Reducing Lifecycle GHG Emissions of Construction Materials

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US Army Engineer Research and Development Center
US Army Corps of Engineers

8 June 2022

USACE Mission Areas

Military Missions

DoD Construction Agent

CCMD Support, Overseas Contingency Operations (OCO)

Installation Support, Environmental, Energy and Sustainability

Civil Works

Navigation, Flood Control, Disaster Response, Shore Protection, Hydropower, Water Supply, Regulatory, Recreation, Environmental Restoration

Contingency Operations

"Whole of Government" Disaster Response and Recovery

Life-Cycle Flood Risk Management

Critical Infrastructure

International & Interagency

Federal / State / Local

"Whole of USACE" Capabilities

Capacity Development

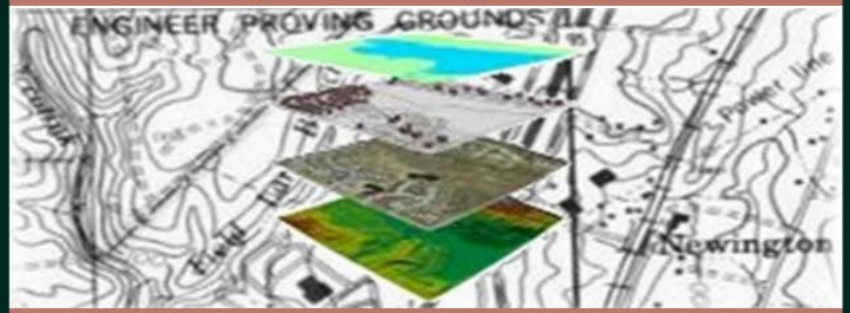
Geospatial Support

Common Operating Picture / Environment

Civil Works Programs

Military Programs

Emergency and Contingency Operations



Research & Development

Support to Warfighter Readiness

Force Projection, Installations & Resilience

Environment

Water Resource Modeling

Real Estate – Acquire, Manage and Dispose / DoD Recruiting Facilities / Contingency Operations

Top 10 USACE R&D Priorities

ADDRESSING THE NATION'S TOUGHEST CHALLENGES WITH MULTI-DISCIPLINARY SOLUTIONS

APPROVED

USACE Command Council
17 NOVEMBER 2021

1. Mitigate and Adapt to Climate Change
2. Win Future Wars
3. Modernize our Nation's Infrastructure
4. Support Resilient Communities
5. Enable Smart and Resilient Installations
6. Ensure Environmental Sustainability and Resilience
7. Secure Reliable Installation Energy
8. Revolutionize and Accelerate Decision Making
9. Improve Cyber and Physical Security
10. Protect and Defend the Arctic

Climate Change is an Existential Threat

"We face all kinds of threats in our line of work, but few of them truly deserve to be called existential. The climate crisis does. ***Climate change is making the world more unsafe and we need to act.***"

Secretary of Defense Lloyd J. Austin III
Leaders Summit on Climate, 22 April 2021

DoD and Climate Change

Objectives:

1. **Identify short-and long-term solutions to adapt, mitigate, and prepare the DoD for climate change**
2. **Leverage the DoD's buying power to enable societal change:**

Actions:

- **Minimize DoD's adverse impact on the climate**
- **Increase DoD's resilience to climate change (This is what we do!)**
  a. **Advance science and technology solutions to solve climate change challenges**
  b. **Prepare the Joint Force for missions in response to climate change**
- **Determine metrics for tracking performance outcomes and outputs**
- **Leverage DoD buying power to drive big ideas for climate mitigation**
- **Identify analytically robust frameworks for prioritization and decision support**

Adapted from the
Climate 3-Star Program-Resource Management Group (PRMG), 17 March 2021

