USACE Approach to SLC, Design & Construction Criteria and Quality Processes

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Climate Resilient Infrastructure Workshop
Kingstown, Saint Vincent & the Grenadines
Agenda

- Overview of USACE
- Latest Guidance on SLC
- Design Criteria
- Drawings & Specifications
- Construction Quality
- Case Study: Hotel Montana, Haiti
- Renewal of Haiti *(Provided for Awareness)*
- Bridge Retrofit and Concrete Repair *(Provided as Reference)*
- Questions & Discussion
Overview of USACE (United States Army Corps of Engineers)

- Federal agency and Army organization (major command) made up of 36,000+ civilian and military personnel
- HQ, 9 Divisions, 45 Districts
- On-going projects in 100+ countries, physical presence in 34 countries
- Over $33 B of work in FY10
  - Military Program = $24.8 B
  - Civil Works Program = $6.7 B
  - R&D = $1.5 B
Overview of USACE (Cont.)

- Military Program
  - Military Construction (MILCON)
  - Base Realignment and Closure (BRAC)
  - Overseas Contingency Operations (OCO)
  - Installation Support
  - Environmental/ Formerly Used Defense Sites (FUDS)
  - Interagency & International Services (IIS)
  - Real Estate
  - American Restoration and Recovery Act (ARRA)
Overview of USACE (Cont.)

- Civil Works Program
  - Flood Risk Management
  - Navigation
  - Ecosystem Restoration & Infrastructure
  - Recreation & Natural Resource Management
  - Hydropower
  - Regulatory Program: Wetlands & Waterways
  - Disaster Preparedness & Response
  - Water Supply
Overview of USACE (Cont.)

- Engineer Research and Development Center (ERDC)
  - Four Primary Facilities
    - ERDC Headquarters, Vicksburg, MS
    - Construction Engineering Research Laboratory, Champaign, IL
    - Cold Regions Research and Engineering Laboratory, Hanover, NH
    - Geospatial Research and Engineering Division, Alexandria, VA
  - 2500 Employees
  - 991 Scientists and Engineers
  - $1.2 B in Unique Facilities and Equipment
  - $1.5 B Annual Program
  - 77 Active Patents
Overview of USACE (Cont.)

- USACE Headquarters website: http://www.usace.army.mil

- ERDC website: http://www.erdc.usace.army.mil
USACE Guidance on SLC

- EC 1165-2-212, Sea-Level Change Considerations for Civil Works Programs, 1 October 2011
  - SLC projections must be incorporated into all planning, engineering, construction and O&M activities.
  - Provides background, philosophies, methods
  - Appendix A provides references
  - Appendix B provides technical supporting material
  - Appendix C provides flowchart for process

- A “Technical Letter” publication is under development and will provide more explicit “how to” guidance.
Key Issues Relevant to SLC/Climate Change

- **Nonstationarity** – past magnitudes, frequency, rates, and patterns will not apply.
- **Robustness** – Provide a framework for the analysis and adaptation irrespective of any particular number or assumption; Get away from the “climate change question”.
- **Combinations** – Cumulative and system effects are important though we often isolate them for analyses.
- **Connectivity** – of critical systems and infrastructure is essential (transportation, electrical, communication, water); Where are the weak links and thresholds?
- **Time** – Planning Horizon (50 yrs) vs Adaptation Horizon (100 yrs)
- **Decision-making** – Strategic and tiered. What could go wrong?
  - Be cautious of down-selecting prematurely.
  - Consider level of consequences.
- **Acceptance** – We have always dealt with uncertainty…… (physical, social, political)
Three estimates of future SLC must be calculated for all Civil Works Projects within the extent of estimated tidal influence:

- Extrapolated
- Modified NRC I
- Modified NRC III

Requires creativity, funds to evaluate options

Current guidance assigns equal probability to each curve.
Tier 1: Project Area Vulnerability to SLC

- Planning steps 1 and 2:
  - Identify problems and opportunities,
  - Inventory and forecast conditions

- Using high SLC curve, define future affected area for 3 epochs (20, 50, 100 years).
- When in the planning horizon are impacts expected to be realized? (thresholds, geomorphology)
- Loading: Bracket SLC within overall loading parameters.
- Assess capacity or resilience using the USGS coastal vulnerability index (CVI).
- Identify to what extent decisions made now preclude or define future actions.
- Using inventory and forecast methods to summarize critical infrastructure, weak links, thresholds.
Strategic and Tiered Decision-Making Based on Potential Risk of Sea Level Change

**Establish strategic decision context**
- Small project, no significant or system consequences.
- Large project, significant or system consequences.
- Strategic development investments, e.g., major port expansion or flood risk reduction system upgrades, shapes future long term community development.

