USAE CW R&D Program Workshop
Seismic Rehabilitation of Hydraulic Infrastructure

Sacramento, CA

11-16 Nov 2000

USAE CW R&D Program Workshop
Seismic Rehabilitation of Hydraulic Infrastructure

Purpose:

Identify Corps " Future Operational Capabilities" needed for the evaluation and rehabilitation of dams and appurtenant structures

USAE CW R&D Program Workshop
Seismic Rehabilitation of Hydraulic Infrastructure

Process:

- ***Share*** **field experiences**
- ***Share*** **results of EQEN research program**
- **Identify field needs**
- **Define and prioritize future R&D**

Capabilities

WEB Page Posting of Workshop

Earthquake Engineering Research Program

SUMMARY

RESEARCH

SOFTWARE

NEWS

CONTACTS

EQEN II

The objective of the Earthquake Engineering Research Program is to reduce damage from a potentially devastating earthquake by advancing state-of-the-art knowledge of earthquake hazard assessment, seismic design, and remediation of Corps infrastructure, and by developing technical capabilities to improve rapid Corps response to earthquake-induced life-threatening emergencies.

In spite of major advances over the last 25 years, serious gaps still exist in the areas of earthquake hazard predictions, site characterization for seismically sensitive parameters, constitutive behavior and material properties of rock, soils, and composite (reinforced) materials under seismic loads, and the stress and deformation responses of sites and facilities to seismic loading. Economical remediation and defensive design techniques are needed, in addition to careful calibration of fast advancing numerical methods to actual field performance. In order to address these issues, the Army Corps of Engineers is funding a consistent Earthquake Engineering Research Program (EQEN) which will produce design tools and criteria to incorporate innovative measures for increasing the seismic safety of Corps and other public facilities.

Research areas have been prioritized and are being studied within funding constraints to improve hazard assessment, ground response prediction, seismic design and remediation techniques; to assemble a database of relevant information for assessing site behavior under seismic excitation; to advance in situ and laboratory testing technology; to develop constitutive models for seismic deformation behavior of these materials; to develop efficient numerical techniques to compute seismically-induced stresses and movements and calibrate these techniques to field performance; to develop economical remediation techniques for existing Corps infrastructure.

WEB Page Posting of Workshop

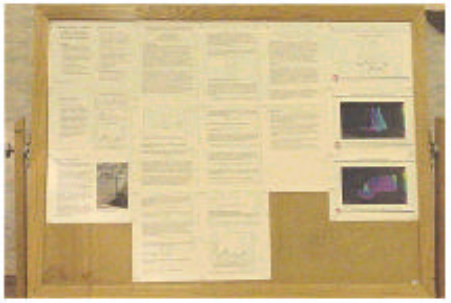
EQEN II

USACE Civil Works R&D Program Workshop: Seismic Rehabilitation of Hydraulic Infrastructure

November 13 - 16, 2000 - Red Lion Inn, Sacramento, CA

Purpose: Identify Corps "Future Operational Capabilities" needed for remediation of the Corps' hydraulic infrastructure with seismic safety deficiencies -- emphasis is on reservoir dams.

- Workshop Announcement
- Agenda
- Committees
- Committee Reports



Breakout Sessions

Concrete Dams

Appurtenant Structures

Embankment Dams and Foundations

FOC's

Set Goals → Define Needs →

Brain storm → Reflect → Consensus → Report

Breakout Session- Concrete Dams

Goal

- Identify tools, methods, guidance, criteria, and procedures for concrete dams under seismic hazard, to evaluate existing conditions, and to design and implement remediation.

Breakout Session- Concrete Dams

- Needs

– **Database: Case Histories, Project Statistics**

– **Condition Evaluation: Static & Dynamic**

– **Electrical / Mechanical Equipment**

– **Analytical Tools**

– **Guidance**

– **Organizational Requirements**

– **Other**

Databases Rating [H,M,L : 7,5,0]

- Case Histories
  - Past performance, Original Design, Assumptions, Subsequent Evaluations
  - Remediations, Modifications, Lessons learned,
  - Geotechnical hazards
- Project Data: Response characteristics
  - First few frequencies with reservoir assumptions stated
  - Dimensions, Material properties including foundation
  - Measured performance (Instrumentation, Field Testing
    Actual earthquake loading)
  - Reservoir design pools, Actual historical maximum/minimum
  - Ground motion
  - Sedimentation / Scour

Condition Evaluation:Static and Dynamic Rating [H,M,L: 11,1,0]

