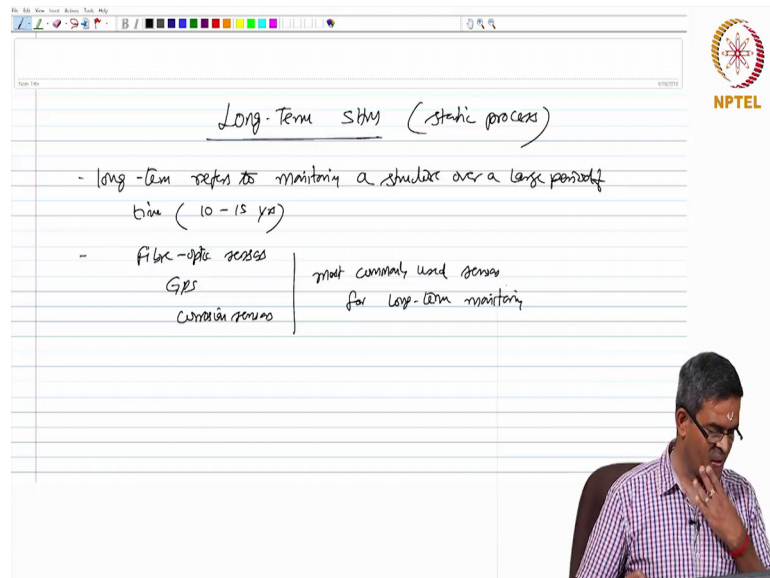


Structural Health Monitoring (SHM)
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Lecture - 38
Part - 2: Long term SHM (Structural Health Monitoring)

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The image shows a digital whiteboard interface with a toolbar at the top. The main content is handwritten text in black ink. The title is "Long-Term SHM (static process)". Below it, there are two bullet points: "- long-term refers to monitoring a structure over a large period of time (10-15 yrs)" and "- fibre-optic sensors, GPS, Corrosion sensors". A vertical line separates these from the text "most commonly used sensors for long-term monitoring". In the bottom right corner, there is a small inset video of a man with glasses, wearing a checkered shirt, looking thoughtful with his hand to his chin. The NPTEL logo is visible in the top right corner of the whiteboard area.

Let us now talk about long-term structural health monitoring essentially this is a static process. What do you mean by long-term? Long-term refers to monitoring a structure over a large period of time. This can anyway vary from 10 to 15 years. What kinds of sensors are being used for this kind of monitoring? People use fiber optic sensors, GPS, receivers and corrosion sensors. These are most commonly used sensors for long-term monitor.

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The image shows a digital whiteboard interface with a toolbar at the top. The main content is handwritten text in blue ink. At the top, it says "Long-term SM - is a 7 stage process". Below this, the first stage is identified as "Identify the structures that need long-term monitoring". A bulleted list follows, detailing types of structures that require monitoring: new structures with innovative aspects, new structures with unusual levels of risk (geotechnical, seismic, or aggressive/corrosive environments), and structures near faults. In the bottom right corner, there is a video inset showing a man in a checkered shirt speaking. The NPTEL logo is visible in the top right corner of the whiteboard area.

Long-term SM - is a 7 stage process

1st stage Identify the structures that need long-term monitoring

- New structures, including those have innovative aspects in design, construction, material etc
- New structures, associated with unusual level of risk
 - Geotechnical conditions of the soil
 - seismic risk conditions (near-fault)
 - aggressive/corrosive environment

Now, long-term monitoring is a 7 stage process. The first stage is to identify the structures that need long-term monitoring. Generally, we do not do long-term monitoring for all kinds of structures, which structures should need long-term monitoring new structures including those have innovative aspects in design, construction, material etcetera they can be monitored.

Second could be new structures associated with unusual level of risk examples could be they have a special geotechnical conditions of the soil, where they are constructed. They can be or they must have been located in seismic risk conditions. For example, there can be an active fault nearby. It can be an aggressive corrosive environment. So, when structures are located under unusual level of risk then one can go for long-term monitoring.

