Environmental Geomechanics
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Lecture - 24
Application of Industrial By-Products - II

Now, this is the summary of what is happening in the cement-based, the fly ash based cement in India. Everybody is aware of the fly ash is no more waste material. It has a lot of utility in the manufacturing of cement and even if you are replacing 35-40% of cement, it is a great service to the society because that much less cement is produced, that much less amount of carbon dioxide is produced.

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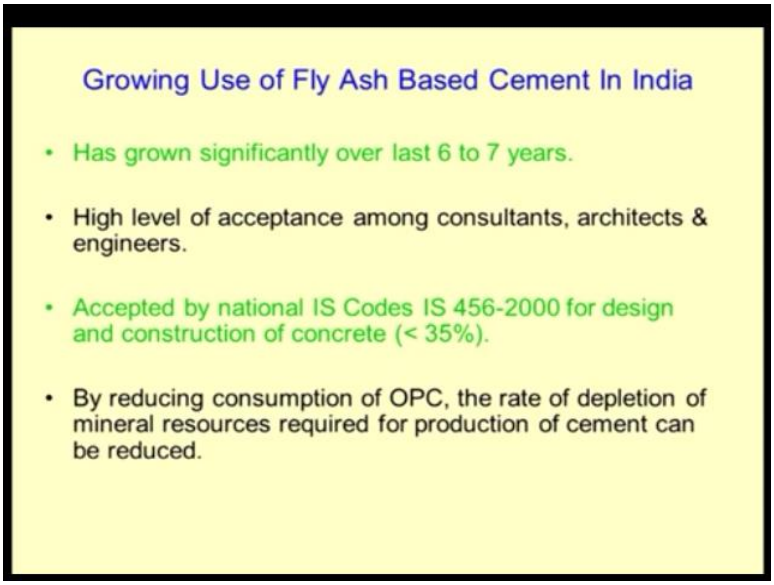

And the application of fly ash in cement and concrete is beneficial. This has already been proven by several guys, and there IS 456 also which talks about the replacement of cement by the fly ash. You might come across people who are grinding the fly ash. This becomes ultra fine fly ash, and ultrafine fly ash has a very niche market all over the world. This is what is known as ultrafine in the fly ash. There is another way of filtering out the fines from the fly ash.

It could be by adopting different type of classification systems. So they are classifiers. In your 10+2 chemistry, you must have come across different type of classifiers, is it not? Different

particles of different densities can be classified by using either the very high jet pressure of air or by centrifuging them, and another good example would be the cenosphere, which I will show you when I am talking about the material characterization.

These are the materials of today, contemporary materials. So, if you check on net, what are the applications of cenosphere, ultrafine fly ashes, classified fly ash and this is the need of the hour. Every power plant should have the facilities to classify the soils fly ash and grind the fly ash and so on to make it as a value-added material. Lot of practical work is also going on in this context.

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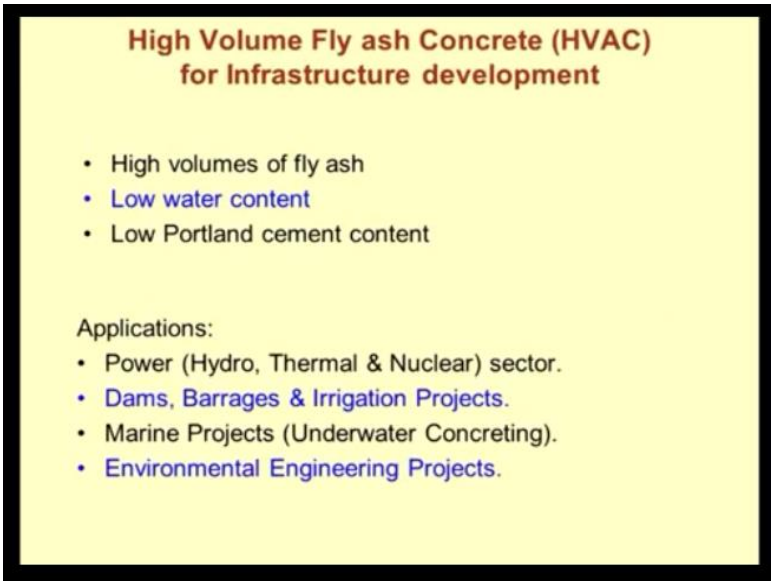

