Advancement in Tunnel Lining Monitoring Using Fibre-Optic Distributed Sensing

TUNNELLING AND UNDERGROUND SPACE TECHNICAL DIVISION

reported by
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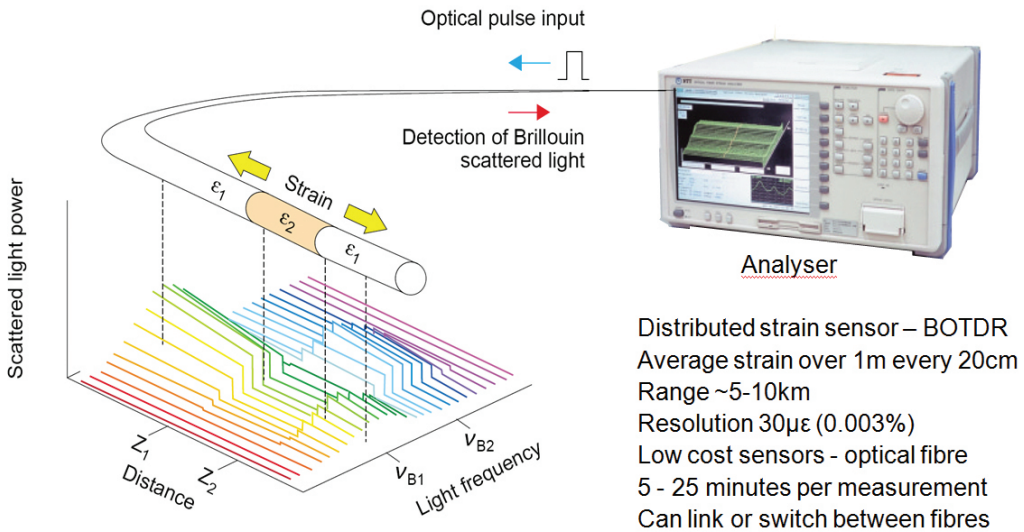
The Tunnelling and Underground Space Technical Division (TUSTD) organised an evening talk on "Advancement in Tunnel Lining Monitoring using Fibre-Optic Distributed Sensing" on 25 May, 2016, at the C&S and TUS Lecture Room, Wisma IEM. The talk was delivered by Associate Professor Ir. Dr Hisham Mohamad from Universiti Teknologi Petronas. There were a total of 35 participants.

First, Dr Hisham gave a brief introduction to tunnel-induced ground movements and various in-tunnel instrumentation schemes available such as Automated Total Station, accelerometer, crackmeter, tilt beam and strain gauges. However all the systems are primarily limited to discrete or localised sensing. Then, he presented a novel approach to monitoring tunnel lining deformation and crack detection in a distributed manner, where a single optical fibre cable can potentially replace hundreds of point-wise sensors and detect tunnel movements of kilometres in length in a cost-effective manner. This technology is called Brillouin

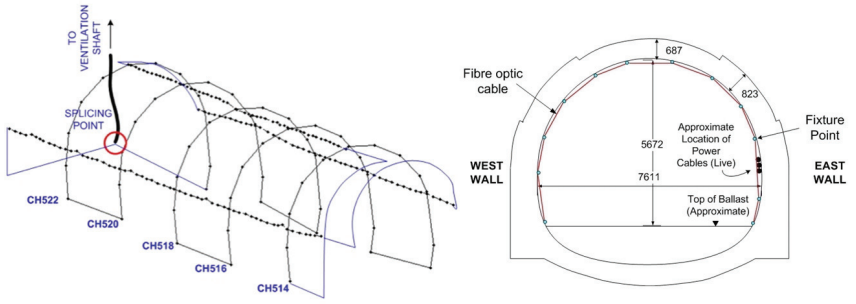
The speaker, Assoc. Prof. Ir. Dr Hisham Mohamad

Optical Time-Domain Reflectometry (BOTDR) or Brillouin Optical Time-Domain Analysis (BOTDA).



The frequency shift of the Brillouin scattered light is proportional to the strain.

Distributed strain sensor – BOTDR
Average strain over 1m every 20cm
Range ~5-10km
Resolution 30με (0.003%)
Low cost sensors - optical fibre
5 - 25 minutes per measurement
Can link or switch between fibres



Optical fibre sensing in general relies on the interaction between laser light and glass material in an optical fibre. Strains and deformations alter the refractive index and geometry of the optical fibre material. These changes perturb the intensity, phase and polarisation of the light-wave propagating along the fibre. A complete strain profile along the full length of the fibre can be obtained by resolving the back-scattered signal in both time and frequency, which is shifted by an amount linearly proportional to both the temperature and strain applied at the scattering location.

Dr Hisham said a particular advantage of optical fibre technology is that low propagation losses can be obtained with a single-mode optical fibre, which means the strain can be measured along the full length (up to 10 km) of a suitably installed optical fibre by attaching a BOTDR analyser at one end. He further discussed the various types of distributed fibre optic sensing and gave a comparison of the various strain sensor technologies.

From the many applications of distributed fibre optic sensing in civil engineering for smart infrastructure, the talk focused on tunnel monitoring. Case experiences of tunnel monitoring at London's Channel Tunnel Rail Link (CTRL) and Singapore's MRT Circle Line were presented in detail. Other examples of recent implementations of BOTDR/A fibre optic monitoring were National Grid London Cable Replacement Tunnels in the UK, Telecom tunnels and NATM tunnel of Tokyu Toyoko Line in Japan. Its application in monitoring ground movement caused by pipe-jacking was also briefly discussed. These examples of distributed optical fibre sensing illustrate the advantages of the technique, compared with conventional instrumentation devices, owing to its ability to monitor both the overall deformation of the structure and the detection of local movements such as cracking.

Dr Hisham ended his talk by highlighting issues and challenges faced in the development of optical fibre sensing technology for civil engineering application. He fielded several questions from the floor before the talk ended with a round of applause. The Chairman of TUSTD, Ir. Syed Rajah Hussain Shaib, presented Dr Hisham with a token of appreciation. ■