**First Decision and Review Point**
- Who should be involved?
- How much analysis time is required?
- What is the expected level of effort?

**Tier 1: Project Area Vulnerability to SLC**
**Planning Steps 1 and 2**
- Identify problems and opportunities
- Inventory and forecast conditions

Using high SLC curve, define future affected area and conditions which impact project. Establish impacted area for 3 epochs (20, 50, 100 years). When in the planning horizon are impacts expected to be realized? Brackets SLC within overall loading parameters. Assess coastal vulnerability index (CVI). Identify to what extent decisions made now preclude or define future actions.

Using inventory and forecast methods to summarize critical infrastructure, weak links, thresholds.

**Coastal Vulnerability Index (CVI)** is a function of 6 input parameters: geomorphology, coastal slope, relative SLC, shoreline erosion/accretion, mean tide range, and mean wave height. (USGS, 2000)

**Intermediate Decision and Review Point Using Results from Project Area Vulnerability Assessment**

Small project area, SLC provides relatively small contribution within overall loading, CVI is low, robust thresholds, minimal critical infrastructure.

Qualitative SLC analysis; limited quantitative analysis.

**Tier 2: Alternative Development Considering SLC**
**Planning Steps 3 and 4**
- Formulate and Evaluate Alternatives

Develop measures to address Problems & Opportunities with consideration of project area vulnerability to SLC.

Evaluate measure adaptability to SLC.
- Develop qualitative and quantitative performance metrics.
- Evaluate frequency impacts from SLC. Are impacts extreme event driven or overall process driven?
- Define measure stability and performance mode sensitivity to SLC.
- Assess how inundation, erosion, wave attack may change with SLC.

Combine measures into alternatives that are resilient to SLC over the planning horizon.

Implementation strategies range between anticipatory, reactive, adaptive, and combinations of the three.

Establish start and finish points at which alternatives remain viable and determine if alternatives are adaptable at the end of the planning period.

**Tier 3: Alternative Selection Considering SLC**
**Planning Steps 5 and 6**
- Compare Alternatives and Make a Recommendation

Reassess adequacy of measures to address problems and opportunities and planning objectives.

Are residual risks manageable and does a plan exist to manage them? Is the strategy sustainable? Are resources available for the system to remain viable? How do the alternatives compare given the defined performance metrics? What can go wrong, how can it happen, what are the consequences, how likely is it? Does implementation of this strategy preclude future decisions or opportunities?

**Final Decision and Review Point**

- What is the expected level of effort?
Potential Strategies of Approach for Alternatives

- **Anticipatory Strategy**
  Implements features and design robustness now; for example, increases design parameters for engineered features.

- **Adaptive Management Strategy**
  Uses sequential decisions and implementation based on new knowledge; implementation prior to SLC impacts. Requires advance planning to maintain the ability to adapt.

- **Reactive Strategy**
  Can be planned or ad-hoc, but in either case no actions would be implemented until the impacts of SLC begin.
Future storm tides will reach higher elevations than past storms and will do so more frequently impacting both flooding and structural loading.

Hurricane Isabel
Sep. 2003

Dr. David Kriebel, USNA
Best Practices for Infrastructure Planning

- **Identify cumulative and extreme events** (frequency and magnitude)
  - Accept uncertainty; don’t attach approach to a specific number or theory
  - Utilize estimated upper bounds to identify vulnerability and risk

- **Define greater framework** (time, spatial, system)
  - Determine the strategic importance of impacts

- **Know your system**
  - Elevations, weak links, thresholds
  - Key economic, life safety, operation issues
  - Assess connectivity and potential for cumulative or system effects

- **Develop graduated levels of response; potential range of actions**
  - Identify items which are adaptable as well as items which are not
  - Develop a reasonable timeline
  - Don’t prematurely down-select alternatives

- **Acknowledge potential risk. What could go wrong?**

- **Develop plan which monitors new developments and can make adjustments**
USACE Guidance on SLC (Cont.)

