Air Pollution and Control
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Lecture – 05
Impact of Air Pollution on Building Materials and Structures

Hello friends. So, as you know, these days we are discussing about impacts of air pollution. Various impacts of air pollution in the sense like on the human health, or on property, on environment, ecosystem, etc. So, today in that series we will discuss about impacts of air pollution on building materials and structures.

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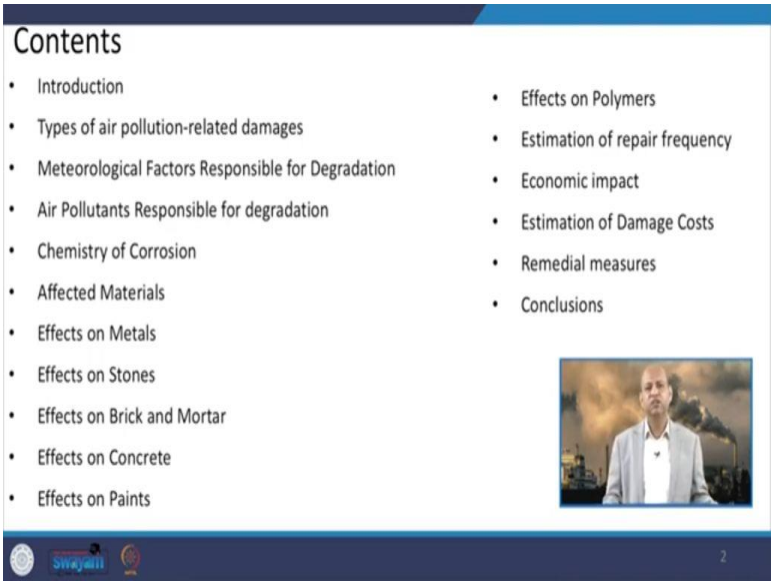

So, in that you can see the content list for today's lecture like of course, introduction, brief introduction will be there. Then the types of air pollution-related damages which occur to building materials and building structures; and the meteorological factors, which are responsible for degradation, which enhances the degradation you can say because of air pollution. And then the air pollutants which are known for the degrading building material; then chemistry of corrosion because the corrosion and abrasion these two factors are very important, when we talk about the relationship of air pollution or the weathering of building material.

Then we will see the effect those materials, which are affected and on different kind of material like on metals, stones what kind of effects are there. We will also see on the brick and mortar

effects of air pollution, and then the own concrete, paints, polymers etc. Then we will see how repair frequency is estimated by that particular range of the cost parameters; and the economic impact and the estimation of damage cost, and then the remedial measures and we will conclude accordingly.

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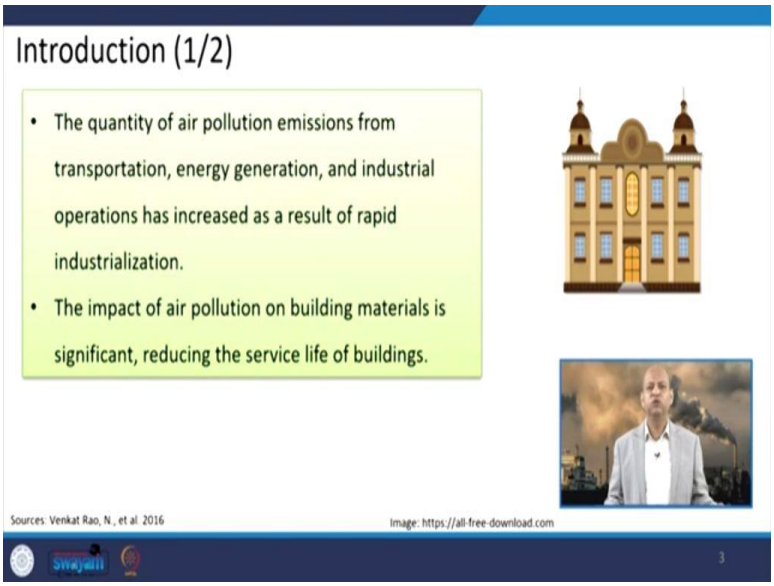

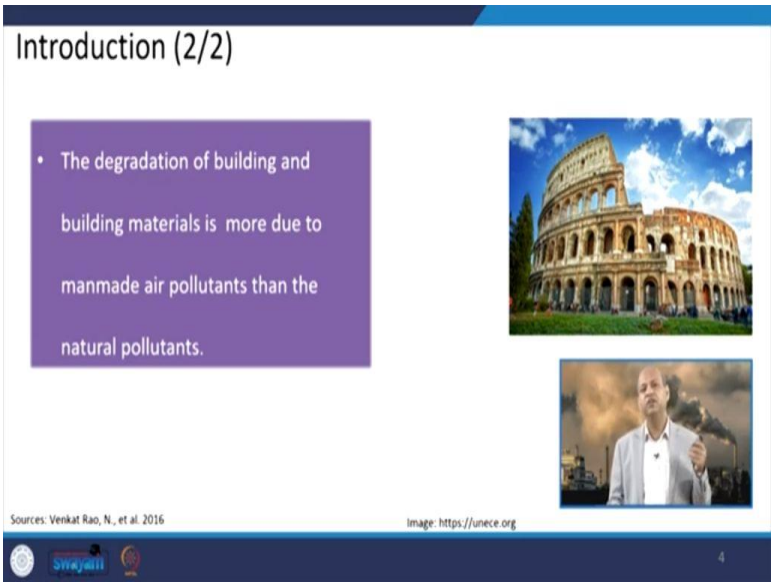

So, when we talk about the air pollution relationship with the buildings; so basically, all kind of air pollutants have certain effects on the buildings. And it can affect the building's appearance as well as it can also damage the structural component of the building; so it can reduce the life of the building. And it is also found out that the air pollutants which are emitted by manmade

activities; they are more responsible in comparison to the natural pollutants to damage the buildings. So, we will see accordingly those aspects.

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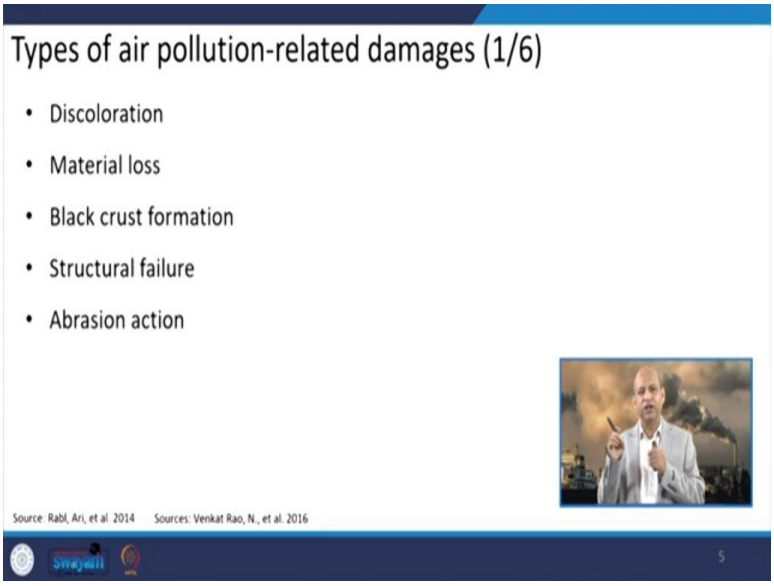

When we talk about types of air pollution related damages; so, those can be classified like it can discolor the building, or it can result in losses of the material. Then it can also cause like black colored crust formation; you might have seen discolored buildings, even if they are painted. So, after one season like monsoon, you will see blackish or grayish, or sometimes greenish kind of color is there. Then, a structural failure maybe there because of long term effect of these air pollutants. And abrasion action because when friction is there and particulate matters etc; the constant abrasion happens then the building is damaged.

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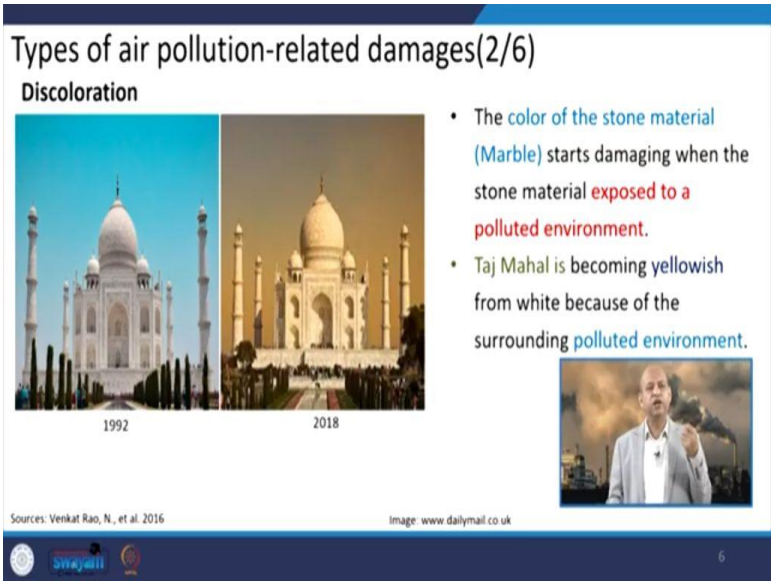

So, you can see the effect from pictorial representation like about the Taj Mahal. It is said that because of pollutants, the appearance of the Taj Mahal stone this marble from why it has been to yellowish. So, that that has been because of particulate matter as well as this sulphur dioxide related, or other kind of pollutants which are present in the air.

