

**Architectural Conservation and Historic Preservation**  
**Prof. Sanghmitra Basu**  
**Department of Architecture and Regional Planning**  
**Indian Institute of Technology, Kharagpur**

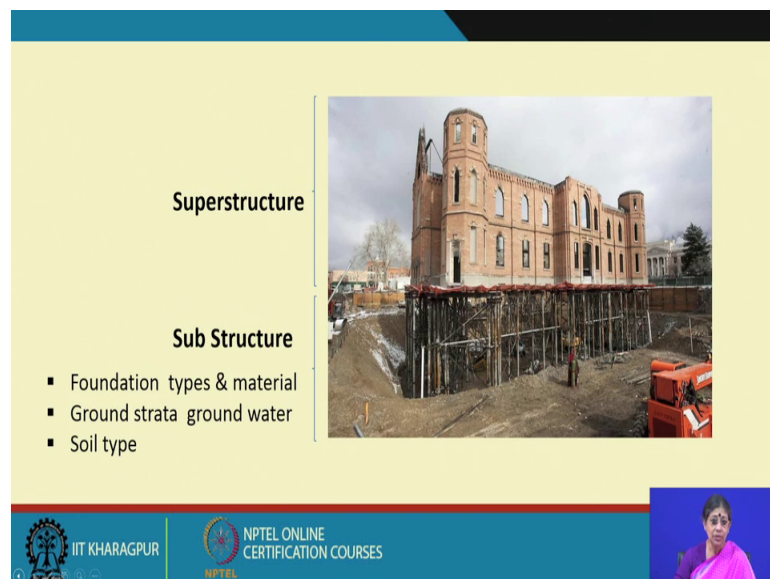
**Lecture – 30**  
**Conservation of Historic Structures: Maintenance and Repair**

In your last two lectures, we discussed two very interesting case study; the leaning tower of Pisa and York Minster foundation repair. And, in that process you have seen how the diagnosis is very important before some sort of intervention is taken in the historic place. Today, we will talk in general about some of the maintenance and repair methods and some guidelines and in particular some cases of India in a nutshell.

So, that even understand that even when the diagnosis is done and the type of decays what we have discuss about and what can be done, we of course, we not able to discuss in very much detail, but it will give you some idea that what are the general maintenance and repair methods and then one has to talk that in very very specific nature there is a very wide scope of doing the so, it is just an general idea about this.

So, our topic today is the maintenance and repair.

(Refer Slide Time: 01:17)



The slide features a diagram on the left and a photograph on the right. The diagram is divided into two sections: 'Superstructure' and 'Sub Structure'. The 'Sub Structure' section includes a bulleted list: 'Foundation types & material', 'Ground strata ground water', and 'Soil type'. The photograph shows a large, multi-story brick building with a prominent tower, undergoing foundation repair. Scaffolding and construction equipment are visible at the base of the building.

**Superstructure**

**Sub Structure**

- Foundation types & material
- Ground strata ground water
- Soil type

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

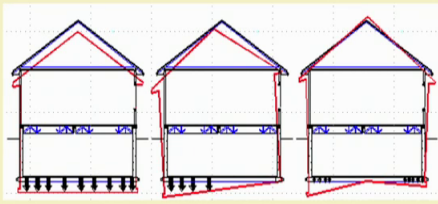
Now, when we talk about any historic structure there were two parts of the historic structure; one is the superstructure that we see above the ground and the other is the sub

structure which is below the ground generally the foundation and others, but foundation means the foundation with other things. So, sub structure means the foundation types of the material, the ground strata and the ground water and the soil type. All of this very important to understand for even if you try to understand that the what is happening to the sub structure, because whatever the if say crack or the signs of decay happen it happens in the superstructure, but sometimes the cause is as we have seen in both the cases of leaning tower of Pisa and York Minster the actually the problem was there in the substructure and then of course, we have to see that what can be done about that.

So, we have to remember these two parts and they are very integral and until and you can imagine that when we are talking about a historic structure understanding the substructure is not easy, because it is always covered. Sometime there are development around the structures, so, how do we understand that and how certain type of mitigation measures have to be taken there very very important part of understanding any repair measure on.