Army and Climate Change

Army Climate Change Kick-off, 10 March 2021

ERDC

AMERICA'S ARMY:
Globally Responsive, Regionally Engaged

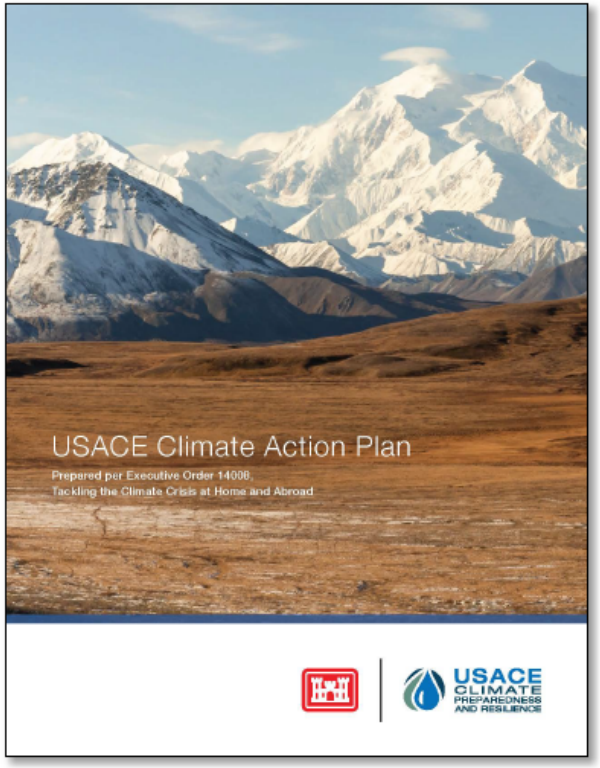
Definitions

- **Adaptation** "means adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects" (See Chapter 28 of NCA 4 Reducing Risks Through Adaptation Actions.) Adaptation is an action.
- **Resilience** "means the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions." Resilience is a trait, capacity, or attribute.
- **Climate Change Mitigation: Addressing the** *Causes* *Generally: Consists of actions to limit global warming and its related effects. This generally involves reductions in human emissions of greenhouse gases (GHGs). Fossil fuels account for more than 80% of all GHG emissions.*
- **Climate Change Adaptation: Addressing the** ***Impacts*** *Generally: The process of adjusting to current or expected climate change and its effects. For humans, adaptation aims to moderate or avoid harm, and exploit opportunities.*

M ADAPTATION

A MITIGATION

USACE and Climate Change



USACE is committed to "integrate the best available observed and forward-looking climate information into its missions."

Action 1: MODERNIZE USACE programs and policies to support climate-resilient investments

Action 2: MANAGE USACE lands and waters for climate preparedness and resilience

Action 3: ENABLE state, local, and tribal government preparedness

Action 4: PROVIDE actionable climate information, tools, and projections

Action 5: PLAN for climate change-related risks to USACE missions and operations

ERDC Line of Sight

- Climate considerations are an **essential element of US foreign policy and national security**.
- The US will move quickly to **build resilience against the impacts** of climate change.

- Advance **science and technology solutions** to solve climate change challenges.
- **Prepare the Joint Force for missions** in response to climate change.

- Mitigation actions to **limit global warming** and its related effects.
- **Adaptation to current or expected climate change** and its effects.

- **Integrate the best available observed and forward-looking climate information into its missions.**

"I'm grateful to all the leaders who've announced new commitments to help us meet the existential threat of climate change… we're going to make these commitments real, putting all of our nations on a path to a secure, prosperous, and sustainable future."

US President Joe Biden
Leaders Summit on Climate, 23 April 2021

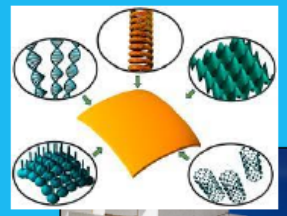
- **Three Thrusts**
- **Five Core Competencies**

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

ERDC and Emerging Climate Change Challenges

Water Treatment Reuse and Energy Production

Lifecycle building design are materials management

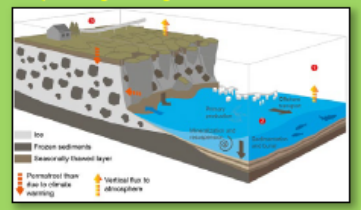


Future low-energy materials for safe, secure installations

Safe and Sustainable Range Operations

Resilient coastal shores and ecosystem impacts

Fritz, M., Vonk, J. E., & Lantuit, H. (2017). Collapsing Arctic coastlines. Nature Climate Change 7, 6–7. https://doi.org/dx.doi.org/10.1038/nclimate3188

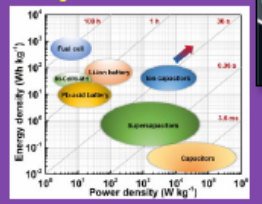


ERDC's Intelligent Environmental Battlefield Awareness

ERDC's Power Projection in A2/AD

All-weather high-energy density, low carbon vehicle power

Zhang, Y., Jiang, J., An, Y., Wu, L., Dou, Zhang, J., ... & Guo, Z. (2020). Sodium ic capacitors: materials, mechanism and challenges. *ChemSusChem*.



