PORTUGUES DAM

PROJECT UPDATE

US Army Corps of Engineers ®
Jacksonville District

PORTUGUES DAM

- Alberto Gonzalez, P.E. – Project Manager
- Jim Mangold, P.E. – Project Engineer
- Dave Dollar, P.E. – Structural Designer
- Geotechnical, Geology, Materials, Hydraulic, Civil, Mechanical, Electrical, ITR Team

US Army Corps of Engineers ®
Jacksonville District

PORTUGUES DAM

- **Jim Hinds - CENWP – RCC Mix Design**
- **Tony Bombich and Billy Neeley – CEERD – Materials Testing**
- **Ahmed Nisar, Paul Jacob – MMI Engineering – Thermal Stress/Strain Analysis (NISA)**

PORTUGUES DAM

I. Project Overview

II. ITR Process

III. Current Schedule

IV. MCE Update

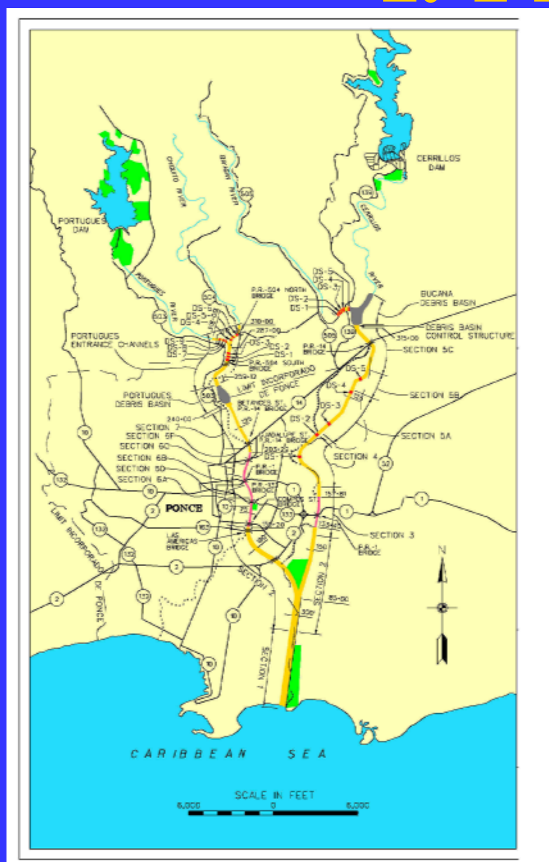
V. Dam Design

PORTUGUES DAM
I. Project Overview

PORTUGUES DAM
I. Project Overview

PORTUGUES & BUCANA RIVERS PROJECT

I. Project Overview



- CHANNEL IMPROVEMENTS
  - CONCRETE U-CHANNEL
  - GABION LINED
  - UNLINED
- DROP STRUCTURES
- CONTROL STRUCTURES
- DEBRIS BASINS
- CERRILLOS DAM
- PORTUGUES DAM

PORTUGUES DAM

I. Project Overview

PORTUGUES DAM
I. Project Overview


Portugues Dam Site Prior to Start of Construction

PORTUGUES DAM
I. Project Overview

Concrete Thin Arch Dam was advertised in September 2000 and the bid was outside the awardable range

Design changed to RCC

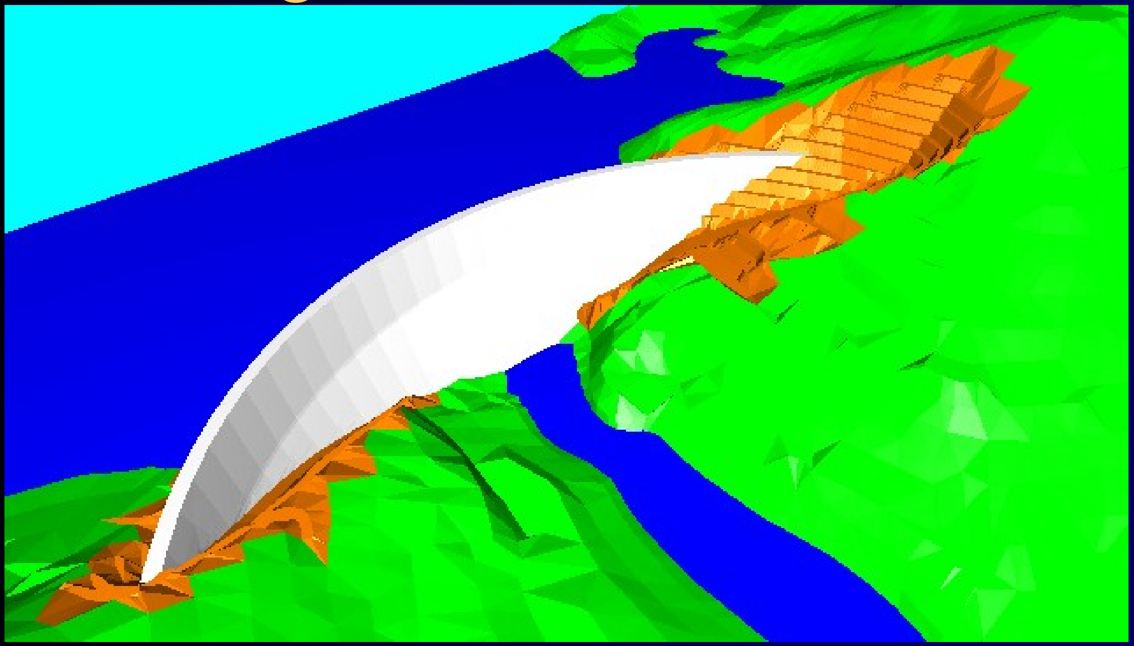
PORTUGUES DAM
I. Project Overview

Pertinent Data:

- **HEIGHT: 219.6 FT**
- **CREST LENGTH: 1300 FT**
- **SPILLWAY CREST WIDTH: 150 FT***
- **FLOOD CONTROL STORAGE: 9484 AF**
- **MAX POOL AREA: 215 ACRES**

PORTUGUES DAM
I. Project Overview

Portugues Dam - Thick Arch



PORTUGUES DAM
I. Project Overview

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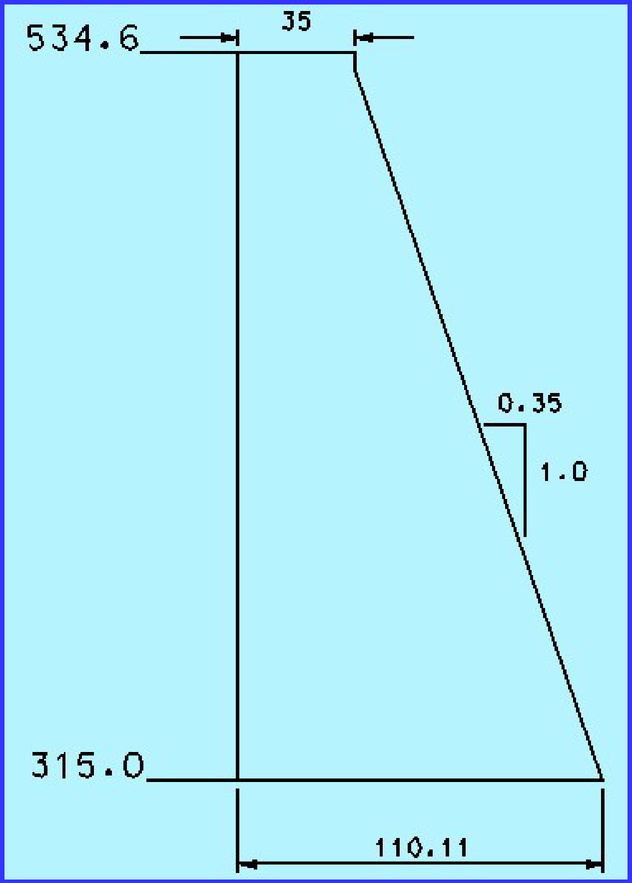
I. Project Overview



- TYPE OF SECTION
- CUT CONTRACTION JOINTS
- GROUT CONTRACTION JOINTS?
- GERCC FACING
- TEST PLACEMENT
- MIX DESIGN
  - 18 sec VEBE
  - 340 lbs cementitious mat'ls, 40% class F fly ash
- VOLUME ~ 375,000 CU. YDS.

PORTUGUES DAM
II. ITR Process

- THIN ARCH
- RCC
  - FORMALIZED PROCESS
  - CONSISTENT WITH INDUSTRY PRACTICE

PORTUGUES DAM
II. ITR PROCESS

- Multidiscipline ITR team.
  - Concrete dam design, RCC mix design, seismology of the Caribbean, engineering geology, geotechnical engineering, hydraulics, electrical and mechanical engineering.

PORTUGUES DAM
II. ITR PROCESS

Multidiscipline ITR team:	Individuals:
Concrete dam design	Glenn Tarbox
RCC mix design	Gary Mass
Seismology of the Caribbean	Dr. William McCann
Engineering geology	Alan O’Neil
Geotechnical engineering	Dr. Gregg Korbin, Dr. Don Banks
Hydraulics	MWH staff
Electrical engineering	MWH staff
Mechanical engineering	MWH staff