- USACE contact for additional questions on SLC:
  - Ms. Heidi Moritz, Hydraulic Engineer, Portland District,
    Tel: 503-808-4893
    Email: Heidi.P.Moritz@usace.army.mil
Design Criteria

- For buildings, migration from USACE/DoD criteria to industry criteria with minor modifications.

- HQUSACE Publications Site: [http://140.194.76.129/publications/](http://140.194.76.129/publications/)


- Example: Structural Design Criteria (for buildings)
  - General Building Requirements
  - Structural Engineering
  - Seismic Design
  - Design of Buildings to Resist Progressive Collapse
  - Design Analysis, Drawings & Specifications
Example: Structural Design Criteria

- General Building Requirements
  Unified Facilities Criteria UFC 1-200-01
  - Based on International Building Code (IBC) and core UFCs
  - Organized in Chapters that correlate with IBC Chapters
  - Identifies modifications to IBC
  - Provides other applicable criteria (e.g. AT/FP*)
  - Chapters 16, 17, 18, 19, 21 & 22 refer to UFC 1-301-01, Structural Engineering

* AT/FP criteria not included in this example
Example: Structural Design Criteria (Cont.)

- **UFC 1-301-01 Structural Engineering**
  - Organized in Paragraphs that correlate with IBC Chapters 16, 17, 18, 19, 21 & 22.
  - Provides modifications to IBC
  - Modifications can be
    - Addition
    - Deletion
    - Replacement
    - Supplement
  - For seismic design, refers to UFC 3-310-04
  - For progressive collapse resistance, refers to UFC 4-023-23
  - Appendix B: Best Practices
  - Appendix D: Minimum Live Loads
  - Appendix E: Site Specific Loading Data
Example: Structural Design Criteria (Cont.)

- **UFC 3-310-04 Seismic Design**
  (Current draft update attached)

  - Chapter 1 is an overview
  - Chapter 2 provides modifications to IBC 2009 and ASCE 7-05. Modifications can be
    - Addition
    - Deletion
    - Replacement
    - Supplement
  - Chapter 3 provides optional non-linear analysis procedure
  - Chapter 4 provides requirements for Occupancy Category V
  - Appendix A: References
  - Appendix B & C: Non-structural (M&E components)
Example: Structural Design Criteria (Cont.)

- **UFC 4-023-23 Design of Buildings to Resist Progressive Collapse**
  - **Design Approaches**
    - **Direct Design**
      - Removal of member (AP) or
      - Specific/Enhanced Load Resistance (SLR)
    - **Indirect Design**
      - ASCE 7: 1) good plan layout, 2) integrated system of ties, 3) returns on walls, 4) changing span directions of floor slabs, 5) load-bearing interior partitions, 6) catenary action of the floor slab, 7) beam action of the walls, 8) redundant structural systems, 9) ductile detailing, 10) additional reinforcement for blast and load reversal, if the designer must consider explosive loads, and 11) compartmentalized construction.
  - This UFC: Tie force system

- Level of PC resistance is correlated to Occupancy Category
- Chapter 3 provides procedures
- Chapters 4-8 are guidance for specific materials
Example: Structural Design Criteria (Cont.)

- **ER 1110-345-700 Design Analysis, Drawings and Specifications**
  - For Design Analysis, provides the following:
    - Policy
    - Organization requirements
    - Content requirements (discipline specific)
    - Quality control

- Detailed drawing guidance is now provided by A/E/C CAD Standards

- Unified Facilities Guide Specifications (UFGS) are mandated
Example: Structural Design Criteria (Cont.)

- Drawings must comply with A/E/C CAD Standards
  - Based on U.S. National CAD Standard
  - Covers everything: size, layout, format, accuracy, file names, sheet names, line widths, colors, layers, units, standard symbols, etc.

- Unified Facilities Guide Specifications (UFGS)
  - Proper specifications are essential to ensure the design intent, material properties, and level of quality desired is realized during construction.
  - Numbering of UFGS is CSI Master Format.
  - Continuous review and update via Criteria Change Requests (CCR)
Example: Structural Design Criteria (Cont.)