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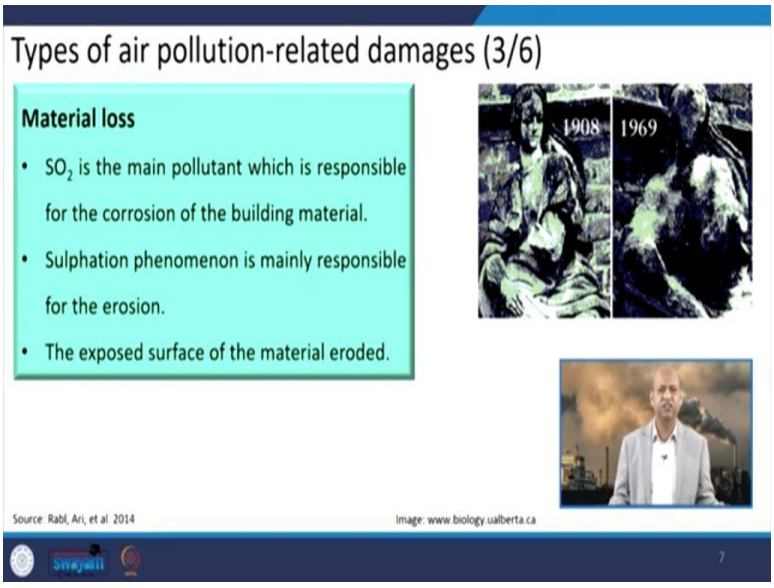

When we see these kinds of structures artifacts; so, in 1908, all you could see those features of this particular statue. But in 1969, over the years of around 60 years or 61 years; the all those features has gone. And the reason is because this acidic rain, or this acid rain as well as the

abrasion because of particulate matter all in combined, weathering effects etc; they result into such kind of damage to very important artifacts of our history.

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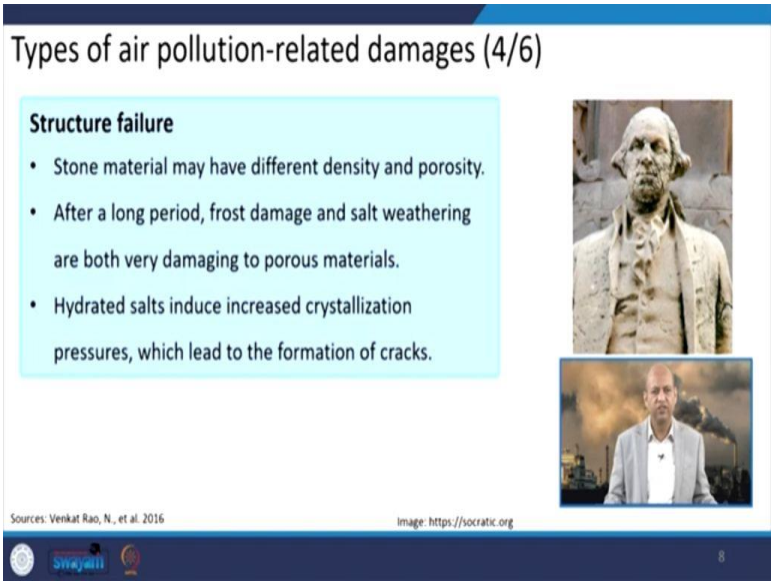

Well, it is also known that in the stone materials they have porosity as you know and different densities at different places. So, accordingly after a long period like frost happens, so, because of temperature increase, then temperature decrease. So, this weathering effect happens and this porous material is more susceptible for those kind of things. And then the hydrated salts, which go inside these pores and they crystallize, and they generate the pressure; and that can lead to some cracks etc from inside to outside.

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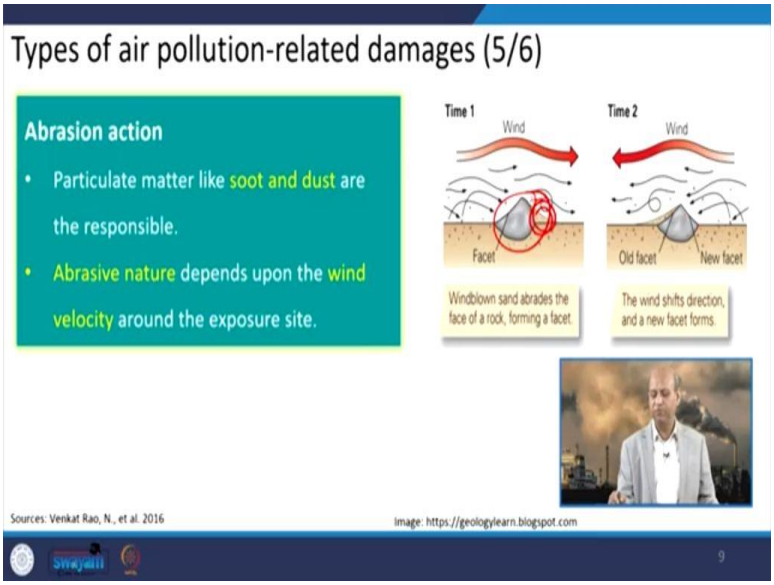

So, you can see this effect of this abrasion action. So, if you know that that kind of feature is there. So, wind is coming particulate matters are also there, and because of that, this kind of situation occurs. And according this kind dust deposition happens So, over the period of time, their surface get abraded and it gets damaged. You can see the old facet and the new facet because of changes due to the abrasion.

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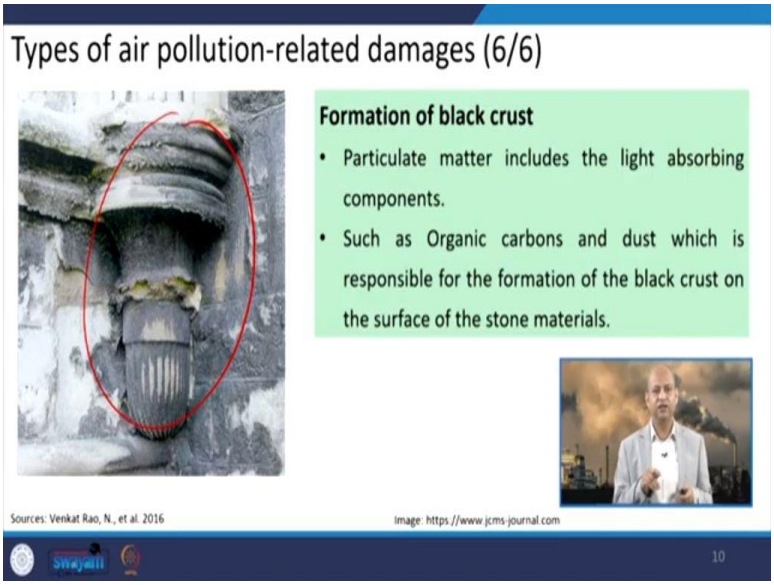

And then we talk about this black crust formation. You see these kind of deposition occurs, because of particulate it matters which absorbs the light and black carbon, organic carbon or

dust, moisture, everything mix; and then they get deposited on certain places. And they disfigure as well as they also cause chemical and physical damage to the property.

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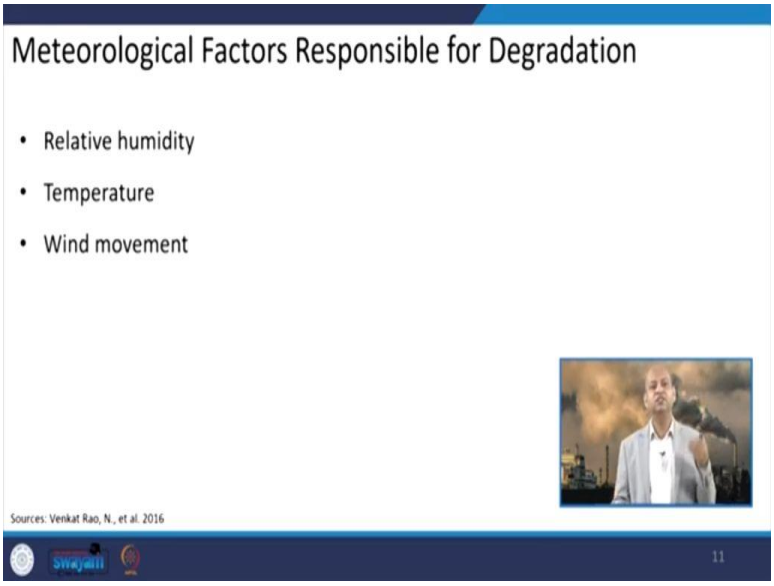

Then there are meteorological factors which enhances these air pollution related damages to the building material and buildings. So, these are like relative humidity, temperature, wind movement. And we will see how they affect like when we talk about relative humidity, they basically contribute into acid rain; because they react with sulphur dioxide or nitrogen dioxide; and in that way they can cause the damage to the building material.

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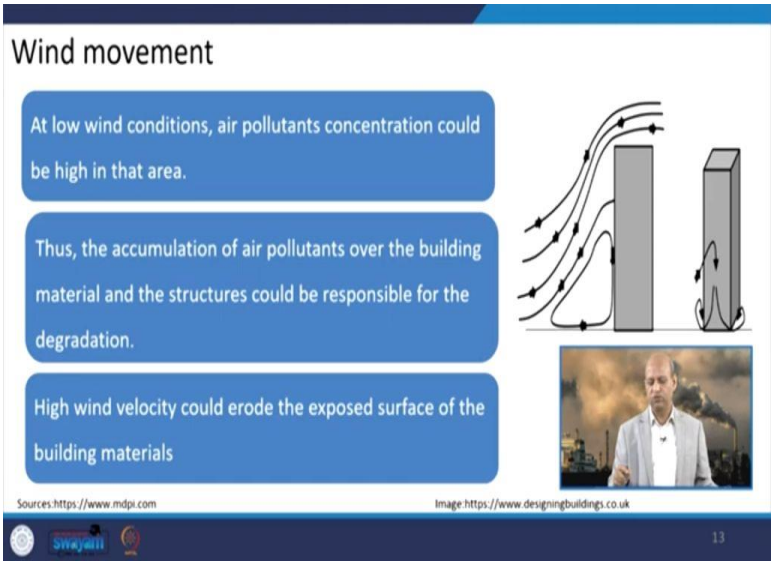

Wind movement has its own effect because of certain patterns. So, they are responsible for deposition of particulate matter, they take the particulate matter along with them. Then abrasion occurs, friction occurs; they damage the surface of the building.

