

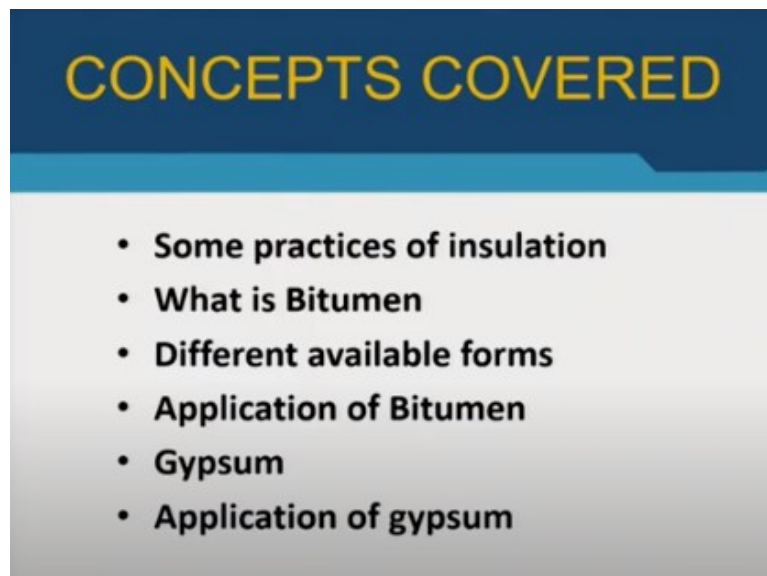
Building Materials and Composites
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Lecture - 34
Insulation, Bitumen and Gypsum

Well, we are in the lecture 4 of module 7, and this module was mostly dedicated for damp proofing and insulation. So damp proofing was taking care of building against water. In case of Insulation we were discussing how to protect the building from thermal gain or from thermal loss and also we have given some highlights on sound insulation.

Although sound insulation is dealt further in details in architectural acoustics, but today we are going to discuss on the materials which were essential for damp proofing and also for insulation. We will also learn that how traditionally in our country or in similar climatic contexts, some methods are adapted for insulation, which are very cost effective. We have discussed some of them in our previous lectures.

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So we will see some practices and gradually we will move to bitumen, since bitumen has wide range application in damp proofing. So we need to know what that material is actually and how it is available in its different forms. That obviously opens up the application of it and we had also its application in damp proofing. Gypsum is the

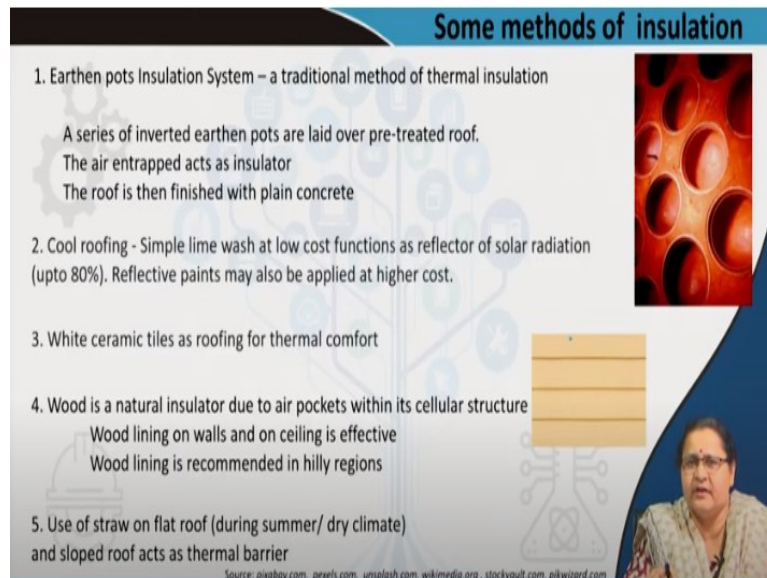
other insulator which is used for covering up either the fiberglass or the mineral wool or the rock wool and gives a neat finish.