(Refer Slide Time: 01:38)

**Principles of Foundation Behaviour**  
**Settlement - its Nature , Significance and Effects**



Three types of settlement categories :

- Uniform** - settles straight down
- Tilt** - settles intact but on an angle
- Non-uniform** - settles at varied angles

**No foundation carries load without settling**

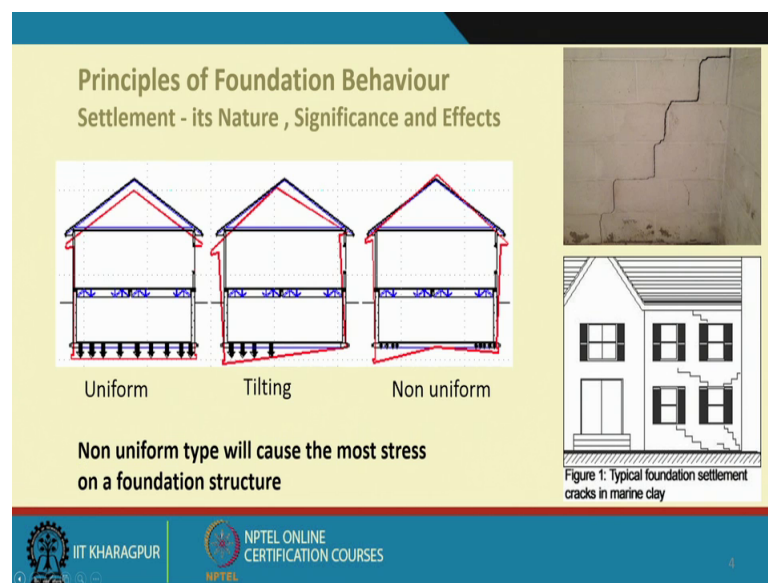
IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Now, one thing we must understand when we are talking about the substructure is the principle of foundation behavior in a nutshell. Now, the if there is a settlement which is generally manifested in terms of crack, if there is a settlement we have to understand what is the nature and significance and effects of the settlement. So, generally there are three types of settlement broadly the three types of category; one is the uniform that

when the entire structure settles uniformly and then straight down and then there is it tilt when the settles intact ah, but on an angle. So, there is not much, what is then it can be done that a non-uniform settlement the settles at a varied angles.

In case of York Minster strata was that differential settlement which diagnosis as the major cause of the settlement. So, of we also most important that no foundation carries load without settling. There will be some settlement, but all settlement is not very dangerous there because there will be some adjustment. Then uniform and tilting generally there is a not much a problem. The problem is that non uniform settlement which is actually manifested in terms of cracks and if that continues as we have seen in the case of York Minster then absolutely it is a very important that some measure has to be taken to prevent that.

(Refer Slide Time: 04:07)



And also in that that non uniform settlement what we are talking about it cause the most stress on a foundation structure. Even in tilting also there can be the cracks and other thing. Uniform sometimes is a horizontal crack, but if it is no longer continuing is probably is not problematic until and unless it settle. So, much that there is a from the surrounding ground there is a lot of problem of the water, but anyway the most important or most dangerous should say the non-uniform type.

And, as you can see that in if you try to study the nature of the cracks and that cracks will tell you that what is the problem. In this case as you can see that there is a steps like

crack. So, that generally indicates generally a typical foundation settlement crack and it also depends as I said foundation and the clay all are very important factors which can cause to that (Refer Time: 05:03) one has to understand that what is the factor which causing that settlement and the crack.

(Refer Slide Time: 05:23)

**Factors governing foundation behaviour**

1. The load from , and the nature of , the superstructure
2. The nature and dimensions of the foundations
3. The nature and history of the ground strata (soil or rock) under the foundations
4. The ground water , its levels and fluctuation
5. Any interference after the initial constructions with factors 1,2,3 or 4

The slide includes three images: a photograph of a building facade with a vertical crack, a photograph of a foundation with a horizontal crack, and a cross-section diagram of a house on a hill. The diagram labels the 'Original slope of hill', 'Settlement crack' (noting it is 'Typically wider at top, goes through weaker wall areas (windows)'), 'Fill area', 'Settlement' (indicated by a downward arrow), and 'Surface water runoff often causes problems here' (indicated by an arrow pointing to the ground).

