Building Materials and Composites
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Lecture - 04
Stone

Welcome everyone to lecture 4 of module 1. We had in the last lecture tried to finish some of the clay products, and now we will move to stone.

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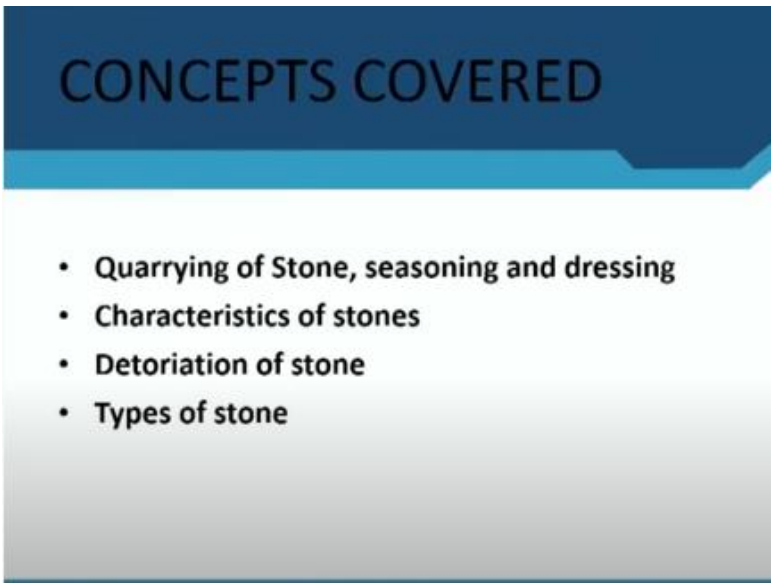

The concepts that will be covered here are particularly the quarrying of stone, seasoning and dressing, characteristics of stone, deterioration of stone, and types of stone. Now, what is the basic difference between clay products and stone? The first part is that stone is naturally available, whereas, in the case of clay products, we have to make or prepare it by the process of burning; we had already discussed those.

But unlike brick, tile, terracotta, or any other product made from clay, we have to look into how we can get or get stone from the mines.

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So, let us see how we can obtain the stone. These are some pictures where you can see the stone has been cut from the quarry. A quarry is the stone mine from where you can get the stone, and specialized vehicles/ machines are used (see image) to mine or quarry out the stone.

After doing some treatment to the stone (seasoning and dressing), it is ready for use. Stones can be used as building blocks themselves. They can be used as a finish on top of a surface. Stones can be ornamentally used by working on them (like making sculptures, jafri works).

Stone may be used in ways similar to clay tile, like for roofing purposes, as well as for aggregates in concrete mixes- identical to the way fourth-class bricks that are charred (dark brown/ black in color) can be used for a building foundation. The debris from the stone quarry can be selected and used as aggregates in concrete.

When we visit the module on concrete, we will elaborate more on aggregates, where we will see how stones are used.

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These images are some examples demonstrating the use of stone as a building material. The entire rock-cut structure of Ajanta and Ellora caves are entirely made of stone. The stepwell in Rajasthan is also cut out from stone. In our country context, Rajasthan (particularly Kota town) have lots of quarries.

You can see the monolithic rock-cut temple of Mahabalipuram. So, it is it has been carved from a single rock.

