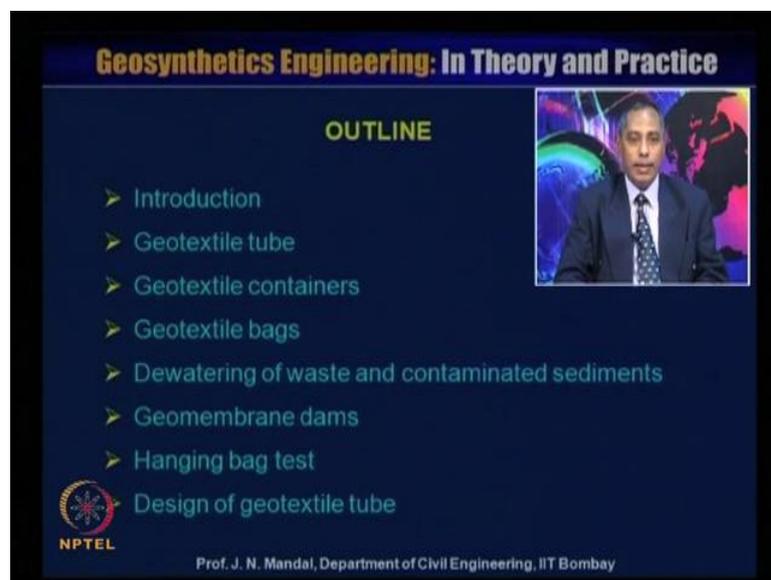


**Geosynthetics Engineering: In Theory and Practices**  
**Prof. J. N. Mandal**  
**Department of Civil Engineering**  
**Indian Institute of Technology, Bombay**

**Lecture - 51**  
**Designing with Geotextile Tube**

Dear student warm welcome to NPTEL phase 2 program video course on geosynthetics engineering in theory and practice. My name is Professor J. N Mandal, department of civil engineering, Indian Institute of Technology, Bombay, Mumbai, India. This is lecture number 51 and module 11, designing with geotextile tube.

(Refer Slide Time: 00:56)



So, outline of this course is as follows, introduction, geotextile tube, geotextile container, geotextile bag, dewatering of waste, and contaminated sediment, geomembrane dam, hanging bag test and design of geotextile tube.

(Refer Slide Time: 01:27)

**Geosynthetics Engineering: In Theory and Practice**

- In India, discharge of untreated sewage is the major source for surface water pollution. One out of five sewage treatment plants is non-operational.
- Sewage generated in cities and towns = 38,000 million liters per day (MLD); Treatment capacity exists = 12,000 MLD only
- 80% of the water supplied for domestic use come back as waste water. A huge volume of the waste water is discharged to the surface water bodies without any treatment resulting in the deterioration of water quality.
- To preserve water quality of the surface water bodies, geotextile tubes can be used effectively.

 (The Times of India, Mumbai, Thursday, September 26, 2013)  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

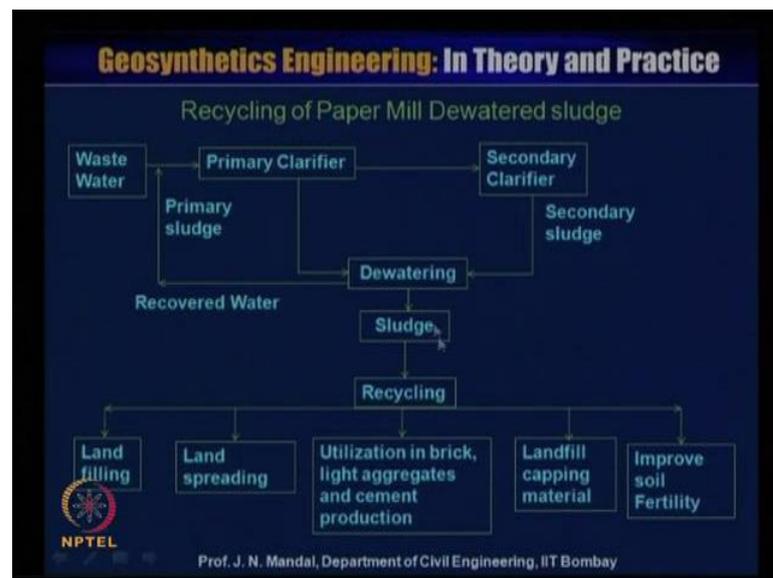
So, in India discharge of untreated sewage is the major source for surface water pollution. One out of five sewage treatment plant is non operational. Sewage generated in cities and town is about 38000 million liter per day, M L D and treatment capacity exist 12000 millions liter per day. Only 80 percentage of the water supplied for domestic use come back as waste water. A huge volume of the waste water is discharged to the surface water bodies without any treatment resulting in the deterioration of water quality. To preserve the water quality of the surface water bodies, geotextile tubes can be used effectively.

