ASCE | SUSTAINABILITY

International Conference on Sustainable Infrastructure (ICSI 2021)

Technical Track Abstracts

Friday, December 10, 2021

Table of Contents

Track 1: International Coalition on Sustainable Infrastructure

More information soon

Track 2: Imagining Future Cities

Moderated by Cliff Davidson and Mikhail Chester

Urban Infrastructure: Reflections for 2100

Cliff I. Davidson*[1], Mikhail V. Chester[2], Sybil Derrible[3], Lynette Cheah4, Matthew J. Eckelman5, Kris Hartley6, Nadine Ibrahim7, Shoshanna Saxe8, Yoram Shiftan9 and Alona Nitzan-Shiftan10

[1] Professor, Syracuse University (davidson@syr.edu)
[2] Associate Professor, Arizona State University (mchester@asu.edu)
[3] Associate Professor, University of Illinois Chicago (derrible@uic.edu)
[4] Associate Professor, Singapore University of Technology and Design (lynette_cheah@sutd.edu.sg)
[5]Associate Professor, Northeastern University (m.eckelman@northeastern.edu)
[6]Assistant Professor, The Education University of Hong Kong (hartley@eduhk.hk)
[7]Turkstra Chair in Urban Engineering, University of Waterloo (nadine.ibrahim@uwaterloo.ca)
[8]Assistant Professor, University of Toronto (s.saxe@utoronto.ca)
[9]Professor, Technion (shiftan@technion.ac.il)
[10]Associate Professor, Technion (alona@technion.ac.il)

Keywords: Climate Change, Infrastructure, Sustainability, Transportation, Urban Design

ABSTRACT

The book *Urban Infrastructure: Reflections for 2100* edited by Sybil Derrible and Mike Chester contains a wide variety of ideas for sustainable infrastructure that could be envisioned if cities are rebuilt. In this extended abstract, we present ideas from nine of the chapters in this unique book, which will be discussed by their respective authors at ICSI.

"The City of 2100: An Idealistic Look" (Cliff I. Davidson) An idealized city 80 years from now located in upstate NY would be largely self-sufficient, growing and processing food from two sources: agricultural crops from surrounding farmland in Central NY and fishing in the Great Lakes. The population would be roughly steady-state at a level determined largely by the amount of food and water available. People would live close to places of work, schools, medical centers, churches, grocery stores, and other necessities of life. The availability of public transportation and rideshare would make private vehicles unnecessary. Energy would be generated using wind and solar in the region. Travel would not be common; family members would live in the same region, and meetings with colleagues elsewhere would be arranged via electronic media. With the high population density in the central city and absence of suburbs, much of the land would be undeveloped forest needed to provide ecosystem services as well as hiking, camping, and other recreation. The ecological footprint of a typical resident in this city would be a small fraction of what it is in 2021.

"The Great Infrastructure Decoupling" (Mikhail V. Chester) At the dawn of the twenty-first century the world is changing fast. Yet our core infrastructure systems remain rooted in principles that assume long term sustainability. The growing chasm between what our infrastructure can do and what we need them to do represents a decoupling that threatens the viability of the systems that we often take for granted. There are two paths forward. In the first we operate under business-as-usual conditions and make marginal changes to infrastructure that do not meaningfully address this decoupling. In this vision infrastructure continue to provide value (albeit diminishing) and where demands are not met new players and technologies emerge, a decentralization of control. In the second path we commit to modernizing infrastructure to meet the rapidly changing conditions and associated uncertainty in the future. This path will be difficult but will position services for the betterment of future societies. Which path do we choose?

"Peace Day in Saint Pierre and Miquelon" (Sybil Derrible) What is infrastructure but a support to provide for our needs as humans and as a society? To reflect on the future of infrastructure, we can reflect on how we will evolve as humans. The short story follows a kid in the French archipelago of Saint Pierre and Miquelon on July 14, 2100, for Peace Day. Like all kids, this one has a lot of energy and seeks to have fun with friends and family. In the story, through the experience of this child, we learn how home technology may evolve. We learn how people may travel. We learn how electricity and water may be distributed. We also learn how culture may evolve in the twenty-first century, and how, despite impressive advances in technology, getting together and sharing moments and a good meal remain timeless and central to who we are as humans.

"How will city dwellers get around in 2100? Personas using future mobility services" (Lynette Cheah) In user-centered design processes, personas are sometimes developed to better understand how potential users will make use of new products or services. Personas are fictional characters projected into future settings and situations. By identifying and characterizing representative users, designers and planners can better address their diverse needs and concerns. In this chapter, we get to know four different personas living in future Asian cities. We explore how these individuals interact with urban transport infrastructure and achieve their mobility needs. While it is not possible to predict how city residents will travel in year 2100, we can imagine their urban lifestyles through these personalities.

"The Future of Today's Infrastructure" (Matthew J. Eckelman) In a future of new technology, materials, and modes, what will become of our current infrastructure that is no longer needed? Will we simply build our new infrastructure on top of what we have, perpetuating the land use decisions and ecological impacts of past generations? Or will we adapt these spaces and use valuable rights of way to tie our communities together in new ways, as we have converted old canals and railroad beds to recreation and commuting paths? While visions of future cities often center on marvelous new creations, the greatest opportunities in the future of infrastructure may be in cleverly repurposing what we have in the present. Case studies from around the world show potential benefits and pitfalls of different approaches to obsolete infrastructure.

"Urban infrastructure and the politics of crisis" (Kris Hartley) In this era of global crisis and potential for productive renewal, it is appropriate to contemplate the prospects of the rationalist policy project amidst growing political and epistemic instability. While contestation in how policy problems are named and framed is blandly evident in the operations of public organizations and their interactions with society, infrastructure provides a clearer and more embodied illustration of the facts-values interface and fading promise of policy rationalism. This presentation reflects on the moral hazard of technocratic fundamentalism through the lens of 'fortress infrastructure' – a tool of escape for the privileged that works only by exploiting the society it leaves behind. The presentation concludes by making broader points about the co-evolution of competing epistemics, infrastructure as a technocratic solution to existential and behavioral problems, and the cyclicality of 'human progress.'

“Only you know if we did it” (Nadine Ibrahim) To create future sustainable cities, we know what needs to be done today, but we are not moving as fast as the urgency of the climate crisis would demand. This chapter picks up on the message in “A letter to the future” engraved on the memorial plaque in 2019 commemorating the loss of the glacier Okjökull, that ends with the statement “Only you know if we did it”. Part prose and part poetry, the setting of the chapter is the year 2100, and presents a vision for an optimistic future where climate targets were met, cities were built for the convenience of people not the comfort of cars, and circular economies were created by consuming less and reusing more, and finally we had the cities that we’ve always dreamed of living in. We’re far off course relative to the prediction engraved on the plaque, though we acknowledge the science and evidence that exist today that urge us to take action. It was largely the younger generation that pushed us to make such bold decisions in renewable energy, building science, transit, water conservation, waste disposal, forest management, among many others. When revisiting the plaque in 2100, we knew we finally did it!