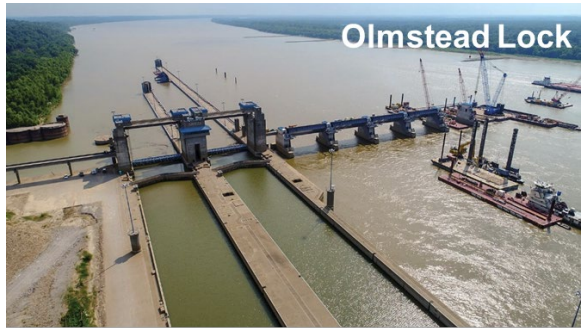
Agile basing in remote locations

Built – Natural – Mission

Civil and Military Facilities and Infrastructure Footprint

Military Mission:

- Facilities at 800+ bases
  - 560k+ facilities
  - Buildings: warehouses, offices, barracks, etc
  - Structures: bunkers, bridges, wharfs, etc
  - Linear systems: airfields, rail, roads, etc
- Severe environments from the South Pacific to operations in the Arctic
- Concrete, Steel, etc!



Civil Works Mission:

Sustainability and Climate Change Drivers

Civil Works

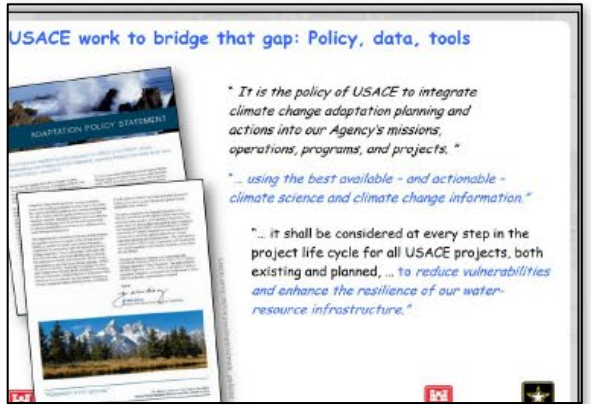
- Aging infrastructure burden outweighs new infrastructure
- Limited sustainability drivers for materials and construction
- Strong emphasis on 100+ year service lives, service life extension, and asset management
- Long-standing practices that have sustainability benefits

Military

- Post 9/11 threats transition towards peer and near-peer
- Modernize to fight and win
- Limited direct drivers for sustainability and climate change
- Operational impacts of climate change on warfighting functions
- Energy, water, and natural hazard resilience drives modernization

Opportunities

- Sustainability and climate resilience drivers are forefront drivers
- People and $$ applied toward action on climate change and resilience
- R&D initiatives growing in:
  - Nature based solutions
  - Multi-hazard resilience
  - Design / materials / manufacturing nexus
  - Advanced materials-by-design (+biotech)
  - Manufacturing / construction processes