Gypsum perforated boards were used for sound insulation. That was on top of a inside hidden material of a sound insulator of maybe fiberglass or glass wool or rock wool. So we will try to see the other applications of gypsum also.

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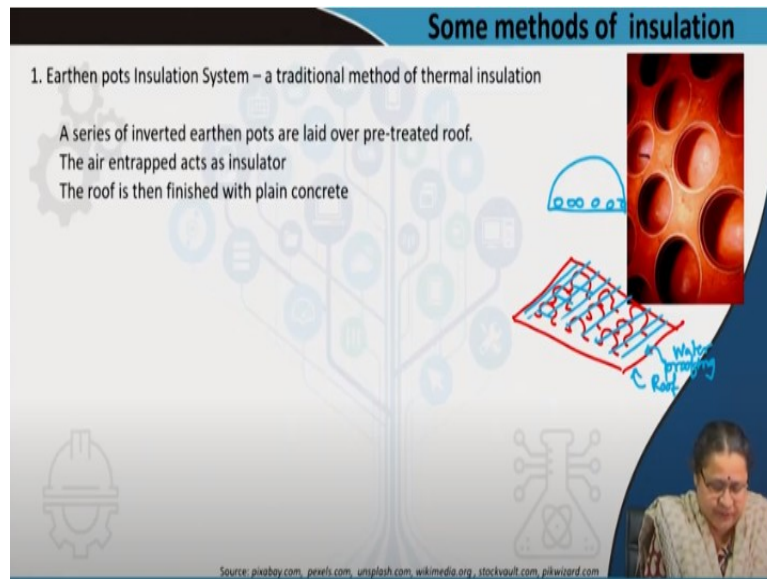
Some methods of insulation

1. Earthen pots Insulation System – a traditional method of thermal insulation
A series of inverted earthen pots are laid over pre-treated roof.
The air entrapped acts as insulator
The roof is then finished with plain concrete
2. Cool roofing - Simple lime wash at low cost functions as reflector of solar radiation (upto 80%). Reflective paints may also be applied at higher cost.
3. White ceramic tiles as roofing for thermal comfort
4. Wood is a natural insulator due to air pockets within its cellular structure
Wood lining on walls and on ceiling is effective
Wood lining is recommended in hilly regions
5. Use of straw on flat roof (during summer/ dry climate) and sloped roof acts as thermal barrier



The picture you can see this is made of terracotta. What you see is holes. We had discussed that air is a bad conductor of heat and sound. So you can see this kind of inverted earthen pots, they are still in practice in our country, particularly when it is a large expanse roof you can put in these earthen pots inverted on the entire roof surface.

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Actually you can place earthen pots on rooftop and then cover it with a screed concrete (mortar). So this is the main roof. You have to have the waterproofing. Here you need to place these earthen pots and then cover it with some light concrete mix. So these trapped in air inside these pots act as insulator. This is practiced since many years. These kinds of pots also act as sound resonators.

These can trap in particular frequency of sound, when the case is the open sides of the pots are there to trap in the sound. That is seen in Suleymaniye Mosque or the Hagia Sophia mosque. There you can see holes all along the entire dome. Those are nothing but pots or pitchers placed to trap a particular frequency of sound generated in that space.

So you can understand that we can use earthen pots inverted with air inside to trap in sound and not allow heat to get accumulated. So it can be used for both thermal and sound insulation. Again we come to a term called cool roofing. What is it? It is very simple the other used for lime wash. Lime wash is a very low cost paint that is put on top of the roof surface. This is practiced in Ahmedabad and Bhopal.

Around 3000 houses were done so and there was a very good response. The inside got insulated. The solar radiation got reflected. So we had learnt reflective insulation. Here we are applying the same principle in a very cost effective way to prevent the

solar radiation to get entrapped to the inside of the building from the roof. It can help in reducing 80% of the radiation and it is a very cheap method.