- Sample Guide Specification: Section 04 20 00 Masonry
  
  - Organized in three parts (typical)
    - General
    - Products
    - Execution
  
  - Most paragraphs have notes to the designer
  
  - Select from bracketed items, fill in blanks, delete non-applicable paragraphs, add more if necessary.
Construction Quality

- Contract documents spell out roles, responsibilities, processes and deliverables to ensure quality.

  - Based on ER 1180-1-6, Construction Quality Management
    - Contractor Quality Control (QC)
    - Government Quality Assurance (QA)

  - UFGS 01 45 00.10 10, Quality Control System
    - Management and administrative requirements

  - UFGS 01 45 00.00 10, Quality Control
    - Contents of QC Plan
    - Processes, documentation, deliverables
Construction Quality (Cont.)

- **Contractor Quality Control:** The primary function of CQC is the successful execution of a realistic plan to ensure that the required standards of quality construction will be met. In CQC, the contractor defines procedures to manage and control his own, all subcontractor and all supplier activities so that the completed project complies with contract requirements.

- **CQC Responsibilities**
  - Produce the quality required by the plans and specifications,
  - Develop and maintain an effective CQC system,
  - Perform all control activities and tests, and
  - Prepare acceptable documentation of CQC activities.
Construction Quality (Cont.)

- Three-Phase Quality Control System
  - Preparatory
  - Initial
  - Follow-up

- The primary purpose of the Three-Phase Control System is to require the contractor to plan and schedule the work to ensure that he is prepared to start each new definable feature of work. The three phases are the core of the Construction Quality Management System. When they are performed as outlined in the specifications, success in completing the work to comply with requirements of the contract is enhanced.
Construction Quality (Cont.)

- Preparatory Phase
  - Review applicable specifications and references.
  - Review of contract plans.
  - Check all materials and equipment have been tested, submitted, and approved.
  - Check that provisions have been made to provide required control inspection and testing.
  - Examine the work area to assure that all required preliminary work has been completed.
  - Examine required materials, equipment, and sample work to assure that they are on hand and conform to approved shop drawings or data.
  - Review the appropriate activity hazard analysis.
  - Discuss procedures for constructing the work including the review of repetitive deficiencies.
Construction Quality (Cont.)

- **Initial Phase**
  - Review minutes of Preparatory Meeting.
  - Check preliminary work.
  - Verify adequacy of controls to ensure full contract compliance.
  - Establish level of workmanship.
  - Resolve all differences.
  - Check safety to include compliance with the safety plan and activity hazard analysis. Review the activity hazard analysis with workers.
Follow-up Phase

- Daily checks shall be performed to assure continuing compliance with contract requirements, including safety and control testing, until completion of the particular feature of work. The checks shall be made a matter of record in the CQC documentation. Final follow-up checks shall be conducted and all deficiencies corrected prior to the start of additional features of work. QC personnel should continually refer back to the standards set in the “Preparatory and Initial Phases.”

- Cautionary Note: QC personnel, in the midst of day-to-day duties, can easily fall into the trap of only working to detect deficiencies when in fact their role is to prevent deficiencies.
Construction Quality (Cont.)

- **Quality Assurance (Gov’t):** The primary function of quality assurance is to obtain completed construction that meets all contract requirements.
  
  - Examine the quality control methods being used to determine if the contractor is properly controlling activities.
  - Make certain that the necessary changes are made in the contractor's QC system, if excessive construction deficiencies occur.
  - Assist the contractor in understanding and implementing the contract requirements.
  - Examine ongoing and completed work.
  - Review QC documentation to assure adequacy.
Case Study: Hotel Montana, Haiti

- Largest hotel in Haiti, an icon in the international community. Most distinguished visitors, USG representatives, and US business personnel visiting Port Au Prince stayed at HM.
- 144 hotel rooms, 90 other spaces including restaurants, conference rooms, cafes, bars, hair salon, etc.
- Original structure built in 1947.
- Built in multiple segments over 62 years, utilizing different building styles/standards.
- Utilized typical Haitian construction.
Case Study: Hotel Montana, Haiti (Cont.)
Case Study: Hotel Montana, Haiti (Cont.)

