

## DISTRIBUTED FIBRE OPTIC TEMPERATURE SENSING

**Monitoring of Dams, Dikes, Hydraulic Structures** • Early detection and exact localisation of leaks in sealing systems in the field of hydraulic engineering are the most important prerequisites for a pinpointed and inexpensive rehabilitation. If leaks are not detected in time internal erosion processes could damage the construction severely.

Since 1955 soil temperature measurements are used for the surveillance of dams and dikes. Using temperature soundings (Pat. No. DE 4127646) over 500 km of dams throughout Europe have been investigated successfully upon leakage by GTC since 1991. The percolation of water through the sealing system of a dam is always combined with a heat transport. Therefore, percolated dam areas stand out during summertime as positive ground temperature anomalies and during winter time as negative ground temperature anomalies on the northern hemisphere.

Modern fibre optic temperature sensing methods enable temperature measurements along an conventional optical fibre of up to 110 km of length. Therefore, they are extremely suitable for the surveillance of dams, dikes and other hydraulic structures. Integrating an optical fibre already in the structure of a new construction or within the scope of a rehabilitation, the temperature can be measured readily along the inexpensive optical fibre and emerging leaks can be detected exactly.



*Midlands Dam, rockfill dam, Mauritius  
Leakage detection at the joint asphaltic facing / cut-off wall*

The amount of large-scaled conventional monitoring systems could be reduced considerably.

GTC and VAO Research Institute for Hydraulic Engineering of Technische Universität München have performed detailed investigations concerning the feasibility of fibre optic temperature sensing for the scope of leakage detection. The entire measurement method was tested successfully under construction conditions at the VAO test site.

In co-operation with the "e-on Wasserkraft GmbH" more than 1.5 km of fibre optic cable were deployed underneath the asphalt membrane during the rehabilitation work at the "Mittlerer Isar" hydro power supply canal in Munich. This worldwide first application in hydraulic engineering is already every day practice.

At the ship-turnout Eberswalde at the Havel-Oder canal geotextile bentonite blankets were used for the first time as a sealing system in a navigational canal. To monitor the sealing efficiency of the bentonite blankets a fibre optic temperature sensing system was installed and taken into operation by GTC together with the "Wasser- und Schifffahrtsamt" (navigational service) in Eberswalde and the "Bundesanstalt für Wasserbau" (Federal Waterways Engineering and Research Institute, Germany).

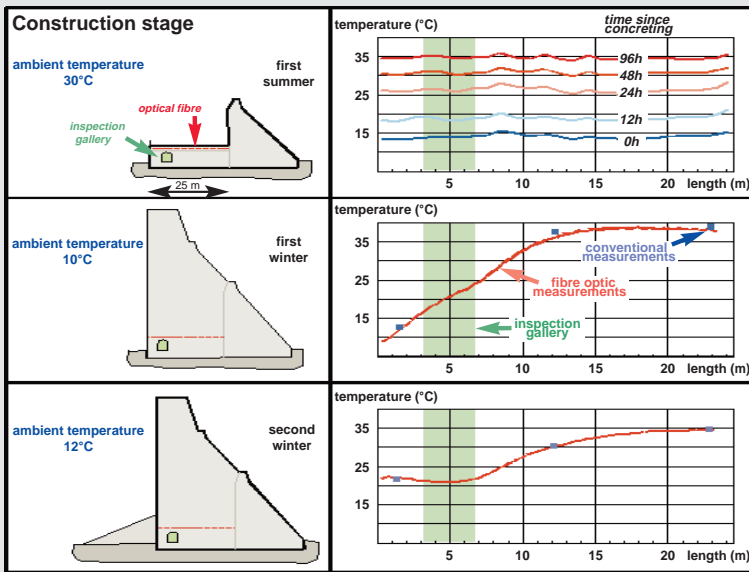
During the rehabilitation of the asphaltic facing of the Ohra dam in Thuringia a fibre optical system was integrated into the drainage layer of the new double layered surface sealing. Due to the lack of a natural temperature difference the heat pulse method is applied for leakage detection by using a hybrid fibre optical cable. The new 200 m long ship-lock of Hohenwarthe is equipped with a fibre optical leakage detection system involving more than 7 km of hybrid cable. To give only a few examples out of more than 25 applications.