- Fc, Ft, Fs, lift lines and foundation contact
- E, Poisson ratio
- Rock Mass Rating/Classification
- Determination of % of intact joints
- Determination of distribution of concrete properties
- Core/Lab testing /In-situ nondestructive
- Aggregate-alkali reaction
- Sediment/Properties alpha, unit weight
- Geometry is needed
- System discontinuities (cracks, joints,foundation)
- Condition of drains
- Field tests to determine prototype response

Electrical/Mechanical Equipment
Rating factors [H,M,L: 0,10,2]

- Evaluation of gates/valves/bulkheads, etc.
  - Guidance
  - Methods
  - Dynamic testing
- Performance criteria
- Details of elements crossing joints
- Cranes

Analytical Tools Rating [H,M,L: 7,5,0]

- Economical development of user-friendly and adequate tools
- Pre/post-processors to apply to in-house, and proprietary and academic software
- Risk analysis and probabilistic models
- Seismic uplift tools experimentally verified
- Two-dimensional finite element model to do static and dynamic linear elastic analysis with capability to represent modification options (post-tensioning, stage construction, etc.)
- Analytical tools that include geometric discontinuities (i.e., lift lines, contraction joints, existing cracks, etc.)
- Acceleration response at any given nodal point of the dam to be used as excitation on other structural elements

Guidance rating [H,M,L: 4,8,1]

- Performance criteria
- Design criteria
- Instrumentation programs (Types of instruments,Monitoring plans, Evaluation of data
- Clarification of definition and determination of ground motion (Continuum from OBE to MCE, and selection of MDE)
- Probabilistic load combinations
- Analysis of consequences of structural failure
- Sliding stability including slip displacements in dam foundations systems
- Overturning stability including rotational displacements
- Significance of the vertical component in stability calculations
- Inspection manual

Organizational Requirements

Rating [H,M,L: 4,8,0]

- Training
  - Ground motion: definitions, selection, and applications
  - Analytical tools
  - Guidance
  - Inspection
- Demonstration projects to leverage work on individual on-going projects

Organizational Requirements

Rating [H,M,L: 4,8,0]

- Means for resource sharing among Districts to address specific and common issues
- A search engine to allow input of keywords to identify pertinent guidance
- COE developed vs. commercially available software (com624 vs. LPILE)
- Funding maintenance cost of COE and proprietary software

Others

Rating [H,M,L: 0,7,3]

- Evaluation of powerhouses
- Interaction between adjacent embankment-concrete structure
- Seismic response of post-tensioning
- Spatial variation of ground motions
- Spillway bridges and piers
- RCC
  - Seismic properties
  - Seismic behavior

Breakout Sessions

Concrete Dams

Appurtenant Structures

Embankment Dams and Foundations

Break Out Session

Rehabilitation Of Embankment Dams And Foundations

Goals

- Improve ***site characterization*** techniques
- Better define guidance for earthquake ***ground motions***
- Evaluation of ***remediation*** techniques
- Technology transfer
  - Develop lessons learned database
  - Leverage with other agencies
- Develop performance based criteria for tolerable damage and acceptable risk

Break Out Session

Rehabilitation Of Embankment Dams And Foundations

- Needs
  - **Site Characterization**
  - **Ground Motions**
  - **Remediation**
  - **Other**

Desired Products

Site Characterization

- Modernize penetration tests — M
  - automatic recording of delivered energy
  - energy and force measurement at the sampler
- Better correlation of SPT, CPT, BPT, LPT, Vs data — H
- Improve lab capability for special tests — H
- Correlation between laboratory and in situ measurements — H
- Evaluation of non-destructive geophysical methods and ability to determine liquefaction — H

Desired Products

Site Characterization (cont.)

- Effect of high confining stress and sloping ground on liquefaction potential and strength loss for all soils — H
- Validation of the Chinese criteria — H
- Refine post earthquake shear strength evaluation for all soils — M
- Correlations between CPT and post earthquake strengths — H
- Develop correlation between strength and earthquake parameters — H

Desired Products : Ground Motions

- Earthquake ground motion analysis and design systems, study must be completed & maintained (**EQAS**) — **H**
- Method to evaluate lateral forces and displacements of retaining walls due to large peak accelerations — **H**
- More information on latest seismological factors such as fling and directivity — **M**
- Unification of ground motion requirements from geotechnical and structural point of view — **H**
- Access to software for conducting PSHA including disaggregation — **M**