There is something known as HVAC. This is high volume fly ash concrete which I am sure you must have come across, and this is being used for infrastructure development. So the HVAC concept is the high volumes of fly ash are used to make the system more durable, and these type of systems need very low water content. So if you remember W by C ratio, the present-day research is on the concept that W by C should be tending to zero. What is the meaning of this?

I should be using as less water as possible to make concrete. Why? So in a city like Bombay, do not have fresh water, Chennai, coastal areas. Why? Most of the water is adulterated or the salty seawater water. Sand is not available, contaminated sand. Now people are trying to work on as minimum water as possible. So when you balance W by C mathematically. When the moisture content decreases, C also decreases.

So this is a very interesting concept, where the water is less, and the volume of cement which is required of the weight of the cement, which is required is also less. So you are not overdosing the concrete, and hence you are trying to create systems, which are going to be more durable. These are new concepts in construction technology. What are the applications, these type of materials find a lot of applications in hydrothermal and nuclear power sectors?

I have been closely associated with some of these design of structures and the foundations, and this is where people are using HVAC for either piles or the foundations in aggressive soils. Check it on the net, what is the meaning of word aggressive soils. So aggressive soils are the ones which might be having a lot of sulfate content in them. So it becomes a big challenge to lay the foundations when the soils are aggressive in nature.

They could be highly contaminated soils, very low pH, very high pH, different types of contamination. Chloride contents could be very high. Sulfate contents could be very high. So, the implications of these type of situations. At the same time, when you are talking about the strategic structures, where nuclear power is being produced, domes, shells of the atomic power plants where you want extremely durable systems.

And they should be thermally insulated, is this correct or not? Because imagine inside the reactions are going on where the temperatures might go very high and normal concrete might crack and if normal concrete cracks, the chances are the radiations may come out into the atmosphere. So these are very niche areas, in which HVAC are being used to create highly durable systems.

A lot of research is being done in the realm of materials in civil engineering. Similarly, for dams, barrages, irrigation projects, these type of materials are being used. Lean concrete is a good example. Roller compacted concrete; I do not know whether you have come across this type. These type of projects have been done in India, particularly in the southern part of the country and close to Bombay, where the entire dam was constructed by compacting the roller compacting the concrete.

So sometimes when you type on the net, you will get this information and present this situation is that people are aware of how to utilize the geomaterials for creating high-value products. Another species of projects is marine projects, where it is very difficult to do underwater grouting, cementing, construction and you have special requirements of concrete. Most of the developmental work is going on in the marine environment pipelines of piling different types of land creations, and so on.

"Professor - student conversation starts" How well understood are the properties of concrete that have a large amount of fly ash, like mechanical properties. Very well, very well. It is quite in control. Most of the construction is going on in this by using these materials. Everything, a lot of research is being conducted. The material science in civil engineering has become a big subject. It is not only limited to the way you made concrete and steel and Glass and wood.

Nowadays, it is becoming extremely multifacet, multidisciplinary, multi-component infrastructure materials. "Professor - student conversation ends" Different types of environmental nearing projects where you require to stop shielding against acid attacks, particularly sewage lines. Imagine the tunnels which are being constructed for carrying water or the sewage, they are mostly sulfate attacks are very high, H2S formation is there.

The entire environment, because of the presence of acid formation, acid-forming bacteria could be under anaerobic condition, how would you protect your structures, a big challenge. So specialized environmental engineering projects require these type of high volume fly ash concrete, which are quite durable. The lining of the tunnels, you read a lot on the net, and you will realize where these type of concretes are being used. Lining, internal lining for the tunnels in which the water is flowing, or the sewage is flowing.