- Mostly reinforced concrete frame (column & beam) with non-load bearing CMU infill walls/partitions
- Concrete construction appears to be sub-standard based on the following observations:
  - Use of low strength concrete during construction (evidenced by fracturing of concrete that did not fracture through the aggregate)
  - Non-uniformity of concrete mix and poor consolidation resulting in honey-combed and porous concrete
  - Areas of low-cement concrete that could be crushed with hand pressure
Case Study: Hotel Montana, Haiti (Cont.)

- Substandard steel reinforcement (Steel Detailing)
  - Both unreinforced and improperly reinforced concrete and masonry
  - Much of the rebar appears to be improperly sized.
  - Rebar laps are too short or nonexistent.
  - Column confinement reinforcing steel (ties and spirals) was insufficient to confine the column concrete core and allow plastic capacity of the columns to develop.
  - Use of smooth reinforcing steel in conjunction with or instead of deformed (ribbed) reinforcing steel. Smooth reinforcement provides less bonding with concrete.
  - Insufficient clear cover (rebar not deep enough in concrete)
Case Study: Hotel Montana, Haiti (Cont.)

- **Building Construction Techniques**
  - Inadequate connectivity between structural elements (beams, columns, load bearing walls).
  - Non-structural elements (non-load bearing walls, parapets) not sufficiently tied in with structural elements.
  - Non uniformity of concrete / poor quality
  - Lack of proper consolidation (vibration).
  - Cantilevered masonry walls used as fences constructed without horizontal steel reinforcing and inadequate vertical reinforcing.
Case Study: Hotel Montana, Haiti (Cont.)

- Building Records and Plans:
  - No record of design calculations or assumptions. Very limited drawings available. Cannot tell what design standard was utilized. (Building was constructed in several separate segments over a period of many years.)

- Ability of structure to resist dynamic loads (collapse aspects).
  - Structural members and connections not constructed to withstand shear and uplift loads experienced during an earthquake.
  - During earthquake of 12 January, 2010, majority of the hotel experienced pancake collapse of multiple floors.
Case Study: Hotel Montana, Haiti (Cont.)

- 100 hotel occupants and workers at time of Earthquake.
- 21 live victims were rescued from the hotel.
- 66 deceased victims were recovered from the hotel.
- 7.0 magnitude that shook for almost a full minute.
- Peak ground acceleration was 0.35g.
- Epicenter approx. 17.2 miles away from hotel.
- More than 60 aftershocks greater than 4.0, as high as 6.2.
- Estimated 316,000 deaths (Total for Haiti, per Prime Minister).
- Largest cause of death from a natural disaster in the Western Hemisphere.

Contrast: U.S. Embassy design-built in accordance with IBC and U.S. construction standards only had minor cosmetic damage.
Case Study: Hotel Montana, Haiti (Cont.)

Common practice for mixing and transporting concrete
Case Study: Hotel Montana, Haiti (Cont.)

- Extensive honeycombing
- CMU filler used throughout concrete floors
- No cover on rebar
Renewal of Haiti
Recommendations for a long-term building strategy

- Facilitated by the U.S. National Institute of Building Sciences (NIBS)
  - The attached White Paper serves as the first step in identifying what is needed to assure a safe, secure, and prosperous long-term building program within Haiti.

- Haiti “Toolkit” Project Portal
  - Web site is: http://www.nibs.org/index.php/newsevents/haititoolkit/portalaccessrequest/
  - Anyone can apply for access to Toolkit

- Haiti Center for Sustainable Reconstruction & Development
- Plan to develop HAZUS like program for Haiti
- NIBS POC is Mr. Ryan Colker, rcolker@nibs.org
Bridge Retrofit & Concrete Repair

- The presentations below were made as part of a joint USACE/FHWA/FAA Seismic Vulnerability Procedures Workshop and Field Assessment held in Kathmandu, Nepal to assist Nepal’s Ministry of Defense (MoD), Ministry of Physical Planning and Works, and the Civil Aviation Authority of Nepal (CAAN).

- Retrofit Measures for SRC A&B Bridges

- Concrete Repair
Questions & Discussion