But yes there are problems. One may use the roof for some social purpose, for gathering, for keeping some item or maybe use it for kind of storage. So then this may not be that effective. But yes, it is an answer for insulation at a very different way. White ceramic tiles can be put on the rooftop. The white color acts as reflector. Although metal is also a reflector, we are not using any metallic reflector here.

Glass can also act as a reflector, but here we are using the color white as a reflector with lime, with ceramic tiles so that it can also help in achieving thermal comfort inside the building. The trapped in moisture or trapped in air within glass fiber, rock fiber, mineral wool and glass wool is the crux for thermal insulation.

Wood is also a natural fiber, where within the wood there are air pockets formed due to the removal of the moisture. These are very small cellular structures at microscopic level. So this wood can act as a very good insulator. This wood lining on the inside walls, on ceiling particularly in hilly regions where it is abundant, you can get a thermal comfort inside. So whatever be your building material, it may be concrete or it may be of stone because stone is also abundantly available in hilly areas.

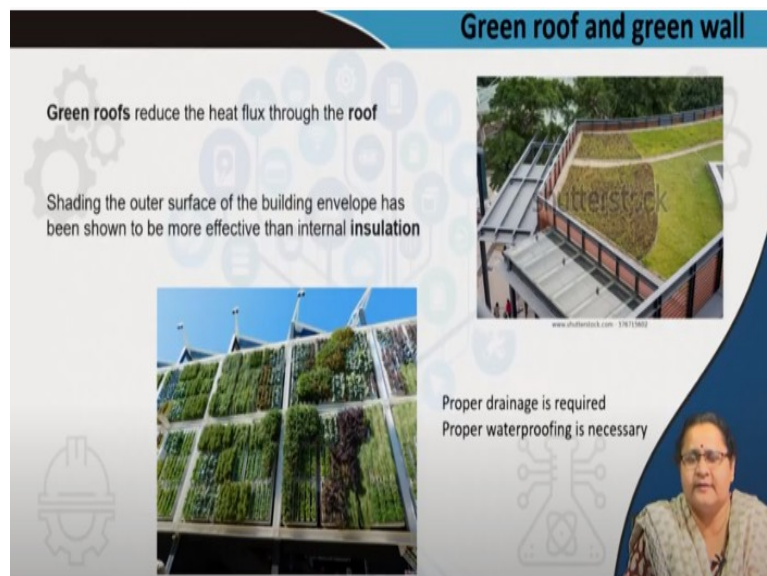
You can put wood lining or the building maybe itself made of wooden logs. So wood in its different forms can be used as a lining inside the building which is for the purpose of thermal insulation. If you visit a hotel in a hilly area, when you enter inside you may find that the room is having a wood lining.

Wood not only adds to the decorative value which gives a pleasing inside aesthetic beauty but it also serves the purpose of cutting down their energy costs. So you are enjoying the environment, but the hotel owner is actually getting the return in cutting down his/her energy bills. So the functional part lies there. We also see very nice applications in our rural India especially in the plains where lot of paddy or wheat is being grown.

You will see the use of straws for thatched roof. We always see roofs are having clay tiles. Even on top of it you can have straws placed. So during summer you get a very comfortable interior. So these sloped roofs are treated with straw on top of some bamboo framework or maybe on top of clay to have a thermal comfort. These thatched roofs provide lot of thermal comfort unlike tin roof or asbestos roof because they trap in lot of thermal energy.

But the cushion with straw, straws are filled with air pockets. So those are actually helping in the insulation. So you have to keep your eyes open and find out the what is the purpose of the material and why people have adopted it traditionally.

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Now let us also discuss on green roof and green wall. Is it really giving you an insulation? So when it is a green roof, it reduces the heat flux through the roof. But it has multiple layers of different things so that water does not enter or there is no leakage. There should be drainage, there should be soil, there should be learning on the roots, which is how the roots of the plants will grow.