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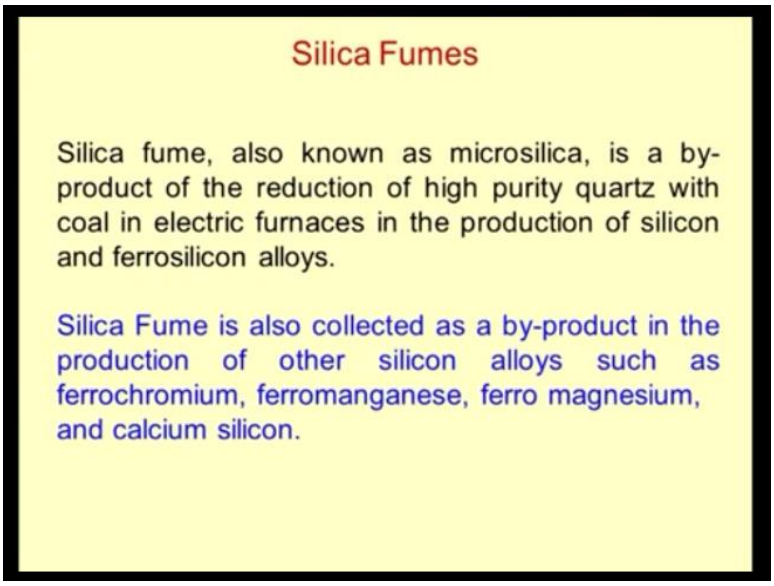

Silica fumes is another interesting manmade geomaterial, and this is a very high-end material, which is used for creating concrete, extremely fine particles and what do they do is, they clog the pores of the concrete, and hence the concrete becomes highly durable. So silica fume is also known as microsilica, very active form of silica, super active silica and specific gravity would be of the order of 0.5, 0.6, 0.7. So it is a big challenge to transport this material.

Most of the time, this material is imported in India. So when you are bringing it through sea liners, I think you can imagine if though these specific gravities are less than water the bulk volumes cannot be carried because you require very high volumes for very small weights and the stability of ships is a big question. You should read all these things. It becomes a multidisciplinary subject. So it is a byproduct of the reduction of high purity quartz with coal in electric furnaces, in the production of silicon and ferrosilicon alloys.

It is a boon for concrete, but the issue is if you add more than 4-5%, this becomes a deterrent for gain in strength of the concrete because silica fumes are highly corrosive. Finer the particle surface area is going to be extremely high, and then it has a tendency to suck water, retain water. So when you are adding it in concrete, the chances are that silica fume will adsorb most of the water which is present the concrete and the concrete would not get water to get cured. So that is why the dose has to be properly monitored.

So when you produce ferrochromium, ferromanganese, ferromagnesium and calcium silicon type of things, then this type of material is becoming industrial byproduct.

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Another interesting thing which I was discussing in the previous lecture is the reuse of tires. So in small area nations, which are surrounded by water, particularly oceans these types of technologies are being studied quite a lot. So Japan is a leading country where a lot of reuse of tires is being practised. So if you type on the net whenever you get time, you will realize that tires which are coming out of the automobile industry, which has been discarded.

Find a very special application for designing offshore structures and ground improvement is also being made by using this type of elements. So basically, rubber tires are a threat to the environment, because if you stack them, they catch fire and even if you do not stack them, this could be a place for mosquitoes to breed, and it is very unsightly. So they collect water also, and they become the breeding space for mosquitoes.

The question is, can something be done with this or not. Read the papers which are available on the internet. This is where people have tried to reuse the rubber tires. I will show you one a good example, which was proposed by Professor Joshi from Calgary University long back and I have the animation with me.