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

So, let us see, what are the factors which is governing the foundation behavior, once we talk about the sub structure. One is the load from and the nature of the superstructure. So, sometimes there can be a load which is coming from the superstructure the foundation as you seen in the York Minster also they have foundation itself there was a problem it was not, even in the Pisa also leaning tower of Pisa also we have seen that that there was a initially it was not designed properly. So, the load from, and the nature of the superstructure that is also can be a factor which is causing some sort of a foundation problem.

In this case as you can see that there is a temple a small temple it is that step type of crack, but one of the thing it can be a settlement, but also what has happened in this particular case is that there is a huge tree which has grown over the things and it is causing a problem and there is a crack developed and structure is almost it is a major problem that structure is facing.

But, it is basically due to the superstructure not initial design, but some problems which has happened. The second is the nature and dimensions of the foundation that how the

dimension and sometimes what happen in historic structure initially it was designed as a small structure with some sort of foundation and then there was certain additional powers which have come or additional flows which have been built on it. So, that it may cause some sort of a problem. So, the nature and dimension of the foundation is not able to withstand that in this also very important aspect.

The nature and history of the ground strata, the soil or a rock, under the foundation the what is the soil condition, what are the types of soil, what is the layers of the different strata that is one and also the history because there may be some sort of like we have seen in the leaning tower of Pisa that the groundwater was being excavated that cause some sort of disturbance in the strata and that cause or enhance the foundation problem then. So, the nature and the history of the ground strata what it is made of what is happening, what are the surrounding condition, where there has been tunnel or the ground water excavation going on extraction was going on. So, all this is important to understand.

In this case as you can see is that original hill slope and then the settlement crack is typically wider at the top. This is also one of the thumb rule that it is wider at the top and then they see that this is a fill up area which is happened there and this fill up area is actually there is a difference between this soil and that soil this fill it filled up area and that is causing some sort of a problem and exactly there you see that crack is happening. So, and there is a surface water runoff which often causes a problem there. Is of course, sloping scenario, but it also can happen in a horizontal ground level or a flat soil where there can be a difference and some sort of a intervention has happen when the ground strata is changing in his behavior and that is causing a problem of the foundation.

Here again you see that this is these type of crack what we have seen that it has happened and this is happened in a very structure failure and which most probably and one has to sort of do a some sort of a carry out some sort of an investigation and to see that what is the actual reason. But, this is the initial signs and again I mentioned earlier that one has to ascertain whether is a life crack or whether is a dead crack there with a continuous monitoring.

The groundwater is again and again I am saying that groundwater the change in the groundwater level especially in an urbanized area which was earlier not so urbanized and

development is happening and (Refer Time: 09:16) being there also the change in the groundwater level that can cause a problem in the fluctuation of the groundwater level can cause a change in the behavior of the foundation and any interference after the initial construction any of this 1, 2, 3, 4, is a combination of that can cause.

So, these are the major factors which govern the foundation behavior and we have to remember some of the thumb rules what we have seen that that of the crack and all things in a nutshell.

(Refer Slide Time: 09:48)

### Factors governing foundation behaviour

The nature and history of the ground strata (soil or rock) under the foundations

Ground Strata and their behaviour

1. Rock
2. Gravel and sand
3. Clay
4. Silt

### Gravel and sand

Grain size- Gravel 2-3 mm Sand 2–0.06 mm



- When compacted and moist holds together fairly well, good soils to support a foundation because of their non-water-retaining properties.
- When moist the particles lose their friction and can be washed away, leave gaps beneath the foundation.