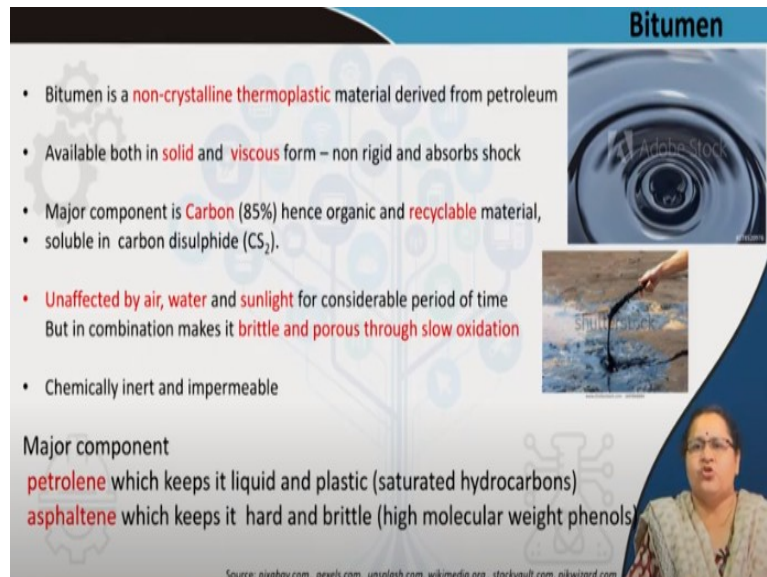
So you have to have a good thickness allowed for having green roof. So automatically it reduces the heat flux through the roof, but at the same time there are multiple things happening in between the layers. So we have to be very careful to recommend a green roof just for the purpose of insulation. Yes, it replaces the amount of green you are losing at the ground level and you are replacing that on the top maybe partially.

But it does not mean it is giving you a thermal insulation and that is why you need to do green roof. The same applies for shading of outer façade, which is kind of vertical garden. You can see this is a picture from an exhibition. The wall has been created. It was in Milan in 2017. So this is the exhibition pavilion whose wall has been made green. Now any shading from outside and not allowing the entry of sunlight will obviously be an effective barrier to the thermal gain.

So we instead of putting an internal insulation, you are giving a different kind of look to the building and at the same time preventing the sun rays or the wall surface to get heated and heat being trapped inside. But in both the cases one has to be very careful on the drainage part. Otherwise it will lead to damp. So your roof will likely to become a leaky one.

It will finally disturb and ruin the structural part of the roof. Same applies with case of wall. The wall surfaces you have to be very careful on the roots, plant shoots etc., and also on the water logging.

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Bitumen

- Bitumen is a **non-crystalline thermoplastic** material derived from petroleum
- Available both in **solid** and **viscous** form – non rigid and absorbs shock
- Major component is **Carbon** (85%) hence organic and **recyclable** material, soluble in carbon disulphide (CS₂).
- **Unaffected by air, water and sunlight** for considerable period of time
But in combination makes it **brittle and porous through slow oxidation**
- Chemically inert and impermeable

Major component
petrolene which keeps it liquid and plastic (saturated hydrocarbons)
asphaltene which keeps it hard and brittle (high molecular weight phenols)

Source: pixabay.com, pexels.com, unsplash.com, wikimedia.org, stockvault.com, pikwizard.com

The slide includes two images: one showing a close-up of a circular, textured surface (likely a roof or wall) and another showing a person applying a dark, viscous substance (bitumen) to a surface with a brush.

So now let us come to the material bitumen. Bitumen is one material, which is extensively used in damp proofing when we were talking about damp proofing the building. But bituminous materials are widely (about 80% of bituminous materials) used for roads, which is not under our purview, but we always have seen during road constructions that a black dark jet color is being heated and being applied on road.

Sometimes it is also being mixed with aggregates and is spread on top of the road to have a layer on top of the road. There are two types bituminous material, one is bitumen and the other is tar. Tar is again obtained from coal or wood. So you can have cold tar or you can have wood tar. And bitumen may be naturally occurring or may be obtained from petroleum industry.