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There are several applications on the scrap tires, and some of them are road embankment. You can shred the tires, you can use them as aggregate for making the road embankments, and I am sure you will realize that once the shredded tires are being used the elastic modulus and the bouncing property of the finished surface are going to be much better, and damage to the automobile vehicles tires would be extremely less as compared to the rigid pavements, which are fairly aggressive.

You can think of creating sub-grades, which are thermally insulated. Imagine the countries where the temperatures are extremely low or very high, and you would require thermal insulation there between the formation and the embankment or the crust of the pavement. So this is where very judiciously these type of materials have been inserted, and a lot of case studies are available in the literature. You can lay your hands on and become state of the art.

Art another good example is asphalt rubber pavement. So, you can mix the asphalt and the crumb rubber, and you can create pavements most of the developed countries have used this technology and hence this type of finished product will give more riding quality and comfort. CRB, you must have heard about, crumb rubber bitumen. So, this is another form of utilizing the scrap tires. You can shred it, and you can mix it with asphalt, and you can create pavements out of it.

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What are the pavement requirements, which are fulfilled by this concept? So you will realize that durability increases when you enhance the flexibility or rigidity of the system, and this can be controlled by adding the shredded tires. Deformation modulus can be controlled. This is what you are talking about. One of the examples is people have shown that the deformation and the modulus of deformation can be changed by using this type of composites.

Thermal resistance is the keyword. So these tyres act as the thermal insulators. In our country also, sometimes we should be proposing this type of test tracks, and we should be testing them where the climatic conditions are the very harsh or northern part of the country, where sub-zero temperatures are there and because of what happens freeze and thaw. The pavement gets distorted. There this seems to be a good technology.

When you add the shredded tires with the asphalt, you can enhance the rutting resistance also. You must have studied about the rutting of the pavements. So because of more bouncing effect when you add the rubber tires. Chips into the asphalt. The rutting resistance can be overcome, can be enhanced. Wearing can be reduced wearing of the tires. Shrinkage resistance can be reduced, and so on. So there are a lot of applications, you can think about.

We can modify the skid resistance of the pavements also. The biggest problem in the temperate climates is that due to very high temperatures, what happens, the asphalt or the bitumen melts

and particularly in countries like India and because of the melting of asphalt and bitumen, what happens, the skid resistance decreases. So this causes a lot of accidents on the roads. Now I will show you one animation, where you can appreciate how rubber tires with steel mesh can be utilized for creating a different type of turfs or embankments, particularly for sports.

Velodromes where the vehicles are tested. It could be a cycling velodrome; it could be an automobile testing facility, where you are creating a velodrome. So, this is how it looks like.

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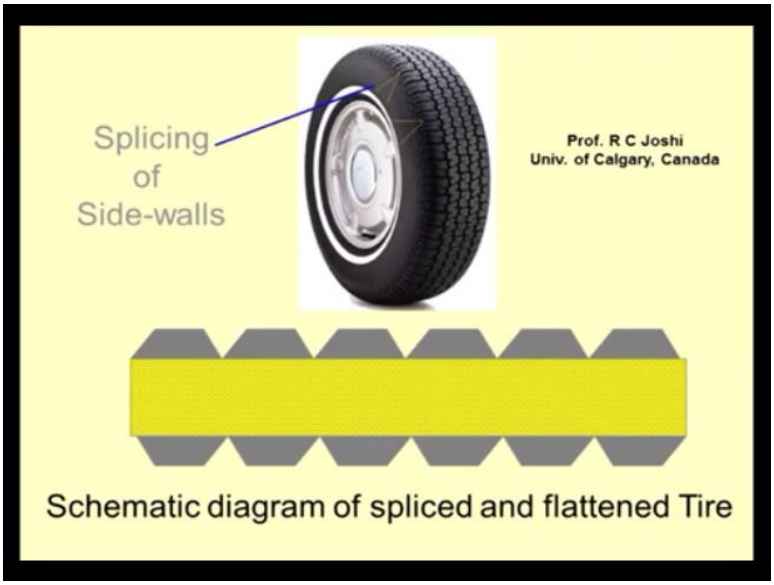

These slides, I have borrowed from Professor R. C. Joshi, University of Calgary. This is his idea, but I thought of sharing with all of you. So, what is done normally is, that you take the rubber tires, you slice them, and after slicing, you flatten them, and once you have flattened, this becomes one of the units, which can be used for creating.