So, this is the times of India, Mumbai, September 26, 2013. In addition you also have shown that costal water how is go for bad to worst and how the sea is sinking. So, what is happening that accepted standard for the fecal coliform, a kind of the bacteria is 500 count per hundred ml. Whereas, we observed that fecal coliform is about 1445 count per hundred as per reported 2012 to 13.

So, what is the reason? What is the main reason? The main reason was untreated sewage falling into the sea and our discharge standard are deteriorated, the presence of fecal coliform a kind of bacteria which causes the number of the diseases. So, we have to take care for this kind of the waste water, because this waste water is increasing from 46 percentage to 103 percentage as per reported in the west course of the city in 2012 and the 2013 also.

Once upon a time that dissolve oxygen can also reduce and then the lot of pieces will be a problem. Also number of different kind of the diseases may affect the humanity. So, keeping in this mind what is happening also in the paper mill dewatered sludge is the recycling of the paper mill dewatering sludge.

(Refer Slide Time: 05:28)



So, this is the waste water and you go for the primary clarifier. And then for the dewatering and recover, the water again go for primary sludge and again you go for secondary clarifier, and secondary sludge and dewatering and then to the sludge again. And then you go for recycling, with the recycling you can use for the land filling or land spreading or utilization in the brick light aggregate and cement production landfill capping material and improve soil fertility.

So, instead of this very simple way to use the geotextile tube for dewatering the sludge and you can directly the inserted the waste water into the geotextile tube and can rectify this problem. And also the waste material can be used for the brick or aggregate or for the land spreading or land capping material. Also sometimes depending upon the content of the material in the geotextile tube can be used as a fertility, and if worst case if it is a contaminated it can be placed into the landfill.

(Refer Slide Time: 07:19)

**Geosynthetics Engineering: In Theory and Practice**

- Geotextile tube, geotextile container and geotextile bag have a lot of potential applications in marine and hydraulic, environmental and agricultural engineering.
- Mumbai has 720 km coastline. The water pollution is increasing in coastal areas.
- If the sewage water is discharged to the seashore, river, canal and lake without any scientific procedure, this causes health hazards and pollution.
- The contaminated sewage water should not be used for the construction and industrialization purposes. Industries dispose huge amount of waste materials, contaminated sediments and/ or byproduct in a contaminated area.

NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

So, geotextile tube is mainly that it may be geotextile tube. It may be geotextile bag or it may be geotextile container. So, use of geotextile tube is gaining very fast and it has a lot of application like this erosion control, also dewatering problem. So, erosion control you can use for the fine cohesionless sand or the gravel or dewatering. You can use the fine grain dead soil or any industrial ways say agricultural ways, etcetera.

So, it is also it is required the beneath soil cover placed because it is necessary for the UV degradation, also any accidental damage or intentional damage may occur, that also used to be avoid. So, geotextile tube, geotextile container and geotextile bag have a lot of potential application in marine and hydraulics environmental and agricultural engineering. You know Mumbai has 720 kilometer coastline, the water pollution is increasing in coastal areas.

If the sewage water is discharged to the seashore, the river canal and the lake without any scientific procedure, this causes health hazards and pollution. The contaminated sewage water should not be used for the construction and industrialization purposes. Industries dispose huge amount of waste material, contaminated sediment and or byproduct in a contaminated area.

(Refer Slide Time: 09:29)

**Geosynthetics Engineering: In Theory and Practice**

- The sewage water generated in India is about 6500 million liters per day, out of which only 24.7 percent is treated.
- India has a vast coastline of 7,517 km. Therefore, it is needed to treat the waste materials before discharging in to the sea, river, lake and canal.
- The slurry like waste material is very difficult to handle, transport and dispose for the landfilling. The geotextile tube can mainly be used for the dewatering of contaminated sediments, municipal sludge, dredge materials, mining waste and fine grained soil and to protect against soil erosion in river and coast areas, retaining structures, embankments and artificial island.

 NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

The sewage water generated in India is about 6500 millions liter per day, out of which only 24.7 percentage is treated. India has a vast coastline of 7515 kilo meter. Therefore, it is needed to treat the waste material before discharging into the sea, river, lake and canal. The slurry like waste material is very difficult to handle, transport and dispose for the land filling. The geotextile tube can mainly be used for the dewatering of contaminated sediment, municipal sludge, dredge material, mining waste and fine grained soil. And to protect against soil erosion in river and coastal area, retaining structure, embankment and artificial island.