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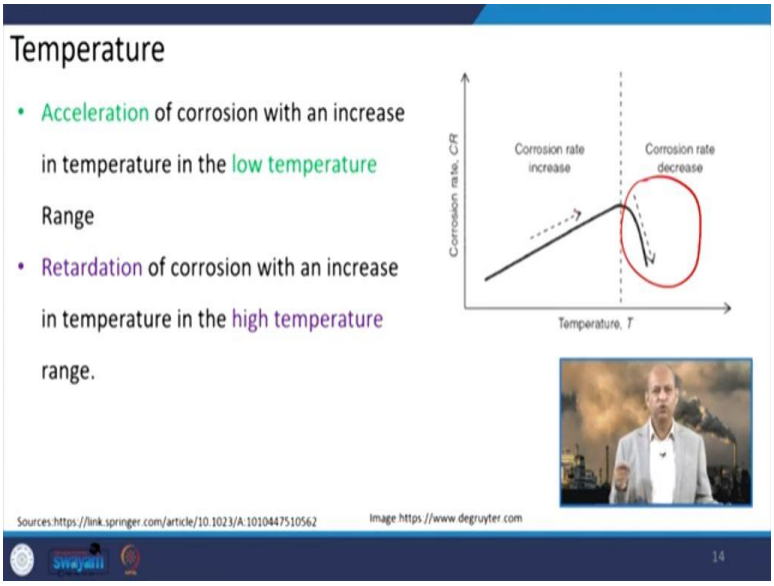

Temperature basically, temperature difference in different kind of materials. They get expansion then contraction; so, that changes its physical phenomena and it causes the damage. But high temperature, this corrosion related effect does not occur; because moisture is not there. Otherwise, corrosion rate increases with the temperature; this is the result of a study.

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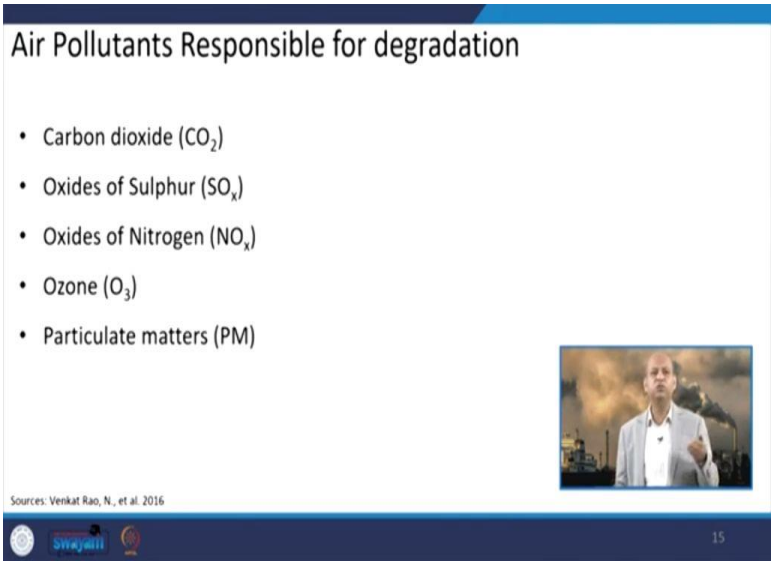

When we talk about air pollutants which are responsible for degradation; so, the major air pollutants, which are responsible for degradation of buildings are basically carbon dioxide, oxides of sulphur, oxides of nitrogen, ozone and particulate matter. Now, you can see the difference. Health effects may be there like VOCs and other pollutants are there; they are responsible for health effects. But when we talk about building damages, then only a few are listed here, which are majorly contributions occurs from their side.

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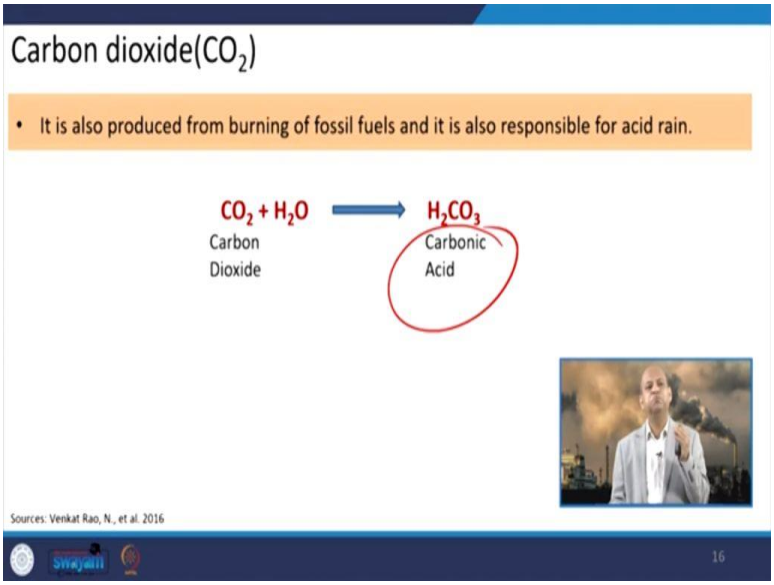

When we see this carbon dioxide because of moisture in the air, this carbon dioxide gives this formation of carbonic acid. And that is why the rainwater always has somewhat lower pH; and, but we do not call it acid rain. Acid rain is called only when the pH is very very low of the water. So, this is always present in the air, and this causes this acidic kind of behavior of the air moisture.

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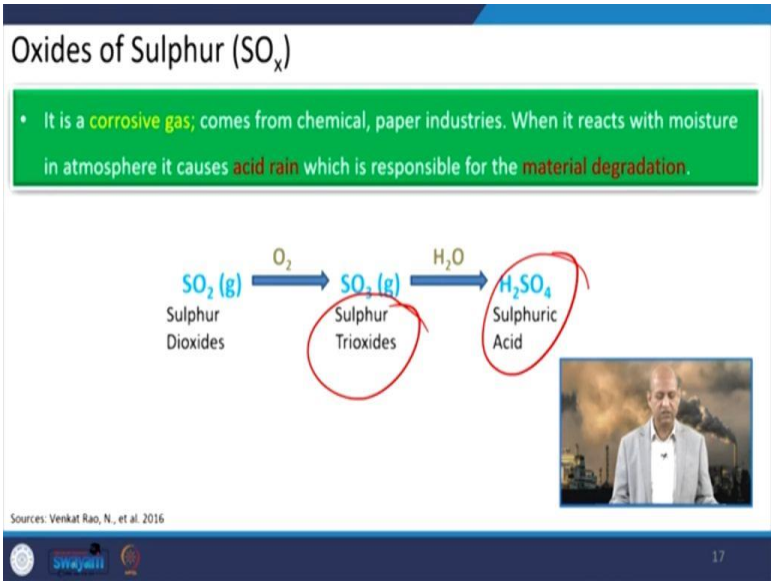

And the oxides of sulphur as you know, we have seen that it can get converted to sulphur trioxide; and then because of moisture, it can converted into sulphuric acid. Sulphuric acid is very very corrosive as you know; and that is why the SO_2, high concentration in air is the major cause for damaging the building materials, especially, like calcium carbonate related building stones.

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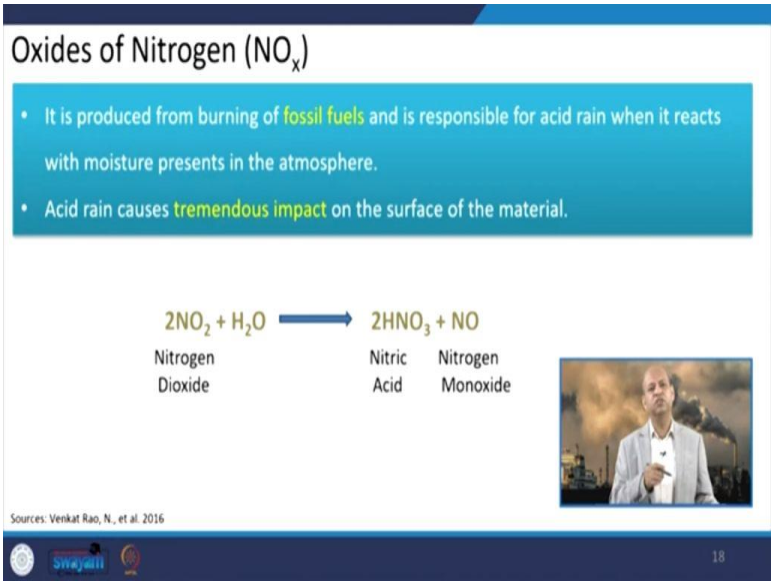

And metals like iron ferrous, ferrous related, we will see that in detail when we talk about oxides of nitrogen. So, again, because of moisture, it is converted to nitric acid; but it is not as much damaging as sulphuric acid, but it is also the causing cause factor for the acid rain.

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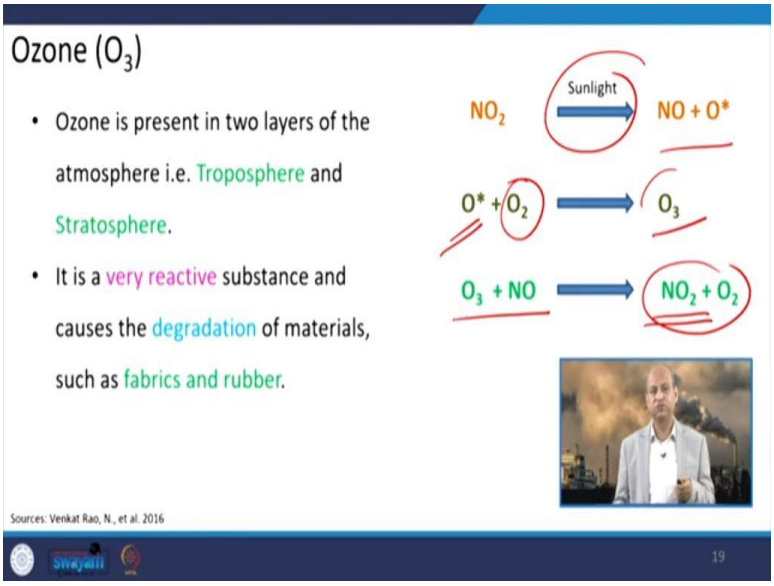

Ozone, as you know Ozone is a secondary pollutants formation in the troposphere because of photochemical reactions; like in the presence of sunlight, NO_2 it goes to NO and O. And then one molecule of oxygen when it is connected to this atom, then Ozone becomes in existence. And this is a kind of titration reaction. So, NO if is there from like transport sector vehicular emissions, it can give NO_2. So, that is why, this is the titration effect that in city centers where a lot of emissions are there, from vehicle exhaust emissions; so ozone is less there.