“Detours and Funiculars: Towards sustainable urban transport infrastructure in 2100” (Shoshanna Saxe) One of the great hopes of working on sustainable infrastructure is that we have all the tools we need to get to sustainability, and one of the great frustrations is that we fail to use them. “Detours and Funiculars: Towards sustainable urban transport infrastructure in 2100” – a riff on the well known children’s game Snakes and Ladders – makes visceral these hopes and frustrations through leaps forward and slides backwards on the board. The funiculars are low tech and well known (long term planning, automobile road use charges, bike infrastructure); the detours well trod (highway expansion, single family zoning). The more players who make their way to the end of the board and sustainable transport infrastructure, the bigger the win for all.

“Mobility and the City in 2100” (Yoram Shiftan and Alona Nitzan-Shiftan) We envisage the future city to adjust the physical form of the present-day city and specifically the urban infrastructure we know today, to accommodate new mobility technology in ways that ensure the best livability of its people. We illustrate an urban center of a metropolitan area and its transport system and discuss the policies and behavior of travelers that keep the city vibrant, sustainable, and just.

Acknowledgment: This work was supported in part by NSF award SBE-1444755, Urban Resilience to Extremes Sustainability Research Network and NSF award 1551731, CAREER: Understanding the Fundamental Principles Driving Household Energy and Resource Consumption for Smart, Sustainable, and Resilient Communities. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Reference:

Derrible, S. and Chester, M.V., editors (2020). *Urban Infrastructure: Reflections for 2100*, Independently published, available at https://www.amazon.com/gp/product/B08LZV66YK/

Track 3: Standards, Technology, and Modeling

Moderated by Krishna Reddy

Will it Work? Examining Alignment of Four Infrastructure Solutions with the Draft *ASCE 73: Standard Requirements for Sustainable Infrastructure*

Duncan G. Russell,[1] Andrew T. Zeidler,[1] James A. Bieler,[1] Brad C. McCoy*[2], and Claude E. Barron[3]

[1] Cadet, United States Corps of Cadets, Department of Civil and Mechanical Engineering, United States Military Academy, West Point, NY 10996
[2] Director and Academy Professor, Center for Innovation and Engineering, Department of Civil and Mechanical Engineering, United States Military Academy, West Point, NY 10996
(E-mail: brad.mccoy@westpoint.edu)
[3] Assistant Professor, Department of Civil and Mechanical Engineering, United States Military Academy, West Point, NY 10996
(E-mail: claude.barron@westpoint.edu)

Keywords: Standard, **S**ustainability, Sustainable Infrastructure, Triple Bottom Line

ABSTRACT

This study examines ASCE's draft sustainable infrastructure standard – *ASCE/COS 73: Standard Requirements for Sustainable Infrastructure* – to assess its alignment with current construction and design practices. A team of students and faculty from the United States Military Academy applied the draft document to four current and planned infrastructure projects. The scope of the study included an analysis of a university dormitory, a mass-timber residential skyrise, a ferry port expansion, and a multi-purpose mass-transport project. The objective was to assess alignment of the draft standard with current construction and design practices, not to assess or rate the projects themselves. The research team generated questions and gathered information from project owners and key leaders through surveys, interviews, and shared files. Both quantifiable and non-quantifiable measures were used to assess alignment with the sustainable infrastructure outcomes presented in the draft standard. The results indicate the draft standard challenges infrastructure development toward needed sustainability practices, while still being achievable within the current state of design and practice in the construction industry. Additionally, the study identifies recommendations for future studies using ASCE/COS 73.

What Does Sustainable Infrastructure Mean….
and What Should it Mean?

Josh Jacobs

Director of Environmental Codes & Standards, UL
(josh.jacobs@ul.com)

Keywords: Carbon, Embodied Carbon, Environment, Net Zero, Sustainability, Sustainable

ABSTRACT

Sustainability is a word that gets used to mean so many different things. But what does sustainability mean in today's environmental social governance (ESG) world? Have you looked at the embodied carbon in your specifications; has the equity of the community been taken into account; have you looked at the transparency required in the Sustainability Accounting Standards Board (SASB) standards? Where does the triple bottom line come into the conversation around your infrastructure projects? If you are simply asking for the amount of recycled content in your materials....you are falling behind where the world is. We will look at the state of the market in regards to sustainable infrastructure rating systems or standards such as Envision, ASCE 73 (in development), SASB, and other tools from around the world to decipher what sustainable infrastructure means today. Then we will have an interactive session on what can and should be included in truly sustainable infrastructure of tomorrow.

Using Design Automation to Make Smarter Infrastructure Decisions: An Engineer Learns to Code

Tyler R. Ortego*[1] and Nicholas Brady[2]

[1,] Technical Resource Engineer, Forterra Inc.
(E-mail: tyler.ortego@forterrabp.com)
[2] Software Lead, Natrx, Inc.
(E-mail: nick@natrx.io)

Keywords: Armoring, Automation, Coasts, Ecosystems, Resilience, Shorelines, Sustainability

ABSTRACT

Roughly 50% of the world's population lives within 50 miles of the coast, which is expected to increase to 65% by 2040, increasing demands on public and private sector infrastructure. The UN anticipates the need for hundreds of millions of dollars in adaptation infrastructure on an annual basis. Concrete remains by far the most utilized construction material on earth and remains an essential component of most adaptation infrastructure. However, concrete has its own environmental footprint, and adaptation infrastructure often comes at the expense of biodiversity and natural processes. Looking especially at the waterfront, a range of innovations have been proposed from traditional dikes and armoring and massive mechanized infrastructure to biocompatible materials, ecosystem engineered armoring and water-cleaning floating islands. We propose to use digital automation tools to optimize coastal shoreline armoring for ecological cost and benefit. The split focus is on the author's own personal journey and how busy professionals can learn new skills, along with a look into more advanced outcomes that can be achieved when you partner with the pros. As technology progresses, we have a growing availability of satellite and aerial data at our disposal. This opens up many possibilities to provide innovation in industry to protect our coastlines.

Assessing Climate Change Uncertainty for Infrastructure Planning with Physical-Parameter-Based State-Space Models and Bayesian Inference

Yuchuan Lai*[1], Peter J. Adams[2] and Matteo Pozzi[3]

[1] Postdoctoral research associate, Carnegie Mellon University
(E-mail: ylai1@andrew.cmu.edu)
[2] Professor, Carnegie Mellon University
(E-mail: peteradams@cmu.edu)
[3] Associate Professor, Carnegie Mellon University
(E-mail: mpozzi@cmu.edu)

Keywords: Climate Change, Infrastructure Planning, Statistical Analysis, Uncertainty

ABSTRACT

Predicting future climate conditions is crucial for improving community resilience and engineering adaptations against climate change. Underestimated climate change can induce managers to adopt insufficient mitigation measures, while overestimated climate conditions can lead to higher costs and less efficiency in engineering adaptations. Substantial progress has been made in the scientific community to improve climate models and climate model projections (Eyring et al. 2016), although these projections were not developed specifically for any practical applications and there is a substantial barrier in translating climate model results into engineering practice. Climate model projections are affected by the deep uncertainty with different sources such as natural variability, model uncertainty, and scenario uncertainty (Hawkins and Sutton 2009). At the same time, more and more climate model projections are becoming available (Deser et al. 2020), with new, recently-developed future climate scenarios (O'Neill et al. 2017). Translating these climate model projections into actionable information for engineering is an urgent and critical task to perform.