Desired Products

Remediation

- Screening tool for seismic risk analysis — H
- Access various existing models for deformation analysis to compare results — H
- Develop a new constitutive model for soil behavior WRT deformation analysis — H
- Access various remedial measures WRT cost and effectiveness — M
  - Tie in with case histories

Desired Products

Remediation (cont'd)

- Develop guide specifications for ground improvement techniques — M
- Need more cost effective techniques for ground improvement — M
  - Test the above techniques
- Think globally when looking for ideas — M
- Guidelines for post construction evaluation — M
- Policy requirement to have design engineer onsite during remediation Screening tool for seismic risk analysis — H

Desired Products

Other

- System wide evaluation of remediation activities — M
- Cross agency training courses and funding — H

Breakout Sessions

Concrete Dams

Appurtenant Structures

Embankment Dams and Foundations

Rehabilitation of Appurtenant Structures and Locks

GOAL:

Provide guidance, programs, tools, and example problems to facilitate the efficient seismic design and evaluation of appurtenant structures and locks.

Breakout Session-

Rehabilitation of Appurtenant Structures and Locks

- Needs
  - **Software and Analytic Tools**
  - **Guidance**
  - **Soil-Structure Interaction**
  - **Other**

Capabilities for districts to perform linear elastic finite element analyses of intake towers, navigation locks, gravity dams, and retaining walls using commercially available FE software.

The Corps would like EM's that include procedures, examples and guidance so that we can overcome the problem of developing appropriate numerical models. EM's should include guidance on input for material properties, foundation effects, hydrodynamic effects, uplift forces/pore pressures, and recommendations on evaluation criteria, assessment and interpretation and presentation of results.

FOCs

Capability for districts to analyze and design new hydraulic steel structures and to analyze and assess existing hydraulic steel structures subjected to seismic loads.

The Corps would like to see the appendices in EM 1110-2-2105 completed for various hydraulic steel structures and for the EM to be expanded/revised to specify design criteria and methods of evaluation for the OBE and MDE conditions.

Capability for districts to develop simple dynamic models to analyze and assess pile foundations.

The Corps would like guidance, examples, and procedures that include pile cap fixity, pile group effects, reduction factors for dynamic behavior, methods for developing spring constants to represent soil and/or rock, and evaluation criteria.

The Corps would also like guidance and software to evaluate the rebound effects of piles in non-cohesive and cohesive soils to evaluate ultimate forces, final displacements during seismic events, and for the evaluation of subsequent events.

Pushover Analysis Techniques

Capability for districts to perform Pushover Analysis for lock-walls, intake towers, spillway piers, and retaining walls using commercially available software.

The Corps would like guidance to include procedures, criteria, and examples on Pushover Analyses on various structures

Evaluation and rehabilitation of dams and appurtenant structures

FOCs

Formulate Procedures, Guidance and Tools for the Safe, Economical and Functional Design of Appurtenant Hydraulic Structures.

Goal: Provide guidance to estimate expected material strengths.

- Taking site samples can be extremely costly and sometime impossible to obtain (e.g. upstream toe of a tall concrete dam).
- Drawings and specifications indicate the minimum strengths of concrete and steel. However, actual strengths may be greater due to age of concrete and steel strengths in general will exceed minimum values.
- Due to the age of the structure or deterioration, strengths of concrete and steel may be less than the original design values.
- Product: ETL with relationships of material strength versus age, deterioration, structural use and other parameters to aid in determining expected material strengths.

Evaluation and rehabilitation of dams and appurtenant structures

FOCs

Goal: Determine ductility/capacity of unreinforced and under-reinforced mass concrete sections of intake towers, navigation locks and retaining walls.

- ER 1110-2-1806 allows the use of some inelastic structural response for design of the Maximum Design Earthquake (MDE). Existing Corps guidance does not address the inelastic strength of mass concrete.
- Current codes, including ACI, underestimate the inelastic strength of concrete.
- Corps guidance requires the seismic reevaluate of seismic structures every third periodic inspection not to exceed 15 years. Current seismic loads are greater than the original design loads. Allowing inelastic behavior better represents the actual conditions and results in fewer and less costly retrofits. By allowing appropriate inelastic strengths, these structures may meet or exceed the increased seismic demand.
- Products: ETL with methodology to determine inelastic strengths of unreinforced and under-reinforced mass concrete sections for hydraulic structures.

Determine the reliability and risk of hydraulic structures.

- The reliability of existing structures may decrease over time due to deterioration.
- When evaluating existing structures for modification and/or interaction with new structures, assumptions need to be made about the structure's ability to function as originally designed and meet any newly imposed criteria.
- An examination of case studies would aid the designers in determining the structure's adequacy and establishing hazard curves to aid in the decision making process.
- Products: EM with case studies and recommendations for evaluation.

