Note Title 4/3/2018

Module 1 Lecture 7

SHM issues - as applied to concrete structures

Note Title 4/3/2018

issues as applicable to concrete structures

- They are affected by a variety of issues

- Being a heterogeneous material, issues are further complicated

Strength degradation,

(i) chemical
(ii) physical
(iii) Mechanical

Degradation

examples

- chloride penetration
- sulphate attack
- carbonation
- freeze-thaw cycles
- shrinkage
- Mechanical loading

chemical degradation

- includes essentially
  - corrosion of steel
  - chloride penetration
  - carbonation
  - leaching of concrete
  - acid attack
  - sulphate attack
  - alkali-aggregate attack

Note Title 4/3/2018

Physical degradation includes

- temperature variation and associated thermal expansion / contraction
- variation of relative humidity and associated with drying shrinkage / wetting expansion
- frost attack
- wear & tear
- abrasion

Mechanical degradation

- externally applied overload or impact load
- cyclic fatigue loads
- differential settlement of foundation
- seismic activity

Influence of these degradation on concrete (construction material)

- It can alter porosity and permeability of concrete
- It can further initiate (or) aggrevate different material flaws
  - scaling
  - spalling
  - swelling
  - debonding
  - cracking
  - disintegration
- It can impair water tightness of concrete member
- It can reduce the load capacity of the member

Note Title 4/3/2018

Major challenge is that

damage under different deterioration processes accumulates @ different rates

- time-scale variations of these degradations are different
- They get integrated/mixed to alter behavior of concrete

There will be a multi-physics degradation process

- special type of analysis, which can account for different time scales in different process of degradation

Note Title 4/3/2018

Solution

- If a numerical analysis is required to be carried out, then governing differential Equation should account for the Coupled physical & chemical process dependency

- It should characterize the following
  - mass – energy balance
  - Thermodynamic & chemical Eqm of the coupled heat conduction, ionic diffusion, moisture transport phenomena & the corresponding chemical reaction

What is the major factor that contribute to degradation of concrete

ordinary concrete posses <u>high</u> porosity and <u>low</u> permeability

inter-connected pores (micro-pores) & micro-cracks in concrete contribute to the permeability

- This makes concrete more vulnerable for <u>deterioration</u>

Rheology & crack structure of concrete – <u>complex</u>

Note Title 4/3/2018

Non-Destructive Evaluation (NDE) - concrete structures

Clayton D. 2014. NDE testing for Nuclear power plants & concrete structures, Light water Reactor sustainability Newsletter, 14, U.S Dept. of Energy

- shear wave ultrasound
- Ground penetration radar
- Impact echo
- Ultrasonic surface wave
- Ultrasonic Tomography

Note Title 4/3/2018

In addition, for large-volume structures, we can also use Full-Field Imaging technique

- Example
  - gravity-based offshore platforms
  - Nuclear reactors
  - etc

Full-Field imaging techniques - concrete structures

(1) Infra-red imaging

- It tracks the thermal load path in a material, travelled longitudinally over a period of time

Note Title 4/3/2018

onset changes is the path (load path)
changes the composition of material
which is an indication of the mechanical
damage caused to the material

- This method can be also combined with stand-off
Acoustic sound pressure technique
to quantify the extension of damage

- Material is insonified with acoustic source
- full-field vibro-Thermograph measurements
are recorded to characterize
the material

(2) To measure the thermal response under an applied uniform heat flux

Thermal gradients in the material are analyzed to identify the non-uniform material composition

- essentially arises from the material defect

(3) Digital Image correlation (DIC) technique

- useful to detect micro-cracking in the chopped fibre-glass compressive moulded parts

- DIC image shows principal strains in the damaged region, where cracks are formed.

- This method is useful to detect localized residual stresses, which are caused in the material on removal of load

- This can also be used to track the strain variations that occur under temperature variations

(4) <u>Velocimetry</u>

is useful to detect the sub-surface nonlinearity caused due to material damage

For example,

when a composite structure is subjected to ambient vibration, change in ϵ variations can be analyzed to detect the damage

Damage indices Quantify

degree of non-linear stiffness

non-linear dampin

which are observed locally @

each measured point on a grid of

the member

Key issues in choosing STM system (Summary)

STM system – is not a commodity to purchase
but
need to be designed and developed
– Problem – specific
and cannot be a
generic system

High Engineering cost
lack of resource availability

makes no choice for the
designer except to
choose one of the existing
stem systems

Most of the SHM system rely on the point sensors

- which obtain data @ only one point to monitor

There are a few limitations

(1) Limitations are not about their accuracy & reliability but it's insight

Event that occurs between the critical points where point sensors are installed

major information about the health will be lost

(2) Data normalization

- process of seperating the data occured from different changes in the behavior of the structural system

sensor output contains a combined information which is very complex to seperate

complex is due to linear combined representation

- include damage caused by environmental
- structural/ material degradation

Non-continuous monitoring will not be helpful to normalize the data

Solution

Fiber optic sensors

- Application example of FOS is established by the company SENSURON (Europe)
- FOS can be fully automated to detect the local damage through continuous monitoring
- system relies less on the interpolation of data
- since the data is continuous, it is also easy to

attribute the changes that arise from various conditions

- environmental factor || time - scale
- material degradation

- continuous monitoring can separate them easily

- FOS - long - term benefit
    - easy to use

Summary - SHM - concrete structures
    NDE - concrete structures - large-volume
    - FOS - their advantages