MICRON OPTICS

Monitor Optics Systems

RTA New South Wales Government

bhpbilliton resourcing the future

Case Study

Road Pavement Monitoring

July 2007

Road Pavement Monitoring

Aim	As part of investigations into the safe management of future mining beneath the Hume Highway, the Roads and Traffic Authority of NSW and BHP Billiton Illawarra Coal have successfully used optical fibers to monitor mining-induced strains in a road pavement. This was the first documented use of fiber sensors in this way.
Location	Wilton Road, Appin, Australia
System Integrator	Monitor Optics Systems, Ltd., Australia
End Customer	Mine Subsidence Engineering Consultants, Australia
Date	July 2007
Instrumentation	(1) Micron Optics sm125, Optical Sensing Interrogator
Sensors	FBG Distributed Temperature Sensor Cable (5 FBGs) FBG Distributed Strain Sensor Cable (10 FBGs)
Software	System Integrator Designed, LabVIEW-based
FBG Technology Benefit	The FBG technology was selected based on its affordability, proven performance in structural engineering and the relatively short lead-time required to customize and deploy a complete monitoring solution that includes data management.

Road Pavement Monitoring, Description

- Road pavements have suffered impacts in the form of structural distress resulting from mine subsidence movements and mining-induced ground strains. Much of the ground strain is transferred to the pavement through the ground movement and interface friction between structural layers.
- Monitor Optics Systems has developed a method of embedding one or more optical fibers into a Glass Fiber Reinforced Composite (GFRC) cable.
- These cables can be up to kilometers in length, are readily deployed in the field and provide a very high level of protection to the optical fiber while maintaining its sensitivity to changes in temperature and strain.

1 km long, 1 mm diameter cable

Road Pavement Monitoring, Description

- The monitored road was subjected to mine subsidence movements during the mining of Longwall 302 at Appin Colliery, which is located in the Southern Coalfield of New South Wales. The site is approximately 90 kilometers southwest of Sydney.
- Wilton Road is a two-lane road with an asphaltic concrete (AC) pavement at this location. Four core samples were taken and these indicated a 14 mm chip seal above multiple layers of AC10 and AC14 of depths between 90 and 180 mm, with 100 mm thick sub-base of unbound or bitumen stabilized crushed rock, and a select sub-grade layer of crushed sandstone.
- Optical fiber sensors were placed in the asphalt layer approximately 5 cm below the surface along a 90 meter long section of pavement on this road.

Photograph courtesy Roads and Traffic Authority of NSW

Road Pavement Monitoring, Installation

- The cables were fixed to the pavement with an epoxy resin called Megapoxy CT5.
  - The selected epoxy is used by the RTA for other road installations and in the airline industry for runway lighting.
  - The epoxy is resistant to physical damage and is colored black.
  - The epoxy was poured into the groove and trowelled smooth.
- The sensor cables were placed directly above Longwall 302 at the locations shown in the picture below. The FBG strain sensors are shown as yellow dots, the FBG temperature sensors are shown as blue dots and the ground survey pegs are shown as purple dots.

Location of Installation

Road Pavement Monitoring, Installation

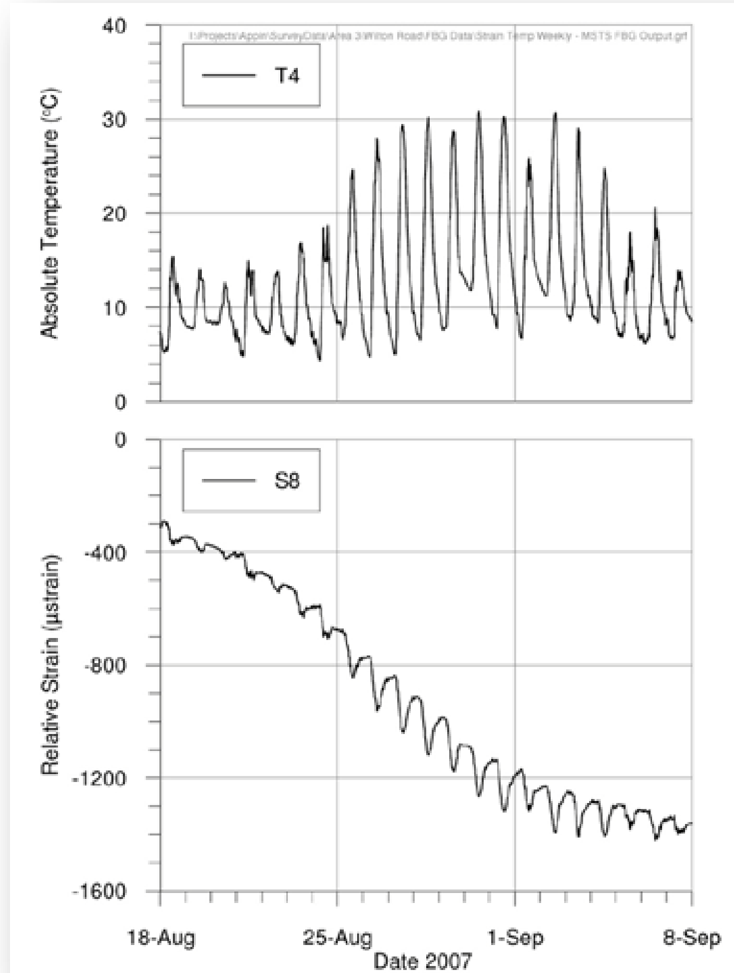
- The sensors were embedded into the pavement in July 2007.
  - A groove of approximately 8 mm wide and 20 mm deep was saw cut into the pavement along the center line of the eastbound lane.
- The following cables were manually placed into the groove via spool reels:
  - One Distributed Strain Sensor Cable of 1mm diameter containing 10 FBGs at 10 m spacing.
  - One Distributed Temperature Sensor Cable of 5mm diameter containing 5 FBG temperature sensors at 20 m spacing.
- The epoxy resin was poured around the two 1 mm diameter cables in one application.

