. The principles of the qualitative and quantitative analyses are shown for the efficient evaluation of the wind climate created in the open spaces of the typologies and determining the relevant outdoor activities that can take place in them in respect to human thermal comfort (Figure 1, right).

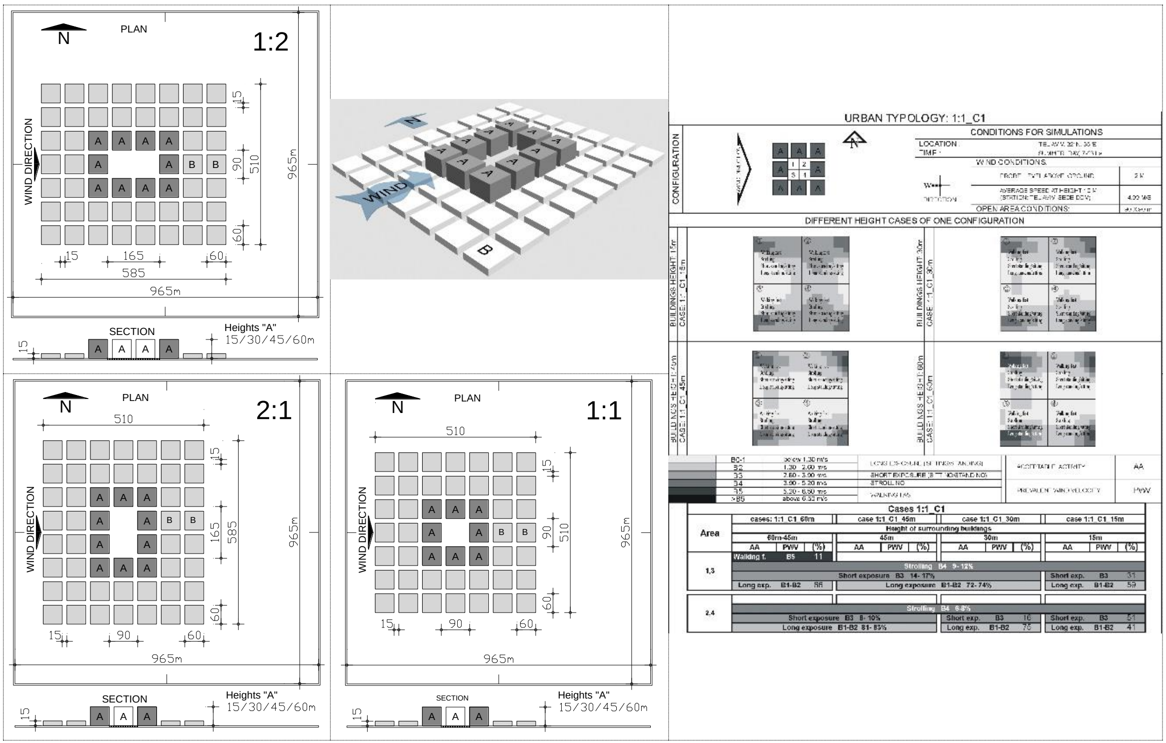


Figure 1: Examined prototype urban typologies and summarized recommendations for one case

CONCLUSIONS

The advantages of the suggested system are the graphical, easy to use, recommendations and the guidelines. They enable the planner with general knowledge to make quick decisions and apply the correct principles for open public spaces in respect to opening or closing them to the wind.

In a time where dense cities are growing by the day, it is more important to provide citizens with more comfortable and livable public spaces between buildings. Future research will couple different environmental factors affecting thermal comfort in order to create more comprehensive design guidelines for a more sustainable environment.

REFERENCES

Arens E., McNall P., Gonzalez L., Berglund L., Zeren l., 1980, “A New Bioclimatic Chart for Passive Solar Design ”, Proceedings of the 5-th National Passive Solar Conference, American Section of the International Solar Energy Society.

Blocken B., Carmeliet J., 2004, “Pedestrian Wind Environment around Buildings: Literature Review and Practical Examples” in Journal of THERMAL ENV. & BLDG. SCI., Vol. 28, No-2, (pp. 107-159).

BRE (Building Research Establishment), 1994, “Wind around Tall Buildings “, BRE Digest 390, Building Research Establishment, Garston, Watford, WD2 7JR.

Bruse, M., 1999, “Modelling and Strategies for improved urban climates” Invited Paper. In Proceedings International Conference on Urban Climatology & International Congress of Biometeorology, Sydney, Australia.

Capeluto I. G., Yezioro A., Shaviv E., 2003, ” Climatic aspects in urban design – a case study”, in Journal Building and Environment, Vol. 38, (pp.827-835).

ENVI-met. http://www.envi-met.com/. Last accessed February 2014.

Ferriera, A., D., Sousa, A.,C.,M., Viegas, D.,X., 2002, “Prediction of Building Interference Effects on Pedestrian Level Comfort”, in Journal of Wind Engineering and Industrial Aerodynamics, Vol.90, (pp.305-319)

Murakami, S., Ooka, R., Mochida, A., Yoshida, S., Kim, S., 1999, "CFD analysis of wind climate from human scale to urban scale" Journal of Wind Engineering and Industrial Aerodynamics, Vol.- 81, (pp.57-81).

Olgyay, V., 1963, Design with Climate-Bioclimatic Approach to Architectural Regionalism, Princeton University Press, Princeton, New Jersey.

Penwarden, A., D., Wise, A.,F.,E., 1975, “Wind Enviroment around Buildings”, Department of the Environment Building Research Establisment, H.M.S.O, London.

SEEKING SYNERGIES BETWEEN BUILDINGS AND SURROUNDING ECOSYSTEMS FOR A SUSTAINABLE BUILT ENVIRONMENT

Erin L. Gibbemeyer and Bhavik R. Bakshi
William G. Lowrie Department of Chemical and Biomolecular Engineering at The Ohio State University
Corresponding Author: Bhavik R. Bakshi, Bakshi.2@osu.edu

SUMMARY

We propose integrated design of technological and ecological systems to reduce the impact of technologies while enhancing ecosystems that provide needed services. This can result in innovative designs that are economically and environmentally beneficial and encourage engineering within ecological constraints. This is demonstrated by application to the built environment.

Keywords: Techno-Ecological Synergy (TES), Ecosystem Services, Ecosystem Capacity, Sustainable Design, Building and Landscape Design

INTRODUCTION

Ecosystem services are essential to all human activities, yet are widely being degraded. The Millennium Ecosystem Assessment looked at the status of 24 ecosystem services and found that 62.5% of them were degraded on a global scale, with another 21% degraded in some parts of the world (Millenium Ecosystem Assessment Board, 2005). When the demand for ecosystem services is greater than its capacity to supply those services, this overshoot stresses the ecosystem and leads to ecosystem degradation (Wackernagel & Rees, 1996), (Wackernagel, et al., 2002). We propose that by considering both the demand for ecosystem services and their available supply in the design process, we can develop systems that not only reduce their environmental impact, but also enhance the supply of ecosystem services. For developing such techno-ecological synergies, we find the supply of ecosystem services available to our system and compare it to our proposed demand for services created by the technological systems. Using many different technological and ecological design alternatives that decrease the demand or increase the supply of ecosystem services, we look for synergies and trade-offs. It is hoped by explicitly accounting for the ecosystem service supply and demand, more techno-ecological synergies can be found in the design phase that will result in more sustainable systems.

METHODOLOGY

A techno-ecological synergy study was done looking at a portion of The Ohio State University Columbus Campus as the techno-ecological network. This builds on a study previously done of a simplified residential techno-ecological network (Urban & Bakshi, 2013). The study focuses on a portion of campus that includes academic buildings, green space, and the portion of the Olentangy River that runs through campus. This provides a wide array of spaces, looking at where the campus community works and plays, as well as the major ecological features on campus. In this system, technological and ecological variables are investigated, as well as a few behavioral variables, which include things like the amount of fertilizer applied to the green space and the heating and air conditioning set points in the buildings. Following is the network diagram for a single selected building currently in the model, Scott Laboratory, and its surrounding ecosystem, including the river, with the systems containing the relevant technological, ecological, and behavioral variables.

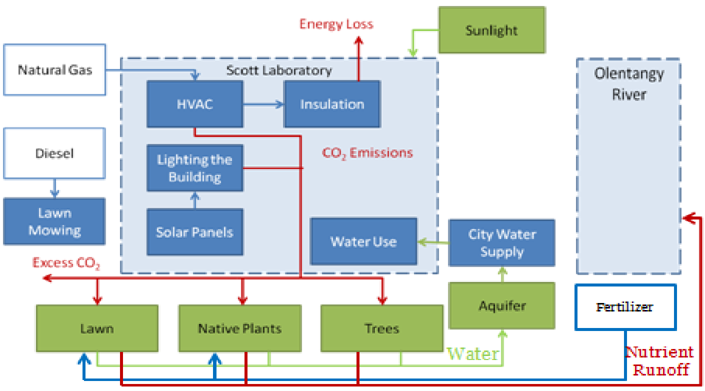


Figure 1: Techno-Ecological Network for Scott Laboratory

This campus study aims to minimize cost, carbon emissions, nutrient runoff, and water use compared to the current state of campus. The buildings are modeled through the EnergyPlus software developed by the Department of Energy for building energy analysis (US Department of Energy, 2012). This building model is then combined with ecological models taken from literature (Qian, et al., 2003), (Schuman, et al., 2002), (Wenger, 1984), (Poeplau, et al., 2011), (Selbig & Balster, 2010). These models are all then fed into the GenOpt software, a generic optimization software developed by Lawrence Berkeley National Laboratory to come up with a set of Pareto optimal solutions (Lawrence Berkeley National Laboratory, 2011). A set of solutions is obtained because this is a multi-objective optimization, and any solution that cannot decrease one objective without increasing another is a part of the optimal set. Though we do find a Pareto optimal set of solutions, we also find that some variables lead to win-win scenarios. For example, the installation of thicker roof insulation lowers both the carbon footprint and utility costs. Because these win-win scenarios provide opportunities to save money and move towards a more sustainable campus, these solutions should be acceptable to decision-makers with different motivations, whether motivated by cost or environmental impact.

RESULTS AND DISCUSSION

This study was run for optimization over the short term of one year and the long term of 37 years, to take the study out to 2050, the deadline for many OSU Campus sustainability goals. Though this won't always happen, with the variables chosen, the short term solutions compressed down into a smaller than expected set of optimal solutions, where the minimum carbon, water, and nutrient runoff solutions were identical, with only the minimum cost solutions differing. This means there were no variables that caused any sort of tradeoffs for the ecologically based objective functions. Although, many of these ecologically improved solutions come with a high capital cost that cannot be paid back in a single year, even if operating costs are lower, which is why the minimal cost solutions remain different. However, once the study is taken out to 2050, the optimization ends in one optimal solution with minimal carbon, water, nutrient runoff, and cost. Again, this will not happen for every TES study, but for the variables chosen, there is enough savings in operating costs to offset the capital costs completely. In addition, it is important to note that all three types of variables (technological, ecological, and behavioral) are being used to attain these optimal solutions. In fact, if not all three types of variables are part of the optimization, the solutions will not be as low, since every type of variable contributes towards lowering the objective functions. This conveys the ability of the TES approach to find superior designs that cannot be found by a disintegrated approach. Looking at CO2, we found that making technological changes will decrease the carbon footprint, and also making behavioral and ecological changes will decrease it even more significantly, but the carbon emissions can only be decreased about 20% through the variables we considered here. Water can be halved by making the technological change of switching to low flow fixtures, and while ecological variables are lowering the water use somewhat, it pales in comparison to what the technological changes achieve. The nutrient runoff from nitrogen and phosphorus is the opposite, though. There are no technological changes affecting the runoff, while the behavioral and ecological variables allow the demand for ecosystem services to go below the supply, which leads to the negative values on the graph. Ideally, we would design systems where all of the objectives are negative and would operate within the ecosystem capacity.

CONCLUSIONS

The local level campus study has already shown us win-win solutions that can be used to make improvements on campus. This indicates that integrated design of technological and ecological systems can help in developing innovative designs that are economically and environmentally superior to designs found by conventional techno-centric methods. In this example, only the nutrient runoff could be taken down to levels below the ecosystem capacity. In general, for most human activities it may not be possible to balance the supply and demand of ecosystem services at a small scale. On-going research is developing the TES approach for considering larger spatial scales. This raises many challenges and opportunities. For example, the carbon emitted by the densely populated Columbus Campus may be offset by forest areas elsewhere in the state, but this raises the issue of partitioning the sequestration capacity between various CO2 emitters. Since CO2 is a global pollutant, this material cycle may be closed even at a global scale. In contrast, closing the material cycle for a resource such as water may be possible only at a watershed scale. Given the unsustainability of current human activities, many material loops, particularly for greenhouse gases, cannot be closed at any scale. The proposed TES approach incorporates opportunities for enhancing or restoring ecosystem services along with reducing the impact of technological activities. Metrics indicating the degree of over- or under-shoot for various ecosystem services need to be devised for quantifying the absolute sustainability of an activity at multiple spatial scales.

REFERENCES

Lawrence Berkeley National Laboratory, 2011. *GenOpt v3.1.* s.l.:s.n.

Millenium Ecosystem Assessment Board, 2005. *Living Beyond Our Means: Natural Assets and Human Well-being.* [Online] Available at: http://www.maweb.org/documents/document.429.aspx.pdf
[Accessed 13 July 2011].

Poeplau, C. et al., 2011. Temporal dynamics of soil organic carbon anfter land-use change in the temperature zone - carbon response functions as a model approach. *Global Change Biology,* p. 2415–2427.

Qian, Y. et al., 2003. Long-Term Effects of Clipping and Nitrogen Management in Turfgrass on Soil Organic Carbon and Nitrogen Dynamics. *Journal of Environmental Quality,* 32(5), pp. 1694-1700.

Schuman, G., Janzen, H. & Herrick, J., 2002. Soil Carbon Dynamics and Potential Carbon Sequestration by Rangelands. *Environmental Pollution,* Volume 116, pp. 391-396.

Selbig, W. R. & Balster, N., 2010. *Evaluation of Turf-Grass and Prairie-Vegetated Rain Gardens in a Clay and Sand Soil, Madison, Wisconsin, Water Years 2004–08,* Reston: U.S. Geological Survey.

Urban, R. A. & Bakshi, B. R., 2013. Techno-Ecological Synergy as a Path Toward Sustainability of a North American Residential System. *Environmental Science & Technology,* 47(4), pp. 1985-1993.

US Department of Energy, 2012. *EnergyPlus v7.2.0.* s.l.:s.n.

Wackernagel, M. & Rees, W. E., 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth.* Gabriola Island: New Society Publishers.

Wackernagel, M. et al., 2002. Tracking the ecological overshoot of the human economy. *PNAS*, 99(14), p. 9266–9271.

Wenger, K. F., 1984. *Forestry Handbook, 2nd ed..* New York: John Wiley & Sons.