PORTUGUES DAM
III. Current Schedule*

- COMPLETE P&S – MAY 2006
- ADVERTISE – MAY 2006
- AWARD – AUG 2006

*THIS SCHEDULE IS DEPENDENT ON AVAILABILITY OF PROJECT FUNDING

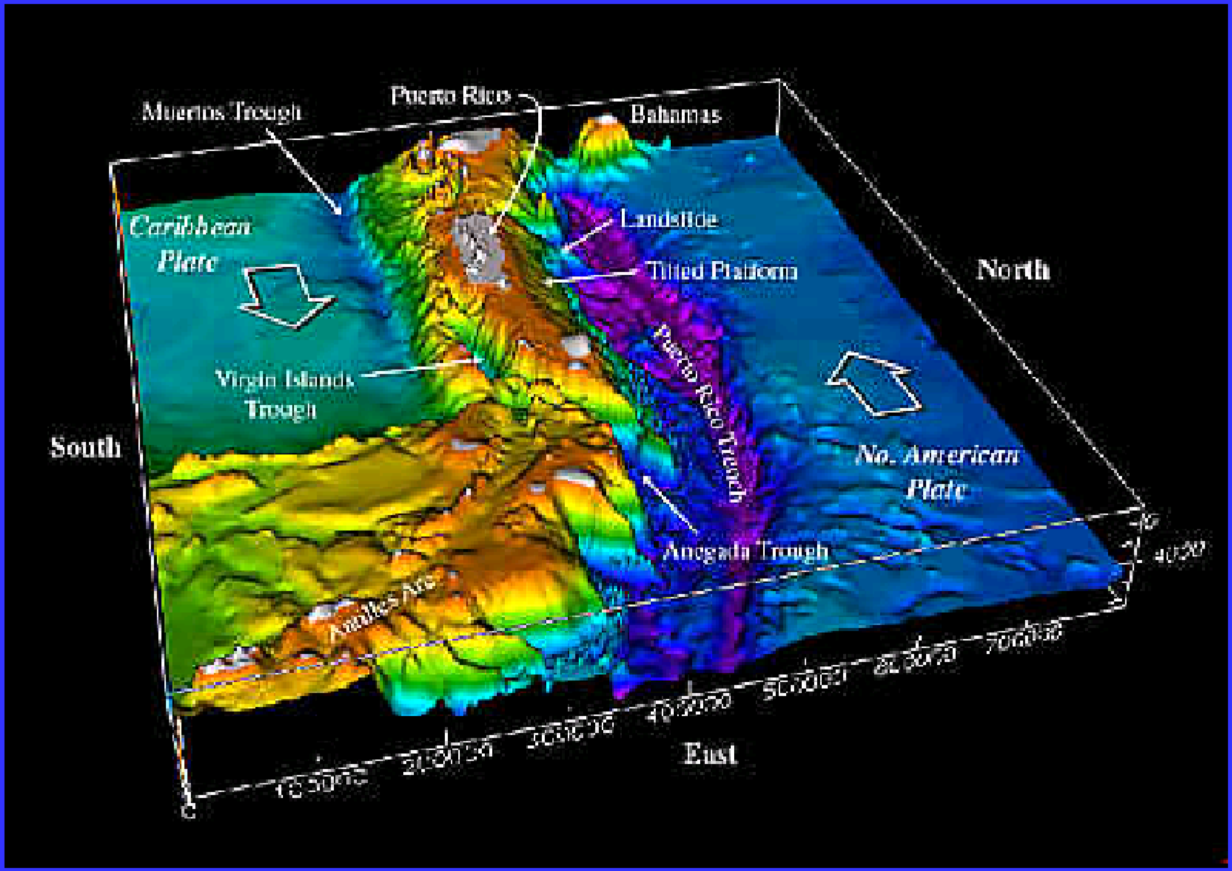
PORTUGUES DAM
IV. MCE Update

MCE – Controlling Events:

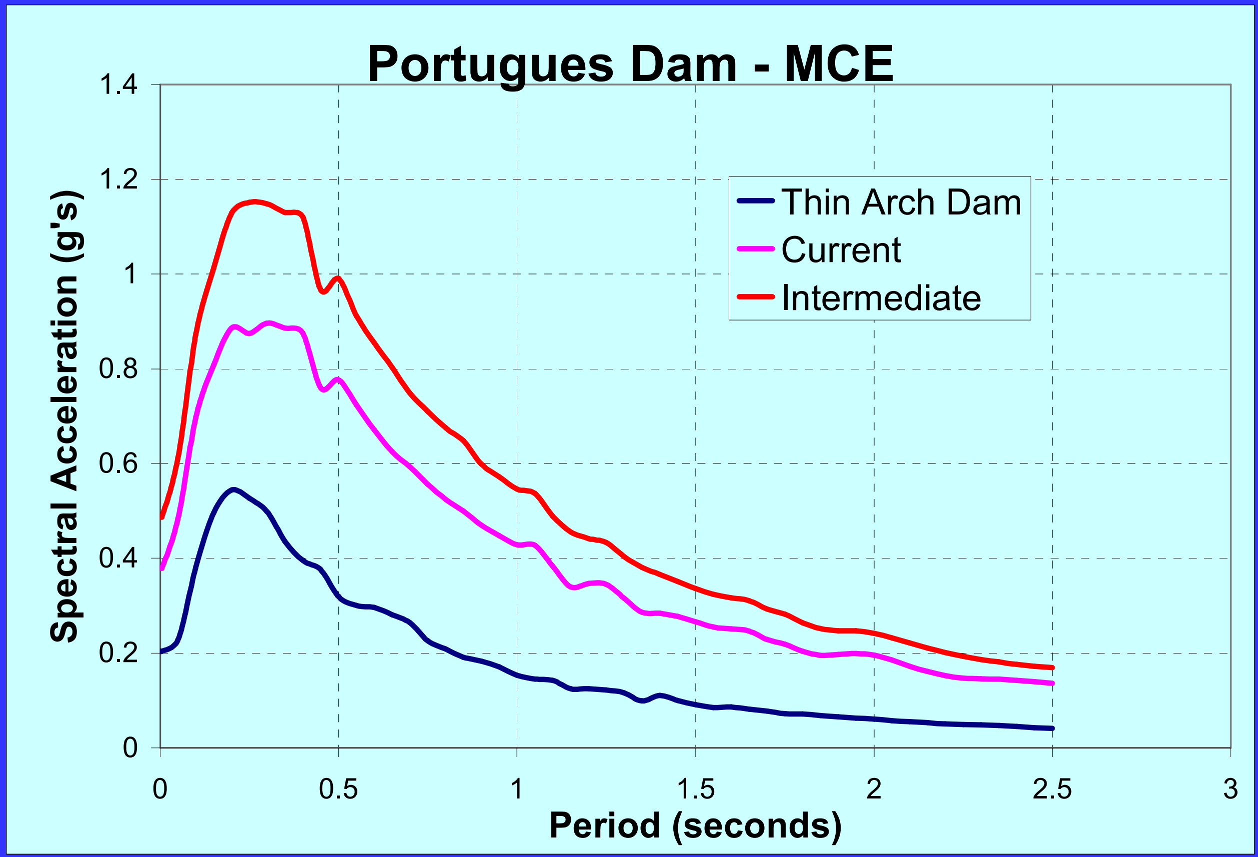
- **Thin Arch Dam**
  - **M6.5 @ 18km – Salinas Fault – 1988**
- **RCC Thick Arch Dam**
  - **M8.25 @19.6km – Muertos Trough – 2004**