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The image shows a digital whiteboard interface with a toolbar at the top. The whiteboard contains the following handwritten notes:

- Structures of strategic importance (Offshore oil, Nuclear reactors etc)
- ^{existing} structures whose disruption will affect the critical network
 - Important Railway/Highway bridges
 - Reservoirs
 -
- New structures in which their features represent a large unit of subset of structures
- Existing structures with known deficiencies
- Existing structures, which are recommended for rebuilding

In the bottom right corner, there is a video feed of a man with glasses and a checkered shirt, looking down. The NPTEL logo is visible in the top right corner of the whiteboard area.

Structures of strategic importance like offshore structures, nuclear reactors etcetera can be going for long-term monitoring. Structures, we can say existing structures whose disruption will affect the critical network. For example, some important railway and highway bridges, reservoirs etcetera can be under long-term monitoring. New structures in which their features represent a large unit of subset of structures, existing structures can also be long-term monitored with known deficiencies, existing structures which are recommended for rebuilding can also belong to monitor.

So, friends before we apply long-term monitoring the primary question comes identify those structures which need long-term monitoring.

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2nd stage ✓ Risk Analysis

- Carry out Risk Analysis on the identified structures
- to list out possible events & degradations that can affect the structure

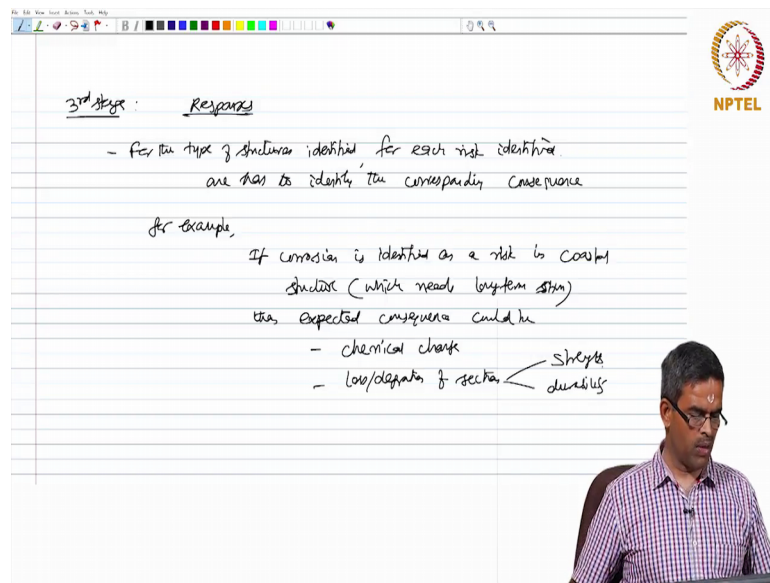
Example

corrosion	poor execution of public structure
loss of pre-stress	
creep	
settlement of foundations	
earthquake strike	
impact load	

The second stage deals with risk analysis once we decide the types of structures which ought to be meant for long-term monitoring then one has to carry out risk analysis on these identified structures to list out possible events and degradations that can affect the structure. I can give some examples; let us say corrosion loss of pre stress in highway girders, presence of creep settlement of foundations, earthquake strike, impact load effects and above all poor execution of public structure.

So, let us carry out the risk analysis of these to identify what are the possible events and the degradation that can happen to these structures, that is the second stage before we plan for long-term structural health monitoring.

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3rd stage: Response

- For the type of structures identified, for each risk identified, one has to identify the corresponding consequence.