IMPACT OF INCREASING THE HEIGHT OF TEL AVIV BUILDINGS ON BUILDING HEATING AND COOLING LOADS

Evyatar Erell, Yannai Kalman
Ben-Gurion University of the Negev
Corresponding Author: Evyatar Erell, E-mail: erell@bgu.ac.il

SUMMARY

Computer simulation was used to predict the effects on urban microclimate of increasing the height of existing buildings in Tel Aviv. The nocturnal urban heat island is expected to intensify and wind speed to be reduced, thus reducing the potential for free cooling in summer - but annual energy consumption is not increased in fully air conditioned buildings.

Keywords: Urban microclimate, computer simulation, CAT model, climate cooling potential, ENERGYui

INTRODUCTION

Many of the existing buildings in Tel Aviv's older neighbourhoods suffer from structural weaknesses and might collapse in the event of a major earthquake, of which there is a high probability. Israel's National Guideline Plan 38 (NGP 38) seeks to address this problem, facilitating the renovation of unsafe buildings by allowing construction of additional storeys to existing buildings undergoing reinforcement, thus providing a financial incentive and a suitable regulatory framework. However, the increase in urban density, although desirable from other aspects, may also be expected to exacerbate the urban heat island and to reduce wind speed at street level.

METHODOLOGY

The study examines the potential effects of increasing building height by means of computer simulation. First, the Canyon Air Temperature (CAT) model (Erell & Williamson, 2006) is used to generate site-specific weather data from time-series measured at a meteorological station in the region, accounting for urban geometry, materials and surrounding hydrological conditions. These data are used as inputs for assessing:

a) The 'climatic cooling potential', a metric which is similar to Cooling Degree Hours but which relates to free-floating (non-air conditioned) buildings.

b) Building energy performance, using ENERGYui, a graphic user interface for the EnergyPlus building thermal simulation software (Yezioro et al, 2011). ENERGYui was developed to generate building energy efficiency labels according to Israel standard IS 5282.

Both indicators were calculated first for the reference weather station at Bet Dagan; then for conditions in typical streets in southern Tel Aviv; and finally for different scenarios of increased building height, up to a total of 8 floors.

RESULTS

Urban Microclimate

The CAT model simulation first reproduces differences between the Bet Dagan weather station which is about 7km inland, and the Tel Aviv streets, which are affected by proximity to the sea: In Tel Aviv, daily minima are higher but maxima are typically slightly lower. CAT was then used to evaluate the effects of the addition of buildings, which generates a nocturnal heat island whose intensity increases as building height grows. Concurrently, wind speed is reduced with increasing canyon aspect ratio (ration of building height to street width, H/W). Predicted daytime differences in air temperature are modest – less than 1 degree.

Climatic Cooling Potential

The 'climatic cooling potential' (CCP) proposed by Artmann et al (2007) estimates the potential for cooling by ventilation in a non-air conditioned building. Rather than prescribing a fixed reference temperature for cooling, as is done in the calculation of the Cooling Degree Days metric, this method assumes that internal building temperature is allowed to oscillate harmonically in response to the diurnal cycle of external air temperature, with a time lag and decrement factor that are due to the presence of thermal mass. For this analysis, the building temperature at time *h* is given by the expression $T_{b,h} = 24.5 + 2.5\cos(2\pi \frac{h-h_i}{24})$, and h_i is the time ventilation normally starts (for example – at 19:00). Ventilation is considered to be effective if there is a temperature difference of at least 2K between the building and the outdoor air.

The effect of elevated night time air temperature in Tel Aviv is reflected in the values of the CCP. In Bet Dagan the total cooling potential for the month of July is 947 degree-hours; the comparable value for an exposed area near the sea is only 744 degree-hours, because nocturnal cooling is moderated by proximity to the sea. When the effect of existing 2-story buildings on air temperature is included, the cooling potential is reduced slightly to 696 degree-hours. Increasing building height to 4, 6 or 8 floors results in further reduction of the potential to 521, 374 and 178 degree-hours for the month of July, respectively.

Building Energy Consumption

The buildings modelled are typical of those found in the older quarters of Tel Aviv, with concrete block walls and flat concrete roofs with minimal thermal insulation. Windows are small, single-glazed and display no preferred orientation. Although any major retrofit may be expected to include a thermal upgrade, the study modelled energy consumption on the assumption that additional floors were identical to existing ones, in order to isolate the effects of possible modifications to microclimate. Simulated building energy consumption for space heating and cooling is reduced with increasing building height, from about 34 kWh/m^2 for a 1-floor building to about 26 kWh/m^2 for a 7-floor building. This is firstly because the effect of elevated night-time air temperature in deeper streets, which may be expected to increase cooling loads in summer, is offset by mutual shading between adjacent buildings, which reduces the radiant load on the external walls and windows; and secondly, because increasing the number of intermediate stories reduces the relative effect of the exposed top story, which requires more energy to heat in winter heating and to cool in summer.

Building energy modelling shows that in the case of Tel Aviv, altered canyon microclimate plays less of a role in energy efficiency of fully AC buildings than do other factors, such as the proportion of building envelope exposed to the sky and mutual shading by adjacent buildings. Thus, although increased summer cooling requirements are offset by a reduction in winter heating, taller buildings are, overall, slightly more economical under the conditions simulated.

DISCUSSION AND CONCLUSIONS

The simulations confirm that deeper streets resulting from implementation of NGP 38 are, in fact, likely to create more intense nocturnal heat islands as well as to reduce wind speed. However, the effect of these changes on building energy consumption and on thermal comfort in non-AC buildings depends on additional factors. While the properties of the building may be accounted for in conventional building thermal simulation, several potentially confounding factors are often ignored: a) local microclimatic characteristics are not accounted for because such data are not available, despite potentially significant differences, and b) the effect of shading by adjacent buildings is disregarded because the software does not explicitly require them to be included in the model. Finally, the simulation results predict the behavior of the specific buildings modelled, and might be sensitive to changes in the buildings undergoing retrofit (such as increasing roof thermal insulation).

It should also be noted that assumptions regarding occupant behavior, including thermal preferences and the thermostat set points for heating and cooling, may have a greater impact on energy consumption than specific building properties such as the amount of thermal insulation. Additionally, the simulations emphasize the effect of building design on mechanical cooling loads – but do not account for the effect on thermal comfort of the occupants of non-air conditioned buildings, which would suffer disproportionately from elevated nocturnal temperatures and reduced wind speed on warm summer nights.

REFERENCES

Artmann, N., Manz H. and Heiselberg P. (2007). Climatic potential for passive cooling of buildings by night-time ventilation in Europe. *Applied Energy* 84: p. 187-201.

Erell, E. and Williamson, T. (2006). Simulating Air Temperature in an Urban Street Canyon in All Weather Conditions Using Measured Data at a Reference Meteorological Station. *International Journal of Climatology,* 26: p. 1671-1694.

Yezioro, A., Shapir, O. and Capeluto, G. (2011). A simple user interface for energy rating of buildings. Proceedings of *Building Simulation 2011*, 12 IBPSA Conference, Sydney, 14-16 Nov. 2011, p. 1293-1298.

4th Session: Probabilistic Design and Risk-Based Analysis of Sustainable Built Environments

Yue Li, Carley Feese, William M. Bulleit: Risk-based assessment of seismic performance of buildings and related environmental impacts

Yehuda Kahane: Urbanization - the challenge

Michael Lepech: Probabilistic sustainability evaluation of new engineering materials

Pavel Grabov: Operational risk management (ORM) in civil engineering

RISK-BASED ASSESSMENT OF SEISMIC PERFORMANCE OF BUILDINGS AND RELATED ENVIRONMENTAL IMPACTS

Yue Li, Carley Feese, William M. Bulleit
Department of Civil and Environmental Engineering, Michigan Technological University
Corresponding Author: Yue Li, E-mail: yueli@mtu.edu

SUMMARY

Sustainable development has recently begun considering damage loss due to natural hazards. A sustainable perspective on building design entails an understanding of a structure's life-cycle environmental costs and consideration of associated environmental impacts induced by natural hazards. Merging results obtained from a natural hazard evaluation and related environmental impacts, for buildings located in seismically prone areas, will give a novel outlook for sustainable design decisions.

Keywords: Buildings, Earthquake, Environmental Impact, Life-Cycle Analysis, Risk Analysis.

INTRODUCTION

In the United States (U.S.), the building sector accounted for about 41% of primary energy consumption in 2010, 44% more than the transportation sector and 36% more than the industrial sector (D.O.E. 2013). 54% of energy consumption in the U.S. is related to buildings and their construction (Horvath 2004). This will make sustainable design a priority for building owners and designers. A key aspect in sustainable development is the building sector's energy consumption and material production, due to the world's energy shortages and associated anthropogenic environmental effects. Few studies have linked the relationship between natural hazard mitigation and environmental impacts. To incorporate new views on a building's energy consumption, this study explores the integration of the environmental impacts inherent to buildings, including damage from potential natural disasters (e.g., earthquakes) and building seismic performance. The motivation behind this research is largely driven by the worldwide depletion of natural resources and the increase of environmental concerns relating to natural hazards.

LIFE-CYCLE ANALYSIS RESULTS OF ENVIRONMENTAL IMPACT

Life-cycle assessments (LCA) for buildings have become a major advancement in the design process for engineers. Sustainable development is an issue recognized worldwide, and only recently has attention been directed towards the built infrastructure (i.e., buildings). LCAs provide key considerations for evaluating environmental impacts produced by buildings throughout their life-cycle. Low impact buildings most commonly rely on advanced design techniques and innovative material technologies; both of which can require additional upfront financial and environmental investments. Not often do they consider the impacts caused by natural disaster events, which presents an opportunity for structural engineers to communicate the importance of a building's seismic risk, and to employ mitigation strategies that minimize a building's life-cycle impact with these potential risks in mind.

EARTHQUAKE INDUCED DAMAGE

FEMA estimated that, on average, earthquakes cost the U.S. over $5 billion per year and, of that, California, Oregon, and Washington account for approximately $4.1 billion (77%) of this total estimated average annualized loss (Folger 2011). Many studies have examined structural building schemes and their resistance to earthquake events, although not considering environmental impacts incurred by repair and damage costs. While both natural hazard mitigation and LCA evaluations have evolved over the past years, they are not closely related. Only limited research has linked the two concepts, though they both strongly relate to sustainable design.

CASE STUDY

The two case study buildings under consideration were modeled as low-rise commercial buildings, located in Los Angeles, California. Both office buildings were analyzed as four stories, with a total floor area of 86,400 square feet. The environmental impact results for both the concrete and steel generic building types using Athena (2013). are provided in Fig. 1. HAZUS-MH (FEMA 2002) is used to determine potential damage and repair costs under various seismic events. Table 1 shows the damage cost of the concrete building with different design codes, if a 100-year return earthquake event took place.

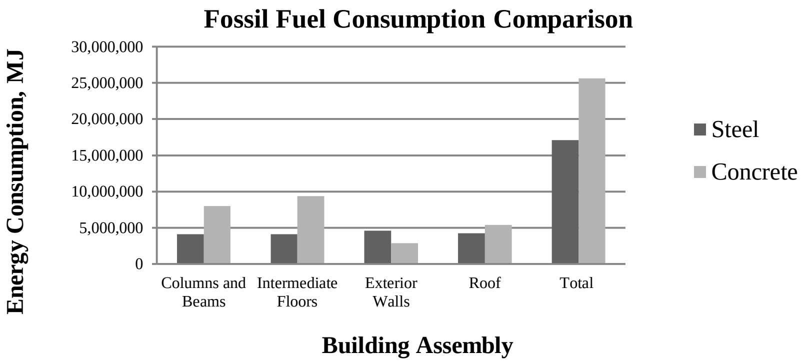


Figure 1: Global Warming Potential

Table 1: Concrete Building Damage Cost from an Earthquake with 100-Year Return Period

Design Code	Damage State	Probability of Damage %	Replacement Cost %	Damage Ratio %	Damage Cost $	Repair Energy MJ
High	Slight	**24.23**	0.4	0.0009692	**56,819**	**91,778**
	Moderate	**6.7**	1.9	0.001273		
	Extensive	**1.15**	9.6	0.001104		
	Complete	**0.12**	19.2	0.0002304		
			Total	0.0035766		
Moderate	Slight	**22.06**	0.4	0.0008824	**104,138**	**168,212**
	Moderate	**12.88**	1.9	0.0024472		
	Extensive	**3**	9.6	0.00288		
	Complete	**0.18**	19.2	0.0003456		
			Total	0.0065552		
Pre-Code	Slight	**20.15**	0.4	0.000806	**487,038**	**786,699**
	Moderate	**31.96**	1.9	0.0060724		
	Extensive	**18.15**	9.6	0.017424		
	Complete	**3.31**	19.2	0.0063552		
			Total	0.0306576		

CONCLUSIONS

This study proposed a method for combining seismic analysis and LCA results to obtain a building's overall environmental impact including the costs of repairing damage caused by earthquakes. Using Athena and HAZUS-MH, this study explored the differences between steel and concrete buildings using the proposed method. It showed that code design-level greatly affects a building repair and damage estimations. The challenge of quantifying the environmental impacts due to buildings and seismic damage was approached in two separate analyses. Future study will examine the damage and repair costs explicitly caused by each building's structural components; this approach will allow a clear comparison between the two building materials, steel and concrete. This type of building examination can assist building owners and engineers in choosing between building design options, and ultimately lead to environmentally conscious and seismically resilient design choices.

REFERENCES

Athena® Eco-Calculator for Buildings V3.71 Software and Database Overview. (2013). Athena Sustainable Materials Institute, Ontario, Canada.

Horvath, A. (2004). "Construction materials and the Environment." Annual Review of Environment and Resources 29: 181-204.

D.O.E., U.S. (2013). "Buildings Energy Data Book," Chapter 1: Building Sector. Washington, D.C.
Folger, P. (2011). "Earthquakes: Risk, Detection, Warning, and Research." Congress Research Service 7-5700.

URBANIZATION – THE CHALLENGE

Yehuda Kahane, (Prof. Emeritus)
Recanati Business School and the Porter School of Environmental Studies, Tel Aviv University, and YKCenter for Rebooting and Prosperity. kahane@post.tau.ac.il

SUMMARY

Technological development over history had an immense impact on the demography, lifestyle, and way that people think, behave, work, and consume (Kahane 2006). The coming decades will continue to be characterized by remarkable population growth and a strong wave of urbanization, which will involve huge investment in housing and infrastructure that will challenge and bring opportunity in the social, economic, and environmental arenas. This paper discusses the challenges arising from the conflict between traditional capitalism and the rules of the new economy that emerge from the post-industrial era.

Keywords: capitalism, rebooting, prosperity, urban planning, urban asset management, construction, infrastructure.

INTRODUCTION

Until some 200 years ago, at the beginning of the industrial revolution, most people experienced the same level of technological advancement as their parents and grandparents, and experienced very minor technological changes. The world population was roughly 1 billion - by far smaller than today - and was mostly agrarian. Since then, tremendous technological changes have transformed almost all aspects of life. One of the most noticeable changes was the massive urbanization and the adoption of industrial way of life. In last four decades alone the world population has nearly doubled, urban population has more than tripled, while rural population has increased by only 40% (UN 2011). The UN forecasts that these trends will continue, and that total world population will increase by 2.3 billion by 2050, while the urban population will grow by a higher number- 2.6 billion - and will reach 6.3 billion in 2050.