IIT KHARAGPUR



NPTEL ONLINE  
CERTIFICATION COURSES



Now, when we are talking about the ground strata the nature and history of the ground strata we have to understand that there are different types of soils and different types of soils are the different type of behavior and the difference in the varying capacity and. These need to be understood and in relation to the type of the structure and so, let us see what are the major types of ground strata, which can happen. One is rock the rock generally there is not much of a problem because its bearing capacity is more, but also if it is a general statement there are different types of rock can be there and depending on if it is a limestone or there different types of sandstone this will behave in a different way and they can be having some sort of decay because of some other factor, they can be mining subsistence there can be the calculus material which is soluble in the water and out without seeing that there can be the large holes which can develop understand.

So, rock we cannot just say the rock is generally is not a problem, there are problem depending on the which type of rock and there is sometimes different combination of the rock strata which can create a problem, but generally the rock is not that much of a problem. The second is the gravel and the sand. Now, when we talk about the gravel and the sand and then there is a clay and there is a silt, there is a four broad categories of the ground strata which can say. Now, when we can talk about a talk about a gravel and sand now it is basically the difference between the grain size whether gravel is 2 to 3 millimeter and sand is 2.2, 0.06 to 2 millimeter that the gravel size. Otherwise in behavior wise they are more or less same it is the difference in the size which makes the difference.

Now, what is that behavior? Now, behavior is that when compacted and moist with gravel or sand it holds together fairly well, but good soils to support a foundation because of their non-water-retaining properties, but the problem is that that gravel and out sand their carrying capacity comes from the friction and so, when it is moist the particles lose their sort of frictional quality and can be washed away leaving gaps beneath the foundation. So, that becomes a problem, that the water actually acts as a sort of a lubricant and it is that when the it loses the friction then their capacity to bear a foundation becomes a problem ah. This is the general thing and there much more in detail analysis which has to be done.

(Refer Slide Time: 12:44)

### Factors governing foundation behaviour

Ground Strata and their behaviour **Clay & Silt**

- Clay tiny particles , stores water well
- Expands greatly when moist and shrinks significantly when dry
- When moist, very pliable, and can easily be moved and manipulated
- Extreme changes put a great deal of pressure on foundations, causing them to move up and down, and eventually crack, making clay a poor soil for support

**Clay & Silt**





IIT KHARAGPUR



NPTEL ONLINE  
CERTIFICATION COURSES



When we are talking about the third one which is the clay and silt here the bearing capacity it happens because of the pore pores within the clay and the water which comes within the pore and the pore pressure develops these actually gives the bearing capacity and the when the clay is squeezed then the water goes out, there is a pressure which develops so, the structural engineers are very helpful in making us understand that what is happening in that ground behavior. So, clay a basically tiny particles which stores water well because of the pores within the clay and it expands greatly when moist. So, when it behavior changes when it is moist or when it is dry. So, when it expands greatly when moist and shrink significantly when it dries. So, we can see that when it is dry there is a crack which has developed and when is moist.

Now, what happens is that that; that means, there is a change in the pore the pressure which develop because the water which is retained or the if there is a pressure which is coming then the water is going out of the pores so, the bearing capacity changes. So, that that makes a difference. So, when moist it is very pliable and can easily removed and manipulated, but when extreme changes put a great deal of pressure on the foundation causing them to move up and down and eventually crack making clay a poor soil for support and their probably what you need is the different type of foundation and if that is not there and originally it has not been built then the some sort of a problem can happen.

So, each of the soil has needs a different types of foundation they have a different bearing capacity and the change in the ground structure or the water level act differently to the different types of soil category.



(Refer Slide Time: 14:38)

**Foundation strengthening**

- Soil improvement by grouting
- Underpinning
- Conventional Bored Piles
- Mini Piling
- Foundation strengthening by Lateral Extension

The slide includes several images illustrating these methods. One image shows a cross-section of a foundation with labels for 'Original footing' and 'Mass concrete underpinning'. Another image shows a construction site with a large concrete structure being built. A third image shows a 'PILE & BEAM' structure. A fourth image shows a construction site with a large concrete structure being built. The slide also features logos for IIT KHARAGPUR and NPTEL ONLINE CERTIFICATION COURSES, and a small video inset of a presenter.