The main objective of this study is to assess climate model projection uncertainty with statistical time series analysis and Bayesian inference for engineering decision-making and infrastructure planning. This work aimed at assessing the performance of different climate models based on historical observation data, reducing model projection uncertainty by selecting best-performed models, and providing improved future climate information. The dependence of future climate projection uncertainty on the availability of observation data can be assessed, allowing the adoption of more flexible engineering planning schemes. While the overall objective is to facilitate the analyses of regional climate for forecasting the rate of occurrence with extreme events, some preliminary results with the analyses on the global average temperature series are available and are presented. The overall approach of applying the time series analysis and Bayesian inference is expected to be applicable for regional climate assessment.

This work utilized a state space model (SSM) approach to model time series of temperature anomaly, integrating physics-based parameters. Using statistical time series models serves as a useful alternative for forecasting the time series of climate variables according to the previous work (Lai and Dzombak 2021). Consistent with a simplified global energy balance

model, the physical-parameter-based SSM provides a parametric form to evaluate the available climate model simulations with a set of parameter values for individual models, as presented in Figure 1 as an illustration. Both the number of global climate models (currently 36 models are used) and the number of simulation runs from each model are relatively large (up to more than 100 simulation runs for one future scenario), facilitating the analyses using SSM.

The evaluation of the model performance and the estimation of future climate projections follow a Bayesian model averaging approach. Under the same parametric form of SSM, the estimated parameter values from individual climate models are used to calculate the marginal likelihood for these models based on historical observation data and this marginal likelihood is combined with the sets of posterior parameter values (across all models) to obtain climate projections.

The SSM approach can assess the performance of climate models and provide improved climate projections for engineering applications. With the framework of the Bayesian model averaging and the integration of physical parameters, the best performed climate models or the sets of corresponding parameter values can be selected to reduce both the projection uncertainty for the variable of interest and the uncertainty with respect to the individual physical parameters. An example is provided in Figure 2 as an evaluation result for the projection uncertainty with different availability of historical data. With this application of physical-parameter-based technique and further development in modeling of regional climate and other climate variables, the SSM is expected to be a useful approach to facilitate assessing projection uncertainty and to help improve engineering decision-making by combining with other techniques such as those presented in Pozzi et al. (2017).

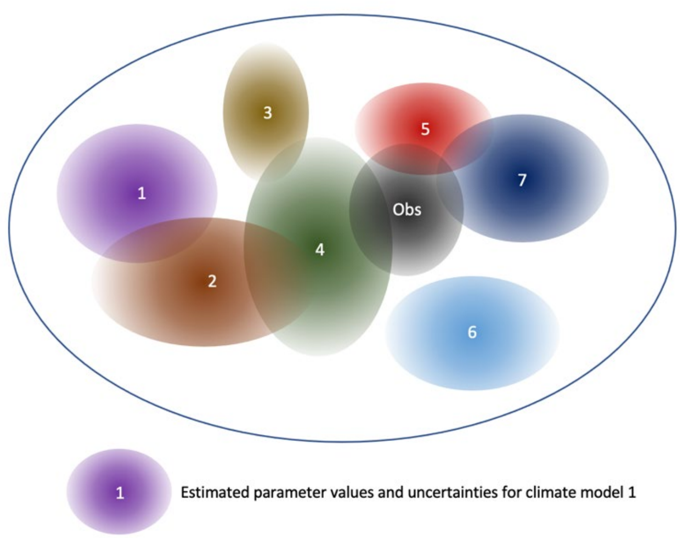

Figure 1. A conceptual framework for evaluating climate models in a two-dimensional space. The same parametric form of SSM is used to assess different climate models, by the estimation of parameter values for the SSM and their uncertainties (presented as the different ellipses). The Bayesian model averaging approach is then applied to evaluate the individual model performance and to provide improved projections based on historical observation data.

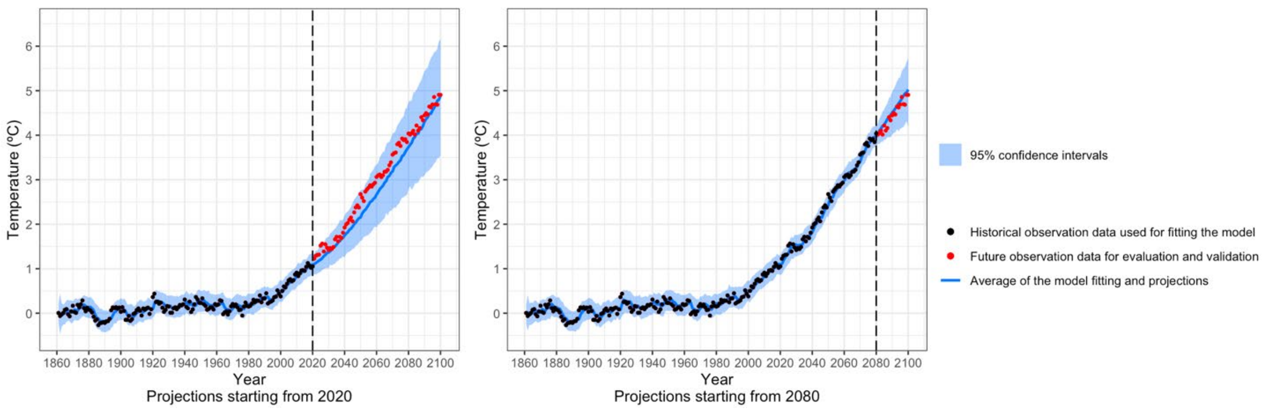

Figure 2. Examples of projection uncertainty for the global average temperature anomaly series using different lengths of historical data (up to 2020 on the left and up to 2080 on the right) for evaluation of climate models. Simulation series from climate model ACCESS1.3 were used as the synthetic observation data in this figure. The projection uncertainty can be reduced when additional observation data become available and used for assessing climate model simulations.

Acknowledgment: The research is supported by the National Science Foundation (NSF project CMMI #1663479, titled "From Future Learning to Current Action: Long-Term Sequential Infrastructure Planning under Uncertainty").

References:

Deser, C., Lehner, F., Rodgers, K. B., Ault, T., Delworth, T. L., et al. (2020). "Insights from Earth system model initial-condition large ensembles and future prospects." *Nature Climate Change*, 10(4), 277–286.

Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., et al. (2016). "Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization." *Geoscientific Model Development*, 9(5), 1937–1958.

Hawkins, E., and Sutton, R. (2009). "The potential to narrow uncertainty in regional climate predictions." *Bulletin of the American Meteorological Society*, 90(8), 1095–1107.

Lai, Y., and Dzombak, D. A. (2021). "Use of Integrated Global Climate Model Simulations and Statistical Time Series Forecasting to Project Regional Temperature and Precipitation." *Journal of Applied Meteorology and Climatology*. 60(5), 695–710.

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., et al. (2017). "The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century." *Global Environmental Change*, 42, 169–180.

Pozzi, M., Memarzadeh, M., and Klima, K. (2017). "Hidden-Model Processes for Adaptive Management under Uncertain Climate Change." *Journal of Infrastructure Systems*, 23(4), 04017022.

