Building resilient urban coastal environments & communities through science based eco-engineering

Shimrit Perkol-Finkel – Session Moderator Intro
1) Shimrit Perkol-Finkel, ECONcrete – Bringing Concrete to Life
2) Mart Black, TPCG – Promoting Resiliency through Science-Based Eco-Engineering
3) Tyler Ortego, ORA Technologies – Let The Oysters Do The Work
4) Leslie Suazo, Ducks Unlimited – Powerful Partnerships Promote Community Resilience

Time permitting - Q&A
Global Climate Change → Coastal Protection

2018 HURRICANE NAMES

• ALBERTO • HELENA • OSCAR
• BERYL • ISAAC • PATTY
• CHRIS • JOYCE • RAFAEL
• DEBBY • KIRK • SARA
• ERNESTO • LESLIE • TONY
• FLORENCE • MICHAEL • VALERIE
• GORDON • NADINE • WILLIAM

http://www.sintmaartengov.org/special-campaigns/Pages/Hurricane-Campaign.aspx
Climate change made Louisiana's catastrophic floods much more likely

Human-derived rising temperatures increased the risk of the natural disaster by at least 40%, a National Oceanic and Atmospheric Administration study found.
Storm drifts away from Hawaii 'almost biblical' rains

AUDREY McAVOY and CALEB JONES | Associated Press
Global Climate Change → Coastal Protection

Increase proliferation of coastal defense structures

SCAPE TEAM
Coastal Development → Severe Stress on Natural Ecosystems

- Habitat Loss
- Pollution
- Low Biodiversity
- Invasive Species

Pre settlement Harlem

Harlem Today

Harlem Swamp

http://bedfordcarp.com/projects/governors-island-seawall-rehabilitation/

www.environment.gov.au
Ecosystem Restoration - Engineering Change


http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/newyork/ucr-infographic.pdf

http://www.ecoshape.nl/files/paginas/ECOSHAPE_BwN_WEB.pdf

http://nebula.rowan.edu/

http://www.t-book.unina.it/
Building resilient urban coastal environments & communities through science based eco-engineering
Bringing Concrete to Life
Harnessing biological processes for building resilient coastal infrastructure

Shimrit Finkel, PhD
Shimrit@econcretetech.com
Climate Change
A Concrete Problem
Destruction of Natural Coastal Habitats
Ecosystem Restoration - Engineering Change

Rural

Urban

Ecosystem Restoration - Engineering Change

Boeri Studio
Design solutions

Seattle Waterfront 2015- in progress

- Light penetration
- Vertical Habitats
- Sloping Habitats

http://waterfrontseattle.org/
Design solutions

THESEUS - coastal risk assessment and mitigation funded by the EU Commission
http://www.theseusproject.eu

(Firth et al., 2014)
Bringing Concrete to Life

Material composition

- Rich and Diverse Marine Life
- Enhanced Ecosystem Services
- Improved Structural Performance

Surface complexity

- Low Carbon Solution
- Cost Effective
- Aesthetic

Macro Design
Bringing Concrete to Life
Changing Paradigms: Biofouling → Bioprotection

The icing on the cake:
Bioprotection of concrete structures by fucoxoids and barnacles

Dr. Larissa Naylor & Dr. Martin Coombes
Universities of Glasgow and Oxford
With Prof. Heather Viles and Prof. Richard Thompson

http://urbaneproject.org/assets/pdf/(7)%20Larissa%20Naylor_BIOPROTECTION.pdf
Changing Paradigms: Biofouling → Bioprotection

Structural Advantages:
- Strength and durability
- Reduced chloride penetration
- Absorption of wave energy
- Microclimate buffering
- Reduce maintenance

Biological & Ecological Advantages:
- Biological niches
- Ecosystem services
- Carbon Sink
- Water quality (filter feeders)
- Reduce ratio NIS/native species
- Esthetics

Concrete strengthens with time as oyster growth develops (Risinger, 2012)
Bringing Concrete to Life

Two years of Field and Lab Experiments:
Lab settlement experiments:

- Significant differences between concrete matrices
- Portland based concrete - lower results than other matrices in all experiments

(Perkol-Finkel & Sella, 2014)
Bringing Concrete to Life

**Success in Oyster Colonization**

*Crassostrea virginica*

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Avg #</th>
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<tbody>
<tr>
<td>M1</td>
<td>2.73</td>
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<tr>
<td>M2</td>
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<tr>
<td>M3</td>
<td>1.00</td>
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<tr>
<td>M4</td>
<td>1.33</td>
</tr>
<tr>
<td>M5</td>
<td>0.00</td>
</tr>
<tr>
<td>Portland</td>
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Lab settlement experiments
**Bringing Concrete to Life**

- **Inorganic matter:** significant differences
  - Concrete composition: Portland < Other Matrices
  - Months post deployment: 3 < 6 < 12 M
  - Marine Environments: Temperate > Tropical