Now, this is very very nutshell, I mean as I say that much more elaborate discussion needs to understand that the behavior of the soil. Now, if there is a problem whatever the reason that has to be diagnosed first, but then what are the major ways to mitigate or strengthen the foundation? So, one is soil improvement by grouting like we have talked about the grout into consolidation the even in the leaning tower of Pisa if you are remember that the grouting was tried at one of the stage, but it did not work much and the, but the grouting is can be one of the method of foundation strengthening.

Underpinning; underpinning is that like in these case what you can see is that there is an original foundation and which is not able to carry and the new sort of a foundation which is under the foundation has been built up and you can see that here within that you can see it is a view from the top that when a concrete foundation is built under the structure under the original foundation so that take that extra load.

Now, try to imagine and that there is already a structure which is there in sometimes it is a huge structure now to build or underpinning is not a matter of joke. It requires a much more expertise a lot of effort understanding and how it will be done, we have seen York Minster it is a underpinning, but it was also pre-state underpinning was there because of the chat, but the underpinning is one of the way where we can strengthen a foundation.

And, conventional bored piles. So, piles also can be done that when you put the piles under it can piles through the structure and other in this particular case what you see that

the new sort of a bed has been prepared and these is now supporting on a this is a symmetrically balanced one. It sometimes can be an asymmetrically balance that the piles can be on one side to piles and then it can sort of the that new a structure can act as a cantilever and then support the foundation. So, depending on the situation this possible the pile and this beam can be a possible way.

So and there is also a question of mini piles. Mini piling is that when the piling is done through the foundation cross piling and other so boring the holes and the putting concrete into that with the proper reinforcement so that it can take the (Refer Time: 17:09) if you remember the various options which came for the leaning tower of Pisa there were many such sort of suggestions which were given for that and, foundation strengthening.

So, one thumb rule is that either you can go below that which is underpinning or sometimes we can go wider so that you take the foundation you can go wider this is the case from fort William in Kolkata where there was a serious foundation problem and then in that case we did the foundation strengthening by the lateral extension, keeping the original foundation and putting it. So, the bearing capacity increases and it has to be done in phases they very challenging task and these the major waste the foundation strengthening can be done.

(Refer Slide Time: 18:05)

**Materials for building conservation**

**Masonry materials as per original construction details of the historic buildings**

- Stone
- Brick
- Wood
- Metal members
- Mud / adobe

**Qualities of material to be checked**  
material composition, chemical properties, mechanical properties, colour, texture, grain size, compatibility with historic materials, binding characteristics, porosity, presence of harmful materials, source of the materials, economic viability.

The slide includes six images: stone masonry, brick masonry, a metal grate, wooden roof trusses, a carved stone window, and a carved stone archway. At the bottom, there are logos for IIT KHARAGPUR and NPTEL ONLINE CERTIFICATION COURSES, along with a small video inset of a woman in a pink sari.

Now, let us go to some other aspect which is the masonry material, we talked about the substructure let us talk about something about the superstructure. The masonry materials

as per the original construction detail of the historic building we have to understand that what is their property, what is decay we have taken something earlier let us see some aspects of that.

Now, let us talk about one is the stone and stone can be of different type different categories of the different ways they can be the bonding can be different. So, stones again is one of the measure, another is the brick also there is a modular things which is earlier historical time the brick dimension was different and now the brick dimension there also masonry with bricks, but when you are talking about historical building bricks or one of the major material for the masonry structure.

Wood; wood there are places that where the entire structure was built out of wood in our India the Padmanabhapuram palace is one such example where the walls, the roof, floors, structure members all were made of wood. It has its own challenges, own properties, own beauty and own value and significance. And, metal; metal in these cases as you can see that it is sort of a metal which is holding the structure metal columns metal beams the metal finally, details which are there and again for each type of metal it will decay in a different way. The different properties for that it can be used as a main structural material sometimes it can be used for some of the smaller details or ornamentation. So, metal is metal members is another one.