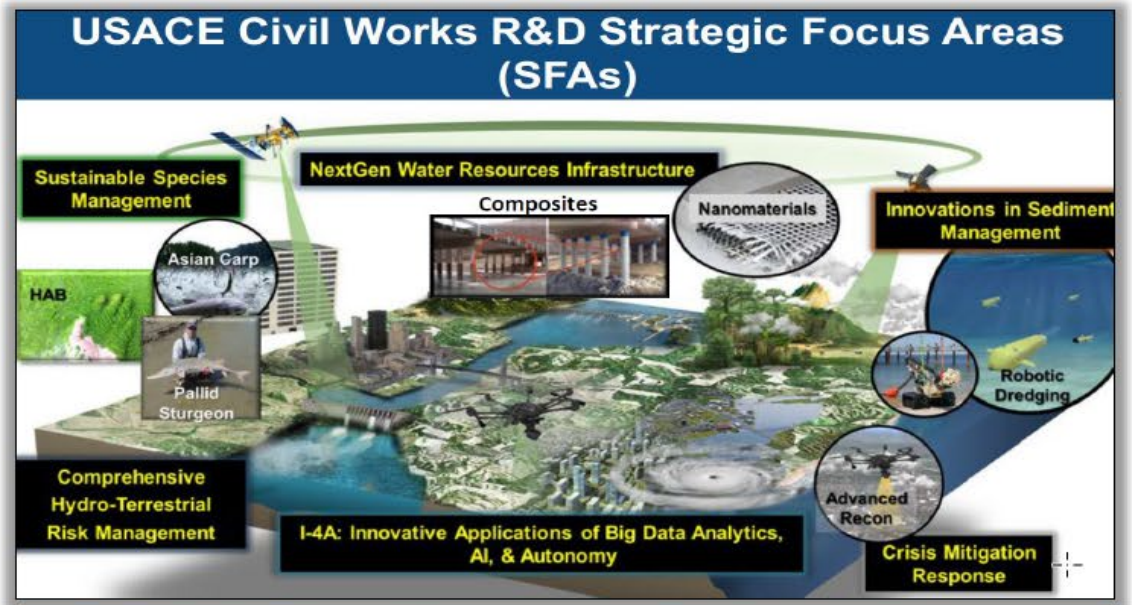


Executive Order 14008 of January 27, 2021

Tackling the Climate Crisis at Home and Abroad

The United States and the world face a profound climate crisis. We have a narrow moment to pursue action at home and abroad in order to avoid the most catastrophic impacts of that crisis and to seize the opportunity that tackling climate change presents. Domestic action must go hand in hand with United States international leadership, aimed at significantly enhancing global action. Together, we must listen to science and meet the moment.

Source: Dr. Kate White, USACE Climate Change and Resilience Community of Practice Lead



Climate Change and Resilience: Materials & Structures

Sustainable Infrastructure Design

- Buildings infrastructure design approaches for sustainable construction materials
- Balanced design approaches considering sustainability / embodied energy with other requirements for function and resilience
- Life cycle durability and service life extension – extending sunk embodied energy
- Modularization that enables future re-use of components / systems

Sustainable Materials and Manufacturing

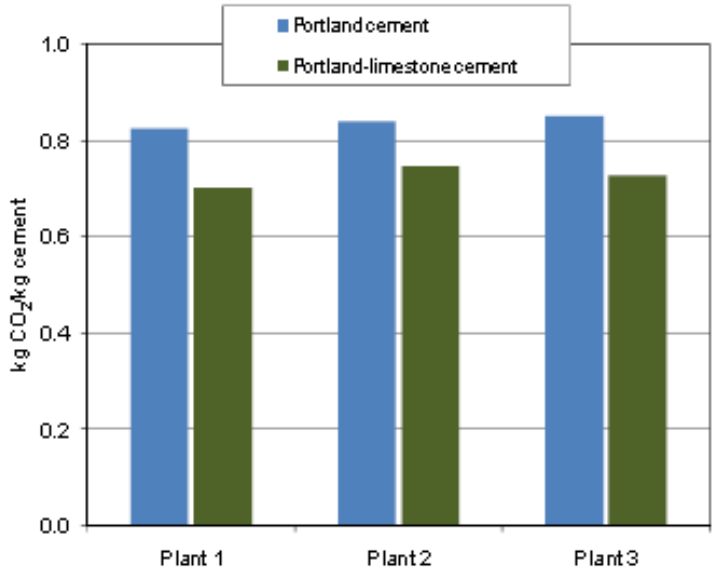
- Novel cement chemistries with reduced embodied energy
- Materials design requirements that promote sustainable optimization
- Bio-based / nature-based solutions and alternatives to concrete and steel
- Low-energy and optimized topologies through advanced manufacturing
- Enable circular economy – consider cradle to cradle in lifecycle metrics