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**Maximal values:**
- Temperate 1 kg/m²
- Tropical 0.5 kg/m²
Tel Aviv Metropolitan Area: > 3.6 M people

Herzliya Marina: One of the biggest & most innovative marinas in East Mediterranean
Blue Flag Marina
Hosts the World Harbor Project Green Engineering experiment
In the process of transforming its infrastructure to Bio-enhanced
Harnessing biological processes for building resilient coastal infrastructure - Herzliya Marina

1) Armoring Units

2) Anchorage Systems

3) Seawalls

4) Tide-pools
Experimental Array

- Treatment panels (150x90x13cm, 300Kg) placed vertically intertidal to sub-littoral
- Control plots composed of existing concrete seawall, same depths zones (scraped after baseline)

Intertidal
4 Treatment + 4 Control

Sub-littoral
4 Treatment + 4 Control
Results

Baseline Survey – Existing Marina Concrete Seawall

- 8 taxa
- 100% cover turf algae
- Thick layer of dead barnacles
- Few small patches of *Mycate erythraeana* sponge
- Some live oysters (sub-littoral)
Following 2 years of monitoring, ECOncrete seawall panels supported 23 different taxa compared to only 12 taxa identified on the marina seawall.

Frequent appearance of motile species (fish, crabs, shrimps) on enhanced panels.

(Perkol-Finkel & Sella, 2015)
**WHP Partners**

<table>
<thead>
<tr>
<th>Original partners</th>
<th>New since 2015</th>
<th>New since 2016</th>
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<tbody>
<tr>
<td>Abu Dhabi, UAE</td>
<td>Coquimbo, Chile</td>
<td>Boston, USA</td>
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<td>Auckland, New Zealand</td>
<td>Darwin, Australia</td>
<td>Penang, Malaysia</td>
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<td>Bremerhaven, Germany</td>
<td>Dublin, Ireland</td>
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<td>Chesapeake Bay, USA</td>
<td>Galway Bay, Ireland</td>
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<td>Heraklion, Greece</td>
<td>Hobart, Australia</td>
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<td>Plymouth, UK</td>
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<td>Jakarta, Singapore</td>
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<td>Santander, Spain</td>
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<td>Vigo, Spain</td>
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Credit: Steinberg et al - World Harbour Project
The efficacy of eco-engineered interventions for enhancing the native biodiversity of seawalls in harbours across the globe
Comparison of benthic recruitment on different substrates
Data collection included full biological survey and biomass measurements

7 typologies x 5 reps at 1.5 meter depth

- ECOncrete Flat
- ECOncrete Complex
- RDL Flat
- RDL 2.5cm
- RDL 5cm
- Portland Concrete Flat
- Cleared Marina Seawall
  (existing Portland Concrete)

Tiles on the day of deployment, and existing seawall scraped as baseline control

Tiles covered with marine growth 12 month post deployment
Species richness was significantly higher on complex ECOcrete tiles compared to all other tiles as of the 9 months sampling (P<0.05)
Species diversity was significantly higher on complex ECOcrete tiles compared to all other tiles as of 6 months sampling (P<0.05)
Inorganic biomass on complex ECOcrete tiles was significantly higher than all other substrates sampled (Permanova P<0.05)
ECO Flat X 2 RDL Flat/Portland/ Seawall (P<0.05)
ECO Comp* X 4 ECO Flat X 11 Marina Seawall (P<0.05)

* Surface area of ECO Comp tile (0.0910m²) is X 1.5 compared to Flat tiles (0.0625m²), yet recruited X 4 inorganic biomass than ECO Flat and more than x 8 than Flat/Portland/ Seawall
ECOncrete® - Up to 86% Reduced Carbon Footprint

I. Combination of proprietary admix integrating by-products and recycled materials

II. Unique ability to enhance biological processes:
   - Biocalcification
   - Photosynthesis

In temperate environments, ECOncrrete gained an average of 2.5 Kg/m²/y of inorganic matter from biogenic buildup by calcifying species storing up to 0.3 Kg/m²/y CO₂
Eco Engineering for Climate Change

Working Together to Build a More Resilient Region

Secretary Donovan announces the winners of Rebuild by Design.