And, adobe; adobe we if you remember Shamuli. Shamuli is an adobe structure and many many in African countries and other there are lot of adobe structure their highlights adobe structure the it has its own properties own way to decay or when way to sort of a resist the decay is a traditional knowledge. So, this modern adobe also is another type of material which is used for the superstructure and variation of that is the terracotta. We have seen a lot of example of terracotta.

Terracotta is the burnt adobe. So, its properties are different because when it is burnt at a very high temperature the silica content within the mud that sort of gets hardened and it gives a lot of water resistance and a very hard material, but before burning it can be sort of a treated, molded different types of decorations can be done that we have seen the Bengal lot of this terracotta temples, there is a unique styles and others.

So, terracotta tiles or terracotta bricks of terracotta which were burnt later on brick; brick inner way also there. Terracotta is another one where lot of decorations were done. So,

stone, brick, wood, metal members and mud and adobe and there are subcategory they are used in combination sometimes. So, these are some of the major masonry materials which we see.

Now, whenever did just this is to be remember when whatever the material we are dealing with for a historic structure the what are the qualities which has to be checked for the material. So, let us go quickly the metal composition, chemical properties, the mechanical properties, colour, texture, frame size, compatibility with historic materials, binding characteristic, porosity, presence of harmful material, source of the materials and economic viability.

So, even within each of this broad category there are a lot of variations and depending on the place when it was built, how it was built and how it was decay this has to be seen. So, these are some of the sort of the checklist that what are the qualities of the materials which have to be checked when we are trying to take care of the historic structure.

(Refer Slide Time: 22:17)

**Conservation of stone masonry**

```
graph TD
    ROCKS --> Igneous
    ROCKS --> Sedimentary
    ROCKS --> Metamorphic
    Igneous --> Intrusive
    Igneous --> Extrusive
    Intrusive --> Gabbro
    Intrusive --> Granite
    Extrusive --> Basalt
    Extrusive --> Rhyolite
    Sedimentary --> Clastic
    Sedimentary --> Chemical
    Clastic --> Sandstone
    Clastic --> Shale
    Chemical --> Limestone
    Metamorphic --> Foliated
    Metamorphic --> Nonfoliated
    Foliated --> Slate
    Foliated --> Schist
    Nonfoliated --> Quartzite
    Nonfoliated --> Marble
```

- Stabilizing and preventing or retarding further deterioration
- Cleaning
- Replacement or substitution
- Dismantling and rebuilding
- Repair

**Questions /characters to be examined**  
Type of stone , place of origin, geological nature , grain type , placing, solubility in water, surface finish, strength , absorption characteristics , pore system

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Now, when some of the questions or the characters which had to be examined when we are talking about first let us talk about the stone masonry as I said the stone also there are varied types of stone one has to take much in much more detail. So, let us see there are broadly igneous, sedimentary and metamorphic rocks and under that there are basalt, granites, sandstone, limestone, marble and each of them under a different family or a

different category their property, their behavior and their looks and aesthetics everything is very different.

So, now when we are talking about the rocks in broad and then we have to know that which type of rock which characteristics are there. So, the question of characters which has to be examined for doing the rocks is the type of the stone, the place of the origin, the geological nature, grain type, placing how they were placed in the structure, solubility in the water, surface finish, strength, absorption characteristics and pore system. Even under the same family or same type there can be a variation depending on which quarry is coming from or where it is coming from, the color texture, porosity, the grain size there can be a lot of variation. So, this has to be understood properly with expertise or taking the advice of the experts.


Now, when we are talking about the stone masonry whatever the type to understand that basically what is the purpose or what should be the care should be taken is the stabilizing and preventing or retarding further deterioration. This is most important factor when we are talking about stone masonry in any historic structure. Cleaning that how it should be cleaned this is also what it varies from stone type to stone type.

Replacement or substitution we have discuss that we have seen in (Refer Time: 24:18) that the original stone they were not there when it was being built upto the foundation, the anastolisis I said that when the stones are put up to build up to certain height there it has been replaced and so there has to be some sort of an harmony or compatibility not only look wise, but composition wise it also has to be seen otherwise they will be differently with the temperature fluctuation with the rain the behavior will be different, so, it very important to take the similar type of stone with the same type of characteristics when you talk about the substitution or replacement.