"Deterministic and Probabilistic Seismic Hazard Analysis for Portugues Dam, Puerto Rico," 6 April 2004, prepared by URS Corporation; reviewed by ITR Team (particularly Dr. William McCann), Dr. Greg Fenves, ERDC (Dr. Donald Yule), USGS (Dr. Charles Mueller)

REGEONAL GEOLOGY



PORTUGUES DAM
IV. MCE Update



PORTUGUES DAM
IV. MCE Update

Significance to dam design:

- **Peak ground acceleration: 0.38g's.**
- **Plateau on the response spectrum throughout the range concrete dam frequencies of vibration.**

PORTUGUES DAM

V. Dam Design

Sequencing of Design Activities:

Construction for the thin arch dam had begun(excavation & grout curtain); therefore, there was a need to minimize the time required to redesign the dam. Activities that would normally run sequentially were performed in parallel.

PORTUGUES DAM
V. Dam Design

<u>Parallel Activities</u>:

- Site Seismicity
- Determination of Foundation Properties
- Foundation and Slope Stability
- Concrete Mix Design and Property Testing
- Dam Design
- Thermal Analysis

PORTUGUES DAM

V. Dam Design

DISADVANTAGES OF PARALLEL ACTIVITIES

ACTIVITY	INPUT REQUIREMENTS
1. Dam Design	1. Foundation Properties, Seismic Input, Concrete Properties.
2. Foundation Stability	2. Dam Shape and Loads, Seismic Input
3. Thermal Analysis	3. Dam Shape, Construction Sequencing, Concrete Properties
4. Mix Design	4. Target Parameters

PORTUGUES DAM

V. Dam Design

Design Approach:

Based on expected magnitude of seismic loading; design a workable mix with reasonable bond strength (tensile strength) and design the dam to maximize cantilever compression on the upstream face under usual loadings and arch compression during the seismic loading.

PORTUGUES DAM

V. Dam Design

Design Progression:

- Corps experience with RCC has typically been associated with gravity dams.
- The district considered an RCC gravity structure in the 1980's but ruled it out, not based on cost, but on the "newness" of the technology.

PORTUGUES DAM

V. Dam Design

<u>Design Progression</u>:

- Gravity dam alignments and sections were evaluated.
- Detailed cost estimates, which included the quantities of RCC and excavation for the gravity dam designs, indicated a cost savings compared to the thin arch dam.

PORTUGUES DAM
V. Dam Design

Design Progression:

- **Now that a more economical construction method was adopted could further savings be realized by minimizing the volume by designing a thick arch structure?**
- **Preliminary layouts indicated that a thick arch dam could be designed with less than 3/4 the volume of the gravity dam.**

PORTUGUES DAM

V. Dam Design

Design Progression:

- To maintain simplicity during construction a section was adopted with a vertical u/s face and a d/s face with a single slope.
- Sensitivity analyses were performed to evaluate:
  - Relative stiffness of the arches and cantilevers
  - Effect of varying the horizontal curvature
  - Effect of stiffening the upper arches
  - Magnitude of temperature and reservoir load compared to gravity load

PORTUGUES DAM

V. Dam Design

Design Progression:

- **Based on the water supply dam, a full reservoir and the foundation properties from the thin arch analysis; the horizontal curvature and alignment were set prior to having the final seismic loading. The left abutment was shifted upstream to avoid highly weathered rock exposed during the thin arch excavation.**

PORTUGUES DAM
V. Dam Design

Design Progression:

- The section was refined to increase u/s cantilever compression; mainly from gravity load, which was applied to cantilevers only.
- The final layout was selected and a dynamic analysis performed.
- The dynamic response was acceptable.