Track 4: Materials and Construction Components (Part 2)

Moderated by Sabrina Moore

Changes in New Pipe Acceptance Standards are Paving the Way to Sustainable Infrastructure

Chuck Hansen*[1]

[1]Chairman and CEO, Hansen Analytics, LLC
(E-mail: chuck.hansen@hansen.com)

Keywords: Capex, Pipeline Resiliency, QA/QC, Sustainability, Water Tightness

ABSTRACT

How many times have you heard, “The sewer and water pipes are nearing the end of their useful life”? Or seen decay curves that recommend repairs, rehabilitation, or renewal programs to re-invigorate networks for the next 100 years? Disruptive technologies are showing that pipe decay curves are not necessarily the best way to prioritize rehabilitation.

In fact, new technologies are showing that poor installation and rehabilitation cause most pipe defects or failures. Confronted by the proverbial ‘pothole in the middle of the road,’ utilities are sometimes faced with repairing or replacing pipelines that were just renewed, representing a detour on the way to smart water sustainability.

As industry insiders have long known, lenient inspection standards do not require pipes to be delivered as watertight. With many utilities allowing contractors and construction firms to self-certify new and rehabilitated pipes based on guidelines established by pipe manufacturers and suppliers that sponsor accreditation programs, results can be questionable.

Aided by machine-intelligent technologies, utilities are finding defects at joints and customer service connections – not pipe wall failures or fractures – that should have been addressed at installation, on pipes that senior managers might have seen installed or rehabilitated earlier in their careers.

Several leading U.S. utilities are adopting machine-intelligent pipe investigation tools to assess new installations and rehabilitation. Representing a contradiction to long-held assumptions and beliefs, they often find pipes leaking more after rehabilitation than before rehabilitation. Changes in new pipe acceptance standards are paving the way to sustainable infrastructure.

Estimating the Effectiveness, Benefits, and Costs of Reflective Asphalt Coatings for Mitigating Extreme Heat in a Desert Urban Environment

Samuel A. Markolf*[1], Ashley Broadbent[2], Matthew Fraser[3], and Christopher Hoehne[4]

[1] Assistant Professor, Civil and Environmental Engineering, University of California-Merced
(E-mail: smarkolf@ucmerced.edu)
[2] Climate Scientist, New Zealand National Institute of Water and Atmospheric Research
(E-mail: ash.broadbent.nz@gmail.com)
[3] Professor, Sustainable Engineering and the Built Environment, Arizona State University
(E-mail: Matthew.Fraser@asu.edu)
[4] Postdoctoral Researcher, National Renewable Energy Laboratory
(E-mail: christopher.hoehne@nrel.gov)

Keywords: Extreme Heat, Urban Heat Mitigation

ABSTRACT

Given urbanization and a changing climate, extreme heat (exacerbated by the urban heat island effect) is a hazard with which many cities must increasingly grapple. In addition to human health impacts, extreme temperatures have been linked to a range of other adverse impacts, including increased energy/water use and infrastructure damage. As a result, adapting to climate change and mitigating extreme heat conditions have become critical sustainability goals for many cities. Municipalities targeting temperature reductions have begun experimenting with heat mitigating infrastructure. For example, Maricopa County in Arizona has implemented reflective asphalt coatings in certain locations with the goal of lowering urban temperatures and providing health and economic benefits to county residents.

This study uses meteorological measurements in conjunction with empirical and dynamical modeling approaches to: 1) quantify the impacts of reflective asphalt coatings on surface energy balance and near-surface air temperature; (2) model the potential cooling impacts derived from large-scale application of the reflective coating across Maricopa County; and (3) estimate/compare the costs and benefits (e.g., impacts on energy and water use, human health, etc.) of the county-scale implementation of the reflective asphalt coating. Considering Maricopa County's position as one of the hottest urban areas in the United States, the results and insights gathered from this study can serve as an exemplar for many cities that are likely to face warmer and drier conditions in the coming decades. Ultimately, this work can also help contribute to a more holistic and multi-faceted understanding of county-level heat mitigation strategies.

Recycling Waste Plastic in Roads: Opportunities, Challenges and Potential

Greg White*[1], Finn Hall[1]

[1]Airport Pavement Research Program, University of the Sunshine Coast, Sippy Downs, Queensland, Australia
(E-mail: gwhite2@usc.edu.au, finn@macrebur.com)

Keywords: Asphalt Pavement, Recycled Plastic

ABSTRACT

With the increased focus on recycling of waste materials in infrastructure construction and maintenance, there is an ever-increasing interest in the recycling of waste plastic in the production of asphalt mixtures for road and other pavement surfacing. However, there are many types of plastic and only some are compatible with asphalt production. Some plastics are capable of extending the mineral aggregate in asphalt mixtures, while others can improve the mixture properties, but they increase the resistance to rutting and cracking. The most valuable plastics can extend and improve the bituminous binder in the asphalt mixture, effectively replacing the synthesized polymers that are commonly used to improve moisture resistance, temperature susceptibility, crack resistance and deformation resistance. Despite these potential benefits, there are many challenges, associated with the categorization of different plastics and their associated effects, as well as the sourcing of consistent and uncontaminated plastic supply. Other challenges include the digestion and stability of plastic in the bituminous binder phase when the wet mixing process is used. It is also essential to confirm and demonstrate that asphalt mixtures containing recycled plastic do not increase the fume generation during construction or chemical leachate of road surfaces during service. These challenges must be resolved if the potential for recycling plastic in road and other pavement asphalt layers is to be fully maximised in the future.

Objective Comparison of Sustainable Asphalt Concrete Solutions for Airport Pavements

Demi Van Den Heuvel* and Greg White

Airport Pavement Research Program, University of the Sunshine Coast, Sippy Downs, Queensland, Australia
(E-mail: demi.vandenheuvel@gmail.com, gwhite2@usc.edu.au)

Keywords: Airport Asphalt, Sustainability Analysis

ABSTRACT

There is an increasing interest in sustainable infrastructure, including pavement structures and materials. Replacing the high-cost materials used for producing cementitious concrete and asphalt mixes provides the greatest return on the investment. For flexible pavement surfaces, this means replacing of the new aggregates, virgin bituminous binder and synthesised polymers commonly used to produce asphalt concrete mixes. Using a triple bottom line approach, the economic, social and environmental cost of different asphalt mixes, containing one or more of recycled asphalt, crumb rubber, processed plastic and crushed glass, were objectively compared. It was concluded that recycling asphalt provides the greatest single opportunity for more sustainable airport asphalt surfaces, with a triple bottom line cost 30% lower than the standard asphalt mix. However, the relative financial cost of the new and recycled materials, as well as the recycled material content, had a great influence on the triple bottom line cost of the various recycled materials, relative to that of the standard asphalt mix.

The Significant Sustainable Benefits Afforded by Geosynthetics in Key Infrastructure Applications: A Review

Ian W. Fraser*[1] and David A. Shercliff[2]

[1] Technical Director, TCS Geotechnics
(E-mail: ianfraser@tcs-geotechnics.co.uk)
[2] Chief Engineer, ABG Ltd
(E-mail: david@abgltd.com)

Keywords: Emissions, Environmental, Geosynthetic, Infrastructure, Resources, Sustainable

ABSTRACT

For decades geosynthetics have been utilized in infrastructure projects worldwide to improve the performance of the ground via, for example, drainage, reinforcement and stabilization. The inclusion of geosynthetics has generally been driven by reduction in construction costs and time and significantly this is typically characterized by a reduction in the volume of imported bulk construction materials like sands and gravels. This can be associated with more efficient performance of the geosynthetic systems or the ability to use marginal materials in conjunction with geosynthetics. In more recent times the considerable sustainable benefits gained from the reduction of these bulk materials have been noted and several specific studies have demonstrated large environmental savings via a range of geosynthetic applications.