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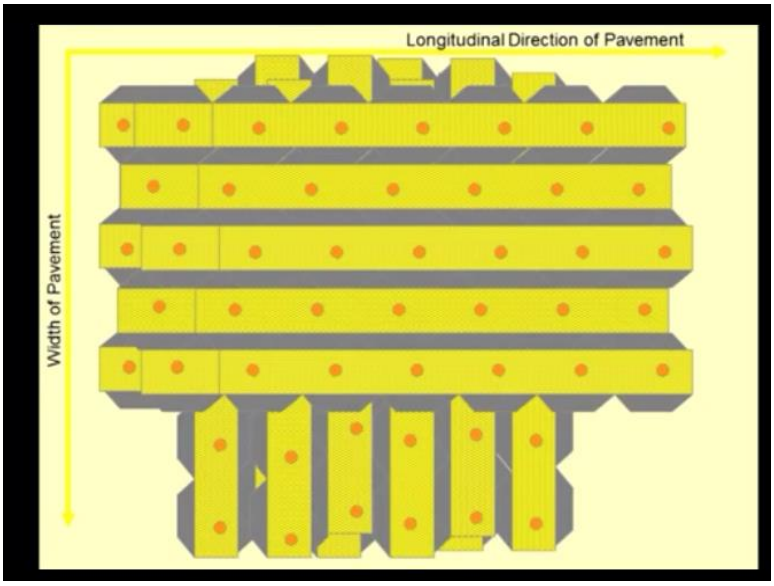

So, if you talk about the width of the pavement and the longitudinal direction of the pavement, you can stack these units one by one, and you can rivet them by using anchors. The next layer would come off another layer of anchors followed by another layer of the sliced rubber tires and keep on repeating this as long as you achieve the desired height of the system. So, I am sure you must be realizing. This is a good, clever idea of utilizing industrial byproducts.

Automobile industry would be very happy if you can correct the practice of this type of construction because you are saving so many millions of tons of natural resources for creating embankments. This type of technology should be promoted, and they should be practised. Yes, please. "Professor - student conversation starts" Are they used in only (()) (17:23) pavements or both rigid also.

You have to do a mix design, and if you remember in your transportation engineering course, so you are designing asphalt for your requirement, is it not? So you can use a rubber tyre chips as the additive, and you can design the whole mixture, and normally in the rigid pavement, we will not use but yes if you want to modulate, if you want to make a composite system, the bottom portion of the pavement is rigid and top you want to give cushioning effect.

Particularly the places close to the signals, where most of the braking action takes place, where you apply brakes, where the rutting is maximum. So there this seems to be a good idea. You can

create a composite system in the embankment itself or on the track. IT can reduce the shrinkage resistance but can the problem swelling occurs during the bouncing. So imagine the density of this material is going to be very much because they are thick sheets. So one of the ways to negotiate with the swelling pressure of the size would be, what is that you do normally CNC, compacted natural clays.

So on the swelling soils, you will be nullifying the effect of swelling pressure by giving a gamma into H. So I can save this $\gamma \times H$ layer and what can I do? I can put this material. I can apply the counterweight, and I can get rid of the swelling of the clays CNC, material compacted natural clays are normally used to balance the swelling pressure or soils in the field. So imagine if swelling pressure is 2 kg/cm^2, you require a very thick layer of compacted clay, which is the clay itself is not available in the market nowadays clear.