PORTUGUES DAM

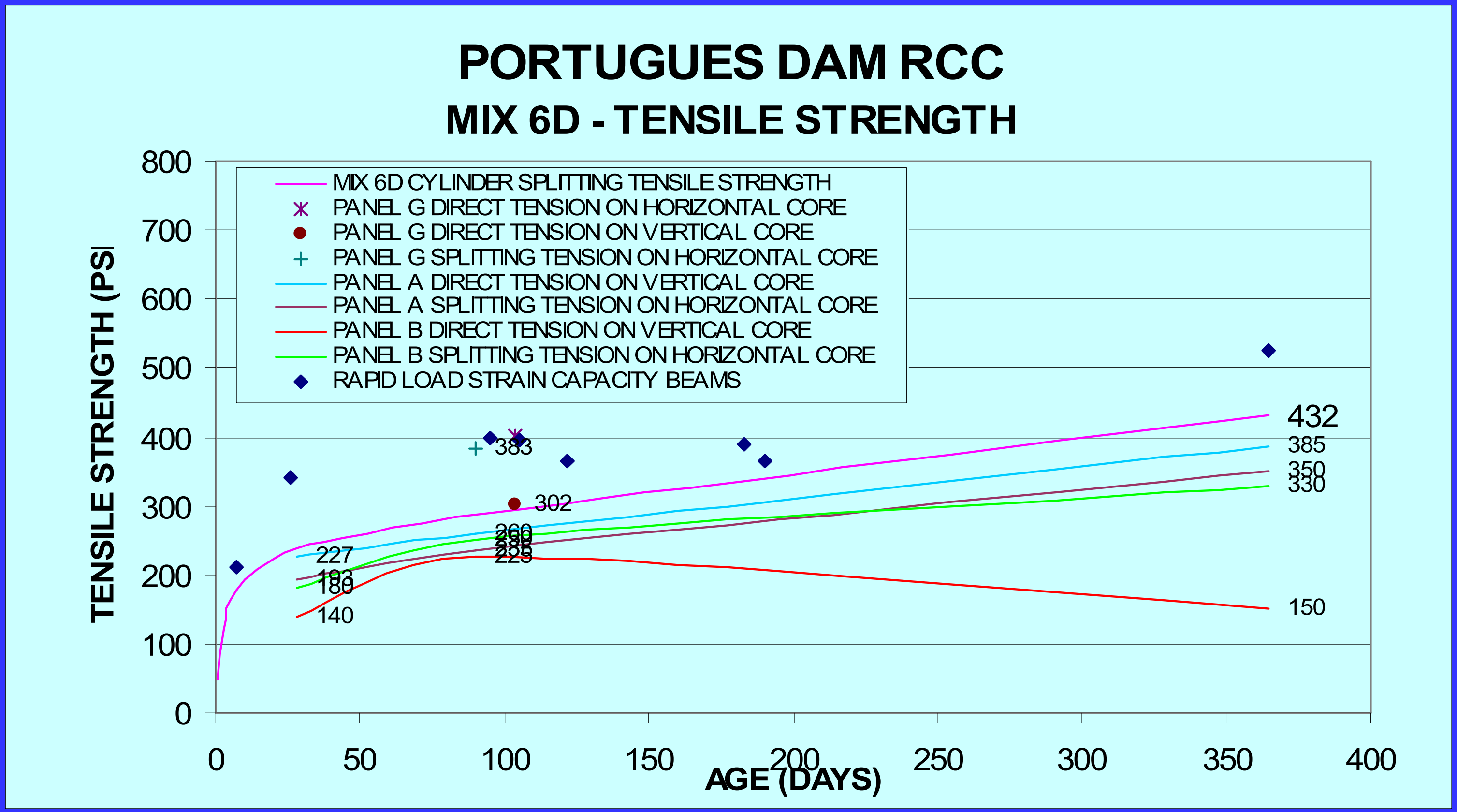
V. Dam Design

Design Progression:

- **The foundation properties were determined for the final layout. (In progress)**
- **All load cases analyzed for the final properties and loadings. (In progress)**