(Refer Slide Time: 10:37)

**Geosynthetics Engineering: In Theory and Practice**

- Methane gas generated from the sewage waste can be used for generating electricity. Geomembrane tube can also be used in the seashore for the construction and recreation purpose.
- The conventional materials like concrete, stone and boulders are generally used for shoreline protection. This kind of geosystem is very expensive and not reliable or safe.
- On the other hand, the geotextile tube can be filled with locally available materials like sludge or sand. These systems have been used in many countries around the world.

 NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Methane gas generated from the sewage waste can be used for generating electricity. Geomembrane tube can also be used in a seashore of the construction and recreation purpose. The conventional material like concrete, stone and boulder are generally used for shoreline protection. This kind of geosystem is very expensive and not reliable or safe. On the other hand, the geotextile tube can be filled with locally available material like sludge or sand. These systems have been used in many countries around the world.

(Refer Slide Time: 11:30)

**Geosynthetics Engineering: In Theory and Practice**

- In U.S.A., the geotextile tube is used for rehabilitation and protection of the coastal area of the Grand Isle in New Orleans.
- The geotextile tube is used for strengthening and protection of river bank in Niger delta.
- In Australia, geotextile tubes have been exclusively used for ocean protection.
- Geotextile tubes have also been used for erosion control in Kolkata port trust, India.

 NPTEL

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

In USA, the geotextile tube is used for rehabilitation and protection of the coastal area of the grand isle in New Orleans. Geotextile tube is used for strengthening and protection of the river bank in Niger delta. In Australia, geotextile tube have been exclusively used for ocean protection. Geotextile tube have also been used for erosion control in Kolkata port trust, India.

(Refer Slide Time: 12:09)

**Geosynthetics Engineering: In Theory and Practice**

**□ Marine and Hydraulic Engineering**

- Geotextile tube is useful for the reclamation of sand and to protect the islands, coastlines or shoreline offshore structures like dikes, jetties and beachfronts from erosion and wave attacks.
- Artificial islands can be created for playing games and also can be habitat for wildlife and birds.

 NPTEL

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Marine and hydraulic engineering, geotextile tube is useful for the reclamation of sand and to protect the island, coastline or shoreline offshore structure like dikes, jetties and beachfront from erosion and wave attack. Artificial island can be created for playing games and also can be habitat for wildlife and the birds.

(Refer Slide Time: 12:42)

**Geosynthetics Engineering: In Theory and Practice**

**□ Environmental Engineering**

- There are lots of environmental problems appeared from industrial sludge, municipal sludge and hazardous contaminated soils.
- These kinds of wastes are generated from industrial plants, chemical manufacturing plants, sewage treatment plants, power plants, paper mills and sugar mills. Many industries pollute the rivers, ports, docks and harbors.
- All kinds of contaminated wastes can be pumped into the geotextile tube for dewatering at the site. This is very cost effective solution.

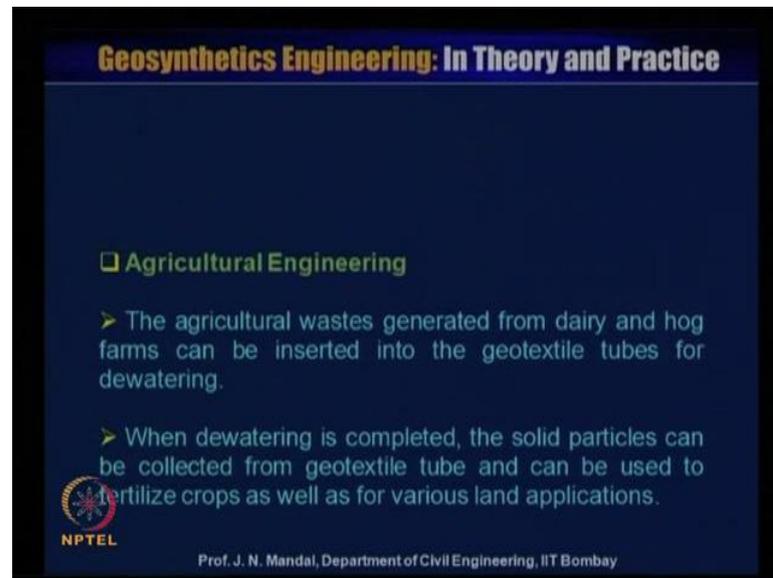
 NPTEL

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Environmental engineering, there are lots of environmental problem appeared from industrial sludge, municipal sludge and hazardous contaminated soil. These kinds of the waste are generated from industrial plant, chemical manufacturing plant, sewage

treatment plant, power plant, paper mills and sludge mills. Many industries pollute the river, port, docks and harbor. All kind of contaminated waste can be pumped into the geotextile tube for dewatering at the site. This is very cost effective solution.