for example,

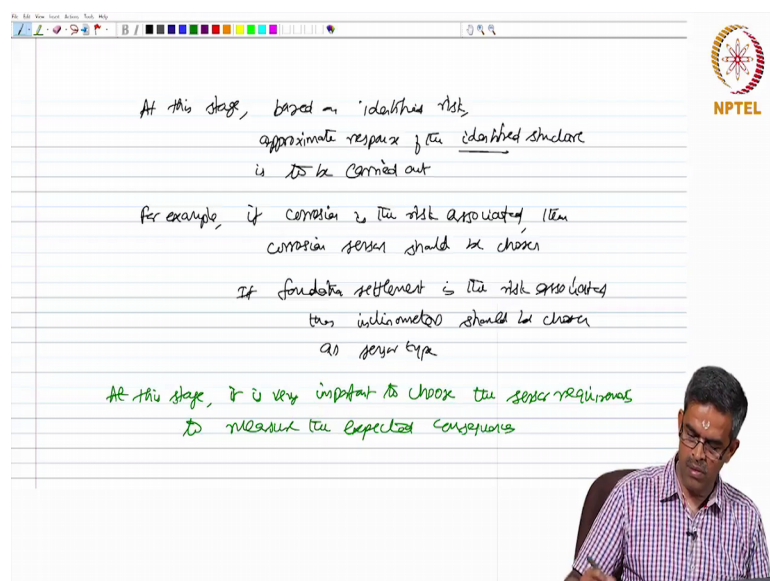
If corrosion is identified as a risk in coastal structure (which needs long-term monitoring) then expected consequence could be

- chemical change
- loss/degradation of section

Strength durability

The third stage is to measure the responses for the type of structures identified for each risk identified in the previous step one has to identify the corresponding consequence. That is, for example, if corrosion is identified as a risk in coastal structure which needs a long-term health monitoring then expected consequence could be a chemical change and loss or degradation of section in terms of strength, in terms of durability that could be one of the consequence.

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At this stage, based on identified risk, approximate response of the identified structure is to be carried out.

for example, if corrosion is the risk associated, then corrosion sensor should be chosen.

If foundation settlement is the risk associated, then inclinometer should be chosen as sensor type.

At this stage, it is very important to choose the sensor requirements to measure the expected consequences.

So, at this stage based on the identified risk approximate response of the structure of the identified structure is to be carried out. For example, if corrosion is the risk associated then corrosion sensors should be chosen if foundation settlement is the risk associated then inclinometers should be chosen as sensor type etcetera.

So friends, at this stage, it is very important to choose the sensor type I should say sensor requirements to measure the expected consequences.

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desired output @ this stage is

- List of Quantities that need to be measured (monitored)
- their likely magnitude
- their likely location

stage 4 Design of SHM & sensor layout

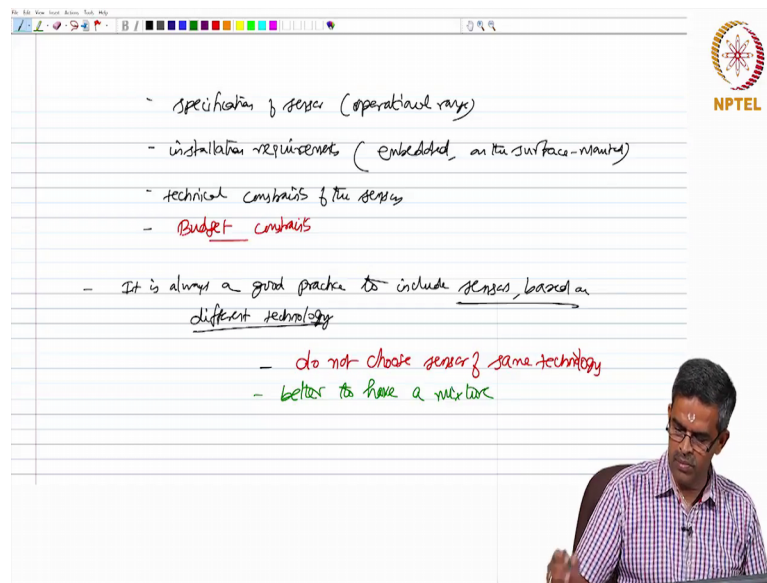
If an inexperienced Engineer carries out SHM he will start from this stage

Objective @ this stage is
to select appropriate type of sensor

So, the desired output of this step or the desired output at this stage is list of quantities that need to be measured. In fact, I should say to be monitored, their likely magnitude and their likely location all should be known at this stage.

