Structural Health Monitoring (SHM)

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Lecture – 21
PART – 1: Estimation of Structural Health i.e. Structural Health Monitoring (SHM)

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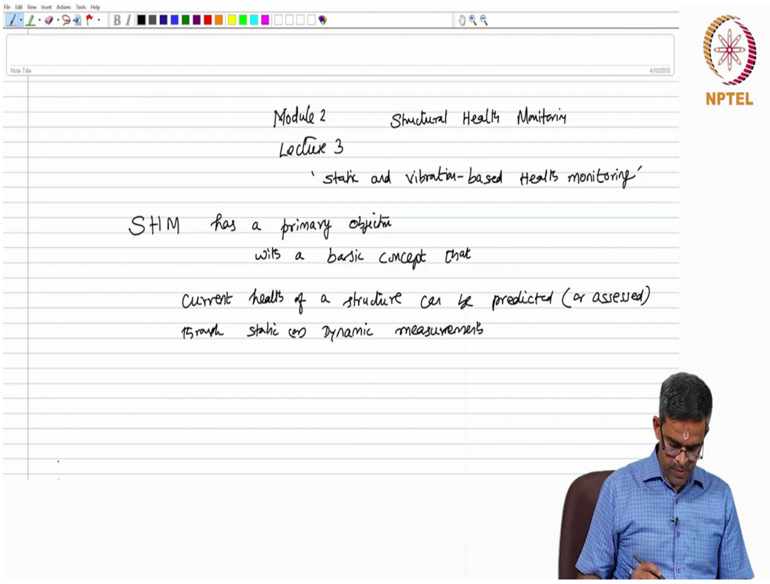

Friends, welcome to the module-2, lecture-3 on the course Structural Health Monitoring.

In this lecture we are going to introduce static and vibration based health monitoring. Having said in the previous lectures that structural health monitoring has a primary objective with a basic concept that current health of a structure can be predicted or I should say assessed static or dynamic measurements.

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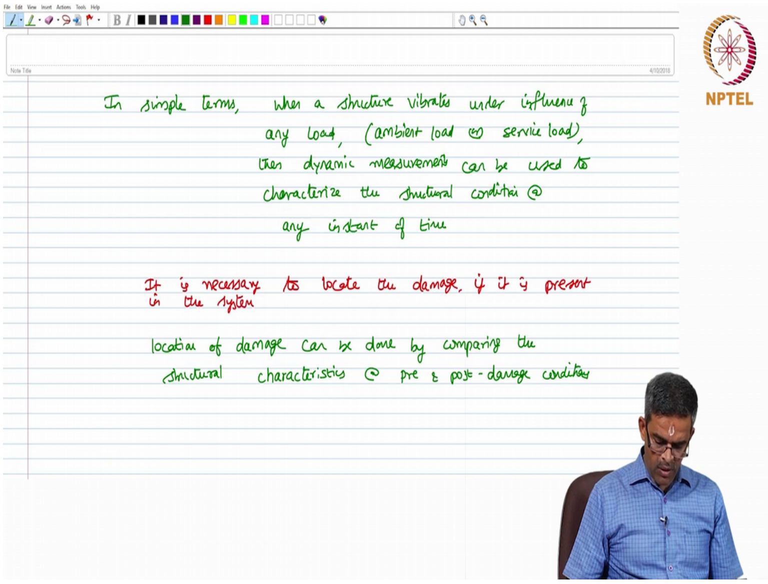

In simple terms when a structure vibrates under influence of any load it may be ambient load or service load for which the structure is designed, then dynamic measurements can be used to characterize the structural condition at any instant of time.

To do this it is necessary to locate the damage if it is present in the system so, location of damage can be done by comparing the structural characteristics at pre and post damage conditions.