Road Pavement Monitoring, Installation

- Temperatures are accurately measured at strain sensing locations for determining thermally induced strains.
  - The temperature sensors were placed within 300 mm of the strain sensors.
- The sensor cables were terminated in a buried pit at each end, located just beyond the pavement shoulder.
  - The cables at one pit were connected to signal carrying cables that were connected to an interrogator housed in a secure container.
  - The cables at the second pit were coiled up and prepared for future connection should some or all of the cables experience a break during mining.
- The installation of the optical fiber cables was very successful and all FBG sensors were operational.
- A Micron Optics sm125 (see photo) instrument was used in the field for its proven reliability and accuracy.

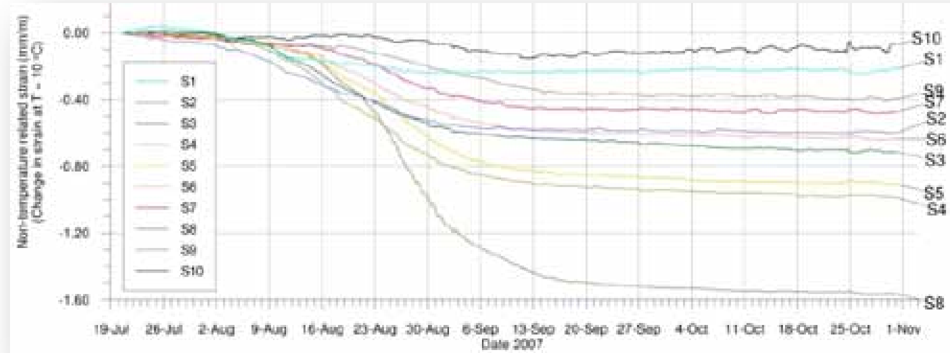
Road Pavement Monitoring, Data Results

- Monitor Optics Systems (MOS) recorded readings taken at 15 minute intervals. Ground surveys were conducted at weekly intervals.
- MOS converted the raw FBG output into temperature and strain.
- The output shows the results from one strain sensor (S8) and the temperature sensor (T4) at a time in which subsidence was most active during the project.
- It can be seen from the results that both temperature and strain follow a diurnal pattern and that a compressive strain is building up due to subsidence from mining.

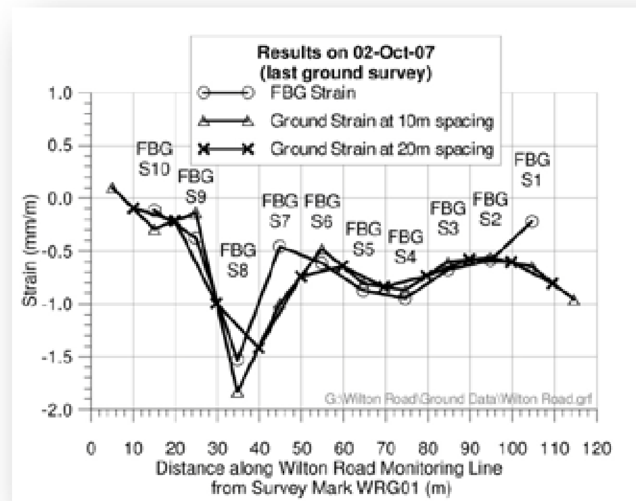


Road Pavement Monitoring, Data Results

- Computer programs were used to automate the data collection and analysis during the mining period.
- Mining-induced strains were calculated every 15 minutes and the results are shown in the graph.

