Hydrostatic Leveling Systems: Measuring at the System Limits

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3 Applications at the system limits

<table>
<thead>
<tr>
<th>Hydropower Dam</th>
<th>Accelerator</th>
<th>Highway Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>differential pressure</td>
<td>half-filled pipe</td>
<td>differential pressure</td>
</tr>
</tbody>
</table>

FIG Congress 2010
Facing the Challenges – Building the Capacity
Sydney, Australia, 11-16 April 2010
**LAS-meter: Large Area Settlement**

- hydrostatic pressure
- membrane deformation
- autocalibration

**Albigna Dam: Calibration Data**

![Graph showing elevation difference over a year with labels for 'Inverse', 'Zero', and 'Normal' with winter, summer, and winter months marked.](image)
Albigna Dam: High resolution

Earth-Tides

Theory

Elevation Difference [microns/20m]

1 day

measured signal

Accelerator SLS: Paul Scherrer Institut
Girder SLS

![Girder SLS Diagram](image)

Schnott et al. 2000

Hydrostatic Leveling System HLS

Collaboration of EMP, geomETH, Winterthur, Stanford Linear Accelerator Center, Paul Scherrer Institute

**Levelsensor: Installation on girder**

**Section of the Levelsensor**
Liquid Loss -> No Error

![Graph showing liquid loss and no error](image)

- North (absolute)
- Global Average
- 1 day
- 0.005mm

Automatic Filling Station

- PSI SLS
- Remote Access
SLS: Deformation During Lunar Eclipse

Average values of sectors West, East, South, Nord

300 m

Sector Average and Single Signals

Average values of sectors West, East, South, Nord

Single signals sector West

FIG Congress 2010
Facing the Challenges – Building the Capacity
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Dynamic Bridge Monitoring with LAS

Broadening of a highway bridge near Lucerne
5 years security monitoring!

- Verification of model assumption
- Recording of long-term settlements
- Recording of Dynamic displacements
due to heavy trucks

Bridge: Long-Term Deformations
**Response Time**

**In-situ control of the time constant**

- **Height variation [mm]**
  - 100% final value
  - 63% step 5 mm
  - 0% start value
  - $\tau = 0.9$ sec = time constant

- **Time [sec]**
  - 0
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9

**Limits of differential pressure systems**

- **LAS Signal Nr. 3**
  - 5s
  - 30 [mm]
  - not possible!

- **Magnetic Signal**
  - [-]
  - for detecting cars

- **Horizontal - Acceleration**
  - 0.6 [mm/s²]
  - interference with „g“

- **LAS Signal filtered**
  - 5 [mm]
### When LAS and when HLS?

<table>
<thead>
<tr>
<th>LAS will be used, when:</th>
<th>HLS is used, when:</th>
</tr>
</thead>
<tbody>
<tr>
<td>the measuring spots are not accessible</td>
<td>long-term stability has priority</td>
</tr>
<tr>
<td>long electrical cables are vulnerable to lightning</td>
<td>all sensors lie on one level</td>
</tr>
<tr>
<td>the power input has to be small</td>
<td>angular measuring lines can be installed staircase-shaped</td>
</tr>
</tbody>
</table>

### Summary and conclusion

- Hydrostatic leveling systems have always to be adapted to the environmental conditions.
- In the field of dynamic systems further research is still needed.
- The bridge near Lucerne offers the possibility. Who is interested, is cordially invited!

Thank you for listening!