(Refer Slide Time: 13:27)



**Geosynthetic Engineering: In Theory and Practice**

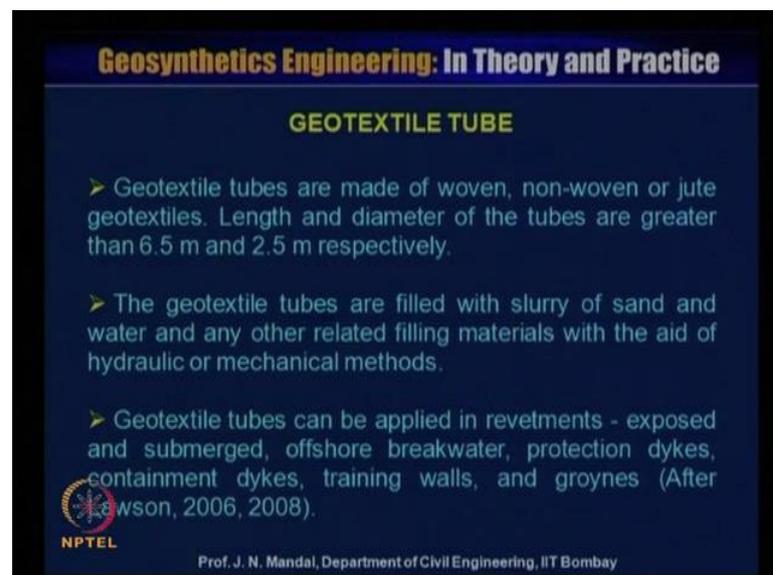
**Agricultural Engineering**

- The agricultural wastes generated from dairy and hog farms can be inserted into the geotextile tubes for dewatering.
- When dewatering is completed, the solid particles can be collected from geotextile tube and can be used to fertilize crops as well as for various land applications.

NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Agricultural engineering, the agricultural waste generated from dairy and hog farm can be inserted into the geotextile tube for dewatering. When dewatering is completed, the solid particle can be collected from geotextile tube and can be used to fertilize crops as well as for various land application. Now, what is geotextile tube and what is made of?

(Refer Slide Time: 14:07)



**Geosynthetic Engineering: In Theory and Practice**

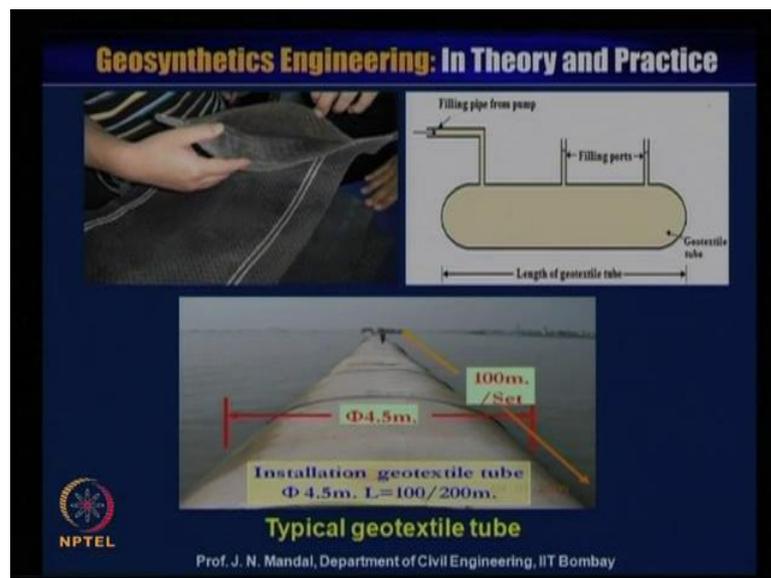
**GEOTEXTILE TUBE**

- Geotextile tubes are made of woven, non-woven or jute geotextiles. Length and diameter of the tubes are greater than 6.5 m and 2.5 m respectively.
- The geotextile tubes are filled with slurry of sand and water and any other related filling materials with the aid of hydraulic or mechanical methods.
- Geotextile tubes can be applied in revetments - exposed and submerged, offshore breakwater, protection dykes, containment dykes, training walls, and groynes (After Lawson, 2006, 2008).

NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Geotextile tubes are made of woven, non woven or jute geotextile, and length and diameter of the tube are greater than 6.5 meter and 2.5 meter respectively. So, geotextile tubes are filled with slurry of sand and water and any other related filling material with the aid of hydraulic or mechanical method. Geotextile tube can be applied in revetments exposed and submerged, offshore breakwater, protection dyke, containment dykes, training walls, and groynes, after Lawson 2006 and 2008.

