

**Engineering and Design
FRACTURE MECHANICS ANALYSIS OF A
GRAVITY LOCK MONOLITH****1. Purpose**

This engineer technical letter (ETL) provides supplemental guidance on applying the principles of finite element analysis coupled with fracture mechanics to assess the safety and serviceability of existing concrete hydraulic structures (CHS). This guidance is intended to supplement that guidance provided in ETL 1110-8-16(FR).

2. Applicability

This ETL applies to HQUSACE elements, major subordinate commands, districts, laboratories, and field operating activities having responsibilities for the design of civil works projects.

3. References

- a. ETL 1110-2-22, Design of Navigation Lock Gravity Walls.
- b. ETL 1110-2-310, Stability Criteria for Existing Concrete Navigation Structures on Rock Foundations.
- c. ETL 1110-8-16(FR). Fracture Mechanics Analysis of Concrete Hydraulic Structures.
- d. Reich, R. W. 1992. *On the Marriage of Mixed Finite Element Methods and Fracture Mechanics: An Application to Concrete Dams*, Ph.D Thesis, University of Colorado, Boulder.
- e. Reich, R. W., Cervenka, J., and Saouma, V. E. 1991. *Merlin User's Manual*, University of Colorado, Boulder.

f. Stern, M., Becker, E. B., and Dunham, R. S. 1976. "A Contour Integral Computation of Mixed-Mode Stress Intensity Factors," *International Journal of Fracture*, Vol. 12, No. 3, pp. 359-368.

g. Zienkiewicz, O. C., Violette, J. P., Toyoshima, S., and Nakazawa, S. 1985. "Iterative Method for Constrained and Mixed Approximations. An Inexpensive Improvement of FEM Performance," *Computer Methods in Applied Mechanics and Engineering*, Vol. 51, Nos. 1-3, pp. 3-29.

4. Background

a. *Previous design practice.* Previous design practice for evaluating structural stability of CHS has been based on a static, rigid body equilibrium analysis. ETL 1110-2-22 and ETL 1110-2-310 were published as guidance for conducting such evaluation of existing navigation structures. Numerous safety and rehabilitation evaluations of existing CHS have indicated potential structural distress for project conditions which were not consistent with observations and measurements of satisfactory structural performance.

b. *Current practice.* Advances in modern structural analysis techniques including finite element analysis and fracture mechanics provide a more realistic basis for evaluation of existing CHS. ETL 1110-8-16(FR) was published to provide guidance on applying the principles of fracture mechanics to assess the safety and serviceability of existing CHS. This ETL is intended to provide supplemental guidance on finite element modeling and application of fracture mechanics for CHS. Appendix A provides guidance on modeling of uplift pressures acting at the base of a CHS and an example

including a detailed fracture mechanics based finite element analysis of a gravity lock monolith with a large culvert. Appendix B includes an analysis of the same monolith with the exception that the culvert is excluded. Appendix B is provided to show the effects that a large void such as a culvert may have on the analysis. Appendix C provides an example for the monolith of the example provided in Appendix A with the exception that uplift pressures along the base of the monolith are not included. Appendix C is provided to compare the traditional method of analysis with a simplified fracture mechanics analysis without uplift.

5. Objective

This ETL is the second of a series which will provide guidance on modern techniques for

FOR THE DIRECTOR OF CIVIL WORKS:

3 Appendixes
APP A - Fracture Mechanics Based Analysis
of a Gravity Lock Monolith
APP B - Analyses With No Culvert
APP C - Analyses With No Uplift

evaluating the stability and strength of existing CHS. This ETL provides supplemental guidance to that included in ETL 1110-8-16(FR) for finite element modeling and structural evaluation for CHS using a fracture mechanics based analysis.

6. Action

The guidance provided in the enclosures should be followed when conducting a fracture mechanics based analysis. A fracture mechanics based analysis should be performed according to the requirements of ETL 1110-8-16(FR).



PAUL D. BARBER, PE
Chief, Engineering Division
Directorate of Civil Works