Note Title 4/24/2018

Module 3

Lecture 2: Fibre optic sensors

Additional reading can be seen at

K. Brener, M. Wollweber, F. Weigand, M. Rahlves, M. Kuhne, R. Helbig, B. Roth. (2016). Fibre optic Sensors for Structural Health Monitoring of buildings, Procedia Tech, 26: 524-529.

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FoS are contrast to Electric sensors

- FoS use Electro-magnetic interference to read/measure data
  - Electric sensors use Electric pulse
- Due to low-light attenuation of optical glass fibres (FoS), these sensors can be used in several kilometers long
  - Electric sensors have serious limitations

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Classification of FOs

depends on various parameters.

1) Light characteristics (Intensity, wavelength, phase or polarization etc)
   - These characteristics are modulated by the parameters to be measured

2) classification is also based on whether light, in the sensing segment is modified inside or outside the fibre (intrinsic or extrinsic)

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(3) They are also classified based on:

- ✓ local
- ✓ quasi-distributed (Fibre-Bragg Grating, FBG)
- ✓ distributed sensors (Brillouin scattering distributed FOS)

(4) Based how are they are installed

- generally they are surface-mounted
- embedded also

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FOS use in measurement of moisture ingression

Moisture ingression is one of the major problems in buildings

- It is very difficult to measure this data
  - difficult to identify the source of moisture ingression
  - path of propagation — surface phenomenon

FOS can be used to identify/solve the location problem of moisture ingression

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(1) FOS used moisture ingression

- consists of a swellable polymeric fibre optic sensor
- used to measure distributed moisture formulation
- This sensor works in combination with optical time-domain reflectometer to determine the spatial location of moisture ingression
- This measures/identifies the point of moisture ingression by attenuation principle.

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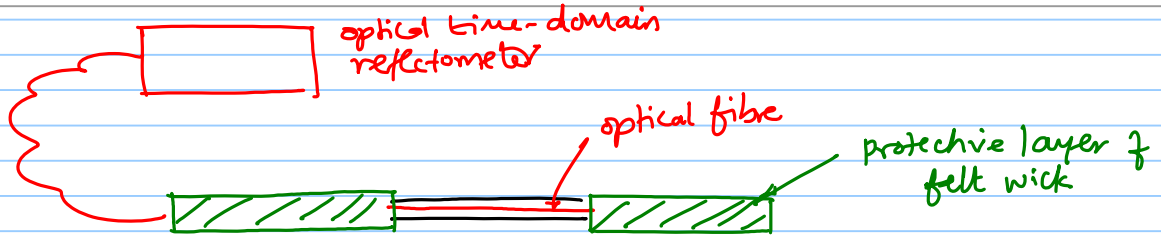

- Device consists of an optical fibre (red color), a polyvinyl alcohol hydrogen rod, which is embedded inside a protective felt
- Device can sense micro-bending of fibres
- Hydrogel has a characteristic of swelling in the presence of water.
  - without dissolution
  - This causes the optical fibre to undergo micro-bending
- micro-bending of the fibre causes / interfers with attenuation of light, which is transmitted thro the fibre

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(2) FOS used as single-point Relative Humidity sensor

- It is made of polymide coated Fiber - Bragg Grating
- Due to the wavelengths, encoded relative humidity readings are measured by the sensor
- FBG sensors are coated with polymide coating to protect them
- several such sensors can be used in UL to measure RH.

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- This device consists of Fibre Bragg Grating coated with polymide
- This acts as a hygroscopic coating that swells in the presence of water vapour, due to absorption of water molecules.
- This causes strain in FBG sensor, which depends on the applied relative humidity (RH), linearly
- By tracing the reflected Bragg wave length, RH values the location (where the sensor is placed) can be measured
- Typical locations, RH can cause material degradation to large extent
- useful to plan preventive maintenance, monumental buildings

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(3) Fibre-optic Crack sensor

- This sensor is used to locate the cracks (flexural cracks) in beams and slabs of building
- optical fibres, are integrated into a textile mesh structure
  - designed to transfer elongation due to cracks developed on the structure to the optical fibres
- Since failure strain of optical glass fibre is relatively low, integrated optical fibre will break even under the formation of small cracks
- with the help of optical time-domain recorder, Cracks are located

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Integration of optical fibre into the textile structure can be done in (2) ways

- stitching
- knitting

principle objective of fabrication is to minimize losses due to bends
- therefore to obtain the best quality

- Alternatively, optical fibres are also used to monitor shape of crack tip in concrete members (Rossi & Le Maou)
- principle followed behind the application is that network of optical fibres break when cracks propagate in the member, intersect these fibres

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They are very helpful to locate the cracks

- optical fibres, can be laid in a zig-zag manner @ the bottom of concrete beam to detect flexural cracks
- When the cracks open in the member, optical fibres, intersecting the crack @ angle other than 90° had to bend.
  - This sudden bending of the fibres causes optical power loss, indicating location of the cracks

(Leung et.al)

- This method is suitable to detect cracks of smaller size (0.1mm)
- fibres should be laid inside concrete, such that these fibres should be free to slide inside concrete

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(4) FOS - used to detect cracks in composites

self-monitoring technique

(Addl reading :

M. Sun, W.J. Staszewski, R.N. Swamy, (2010).

Smart sensing technologies for SHM,

Advances in Civil Eng, 2010.

FOS. contain an Electric Conductive phase such as

Carbon fibre & the conductive power is carried

on polymer matrix

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- These sensors can monitor their own strain, damage and temperature variation effects by the embedded (reinforced) carbon fibres

- self-monitoring sensors

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Composite	Electric conductive material	Matrix
1) Carbon fibre reinforcement concrete (CFRC)	- Short carbon fibre - $L < 10$ mm < 0.5 vol.%)	Cement, mortar, concrete including admixtures
2) Carbon fibre reinforced polymer (CFRP)	- Short carbon fibre $L < 10$ mm - continuous carbon fibre	Resin curing agent

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(3) Carbon fibre glass fibre reinforced polymer (CFGFRP)

Continuous carbon fibre (< 0.5 vol %)

resin
curing agent

(4) Carbon powder dispersed in glass-fibre reinforced plastic

Graphite carbon powder (0.15 vol %)

Average particle diameter = 5 μm

resin
curing agent

They are also examined only in the Lab Scale. Real time application is yet to happen, its large surface area.

Magnetostrictive sensors

- Ferromagnetic materials when placed in magnetic field are mechanically deformed
  - This property is called magnetostrictive effect

- In the reverse, magnetic inductn of material changes when the material is mechanically deformed.
  This is called inverse magnetostrictive effect

These sensors are useful to detect voids in concrete filled steel pipes

- These sensors could generate guided waves of different modes propagating along lengths of the pipe
- These waves are then sensitized to the defects in the pipe
  - They detect the damage
- Received wave amplitude decreases with the increase in voids and inclusions

That indication is useful to detect damage in concrete-filled pipes

Major disadvantage is that the ultrasonic energy emitted is very low in strength

- This can be improved by combining this sensor with other piezo-electric sensors

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Summary

FOS — classification

— (4) – (5) types:
- moisture
- crack detection
- concrete-filled

(moisture, crack detection, concrete-filled) – unique application

— Lab scale – tested – by real-time application – has yet to happen

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