SSI Procedures

Formulate programs, procedures, guidance and example problems to overcome the problem of seismic modeling and designing of retaining walls. Engineering procedures for predicting dynamic lateral earth pressures are not available. Lateral earth pressures are critical for all aspects of design and analysis for retaining wall structures in all seismic zones.

Fracture Foundation Analysis

Programs, procedures, guidance and example problems are required to overcome the problem of seismic modeling and designing of structures on foundations of fractured rock and weak seams.

Evaluation Criteria - Standard

Guidance is required to properly interpret the direction provided by NEHRP concerning seismic coefficients for sliding stability, life-safety and seismic zones.

Rehabilitation of Appurtenant Structures and Locks

- Needs –Software and Analytic Tools

1 -Linear Elastic Finite Element Analysis Towers/Locks/Gravity Dam (Not a WES Program) Guidance Examples – Products

2 & 10-Definition of most appropriate finite element software. Assessment of AE proposed software tools – i.e. acceptability

16-Clearing House for "good" designs

18- EQAS- Maintain/ Update

Rehabilitation of Appurtenant Structures and Locks

- Needs –Guidance

2 & 10-Definition of most appropriate finite element software. Assessment of AE proposed software tools – i.e. acceptability

4-Evaluation Criteria –Standards

5-Guidance on hiring technical assistance of experts (scope of work assistance)

8-Tainter gates/stoplogs-Finish hydraulic steel structures - guidance examples

9-Tools to evaluate AE design based on their proposed products (precast/premade)

13-Extension w/ a new structure at 100 year – how to remediate the existing for additional 100 year (how to evaluate) (composite structures)

Rehabilitation of Appurtenant Structures and Locks

- Needs (cont) –Guidance

14 -Reliability/Risk – How to integrate

17-ER 1806 Rewrite /consistent (Sliding Stability / Coefficient) Zones

19 - ETL – Site specific NERHP Maps

Rehabilitation of Appurtenant Structures and Locks

- Needs SSI

7- Soil/structure interaction pertaining to retaining walls

11- Pile Foundation- How to evaluate and/or models – springs pile head fixity

12- Fracture Foundation Analysis 3D soil/structure (torsional loading)

Rehabilitation of Appurtenant Structures and Locks

- Needs – Other

3- Site Characteristics ---expected strengths of materials

6- Quantify Ductility-mass concrete-Physical models-lock structures-retaining walls

15- Guidance for "pushover" analysis

Rehabilitation of Appurtenant Structures and Locks

NEEDS

1 -Linear Elastic Finite Element Analysis Towers/Locks/Gravity Dam (Not a WES Program) Guidance Examples – Products (10)

2 & 10-Definition of most appropriate finite element software. Assessment of AE proposed software tools – i.e. acceptability (3)

3-Site Characteristics ---expected strengths of materials(4)

4-Evaluation Criteria –Standards (4)

5-Guidance on hiring technical assistance of experts (scope of work assistance) (1)

6-Quantify Ductility-mass concrete-Physical models-lock structures-retaining walls (4)

NEEDS

7-Soil/structure interaction pertaining to retaining walls (9)

8-Tainter gates/stoplogs-Finish hydraulic steel structures - guidance examples (6)

9-Tools to evaluate AE design based on their proposed products (precast/premade)

11-Pile Foundation- How to evaluate and/or models –springs pile head fixity (10)

12-Fracture Foundation Analysis 3D soil/structure (torsional loading) (5)

13-Extension w/ a new structure at 100 year – how to remediate the existing for additional 100 year (how to evaluate) (composite structures) (3)

NEEDS

14 -Reliability/Risk – How to integrate (5)

15-Guidance for “pushover” analysis (2)

16-Clearing House for “good” designs (6)

17-ER 1806 Rewrite /consistent (Sliding Stability / Coefficient) Zones (4)

18- EQAS- Maintain/ Update (1)

19 - ETL – Site specific NERHP Maps (0)

Workshop Summary

Needs:

- Investigation & Analysis Procedures and Tools
- Guidance
- Technology Transfer
- Case Histories
  - Corporate Data Base of Solutions & Decisions
- "Community Action" or Interaction
  - Leveraging & Communication

The problems are not getting easier compounded with less staff solving the problems

Future

Finalize These Committee Reports
Post on Web Site
Open the Dialog to All

and see where we go