McAlpine Lock Replacement
Instrumentation

Design, Construction, Monitoring, and Interpretation

Troy S. O’Neal, P.E.
McAlpine Lock Replacement
Instrumentation

INSTRUMENTATION DESIGN
Instrumentation Design Philosophy

1. Every instrument has a purpose.
2. Envision placement and constructability.
3. Have adequate redundancy of instruments.
4. Use to verify critical or variable design parameters.
Parameters Monitored

1. Concrete temperature
2. Concrete (monolith) strain
3. Monolith base pressures and distribution
4. Earth pressures and backfill sequence
5. Ambient temperature
Shaded Monoliths L11, L22 and SM15 have instrumentation
McAlpine Lock Replacement
Instrumentation

Shaded Monolith SM2 has instrumentation
McAlpine Lock Replacement Instrumentation

Monolith SM2 with location of Strain Gauges
McAlpine Lock Replacement
Instrumentation

Monolith SM15

SM15 showing locations of strain gauges (solid circles) and pressure cells (shaded circles).
McAlpine Lock Replacement
Instrumentation

L11 with locations of strain gauges (solid circles) and pressure cells (shaded circles).
L22 with locations of strain gauges (solid circles) and pressure cells (shaded circles).
INSTALLATION METHODS
McAlpine Lock Replacement Instrumentation

Placement of Pressure Cell

Leveling Pressure Cell
McAlpine Lock Replacement
Instrumentation

Placing Pressure Cell in L22

Completed Pressure Cell
McAlpine Lock Replacement
Instrumentation

Solar Powered Data Reading Station

Strain gauge mounted in L22
Location of Wires for Instrumentation

McAlpine Lock Replacement Instrumentation
DATA INTERPRETATION
Data Interpretation

**L11 Thermistor**

- Note: temperature increases during initial cure then decreases gradually
L11 Strain

- SG 10 is placed perpendicular to the lock centerline and is reading positive.
- SG 11 is placed parallel to the lock centerline and is reading negative.

Strain and Temp vs. Date L11

Strain

-1000
-500
0
500
1000
1500
2000
2500
3000

Date

9/25/2004
10/23/2004
11/20/2004
12/18/2004
1/15/2005
2/12/2005
3/12/2005
4/9/2005
5/7/2005
6/4/2005
7/2/2005

SG 10

376
385

SG 11

405
415

Data Interpretation

McAlpine Lock Replacement Instrumentation
McAlpine Lock Replacement
Instrumentation

Data Interpretation

Pressure and Temp vs. Date (L11)

Pressure
-4000 -2000 0 2000 4000 6000 8000 10000 12000 14000 16000

Date

L11 Pressure Cells
-Note: Extreme spike as concrete is placed.
L22 Strain
Note: Gages placed parallel to lock centerline, reading is negative.
McAlpine Lock Replacement
Instrumentation

Data Interpretation

Pressure and Temp vs. Date (L22)

L22 Base Pressures
McAlpine Lock Replacement
Instrumentation

Earth Pressures
K_o, P_h, F_v = ?

McAlpine Lock Replacement
Instrumentation
McAlpine Lock Replacement
Instrumentation

Monolith Construction

Design Shape

Smooth Surface

Actual Shape

Rough Surface, due to placement of RCC
General Design Methodology

K_o Value used for lateral soil pressure calculations with reduction in lower area of monolith based on anticipated soil arching.

K_o = 1 - \sin\Phi

(Jaky’s Equation)
Design vs. Actual Construction Conditions

DESIGN
- Design attempted to account for arching on smooth sloping wall with $\Phi = 32$.
- Actual design now calls for 3” minus gravel and a stair stepped wall. ($\Phi > 32$).
- Instantaneous loading assumed.
- Arching action invokes increased vertical shear effects that were not included at time of analysis.