So, next is stage 4, which is dealing with design of a SHM and sensor layout. Now, friends, it is very important to note if an inexperienced engineer carries out health monitoring he actually will start from this stage. Please note: the previous three stages are very important to make the health monitoring system more efficient and successful objective at this stage is to select appropriate type of sensor.

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NPTEL

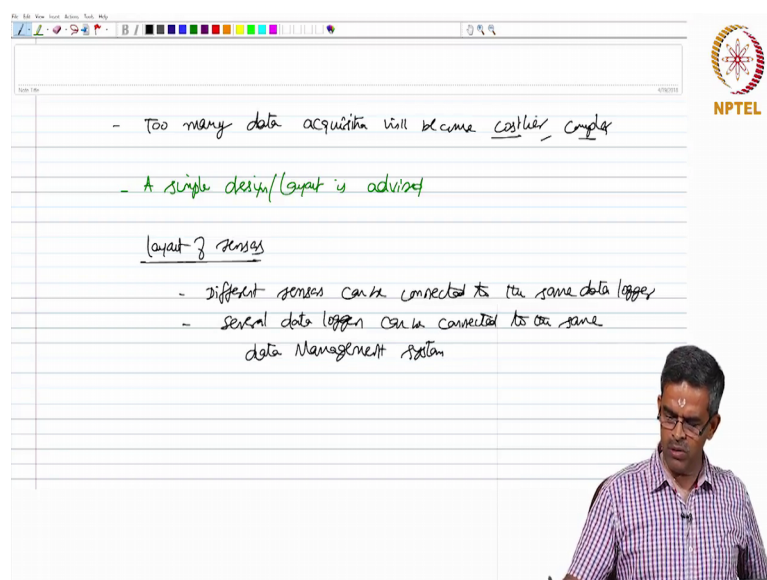
- specification of sensor (operational range)
- installation requirements (embedded, on the surface-mounted)
- technical constraints of the sensors
- Budget constraints

- It is always a good practice to include sensors, based on different technology

- do not choose sensor of same technology
- better to have a mixture

Specifications of sensor that is operational range, installation requirements of the sensor somebody some sensors can be embedded some can be on the surface mounted etcetera technical constraints of the sensors and most importantly the budget constraints. It is always a good practice to include sensors based on different technology that is very important. Do not choose a sensor of the same type it is always better to have a mixture.

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- Too many data acquisition will become costlier, complex
- A simple design/layout is advised

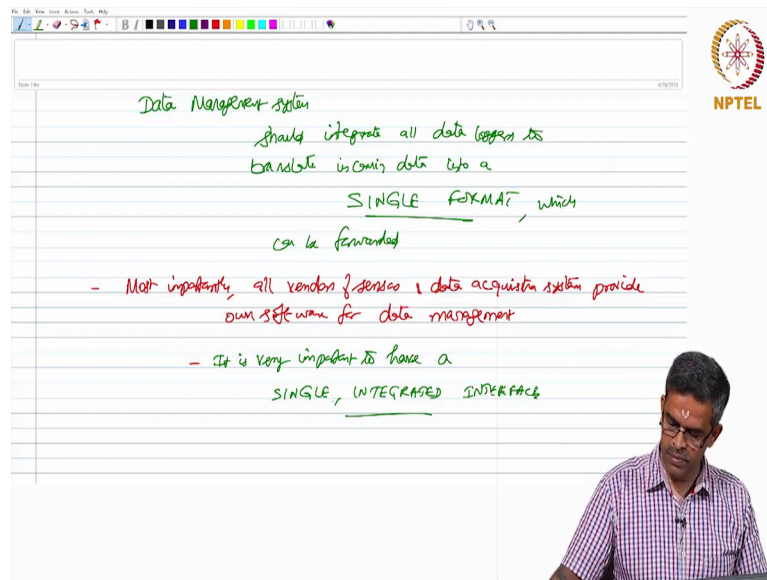
layout of sensors

- different sensors can't connected to the same data logger
- several data logger can be connected to the same data Management system

Further, too many data acquisition will become costlier, that is one part, will also become complex there is another issue. Therefore, a simple design or layout is advised.