Most of the urban growth is expected in Asia (1.4 billion) and Africa (0.9 billion). These numbers (UN 2011) mean that we shall see continuing massive investment in new housing and new infrastructure in these regions. This creates an immense opportunity to deal with sustainability issues, as these countries have by far more flexibility in designing complete neighborhoods, where new materials, new methods, and more sophisticated, modern and sustainable infrastructure can be employed. Sophisticated planning can bring about substantial long term (life cycle) saving in the cost of operation, maintenance and end-of-life cost, as well as additional environmental and social benefits (Spatari & Atkan 2012). Industrialized countries will need to manage the existing housing stock and urban infrastructure, and to focus on maintenance, upgrading, and rehabilitation of obsolete structures, and aging energy, water and sewage treatment systems.

This paper focuses on the social and environmental challenges that cities face among the expected population growth and expansion of infrastructure. The most difficult question is how to make governments, businesses and consumers to work jointly in the same direction within the capitalistic system that ignores non-economic issues.

CAPITALISM IN THE POST INDUSTRIAL ERA

The economy of the industrial world is guided mainly by capitalistic philosophy. Each player in such an economy is striving to maximize her material wealth. This objective automatically creates supply and demand that set all the prices in the market. It thereby generates the mechanism of the "invisible hand" that results in an optimal allocation of all resources, products and services.

Capitalism has indeed led to remarkable material growth of the industrial world. However, the model was not perfect even at the economic field, and it created severe cycles and series of economic crises. Moreover, with the sole focus on the economic aspects, capitalism has created major damages to society, rising inequality, and has caused immense damages to our environment in the form of pollution, climate change, depletion of natural resources, loss of species, destruction of fragile food chains, and loss of resilience due to reduced bio-diversity, all of which threaten the well-being of mankind on planet Earth.

Nowadays we see the limitations and risks associated with a pure capitalistic system, and we observe the emergence of a "new economy", based on an improved form of capitalism which takes into consideration also humane values, and social and environmental objectives besides the pure economic goals. In other words, instead of being concentrated on one dimensional goal, economic success, we extend the model to include a multi-objective function that considers also additional dimensions: society, environment, justice, health, ethics, etc. The main problem of traditional capitalism is that social and environmental considerations do not fully participate in the pricing mechanism, and are therefore absent from the optimization process. Our joint property (the "common") - like air, water, cultural values, public land etc. - is not priced properly – if at all. This leads to many economic "externalities" in which the “players” in the economy can pollute the air or cause other damages to the environment without having to directly bear the consequences.

These considerations are especially relevant when dealing with infrastructure projects: For example, when building governmental housing for the poor, governments try to save on immediate costs by using low quality materials, and this drastically shortens the useful life of the building and creates high future maintenance costs. Moreover, such projects are often built on less expensive grounds, where the risks of being affected by floods or storms is higher ((Dilley et.al 2005 found that almost 900 million city inhabitants are exposed to more than one high hazard). Similarly, a constructor knows that a much better building can be built for an additional cost, but he would often prefer to build a less expensive structure, since the tenant (and not the constructor) will bear the extra air –conditioning and maintenance cost, and is not always willing to pay for a better building with more efficient energy balance and lower maintenance cost. Also municipalities may face the same dilemmas, although the municipality is interested in environmental issues, it is not the direct beneficiary of energy and water saving. The business world, and followers of the late Nobel Prize laureate Milton Friedman, often objects to internalizing socio-environmental considerations into economic decisions, since they fear that this will eventually increase costs and decrease profitability. However this could simply be the result of inappropriate pricing in the market due to externalities, and from incorrect measurement of the "profit".

The capitalistic philosophy that had served the industrial world is not suitable for the post industrial world, and needs to be adjusted and improved. This model is no more relevant for the personal and business management, and only increases the threats on our wellbeing. What is the sense of running businesses that destroy their own environment? We need to quickly build an improved version that is based on multi criteria objectives, and strives to social, economic and environmental prosperity and not merely to the maximization of material wealth or the per capita income. In principle this is a system that resembles the traditional "invisible hand" idea. But the prices are determined by a somewhat more complex system that takes into consideration also additional social and environmental considerations.

This requires a re-definition of a series of leading well-being indicators that will serve as a renewed goal and replace the narrow objective of maximization of material wealth. This is a "rebooting" process – in the sense that we aim for a transformation that will start from a safe point and will define a new economy. In the new economy new products, materials, and production methods will be used, new employment and pension arrangements, new monetary systems, and renewed democratic systems based on modern means of communication on national and local governments.

CONCLUSIONS

Heavy investment in infrastructure is still expected for the next decades, mainly in Asia and Africa due to the continuing trend of urbanization. We argue that well-being indicators that consider social and environmental as well as economic qualities should replace the sole economic considerations in business and public decisions. This will help to introduce a variety of new consideration into the decisions concerning investment in infrastructure by the public and private sector, and will lead to more sustained building.

REFERENCES

Dilley et. al (2005) **Natural Disaster Hotspots: A global Risk Analysis** . Center for Hazard & Risk Research CHRR, Columbia University. http://www.ldeo.columbia.edu/chrr/research/hotspots/

Kahane, Y. (2006) "Technological Changes, the Reversal of Age Pyramids and the Future of Retirement Systems" **European Papers on the New Welfare**, no. 4 February 2006. pp. 17-47.

Lasri, E. (ed.) (2012): **Economy, Society and Privatization in the Local Government.** (Hebrew) Bar Ilan University, Ramat Gan, Israel 2012

Spatari, S. & Atkan E. (2012) "Asset Management in Civil Engineering" in **Structure and Infrastructure Engineering: Maintenance, Management, Life-Cycle Design and Performance** 9:4, 295-296.

UN (2011) World Urbanization Prospects 2011 revision. http://esa.un.org/unpd/wup/index.htm

PROBABILISTIC SUSTAINABILITY EVALUATION OF NEW ENGINEERING MATERIALS

Michael D. Lepech
Department of Civil and Environmental Engineering, Stanford University
E-mail: mlepech@stanford.edu

SUMMARY

New materials, technologies, designs, and management techniques for increased sustainability are continuously being introduced into the architecture, engineering, and construction (AEC) industries. This abstract summarizes a new framework for rigorous, probabilistic, risk-based assessment of sustainable innovations and applies the framework to a new biobased material for use in construction.

Keywords: Sustainability, probabilistic, biocomposite, industrial ecology

INTRODUCTION

The design and construction of built environments that are more environmentally, socially, and economically responsible over their full life cycle from extraction of raw construction materials to end of life management is now being undertaken worldwide. As a critical set of systems that support our quality of life and enable global development and progress, while consuming vast amounts of material resources and energy, it is essential that built environments are designed, built, and operated according to broad, long-term goals for the benefit of our planet and the current and future generations of humans, animals, and plants that will call it home.

While the architecture, engineering, and construction (AEC) community generally agrees with these tenets of sustainability, the creation of built environments that are socially, environmentally, and economically sustainable is not functionally possible using current industry methods. Moreover, as new materials, technologies, designs, and management techniques for increased sustainability are continuously introduced, determining whether sustainability is being achieved becomes increasingly complex and confusing. This is due to the lack of quantitative targets for a “sustainable” design, quantitative metrics for measurement and comparison, and a probabilistic-based design approach that is translatable to engineering practice expectations of rational design procedures that manage uncertainty in design, construction, and operation. This work summarizes a framework for achieving these sustainability goals and demonstrates its application on an innovative construction material.

PROBABILISTIC FRAMEWORK FOR SUSTAINABLE BUILT ENVIRONMENTS

The probabilistic framework for design, construction, and operation of sustainable built environments is based on the probabilistic framework for reinforced concrete service life design proposed in the 2006 *fib* Model Code (*fib*, 2006). This framework is now embodied in the 2010 *fib* Model Code Sections 3.4 and 7.10 (*fib*, 2010), and is shown graphically in Figure 1 (Lepech *et al*, 2013). Probabilistic assessment of sustainability begins with probabilistic assessment of the service life of a built environment or its components. The time at which construction, repair, or any service action is made (t_{rj}) is probabilistically characterized based on reaching a future service limit state unacceptable to the owner or an appropriate design code. The probabilistic time between service actions ($t_{rj+1} - t_{rj}$) is based on the chosen action, the work quality, the variable exposure conditions, and the limit state.

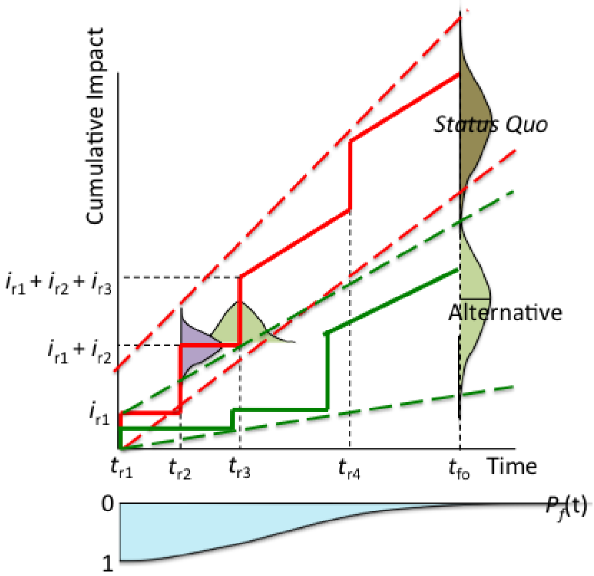


Figure 1: Probabilistic framework for evaluation of new materials for sustainable built environments

In addition to the probabilistic determination of the time of service actions, the amount of impact associated with each action is also modeled probabilistically. The amount of impact associated with a given action, i_{rj}, varies due to uncertainty in construction, repair and service action processes actually used, or uncertainty in the supply chain of materials. Combining the probabilistic models for both service life (t_{rj}) and impact (i_{rj}), a probabilistic envelope is constructed for the entire service life from the time of construction (t_0) up to functional obsolescence (t_{fo}) of a *status quo* built environment. A similar envelope is constructed for alternative, more sustainable designs.

Within the framework, sustainability is defined by impact midpoint indicator targets such as global warming potential reductions, ozone depletion potential reductions, or similar indicators as specified by ISO 14040 life cycle assessment standards. Applying these indicator targets and comparing two alternative envelopes for impact reduction allows for probabilistic design and evaluation (through a probability of failure, $p_f(t)$) of new materials, technologies, or built environments. The evolution of this probability of failure over time is shown in Figure 1. Using this framework, the AEC industry is encouraged to achieve proposed sustainability targets at lowest economic cost, provided that the level of confidence that future sustainability targets are met complies with social expectations. Tradeoffs between confidence (probabilities of failure) and cost can also be considered.

PROBABILISTIC EVALUATION OF BIOBASED COMPOSITE MATERIALS

To demonstrate this framework a new biocomposite material is examined for its potential as a sustainable replacement for a conventional construction material. These biocomposites are a 3-phase material with a protein, mineral, and protein interface phase. The protein phase (bovine serum albumin) accounts for 5-10% of composite mass. The mineral phase makes up 90% to 95% of the mass. A sample of the biocomposite is shown in Figure 2.

Figure 2: Biocomposite material synthesized using Vacuum Assisted Resin Infusion Methods (VARIM) and following desiccation.

The *status quo* building material chosen for this study is a concrete masonry unit (CMU) for probabilistic comparison in terms of energy, and global warming potential emissions. The alternative building material chosen is a biocomposite brick with identical dimensions. CMUs are produced using conventional mixing and curing oven technology. Biobricks are produced using a pneumatic press followed by kiln drying.

Results show that biobricks exhibit a significantly lower impact (approximately 30% lower) over a 50-year life cycle as compared to CMUs. However, due to uncertainty in the supply chain of biobrick components, and uncertainty in their durability when exposed to decades of weathering, it is unlikely that they will reliably meet sustainability midpoint indicator targets over the upcoming decades. As such, without major rethinking of these materials and their constituents, their application as a sustainable alternative to CMU is not recommended.

CONCLUSIONS

This work summarizes the introduction of a probabilistic framework for the evaluation of new materials for sustainable built environments. It applied the framework to compare a novel biobased composite material to concrete masonry units (CMU). While the biobased composites performed more sustainably than CMU, it is unlikely they will be able to meet future sustainability targets if significant changes are not made to their manufacturing and constituent materials. This work provides the foundation for the broad, probabilistic evaluation and design of sustainable built environments. Critical research is needed in the areas of probabilistic service life modeling, probabilistic consequentional life cycle assessment, sustainability limit state definition, and risk-based assessment of achieving disparate (and often contradictory) sustainability targets and goals.

ACKNOWLEDGEMENTS

The author would like to thank graduate students H. Roedel, C. Nowacki, F. Grey, P. AuBuchon, P. Havelia and S. Desai. The author would also like to thank Dr. D. Loftus at NASA Ames Research Center.

REFERENCES

Federation International du Beton *fib* (2006) "Model Code for Service Life Design – Bulletin 34" Pp. 116

Federation International du Benton *fib* (2010) "2010 Model Code - Bulletin 55, 56" Pp. 312

Lepech, M., Geiker, M., Stang, H. (2013) "Probabilistic Design and Management of Environmentally Sustainable Repair and Rehabilitation of Reinforced Concrete Structures" *Cement and Concrete Composites*. 10.1016/j.cemconcomp.2013.10.009

OPERATIONAL RISK MANAGEMENT (ORM) IN CIVIL ENGINEERING

Dr. Pavel Grabov
VP ALD Ltd.
grabov@ald.co.il

SUMMARY

The paper presents most important risk management activities, techniques and tools including their comparative analysis and applicability for different areas. Case studies illustrating application of these tools in Civil Engineering, Industry and Environment Protection are also included.

Keywords: operational risk management, risk severity, risk probability.

INTRODUCTION

ORM represents an integral part of sound System Engineering. It deals with four areas of risks and treats them in an integration fashion:

1. Risks related to System/Program/Project Management: ability to achieve set goals & objectives in the framework of accepted strategy.
2. Risks related to Technical & Informational Efforts: customer satisfaction risks, compliance risks, safety risks, ecology related risks, security risks, efficiency risks, supply chain risks, information security risks, logistics risks, organizational risks, business continuity risks, etc.
3. Cost/Budget/Schedule related risks: ability to meet cost and budget goals & constraints, as well as ability to meet due dates and project progress in accordance with the imposed schedule.

Main ORM goals could be formulated as follows:

- Assess whether the system/project goals, budget and schedule targets are realistic and achievable.
- Understand the uncertainty affecting the system/ project goals, budget and schedule targets.
- Study the dependences among goals, budget and schedule and understand in what extent uncertainty in one affect the assessment of risk in the other two.
- Identify so-called 'Critical Drivers' from ORM point of view, develop and implement risk reduction/mitigation program for unacceptable risks.
- Set a control system for uncertainty and risk continuous monitoring covering all critical aspects of a system behavior and/or a project performance.