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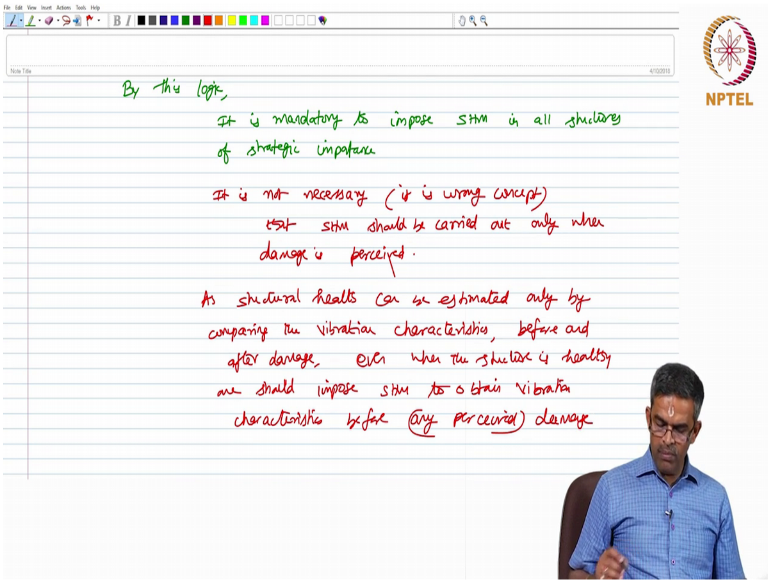

By this logic, friends, it is mandatory to impose structural health monitoring in all structures of strategic importance. It is not necessary. In fact, it is a wrong concept that SHM should be carried out only when damage is perceived.

As structural health can be estimated only by comparing the vibration characteristics before and after damage even when the structure is healthy one should impose structural health monitoring to obtain vibration characteristics before any perceived damage.

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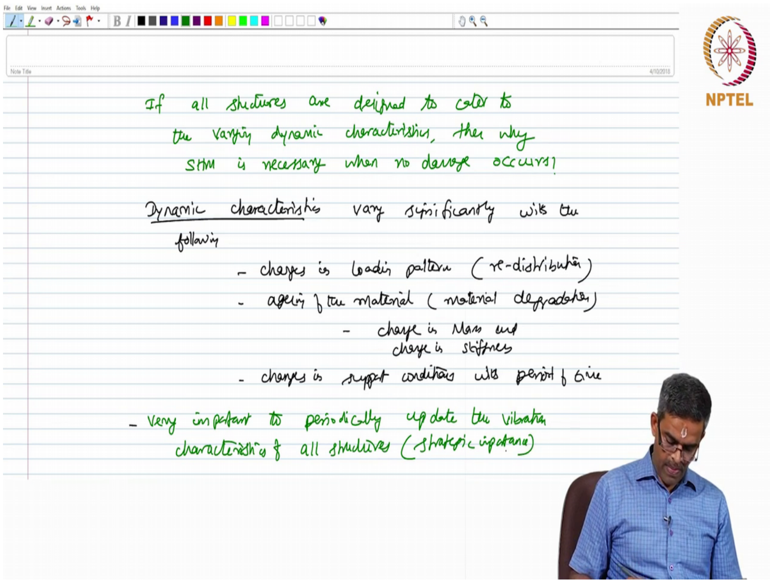

Then one may ask me a question if all structures are designed to cater to the varying dynamic characteristics then why structural health monitoring is necessary when no damage occurs? That is a very interesting question.

Friends, it is important to note that the dynamic characteristics vary significantly with the following; changes in loading pattern because loading pattern will invoke redistribution, ageing of the material which we call material degradation which can cause change in mass and change in stiffness, changes in support conditions with period of time etcetera can make the dynamic characteristics to be different from the top it is being designed.

So, it is very important to periodically update the vibration characteristics of all structures I should say, but at least for structures of strategic importance this is necessary.

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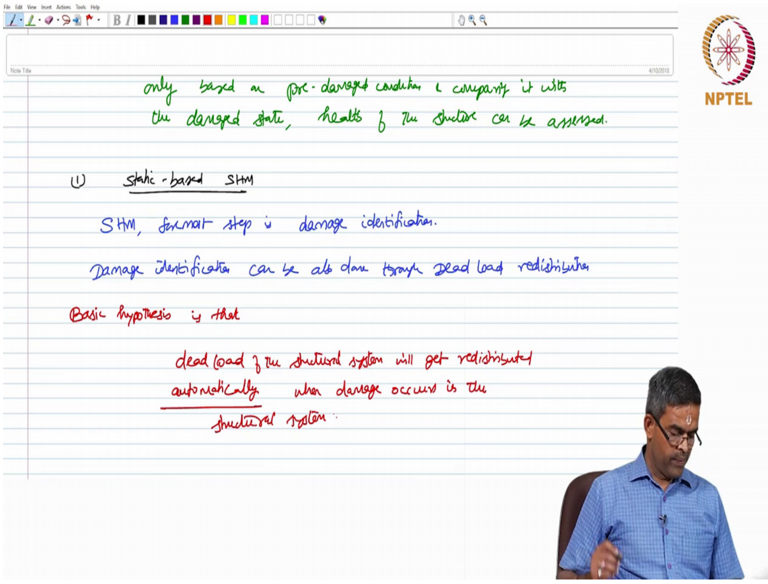

Because, only based on the pre-damaged state and comparing it with the damaged state, health of the structure can be assessed.