But in countryside, Ozone is more because this NO_2 goes with the downwind pattern in the countryside and sunlight is there; and this gives the formation of Ozone. So that cyclic reaction occurs all the time. And the ozone is very reactive as you know; it is very highly oxidizing gas; and it is also greenhouse gas, this is also interesting to see. Ozone is not only the health damaging pollutant, but it also contributes to global warming and climate change related issues.

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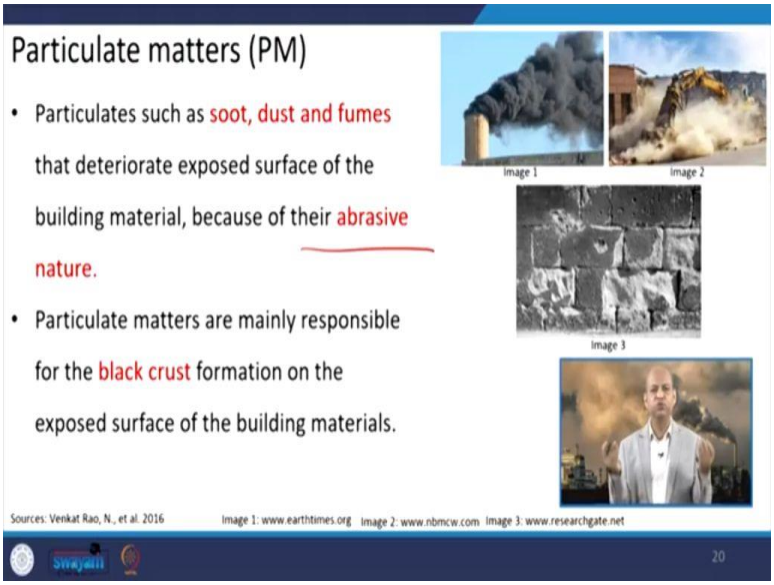

Particulate matter when we talk as I said, this particulate matter in the last lecture as I said that it caused several kind of health effects. And it is also responsible for several kinds of building degradation. You can see the sources of particulate matters which occurs in terms of source smokes, and then these activities construction activities. So they have this abrasive in nature because friction occurs whenever they strikes to the surface, dry deposition can occur. And then it can slowly damage the surface of the building.

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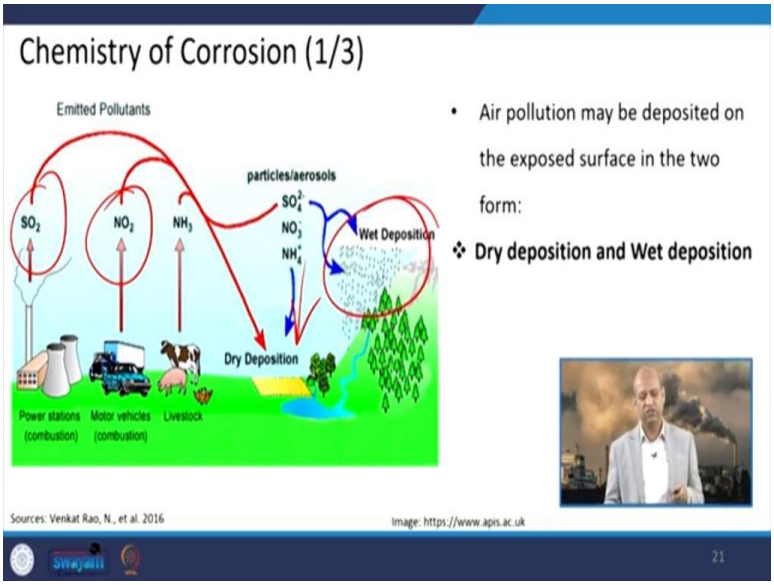

When we talk about the chemistry of the corrosion basically; so, the emissions of sulphur dioxide or nitrogen dioxide, ammonia etc, they go into the air; and then dry deposition occurs, wet deposition occurs. So, then this acid rain formation is there and this acidic effect is there.

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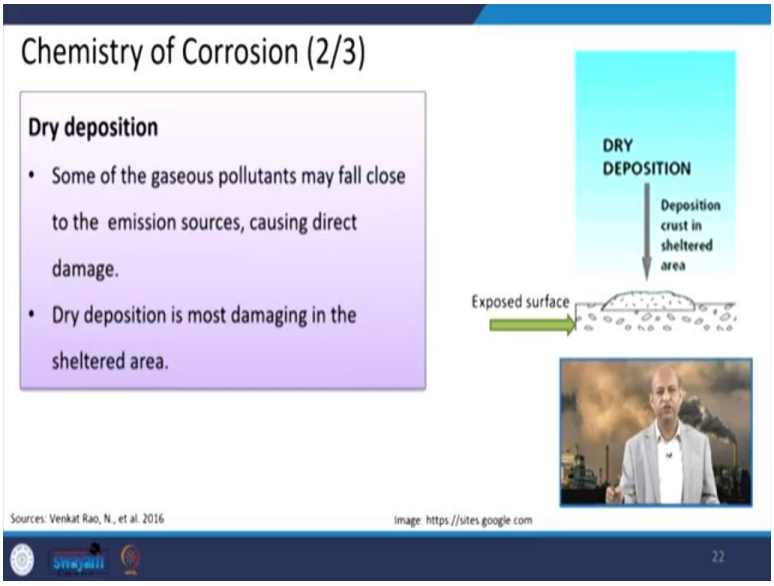

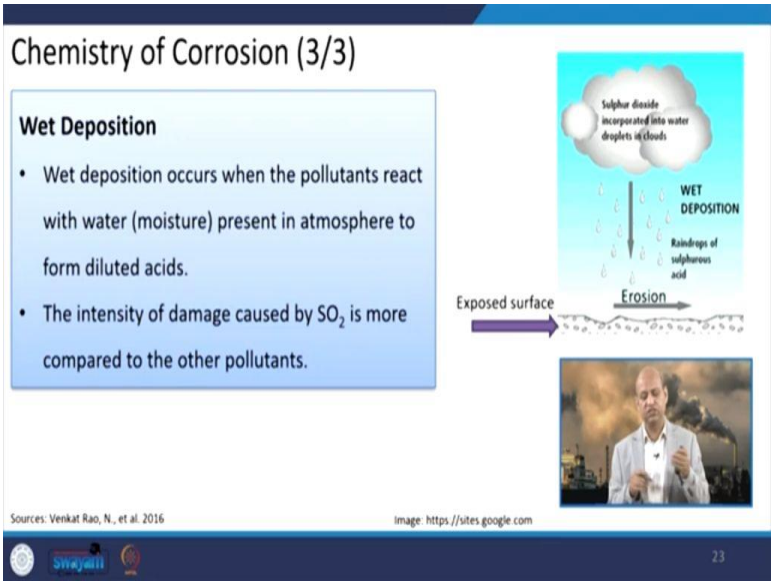

So, the corrosion effect is because of those reasons. Dry deposition, simply because of gravity particulate matter, even the gases that descends to the surface; and the, wet deposition because of that precipitation effect is there and that is more dangerous for building materials etc. If there is a lot of SO_2 concentration in air, and that is got converted into sulphuric acid.

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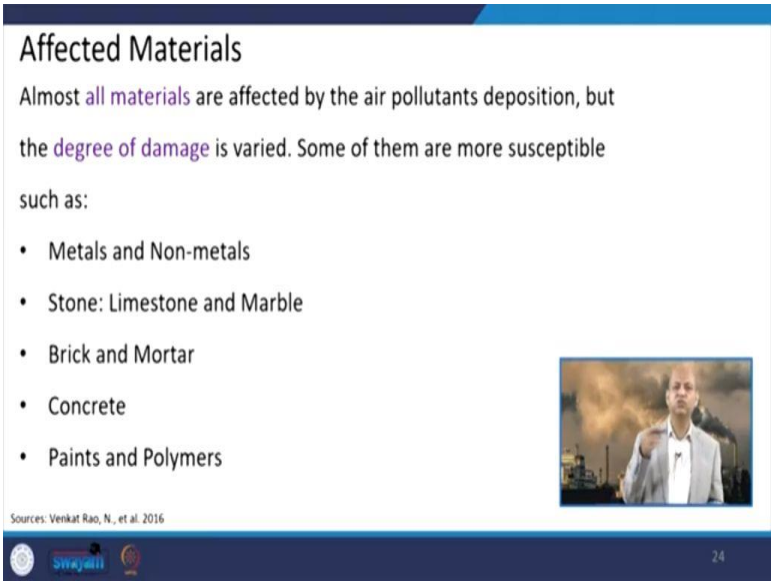

So, when we talk about how materials are affected, so we can see all kinds of materials are affected by these air pollutants, whether they are metals or non-metals. Even stones like limestones or marble, and then brick, and mortar, concrete, paints and polymers; all these building materials are damaged in one or other way by air pollutants. And we will see how they are damaged.

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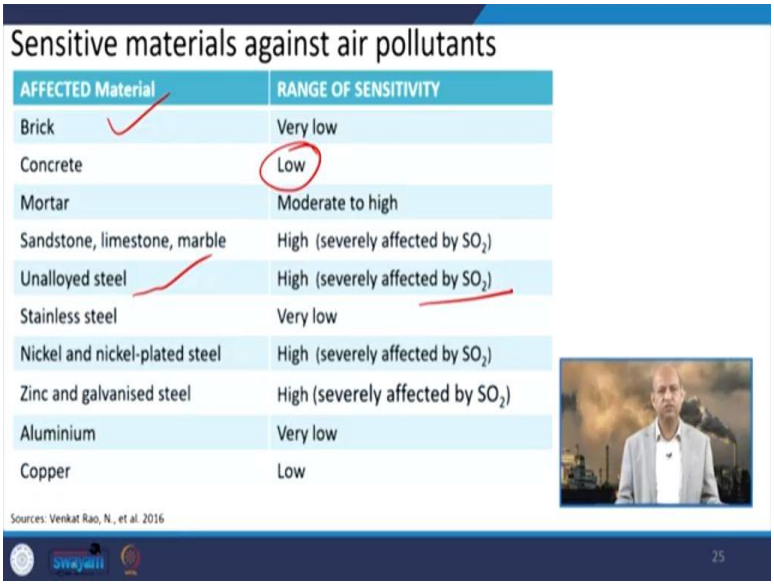

So, you can see these sensitive materials against air pollutants like brick; it is not so much sensitive to the air pollutants, because of its at high temperature it is manufactured; and it is not

so much susceptible. It can afford to be exposed by high concentration of those kind of air pollutants.