Let us talk about layout of sensors. Now, interestingly different sensors can be connected to the same data logger, several data loggers can be connected to the same data management system.

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The image shows a digital whiteboard with handwritten notes. The text is as follows:

Data Management system
should integrate all data loggers to
translate incoming data into a
SINGLE FORMAT, which
can be forwarded

- Most importantly, all vendors of sensors & data acquisition system provide
own software for data management
- It is very important to have a
SINGLE, INTEGRATED INTERFACE

The NPTEL logo is visible in the top right corner of the whiteboard.

It is very important to note that data management system should integrate all data loggers to translate incoming data into a single format which can be forwarded. Most importantly, almost all vendors of sensors and data acquisition system provide their own software for data management.

So therefore, please note it is very important to have a single integrated interface.

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A detailed design document should be prepared containing the following:

- 1) List of sensors/type of sensors
- 2) Layout Architecture
- 3) Installation plan & Cable Layout
- 4) Installation procedure for every type of sensors
- 5) Budget details etc.

The whiteboard also features the NPTEL logo in the top right corner and a small inset video of a man in a checkered shirt speaking in the bottom right corner.

A detailed design document should be prepared at this stage containing the following; 1 – list of sensors and type of sensors, 2 – layout architecture, 3 – installation plan and cable layout in case of wired sensors, fourth your detailed documentation about installation procedure for every type of sensor, then the budget details etcetera. So, this is the outcome of this stage.

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Stage 5 Installation & Calibration

- one should follow the manufacturer's instructions to install sensors
- once they are installed and connected, then they need to be tested & calibrated
 - Site Acceptance Test (SAT)
- one need also fix the threshold values, in case of automated Homing system
 - Check this output for its successful working

The whiteboard also features the NPTEL logo in the top right corner and a small inset video of a man in a checkered shirt speaking in the bottom right corner.

The next of course, is the stage 5, which talks about installation and calibration. One should follow the manufacturer's instruction to install sensors. Once they are installed

and interconnected then they need to be tested and calibrated. This is what we call as Site Acceptance Test, a SAT should be conducted to check the efficient working of sensors. To do this one need to also fix the threshold values in case of automated alarming systems. Therefore, check this layout for its successful working.

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At this stage, a complete manual, and calibration report should be generated

Stage #6 Data acquisition & Management

Data should be acquired and stored in the database

- appropriate backup
- access authorization

need to be checked

- major outcome of this stage is

- * complete document of project management of data acquisition, management, log of events

So, at this stage a complete manual and calibration report should be generated.

Stage number 6, is data acquisition and management. Data should be acquired and stored in the database. It should have an appropriate backup, it should also have an access authorization; this need to be checked. The major outcome of this stage is a complete document of the project management of data acquisition and management with log of events.

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Stage #7 Data Assessment

At this stage, Engineer should be able to identify a foreseen risk & expected outcome of the risk

- A set of procedure to respond to any type of damage is to be created

For example,

- If the outcome is simple degradation, then procedure could be maintenance
- If the outcome of recorded data is capacity reduction, then closure of the services.

The last could be stage 7, which is essentially data assessment. The engineer should be able to identify a foreseen risk and expected outcome of the risk. A set of procedure to respond to any type of damage is to be created. For example, if the outcome is a simple degradation then procedure could be maintenance. If the outcome of recorded data capacity reduction, then there should be closure of the services of the system should be recommended.

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Summary

- SPR method
 - decision making process of SHM
- long-term SHM
- stages in long-term SHM
 - Each stage is Effective SHM.

So, friends, in this lecture we learned a statistical pattern recognition method which is useful in decision making process of structural health monitoring. We have also seen what do we understand by long-term monitoring, what are the different stages in long-term structural health monitoring and how each stage is important in effective health monitoring.

Friends, I hope you follow the lecture and understand them very well. In the next lecture, we will talk about non destructive evaluation methods and techniques which are useful for health monitoring measurements.

Thank you very much and bye.