Future Threats, Hazards, and Resilience

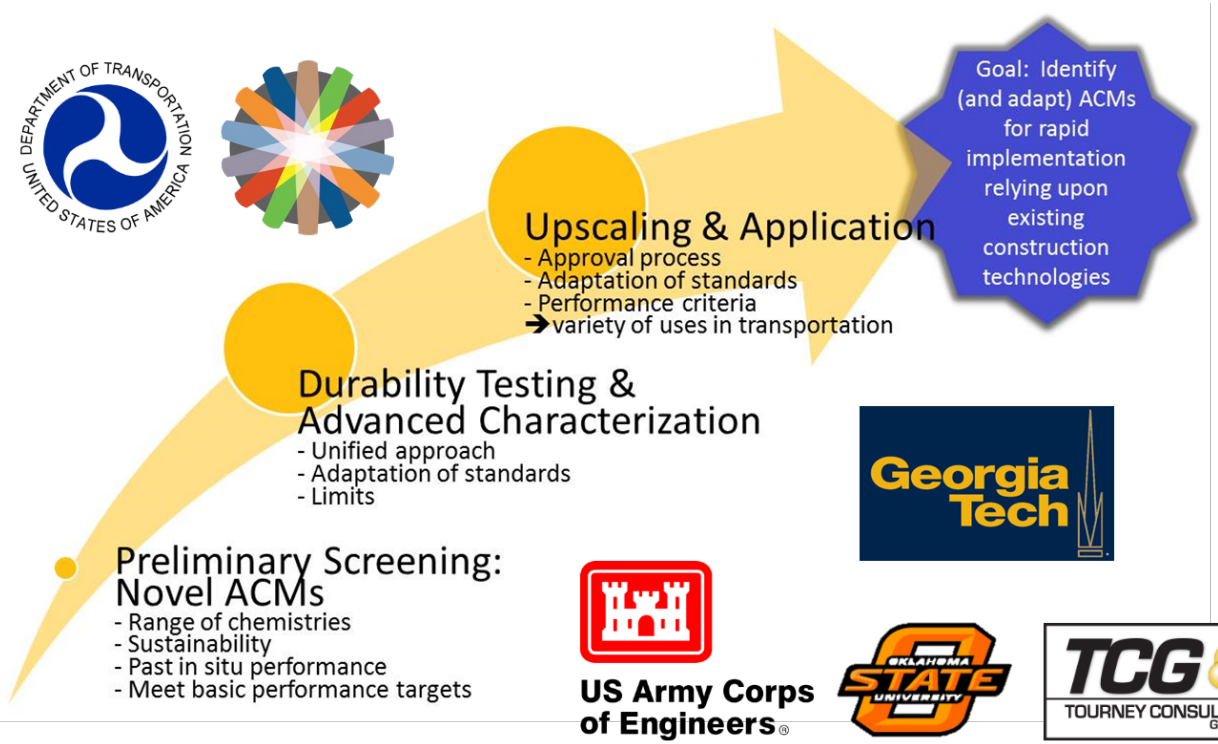
- Future climate impacts on serviceability and performance of critical facilities
- Future hazards on military and civil infrastructure (flood, fire, wind, storm surge, compound hazards)
- Social / humanitarian impacts on facilities, infrastructure, and communities
- Translation of uncertain future hazards / resilience requirements to ENGINEERING

Recent Activities in Sustainable Cement and Concrete

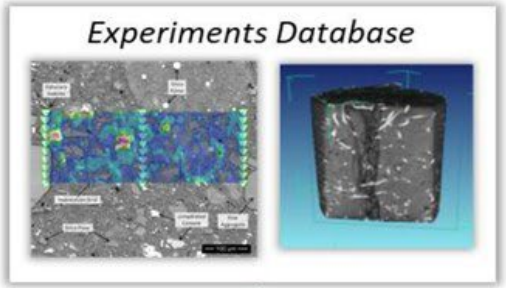
- Portland Limestone Cement
- Specifications
  - ASTM C1157
  - ASTM C595 or AASHTO M240
  - Pervasive use of SCMs

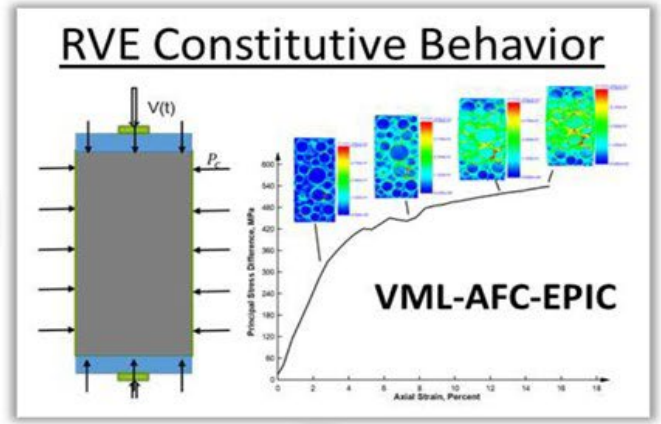


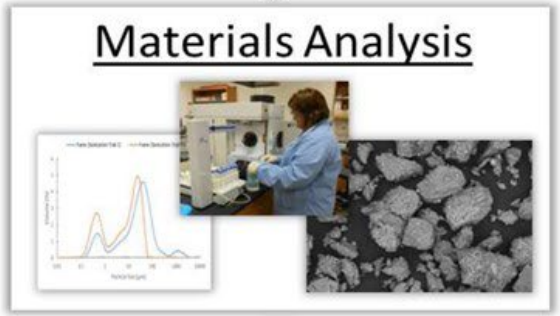
- Alternative Cementing Chemistries
  - Multiple activities Civil and Military
  - Leveraging experience in specialty military apps
  - PLC, CSA, CAC, MPC, LC3, Belite, Carbonating…
  - along with manufacturing innovations…

