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Module 2

Lecture 2 : local and Global monitoring

local monitoring refers to observations local phenomena & other local effects like

crack initiation
crack propagation etc
extraneous strain

- local monitoring is carried out ND Tests
- local monitoring is helpful to determine severity of damage
- mostly it is very useful in lab scale when certain parameters need to be controlled

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Ex:

modeling . a girder of deck of the bridge under traffic load (rolling loads)

- need to control speed of load movement etc

Global Monitoring

- will focus to determine deformations (large displacements) under excessive loads, when the structure is vibrating

- Usually, modal parameters like

frequency
mode shape
damping estimates

are measured

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They are then correlated with the analytical studies to identify/quantify the damages on the structural system.

Static & Dynamic monitoring

Variation of parameters like

- deflection
- inclination
- settlement of foundation
- crack width
- corrosion of rebar

$\Bigg\}$ slow-varying process need to be carefully monitored

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Simultaneously, changes can be also be caused due to Environmental conditions such as:

- temperature variation
- humidity
- wind force/direction
- current on wave etc
- wave force/ heights & direction

Both of these set of effects, put together can sometime exhibit a Quasi-static behavior

- While monitoring these parameters, we should measure avg the peak value, which is observed over a long-period of time
  - This kind of monitoring as Static monitoring

Dynamic Monitoring

- This kind of monitoring is carried out with a higher sampling rate
- Dynamic monitoring is used to obtain variation in structural characteristics under dynamic load effects

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Phenomenon	Monitoring strategies	Sensor types
(1) foundation settlement	local	LVDT
	continuous	Laser
	static monitoring	Hydro-static leveling system
	long-term monitoring	All types.
(2) Displacement	- Global monitoring	LVDT
	- short-term monitoring long-term monitoring	Laser
	periodic or triggered monitoring	GPS

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(3) Inclination & rotation	- local	inclinometer
	- short-term / long-term	(uniaxial / biaxial)
	- continuous	
(4) Crack detection	- Global	FOS
	- dynamic	
(5) Crack width	- local	LVDT
	- periodical	crack sensor
	- static	

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(6) Vibration

- Global
- short - term
- periodic
- Dynamic

Accelerometers (uniaxial, biaxial triaxial)

(7) corrosion

- local
- continuous
- static monitoring

- scanning sensors
- embedded sensors

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Data Evaluation and Assessment

- once, data is collected from the sensors, it need to be processed to evaluate the condition of the structure

- one of most common methods of evaluation is using probabilistic tools

- performance of the structure, need to be upgraded - out come of the assessment of SHM
  - under economic constraints, if the revised design of the structure shows higher safety
    - then we should check this assessment using Reliability tools

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Reliability-based classification is also important in such cases

S. Chandrasekaran. Risk & Reliability of offshore structures, NPTEL, IIT Madras

S. Chandrasekaran. 2016. Risk & reliability of offshore structures, CRC press, USA

For satisfactory performance of the structure, follg condition should be satisfied:

$$R \geq S$$

where R : resistance of the structure

S : load effect on the structure

To obtain load effect on the structure, distribution of loads, in terms of

- location
- intensity
- time/space dependence
- direction etc

variations that time dependent need to be known

This can be obtained readily from continuous monitoring data

Target Reliability Index (β), which is useful in assessing the condition of the structure is estimated

A Table is recommended by ISO: 13822, also is the Basis for design & structural assessment of existing structures

Limit state	β	Reference period
a) serviceability		to calculate remaining service life
i) reversible	0	
ii) irreversible	1.5	
b) fatigue		- remaining service life of the st
i) can be inspected	2.3	
ii) cannot be inspected	3.1	
c) ultimate		To design for service life of the st (about 50 y)
i) very low consequence of failure	2.3	
ii) low consequence of failure	3.2	
iii) medium "	3.8	
iv high consequence .	4.3	

Relationship b/w (β) & P_f.

$$\beta = \Phi^{-1}(P_f)$$

P_f	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
β	1.3	2.3	3.1	3.7	4.2	4.7	5.2
Safety class				1	2	3	

In general P_f is given by: $\quad P_f = P(R - S \leq 0)$

where (R, S) are stochastic variable

But, as the structure with same classification are designed for equal load with different material,

design codes recommend partial coeffs

Design value (f_d) will be based on
partial factor for material
partial factor for load effects
modeling uncertainties
& load estimate error

$$f_d = \frac{f_k}{\gamma_m \gamma_n} \frac{k}{\eta}$$

f_k = stress capacity, which is reduced by the factors (γ_m) & (γ_n)

k = load capacity factor

η = model uncertainties, effects accounting for scaling up the lab-scale results & full scale structures.

Summary

- local & global monitoring
- static & Dynamic monitoring
- different sensor - different phenomenas
  states of stry
- Data assessment & Evaluation
- Reliability tool to assess condition of the structure
- P_f - linked to β - partial factors in design.

Ref:

Arvid Hejll 2007. Civil structural Health Monitoring - strategic methods and applications, Lulea University of Technology, Sweden

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