Dismantling and rebuilding. So, this also sometimes what happen in the stone masonry that one it is becomes so deteriorated or there is can be a tree which is grown up there some reason is there. So, we have to dismantle and you have to rebuild that there are possibilities probably the joining the pointing has become loose or some other factors. So, as you can see this is one from Bhubaneswar small temple where the numbering has to be done, it has been properly recorded and then it is dismantled and then it can be rebuilt.

So, these are the some of the characteristics when we talk about the conservation of the stone masonry and repair different types of repair what is required.

(Refer Slide Time: 25:48)

Conservation of stone masonry	
<b>Cleaning</b> <ul style="list-style-type: none"><li>• Depends on the material (lime stone/ marble / sandstone/ granite etc.</li><li>• Non ionic detergent</li><li>• Removal of moss &amp; lichen</li></ul>	<b>Repair</b> Plastic repair / Dentistry
<b>Cleaning efflorescence from masonry</b> <b>Removal of salts</b> <ol style="list-style-type: none"><li>1. Prolonged washing with fresh water</li><li>2. Repeated application of moist paper pulp (example Konarak Sun Temple)</li><li>3. Poultices can be successfully used to clean delicate stonework (example Taj Mahal at Agra)</li></ol>	 <b>A mortar / synthetic resin</b> composite mixed with stone dust and other materials to form a stable patch matching the original colour and texture .
	<b>Water repellents</b> Generally not advisable

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES | 11

Know when we talk about the cleaning it depends on that what is the material, is a limestone or it is a marble, it is sandstone or granite depending on the cleaning agent should be decided accordingly. It should be in non ionic detergent not the normal detergent what we use at home removal of the moss and lichen, this is a part of the cleaning process and cleaning the other thing which is happening is the cleaning if you we have discussed when we discussed the decay that efflorescence from masonry, the removal of the salt which is very important.

And, what is the method for removal of the salt? It is a prolonged washing with the fresh water. The water should not contain any chemical or any other types of things or any salinity and repeated application of the moist paper pulp. This is a method which has been used even in Mahabalipuram it has been used in the Konarak sun temples because it because it is a poorest building material when we repeated application of the moist paper pulp on the surface it sort of extracts the water and the along with the soil the salt in the water and that is one of the process of removal of the salts.

Poultice, we have talked about the poultices which is a foolish which is kept on the surface and it also helps in removing the grease, stain and other Taj Mahal, Agra this is what happens. So, the poultice the moist paper pulp it also depends and that which is the

stone category and what type of decay damages or what we are trying to clean that is very important to understand. So, these are generally very well known methods.

Now, when we were talking about a repair apart from the cleaning or salt removal of the soil there is one particular type of repair there are many many ways of repairing. One particular type of repair is that which is plastic repair or dentistry. Let us see what it means you can see here that this is a sort of a part which has sort of a decayed and this part has been sort of repaired here and this repair is a mortar or a synthetic resin has been done is a composite mixed with stone dust and other materials to form a stable patch matching to the original color and texture.

So, this is a sort of which you call plastic repair or dentistry how to a historical structure to keep it like that and some sort of a composite material, what is that and how it is because sometime wrongly we use a lot of cement in that and then we see the cement is stronger element, it may initially look good, but it is sort of ultimately the compatibility is not there, it falls and in that process it can take out the original material. So, even if you do that plastic repair or dentistry one has to be very careful what is the method what type of mixture what is used and has to be done a lot of skill is also required for that.

Another thing about the water repellent because that is a problem, but generally the it is not advisable because whatever water repellent has been used it in a long term is not a good thing it causes for the damage, but hopefully with the technological improvement like with nanotechnology and other there are different types of technology being improved which water repellent qualities it has depending on some of the our natural phenomena, we have read it and perhaps there will be a time coming with lot of interdisciplinary research and other when we can find out some water repellent which does not cause decay to the existing structure. So, this is something of the stone and some of the ideas about the repair and maintenance. We will continue in our next lecture with a break and pointing and mortar joints.

Thank you.