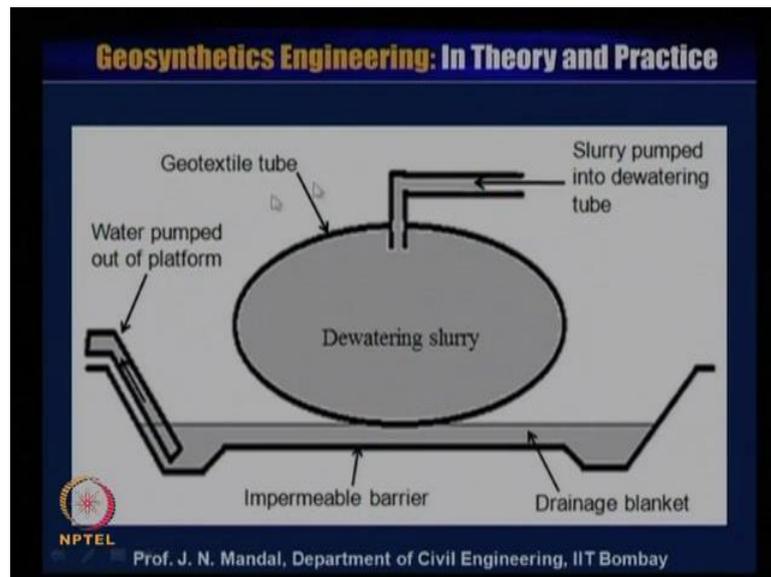
(Refer Slide Time: 15:01)



So, here is the typical geotextile tube. You can see here, this is a geotextile tube and this geotextile tube has a length, and also has a particular size. It may be the 20 meter in circumference and unlimited length. So, larger geotextile tube like this, like this so larger geotextile tube filled with the dredged sand acting as a bridge erosion control system and here you can see this is the length of the geotextile tube. And this is the filling port and this is the filling pipe, where it should be pumped. This is one installation of the geotextile tube and this distance is about 0.4 0.5 meter, and length about 100 to 200 meter.

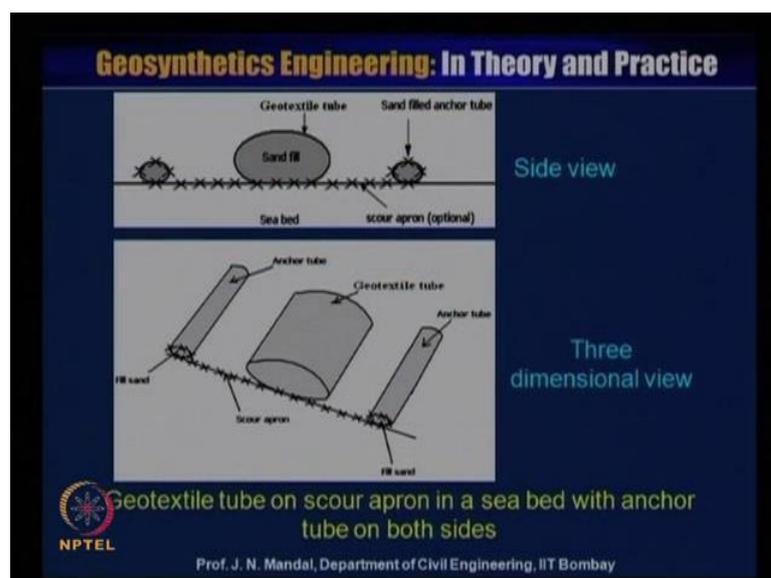
So, this geotextile tube may be made of woven or nonwoven geotextile or the jute geotextile material. And also it may be the double layer, not only single layer, double layer of material also can be used. So, when you will joint one geotextile with other that seems also are critical, and also the geometric dimension of the main tube after final pumping and the filling.

(Refer Slide Time: 16:54)



So, here is the geotextile tube. This is geotextile tube and the slurry pump into the dewatering tube here and here. At the base it is a impermeable material, may be like a geomembrane and there is a drainage blanket, and when it should be filled it up with the slurry. And then you apply the load, then water comes out from the geotextile tube and then this water pump out from the platform for the rectification or other treatment.

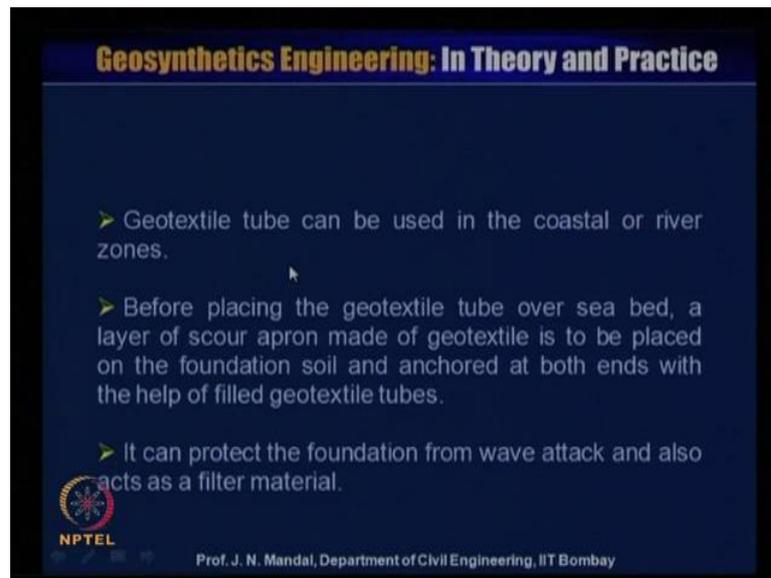
(Refer Slide Time: 17:44)