ORM MAIN ACTIVITIES AND SUPPORTING TOOLS & TECHNIQUES

There are 10 different kinds of ORM activity intended to management of both Pure Risks (related to some external factors) and Speculative Risks (Risks that we initiate ourselves):

1. Risk Identification and Characterization – preparation of so-called risk register and risks characterization covering a comparative analysis with relevant ‘Good Practice’ in given area.
2. Risk Assessment and Prioritization – risk analysis covering (but is not limited) some most important issues: time to risk realization, mode (scenario) of risk realization, likelihood of risk realization (Probability), effect of risk realization (Severity), risk detectability, etc. Risk prioritization serves for identification of main Risk Drivers that should be chosen as the objects for planned risk reduction & mitigation activity.
3. Risk Communication and Allocation – this activity objective is to inform all relevant parties (managers, decision makers, stakeholders, general public, etc.) about risks facing them, and to insure that they understand the implications of these risks. Risk Allocation implies making decision about personal responsibility or ownership of a particular identified and classified risk within company.
4. Risk Retention – since any business activity is risky and there is strong positive dependence between a project’s expected added value and a project’s risk, we should take risks if we don't want to loss an opportunity. Obviously, this risk taking should be accompanied by an intelligent analysis 'If the Risk is in balance with the reward that may be gained?'

5. Risk Transfer – there are some paths of Risk Transfer: insurance, sharing, outsourcing and out tasking, etc. Usually Risk Transfer is used when the particular risk is characterized by low probability of occurrence and high (severe/critical) effect, e.g. such natural phenomena as severe incident, earthquake, flood, etc.
6. Risk Planning – activities intended to prevent risky situation (protection and security measures, training, warning, safety instructions, etc.), to inform about risky situation nearing or occurrence (indicators, monitors, visible or audible alarms, etc.), to deal with Risky Situation at time of event (control rules, systems, devices, safeguards, etc.) and to deal with Risky Situation after its realization (emergency response/action plans & instructions, creation of administrative or personnel systems, construction of redundancy systems, etc.).
7. Risk Reduction – this activity implies reduction of risk realization probability through one of three possibilities: to prevent cause from occurring, to detect and correct cause after its occurring or to keep this cause from risk generation.
8. Risk Mitigation – three kinds of activities intended to reduction of risk realization effect and separated in time: before some undesirable event (preparedness to this event, detection and protection measures, etc.), at time of risk realization (system interlocking or shut down, safeguards initiation, pushing event to the accident path evolving along the 'Minor Losses' consequences, accident localization and prompt treatment, communication with all relevant parties, protection of undamaged personnel, property, environment, etc.), and post-event activities (rehabilitation of injured personnel, prompt restoration of the system and environmental safety to pre-event levels, etc.).
9. Risk Control and Monitoring – sin**ce** all risk estimates are strongly time related, we should establish a system for risk continuous monitoring and feedback control, helping to understand "Whether the risk register is still relevant or it should be updated, what is the current risk level, whether some immediate risk prevention/reduction/mitigation activity is required, etc.".
10. Risk Avoidance - when the risk level is unacceptable, and not manageable, then the Risk Avoidance is the only remaining option (change the plans/goals/targets/deadlines, change the partners/clients, change the project team, choice of another alternative, activity delay or stop, etc.).

There is variety of different tools & techniques (T&T) supporting all above mentioned ORM activities, but most appropriate T&T for Civil Engineering are as follows:

- HAZOP (Hazard Operability Analysis) – strongly OSHA oriented step-by-step risk analysis of process / material / energy flow through a system/process. Two-dimensional risk evaluation: Severity & Probability.
- ETA (Event Tree Analysis) - ORM tool enable to reveal the design and process weaknesses. It is especially effective for evaluation of the systems where multiple safeguards are in place as protective features. One-dimensional risk evaluation – Probability only.
- FTA (Fault Tree Analysis) - failure Top-Down analysis in deductive manner in which an undesired state of a system is analyzed using Boolean Logic to combine a series of lower-level events. FTA is mainly used in the fields of Reliability & Safety Engineering. One-dimensional risk evaluation – Probability only.
- FMEA (Failure Mode and Effect Analysis) – one of most effective ORM tools applicable at Design (DFMEA) and Operation (PFMEA) stages for risk analysis, prioritization and evaluation of risk mitigation plan adequacy. Three-dimensional risk evaluation: Severity, Probability and Detectability.
- Equi-Risk Contour Method – graphical technique used for alternatives comparative risk analysis, using risk assessment chart (so-called 'Heat Map'**)** with pre-defined boundaries of four risk areas: Negligible Risk, Low Risk, Medium Risk, High Risk. Analyzed alternatives are assigned to risk domains in accordance with the results of the expert evaluations.

All above mentioned T&T are illustrated by examples of these tools application in Civil Engineering, Industry and Environment Protection

5th Session: Integrated Modeling and Analysis Tools for Sustainable Built Environments

Vered Blass: Using industrial ecology tools to estimate resources use and environmental impacts

Sabrina Spatari, Jonathan F. Hubler, Suk Joon Na, Y. Grace Hsuan: Life Cycle-based decision support for sustainable infrastructure: Guides to materials selection and design

David Pearlmutter: Multi-scale energy modeling: materials, buildings and urban spaces

Vivek Shandas, Michael Weisdorf: Using agent-based modeling in addressing urban water use

Chanoch Friedman, Nir Becker, Evyatar Erell: Private and social motives in understanding green behavior in the building sector

Brucin Becerik-Gerber, David Gerber, Zheng Yang, Arsalan Heydarian, Joao Carneiro: Integrated Cyber-Social-Physical systems for sustainable built environments

USING INDUSTRIAL ECOLOGY TOOLS TO ESTIMATE RESOURCES USE AND ENVIRONMENTAL IMPACTS

Vered Blass
Tel Aviv University
vblass@post.tau.ac.il

SUMMARY

In this talk we present the foundation tools of industrial ecology and we discuss how these tools can be applied when estimating resource use and environmental impacts, with emphasis on research related to Sustainable Built Environment. We first discuss industrial ecology in general and then review some of the exiting tools giving relevant examples of different studies and existing research groups. We conclude with thoughts how the IE tools and methods can further be integrated into the Sustainable Built Environments research and applications.

Keywords: Industrial ecology, environmental impact, LCA, MFA

Although a fairly young field of research, Industrial Ecology (IE) can offer quantitative methods to evaluate the environmental and social impacts of production and consumption systems, including different aspects of the Sustainable Built Environment such as buildings, infrastructure, and larger complex systems such as cities.

Tools such as Life Cycle Assessment (LCA) and Materials Flow Analysis (MFA) specifically fit for analysis of such systems to support development and design decision making as well as policy making. Because many of such systems are designed to exist few ten years if not more, sometimes the impacts of construction and demolishing of such systems are not taken into consideration since the use phase is so long. However, with the recent attention for raw materials sourcing and waste management, LCA and MFA can help identify opportunities for raw materials savings and higher rates of reuse and recycling. It also allows us to better understand the sources, stocks, and sinks of the different materials, emissions, and wastes associated with the studied systems.

Examples of relevant studies that used IE tools include empirical assessment of energy use and greenhouse gas emissions associated with residential development (Norman et al 2006), Life Cycle Assessment for Water Systems Planning (Lundie et al 2004), MFA for urban construction (Huang and Hsu 2003), and more.

Other concepts of IE such as industrial symbiosis should also be considered since many different waste streams could be used and mixed in with some construction materials (for examples tires waste, some waste generated in mining etc) and save some raw materials, transforming waste to a resource.

Within the Industrial Ecology field, there is a sub-filed that is focused on Sustainable Urban Systems. This sub-field use IE concepts and tools towards the sustainable development of cities, their supporting hinterlands, and the networked infrastructure that connects them (ISIE 2014). Researchers in this field come from different disciplines including urban planners, architects, geographers, civil and environmental engineers, economists, etc.

In addition and more practically, with the growing interest in green building, new research and training programs emerge to educate designers and planners to take a life cycle management approach and look at construction projects in a more holistic way including social and environmental approach.

Overall, there is a need to get more scientists familiar with the field of Industrial ecology and the tools it has to offer in sustainability analysis and future planning.

REFERENCES

International Society for Industrial Ecology Web site, accessed on 1/31/14 www.is4ie.org

Lundie S., Peters G.M., and Beavis P.C, (2004), Life Cycle Assessment for Sustainable Metropolitan Water Systems Planning, *Environmental Science & Technology 38* (13), 3465-3473

Norman, J., MacLean, H., and Kennedy, C. (2006). Comparing High and Low Residential Density: Life-Cycle Analysis of Energy Use and Greenhouse Gas Emissions, *J. Urban Plann. Dev*., 132(1), 10–21

Huang S-L, Hsu W-L, (2003), Materials Flow Analysis and Emergy Evaluation of Taipei's Urban Construction, Landscape and Urban Planning 63, 61-74

LIFE CYCLE-BASED DECISION SUPPORT FOR SUSTAINABLE INFRASTRUCTURE: GUIDES TO MATERIALS SELECTION AND DESIGN

Sabrina Spatari[1], Jonathan F. Hubler[2], Suk Joon Na[1], Y. Grace Hsuan[1]
[1]Department of Civil, Architectural, and Environmental Engineering, Drexel University, Philadelphia, PA, USA
[2]Graduate Student, Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI, USA
Corresponding Author: Sabrina Spatari, E-mail: spatari@drexel.edu

SUMMARY

Opportunities exist to integrate recycled materials beneficially in the urban landscape to minimize waste and design integrally with the hydrologic cycle. LCA tools can measure the environmental performance of infrastructure materials and support the sustainable design and maintenance of urban-engineered systems through novel uses of recycled polymer in geo-pipe and geosynthetics.

Keywords: LCA, infrastructure materials, low impact development, sustainable geotechnics, asset lifetime prediction.

INTRODUCTION

Material selection decisions have long term impacts on the environmental performance of civil engineering assets and their costs to society. Pipeline networks, which occupy more than 1.6 million miles in the U.S., are among the extensive above-ground and buried infrastructure that provide essential resources to cities for water supply, stormwater conveyance, and liquid and gaseous energy distribution. Systems-based methods that include life cycle assessment (LCA) are highly valuable towards guiding the design, material selection, and on-going maintenance of urban infrastructure systems. In many cases, LCA has been integrated into urban decision support on a variety of applications from municipal water management (Herstein et al. 2009; Spatari et al. 2011), to road and highway drainage (Hubler et al. 2012), and geo-infrastructure (Inui et al. 2011).

Moreover, the urban built environment poses many site-specific challenges towards the sustainable design, maintenance, and management of infrastructure. Often, site conditions pose immediate constraints on the selection of materials in above and below-ground infrastructure (Inui et al. 2011); they dictate the factors that define infrastructure design life, performance, and failure risk. Opportunities to integrate fractions of recycled content into building materials such as aggregates (McIntyre et al. 2009) have environmental benefits over a range that preserves the engineering properties of the material, which, in LCA is factored into the functional unit. We explore opportunities to introduce nanoclay-recycled-polymer blend composites into new and replacement pipe infrastructure and use LCA to measure the environmental performance of these novel materials.

CASE STUDY: DRAINAGE PIPE

We use standardized life cycle assessment (ISO 2006) methods to characterize the energy consumption and environmental performance of conventional high density polyethylene (HDPE) pipe available on the market and advanced nanocomposite materials made using a blend of pristine (primary) and recycled (secondary) HDPE polymer and nanoclay (Montmorillonite). We explore opportunities to combine numerical modeling to predict failure mechanisms in recycled polymer (44% by weight) nanoclay (6% by weight) composites to inform the in-use phase of the pipe life cycle. Since stress cracking is a common cause of failure in polyethylene pipe, understanding the fracture behavior of testing materials is essential for predicting new material design life. In order to numerically determine the fracture resistance of polyethylene resins, a newly developed numerical method called the extended finite element method (XFEM) was employed and reported by (Na et al., 2013).

Sample life cycle energy modeling results that include drainage pipe material production (primary material resource extraction, secondary material recovery from post-consumer waste, pelleting of HDPE commodities), commodity transportation, pipe extrusion, and pipe transportation and site installation were estimated for conventional and advanced pipe materials (Figure 1). In spite of the incremental energy “costs” associated with nanoclays added to the advanced pipe, there are significant energy savings when blending recycled HDPE into nanoclay material for pipe due to the reduced energy from natural gas and crude oil feedstocks needed for manufacturing primary HDPE pellets.

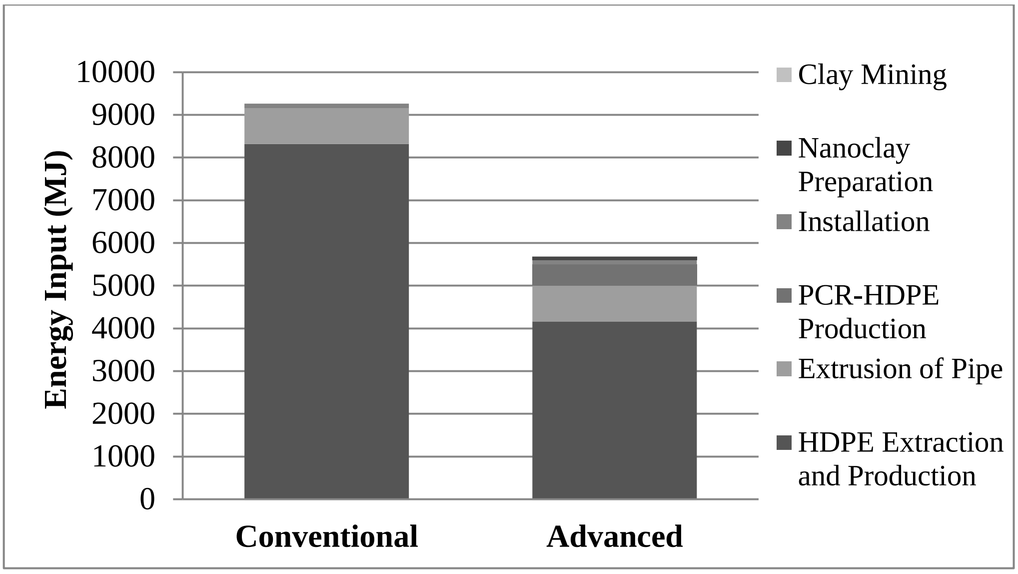


Figure 1: Cradle-to-gate energy consumed for conventional (100% primary HDPE) and advanced (6% Montmorillonite nanoclay, 44% secondary HDPE, 50% primary HDPE) highway drainage pipe. Source: Hubler et al. (2012)

CONCLUSIONS

Advances in materials science have introduced novel polymeric materials for pipe in civil and geotechnical engineering applications. Such materials exhibit resource reuse and environmental performance benefits that could extend to better pipe conveyance applications and also to geosynthetic materials for use in low impact development and green infrastructure (Spatari et al. 2011). A major challenge for LCA research on materials is the integration of lifetime prediction models that can robustly describe new material failure risk to inform infrastructure material selection and replacement tradeoffs for sustainable asset management. Understanding the time-dependent fracture behavior of recycled and nanoclay composite materials in long-lived infrastructure assets through materials testing and model prediction is critical to ensuring their successful performance.

ACKNOWLEDGEMENTS

This work was supported by the U.S. National Science Foundation under grant # 1030783.