Concrete is also low; but once you know concrete is damaged and somehow this acidic water goes inside; and if it starts corrosion of the (reinforced) that you know the steel or iron that ferrous material. So, because of rust, the volume increases; and then concrete starts to crack, and then this can get affected.

But, it also you can have very high grade concrete which may not be affected; but that is very expensive. Mortar, moderate to high effect maybe there because of air pollutants. Sandstones, limestones: they are high because of this SO_2. Similarly, these unalloyed steel is also highly susceptible to air pollutant because of SO_2.

Stainless steel, as you know because the stainless, its name is there; so that is very low affected by these acidic pollutants. Nickel-plated steel: they are again because of SO_2. Zinc, galvanized steel all these are highly susceptible. Then aluminum, very low; but aluminum has its own problem you can know about that. But, at least from this air pollutant, it is not so much problematic. Copper has low, but it is affected.

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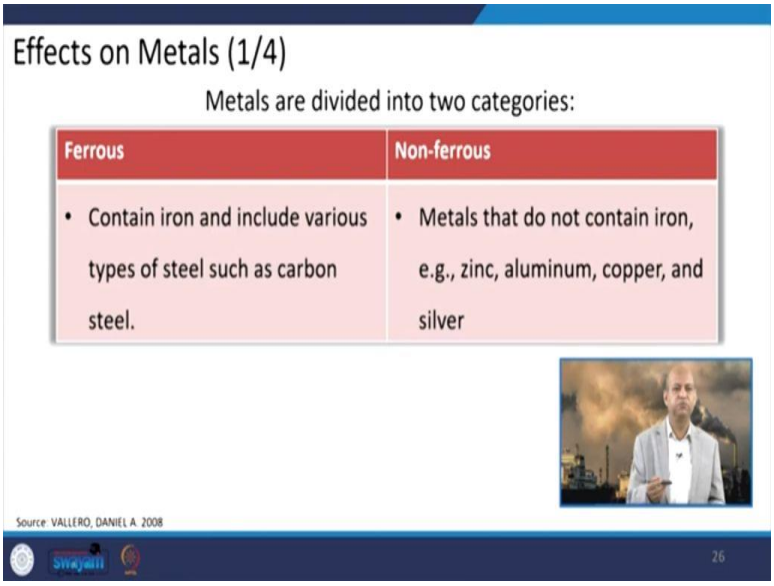

When we talk about these metals, so ferrous metals they are affected by severely by SO_2, etc. Non-ferrous like zinc, aluminum, copper, they are not so much affected.

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Effects on Metals (1/4)

Metals are divided into two categories:

Ferrous	Non-ferrous
• Contain iron and include various types of steel such as carbon steel.	• Metals that do not contain iron, e.g., zinc, aluminum, copper, and silver

Source: VALLERO, DANIEL A. 2008

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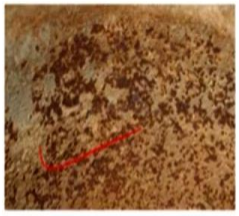
Effects on Metals (2/4)

- Atmospheric corrosion of metals is generally an electrochemical process only occurring when the surface is wet.
- The most important parameters for the corrosion which are humidity, precipitation, temperature and levels of atmospheric pollutants.



Source: VALLERO, DANIEL A. 2008

Image: www.dreamstime.com

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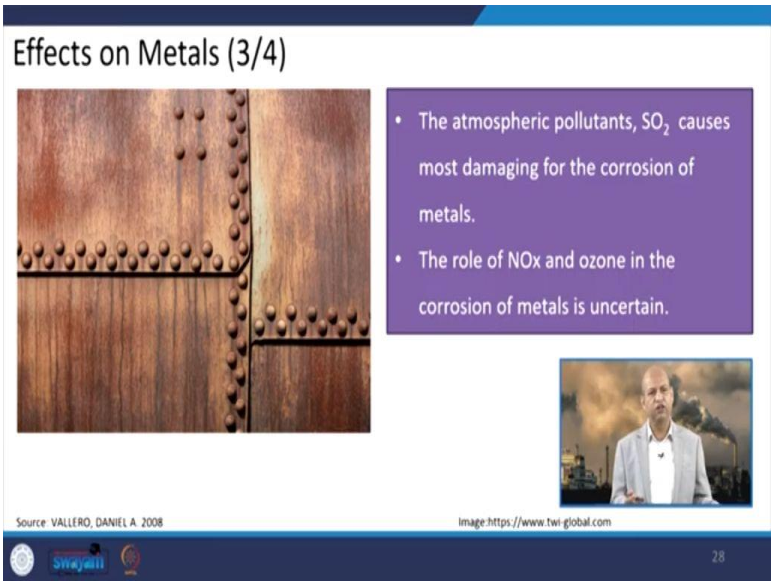

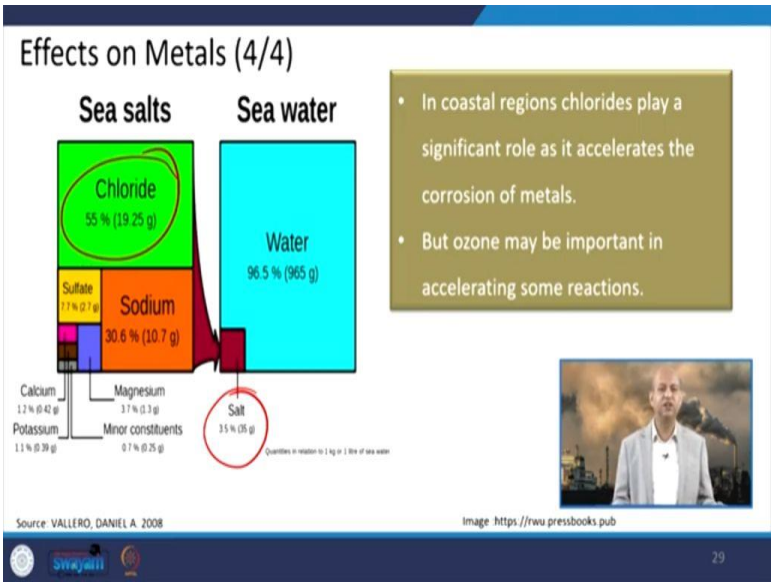

And like you can see this figure, this corrosion effect is there; and this is because of this electrochemical process, which occurs in wet surfaces because of these air pollutants. And the important parameters which affect the corrosion, reactions are like humidity, precipitation, temperature, levels of atmospheric pollutants. All these will govern how much corrosion may occur and how much it may be damaged. You can see these kinds of iron gates can be affected by corrosion and rust because of this SO_2, etc.

And NOx also has some effect Ozone corrosion on the metals is uncertain; means more research is needed. When we talk about at the places like sea shore; so, sea water has this a lot of salt. And with air, you know salt comes to the air; and within salt if you see like sulfate sodium is

there. But the huge quantity portion 55 percent, more than 55 percent is chloride. And that plays a significant role when this corrosion related action is accelerated because of this chlorides. But Ozone may be important in accelerating some other reactions.

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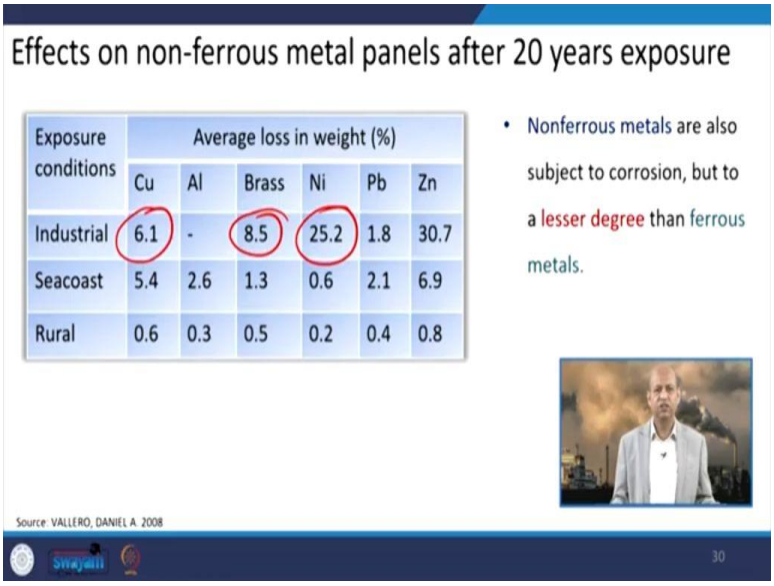

When we talk about effects on non-ferrous metals, like 20 years exposure study has been conducted. So, you can see like exposure conditions in industries, it is very high 6.1. On the brass 8.5, nickel 25.2; in sea coast, it is less than the industrial area, in rural it is further less. So, you can see that industrial, because in industrial areas, lot of pollution is there; and the air is polluted in terms of several kinds of air pollutants, whether sulphur oxides or particulate matters or other kinds of toxic materials are there.