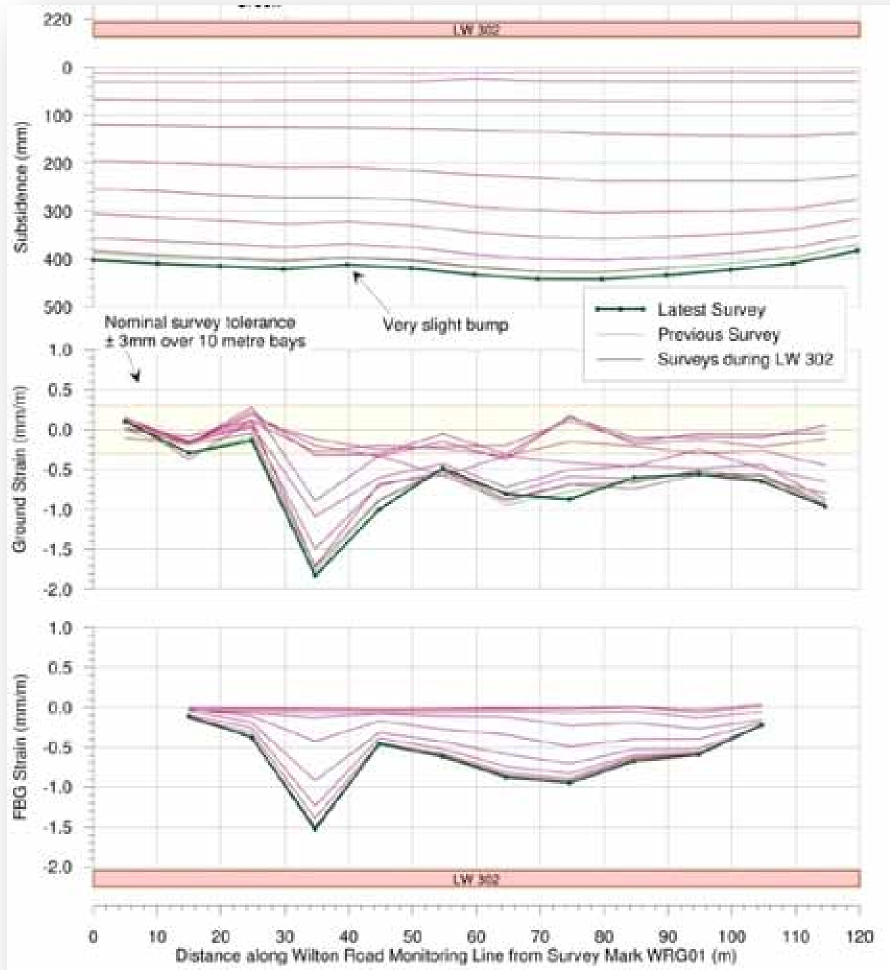


- Calculations were made over 20 meter bay lengths and correlation between ground strain and FBG strain is good for either bay length.
- The good correlation indicates that full transfer of ground to pavement strain occurs with little or no redistribution of strain along the pavement.



Road Pavement Monitoring, Data Results

- A comparison between subsidence, ground strain and calculated mining strains from the FBG results (FBG strain) along Wilton Road.



Results & Acknowledgements

- Results & Conclusions
  - The optical sensing monitoring conducted at Wilton Road has successfully demonstrated that Distributed FBG Sensor Cables can reliably be used to measure mining-induced strains in a road pavement as the sensors and monitoring system remained stable throughout the monitoring period.
  - The results indicated a very good correlation between ground and pavement strain at all times.
  - Comprehensive pavement risk management requires that the FBG-based monitoring is conducted in conjunction with other monitoring such as ground survey and visual monitoring.
  - FBG sensors cannot properly measure strain unless the optical fiber cable is adequately fixed to the substrate at the sensor locations which was successfully achieved during this application.
  - The sensing network can incorporate tens, hundreds, or even thousands of FBG sensors distributed over large distances. Based on the success of this project, larger installations of this type are now planned in Australia.

- Acknowledgements
  - BHP Billiton Illawarra Coal , Australia
  - Roads and Traffic Authority of NSW, Australia
  - Mine Subsidence Engineering Consultants, Mine Subsidence Board, NSW, Australia
  - Monitor Optics Systems Ltd.,email:info@monitoroptics.com, web: www.monitoroptics.com
  - Micron Optics, Inc., email: info@micronoptics.com, web: www.micronoptics.com