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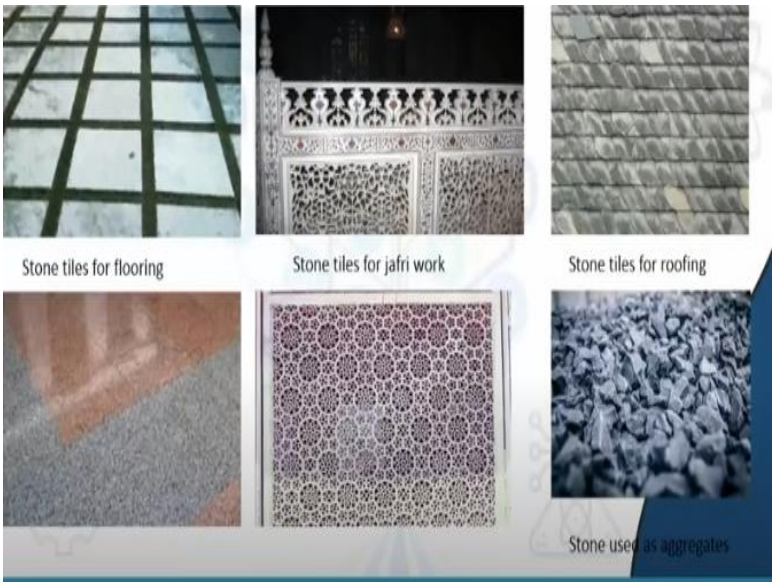

Similarly, you can see a very different application of stone. Stones can be used instead of tiles. You can see here the flooring is made of stone tiles. These are not bearing any structural load; they are just withstanding human load since people will be walking on

top of it. Whereas these stone tiles have decorative use. They are from the Taj Mahal. Flooring tile is not recommended for this Jafri work.

And similarly, when you see this picture, where the roofing is made of stone tiles, it serves a totally different purpose. And finally, here are the aggregates which also are obtained from the quarry. They also do not go waste and have a purpose or use in the building industry.

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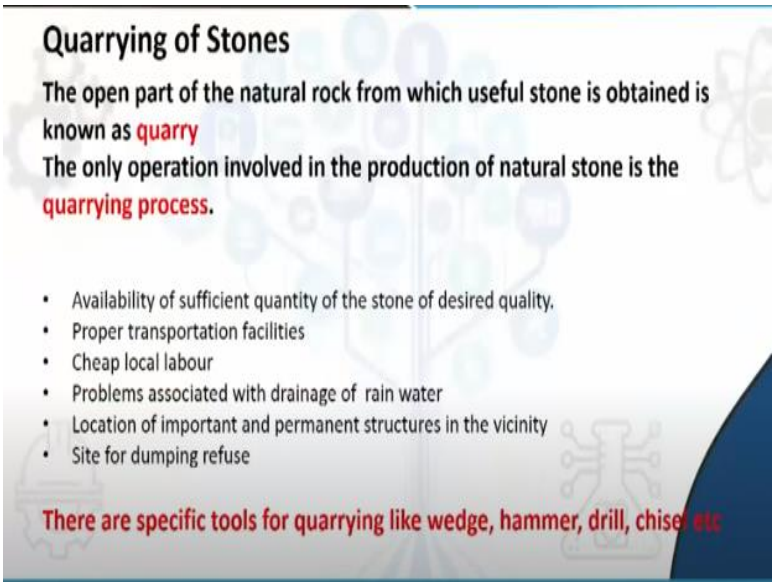

So, let to see what is quarrying and what mechanism is involved in that. The open part of a natural rock from which useful stone is obtained is called a ‘quarry’, and the operation involved in the production of natural stone is called ‘quarrying’. For this process to be viable, sufficient stones must be available in the quarry; otherwise, this prolonged exercise will be futile.

A proper transportation facility should be available since you have to carry the stone from the quarry to the site. You also require a lot of heavy machinery to reach and perform the operations. Local labor should be available, trained through experience or through their family lineage (generations who are proficient at the work).

If the quarry faces a lot of rainfall, then draining out accumulated water also becomes an issue . Knowledge of the locations of prominent structures in the vicinity is also required to be noted since they might get damaged in case any blasting operations are

necessary to dislodge the rocks from the quarry for use. There should be a nearby dumping or refuse site.

All these points are to be checked while before initiating a quarrying process. There are specific tools for doing the quarrying, which are wedges, hammers, drills, chisels, and specialized tools.

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So, if we look into the types of quarrying, one is ‘excavating’ (digging out the stone buried under the earth by use of pickaxe and crowbar). The second type is ‘wedging’. Here, you demarcate a portion of rocks within the quarry by inserting a large number of wedges all along the perimeter of the part and carve them out.