So it is a kind of very thick crude oil. Naturally occurring bitumen may be found in forms of lakes as shown in the picture. So you need to know what is it and how it is to be extracted or taken. It is a non-crystalline thermoplast. And obviously, we use it mostly when it is derived from petroleum.

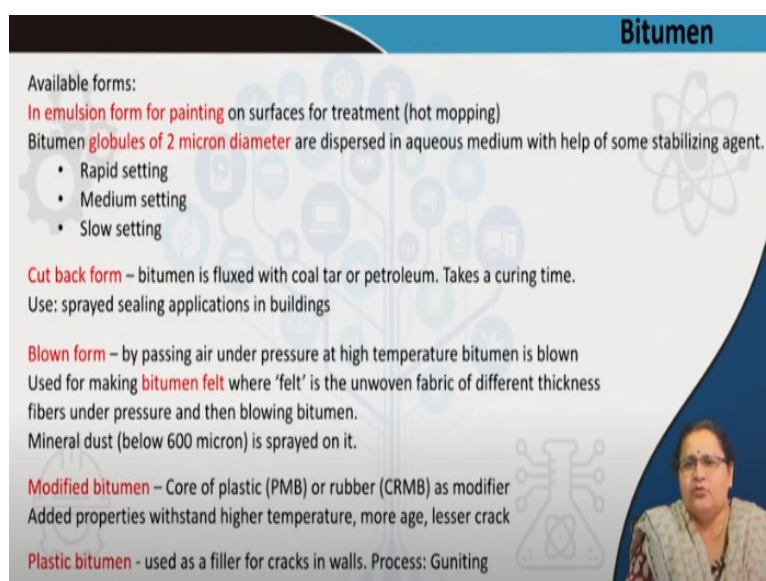
It is something solid, somewhat viscous and non rigid. It does not have any fixed shape. It can absorb shock; it has a softening point, but not a melting point. It softens at a temperature and then you can actually work with it. It is organic in nature, it is composed of hydrocarbons rather with very traces of some sulfur, some other minerals.

It is soluble in carbon disulfide that is CS_2 . It is a recyclable and is a very impervious material. It can be continuously used. It is weatherproof. It can sustain temperatures and can sustain shocks. So all the qualities we had discussed for a damp proof membrane are with bitumen. It is unaffected by air, water and sunlight separately and hence it is widely used.

With long term exposure to air, water and sunlight, it oxidizes slowly and gradually loses its strength that is it becomes brittle. Chemically it remains as an inert and impermeable as already mentioned. There are two parts of bitumen. One is petrolene and the other is asphaltene. The petrolene is the liquid or the plastic part, which is saturated hydrocarbon and the asphaltene is the hard and brittle part which is having high molecular weight phenols.

So these two when mixed in different proportions, you may get different consistencies. So when you are getting or extracting bitumen, if you know the petrolene and the asphaltene, you will understand how much viscous it will be or how much solid it will be.

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Bitumen

Available forms:

In emulsion form for painting on surfaces for treatment (hot mopping)
Bitumen **globules of 2 micron diameter** are dispersed in aqueous medium with help of some stabilizing agent.

- Rapid setting
- Medium setting
- Slow setting

Cut back form – bitumen is fluxed with coal tar or petroleum. Takes a curing time.
Use: sprayed sealing applications in buildings

Blown form – by passing air under pressure at high temperature bitumen is blown
Used for making **bitumen felt** where 'felt' is the unwoven fabric of different thickness fibers under pressure and then blowing bitumen.
Mineral dust (below 600 micron) is sprayed on it.