So these are the situations, which are forcing people to think ahead and apply new concepts. Sir, which all properties of soil get improved when a rubber tire chip is used for soil stabilization. See people you will find in the literature. Actually, I have not done much research in this area. So I am just talking about, whatever I have learned from the literature. Basically, what they do is, they modulate these swelling properties and mostly very fine shredding of these tires could be fibre reinforced soils.

Because if you remember that the composition of the rubber tires would be carbon and carbon could be used as a fibre also or if you can grind it and cut it and chop it in very small particles then it could be used as an amendment of the soil properties also. You can mix it with the soils. "Professor - student conversation ends" These are the idea which you can use, and you can create your own recipe and then what you have to do after creating a recipe.

You have to test it in the laboratory and prove how the properties have been modified and then recommended for applications. Now, these things are going to be useful in days to come and using these concepts you are trying to help the industry. Now the previous lecture, I was talking about the Glass, and I think I was talking about social, economic, technical issues related with this. Glass has become a very interesting industrial, domestic byproduct in today's world.

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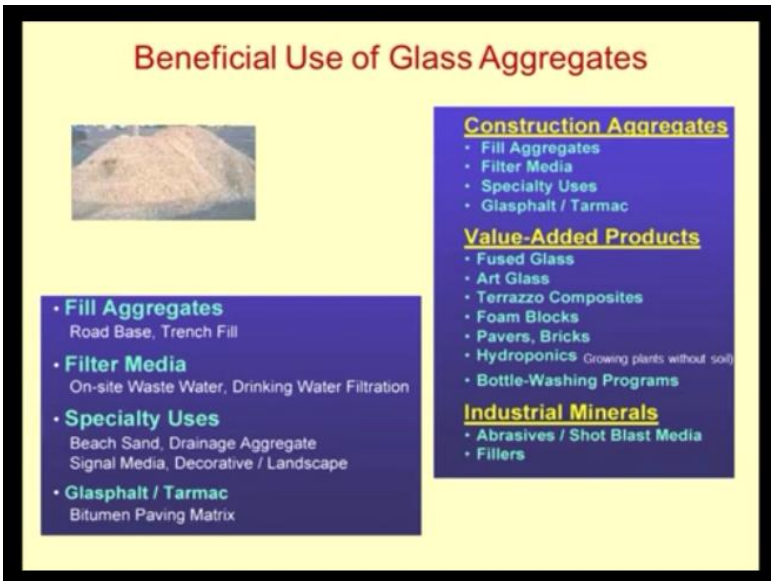

Particularly I have been professing the application of Glass for artificial beach creation. There is something known as beach nutrition. So sea beaches can be created overnight. What you to do? You have to take the unused Glass, crush it, and that is similar to the sands, and this hand can be utilized for making beaches and different other artificially created systems. You will be surprised to know that a lot of application is already there in the industry.

So the crushed Glass would look like this. It is similar to the sands. It is being used in construction aggregates as a fill material, filter media, glassphalt, tarmac. There are people are making value-added products out of this. Fused Glass, art glass, terrazzo composites, foam blocks, you must have come across hydroponics, is it not? Hydroponics is nothing, but they grow plants without soil.

So this is something very interesting people have been doing this, and they can also be used as an abrasive in the mineral sector and as a filler material. So depending upon this, there are a lot of applications. This can be used in concrete also because composition wise this metal is going to be same as quartz, go in road base, fill trenches. This can be a good filter media for wastewater treatment. You can replace sands and sands are not available right now.

As I was discussing speciality uses like beach sand, sand nourishment of the beaches. If you want to create a different type of landscape, then there you can use this and glassphalt is a new term.

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Then comes the dredging. This is something which is magnanimous. Long back I had told you in the class that nowadays geographical boundaries of the country keep on changing, particularly in the coastal areas. So in coastal areas, if you see through the net and the web, you will find a lot of case studies are available, where the artificial land was created by dredging. So there are different types of dredgers, which are able in the market. So these are suction dredgers.