Winning Proposals

- **LIVING BREAKWATERS**
  - SOAPE / Landscape Architecture
  - Staten Island, New York

- **Hunts Point Lifelines**
  - PennDesign/OLIN
  - Bronx, New York

- **Resist, Delineate, Store, Discharge**
  - A Comprehensive Strategy for Infiltration
  - CMA
  - Hoboken, New Jersey

- **NEW MEADOWLANDS: Productive City + Regional Park**
  - MIT DAU + ZUS + URBANISTEN
  - The Meadowlands, New Jersey

- **Living with the Bay: A Comprehensive Regional Resiliency Plan for Nassau County’s South Shore**
  - Interboro Team
  - Long Island, New York

Since June 2013, ten interdisciplinary design teams have been working with a diverse range of stakeholders throughout the Sandy-affected region to develop innovative solutions to rebuild. On June 2nd, Secretary Shaun Donovan at HUD announced the winning proposals. Read More about the Final Designs.
Eco Engineering for Climate Change

LIVING BREAKWATERS & TOTTENVILLE SHORELINE PROTECTION PROJECT

Governor's Office of Storm Recovery

SCAPE TEAM

SCAPE / LANDSCAPE ARCHITECTURE
OCEAN AND COASTAL CONSULTANTS
PARSONS BRINCKERHOFF
ARCADIS
SEARC ECOLOGICAL MARINE CONSULTING
NEW YORK HARBOR FOUNDATION
LOT-EK ARCHITECTURE
MPS CONSULTING ENGINEERS
PRUDENT ENGINEERING
Eco Engineering for Climate Change

Living Breakwaters & Tottenville Shoreline Protection

SCAPE Team
Eco Engineering for Climate Change

LIVING BREAKWATERS DESIGN
PRELIMINARY 60% DESIGN

TYPE A
TYPE B
TYPE C

LIVING BREAKWATERS & TOTTENVILLE
SHORELINE PROTECTION

Eco Engineering for Climate Change
Eco Engineering for Climate Change

BREAWATER MATERIALS

- Navigation Aid
- Reef Ridges
- Reef Streets
- Bio-enhanced Concrete Unit
- Armor Stone: D10=40"
- Geotextile
- Core Stone: D50=4"
- Internal Reef Ridge Rip Rap Stone #2: D50=30", 24", 15"
- Internal Reef Ridge Rip Rap Stone #1: D50=30"
- Toe Armor Stone: B12=46"
- Marine Mattress: B12=12"

- Internal Core Stone: D50=4"
- Marine Mattress: H1=12"
- Internal Reef Ridge Rip Rap Stone #1: D50=30"
- Reef Ridge Crest Rip Rap Stone #2: D50=36", 24", 15"
- Stone Armor Unit: D50=40"
- Stone Toe Armor Unit: D50=46"
- Bio Enhancing Concrete Toe Armor Unit: Dimension: 48"x46"
- Bio Enhancing Concrete Tide Pools

Dimensions vary with placement
Eco Engineering for Climate Change

BIO-ENHANCED CONCRETE UNITS

LIVING BREAKWATERS & TOTTENVILLE SHORELINE PROTECTION
Eco Engineering for Climate Change

BIO ENHANCING CONCRETE TOE ARMOR UNIT
Dimension: 48" x 48" x 48"

BIO ENHANCING CONCRETE TIDE POOLS
Dimension: 44" x 48" x 27
Breakwater Cross-section: Habitat Potential

**CORE / LEESIDE**
- Higher likelihood of fine grain sediment build up
- Habitat for Hard Clams and Flounder
- Eelgrass habitat creation

**CORE / WAVESIDE**
- Habitat for predatory fish and other larger animals
- Likely to have low amounts of sedimentation

**REEF FINGER / STREET**
- High diversity of niche ranges & varied habitat
- Habitat for juvenile fish and crustaceans
- Sediment halo provides enhancement to soft-bottom
- Increased water circulation through streets

**EMERGENT**
- Provides habitat for marine mammals (seals) and birds

**Eco Engineering for Climate Change**
- Eco-Design reduced mitigation penalty by over 50%
- All Breakwater regions below MHHW = Habitat Creation
Blue is the new Green

Need for established incentives/regulations

While “green” building standards such as the LEED system are applied globally, “blue” standards for coastal infrastructure are only now spurring (Envision™, WEDG) calling for further R&D of innovative environmentally sensitive technologies

Waterfront Edge Design Guidelines (WEDG)

"A well-designed edge is one where waterfront access, resilience, and ecological benefits are all incorporated into an integrated design."

www.waterfrontalliance.org/WEDG
Blue is the new Green
Blue is the new Green

ECOSYSTEM GOODS & SERVICES
- Biodiversity, Nursing grounds, Food & Shelter, Water Quality

BIOPROTECTION
- Resistance to Wave/Temp/Chlorides

OUTGREENING VALUES
- Reduced Carbon Footprint, Permitting, Bidding

Invasive & Nuisance Species

Sensitivity to Wave/Temp/Chlorides
Bringing Concrete to Life

Conclusions & Recommendations

- Bringing life to coastal and marine infrastructure is a feasible, scalable and effective means for reducing the ecological footprint of coastal infrastructure even in a heavily urbanized settings.
- Sustainable project - Importance of multi-disciplinary collaborations.
- Harnessing biological processes can increase both ecological and structural performance.
- Benefits of biogenic buildup and bioprotection (longer life span, reduced maintenance).
- Importance of integrating ecological considerations into planning, design, and implementation of future hard coastal infrastructure and management schemes in light of global climate change and population growth.