So, here geotextile tube on a scour apron in a sea bed with anchor tube on both side. So, when you place this geotextile tube, you place a one layer of the geotextile. This is scour

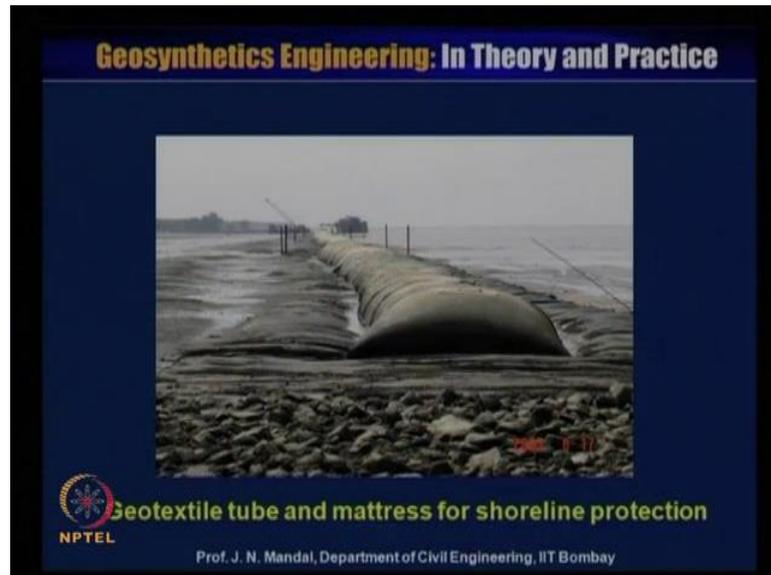
apron, this is optional in a sea bed and this is a geotextile tube, and this you have to sand fill with the anchor tube. So, you have anchoring like this. This geotextile tube like this here, here is a filled with the sand, this also filled with sand. So, this is a anchor tube and this is the main geotextile tube. So, this is a scour apron, so this geotextile, this is a three dimensional view, this is a side view. So, here geotextile tube or scour apron in a sea bed with anchor tube on both side. So, how you can make the anchor on the both side?

(Refer Slide Time: 18:43)



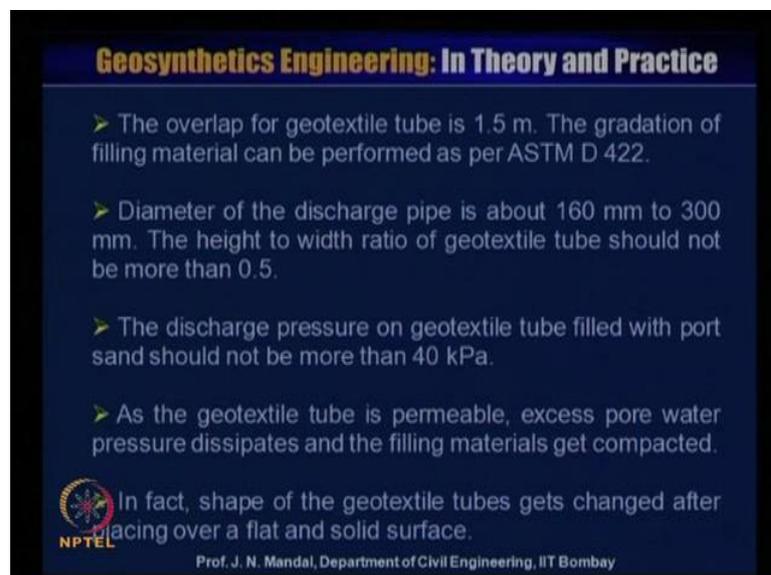
Now, geotextile tube can be used in the costal or the river zone, before placing the geotextile tube over the sea bed, a layer of scour apron made of geotextile is to be placed on the foundation soil and anchored at both end with the help of filled geotextile tube. It can protect the foundation from wave attack and also act as a filter material, because you know that woven, nonwoven geotextile material is a very good filter material.

(Refer Slide Time: 19:19)



This is geotextile tube and mattresses for shoreline protection. The overlap of geotextile tube is 1.5 meter.