The area may be a region of 10 m ×10 m, and we have to apply force by hammering. Obviously, there will be stratas in stones, and this part gets loosened, which you can carve out by hammering. You may also apply heat. So, by putting fuel in some portions, you create a localized unequal expansion that will lead to segregation of the layers.

Small regular blocks, mainly igneous rocks like granite, are extracted in this way. If you want large and hard rocks, then you may go for blasting. Here explosives are charged and fired, which dislodges the block that is intended to be separated.

Another method is ‘boring’. You make deep bores (holes), and then by firing or tamping, the desired stone (which is useful or productive for the construction) may be ejected.

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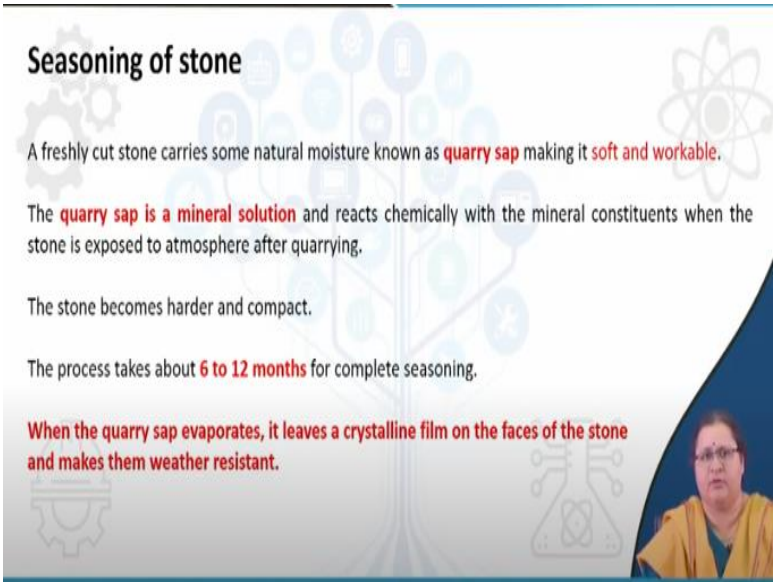

So, after extracting the stone by quarrying, the next step is to leave the stone for seasoning. Why is the seasoning required? Because when this stone is mined, a sap (a liquid secretion) oozes out from the stone, which keeps it soft as well as workable. Thus the stone is still soft in nature.

It is a mineral solution that covers it and keeps on oozing out, and during this time, if it is dressed (cut into its desired shape or form), it will be less labour-intensive. It becomes easier to carry it to the site. For complete seasoning, these should be kept for 6-12 months.

The sap keeps oozing till the entire period of seasoning. The sap leaves a crystalline film on the face of the stone and makes it weather-resistant, and makes the stone surface capable of withstanding inclement weather for hundreds of years. As you can see, the Colosseum at Rome (built of stone) has been standing for so many years, yet it remains mostly unaffected by the weather.

These old structures neither have a paint coat nor a plaster coat. It remains exposed. The weather-resistance effect will be better achieved if we allow the sap to accumulate on top of it as a thin crystalline film. That is the purpose of seasoning.

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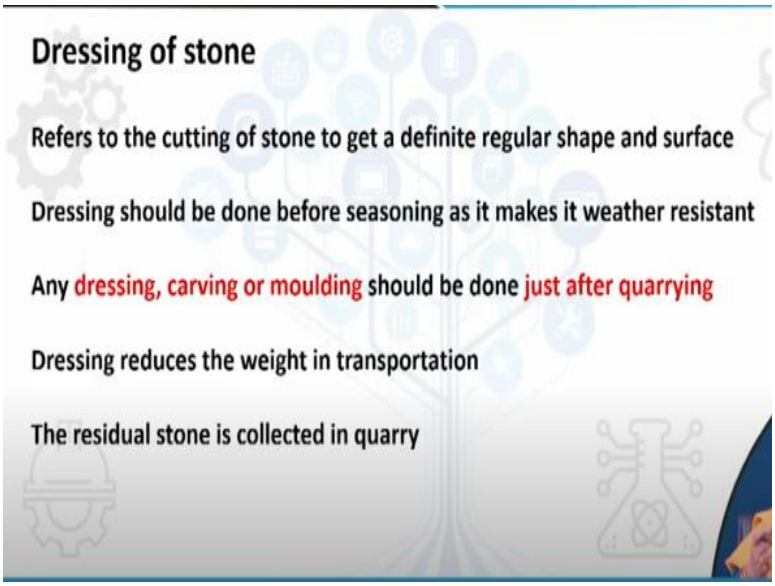