So what you are observing here is a lot of pumps on the ship, and they suck sands, and then this is what is known as a rainbow methodology for sprinkling sand on the seashores. So, the whole area has been developed like this, and the sand gets deposited because of the natural phenomena. Sediments they get deposited in the base or the ocean bodies, ocean surface and then you can create land out of it.

Do a bit of internet checking, and you will find that most of the airports which are coming up recently internationally, they are all sitting on the dredged sediments. Japan is a beautiful example. Osaka Airport, you can see that these are satellite airports. They are not part of the

land. They do not have land. So, what they have done is, they have created a satellite airport in the sea, and they have connected it with a viaduct to the mainland.

These are some beautiful examples of advanced geotechnical engineering, which is being done by a different type of islands, palm island, pearl islands. In our own country, a lot of activities are being done in the Indian Ocean. If we check on the net, both for strategic as well as for civilian application and Chinese example you must be reading in the everyday newspaper. So, they have created thousands of islands, and what they are doing now?

In the South China sea, they are not allowing traffic. They charge toll and then these lands are now becoming strategic lands, where they can do strategic activities. So, it is an expansion of the country. Imagine we never bothered about these things, but these are activities with geotechnical engineers involved. A lot of interesting videos are there. Many projects are going on Bombay city. They do deep ocean blasting. They cut the rock; they blast it, they take out the rocks.

They bring it close to the seashores, and they create seabeds, sea beaches for strategic activities and for public activities also.

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Now, what are the beneficial applications of the dredged materials? There are several applications of the dredged materials. I have included few industrial byproducts because

dredging is an industry and dredging is normally done for two purposes. One is for maintenance if a lot of siltation occurs in the channels, which are bringing ships to the, what you call it, to the let us say port, seaport. So, ships which have big hulls cannot really navigate through. So, you have to first maintain the channels.

The way you maintain channels in your drains in your household. Second is what is known as when you are creating infrastructure. So, one is the maintenance dredging; another one is capital dredging. So capital dredging is normally done to create infrastructure in the ocean or the lakes or a water body. So, these are capital dredging, but there are a lot of challenges. So, I had been doing projects from different ports, and I have been guiding them.

How to utilize these materials for beach nourishment, shore production, soil creation and enhancement, land reclamation, the different type of habitat restoration. So, these things are becoming a part of geotechnical engineering. Do not think that someone else is going to do all these things. Only you have to be an expert tomorrow to guide the industry or the ports in the country.

Habitat restoration would be an excellent example of the guys who are more interested in the conservation of wildlife, aquatic life. So, if you are creating a facility or infrastructure somewhere in the water body, the aquatic life gets disturbed, is it not? We have disrupted the marine environment. So now people have started pitching in this concept of how to restore this habitat. So, they create islands for flora and fauna to flourish, and these are dedicated places.

And I am sure that you can realize that geotechnical engineers play a significant role in this area. Soft clay engineering, because most of these deposits after taking out from the sea, you are going to place on the seabed itself. So consolidation, settlement all these things you have to study, strength shear strength parameters and how to create an embankment which is two-thirds submerged in water, one-third coming out of the water and so on.

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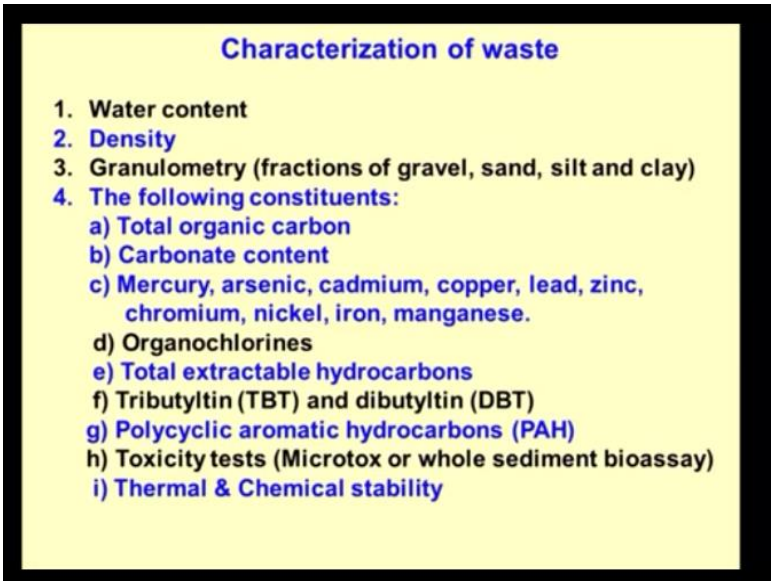