PORTUGUES DAM

V. Dam Design

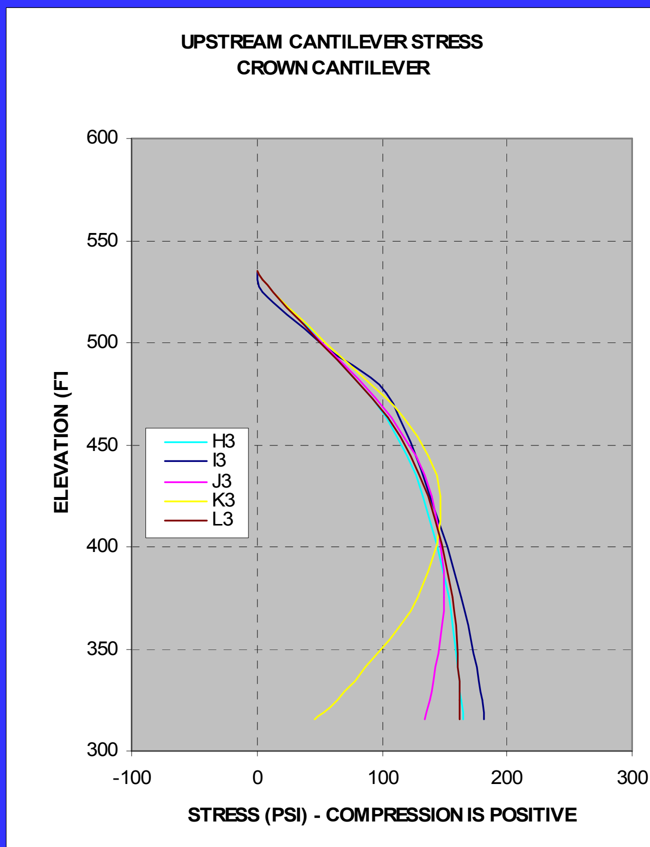


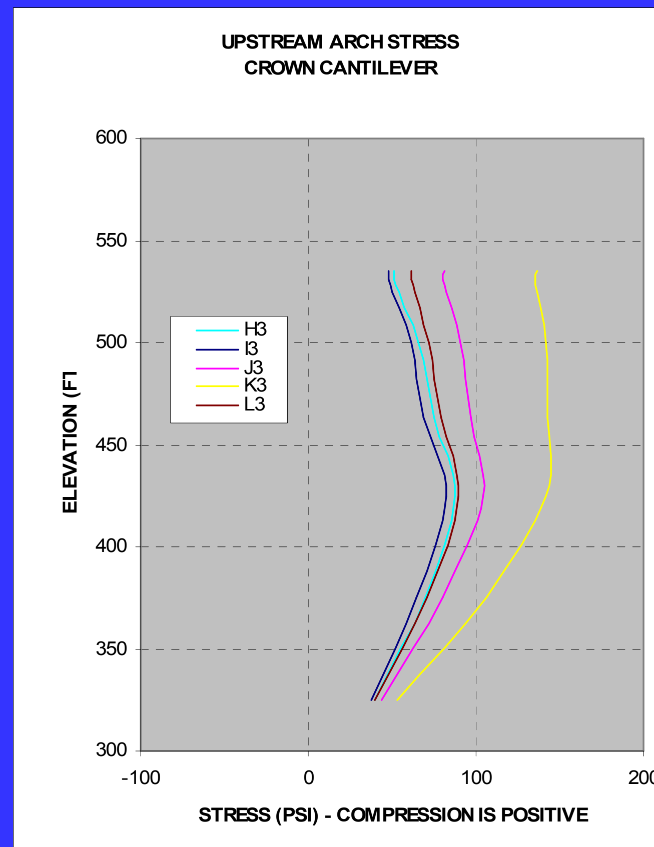
PORTUGUES DAM
V. Dam Design

LAYOUT:	VOLUMES:
G - Raxis = 825 ft, S=0.50, Crest Thickness = 25 ft	257710 CU.YDS.
H - Raxis = 825 ft, S=0.40, Crest Thickness = 30 ft	356284 CU.YDS.
I - Raxis = 825 ft, S=0.40, Crest Thickness = 35 ft	379937 CU. YDS.
J - Raxis = 825 ft, S=0.30, Crest Thickness = 35 ft	343610 CU.YDS.
K - Raxis = 825 ft, S=0.20, Crest Thickness = 35 ft	301013 CU.YDS.
L - Raxis = 825 ft, S=0.35, Crest Thickness = 35 ft	367141 CU. YDS.