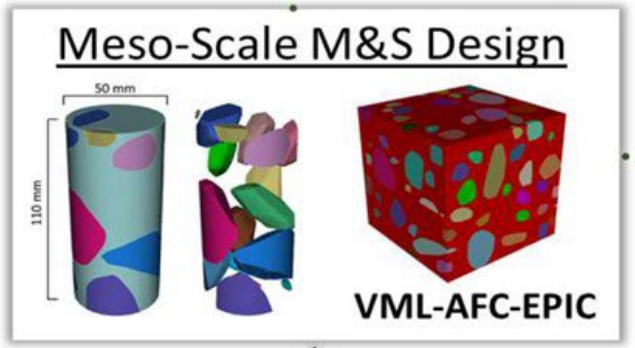


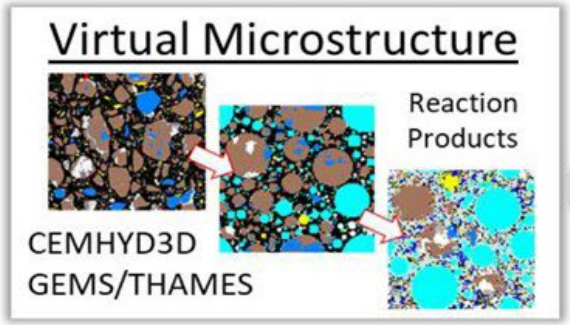
Optimizing Construction Materials-By-Design

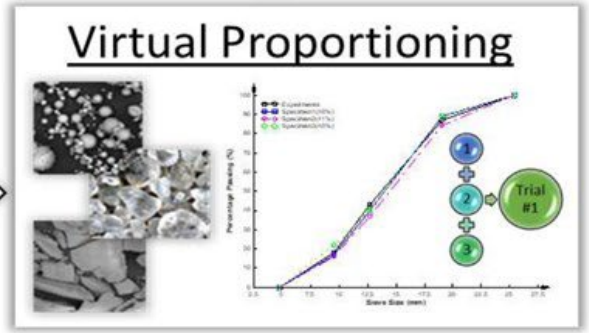


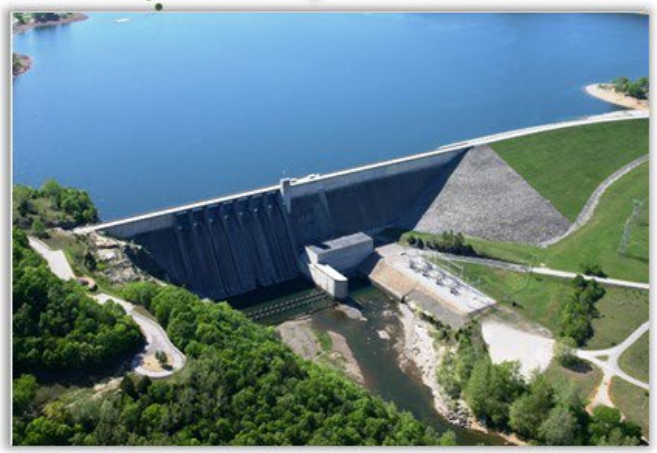












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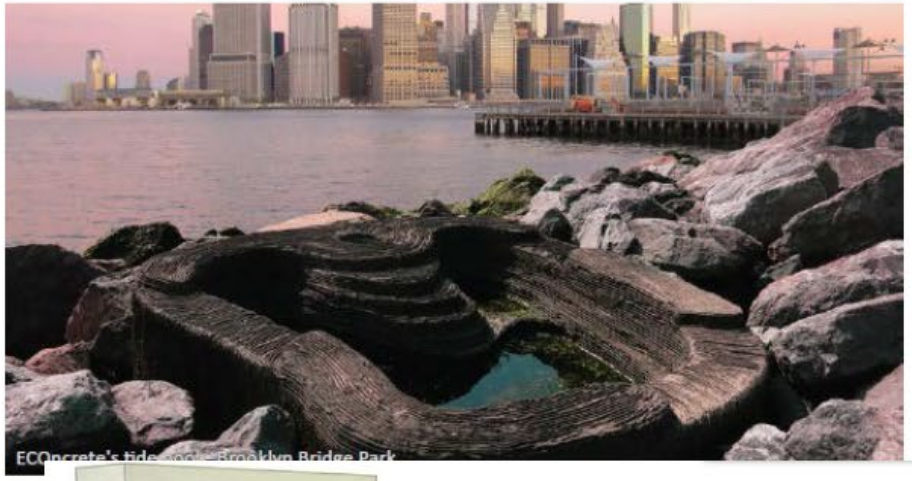
Civil and Military Aging Infrastructure Challenges