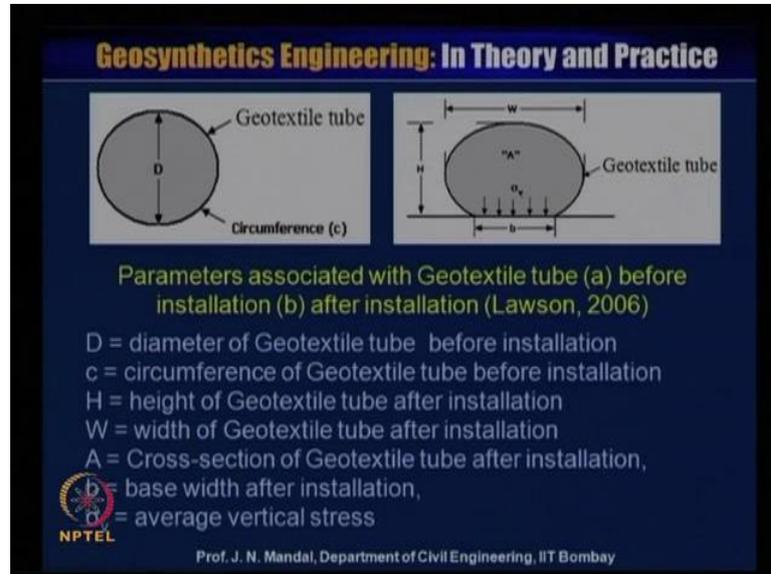
(Refer Slide Time: 19:26)



The gradation of filling material can be performed as per ASTM B 422, diameter of the discharge pipe is about 160 millimeter to 300 millimeter. The height to width ratio of geotextile tube should not be more than 0.5. The discharge pressure on geotextile tube filled with port sand should not be more than 40 kilopascal. As the geotextile tube is

permeable, excess pore water pressure dissipated and the filling material get compacted. In fact shape of the geotextile tube get changed after placing over a flat and solid surface.

(Refer Slide Time: 20:22)



So, you can see here that what are the parameter associated with geotextile tube before installation and after installation, that is Lawson, 2006. So, you can see the circumference that c and almost diameter of the geotextile tube is D. But when you place on the side, you do not have the same geometry as way you want to design. So, when you place then you can see that size and shape of the geotextile tube. So, here D is the diameter of the geotextile tube before installation and c is the circumference of geotextile tube before installation. And here H is the height of the geotextile tube after installation.

So, H is not the D, and this W is the width of the geotextile tube after installation. And if A is the cross sectional of geotextile tube after installation and this is the  $\sigma_v$ , that is average vertical stress. And this is the small b is the base width after installation. So, you can see that what is parameter associated with geotextile tube before the installation or after installation. There is lot of variation of the parameter.

(Refer Slide Time: 22:08)

**Geosynthetics Engineering: In Theory and Practice**

Relationship of various parameters after installation with the diameter and circumference before installation of geotextile tube (Lawson, 2003)

Engineering parameters	Diameter (D)	Circumference (c)
Maximum filled height, H	$H \approx 0.5D$	$H \approx 0.17c$
Filled width, W	$W \approx 1.5 D$	$W \approx 0.50c$
Base contact width, b	$b \approx 0.9 D$	$b \approx 0.29c$
Cross-sectional area, A	$A \approx 0.65 D^2$	$A \approx 0.07c^2$
Average vertical stress, $\sigma_v$	$\sigma_v \approx 0.72 \gamma D$	$\sigma_v \approx 0.24\gamma c$

Note:  $\gamma$  is the bulk density of the Geotextile tube-fill.

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Now, this relationship for various parameter after installation with the diameter and the circumference before installation of the geotextile tube is given by Lawson, 2003. This is the engineering parameter. What should be the diameter and what would be the circumference c?

Its maximum filled height is H. So, H related with the diameter will be approximately 0.5 D whose circumference H will be 0.17 c. So, that lawson has given very nice chart relationship between all the parameter filled with W. W is equal to 1.5 D and W is equal to 0.5c, c is circumference base contact width. Small b is equal to 0.9 D and b is equal to 0.29 c. Cross sectional area A is equal to 0.65 D square and A is equal to 0.07 c square. Average vertical stress, sigma v is equal to 0.72 gamma D, where gamma is bulk density of the geotextile tube filled, and sigma v is equal to 0.24 gamma c. So, he has given very nice correlation between the diameter and the circumferences of a geotextile tube before and after installation.

(Refer Slide Time: 23:55)

**Geosynthetics Engineering: In Theory and Practice**

Three major properties should be confirmed before installation of geotextile tube.