The sustainable benefits include preservation of limited natural resources (e.g. gravel), emission and energy savings from the reduction in transport of bulk materials, reduction in onsite excavation and placement activity and reduction in construction programmes. Theoretical and case study examples are provided demonstrating significant sustainable benefits for a range of geosynthetic materials and infrastructure applications.

It is concluded that geosynthetic solutions offer such a clear and significant opportunity for more sustainable infrastructure development that there is a strong case to consider their inclusion in all such projects.

Track 5: Contaminants and Repurposing Waste

Moderated by Julia Clarke

Incorporating Spatial Scale into Resilience Ratings for Sustainable Post-Disaster Material Management Systems

James L. Hanson[1], Derek C. Manheim*[2] and Nazli Yesiller[3]

[1] Professor, Civil and Environmental Engineering Dept., California Polytechnic State University (E-mail: jahanson@calpoly.edu)
[2] Fellow, Civil and Environmental Engineering Dept., California Polytechnic State University (E-mail: dmanheim@calpoly.edu)
[3] Director, Global Waste Research Institute, California Polytechnic State University (E-mail: nyesille@calpoly.edu)

Keywords: Climate Change, Disaster Waste, Recovery, Spatial Scale, Sustainable Resilience

ABSTRACT

Natural disasters generate large quantities of debris and waste materials (Brown et al. 2011) such as the mixed debris in Figure 1. If not managed properly, these materials pose a significant risk to human health and the environment. Critical, yet often overlooked, fugitive gases are emitted from post-disaster materials over various spatiotemporal scales following disasters. Post-disaster debris management activities such as collection, transport, processing at temporary storage areas, and final disposal also contribute to emissions through fossil fuel combustion (Wakabayashi et al. 2017). Despite these adverse impacts, post-disaster recovery efforts have primarily focused on advancing rapidity, resourcefulness, redundancy, and robustness throughout all stages of the debris collection, storage, and ultimate management lifecycle (Bruneau et al. 2003). While these resilience principles are important for disaster response, the principles alone fail to directly prioritize the climate impacts of post disaster materials and management activities that can intensify future disasters. Disaster waste management systems will benefit from integration of sustainability principles that foster resilience while providing long-term effective and enhanced system performance (e.g., Gillespie-Marthaler et al. 2019), hereafter termed "sustainable resilience".

Figure 1. Debris in Florida after Hurricane Michael (from Derrible et al. 2019)

In this investigation, a novel framework is introduced to provide sustainable resiliency to post-disaster material management systems. The framework incorporates two specific

advancements: i) climate impacts of the waste materials and their management and ii) a spatial scale in addition to the time scale. The performance of the disaster waste management system is quantified using an overall sustainable resilience index (SRI). The SRI (Eq. 1) is defined as the combination of two primary metrics that characterize the sustainable resilience of the system: i) the climate impacts resulting directly from the debris and waste materials (EM_1, tonnes CO_2-eq. emissions); and ii) the climate impacts of the disaster waste management system operations, including collection, transport, temporary storage, recycling/recovery, and landfilling (EM_2, tonnes CO_2-eq. emissions). The performance of the system, in terms of the overall SRI, is made a function of time *t* by using existing resiliency analysis (Figure 2a) (Munoz and Dunbar 2015, Yodo and Wang 2016) and newly introduced distance *x* from the most critically affected region (focal point) of the disaster (Figure 2b). Higher values of the SRI indicate a management system that actively lowers the operational and debris/waste material-specific climate impacts.

$$SRI(t,x) = \left[\frac{1}{EM_1(t,x)+EM_2(t,x)}\right] \quad (1)$$

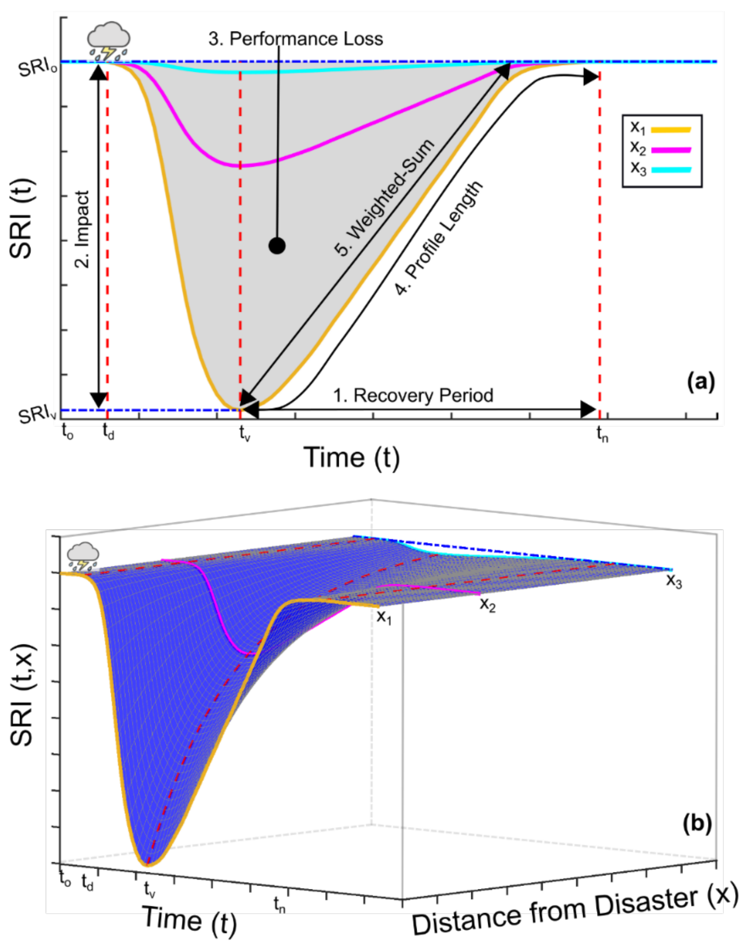

Figure 2. System performance with: a) time (adapted from Yoda and Wang (2016), originally by Munoz and Dunbar (2015)), b) time and distance from the disaster focal point

Prior to the disaster, the baseline SRI of the waste management system in the disaster affected region (SRI_o) includes existing emissions from collection/transportation routes and the waste management infrastructure (i.e., landfills and recycling/recovery centers). At the time the disaster occurs (t_d), there is an abrupt decrease in the SRI to the vulnerability state SRI_v. The magnitude of this decrease in the SRI is typically strongest near the disaster focal point (x_1) and dissipates progressively towards the edges of the affected region (x_2, x_3). During the recovery period (t_v to t_n), the SRI starts to increase as a temporary debris management operation (TDMO) is established to collect, process, and manage the debris and waste materials (i.e., the recovery curve). The recovery effort ends when a steady state in the waste management system performance is re-established at or above baseline SRI.