- Common drivers across civil and military infrastructure systems
- Concrete, steel, timber, polymers, composites, geomaterials
- Extend life of aging infrastructure
- Sustainable new infrastructure
- Consider life cycle embodied energy

Drivers: extend **sunk embodied energy** in existing infrastructure, address sustainability in new infrastructure, balance sustainability with performance and O&M costs

Nature-Based Solutions

- Supported through the USACE Engineering With Nature initiative
  - Natural solutions as opposed to hard civil works infrastructure
  - Science and engineering that produces operational efficiencies
  - Using natural process to maximum benefit beyond built projects
  - Broaden and extend the benefits provided by projects



ENGINEERING WITH NATURE

Additive Construction

Problem

- Expeditionary Structures are:
  - Labor intensive
  - Energy expensive
  - Material expensive

Solution

- 3D print custom-designed expeditionary structures on-demand, in the field, using locally available materials.

Impact

- Saves time
- Saves money
- Saves material
- Saves energy/fuel
- Reduction in hard labor & manpower

New Initiative: Green Climate Resilient and Efficient DoD Installation Technologies (Green CREDIT)

Goal: Deliver advanced and cost-effective technologies to support climate resiliency on DoD installations.

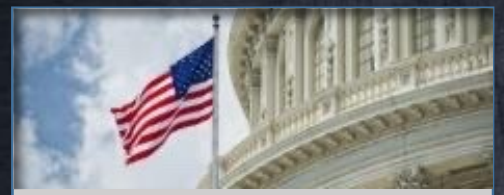
- Comprehensive multi-level data management structure for measuring, analyzing, and accounting for carbon storage on DoD lands including circular economy considerations
- Life Cycle Analysis of additive construction and green materials with carbon-capture / -sequestration capabilities as construction negative emissions technologies (NET)
- New materials and additive construction systems evaluated in parallel with existing MILCON design methodologies
- Unified codes and standards for sustainable manufacturing and materials performance evaluation
- Requirement: E.O. 14008, DoD Climate Adaptation Plan, Army Climate Strategy (Draft), Army Installation Strategy, USACE Climate Action Plan Action, DoD Additive Manufacturing Strategy

Thoughts in Construction Materials and Design

- Large GHG emission drivers in **cement, geomaterials, construction**, and other high-energy manufacturing processes
- Government construction often relies on **commodity products / perf specs**: how can we better enable innovative / sustainable products?
- We need to **think beyond steel and concrete**
- **Materials and lifecycle design are hand-in-hand** and will increasing be driven by the **circular economy – and this is a big paradigm shift**
- We must think full life-cycle of buildings and infrastructure: **design**, manufacturing, construction, operations, disposition, **recycling**
- Many professions (some may call them tribes) **must work together** to innovate:
  - Researchers, engineers, policy, academia, manufacturers, contractors, labor

ERDC Partnerships

FOR SCIENTIFIC INNOVATION AND TECHNOLOGY DEVELOPMENT



GOVERNMENT PARTNERS

Department of Defense
Department of the Army
NASA
Department of the Air Force
Department of State
USDA United States Department of Agriculture
Department of the Interior Bureau of Indian Affairs
Department of Transportation
Department of Homeland Security
USGS science for a changing world

ACADEMIA PARTNERS

Ohio State
Michigan State
West Virginia
Dartmouth
Oklahoma
Illinois
Toledo
Florida
Purdue
Oregon State
Clemson
Alabama
Arizona State
LSU
MIT
Penn State
Texas A&M
Jackson State
Georgia
Alaska Fairbanks
South Alabama
Carnegie Mellon
Bowling Green

INDUSTRY PARTNERS

Eaton
The Nature Conservancy
esri
BAE Systems
Raytheon
EPRI Electric Power Research Institute
Harris
Martin ecosystems
Kenall
Quantum Signal
Lockheed Martin
ARA
MWOBS Mount Washington Observatory
Alden Solving Flow Problems Since 1894