Next, we have dressing of stone. You can obviously dress the stone during the seasoning process itself because it remains softer than it would have been after having been put to use. Dressing refers to the cutting of the stone to its desired shape, size, and form. Dressing, carving, moulding- all these should be done just after quarrying.

Since stone is still softer than it should be, it becomes easier to give it any shape. By the process of dressing, you are giving a shape or form to the stone, or you are making it regular. This will reduce or minimize the space (and thereby reduce weight) it may actually have taken while transporting. The residue remains in the quarry.

This residue does not go waste; we have already discussed one method regarding the usage of residue as aggregates.

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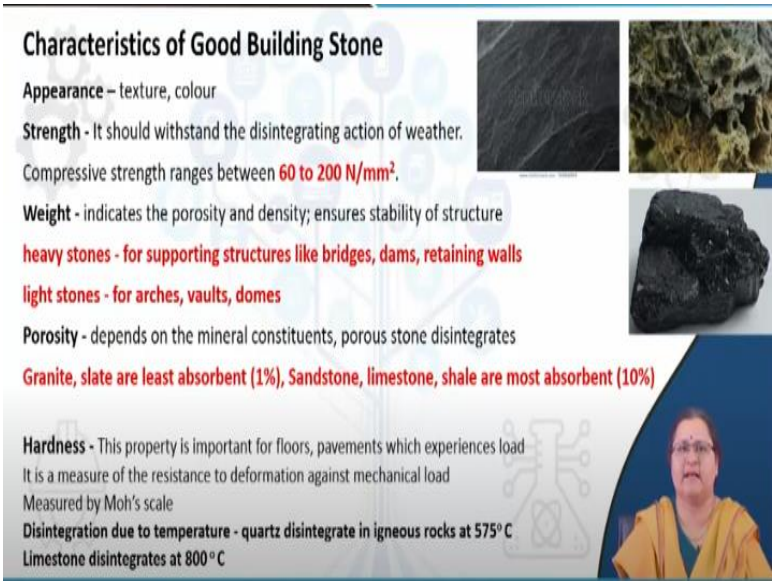

Now instead of moving to how many types of stones are there, let us now move into the characteristics of good building stone. As you know, stones can be used as a building block similar to bricks. So, it must have enough strength. Regarding appearance, the first point is texture and color -it is easy to distinguish stones just by looking at them.

Here are some pictures; you may be able to identify through your own experience (see image)- which one is marble, granite, black stone, and sandstone. It is particularly the texture and the color which provides the clue. Regar strength, a stone should be capable of withstanding weather as well as supporting loads.

The compressive strength of stones ranges from 60 to 200 N/mm². Compared with that of a brick (from earlier lectures), a stone has much higher compressive strength. So, stones are way ahead in taking strength, particularly compressive strength. The weight or the density gives you a clue how heavy (or massy) it is.

The porosity of a stone can also be ascertained from the image of the structure. Here, there are three images. The image here, as you see, is quite porous whereas, this is quite dense. In this picture, you can see the color is black, and the texture is rough. So, just by observation, you can find out whether a stone is porous or not and also check its color or texture.

Heavy stones obviously have higher compressive strength and are used for supporting structures. They are usually used for dams and the construction of bridges. They can stay in the water for a long time. Whereas light (soft) stones can be used for carving arches, walls, domes, cuttings, jafri works.