Modified bitumen – Core of plastic (PMB) or rubber (CRMB) as modifier
Added properties withstand higher temperature, more age, lesser crack

Plastic bitumen - used as a filler for cracks in walls. Process: Guniting

Now let us discuss some of the available forms of bitumen which we had discussed during membrane damp proofing. So what is the membrane composed of? When it was surface treatment, we were talking of a layer of bitumen which was 3 mm thick. What is that of? So when we are talking of the surface treatment, it is type of an emulsion in the form of paint. It is globules of bitumen say around 2 μm (microns) in diameter, suspended in an aqueous medium.

And this aqueous medium is the dispersing agent, which is again having some stabilizing agent added to it and this aqueous medium actually helps to spread these globules and it eventually evaporates. So we have rapid setting, medium setting, slow setting. Usually it is either petroleum or spirit or naphtha.

When these three of them are in the aqueous medium on to which these globules are dispersed and this gives you paint like or hot mopping or brushing like material form of bitumen. Then we have cut back bitumen, which is fluxed with coal tar or petroleum. This takes time for curing, but it is used for sealing applications. You can use cut back bitumen for sealing joints or cracks.

Now this cutter is actually the coal tar or the petroleum and hence it is called cut back. We had seen applications of sheets, bituminous felts which were mostly applied on the rooftops. In the previous lectures we had shown the torch application. So those are

bituminous felts, which is blown form of bitumen. So you have an unwoven felt or a fabric on to which under high pressure bitumen or liquid bitumen is blown.

So that passes into all the gaps of the unwoven fiber which is the felt and it is available in different thicknesses and under pressure the bitumen moves into it when it is blown. So this tar felts, the bitumen felts which we see is actually blown form of bitumen. It is not pure bitumen. It has unwoven fabric inside it which is called felt and hence it is called bituminous felt.

Mineral dust is sprayed on top of it which is below 600 μm and it can be feel since it gives a rough finish. You can visit rooftops at some places or maybe even in your home and you can experience what it is. Another form is Modified bitumen. When you can put plastic as the core it is called plastic modified bitumen. When crumbled rubber is used as the core it is called CRMB or crumbled rubber modified bitumen.

So this crumbled rubber or plastic is the modifier. So what is it modifying? It is modifying its capability to withstand higher temperature; it is getting more age and is experiencing lesser crack. These are used mostly on roofs or maybe on road surfaces, where it is continuously exposed to high temperature. So that is modified bitumen. It may have use in roofs which have larger spans.

Plastic bitumen again is used as filler for cracks on walls. It is pushed through by the process of guniting or by grouting in foundations etc.

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Gypsum

- Non hydraulic binder
- Soft crystalline mineral naturally occurring
- White in colour
- On heating it loses its luster and gains weight due to escape of moisture


Gypsum crystals are soft enough to bend under pressure hence has the unique property of **moulding** when wet – like in sculptures

When water is added to powdered gypsum it forms **interlocking crystals**
This newly formed crystal actually makes it **fire resistant**


Water of crystallization is associated with Gypsum - $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

Loosely connected and a part of it loses on heating and is half hydrated gypsum ($\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$)
The reaction is reversible.

Rapidly dries, smooth surface finish, minimum shrinkage,



Gypsum – as mineral



So after knowing bitumen I hope you understand that this black, dark, ugly looking material is so friendly to a building. All substructures are sometimes bitumen painted so that it does not get ruined by the underground moisture. Many applications of bitumen is there where bitumen is actually saving some of the major structures. Now we come to gypsum which is a mineral, which is a calcium sulfate and is white in color.

On heating it loses its luster and gains weight because it has water or hydrate associated with it. It is hydrated calcium sulfate and when it is heated it loses its water and it gains weight. But we have learned gypsum in a different application when we were covering cement. Here again we have learned gypsum is used for making perforated gypsum boards which act as a sound insulator or a thermal insulator or an internal protective layer.

We had also learned gypsum when used in glass; it was glass fiber reinforced gypsum. So gypsum has plenty of applications. These are actually crystalline in nature which can be molded when it is wet. It can take any shape when under pressure. It can even take hand pressure. So with hand applied you can actually make any shape and it gets dried very quickly.