The five common resilience dimensions are recovery period (*RP*), impact (*IM*), performance loss (*PL*), profile length (*PrL*), and weighted sum (*WS*). The 2D relationships that represent the dimensions (Figure 2a) are modified to account for the system performance on various spatial scales (Figure 2b) extending radially from the disaster focal point (x_1, x_2, x_3). An overall weighted sustainable resilience score (j) is developed to link all of the quantitative dimensions presented in Eq. 2. The weights ($w_{1\text{-}5}$) are determined using the modeling scheme presented in Munoz and Dunbar (2015).

$$\varphi = w_1 \times RP + w_2 \times IM + w_3 \times PL + w_4 \times PrL + w_5 \times WS \quad (2)$$

The *SRI*(t, x) and the associated j will vary significantly spatially and temporally as a function of the community and disaster event characteristics. For example, the variations of the response surface as well as the reliability state are highly influenced by regional demographics (e.g., population density), disaster type and intensity, as well as the availability and condition of existing waste management infrastructure (e.g., age, type, capacity). Incorporating distance from the disaster event in the development of SRI allows for including: geographic spread of disaster impact zone; geographic distribution and density of waste management infrastructure; regional topography; variation of population density and associated civil and industrial infrastructure with distance from the disaster event; and directionality from disaster (as the function of distance will change on a radial basis depending on a specific cardinal direction). The features of the recovery surface as well as the vulnerability state (Figure 2b) will depend on the efficiency and preparedness of the management system; accessibility and connectivity of the transportation network for waste transfer; design and establishment of TDMO facilities; allocation of waste to recycling/recovery centers; and waste disposal in available landfills. Ultimately, this framework can be applied to optimize the sustainable resilience properties of disaster waste management systems on a community- and disaster-event-specific basis.

References:

Brown, C., Milke, M. and Seville, E. (2011). “Disaster waste management: A review article.” *Waste Management*, 31(6), 1085-1098.

Bruneau, M., et al. (2003). “A framework to quantitatively assess and enhance the seismic resilience of communities.” *Earthquake Spectra*, 19(4), 733-752.

Derrible, S., Choi, J., and Yesiller, N. (2019). “Millions of burnt trees and rusted cars: Post-disaster clean-up is expensive, time-consuming and wasteful,” *The Conversation*, Dec. 10, 2019.

Gillespie-Marthaler, L., Nelson, K., Baroud, H., and Abkowitz, M. (2019). “Selecting indicators for assessing community sustainable resilience.” *Risk Analysis*, 39(11), 2479-2498.

Munoz, A., and Dunbar, M. (2015). “On the quantification of operational supply chain resilience.” *International Journal of Production Research*, 53(22), 6736-6751.

Yodo, N., and Wang, P. (2016). “Engineering resilience quantification and system design implications: a literature survey.” *Journal of Mechanical Design*, 138(3), 111408 1-13.

Wakabayashi, Y., Peii, T., Tabata, T., and Saeki, T. (2017). “Life cycle assessment and life cycle costs for pre-disaster waste management systems.” *Waste Management*, 68, 688-700.

Geotechnical Engineering Contribution for Sustainable Dredging

Federica Pasqualini*[1], Mirko Felici[2] and Evelina Fratalocchi[3]

[1] PhD Student, Università Politecnica delle Marche
(E-mail: f.pasqualini@pm.univpm.it)
[2] Post Doctoral Fellow, Università Politecnica delle Marche
(E-mail: mirko.felici@univpm.it)
[3] Professor, Università Politecnica delle Marche
(E-mail: e.fratalocchi@univpm.it)

Keywords: Confined Disposal Facilities, Dredging, Sediments

ABSTRACT

In coastal areas and harbors, dredging activities are increasingly required for maintenance issues, investment purposes and to improve environmental conditions. Hence, dredging represents a routine necessity but, at the same time, it produces huge amounts of resulting materials (dredged sediments) that need to be periodically handled and safely placed somewhere. To get an idea of the involved volumes, in 2015 the annual dredging requirement for the major commercial harbors in Italy amounted to almost 130 million cubic meters (PCM, 2014).

In this scenario, it is critical to set up a sustainable management design of dredged materials which envisages the preliminary characterization of the sediments, analysis of their level of contamination, scheduling of excavation operations, sorting of equipment, and adoption of a reuse application. The management plan should be site-specific and designed in advance, also by foreseeing the collaboration between different expertises (geotechnical and hydraulic engineering, biology, chemistry etc.).

To follow a sustainable dredging strategy, management of sediments should be based on conceiving them not as a waste but rather as a reusable resource (as such or properly treated) for engineering purposes. These solutions are expected to result in lower economic and environmental impact, since they reduce the exploitation of quarries and avoid disposal of sediments in landfills if contaminated.

In the past, dredged sediments were directly discharged offshore, but this practice, although the cheapest, is no longer recommended, since it can "presumptively" alter the aquatic environment (Miller, 1998); besides, the unconfined open-water displacement does not provide a new beneficial fate to the resulting material.

Several sustainable management alternatives are currently viable depending on the physical-chemical characteristics of dredged materials and on their level of pollution. Nourishment is certainly the most desirable option for uncontaminated ones: it involves their placement directly onto a beach or into the shallow areas near shore, to control coastal erosion. Other innovative beneficial uses convert dredged sediments in raw materials for road construction (Siham et al., 2008), bricks fabrication (Mezencevova et al., 2012), self-consolidating

concrete preparation (Rozière et al., 2015), and landscaping and agricultural applications (Miller, 1998).

If dredged sediments are contaminated, they can be placed in a submerged disposal site and then covered with a layer of clean material (capping): the disposal can be done directly onto a flat surface or into an excavated subaqueous pit to provide lateral containment (Miller, 1998). Also, unconventional biological treatments have been proposed to remove organic and inorganic contaminants from sediments (Mulligan et al., 2001): these are very promising solutions but, owing to their high costs and to their inefficacy to neutralize all the contaminants present, they have been scarcely used hitherto.

One of the most used management practices for contaminated sediments is confined disposal (Miller, 1998). It consists in building a secure containment structure (confined disposal facility, CDF) within the port and then filling it with dredged muds, to finally integrate it into the port infrastructure. Dimensions and configurations of the CDF depend on the dredged material volume, pollution levels, and disposal procedure, as well as on local regulations. Often a CDF is the only alternative that is found to be both environmentally and economically acceptable (Bailey et al., 2010). A CDF can represent a sustainable opportunity of resources optimization and harbors modernization, since expansion works usually require large quantities of filling material which can be supplied by means of a careful planning of dredging activities.

However, when dealing with dredged materials fillings, their behavior after placement cannot be neglected. This is especially true for hydraulically dredged fine-grained sediments which typically exhibit very high water contents, high compressibility and poor mechanical properties, when poured into a CDF. They firstly settle at high void ratios, then self-weight consolidation starts, during which they undergo significant volume changes upon reaching the normally consolidated state (De Lillis et al., 2019 and 2020). Soils in such initial conditions require mechanical improvement to become suitable for reusing the area. Indeed, if subjected to overloads, they can experience high settlements and substantially modify their compressibility and permeability characteristics, which should be thus experimentally determined (Liu and Znidarcic, 1991; Krizek and Somogyi, 1984). Therefore, there are geotechnical aspects that a proper CDF management design should consider. First of all, a complete geotechnical characterization should be performed both *in situ* and in the laboratory, to correctly assess the consolidation process. Secondly, optimization of the operational sequences is necessary, with a view to save time, costs and resources. Finally, the selection of the optimal ground improvement technique is a critical step, as it should be effective in accelerating the consolidation process.