So, let us talk about static-based SHM. We all know that in structural health monitoring the foremost step is damage identification damage identification can be also done through dead load distribution. Let see how. The basic hypothesis behind this statement is that dead load of the structural system we will get redistributed automatically when damage occurs in the system.

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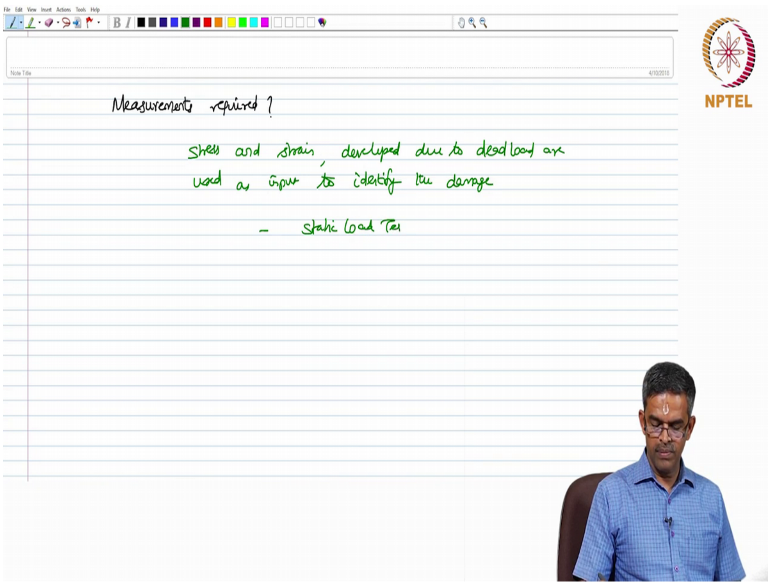

Let us say then in that case what are the measurements required; stress and strain developed due to dead loads are used as input to identify the damage, this is what we call as static load test.

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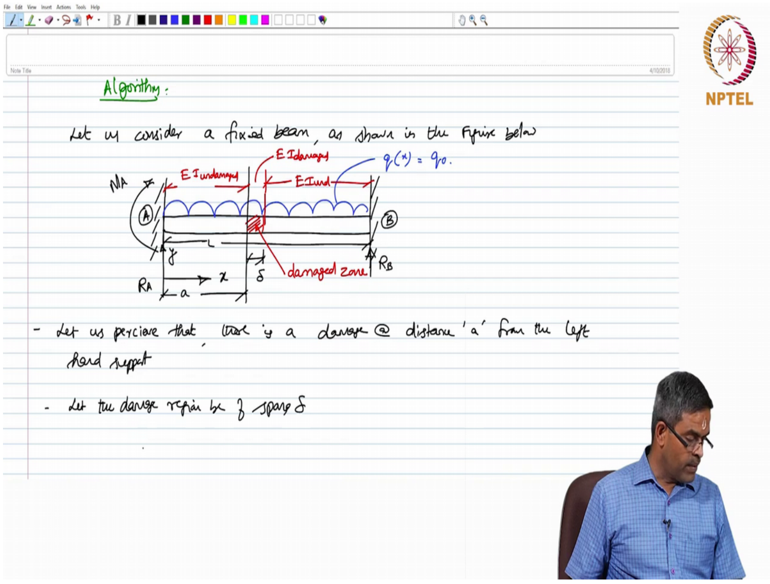

Let us consider a fixed beam as shown in the figure below. The beam is subjected to some loading pattern which is function of x which is considered as q 0 and x is measured positive towards the length of the member and y is measured positive towards upward.

Let us call this end as A and this end as B. Let us say we have a moment applied here which is M A the length of the member is L and let us perceive that there is a damage at a distance a from the origin, that is from the left hand support.