It can also give a finished item look in case of sculptures. We say plaster of paris sculpture. We also use it as casting to treat someone's leg when it is fractured. We do a plastering that is again with gypsum. So when water is added to the powder, it forms

an interlocking crystal and makes it resistant to fire. So when we were putting the gypsum board or embedding inside a thermal insulator, the thermal insulator becomes inflammable.

So to protect that material the gypsum board is actually acting as a barrier. Now this water of crystallization remains loosely connected with gypsum. When it is heated it is half hydrated gypsum and it loses one and a half molecules of water. These reactions are very reversible. It rapidly dries gives a smooth finished surface with minimum shrinkage.

Therefore it does not lead to cracks. Shrinkage is the cause of crack. Gypsum is a finished material because you are putting on top of a wall, which contains the insulator. So finally you are looking the gypsum surface. Finally, you are looking at a false ceiling, which is again gypsum. So it should be have a very seamless look that is with no cracks or no breaks.

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Gypsum: Applications

Plaster of Paris (Gypsum plaster) – 75% dehydrated gypsum
As finish: Gives very smooth finish on interior wall surface, moulded forms
Anti microbial, rust preventive, lightweight in comparison to cement plaster

Gypsum board

- As 'dry wall' partition wall
- As 'rapid wall' with GFRG panel
- As false ceiling in air conditioned rooms like labs

Gypsum board has a relatively low R-value—usually listed as 0.5 like many earthen materials

Gypsum board to serve as a thermal barrier for flammable or ignitable materials like it covers foam insulation used in thermal insulation

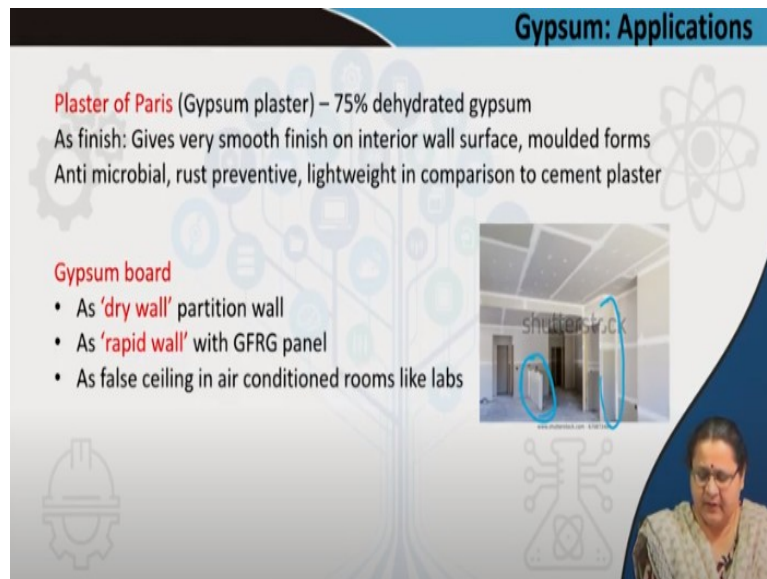
GFRG wall

The slide includes a 3D perspective view of a gypsum board profile and a 2D cross-sectional diagram of a GFRG wall assembly. The diagram shows a gypsum board on top of a GFRG panel, which is supported by a metal channel. Dimensions are indicated: 125mm for the gypsum board thickness, 100mm for the GFRG panel thickness, and 100mm for the metal channel height. The GFRG panel is shown with a grid pattern.

In case of Plaster of Paris where 75% dehydrated gypsum is used, a smooth surface is generated. You can make different molded forms within the interior wall surface in ceilings, carvings. It is better than cement plaster at times. It is non microbial, it is rust preventive and it does not allow water entry. It is lightweight in comparison to cement plaster.

So if you have a very good interior with good quality bricks, with nice pointing, you can actually finish with plaster of Paris instead of the cement plastering.