Now when it comes to the characterization of the waste, this is a very big subject. So as I said at the beginning of lecture today, that before you start using the material for a given application for a given project, the first thing you have to understand what are the fundamental properties of a material and this is where you have to characterize the material.

They're a big series of tests, which has to be done, water content because most of the time these materials have enough water in them, density, granulometry, what is their flowability. So, when we talk about the granulometry, you should check these papers by Rakshit Shetty and myself. We have done I think, we have published 3, 4 papers on the use of sediments and then the illogical characteristics of sediments.

And you have to test these sediments for following constituents, organic content, carbonate content, a different type of heavy metals which are present in the system, organochlorines which are present in the system. Most of the time, these heavy metals come in the sediments because of the discharges from vessels, ships. These soils could be hydrocarbons contaminated also. This is a big issue most of the industries in the coastal regions; they cannot withdraw water because of sedimentation for running their plants, cooling towers and boiler units, and so on.

PAH then toxicity test has to be done, because if you are utilizing a material, which is a dread material and the question would be where to dump it and after dumping, it should not become

toxic to the environment. You have to do a lot of clinical examination of sediments. Not many laboratories in the country and the world are full-fledged, material characterization laboratories. So this is where the interdisciplinary approach has to be adopted, and a lot of work has to be done.

So here I have listed thermal and chemical stability also. You were talking about this thing. So, when you are creating islands by reclamation, the first question would be you are using what type of material, sediments from the sea or the water body and whether they are organic in nature or not. Organic systems cannot be utilized because they will keep on consolidating, and they will decay, but imagine when you create big lands how you will test each sample?

It is not possible. It is a big challenge. Similarly, thermal stability because once you take it out and expose it to the environment, UV and sunlight, the chances are the sediments may decay. I mean this is one set of the experiments, which has to be done where I have not talked about the geotechnics related aspects. That is just the material suitability first of all, and once you say that the material is suitable, then you test it for its mechanical and engineering and geotechnical engineering characteristics. So that becomes a big series.

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So, this basically shows why the characterization of waste is becoming important industrial byproducts. From this point onwards, I shaped up my research in what I call as physico-chemico-

mineralogical thermal and electrical characterization. So, these things we have already mastered. We are quite comfortable, physics of the material, the chemistry of the material, mineralogy of the material, thermal characteristics of the material, electrical characteristics of the material.

Now the bio components and all slowly and slowly, I am adding too, but it seems to be a Herculean task. So, people like you should come forward and take it up and plug them in this matrix of knowledge to make the holistic picture, otherwise not going to be easy. So, Shashank thesis was one good example of, what happens when bacteria interact with the geomaterials. So that was a very fundamental work, which we did. You must have realized.

We were trying to create a lot of questions in mind first of all, and then you are trying to answer a few questions, which we could. So, once you characterize the waste, you can understand how this material is going to behave and how to recommend proper utilization schemes. As I said some time back, there are guys who are talking about waste mechanics.

It is a new concept, which is becoming a part of environmental geomechanics were not only the municipal solid waste, but industrial byproducts and mainly dredged sediments are being tested, and the whole mechanics is being created out of it, maybe 1930s and 40s and soils are tested, and soil mechanics came in force. No wonder in another 2, 3 years, you will find that these mechanics will become a big subject. So, this is how the knowledge keeps on spreading and bifurcating new topics get created.