PORTUGUES DAM

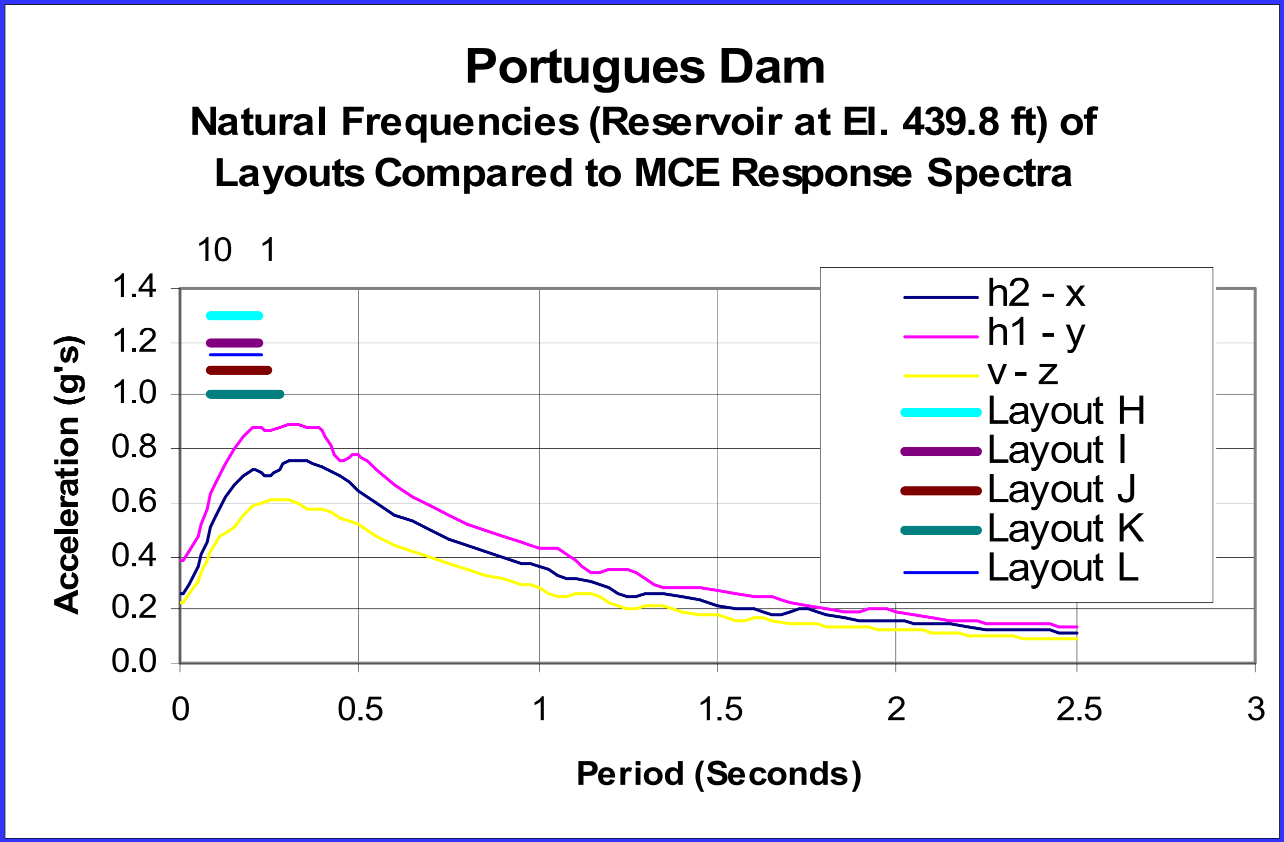
V. Dam Design





WATER TO EL. 523 FT, LOW TEMPS, AND GRAVITY

PORTUGUES DAM
V. Dam Design

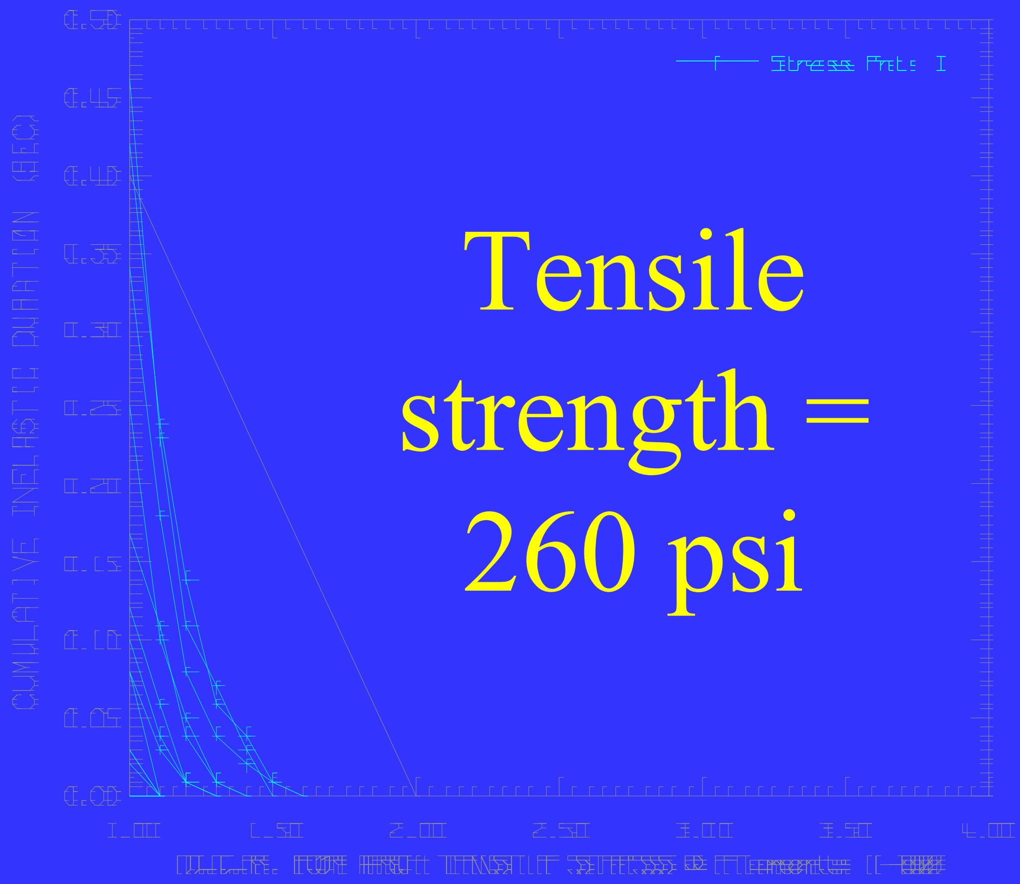


PORTUGUES DAM
V. Dam Design

- **MAXIMUM TENSILE STRESSES**
- `#1- 61,Dir: u/s,Str:arch , Max: 399.474 @ 14.010Sec`
- `#1- 53,Dir: u/s,Str:cantl, Max: 476.163 @ 20.240Sec`
- `#1-296,Dir: d/s,Str:arch , Max: 249.882 @ 14.010Sec`
- `#1-271,Dir: d/s,Str:cantl, Max: 384.474 @ 20.370Sec`