The whole management process is here examined with reference to the Ancona Harbor (Italy), where a CDF was built to collect contaminated sediments from several ports of the central Adriatic Sea, and then to reclaim the area for port commercial activities. This is certainly a sustainable, forward-looking design solution that has combined the need of widening the harbor spaces with the availability of resulting materials which would otherwise be landfilled. The CDF is situated in the commercial dock of the Ancona harbor; it covers an area of 95,000 m^2 and has a volume capacity of about 180,000 m^3. A sectorization of the usable volume has been planned to optimize the filling and consolidation procedure: each sector after filling can be consolidated while filling the adjacent one. In such a way the CDF can be made available for the intended use in a shorter time after overall filling. Its construction has been very complex and required some innovative solutions, as reported in Felici et al. (2017). Owing to the fine-grained nature of the dredged sediments, the selected consolidation technique has been a preloading embankment coupled with prefabricated vertical drains (Felici et al., 2020). The CDF is currently being filled and, in a completed sector, a full-scale field test has been set up to study the consolidation process (Felici et al. 2018).

By referring to the Ancona experience, the study illustrates how geotechnical engineering is crucial to the dredging management cycle, allowing the reuse of filled areas by providing site-specific innovative solutions.

References:

Bailey, S. E., Estes T. J., Schroeder, P. R., Myers, T. E., Rosati, J. D., Welp, T. L., Lee, L. T., Vern Gwin, W., and Averett, D. E. (2010). *Sustainable Confined Disposal Facilities for Long-term Management of Dredged Material.* Technical Note ERDC TN-DOER-D10.

De Lillis, A., Rotisciani, G. M., and Miliziano, S. (2019). "Numerical study of the mechanical behaviour of fine-grained dredged sediments." *Proc., XVII European Conference on Soil Mechanics and Geotechnical Engineering.*

De Lillis, A., Rotisciani, G. M., and Miliziano, S. (2020). "Numerical investigation of the behaviour of hydraulically dredged fine-grained soil during and after filling of the containment facility of the port of Gaeta." *Geotextiles and Geomembranes, 48(4)*, 591-601.

Felici, M., Domizi, J., Di Sante, M., and Mazzieri, F. (2017). "Consolidation of marine sediments in a confined disposal facility. Experimental activities and preliminary results." (in Italian). *Proc., VII Incontro Annuale Giovani Ingegneri Geotecnici*.

Felici, M., Domizi, J., and Fratalocchi, E. (2018). "Consolidation of dredged sediments in a confined disposal facility: hydraulic conductivity constitutive relations." In *8th International Congress on Environmental Geotechnics* (pp. 288-294). Springer, Singapore.

Felici, M, Fratalocchi, E., Di Sante, M., Pasqualini, F., and Pasqualini, E. (2020). "PVD-assisted consolidation of dredged sediments in a CDF: design of the test field." In *3rd International Symposium on Coupled Phenomena in Environmental Geotechnics* (in press).

Krizek, R. J., and Somogyi, F. (1984). "Perspectives on modelling consolidation of dredged materials." *Proc., Symp. on Sedimentation-Consolidation Models: Predictions and Validation*, ASCE, San Francisco, Calif., 296-332.

Liu, J. C., and Znidarčić, D. (1991). Modeling one-dimensional compression characteristics of soils. *Journal of Geotechnical Engineering, 117(1)*, 162-169.

Mezencevova, A., Yeboah, N. N., Burns, S. E., Kahn, L. F., and Kurtis, K. E. (2012). Utilization of Savannah Harbor river sediment as the primary raw material in production of fired brick. *Journal of Environmental Management, 113*, 128-136.

Miller, J. A. (1998). *Confined Disposal Facility on the Great Lakes* (p. 22). Chicago IL: US Army Corps of Engineers, Great Lakes & Ohio River Division.

Mulligan, C. N, Yong, R. N., and Gibbs, B. F. (2001). "An evaluation of technologies for the heavy metal remediation of dredged sediments." *Journal of Hazardous Materials, 85(1-2)*, 145-163.

PCM (Presidenza del Consiglio dei Ministri). (2014). *Iniziativa di studio sulla portualità italiana*.

Rozière, E., Samara, M., Loukili, A., and Damidot, D. (2015). "Valorisation of sediments in self-consolidating concrete: Mix-design and microstructure." *Construction and Building Materials*, 81, 1-10.

Siham, K., Fabrice, B., Edine, A. N., and Patrick, D. (2008). "Marine dredged sediments as new materials resource for road construction." *Waste Management,* 28(5), 919-928.

Phytoremediation: A Cost-Efficient and Environmentally-Sound Remediation Technology for Widespread Applications

Sydney L. Hope

Environmental Engineer, Burns & McDonnell
(E-mail: slhope@burnsmcd.com)

Keywords: Bioremediation, Ex-Situ, Groundwater, In-Situ, Phytoremediation, Soil

ABSTRACT

Environmental remediation of groundwater and soil can quickly become a logistically challenging and costly pursuit. Commonly used remediation technologies include thermal desorption, excavation, chemical oxidation, pump-and-treat, soil vapor extraction and others. Factors such as site location, geologic conditions, geochemical conditions, extent of contamination, and type of pollutants all contribute to the selection of a remediation technology and the overall cost. Unfortunately, current methods come at a high cost regarding materials, off-site processing, and transportation, as well as the negative environmental impacts including accelerated soil erosion, unintended toxic byproducts, and changes to the site ecosystem. Phytoremediation is a unique bioremediation technology that uses plants and microorganisms to destroy contaminants in soil and groundwater. This technology is less costly than traditional in-situ and ex-situ remediation methods while being a more environmentally considerate option. Specifically, phytoremediation reduces soil erosion, maintains soil fertility, and increases overall soil health and biome, while being the most aesthetically pleasing remediation option to the public. Phytoremediation is a sustainable and environmentally resilient replacement for traditional remediation methods.

Sustainability Aspects of Coir-Fiber Geosynthetic Rolled Erosion Control Products

Shobha K. Bhatia*[1] and Jennifer L. Smith[2]

[1] Professor, Syracuse University
(E-mail: skbhatia@syr.edu)
[2] Geotechnical Engineer
(E-mail: jensyr@aol.com)

Keywords: Coir Fiber, Geosynthetic, RECP, Soil Erosion, Sustainability

ABSTRACT

Geotechnical engineering is one of the most resource intensive engineering disciplines. Projects consume vast amounts of resources, change landscapes, and interact across socio-centric (human capital and social expectations), eco-centric (natural resources and ecological capacity), and techno-centric (engineering) boundaries. Improving the sustainability of geotechnical processes is important and necessary for the continued development of resilient communities.

This presentation will provide a unique perspective into the three aspects of sustainability (socio-centric, eco-centric, and techno-centric) for a commonly used geotechnical engineering product: coir-fiber geosynthetic rolled erosion control products (RECPs) (see Figure 1.) RECPs are temporary degradable materials manufactured into rolls that are used to minimize soil erosion and enhance the growth of vegetation on bare soil slopes. Coir fiber, obtained from coconuts, is produced around the world and plays an important role in marginalized rural communities.

A case study was conducted of the coir fiber industry in Kerala, India. Kerala has an abundance of natural resources, including coconuts, backwaters for processing coir fiber from coconuts, and low-income workers. More than 40% of rural women in Kerala work in the coir industry.