INTERNATIONAL PARTNERS

Australia
Canada
Chile
France
Germany
Israel
Italy
Netherlands
Norway
Sweden
Switzerland
UK

12 Countries
54 MOAs/MOUs,
6 CRADAs, 3 PAs,
10 DEA / IEAs

CONNECT: Mechanisms & Authorities

ERDCWERX

OTHER TRANSACTON AUTHORITY (OTA)

Broad Agency Announcement (BAA) Authority

Cooperative Ecosystem Studies Units (CESU) National Network

ERDC

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DISCOVER • DEVELOP • DELIVER

new ways to make the world safer and better

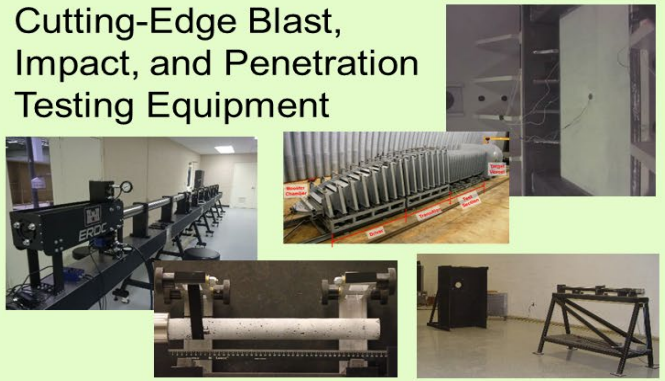
Materials and Manufacturing

Supporting Army S&T, USACE, and Military and Civilian Stakeholders and Partners in ERDC Core Competencies:

- *Blast and Weapons Effects on Structures and Geomaterials*
- *Civil and Military Engineering*
- *Military Installations and Infrastructure*
- *Cold Regions Science and Engineering*

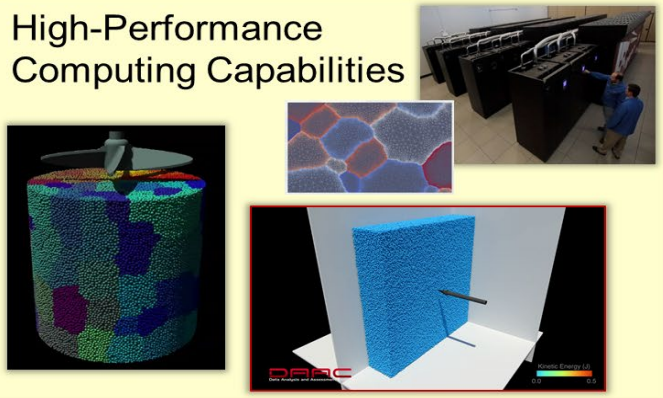
ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

Cutting-Edge Blast, Impact, and Penetration Testing Equipment

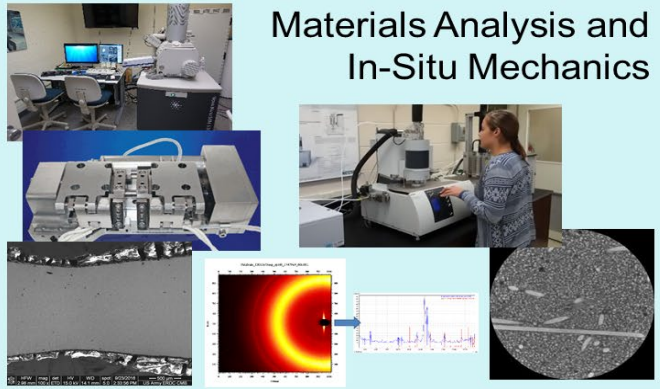


Large-Scale Structural Testing Systems

High-Performance Computing Capabilities



Materials Analysis and In-Situ Mechanics



Force Protection and Weapons Effects

- Advanced weapons effects
- Multi-functional materials
- Structural hardening
- Indigenous materials

Force Projection and Maneuver Support

- Rapid repair and retrofit
- Lightweighting
- Indigenous materials
- Remote assessment

Infrastructure, Installations & Environment Quality

- Sustainability
- Operational energy
- Life-cycle durability / performance
- Environmental impacts

Cross-Cutting Technologies

- Additive / advanced manufacturing
- Multi-scale modeling
- Robotic platforms
- Artificial Intelligence
- Advanced measurement science