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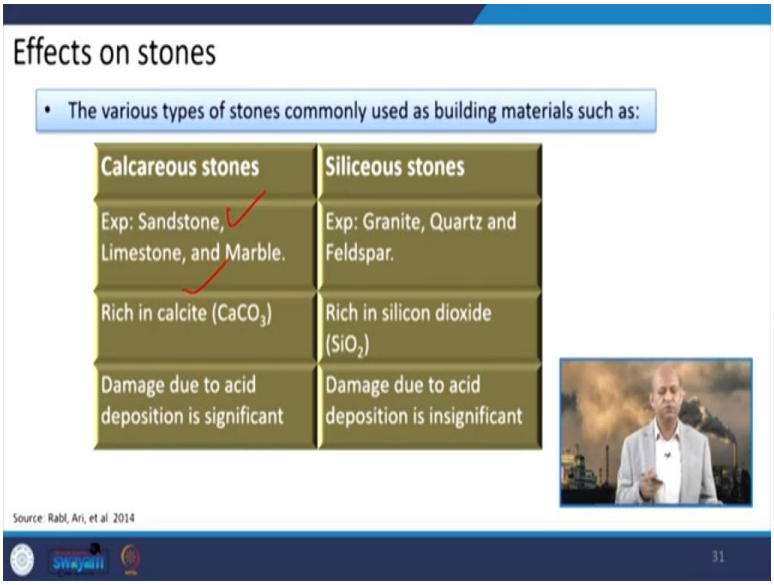

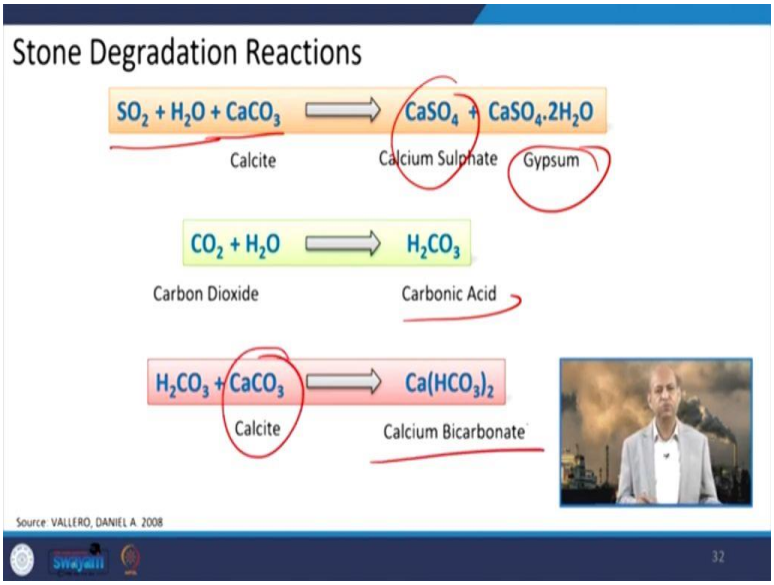

When we talk about the stones, effects on the stones because of air pollutants, then majorly we talk about like calcareous stones and siliceous stones. So, siliceous stones are more sturdy like granite. They are very tough and they are not so much affected by these air pollutants. But, the sandstones, limestones, marbles etc, they are very much susceptible to the SO_2 pollutant; because of this acid rain or acid deposition, they can be there.

There is a very simple reaction as you know, because $CaCO_3$, SO_2, H_2O is there; so the calcium sulfate is formed, Gypsum is also formed. And this carbonic acid can also participate to $CaCO_3$;

and it is calcium bicarbonate is formed. So, that kind of a stone is very much susceptible to acidic atmospheric environment.

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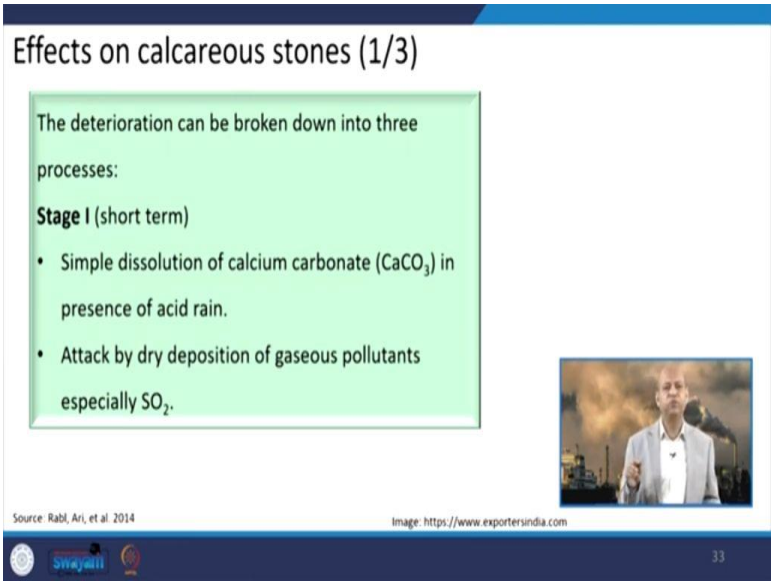

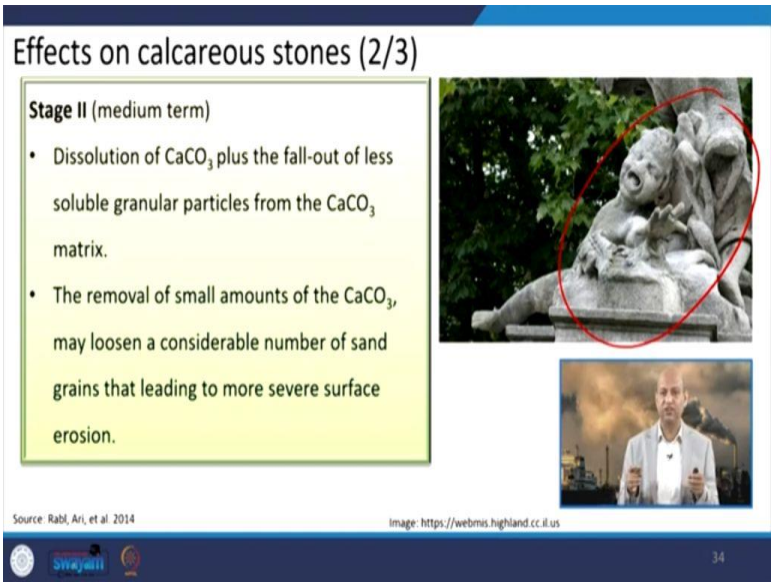

When we talk about in continuation to these calcareous stones; then there are different stages. Like in stage one, simple dissolution of calcium carbonate happens in presence of acid rain. And the attack by dry deposition of gaseous pollutants, especially SO_2 also occurs; but that is slow process. Then the stage second that is the medium term; and you can see this is the effect of the second stage. So, in this dissolution of calcium carbonate happens; fall-out and because of this

acid rain, the surface get damaged, because the dissolution has happened. Calcium carbonate has gone to different kinds of products like calcium sulphate, etc.

And the removal of a small amount of calcium carbonate may lose considerable number of sand grains and the leading to surface erosion. And further this acceleration happens because then more porosity is there and then more attack will be there because of acid rain.

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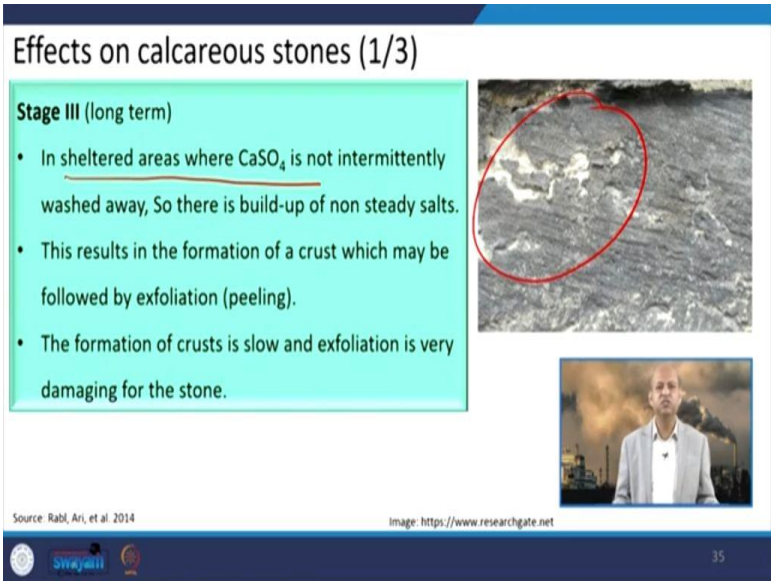

When we talk about stage three, then in stage three basically this sheltered areas, where calcium sulfate is not intermittently washed away. This is deposited there; so it can build up into the concentration and it remains there. And this results in formation of crust, which may be like followed by the peeling of that surface; and the formation of crust is slow and this particular peeling process happens. The further damaging of a stones happens you can see here; so, those kinds of things may happen. So, three stages are there in calcareous stone damage because of air pollutants.

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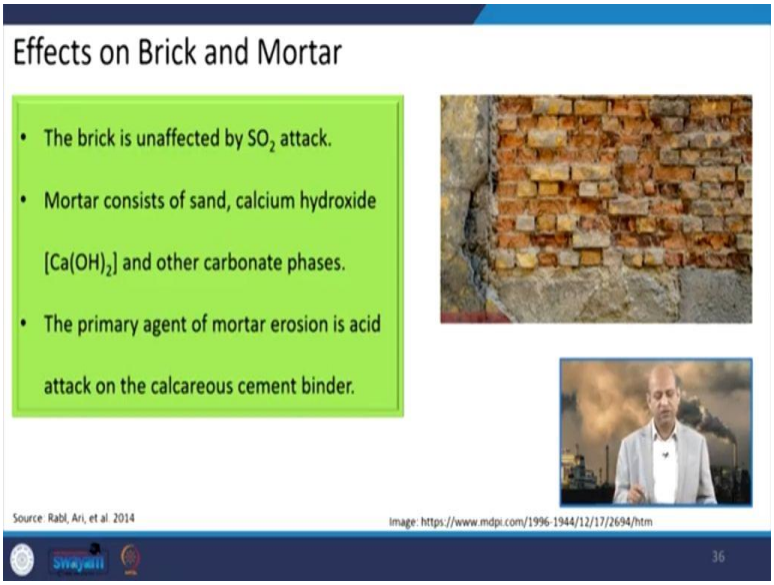

When we talk about brick and mortar, the mortar again has certain calcium carbonate related things. So that is affected, but brick is not so much affected by SO_2 attack. So, you can see the mortar only, those gaps are because of this acid rain you can see.