REFERENCES

Herstein, Filion, Y.R., Hall, K.R., 2009. Evaluating Environmental Impact in Water Distribution System Design. Journal of Infrastructure Systems 15, 241-250.

Hubler, J.F., Spatari, S., Hsuan, Y.G. Environmental Life Cycle Assessment of Conventional and Advanced HDPE Pipe in Highway Drainage Applications, 91st Annual Transportation Research Board Meeting, Washington DC, January 22-26, 2012.

Inui, T., Chau, C., Soga, K., Nicolson, D., O'Riordan, N., 2011. Embodied Energy and Gas Emissions of Retaining Wall Structures. Journal of Geotechnical and Geoenvironmental Engineering 137, 958-967.

ISO, 2006. ISO 14040: Environmental management — Life cycle assessment — Principles and framework. International Standards Organization, Geneva.

McIntyre, J., Spatari, S., MacLean, H.L., 2009. Energy and Greenhouse Gas Emissions Trade-Offs of Recycled Concrete Aggregate Use in Nonstructural Concrete: A North American Case Study. Journal of Infrastructure Systems 15, 361-370.

Na, S., Lau, A.C.W., Spatari, S., Hsuan, Y.G., 2013. Application of extended finite element method to determine the plane-strain essential work of fracture of polyethylene, ANTEC 2013, April 21-24, Cincinnati, OH.

Spatari, S., Yu, Z.W., Montalto, F.A., 2011. Life cycle implications of urban green infrastructure. Environmental Pollution 159, 2174-2179.

MULTI-SCALE ENERGY MODELING: MATERIALS, BUILDINGS AND URBAN SPACES

David Pearlmutter
Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Israel
E-mail: davidp@bgu.ac.il

SUMMARY

This presentation looks at the potential for making radical improvements in the efficiency of energy use by modeling energy flows at three different scales of the built environment: the first is material-centered, the second is building-centered, and third is urban-centered. Findings from recent studies in Israel using these different modeling approaches are discussed, with an eye toward their possible integration in a more holistic approach to sustainable architecture.

Keywords: energy-fficiency, built environment, life-cycle assessment, urban micro-climate.

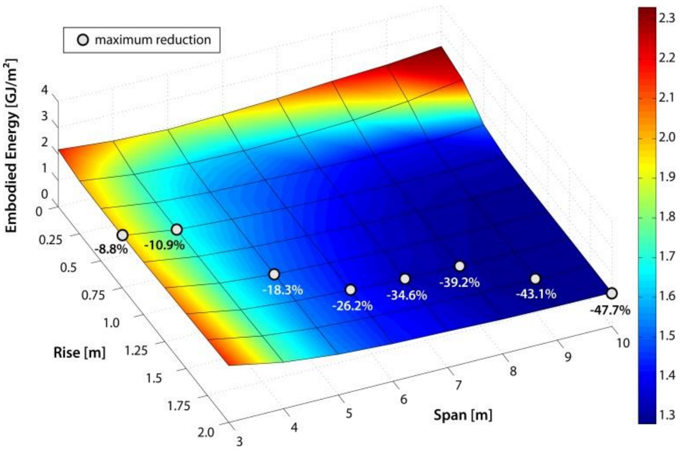
INTRODUCTION

Energy is used in the built environment in many ways and at a variety of spatial scales. While the mode most commonly considered is the consumption of energy for heating and cooling – and the general ongoing maintenance of individual buildings – a considerable demand on energy resources originates outside this box: both in the production of a building's materials, and in the urban context within which it is situated. Further, these different conduits for energy consumption are not independent but rather interrelated, since the choice of materials, for instance, influences the operational as well as embodied energy of the building envelope, and the design of the urban fabric influences thermal loads on the building as well as those on a pedestrian in an outdoor space – which in turn may have an impact on energy-related behaviors, such as people's utilization of public transit or reliance on air-conditioned vehicles and spaces.

MODELING STUDIES

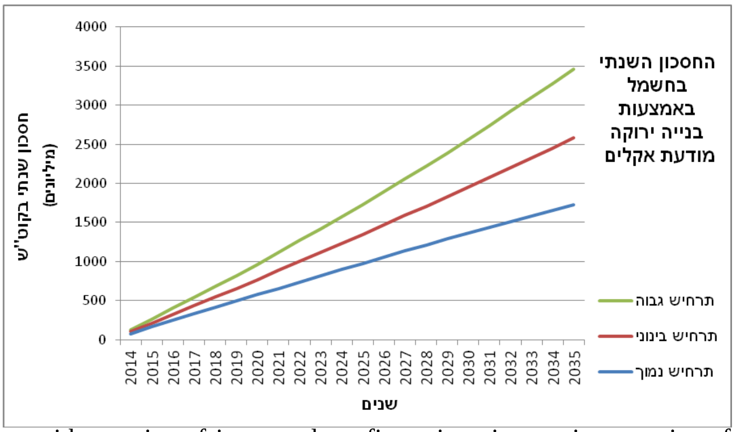
Here we briefly summarize three avenues of research which have been pursued in Israel by way of energy modeling, respectively examining some of the material-centered, building-centered, and urban-centered aspects of energy in the built environment.

Material embodied energy and efficient structural form



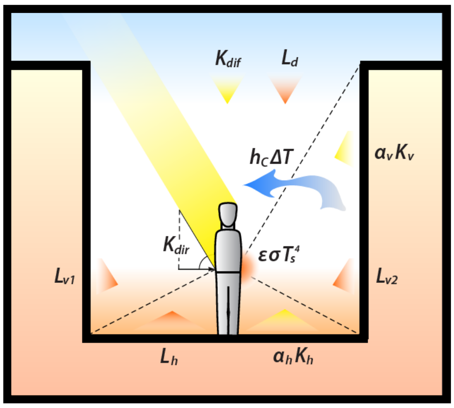
Within the initial embodied energy of a standard reinforced concrete building, the structural system can be the major component – and this is closely related to the geometry of its horizontal spanning elements. This study examines the potential life-cycle energy savings that may be achieved by the exploitation of alternative structural roof forms, such as vaulted thin shells, which by carrying their loads efficiently may greatly reduce the reliance on cement and reinforcing steel, both of which contribute to the high energy-intensity of typical buildings. A multidisciplinary energy-based optimization framework was developed, which integrates two external simulation tools (structural and thermal) and a life-cycle energy assessment (LCEA) methodology, for automated analysis and evaluation of optional non-planar roofs. The optimization tool was demonstrated to effectively identify "best" alternatives, and clearly shows the potential of vaulted roof forms to reduce a structure's embodied energy by over 40%, and life-cycle energy consumption by over 20%.

National energy-saving potential through improved building design



In order to assess the national energy savings potential in Israel of various building design strategies, a series of thermal simulations were conducted to quantify the heating and cooling loads on typical residential buildings. The study was performed using climate data from the country's four standard climate zones, and building data representing prototypical single-family and multi-storey apartment buildings in each of these regions. The relative contribution of various design features to the building's energy efficiency was quantified by comparing a "base case" design configuration with a series of improved configurations integrating a series of design parameters defined in national building energy standards. The lever which showed the most pronounced potential for savings in all zones was improved window design and treatment, which surpassed for instance the marginal gains from improved wall insulation above the mandatory requirement. Statistical and geospatial analyses were used to estimate future construction rates and the overall potential for energy savings in the coming decades. It was found that by the year 2035, the yearly reduction in electricity demand accruing from improved residential construction could surpass the annual output of a large conventional power plant.

Pedestrian energy exchange and thermal stress



A series of modeling studies in the Negev desert examined strategies for the design of urban green spaces which considers the potential for moderating pedestrian thermal stress. Evapotranspiration over vegetated terrain was first analyzed using the Open-Air Scaled Urban Surface (OASUS) model of Pearlmutter et al. (2009), and found to be dictated by the availability of moisture relative not only to the horizontal surface area, but to the three-dimensional surface area of the urban fabric. At the microclimatic scale, the combined effect of shade trees and vegetative ground cover on thermal stress in urban spaces was modeled based on experimental data in semi-enclosed courtyards (Shashua-Bar et al. 2011). The ITS model was used to evaluate thermal stress from radiative and convective energy exchanges, expressed on a thermal sensation scale. Compared to conditions in a paved, unshaded courtyard, shading reduced the duration of discomfort by over half and limited its maximum severity, and when combined with grass yielded comfortable conditions at all summer hours. The effect of trees was more pronounced than that of an artificial mesh, due to the latter's elevated radiative surface temperature. It was found that a combination of locally adapted shade trees and irrigated ground cover not only creates thermally comfortable conditions in otherwise stressful outdoor environments, but requires less water for irrigation than exposed grass alone. Given the exorbitant water requirements of grass, a further modeling study investigated the potential of succulent plants for use as an alternative in urban landscaping. Input data were taken from measurements in small planted plots, which were used to compare the characteristic albedo and radiant surface temperature, as well as the water requirements, of different types of ground-cover vegetation. It was found that while succulent varieties maintained slightly higher surface temperatures than grass, their reduced water loss under conditions of limited irrigation endowed them with a higher cooling efficiency. Modeling showed that in comparison to vegetated surfaces, intense thermal stress is imposed by bare soil due to reflected radiation and by artificial turf due to high radiant surface temperatures.

REFERENCES

Pearlmutter, D., Krüger, E.L. and Berliner, P., 2009. The role of evaporation in the energy balance of an open-air scaled urban surface. *International Journal of Climatology*, 29: 911-920.

Shashua-Bar, L., Pearlmutter, D. and Erell, E., 2011. The influence of trees and grass on outdoor thermal comfort in a hot-arid environment. *International Journal of Climatology*, 31:1498-1506.

USING AGENT-BASED MODELING IN ADDRESSING URBAN WATER USE

Vivek Shandas and Michael Weisdorf
Portland State University
Corresponding Author: Vivek Shandas, vshandas@pdx.edu

SUMMARY

Agent-based modeling offers many opportunities for examining the nexus between built environments and human behavior across multiple scales. In the present study we employ an agent-based model to examine the relationship between residential water use, climate conditions, and the built environment of an urban neighborhood.

Keywords: residential urban water use, agent-based modeling, Portland (OR).

INTRODUCTION

Sustainable built environments require reliable, safe, and consistent supplies of fresh water. Yet public and private water managers are increasingly cognizant of the implications of climate change, and the need to enact conservation measures to ensure adequate future supplies. As a result many urban areas are issuing moratoria on permits for new water use, and implementing education programs to reduce unnecessary use during peak hours. Recent calls to California, Colorado, North Carolina, and many other US states suggest that mediating residential water consumption may offer the largest, yet currently unrecognized, potential avenue for conservation. While the potential water savings from management through this type of conservation are quite large, such efforts require an intimate understanding of demand-side behaviors, which are difficult to assess at the household scale. An even greater challenge lies in understanding how variable climate conditions are likely to impact demand for water. Despite extensive efforts at linking downscaled climate models with water supply forecasts, the climate impacts on individual behavior and its role in regulating demand for water is largely unexamined. The studies that do exist rely on survey research to collect region-specific estimates or anecdotal data from specific households. Without an explicit understanding of household behavioral responses to varying temperature regimes, the task of managing water resources under climate change, population growth, and other uncertainties is a challenging proposition at best.

One way to address the complex challenges facing the future of resource use in urban areas is the development of computer models of urban systems. Ideally, such models will be capable of being adapted to a diverse range of simulation experiments. While no model can capture all the detail of the actual world, an integrative model that is adaptable to a wide-range of spatial and temporal variability at multiple scales would be of tremendous value to resource planning and management efforts. Combining the results of a plurality of specialist researches into a unified simulation system, which still abstracts from much while paying respects to the insights developed in each of the contributing disciplines, is a goal as ambitious as it is essential. Computing infrastructure, social networks, and initiatives can provide a unique opportunity to cultivate this new kind of interdisciplinary, integrative theory. If we are to understand the world that we inhabit, and perhaps more importantly, improve the material conditions under which human life occurs in nature on our planet, it is absolutely essential that we develop the tools and technologies needed to integrate our presently overspecialized and isolated scientific disciplines. Here, we develop and report on an integrated multi-scale simulation platform that provides insight into the current nature of water use, and the implications of climate change for urban water demand in the future.

APPLYING INTEGRATIVE MODELING FRAMEWORK TO URBAN WATER USE

A formidable challenge in assessing household conservation behavior lies in understanding the suite of factors that affect water demand. Empirical research on water demand has explored socio-demographic factors and policy variables, such as price and technology (e.g. water amenities, water metering, and/or water-saving plumbing fixtures). While not all of this information is immediately available, a suite of modeling tools can provide guidance for better gauging the potential of specific environmental and social changes on water use.

Over the last four decades, the literature suggests a set of factors that are central to understanding water use in urban environments. For example, numerous researchers have concluded that differences in water demand are associated with income or lifestyle, and household size. Some urban form attributes have also been implicated in affecting water demand, including dwelling type, land use type, neighborhood density, and the presence of other landscape features (Shandas et al., 2012). More limited evidence links water demand to local environmental conditions, such as inter-annual temperature and precipitation, drought conditions, swimming pools, a high proportion of irrigated mesic landscaping (Gutzler and Nims 2005; Wentz and Gober, 2007; Balling et al., 2008). These and other studies begin to provide the basis for developing agent based models that allow researchers to understand the socio-ecological dynamics of urban water use, thereby constructing a more accurate view of the potential of future water demand in an climate-induced urbanizing context.

MODELING RESIDENTIAL WATER DEMAND: CASE STUDY

Agent-based modeling seeks to reconstruct the salient features of a target system by simulating the micro-level interactions between system participants. The overall (macro-level) behavior of the system in simulation emerges from those interactions, rather than being explicitly modeled or programmed using more conventional techniques. In this case, the target system of the simulation is a particular neighborhood in the southeast quadrant of the City of Portland (Oregon, USA). The objective variable is the demand for city water, and the agents in the system represent households, and potentially other users of municipal water, in a southeast neighborhood known as the “Foster-Green EcoDistrict.” Existing empirical literature provides several variables for modeling the potential water use from one part of the city, which can be extended to encapsulate an entire urban region, in this case, the city of Portland.

The expected maximum daily temperature in this neighborhood can be extracted from downscaled versions of the global climate models published by the IPCC. The Pacific Northwest (PNW) climate predictions used in this model were provided by the Climate Impacts Group at the University of Washington’s College of the Environment. Each agent in the simulation responds to the predicted daily temperature by demanding (i.e. consuming) a calculated amount of water, based on characteristics of the household and dwelling structure. Simulation agent variables include the type, age, and size of each dwelling structure, lot size, assessed value, as well as household behavioral variables such as number of residents, installation of high-efficiency fixtures and appliances, and whether it is a work-day or a weekend. The demand-function is calibrated with the results of a previous, hierarchical linear-regression model of residential water consumption (Chang et al. 2010; Shandas et al., 2012 in the same city.) The agent-based model thus integrates climate model output with household GIS data from a regional survey to predict daily water use for each agent in simulation. Over time, as the climate changes and the composition of the neighborhood develops, the agent-based neighborhood model provides a highly granular prediction of the trends in demand for city water, under multiple scenarios of both climate change and urban development.