A porous stone will keep on absorbing water, but the porosity generally depends on the mineral constituents. Stone degenerates or disintegrates if it is highly porous. Granite and slate are the least absorbent. We will discuss the individual stones later. Sandstone, limestone, shale are most absorbent (up to 10%).

Next is hardness, which is the capability to resist any deformation. If you are applying load on it, it may bend or get tampered with. Hardness property is demonstrated when the stone is used for flooring (or pavement), where it experiences a physical load on top. If you keep on walking over soft stones for a long time (many years), it would slowly wither out just because of frictional force. Thus, hardness is important when we are recommending stones for some purpose.

The minerals in the stone get disintegrated due to an increase in temperature. Particularly for igneous rocks, the quartz part of it gets disintegrated at 575°C, whereas limestone disintegrates at 800°C. Limestone is softer than igneous rocks, but it degenerates later if it is subjected to fire.

So, these were some characteristics of building stone. We will now discuss the weathering action.

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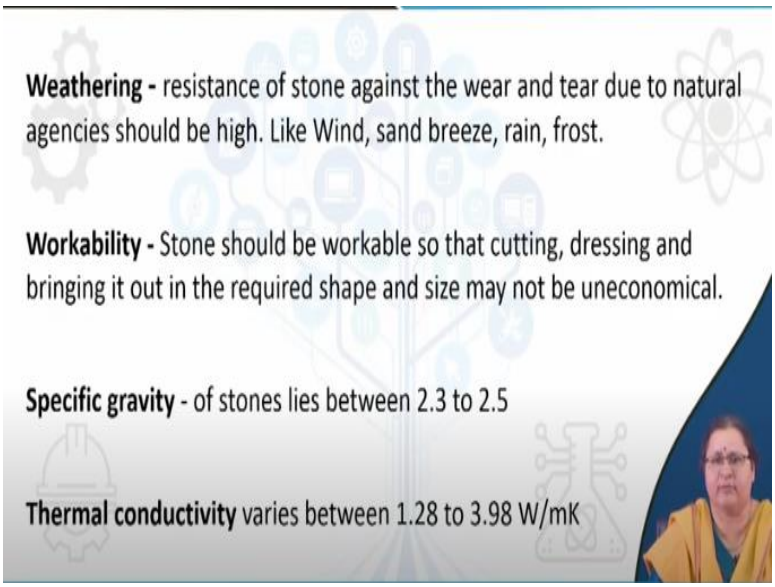

Why does weathering happen? As I told you, since your buildings (of any material) stays uncovered, it has to withstand the natural calamities regularly. Wind, sand, breeze, rain, frost, sun- you have to be careful against the action of all these entities. Another property is workability, which arises because of the hardness or softness of stones. While you can make the jafri walls with marble, you cannot make the same with basalt or an igneous rock.

To withstand weathering action, very close grain sandstone is suitable. The specific gravity of stone is between 2.3 to 2.5. The thermal conductivity of stones are higher than that of a brick. So, that implies stone will conduct external temperature inside the structure, but since stone thicknesses are usually larger than that of a brick, the conducted heat may not be prominent.

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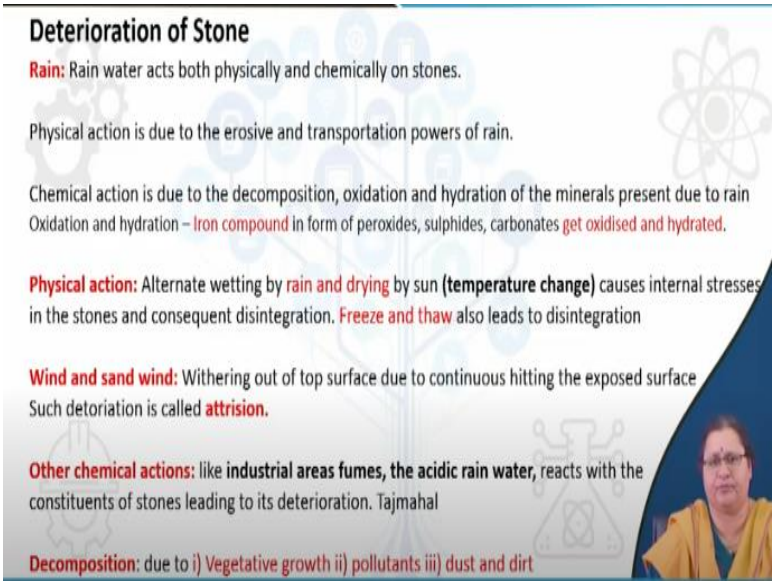