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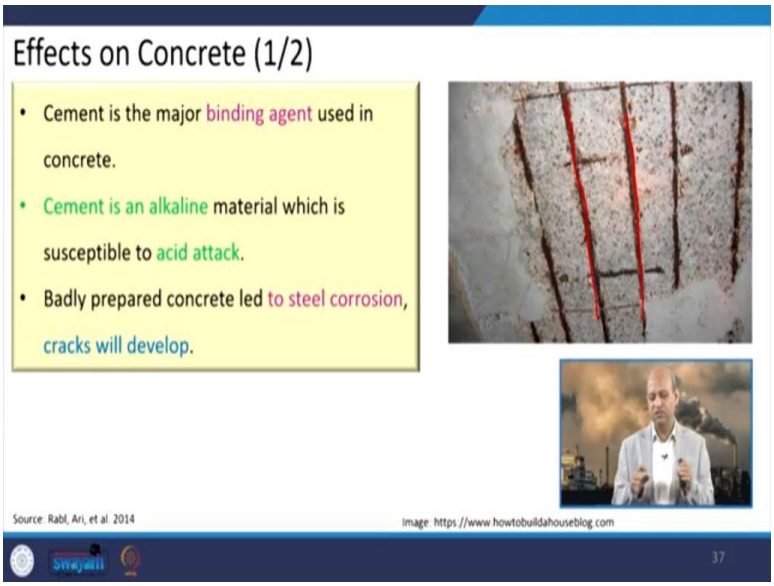

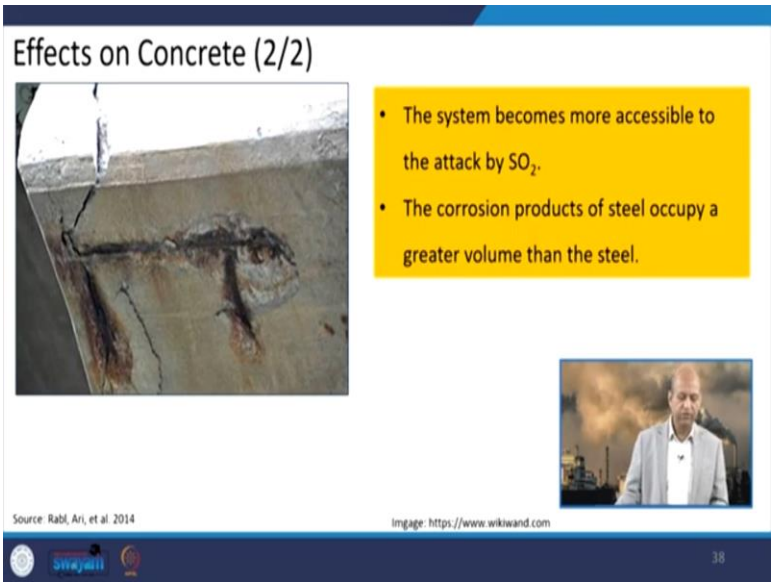

When we talk about the concrete, so in concrete basically this reinforced concrete. Basically, this is about the reinforced concrete. So, like these steel rods, iron rods are there. So, they are damaged by acid rain; and rust happens and then volume increases. So, further cracks developed in concrete and then concrete damage also happens. When we talk about this, this kind of gaps; so you can see this corrosion starts and then damage continues.

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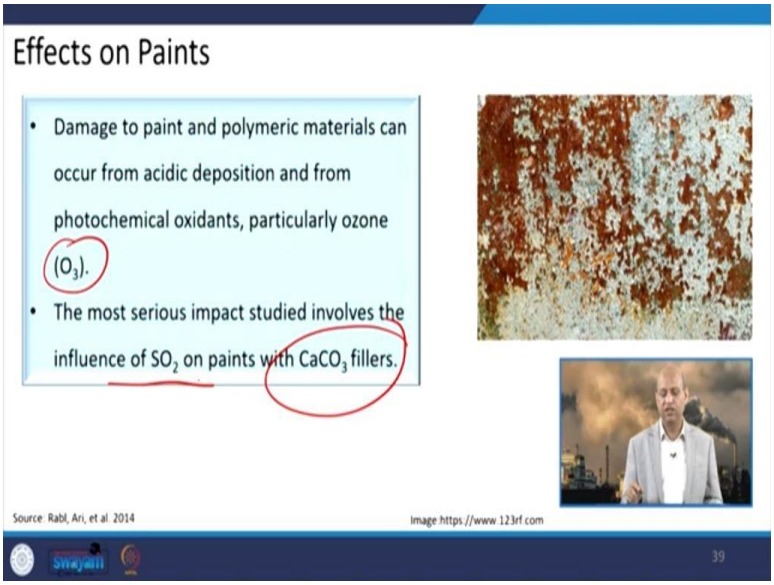

And on paints also, there are paints which can be damaged by like Ozone; because it is very oxidizing highly oxidizing gas as you know. So, because of these, then there is presence of certain calcium carbonate fillers in the paint; so, that can get affected by SO_2 also. But, ozone

takes part initially and then the damage continuous and it progresses quite high in longer term. So, these kinds of things may be seen when paint is there, but it is damaged by polluted environment.

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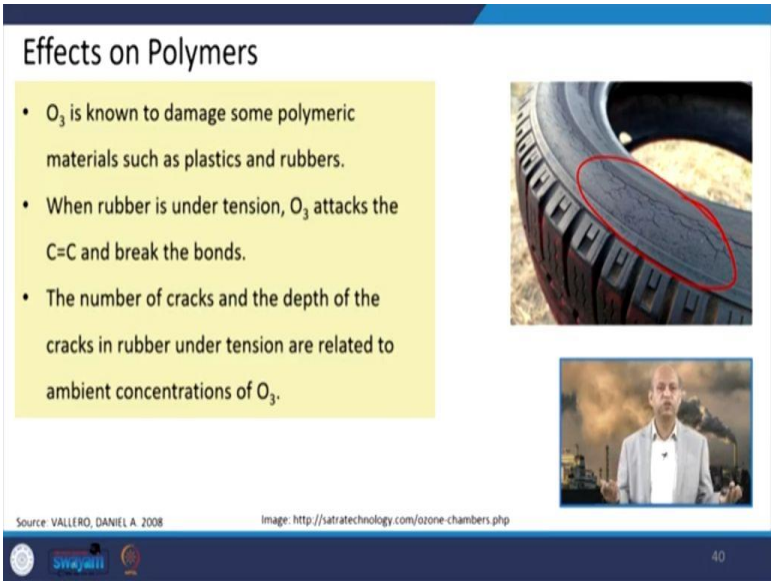

When we see effects on the polymers like rubber or plastic those kinds of things; so, they are badly affected by ozone because of this oxidizing nature. So, you can see here cracks; these cracks are developed by ozone. So, if ozone is very high in concentration in air, so there your tires will be damaged very quickly; so, the economic effect is there, there are many other things. And the number of cracks and depth of the cracks in rubber; it further goes depending upon the ambient air concentration, and the uses of the tires.

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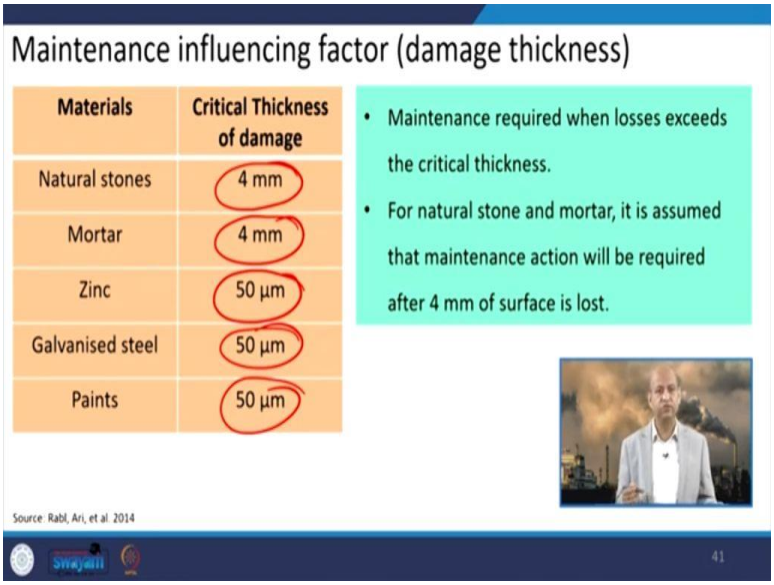

When we want to analyze the maintenance influencing factors like damage thickness etc; so you can see like natural stone 4 mm is there; these are the critical thickness basically. Mortar 4 mm, zinc 50 micro meter only; galvanized steel 50 micro meter, paints 50 micro meter. This much of thickness damage is there, then it is critical. And one should go for some remedial measure; otherwise, it will be highly damaged after some time.

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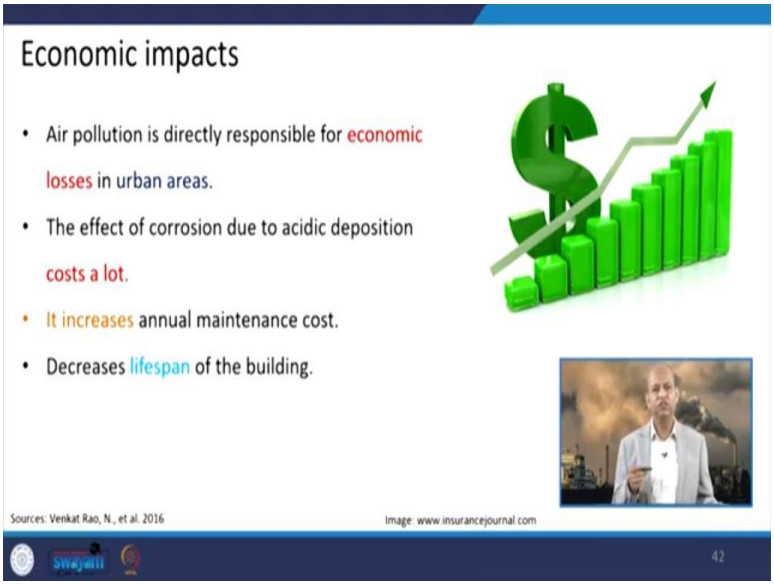

Then, economic impacts are there because when buildings are affected, then we have to repair them; and its age also reduces, the structural components are also get damaged. So, economic

impacts are there and the maintenance cost is also increased; and lifespan of building is decreased. So, economic impact is severe, if you do not care; if you do not deal with the air pollutants, cleaning from the environment from the atmosphere.