**Method Description** • The method of distributed fibre optic temperature sensing was already developed at the beginning of the eighties for the surveillance of power cables. Along fibre optical cables of 10 km of length a measurement accuracy of up to  $\pm 0.2^\circ\text{C}$  and a spatial resolution of up

to  $\pm 0.5$  m can be reached. During the last years the method was developed further and is now applied in many industries.

Fibre optic temperature sensing works by sending a short laser pulse ( $< 10$  ns) down an optical fibre. The determination of the temperature is performed with the help of Raman spectroscopy on the backscattered light. The temperature is calculated from the Stokes to anti-Stokes intensity ratio. Exact localisation of the measurement point results from a precise time measurement under consideration of the propagation velocity of light in the optical fibre. The method delivers a temperature profile along the entire optical fibre.

**Surveillance of the curing temperature in concrete** • The fibre optic sensing method was applied for the first time as a leakage detection instrument in hydraulic engineering in 1997 by GTC. The method is as well suitable to monitor curing temperature in conventional mass concrete and RCC dams.



Temperature development in a 20 m long section of the Birecik gravity dam (Turkey), built by SIRABAG, Philipp Holzmann AG and GAMA

The development of the curing temperature in concrete, e.g. in the construction of dams, is crucial for the occurrence of thermal stresses and the thereof resulting cracks. With the aid of fibre optic temperature sensing it is now possible to record the temperature distribution at low costs over thousands of spatially distributed points at the same time.

Using hybrid fibre optical cables the Heat Pulse Method can be applied to estimate the distribution of the thermal conductivity and the specific heat of the concrete along the cable in situ.



Installation of the fibre optical cable in Shimenzhi RCC dam (P.R. of China) in 2000

**Fields of Application**

- Leakage detection and seepage monitoring in dams, dikes and other hydraulic structures
- Monitoring of curing temperature in conventional concrete and RCC dams
- In situ estimation of thermal parameters of concrete
- Analyses of thermal stresses in dams
- Estimation of seepage flow velocity
- Thermal fluid-logging in boreholes
- Detection of leaks in pipeline systems
- Surveillance of tailings dams and waste water lagoons
- Fibre optical thermal response tests

**References: Leakage detection**

- HYDRO POWER SUPPLY CANALS
  - Alzkanal, Degussa AG
  - Canal d'Oraison, EdF Marseille, F
  - Mittlerer Isarkanal, reach 1 + 4b e.on Wasserkraft GmbH, D
- EARTH AND ROCKFILL DAMS
  - Beveralsperre, Wupperverband, D
  - Fish pass, Rhine dam Iffezheim, EnBW, D
  - Flood regulation dam, Waldbach, A
  - Midlands Dam, Ministry of Public Utilities Mauritius
  - Ohratalsperre Thüringer Talsperrenverwaltung, D
  - Power station Gabersdorf Mur embankment dam, Verbund AHP, A
  - Pump storage scheme Hohenwarte II Vattenfall Europe Generation AG & Co.KG, D
  - Talsperre Bautzen, Landestalsperrenverwaltung Sachsen, D
  - Winscar Reservoir, Yorkshire Water Plc, UK

**CONCRETE DAMS**

- Brändbachtalsperre Stadt Bräunlingen, D

**NAVIGATIONAL CANALS**

- DEK, sector 15, WSA Rheine, D
- HOW reach "Alte Fahrt G" and ship-turnout Eberswalde, WSA Eberswalde, D
- MLK ship-lock Hohenwarte and reach S 12 WNA Magdeburg, D

**References: Concrete monitoring**

- Birecik, gravity dam South East Anatolia, Turkey
- Mujib, RCC dam, Jordan
- Shimenzhi, RCC dam, P.R. of China
- Wala, RCC dam, Jordan