After knowing these basic characteristics, we will look into what can deteriorate stone since stones do not have a covering. Stone can be seen bare from the outside. All stones that are used as flooring, roofing, used as wall surface, etc., all are bare. It has to withstand rain, wind, temperature fluctuations; thus, it may deteriorate.

So, how fast a stone deteriorates is based on what you are going to recommend. The lesser the deterioration of a stone, the higher the chance for us to recommend it as a building material. Rainwater has both physical and chemical action on stones. Physical deterioration implies the erosion (transport) of the top layer. So, the top layer may wash out very gradually, with time.

Chemical actions may happen due to oxidation and the hydration of the minerals within it., due to the rainwater. The rainwater brings the minerals in contact with water, and the atmospheric oxygen helps in oxidation and a lot of iron compounds in the form of peroxides, sulfides, carbonates- get oxidized and hydrated.

Similarly, the physical action, alternate wetting by rain and drying (because of temperature change), can aid in the development of internal stresses within the stone. Similarly, due to temperature change, water may accumulate inside its pores. The water will undergo cycles of freezing and thawing. Every time water is gets solidified, it would expand in dimension, creating pressure on the boundaries (inner surfaces of the pores in stone), and later it melts back to the liquid (water) state.

The force is then relaxed. Again it may freeze during cold temperatures at night. In the daytime, it would melt back to water (reduced volume). So, this mechanism of alternate freeze and thaw can bring in a lot of internal pressure that may eventually lead to the rupture of the stone. Wind can also erode the stone surface and wind along with sand (if it is located in a desert or a near the sea). Accordingly, the sand may be saline (contain salt).

These wind and sand are hitting the wall regularly and gradually wearing away the wall over a long time. This process is called “attrstion”. Other than these, we also have pollutants, industrial fumes, acid rains, which may deteriorate the stone. Taj Mahal is a living example of acid rain pollution. And a lot of efforts are being taken to arrest the decay. Stone decomposition also takes place due to vegetative growth, pollution, dust, and dirt accumulation.

So, you have to keep these points in mind; we need to also know how to maintain the stone.

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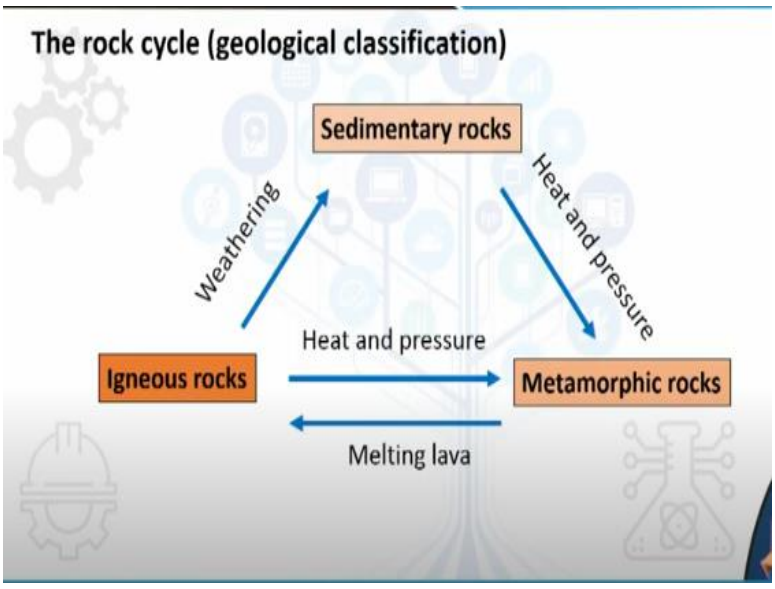