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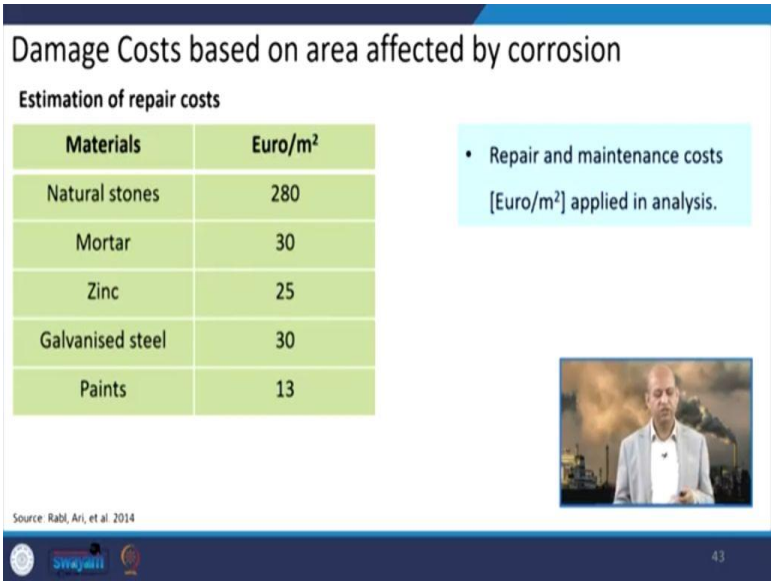

And the damage cost can be calculated, estimated by this kind of study. They have given this table that natural stones and the mortar, zinc etc, how much area that you know is affected; depending upon the affected area, this repair cost can be estimated. So, that is used for estimation of the cost of damage because of air pollutants and corrosion.

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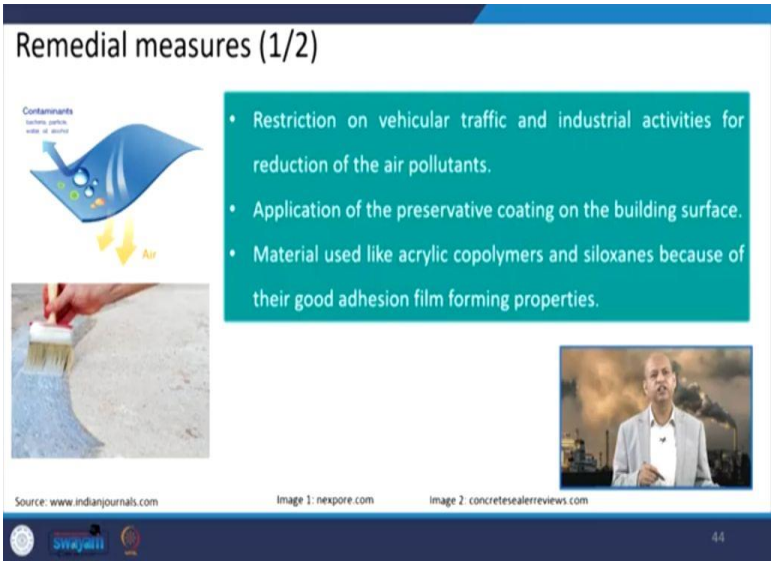

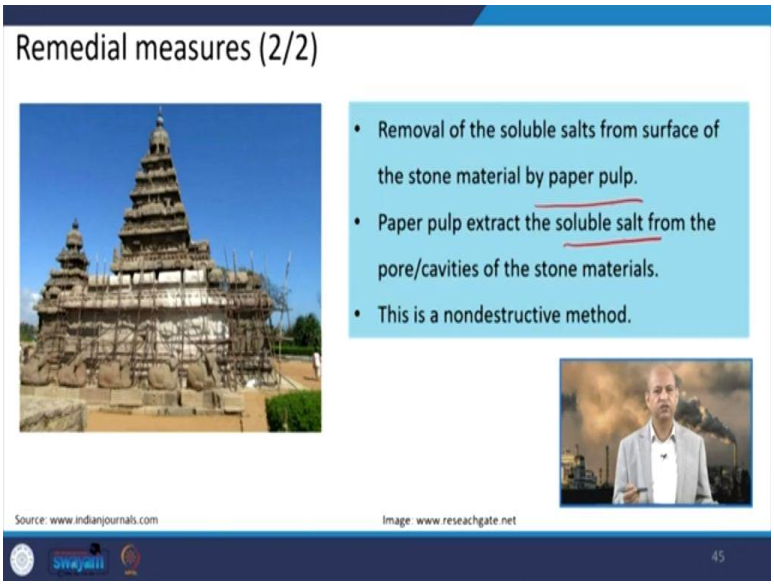

So, remedial measures they may be like coating. There are certain coating which bifurcates or which is kind of wall in between very thin wall, so that this attack of the sulphur dioxide or acidic environment does not happen so quickly. Even you might have seen like nowadays, when you go to the car garage, they say that please get it painted by some coating, the lower surfaces; so that the rust does not happen, corrosion does not happen. So, those kinds of coating materials are there, which can be used for remedial measures, or to reduce the ill effects or negative impacts of corrosion.

When we talk about building materials, stone related building materials; then there are other ways to go for remedial measures like paper pulp, which is used for this soluble salts removal. So, this paper pulp related treatment can be done; and this is a kind of non-destructive method. So, it is a good way of removing those kind of material which was because of crust because of those air pollutants damage.

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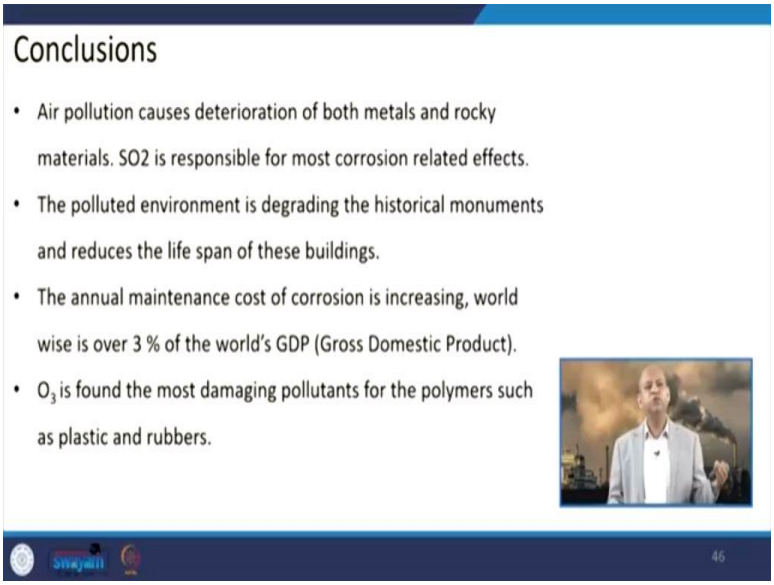

So, in conclusion, we can say that air pollution causes several, not only the health effects, but these effects on the buildings; they can cause deterioration, both the metals as well as the rocky materials. And sulphur dioxide is a major cause of corrosion related the effects on the building materials, and the structural components.

And the polluted environment is degrading the historical monuments. You might have seen, whenever you visit some monuments, there may be some damage; so, the damage may be related to weather as well as related to pollution. So, our monuments have, they are very precious, we should protect them.

So, reduction of air pollution really contribute in protecting our historical monuments. And it can increase its lifespan; otherwise, the lifespan of these buildings will be decreased. And the annual maintenance cost of corrosion is increasing worldwide in over 3 percent of the world's GDP because of this pollution.

So, if we reduce the pollution, we can reduce this maintenance related cost also. And ozone has been found the most damaging pollutant for the polymers such as plastics and rubbers. So again, the property related protection when we talk about, then the reduction of not only the criteria pollutants, simple pollutants, but also secondary pollutants like ozone has to be there. And to reduce the ozone concentration, we have to reduce its precursors concentration like VOCs or like

CO, or the NOx; those kind of which contribute into formation of Ozone. So, this is all for today. Thank you for your kind attention.

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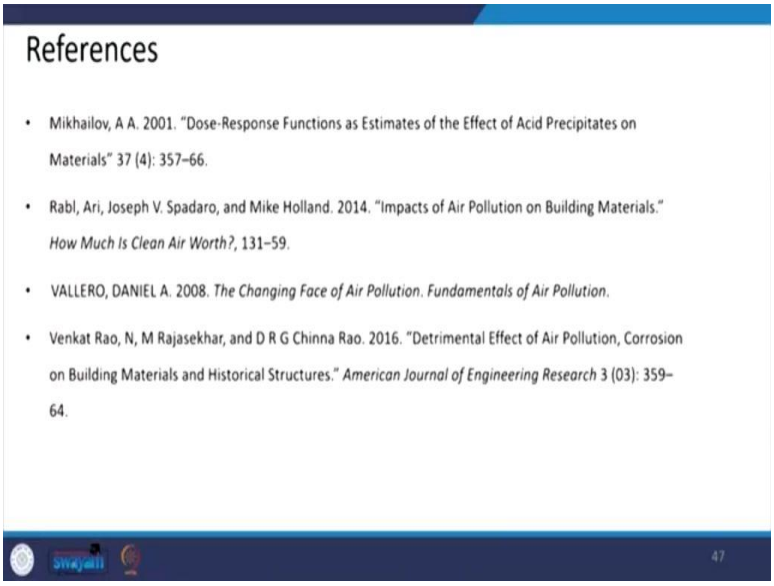

And this is the reference list which you can go through to have more information about these topics which we have discussed. So, see you again in the series of these lectures. Thank you.