CONSTRUCTION CONDITIONS
- Material change
- Stair-stepped back of monolith
- Confined backfill areas with unique configurations
- Staged Fill Placement

CONCLUSION
- Changes from original design will likely increase arching effects, vertical shear, and nonlinearity of load distribution along the back of the monolith.
How Does Arching Effect Lateral earth Pressures on the Monolith?

Free Field Condition

Resultant should be located higher and less in magnitude.

Confined Field Condition
McAlpine Lock Replacement
Instrumentation

Soil Arching Mechanism

Existing Wall

Rock

Differential Settlement Over Time

Soil Arching Over Time
McAlpine Lock Replacement Instrumentation

Vertical Shear

Existing Wall

Rock

Earth Pressure Cells to Record Difference in Vertical Pressures From Wall to Wall Over Time.

Additional Vertical Shear Resultant
Why is Vertical Shear Important?

APPENDIX F

F-2

d. “Filz, Duncan, and Ebeling (1997) present an example calculation using vertical shear for a 30-ft high, step-tapered, rock founded, gravity wall retaining dense sand with surcharge. This example compares the result with a conventional design and shows a 14 percent reduction in base width by including vertical shear, without compromising the design safety requirements.”

If applied to the McAlpine Lock Project (say at only 7 percent) it could yield:

• (3.5 ft reduction in each monolith wide)X(2400 ft) = 23,000 CY
• (23,000 CY)X($150/CY) = $3.5M Savings
McAlpine Lock Replacement Instrumentation

SUPPLEMENTAL EARTH PRESSURE CELL WERE ADDED TO CONTRACT.

Why?

• Verify design assumptions.
• Define earth pressure nonlinearity.
• Capture vertical shear loading over time.
Monolith L22

10 New Pressure Cells
Monolith L11

14 New Pressure Cells
McAlpine Lock Replacement
Instrumentation

Proposed Construction Sequence L11

- Existing 600’ Lock South Wall
- New Storm Drain

- = Proposed Pressure Cell
- = Current Pressure Cell
- = Proposed Horizontal Pressure Cell
- = Current Strain Gauge
McAlpine Lock Replacement Instrumentation
McAlpine Lock Replacement
Instrumentation
McAlpine Lock Replacement
Instrumentation
McAlpine Lock Replacement
Instrumentation
EARTH PRESSURES DURING COMPACTION
McAlpine Lock Replacement Instrumentation

L11 Pressure Cell Readings (psf)
3FT OF Backfill at El. 408.5 With Compaction Effort

Overburden Pressure

Time interval (Minutes)
McAlpine Lock Replacement Instrumentation

L11 Pressure Cell Readings (psf)
Lower EP Cells with 3 ft and 7ft OF Backfill

- L11PC30
- L11PC31.pressure_psf
- L11PC32.pressure_psf
- L11_PC-12.pressure_psf

Pressure (psf)
Time interval (Minutes)
McAlpine Lock Replacement
Instrumentation

Vertical Shear

Existing Wall

Rock

Earth Pressure Cells to Record Difference in Vertical Pressures From Wall to Wall Over Time.

Additional Vertical Shear Resultant
**McAlpine Lock Replacement**

**Instrumentation**

**BASE PRESSURES**

**L11 Pressure Cell Readings (psf)**
Monolith Base Pressures with 3 ft and 7 ft of Backfill


**Time interval (Minutes)**

- 0
- 4000
- 8000
- 12000
- 16000
- 20000
- 24000
- 28000
- 32000

**Pressure (psf)**

- 0
- 400
- 800
- 1200
- 1600
- 2000
- 2400
- 2800
- 3200

- 3 ft of backfill
- 7 ft of backfill

**BASE PRESSURES**
McAlpine Lock Replacement
Instrumentation

K During Compaction

Compaction Effects

Phi = 32 (Design)

Arching?

Time (minutes)

K

K1

K2
Analysis Goals

1. Develop design charts and a simplified procedure for design future walls with similar conditions could be developed.
McAlpine Lock Replacement
Instrumentation

Questions?