CONCLUSIONS

The agent-based model is not limited to the individual household and/or the neighborhood scale however. By redefining the agents in the simulation to be larger aggregations of water-users, such as city blocks, the model can be efficiently scaled up in order to simulate a larger system, such as the entire southeast quadrant, the whole city, the metropolitan region, etc. The granularity of the model, relative to the scope of the target system to simulate, is limited primarily by the available computing hardware and reliable empirical data. The results of the simulation are comparably robust across multiple scales, depending on the quality of the aggregate level input data. The actual water use for any given agent on a particular day may vary considerably from the simulated value—however the actual values for the neighborhood, city, and regional scale trends in total water used were consistently found to be within the confidence intervals predicted by the simulation.

The present study suggests the development of an extensible, general-purpose model for the simulation of urban growth, development, and resource use. Such models need to be grounded in the material facts of human ecology, as well as the significant insights into human motivation and behavior which have been extensively examined by the various social sciences. By developing a scalable model, capable of running on equally scalable computer infrastructure, agent-based modeling offers a means of investigating those complex phenomena which are not amenable to analysis by the methods of traditional, disciplinary science. The goal of the present iteration of our water use model is necessarily somewhat restrained in comparison. Further development of this and similar models is indicated, in order to advance the integration of a wide range of expert knowledge into unified models of urban growth and development across multiple scales.

ACKNOWLEDGEMENTS

We would like to acknowledge Portland State University’s Institute for Sustainable Solution for providing funding to support a graduate student (Weisdorf) in accomplishing this work.

REFERENCES

Chang H, Parandvash GH, & Shandas V. 2010. “Spatial Variations Of Single-Family Residential Water Consumption In Portland, Oregon.” Urban Geography 31, 7, pp. 953-972. DOI: 10.2747/0272-3638.31.7.953

Shandas, V. M Rao, and MM McGrath, 2012. "The implications of climate change on residential water use: A micro-scale analysis of Portland (OR)." *Journal of Climate and Water 3(3): 225-238*

Gutzler, D. S. & Nims, J. S. 2005. Interannual variability of water demand and summer climate in Albuquerque, New Mexico. Journal of Applied Meteorology 44 (12), 1777–1787.

Wentz, E. & Gober, P.2008. "Determinants of small-area water consumption for the city of Phoenix, Arizona." Water Resources Management 21 (11), 1849–1863.

Balling Jr, R. C. , Gober, P. & Jones, N. 2008. "Sensitivity of residential water consumption to variations in climate: an intraurban analysis of Phoenix, Arizona." Water Resources Research 44, W10401, 113–129.

Climate Impacts Group—UW College of the Environment <http://cses.washington.edu/data/data.shtml>

PRIVATE AND SOCIAL MOTIVES IN UNDERSTANDING GREEN BEHAVIOR IN THE BUILDING SECTOR

Chanoch Friedman
Ben Gurion University

Nir Becker
Tel-HaiCollege

Evyatar Erell
Ben Gurion Univey

Corresponding Author: Nir Becker, nbecker@telhai.ac.il

SUMMARY

We demonstrate how private behavior is being used in green behavior in the building sector and compare it to the social desired outcome. This is done for both retrofit in Israel and for a green building project that compares people that chose to act in an environmental friendly way vs. those who did not.

Keywords: Retrofit, Green Building, Cost-Benefit, Motivations.

INTRODUCTION

Improving the energy performance of buildings is essential if Israel is to moderate the rate of increase in its overall energy consumption and to meet its international obligations to reduce emission of CO_2.

The cost of renovation and building depends on numerous factors, including the current state of the building stock, local building practices in the construction sector, availability of materials, and legal and regulatory constraints. Likewise, the benefits too, depend on local characteristics such as the climate and occupant behaviour.

Numerous studies in other countries have demonstrated that green building and building renovation is cost-effective from the point of view of the individual [e.g., 5,6]. The objective of this study was two-fold: to examine whether in Israel, whose weather is not extreme, such environmental activities to save energy are economically beneficial from a private point of view (considering only private benefits); and to assess the benefits from a social point of view (when market failures are internalized and are taken into account as well).

METHODS

Typical building prototypes representing housing constructed during the 1950s and 1960s were identified and renovation strategies were investigated for two types of buildings: small, semi-detached houses and multi-story apartment buildings. The energy requirement for climate-conditioning of the apartments was assessed by computer simulation for each of the renovation strategies, before and after retrofit. The relative contribution of various retrofit scenarios to the buildings' energy efficiency was quantified by comparing the existing configuration as the 'base case' with a series of improved configurations incorporating various improvements. Renovation alternatives examined three types of building envelope elements: Walls, roof and windows. The results of the cost-benefit analysis were presented in terms of the net present value of the investment, assuming a 30-year useful service life and 4% interest, and in terms of the payback period. The calculation was then repeated, to include the benefit to society from avoided environmental impacts resulting from reduced power generation.

RESULTS

Table 1 shows the payback period and the return on the investment when this additional benefit is added to the direct economic savings resulting from roof insulation (the most cost-effective measure), for each of Israel's four climate zones. Both private and social outcomes are presented. Negative numbers appear in parenthesis.

Table 1: Economic analysis of applying roof insulation to a semi-detached 2-family house and to an apartment building, in each of Israel's 4 climate zones.

		Tel Aviv		**Beer Sheva**		**Jerusalem**		**Eilat**	
		private	social	private	social	private	social	private	social
Private house	**Benefit** (€ '000)	(2.5)	(0.9)	(1.34)	0.53	(0.2)	1.9	1.43	3.9
	ROI (years)	68	37	41	28	32	22	24	18
Apartment building	**Benefit** (€ '000)	0.32	2.85	2.1	5	3.2	6.4	5.9	9.7
	ROI (years)	29	21	23	17	20	15	16	12

CONCLUSIONS

Viewed from a narrow economic perspective, most of the renovation strategies assessed, with the exception of adding thermal insulation to roofs, are not cost-effective from the point of view of the individual. Internalizing external environmental benefits from energy saving improves the profitability of retrofit slightly, but it appears unlikely that in Israel's relatively mild climate large scale renovation will take place, unless energy costs rise substantially. A better prospect is to require energy upgrades whenever extensive building renovation is carried out for other reasons. These reasons may be external ones (earthquakes) or environmental motivations.

ACKNOWLEDGEMENTS

The research was supported by funding from the Israel Ministry of Energy and Water, under grant no. 010-11-46/20-8-2009.

REFERENCES

Galvin R., Thermal upgrades of existing homes in Germany: The building code, subsidies and economic efficiency, *Energy and Buildings,* Vol. 42, pp. 834–844, 2010
Soratana K. & Marriott J, Increasing innovation in home energy efficiency: Monte Carlo simulation of potential improvements, *Energy and Buildings*, Vol. 42, pp. 828–833, 2010.

INTEGRATED CYBER-SOCIAL-PHYSICAL SYSTEMS FOR SUSTAINABLE BUILT ENVIRONMENTS

Burcin Becerik-Gerber, David Gerber, Zheng Yang, Arsalan Heydarian, Joao Carneiro
University of Southern California
Corresponding Author: Burcin Becerik-Gerber, E-mail: becerik@usc.edu

SUMMARY

Making significant progress towards sustainable energy use requires a broad shift in how buildings are designed, used and operated. Our research focuses on understanding and quantifying the impact of design on human's energy related activities and behavior in buildings and using the acquired knowledge in building operations.

Keywords: Occupancy, Energy Efficiency, Immersive Virtual Environments, Human Behavior, Human Activities.

INTRODUCTION

People spend about 90% of their time indoors [1] and buildings consume 48% of total energy in the US. Climate change, population growth, decreasing availability of resources, and increasing environmental concerns are forcing us to rethink the way we meet our energy needs. Making significant progress towards sustainable energy use requires a broad shift in how buildings are designed, used and operated. Innovation is required not only in technological solutions but in research that offer an understanding of human behavior and activities on energy use so that user related information is incorporated in operation of buildings to mitigate some of the issues inherently exist in solely technical approaches. Early design and engineering decisions greatly impact building energy consumption. Yet, current design methods are based on assumptions regarding the number of occupants, their movements, and their behaviors, as represented in graphic standards and briefs, which are usually not validated and un-specific. Our research also aims to understand and quantify the impact of design on human's energy related behavior in buildings. By developing a platform to visualize and understand assumptions about occupant behavior and activities, design and engineering teams can reduce the uncertainty and bring accuracy and rigor to these early-stage decisions—our approach includes learning from buildings and their occupants to optimize decisions prior to concretization for shaping early and critical energy-aware decisions.

UNDERSTANDING THE IMPACT OF BEHAVIOR AND ACTIVITIES ON ENERGY USE

We use sensors, sensing systems, and cyber tools to investigate the research questions related to understanding the impact of behavior and activities on energy use. In our research, we bring in the physical properties of buildings, together with social behavior and use cyber tools to emulate behavior and simulate energy consumption. We use ubiquitous computing techniques, social computing, and artificial intelligence as well as social theories to create integrated cyber-social-physical systems to support adaptive, responsive and sustainable built environments. Our presentation will highlight different ongoing projects undertaken at the Innovated in Integrated Informatics Lab, http://i-lab.usc.edu, at the University of Southern California.

Personalized Occupancy Profile Based HVAC Operations

Accurate occupancy profiles are important to determine actual energy demands. A more refined control schedule - based on occupancy - might improve HVAC system related energy efficiency. In our research, we propose a method to revisit zone-based HVAC start/stop schedules based on personalized occupancy profiles, which represent occupants' long-term presence patterns. To incorporate and account for occupancy, most simulation tools use fixed design profiles that are based on statistical methods using large-scale occupant surveys and/or observations from a number of similar buildings. Consequently, fixed design profiles deviate from actual occupancies of a building. We use data acquired by wireless sensor networks to provide high-resolution and accurate information for describing indoor environments and screening irregular occupancy patterns. We propose a framework to model personalized occupancy presence profiles for representing occupants' long-term presence patterns. A personalized occupancy presence profile is described as one-typical-weekday occupancy presence probability as a function of time for a specific occupant. Ambient context gathered from wireless sensor networks is integrated in the profile modeling process for distinguishing the regular presence from irregular presence. We evaluate the impact of different occupancy presence profiles on energy simulation results by simulating energy consumption. The results show that the personalized occupancy presence profiles acquired through time-series modeling, pattern recognition modeling and stochastic process modeling outperform the fixed design profiles and observation-based profiles currently used in building energy simulation. We also use building simulation to evaluate the effects of personalized occupancy profile based HVAC schedules, and show that personalized occupancy profile based HVAC schedules could reduce energy consumption by up to 9%.

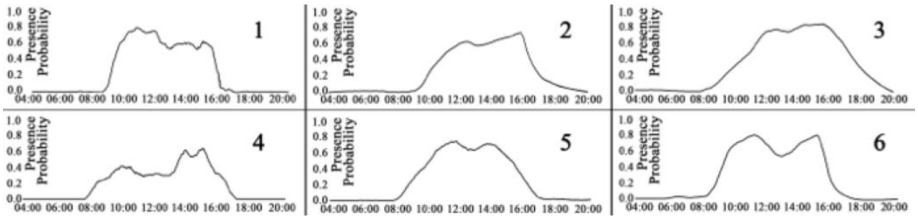


Figure 1: Occupancy profile models of six occupants

Impact of Design on Occupant Behavior

Our research also prefaces the need for engaging with end users in early stages of building design as means to achieve higher performing designs with an increased certainty for end-user satisfaction. This work builds upon the value of use of virtual environments in AEC processes and asks the research question "how can we better test and measure design alternatives through the integration of immersive virtual reality into our digital and physical mock up workflows?" The work is predicated on the need for design exploration through associative parametric design models, as well as, testing and measuring design alternatives with human subjects. Our work uses immersive virtual environments (IVEs) to understand the impact of different design alternatives on occupants' energy related behavior and integrate/use the knowledge during the design stage. We present a set of controlled experiments, and our results where we test performance of human participants in an IVE and the physical environment in everyday tasks; and the impact of having green design features on human behavior.

Figure 1: Photos of the physical environment and virtual models of the physical environment (left) and participants interacting within an immersive virtual environment (right)

CONCLUSIONS

Our work is an attempt towards integrated physical-social-cyber systems for adaptive, responsive, and sustainable built environments. Although our work thus far has proved integrating human behavior and activities to design and operation of built environments is important for energy efficiency and user satisfaction, this area of research is in infancy and there are numerous interesting research questions such as expansion of our understanding on use of spaces, occupant movement, occupant activities on energy use and impact of various design features on energy related user information.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grants No. 1201198 and 1231001. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

[1] USEPA Office of Radiation and Indoor Air (6609J), The inside story: A guide to indoor air quality. EPA 402K-93-007. Updated:1993. Available at: http://www.epa.gov/iaq/pubs/insidestory.html#IAQHome2

6th Session: Sustainability Engineering in Developed vs. Developing Countries

Yu-Ling Cheng: Imagining a house of the future for the urban poor

Mark Talesnick: Integrating sustainable development into a service learning engineering course

Matt Jelacic: Grids, gravity and traumatic urbanization

Aliza Belman Inbal: Climate change technologies for the developing world – Can Israel play a role

IMAGINING THE HOUSE OF THE FUTURE FOR THE URBAN POOR

Yu-Ling Cheng*[1,2], Murray R. Metcalfe[1], Rahim Rezaie[1], Mark S. Fox[3]
1. Centre for Global Engineering, 2. Dept. of Chemical Engineering and Applied Chemistry,
3. Dept. of Mechanical and Industrial Engineering; University of Toronto
*Corresponding Author Email: yuling.cheng@utoronto.ca

SUMMARY

Urbanization, and urbanization of poverty in particular, are major challenges that face humanity over the next few decades. Addressing the needs of the global poor as they congregate in cities is a key part of this challenge. We present a systems engineering perspective, which envisions addressing basic physical needs – food, water, shelter and air – in an integrated and sustainable fashion.

Keywords: Poverty, Urbanization, Systems Design, Modularity, Integration.

INTRODUCTION

Approximately 52% of the world's population lived in cities in 2011, a number that by 2050 is projected to increase to 86% and 64% of the developed and developing world, respectively [1]. This represents an increase of 2.6 billion people, including 1.4 billion in Asia and 0.9 billion in Africa[1]. One third of the urban population globally lived in poverty in 2007[2]. An equal portion of the 2005 urban population in China and India, and more than two thirds in Bangladesh, Nigeria and elsewhere lived in slums[3]. Rapid urbanization represents one of the most significant and complex challenges of our time. At the same time, urbanization of poverty brings more of the poor within reach of products and services, creating an unprecedented opportunity to shape the nature of global development from humanitarian, urban planning and sustainability perspectives.

The most basic of human physical needs are clean water, clean air, nutritious food, and safe shelter. Lack of access to these basic needs is a daily reality for the urban poor. We have an opportunity to address these needs through the development and implementation of contextually appropriate technological solutions.