Let us say at section a which is distance a from here, there is a damage in the beam. So, we call this as damaged zone therefore, this section will have E I undamaged and this section will also have E I undamaged whereas, this section will have E I damaged.

Let us say it has got two reactions R A and R B. So, let us say let the damage region b of span delta. So, this is delta and this is a, ok.

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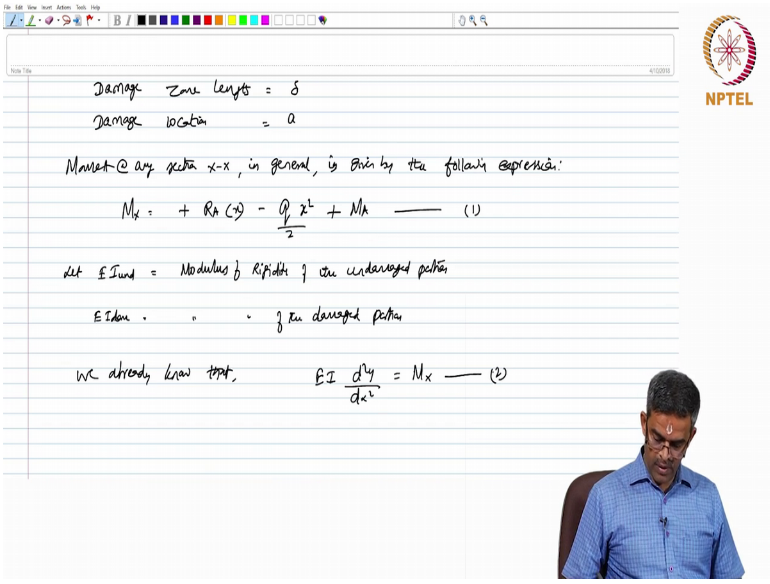

So, from the figure it is clear that the damage zone length is delta and damage location is a from the let support. Let us say moment at any section X-X in general is given by the following relationship M X is equal to plus R A into x minus q x square by 2, plus M A, where M A is this q is the downward low and R A is this, equation – 1.

Let E I undamaged be the modulus of rigidity of the undamaged part and E I damage be the modulus rigidity of the damaged part. We already know that E I d square y by dx square is equal to M X.

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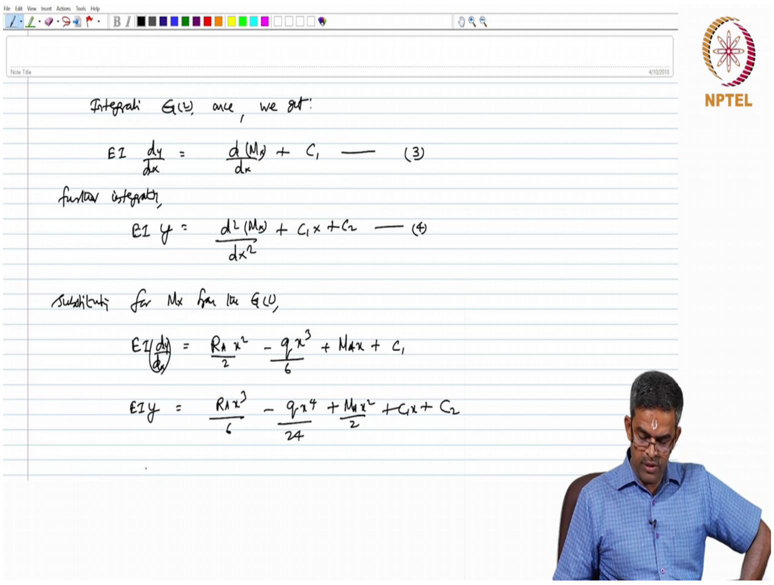

Integrating equation – 2 once we get, E I dy by dx will be equal to d M X by dx plus integration constant C 1. Further integrating E I into y will be d square M X by dx square plus C 1 x plus C 2 substituting for M X from the equation – 1.

Equation – 1 is here, ok. Substitute to M X. So, E I into y will be E I dy by dx will be equal to R A x square by 2 minus q x cube by 6 plus M A x plus C 1. E I y is R A x cube by 6 minus q x 4 by 24 plus M A x square by 2 plus C 1 x plus C 2 , but there are different regions in the beam for which this equation should be separately written.