PORTUGUES DAM

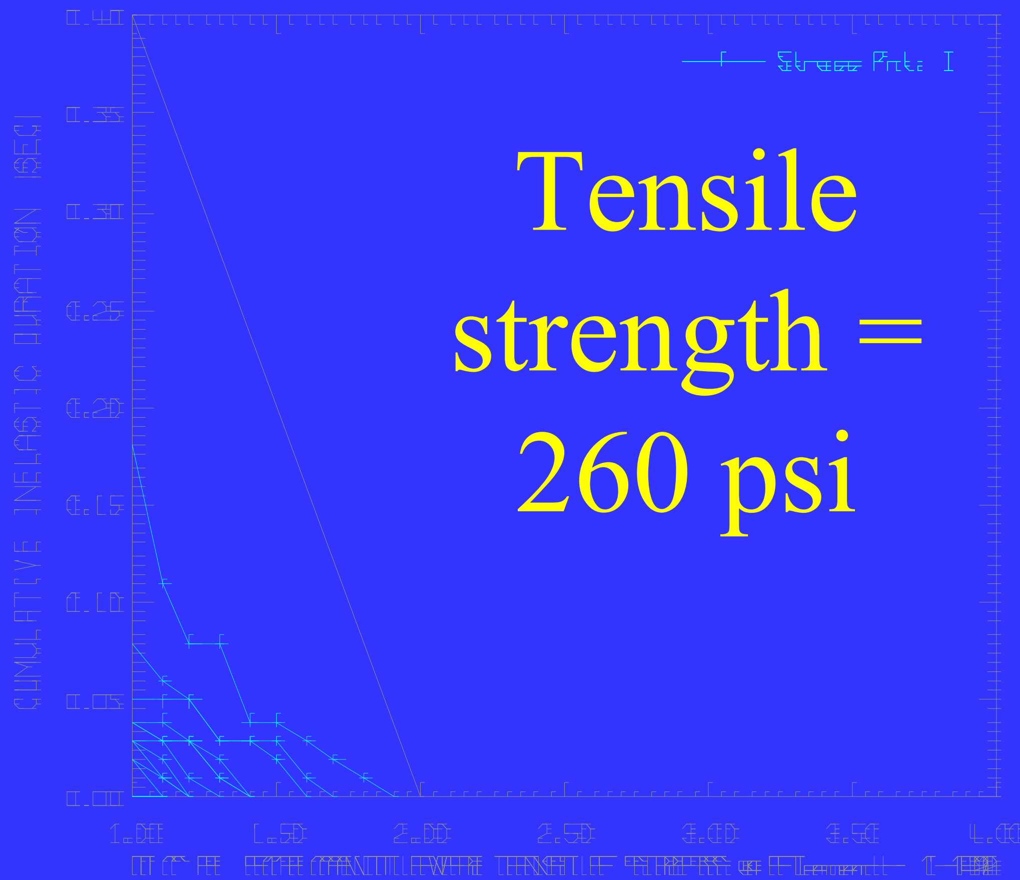
V. Dam Design–Demand/Capacity Curves



Tensile strength = 260 psi

PORTUGUES DAM

V. Dam Design–Demand/Capacity Curves



PORTUGUES DAM

V. Dam Design

Factors affecting dam design:

- Earthquake loading
- Much of the dam design work and mix design preceded the determination of the earthquake loading
- Tensile strength of RCC structures
- Post thin arch excavation site conditions
- Use of existing thin arch grout curtain

PORTUGUES DAM

V. Dam Design

Factors affecting dam design (continued):

- Horizontal curvature compatible with either a flood control or water supply dam
- Need axis before MCE was determined
- Left abutment weathered rock
- Delays and costs associated with exploration upstream of the thin arch left abutment
- Mix design program preceded determination of MCE.

THANK YOU

- RCC CONSTRUCTION PHOTOGRAPHS

RCC Placement – Upper Stillwater

RCC Placement - Olivenhain

RCC Placement - Olivenhain

RCC Placement - Saluda

RCC Placement - Saluda

Cutting Contraction Jt. - Olivenhain

Cutting Contraction Jt. - Olivenhain

Cutting Contraction Jt. - Saluda

GERCC - Olivenhain

GERCC - Olivenhain

GERCC - Olivenhain

GERCC - Olivenhain

GERCC - Olivenhain

GERCC - Olivenhain

Batch Plant - Saluda

Aggregate Cooling - Saluda

Quarry - Saluda

Pre-cast Facing Panels - Saluda

Pre-cast Facing Panels - Saluda

Contraction Joint Details - Saluda

Contraction Joint Details - Saluda

THANK YOU

- Dave Dollar, P.E. – Structural Designer
- Jim Mangold, P.E. – Project Engineer
- Alberto Gonzalez, P.E. – Project Manager

(904) 232-2459

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