Analysis of the Geodetic Monitoring Record of the Ladon Dam (Greece)

Stella Pytharouli, Villy Kontogianni and Stathis Stiros

Geodesy Lab., Dept. of Civil Engineering, University of Patras, Greece

GEODETIC MONITORING OF DAMS

• In the last 50 years there have been many cases of dam failure with high death toll even 200,000 dead and major destruction
• Geodetic Dam monitoring proved necessary to prevent or forecast such failures.
• Still very little is known about dam deformation
• Ladon dam is one of the very few dams for which a long geodetic monitoring record is available

Ladon Dam, Greece

type: concrete gravity dam
crested length: 101.5m
height: 56m
use: generation of electricity

Geodetic Monitoring System
• 6 monitoring stations on the crest of the dam and 2 control stations close to the abutments
• measurements of horizontal deflections and vertical displacements
• 30 years of monitoring record (1968 - 2001)

Horizontal deflections
Measurement of horizontal deflections of control stations along the dam crest from a straight line using a high accuracy theodolite

Vertical displacements
Measurement of relative elevations of control stations are relative to a reference station at the abutments using high accuracy spirit leveling

Results from 30 years of monitoring

ACURACIES
horizontal deflections: standard error: ± 0.7mm
vertical displacements: standard error: ± 1.3mm

Results
• Small-amplitude (up to 7mm) displacements, but statistically significant
• Fluctuations in the sense of displacements

Questions
• Is there a pattern in the observed movements?
• Are displacements controlled by hydraulic load (reservoir level fluctuations)?
• This means, is there a periodic signal in our displacement data?
• Is the period in both displacements and reservoir level change equal, implying a causative relationship?
**Data Analysis to answer these questions**

*Available Data*

- Horizontal and vertical deflections of 6 control stations on the crest of the dam covering the time interval 1968 – 2001 (not equidistant)
- Ambient temperature
- Reservoir level fluctuations

*We examined separately*

- The available data for control stations C3 and C4 in the middle of the crest of the dam for 2 time periods: April 1968 – February 1978
- April 1968 – October 2001

*Techniques we used*

- Autocorrelation function
- Lomb normalized periodogram

*Results of the analysis using Lomb normalized periodogram*

The sinusoidal-type of the autocorrelation function implies a periodicity in all data sets.

**Conclusions**

**Conclusion 1:**

The amplitude of the displacements is small up to 7mm, though statistically significant at $2\sigma$ and even $3\sigma$ precision levels for most stations.

Displacements are maximum at control stations C3 and C4 at the middle of the dam, as is expected in any dam.
Conclusion 2: 
The sinusoidal-type of the autocorrelation function in all 10 data sets of predicted values that were examined revealed that the displacements of the crest of the dam and the reservoir level are periodic.

Conclusion 3: 
The analysis based on the Lomb normalized periodogram method indicated that both horizontal deflections and vertical displacements correspond to periodic functions with a period of 12 months, equal to that of the fluctuations of the reservoir level (20m). This indicates a causative relationship between hydraulic load and dam deformation.

Conclusion 4: 
The analysis indicated that almost 50 years after its construction, the Ladon Dam keeps its structural integrity; a result consistent with the absence of water leakage and other evidence of failure (cracks, etc.).