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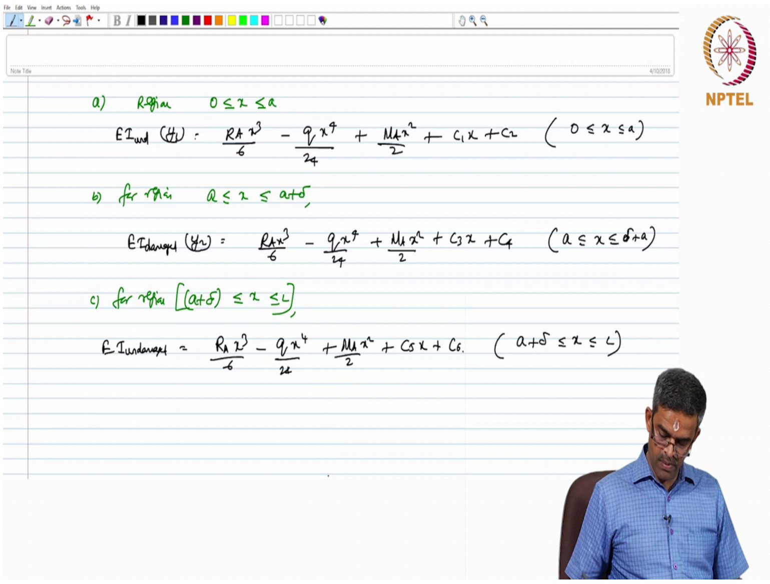

Let us talk about region 0 less than x less than a in that condition E I undamaged of y 1 you can see the equation. A undamaged of y 1 will be R A x cube by 6 minus q x 4 by 24 plus M A x square by 2 plus C 1 x plus C 2 this is for 0 less than x less than a.

Now, for region a less than x which is further less than a plus delta E I damaged because at the damage region of y 2 will be R A x cube by 6 minus q x 4 by 24 plus M A x square by 2 plus C 3 x plus C 4. So, this is a less than x less than delta plus a.

For region a plus delta less than x less than L we can also write again it is an undamaged region. So, undamaged will be V A x cube by 6 plus q x 4 sorry minus q x 4 by 24 plus ma x square by 2 plus C 5 x plus C 6. This is a plus delta less than x less than L.

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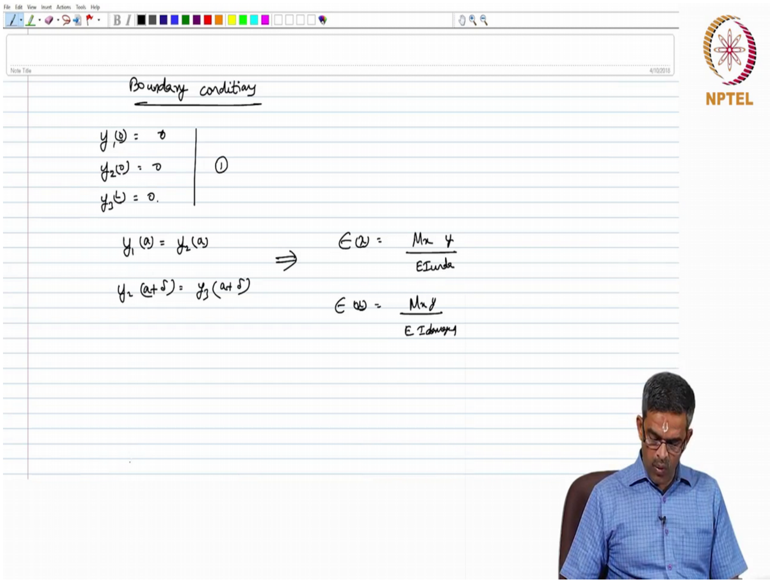

Let us see what are the boundary conditions. Now, let us replace this is the R A, let us see what are the boundary condition to solve. This equation y 1 of 0 is 0, y 2 of 0 is 0 and y 3 of 0 is 0 y 3 of not 0 y 3 of L, this the first set we have.

The second set is y 1 of a will be also equal to y 2 of a and y 2 of a plus delta will be y 3 of a plus delta which imposes an additional condition E x is M x y by E I undamaged E x is also equal to M X y by E I damaged depending upon the region once this is said.