Before going into that, let us see how rocks are geologically classified. Due to the lava coming out from volcanic eruptions, we get igneous rocks. That is the first form of obtaining the rock. And then it gets weathered broken into small parts; they keep accumulating sediments, giving rise to the sedimentary rocks. When again it is subjected to heat and pressure, it gets converted to metamorphic rocks.

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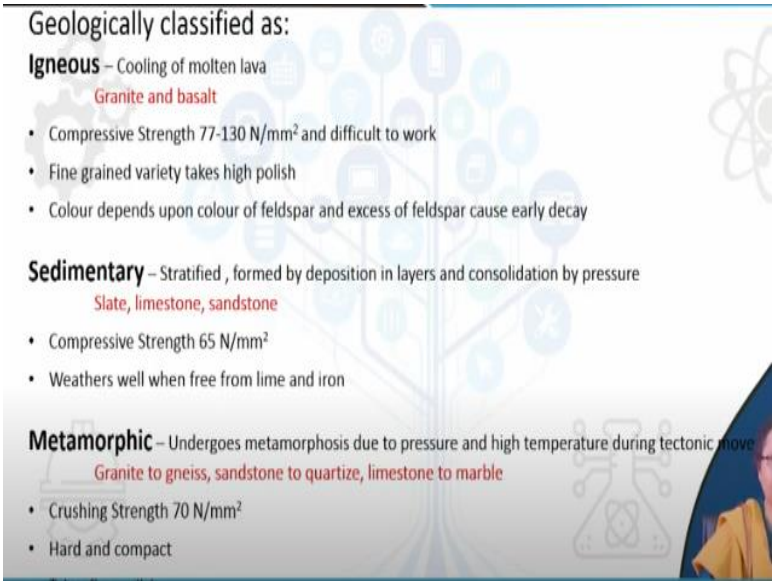

So, if we go further into the geological classification that is the igneous, sedimentary and metamorphic rock, we will see that igneous rock is nothing but cool molten lava, and it is usually the granites and basalts (the hard form). It has a high compressive strength of around 77 to 130 N/mm², and it is challenging to work with. Its density is high. It has very low porosity.

Its water absorption is very low (around 1%), and color depends on the types of minerals present within, particularly the feldspar. A higher amount of feldspar in the composition may decay the rock. Sedimentary rocks are formed by the accumulation of sediments due to the weathering action on larger hard rocks. They get accumulated in strata (layers).

They are stratified and formed over a period of time; the sediments are deposited layer by layer and become consolidated by the pressure. They are the slates, the limestones, the sandstones. These rocks have comparatively lesser compressive strength, around 65 N/mm². When they are free from lime and iron content, they withstand the weather better.

The third is the metamorphic rock, which we had already discussed when due to some pressure and high temperature due to tectonic movements occur. These sedimentary rocks, such as limestone, slate, and sandstone, get metamorphosed- Limestone transforms to gneiss; sandstone forms quartzite, and limestone forms marble.

Sedimentary rocks have a crushing strength of 70 N/mm^2., are hard, and take a fine polish.

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If we go to the other classifications, first, we discuss the physical classification. You can see the strata of rock in this picture. This is called 'stratified' where you can identify the layers. This class of rocks are basically the sedimentary rocks. Next, you see the unstratified blocks which are the igneous rocks formed due to the volcanic eruption. This classification is basically the other way of naming them.

So sedimentary rocks are unstratified, igneous rocks are stratified. Foliated rocks are those that have very defined layers in one direction.