In this abstract, we take a user-centric perspective and attempt to imagine a symbolic "*House in a Box*" solution – an integrated systems approach aimed at meeting the comprehensive basic needs of a poor urban household. Our thinking has been stimulated by involvement in the development of a household scale off-grid sanitation process through the Bill and Melinda Gates Foundation Reinventing the Toilet Challenge. The modular sanitation concept can be extended to other components of a future urban dwelling. What we imagine is an integrated systems design consisting of a set of distributed solutions for each of the physical needs we listed, but with synergistic connections among the different units within each household, and with linkages across several households where efficiency of scale dictates. We discuss this approach below.

CHALLENGES IN MEETING BASIC NEEDS

Air: Outdoor air quality in developing countries can be severely compromised due to the use of unclean fuels such as coal and harvest waste for industrial and home use, as well as lack of rigorous emission standards. Use of cookstoves indoors for instance, can result in the emission of particulate matter that lead to respiratory diseases – including childhood pneumonia, which is the leading cause of death among children under the age of five. In the absence of proper ventilation and/or when outdoor air quality is also poor, indoor air quality becomes a major health hazard. Solutions to address indoor air pollution either aim at reducing emissions by enhancing efficiency of household devices or by capturing/treating toxic emissions. While improved cookstoves exist, their utilization rates in resource-constrained settings are generally low and subsidy-dependent.

Water and Sanitation: An estimated 783 million people do not have access to clean drinking water and 2.5 billion lack basic sanitation[4]. One consequence is diarrheal diseases, which cause 1.6 million deaths annually in children under the age of five years[5]. Yet, in major cities, in India for instance, millions of liters of untreated human waste are discharged into local rivers, which are simultaneously a source of drinking water[6]. While point-of-use technologies exist to purify water, few have reached significant penetration in low-resource settings, and urban water treatment and distribution systems remain inadequate. Low-cost, off-grid approach for the rapid disinfection of human waste, as the system we are developing, can help considerably.

Shelter: Millions of people live in poorly designed and constructed buildings that do not provide adequate protection against the elements, and are vulnerable to natural disasters. The lack of proper shelter is a major impediment to the improvement of their health and living conditions, and is a key obstacle to improving other services such as sanitation and air quality. We envision new and resilient shelters that not only protect occupants from the elements, but also serve as platforms designed to facilitate integration of various systems aimed at addressing the basic needs by allowing for interconnections both within a given household and across proximal units. Building structure can also be designed to maximize ventilation – through windows for instance – and passively absorb particulate matter from indoor air.

Food: Challenges associated with food relates both to food availability/affordability and quality. For example, people in Bangladesh, including the relatively well-off, receive the majority of their calories from starch. More nutritious foods such as fish are frequently contaminated with formalin, a preservative added by vendors to increase shelf life. Improvements in conventional agricultural practice and micronutrient fortification are two of the prevalent approaches to addressing food-related challenges. We believe that creative use of small spaces, supported by appropriate technologies built into urban dwellings and structured to maximize sun exposure, can help grow small but important amounts of vegetables or fish. Furthermore, nutrient-rich byproducts from the sanitation process we are developing can be used as fertilizer, effectively linking food with shelter and sanitation.

HOUSE-IN-A-BOX: FROM CENTRALIZED TO DISTRIBUTED SYSTEMS

A hypothetical *House in a Box* might include a host of items such as: a cookstove, water treatment system, toilet, sanitation system, emissions capture system, and building shell/materials. Certain components, such as cookstoves are naturally household scale units. In contrast, water and waste treatment systems may be more efficient at larger scales. Conventional wisdom holds that efficiency is maximized at level of whole cities, but we question this stand given their complexity, high costs and systemic fragility. An integrated approach would determine optimal scales for various treatment systems, and design linkages to household *interfaces* to ensure privacy – such as a household toilet linked to a several household scale waste treatment system. Some new sanitation systems, such as the one we are developing, uses smoldering or combustion processes that would produce emissions. If the emission capture technology is most efficient at a larger scale, it may be designed to include interfaces with household scale cookstoves, and household cluster scale sanitation systems.

Aside from integration across scales, synergies may exist at each scale. For instance, heat generated from waste treatment may be used for water purification, or to provide energy to air treatment technologies that rely on catalytic reactions that operate at high temperatures. Design evaluations would have to be performed to determine the optimum combination of scales. But in principle, we can imagine clusters of n dwellings, in close proximity as being connected into a localized 'grid' – representing the largest scale of the services being delivered. We expect such a local grid to be significantly smaller than the mega-scale infrastructure common in cities. It is also different from ad-hoc point-of-use technologies, which target specific applications and have thus far seen relatively little market penetration in the developing world. An integrated approach, synergies in design, fabrication and implementation may reduce cost, increase efficiency of service delivery, and reduce infrastructure dependence and environmental impact – and thus lead to a more sustainable solution. It is also significant that such an approach should allow for faster construction times and much lower upfront investment than mega-scale urban infrastructure projects, as well as offer much greater flexibility and resilience to widespread system failure. Supported by appropriate technological innovations, it can empower households and local communities to address their own basic needs instead of perpetual dependence on the State.

CONCLUSIONS

The *House in a Box* Concept compels us to think differently about pro-poor innovation in urban setting. It forces us to consider the relationships between the various components of this proverbial box from the outset, and decipher the optimal 'architecture' of the whole system. While we advocate for decentralized systems, we recognize that some technologies may be more efficiently operated at the level of household clusters, as discussed above. It has been shown that since land availability is limited in many slum areas houses with multiple dwelling units are very common[7]. Given contextual variability however, components must be designed and built at optimal scale, but with interfaces that allow systemic flexibility. This way scale is achieved both through individual component integration, as well as by linking households together for some of the applications. This approach is especially relevant for new cities where there is also an opportunity to re-imagine public infrastructure.

Adopting such a holistic approach makes it is easier to see how issues related to addressing basic needs of food, clean air, shelter, water and sanitation are closely linked. Clearly there are also similarities and scale economies in how solutions might be implemented, and in designing the business systems required to deliver the integrated components of the system. The *House in a Box concept* provides a schema allowing us to visualize the end result first and work backwards to realize it. At its core it is an application of demand-driven and integrated innovation.

REFERENCES

[1] World Urbanization Prospects. 2012. United Nations, New York. URL: http://esa.un.org/unpd/wup/pdf/FINAL-FINAL_REPORT%20WUP2011_Annextables_01Aug2012_Final.pdf

[2] Ravallion, Martin, Shaohua Chen and Prem Sangraula, 2007. "New Evidence on the Urbanization of Global Poverty," Policy Research Paper No. 4199, World Bank, Washington, D.C. URL: http://elibrary.worldbank.org/doi/pdf/10.1596/1813-9450-4199

[3] World Health Organization Statistics. URL: http://apps.who.int/gho/athena/data/download.xsl?format=xml&target=GHO/EQ_URBSLUM&profile=excel&filter=COUNTRY:*;REGION:AFR;REGION:AMR;REGION:SEAR;REGION:EUR;REGION:EMR;REGION:WPR

[4] UN Millennium Development Goals Report, 2012. URL: http://www.un.org/millenniumgoals/pdf/MDG%20Report%202012.pdf

[5] World Health Organization, 2006. Cholera, 2006. *Weekly epidemiological record,* **82**(31), pp. 273-284.

[6] Hamner, S. , Tripathi, A., Mishra, R.K., Bouskill, N., Broadway, S.C., Pyle, B.H. and Ford, T.E., 2006. The role of water use patterns and sewage pollution in incidence of water-borne/enteric diseases along the Ganges. *International Journal of Environmental Health Research,* **16**(2), pp. 113-132.

[7] Rahman, M. Ashiq-Ur, 2012. Housing the urban poor in Bangladesh : a study of housing conditions, policies and organisations. Thesis Dissertation. URL: http://www.ros.hw.ac.uk/handle/10399/2600?mode=full&submit_simple=Show+full+item+record

Integrating sustainable development into a service learning engineering course

Mark Talesnick
Technion-Israel Institute of Technology, UNESCO Chair-Sustainable Engineering for Developing Communities.
E-mail: talesnik@technion.ac.il

SUMMARY

This talk describes a unique service learning course designed to introduce students to sustainable human development through a combination of classroom, laboratory, and field work exercises. It responds to a need to educate engineers in addressing global societal problems. It provides a model that addresses the concerns and recommendations of various engineering accreditation boards in regard to the competencies expected of graduating university engineering students today.

Keywords: Sustainable engineering education, service learning

INTRODUCTION

In many universities around the world today, we are witness to the development of programs focused towards sustainable development. These programs might be, not for credit programs, for example, Engineers with Borders groups; for credit programs such as that initiated at the Mortensen Center in Engineering for Developing Communities, University of Colorado. It is obvious that these programs are very attractive to students. One common reality of some of these programs is that a limited number of faculty members often shoulders them. The objective of this talk is to bring some of these people together in order that they may interact with the aim to stimulate action work groups and leverage their combined experience and abilities so that positive impact can be amplified and propagated to more institutions.

EDUCATIONAL INITIATIVE

As the population of our planet continues to grow, more and more people fall into the category of developing communities. In many ways the future of our world depends on the ability to supply sustainable solutions to the many and complex issues that our globe will face as these communities/countries develop their resources and build capacities. If these growing populations develop in the same fashion that the "developed" countries have done over the past 100 years, our planet will face devastating results. These issues range from the ability to provide health, food, water, shelter, energy, communications and infrastructure. For the most part, standard science and engineering curriculum do not deal with how to approach and conceive these issues and make no attempt to prepare university graduates for the challenges that their generation will ultimately face. We need "engineers" with global aptitudes.

The global engineer is an engineer with the skills, knowhow and experience to go into a developing community and **together** with the community develop:

- an assessment of the main issues affecting a community.
- a causal analysis of the these issues, and definition of root cause problems.
- a method to define the capacity of the community to maintain different solutions.
- a design to implement appropriate and sustainable engineering concepts which work toward social and economic gain.
- a design which will not create a new problem, or at least be aware of its existence.
- a monitoring and evaluation scheme to make sure that steps towards the overarching goals are met over time.
- an exit plan, so that crippling dependence is not created.

Not all engineers need to be global engineers, but we should be developing university graduates of this form in all realms of engineering, science and sociology. In the same way, not all global engineers need to be engineering graduates. We all should be striving to "engineer" a better world.

Over the past several years there has been a marked increase in universities, which have developed programs, which include aspects of "sustainable engineering for developing communities". One positive outcome from such activities is that institutions of higher learning in developing parts of the globe may "copy" these activities and implement them in to their own curriculum.

The course "Engineering for Developing Communities" has been developed and offered by the International School of the Technion. The course was designed as a service learning course and has been taught three times: in the 2010 and 2011 summer semesters in Israel and in the summer semester of 2013 in Nepal in conjunction with Kathmandu University.

The four-week intensive course is taught, in English and involved instructors from various disciplines: civil engineers, medical doctor, an archeologist, and an anthropologist. The course included an important field segment in which participants and staff were divided into teams, each assigned to a developing village community. The concept of the field work was to have the participants apply their newly gained tools to real world, complex problems in a real community.

The course was designed to address, in operative terms, the ABET and Barcelona Declaration criteria. Its objectives were: to raise awareness of social and environmental issues, and of professional ethics; and to transform student's knowledge, skills and attitudes concerning the course themes.

CONCLUSIONS

Mintz et al (2013) described the learning outcomes of the course based upon a series of questions posed to the student participants before the course, immediately following the course and 6 months after completion of the course. Many of the course features and activities that were mentioned as significant learning experiences that could be integrated into other engineering courses in other places and contexts. Theour main learning activities that were identified as most significant were: Field work within communities, Social interactions and teamwork, Hands-on-experiences and Reflective practices.

REFERENCES

Mintz, K., Talesnick, M., Amadei, B. and Tal, T. Integrating sustainable development into a service learning engineering course. Accepted for publication, ASCE, Journal of Professional Issues in Engineering Education and Practice. 2013

GRIDS, GRAVITY AND TRAUMATIC URBANIZATION

Matthew Jelacic
University of Colorado Boulder
Jelacic@colorado.edu

SUMMARY

An enormous number of people will be permanently displaced by climate change and current strategies for housing these people are inadequate. This paper will look at some of the flaws and suggest certain approaches that could allow traumatic urbanization to yield sustainable development over time.

Keywords: refugee camps, urban design, urban design history, sustainable urban development, infrastructure

INTRODUCTION

145 Million people will be permanently displaced by climate change before the end of this century. Already inhumane, the current strategy of 'storing' refugees in camps must be reconsidered in light of the inevitable, global political destabilization that this population shift implies. This reconsideration must begin by questioning the "military metaphysic" implied in current traumatic urbanization strategies especially in terms of the humanitarian impact and loss of opportunities to improve the lives of those displaced over time. In particular, infrastructure strategies, education and food and water security must be reconsidered in terms of their potential to support sustainable urban development over time.

EXTENDED ABSTRACT

The 2007 *Fourth Assessment Report* published by the Intergovernmental Panel on Climate Change estimates that 145 million people will be permanently displaced from their homes in the next 90 years due to man-made climate change. This number is more than three times the number of people displaced today by wars, famine and natural disasters and yet little is being done within the humanitarian aid regime to create strategies for feeding and sheltering this destabilizing human tidal wave.

Perhaps it is the sheer scale of this immanent humanitarian crisis that limits our ability to conceive of more appropriate responses. After all, how can one imagine constructing the shelter, water, food, sanitation, energy, education, security and healthcare infrastructures needed to support a displaced population equal to the population of Israel? Imagining the scale of this undertaking becomes even more daunting when one realizes that this imagined new city is on the far side of the globe and that the equivalent of more than eighteen 'Israels' will be needed.

Another constraint on our ability to conceive of the scale of this crisis stems from the common misconception that impacts will be slow and incremental. We in the Global North discuss the impact of climate change in terms of gradually rising seas or slowly infiltrating deserts; we do not see the immediacy of the crisis. We allow ourselves to think that people will have time to consider their options and make intentional moves out of harm's way. We hopefully resign the responsibility of reversing climate change to advances in science and engineering. The reality, of course, is that catastrophic climate events displace countless thousands overnight. Rather than finding solace and security in the homes of extended families living in urban centers– the preferred and naive approach to sheltering the displaced in the humanitarian aid regime– huge populations will find themselves struggling to survive in areas destroyed by cyclones, fires or flooding.

For the last hundred years or so, the most visible humanitarian response to mass migration in the aftermath of catastrophes has been the establishment of "refugee camps." Characterized by long rows of tents, this strategy has its origins the Roman Republican Army's desire to systematically organize its legions on the battlefield. Machiavelli's use of *The Histories* by Polybius in the 16^{th} C. led to the continued use of gridded army camps in Europe through the end of the 19^{th} C and beyond. Whether for true international refugees or for internally displaced people, most experts now agree that these provisional military cities are a poor response for housing civilians in light of universal human rights and yet their model remains ubiquitous.