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Gypsum: Applications

Plaster of Paris (Gypsum plaster) – 75% dehydrated gypsum
As finish: Gives very smooth finish on interior wall surface, moulded forms
Anti microbial, rust preventive, lightweight in comparison to cement plaster

Gypsum board

- As 'dry wall' partition wall
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- As false ceiling in air conditioned rooms like labs

The slide includes an image of a room with a partition wall and a false ceiling, with blue circles highlighting the wall and ceiling. A small inset image shows a person's face in the bottom right corner.

Let us come to the actual applications where gypsum is used as a dry wall. In the picture you can see a half dry wall. This is a half dry wall made of gypsum. These are full length partition walls made of gypsum. It can be used as a glass fiber reinforced gypsum. It can be used as a rapid wall. That is called a rapid wall because it can be rapidly constructed.

These are all used and promoted by BMTPC and a similar building has been made in IIT Madras with glass fiber reinforced gypsum. So this is again a rapid wall construction system where the external wall can be of having gypsum as one of the components. It can be used as false ceiling in air conditioned rooms like computer labs, some chemical laboratories etc.

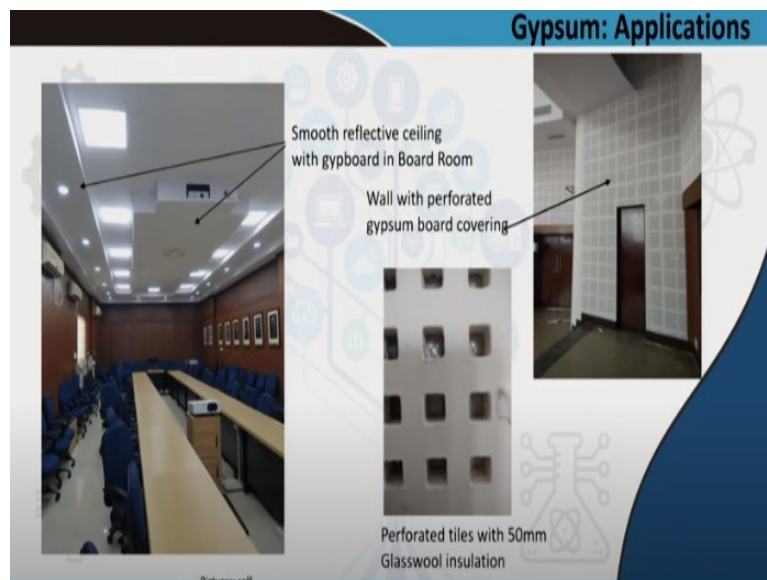
Gypsum board itself has a low R value but it can actually provide a barrier from flame affecting the inside of a thermal insulator. So it can actually cover foam insulation that is we had discussed on polyurethane spray foam, which is flammable. So if you coat it or cover it with a gypsum board, you can actually get the benefit of using gypsum.

The R value of earthen material or earthen pots is also like 0.5 as compared to glass wool etc., which is around 3 to 4. But even then that entrapped air gives it a better or

improved R value. So as a composite with air entrapped within it, it acts as a better insulator. So here also you see in this GFRG these are air pockets inside the material.

So these are all hollow this can act as a insulator though it has not so high R value, which is around 0.5.

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We see other applications as sound insulator. We see that smooth reflective ceiling inside a board room. These are the perforated gypsum board covering the thermal insulator. You can see a very closer picture here, you can see the insulation inside through these perforated boards. This picture has been taken from one of the lecture halls here at IIT Kharagpur.

So there is an insulation embedded inside and on top of it, it is the perforated board one with a closer view and a overall view. So here it is used as a acoustical application. Here also it is reflecting sound other than giving the room or the ceiling a neat finish.

So through these examples, I hope I could touch upon the major uses of gypsum, the major uses of damp proofing and the bitumen. We also covered Insulation; how it has been done, how it is being done, and traditionally what were done. So you should be aware of these materials. We need to know their particular or specific applications and as architects, we need to recommend these in the professional front. Thank you.