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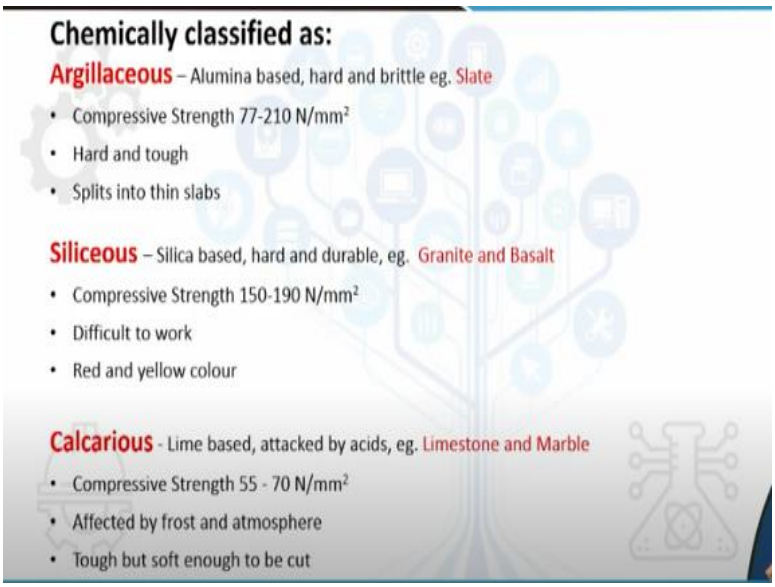

Under chemical classification, it may be divided into- argillaceous, siliceous, and calcareous. Argillaceous rocks are alumina-based. Siliceous rocks are silica-based ones, such as granites and basalts. Calcareous (calcium-based) rocks include limestone and marble. The compressive strengths for argillaceous rocks vary from 77-210 N/mm^2; for siliceous rocks, they range between 150 and 190 N/mm^2, and for calcareous rocks, the strength lies between 55- 70 N/mm^2.

Recall that we have already seen the physical classification as the igneous rocks, the stratified rocks, and the metamorphic rocks. So, rocks may be classified physically as well as chemically.

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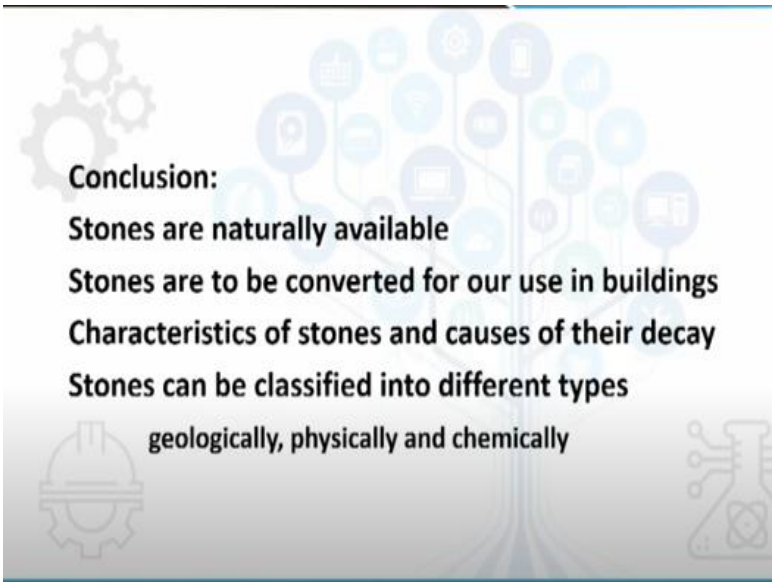

We will conclude by saying that stone is naturally available, unlike clay materials. Stones can be converted for our use in buildings. Characteristics of stones are essential to be known. When recommending, we have to make the appropriate decision because these stones may have to withstand the weather as they do not have any coating or covering other than the natural seasoning.

The points regarding stone decay and the classification of stones have also to be kept in mind. We will carry on with the next lecture, which will be again on stone, where we will highlight the usage, methods of maintenance, and also how to construct stone masonry work similar to bricks. Thank you.