One reason that refugee camps continue to be built is that they are conceived as a "temporary solution." Conventional wisdom dictates that host nations, loath to permanently welcome an influx of 'foreigners', make available only the least valuable land with the fewest resources. Their hope, it is said, is to encourage people to return home by making the refugees' stay uncomfortable. National governments, with the support of the international community, work to reconstruct their homes after a natural disaster, but of course *some* internally displaced people are functionally refugees fleeing internal strife. The reality is, however, that no matter what the theoretical deterrents are to staying in a refugee camp, places like Dadaab in Kenya continue to grow. Created 20 years ago to shelter 90,000 refugees fleeing Somalia, today it is virtually the same size as Tel Aviv, hosting more than 380,000 refugees and IDPs from all over the Horn of Africa. The humanitarian aid regime, shielded by the *realpolitik* of international diplomacy and national sovereignty, is able to focus on stop-gap solutions despite on-the-ground realities including interminable tenures and incalculable expenses as seen in Dadaab and elsewhere.

My presentation will focus on opportunities for the humanitarian aid community to re-conceive the future of urban areas created in the aftermath of traumatic events. What is the minimum infrastructure required? How can essential human endeavors (food and water security, health care, education…) be conceived in an humane and environmentally responsible way?

CONCLUSIONS

Although the current *realpolitik* of displacement limits opportunities for the humanitarian regime to disrupt standard practice, the reality of climate change must force the issue. Events, such as the recent typhoon in the Philippines, will continue to become more severe due to the effects of climate change. Traumatic urbanization, the only response seemingly available in the aftermath of massive and relatively sudden destruction, must be reconceived, not in military terms, but in terms of sustainable, humane urban development.

REFERENCES

Adams, J. (1999) *Managing Water Supply and Sanitation in Emergencies*, Oxford, UK: Oxfam Publishing.

Agier, M. (2008), Fernbach, D. (trans.) *On the Margins of the World: The Refugee Experience Today*, Cambridge, United Kingdom: Polity Press.

Belsky, E.S. (2013) 'Planning for Inclusive and Sustainable Urban Development', in Starke, L. (ed.) *Worldwatch Institute State of the World 2012: Moving Toward Sustainable Prosperity*, Washington, DC, USA: Island Press.

Castagnoli, F. (1971) *Orthogonal Town Planning in Antiquity*, Cambridge, MA, USA: MIT Press.

Crisp, J., Talbot, C., and Cipollone, D. (ed.) (2001) *Learning for the Future: Refugee Education in Developing Countries*, Geneva, CH: UNHCR.

Essa, A. (2010) *Dadaab, The World's Biggest Refugee Camp*, [Online], Available: http://www.aljazeera.com/indepth/features/2011/07/201171182844876473.html

Horst, C. (2008) *Transnational Nomads: How Somalis Cope With Refugee Life in Dadaab*, 2nd edition, New York, NY, USA and Oxford, United Kingdom: Berghahn Books.

Hyndman, J. (2000) *Managing Displacement: Refugees and the Politics of Humanitarianism*, Minneapolis, MN, USA: University of Minnesota Press.

IDEO. (2011) *Human Centered Design Toolkit*, 2nd Edition, San Francisco, CA, USA: IDEO

Lischer, S. (2005) *Dangerous Sanctuaries: Refugee Camps, Civil War, and the Dilemmas of Humanitarian Aid*, Ithaca, NY, USA: Cornell University Press.

Machiavelli, N. (2003), Lynch, C. (trans.) *The Art of War*, Chicago, IL, USA: Chicago University Press.

Mills, C.W. (2000) *The Power Elite*, 2nd Edition, New York, NY, USA: Oxford University Press.

Morgan, S. (2010) *Changing Planet: What is the Environmental Impact of Human Migration and Settlement?*, New York, NY, USA: Crabtree Publishing Company.

Pal, A. (2006) 'Scope for Bottom-Up Planning in Kolkata: Rhetoric vs. Reality', *Environment & Urbanization*, vol.18, no.2, October, pp. 501-521.

Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (ed.) (2007) *Contribution of the Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Polybius (1923), Paton, W.R. (trans.) *The Histories*, Cambridge, MA, USA: Harvard University Press.

Potter, G. (2013) 'Urbanizing the Developing World', in Starke, L. (ed.) *Worldwatch Institute Vital Signs*, vol. 20, Washington, DC, USA: Island Press.

Rykwert, J. (1988) *The Idea of a Town*, 2nd edition, Cambridge, MA, USA: MIT Press.

Schmidt, A. (2003) *Camps Versus Settlements*, [Online], Available: http://www.forcedmigration.org/research-resources/expert-guides/camps-versus-settlements

'Sea Level Could Rise 3 Feet by 2100, Climate Panel Finds', *New York Times* (20 Aug 2013), Page 1

Sinha, V. (2012) *Refugee Camps Spread Life-Threatening Diseases*, [Online], Available: http://reliefweb.int/report/world/refugee-camps-spread-life-threatening-diseases

SPHERE (2011) *The SPHERE Handbook*, [Online], Available: http://www.spherehandbook.org

UNHCR (2001) *Refugees and the Environment*, [Online], Available: http://www.unhcr.org/3b039f3c4.html

Ward-Perkins, J.B. (1974) *Cities of Ancient Greece and Italy: Planning in Classical Antiquity*, New York, NY, USA: George Braziller, Inc.

Williams, H.A. (1990) 'Families in Refugee Camps', *Human Organization*, vol. 49, no.2, pp. 100-109.

LIST OF WORKSHOP PARTICIPANTS

Galit Agranati
Ph.D., Readymix Industries (Israel) Ltd. Group, ISRAEL
agranati@gmail.com

Or Amitai
Shikun & Binui, Arison Group, ISRAEL
amitaior@gmail.com

Bhavik Bakshi
Professor, Chemical and Biomolecular Engineering, Ohio State University, Columbus, OH. USA
bakshi.2@osu.edu

Oded Amir
Assistant Professor, National Building Research Institute, Department of Structural Engineering and Construction Management, Faculty of Civil & Environmental Engineering. Technion, Haifa. ISRAEL
odedamir@cv.technion.ac.il

Gil Ashuah
Readymix Industries (Israel) Ltd. Group, ISRAEL
gil.ashuah@cemex.com

Uriel Babczyk
Architect, Director of Sustainable Planning & Building, City Architect Office – Engineering Authority, Tel Aviv Yaffo Municipality, ISRAEL
Babczyk_u@mail.tel-aviv.gov.il

Lawrence C. Bank
Professor, Department of Civil Engineering, Grove School of Engineering. The City College of New York, NY. USA
lbank2@ccny.cuny.edu

David Bonen
Associate Professor, Sami Shamoon College, Dep. Of Civil Engineering, ISRAEL
bonen.d@gmail.com

Burcin Becerik-Gerber
Assistant Professor, Stephen Schrank Early Career Chair in Civil and Environmental Engineering. Department of Civil & Environmental Engineering, University of Southern California, Los Angeles, CA. USA
becerik@usc.edu

Nir Becker
Ph.D., Chairman, Economics and Management Department, Tel-Hai Academic College, Upper Galilee. Natural Resource and Environmental Research Center, University of Haifa. ISRAEL
nbecker@econ.haifa.ac.il

Rachel Becker
Associate Professor, Head, National Building Research Institute. Department of Structural Engineering and Construction Management, Faculty of Civil & Environmental Engineering. Technion, Haifa. ISRAEL
becker@tx.technion.ac.il

Aliza Belman Inbal
Ph.D., Director of the Pears Program for Innovation and International Development, The Hartog School of Government and Policy, Tel Aviv University. ISRAEL
Alizabel@tau.ac.il

Arnon Bentur
Professor Emeritus, National Building Research Institute, Department of Structural Engineering and Construction Management, Faculty of Civil & Environmental Engineering. Technion, Haifa. ISRAEL
bentur@tx.technion.ac.il

Vered Blass
Lecturer, Recanati Business School, Tel Aviv University. ISRAEL
vblass@post.tau.ac.il

Yu-Ling Cheng,
Professor, Director of the Centre for Global Engineering (CGEN). Department of Chemical Engineering & Applied Chemistry, Faculty of Applied Science & Engineering, University of Toronto. CANADA
yuling.cheng@utoronto.ca

Mike Chester,
Assistant Professor, Civil, Environmental, and Sustainable Engineering. Affiliate Faculty, School of Sustainability, Arizona State University, Tempe, AZ. USA
mchester@asu.edu

Eli Cohen
Thermokir Industries (1980) Ltd., ISRAEL
elic@termokir.co.il

Ronen Cohen
Ph.D., Nesher Israel Cement Enterprises Ltd. , ISRAEL
ronenc@nesher.co.il

Ronny Daniel
The Israel Green Building Council, R&D, and The Natural Step – Israel, ISRAEL
ronny@ilgbc.org

Yoav David
City Architect, Tel Aviv Yaffo Municipality, ISRAEL
david_y@mail.tel-aviv.gov.il

Rami Eid
Ph.D., Sami Shamoon College, Dep. Of Civil Engineering, ISRAEL
ramiei@sce.ac.il

Lior Einy
ME, LEED-AP, Sustainable Unit Manager, Project Management and Green Consulting, Baran, ISRAEL
lior.einy@barangroup.com

Evyatar Erell
Associate Professor, Desert Architecture and Urban Planning, Bona Terra Department of Man in the Desert, The Jacob Blaustein Institutes for Desert Research, Ben Gurion University of the Negev. Sde Boker. ISRAEL
erell@bgumail.bgu.ac.il

Erez Gal
Senior Lecturer, Department of Structural Engineering, Faculty of Engineering Science, Ben Gurion University of the Negev, Beer Sheva. ISRAEL
erezgal@exchange.bgu.ac.il

Bora Gencturk
Assistant Professor, Department of Civil and Environmental Engineering, University of Houston, TX. USA
bgencturk@uh.edu

Pavel Grabov
Ph.D., Vice President, Quality Engineering & Risk Management, A.L.D. Advanced Logistics Development, Ltd. Adjunct Senior Lecturer, Faculty of Industrial Engineering and Management, Technion, Haifa. ISRAEL
grabov@ald.co.il

Nabil Grace
Univ. Distinguished Professor, Dean, College of Engineering. Director, Center for Innovative Materials Research (CIMR). Lawrence Tech. University, Southfield, MI. USA
ngrace@ltu.edu

Yasha Jacob Grobman
Assistant Professor, Technion, Faculty of Architecture and Town Planning, ISRAEL
yasha@tx.technion.ac.il

Matthew Jelacic
Assistant Professor, Program in Environmental Design, University of Colorado, Boulder, CO. USA. Adjunct Assistant Professor, Mortenson Center in Engineering for Developing Communities
jelacic@colorado.edu

Yehuda Kahane
Professor Emeritus, COB. YK Center for Rebooting and Prosperity. Faculty of Management, Tel Aviv University. ISRAEL
kahane@post.tau.ac.il

Amnon Katz
Associate Professor, National Building Research Institute, Department of Structural Engineering and Construction Management, Faculty of Civil & Environmental Engineering. Technion, Haifa. ISRAEL
akatz@tx.technion.ac.il

Shiho Kawashima
Assistant Professor, Department of Civil Engineering and Engineering Mechanics, School of Engineering and Applied Science, Columbia University in the City of New York, NY. USA
s-kawashima@columbia.edu

Konstantin Kovelr
Associate Professor, National Building Research Institute, Department of Structural Engineering and Construction Management, Faculty of Civil & Environmental Engineering. Technion, Haifa. ISRAEL
cvrkost@tx.technion.ac.il

Daniele Kulisch
M.Sc. Student, Technion, Faculty of Civil & Environmental Engineering, ISRAEL
danikulisch@gmail.com

Mike Lepech
Assistant Professor, Department of Civil and Environmental Engineering. Stanford University, Palo Alto, CA. USA
mlepech@stanford.edu

Yue Li
Associate Professor, Department of Civil & Environmental Engineering, Michigan Technological University, Houghton, MI. USA
yueli@mtu.edu

Pinar Manguc
Professor, Director, Center for Energy, Environment and Economy. Head, Mechanical Engineering, Özyegin University, Istanbul, TURKEY
pinar.menguc@ozyegin.edu.tr

Arie Nesher
Ph.D., Tel Aviv Univ. Professional Director, The Porter School of Environmental Studies, ISRAEL
nesheren@post.tau.ac.il

Nathan Ohn-Bar
Architect, Countenance Energy in Buildings, Ministry of National Infrastructure, Energy and Water Resources. ISRAEL
ohn-bar@amirim.com

Yehuda Olander
Manager, Environmental Quality Unit, Sharon Region. ISRAEL
Ecolog1@raanana.muni.il

Ela Ofer-Rozovsky
Ph.D. Student, Technion, Faculty of Civil & Environmental Engineering, ISRAEL
elyaofer@tx.technion.ac.il

David Pearlmutter
Associate Professor, Desert Architecture and Urban Planning. Head, Bona Terra Department of Man in the Desert, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sde Boker. ISRAEL
davidp@bgu.ac.il

Alva Peled
Associate Professor, Ben Gurion University, Department of Structural Engineering, ISRAEL
alvpeled@bgu.ac.il

Sohi Rastegar
Ph.D., Director, Office of Emerging Frontiers in Research & Innovation (ENG/EFRI), National Science Foundation. USA
srastega@nsf.gov

Orli Ronen-Rotem
Ph.D., Executive Director, Heschel Center for Sustainability, ISRAEL
orli@heschel.org.il

Vivek Shandas
Associate Professor, Toulan School of Urban Studies and Planning, Center for Urban Studies, Portland State University, OR. USA
vshandas@pdx.edu

Edna Shaviv
Professor Emeritus, Technion, Faculty of Architecture and Town Planning, ISRAEL
arredna@tx.technion.ac.il

Itzhak Shayer
Orbond Industries Ltd. , ISRAEL
shayer@orbond.co.il

Yossi Sikuler
Hanson (Israel) Ltd., ISRAEL
Yossi.Sikuler@hanson.biz

Sabrina Spatari
Assistant Professor, Civil, Architectural and Environmental Engineering, College of Engineering, Drexel University, Philadelphia, PA. USA
ss3226@drexel.edu

Kirk Steudle
P.E., Transportation Director, Michigan Department of Transportation, MI. USA
SteudleK@michigan.gov

Mark Talesnick
Associate Professor, UNESCO Chair/ UNITWIN Network – Sust. Eng. for Developing Com. EwB-Technion Fac-advisor. NBRI, Dep. of Str. Eng. and Const. Management, Faculty of Civ. & Env. Eng. Technion, Haifa. ISRAEL
talesnik@tx.technion.ac.il

Ari Teger
M.Sc. Student, Technion, Faculty of Civil & Environmental Engineering, ISRAEL
tegera@technion.ac.il

Vikram Yadama
Associate Professor, Department of Civil and Environmental Engineering, Washington State University, Pullman, WA. USA
vyadama@wsu.edu

Abraham Yezioro
Assistant Professor, Faculty of Architecture and Town Planning, Technion, Haifa. ISRAEL
ayez@tx.technion.ac.il

Semion Zhutovsky
Ph.D., Technion, National Building Research Institute, ISRAEL
semionz@tx.technion.ac.il

Ministry of National Infrastructures,
Energy and Water Resources
www.energy.gov.il

Industrial Ecology in
Multi-Scale Design
and Construction of

Sustainable Built Environments

http://sustain2014.net.technion.ac.il/
sustain@tx.technion.ac.il