This three-pronged sustainability study (see Figure 2) began in Kerala, India, with interviews with women coir workers from three different rural villages to gain an understanding of how the industry impacts them, their environment, and how their products enter the local market. The study included interviews with local manufacturers and state agencies to gain an understanding of how locally produced coir fiber and products enter the national and global markets. Finally, the technical components of coir-fiber RECP development and product performance were evaluated through an extensive laboratory rainsplash erosion study conducted at Syracuse University to evaluate the properties and performance of coir-fiber RECPs and their ability to protect and enhance natural soil resources.

Insight into the advantages and challenges of the sustainability of these products in rural communities and globally was gained.

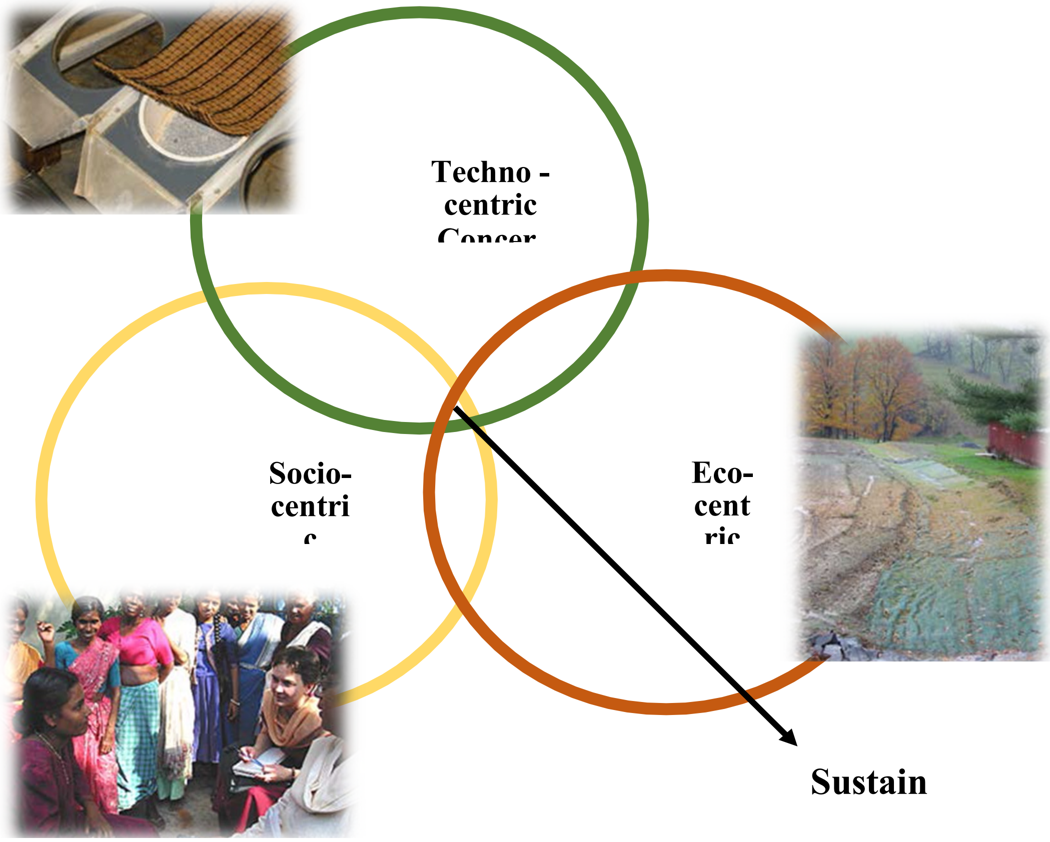

Figure 1. Three aspects of sustainability.

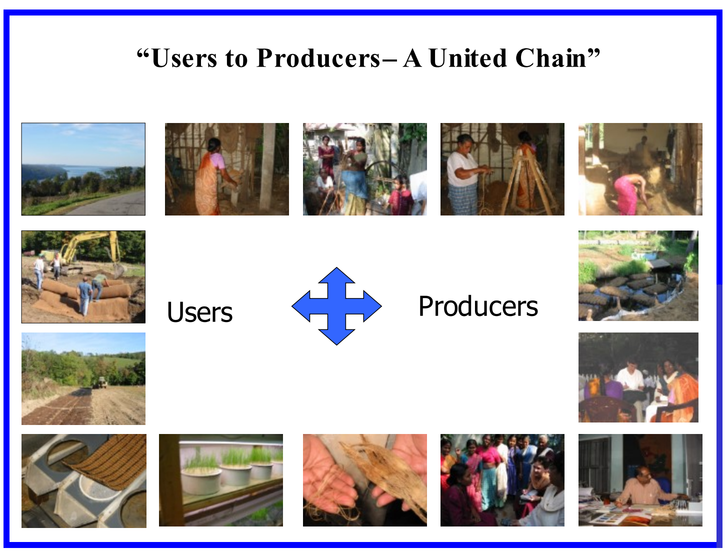

Figure 2. Users to producers – a united chain.

Life Cycle Assessment of Sediment Control Devices

Hejintao Huang*[1], Susan E. Burns[2] and Cameron Troxel[3]

[1] Graduate Research Assistant, Georgia Institute of Technology
(E-mail: huanghejintao@gatech.edu)
[2] Professor and Associate Chair for Administration and Finance, Georgia Institute of Technology
(E-mail: susan.burns@ce.gatech.edu)
[3] Associate, Geotechnical Engineer, Whitman, Requardt and Associates, LLP
(E-mail: ctroxel@wrallp.com)

Keywords: Eutrophication, Global Warming, Sediment Control

ABSTRACT

Sediment control devices (SCDs) are used to manage stormwater runoff and deposition on active construction sites to prevent contamination of waterbodies by suspended solids, nutrients, and heavy metals, which are extremely toxic to the receiving ecosystem. Enriched nutrient concentrations can cause excess growth of plants and algae which also cause severe reductions in water quality and threaten aquatic vegetation and animals due to the transport of chemicals sorbed to suspended solids, which can raise toxicity levels. Due to these detrimental impacts, substantial efforts are spent on liquid/solid separation to retain solids, nutrients, and metals on land before discharge to receiving streams. Currently, silt fence is the most frequently implemented method for erosion control in the early phases of construction projects, with the Georgia Department of Transportation installing approximately 1.0 – 1.5 million linear feet of silt fence per year. However, silt fences, which are composed of silt film and woven geotextile, typically manufactured from polypropylene (Figure 1), rely heavily on fossil fuels for manufacture. Minimal studies have been carried out to compare the feasibility of alternative SCDs that are biodegradable and less fossil fuel dependent. Consequently, the goal of this study is to conduct a cradle-to-grave life cycle assessment (LCA) to compare the environmental impacts of five sediment control devices, including silt fence (type A), high flow silt fence (type C), compost socks, straw bales, and mulch berms. Field and laboratory experimental results were used to assess SCD performance and are paired with the LCA database Ecoinvent 3.2 to model the lifecycle of each SCD using Simapro 9.0 software. The findings of the study indicate that overall low global warming and acidification potentials as well as low aquatic toxicity levels demonstrated by mulch berms suggest their use as a more sustainable alternative to a geosynthetic silt fence.

Figure 1. Type A (left) and Type C (right) silt fence during the test.

Figure 2. 12-in compost sock (left), straw bales (middle) and mulch berm (right) after the test.