- Mechanical property of geotextile tube (i.e. tensile strength and stiffness)
- Hydraulic property of geotextile tube (i.e. permittivity, apparent opening size and discharge capacity), and
- Durability (i.e. design life of geotextile)

 NPTEL

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Now, three major properties should be confirmed before installation of geotextile tube. One is the mechanical property of the geotextile, hydraulic property of geotextile and durability, that is mechanical property of the geotextile tube, that means what will be the tensile strength and the stiffness. So, this is very important to us. So, here this geotextile tube is acting wall aspect, mechanical aspect, hydraulics aspect. So, hydraulic property of the geotextile tube that is required permittivity, apparent opening size and the discharge capacity, and the durability, that is design life of the geotextile.

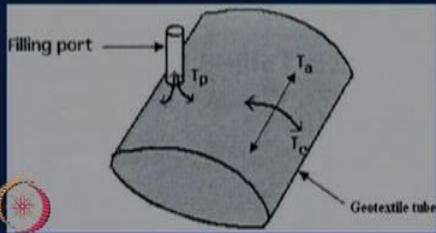
(Refer Slide Time: 24:45)

**Geosynthetics Engineering: In Theory and Practice**

□ Tensile strength of geotextile tube

Tensile strength of geotextile tube has three directions:

- Tensile strength along circumferential direction ( $T_c$ )
- Tensile strength along axis or length direction ( $T_a$ )
- Tensile strength along the filling port direction ( $T_p$ )



(After Lawson, 2006)

 NPTEL

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

So, this is very important to us. Now, you can determine the tensile strength of geotextile tube. Now, tensile strength of geotextile tube has a three direction, you can see here. So, tensile strength along the circumference, circumferential direction here, that is  $T_c$ . And tensile strength along the axis or length direction, that is  $T_a$ . And also the tensile strength along the filling port direction, that is  $T_p$ . So, this is the filling port when the sludge or any waste material inserted into the geotextile material. So, you require some tensile strength along the filling port direction, that is  $T_p$ . So, this is given after Lawson, 2006.

(Refer Slide Time: 25:56)

**Geosynthetics Engineering: In Theory and Practice**

Lawson (2006) followed the Palmerton's procedure (2002) to determine the relationship between maximum  $T_c$  and maximum  $T_a$  for filled tube.

- ❖ The maximum allowable tension  $(T_{max})_a$   
 $= 0.63 \times \text{maximum circumferential tension } (T_{max})_c$
- ❖ The port connection  $(T_p)_c = 0.3 \times (T_{max})_c$

NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

So, Lawson 2006 followed the Palmerton's procedure, that is 2002 to determine the relationship between the maximum  $T_c$  and maximum  $T_a$  for filled tube. The maximum allowable tension  $T_{max a}$  is equal to 0.63 into maximum circumferential tension, that is  $T_{max c}$ . So, if you know one then you can determine the other. And port connection  $T_p c$  is equal to 0.3 into  $T_{max c}$ . So, if you know what will be the maximum  $T_c$ . So, you can calculate what will be the maximum allowable tension,  $T_{max a}$ , and as well as you can calculate the port connection, that is  $T_p c$  with this relationship.

(Refer Slide Time: 27:01)

**Geosynthetics Engineering: In Theory and Practice**

□ **Hydraulic properties of geotextile tube**

Hydraulic properties of geotextile tube depend on the hydraulic environment and also on the period of exposure.

Lawson (2006) reported the hydraulic properties of geotextile for geotextile tubes and also the protections required according to hydraulic regime.



Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Then hydraulic properties of geotextile tube. Hydraulic properties of geotextile tube depend on the hydraulic environment and also on the period of exposure. Lawson, 2006 reported the hydraulic properties of geotextile for geotextile tube and also the protection required according to the hydraulic regime.

(Refer Slide Time: 27:32)

**Geosynthetics Engineering: In Theory and Practice**

Hydraulic regime	Period of exposure to hydraulic regime	
	Intermittent	Continual
Still, or slow moving water	No protection required. AOS $\leq 0.5$ mm, $q_{n,100} \geq 10$ L/m <sup>2</sup> .s	No protection required. AOS $\leq 0.5$ mm, $q_{n,100} \geq 10$ L/m <sup>2</sup> .s
Water current < 1.5 m/s	No protection required. AOS $\leq D_{85}$ fill, $q_{n,100} \geq 10$ L/m <sup>2</sup> .s	No protection required. AOS $\leq D_{85}$ fill, $q_{n,100} \geq 30$ L/m <sup>2</sup> .s
Water current $\geq 1.5$ m/s	No protection required, but some change in shape may occur after repeated events. AOS $\leq D_{85}$ fill, $q_{n,100} \geq 30$ L/m <sup>2</sup> .s	Protection required and some change in shape may occur. AOS $\leq D_{50}$ fill, $q_{n,100} \geq 30$ L/m <sup>2</sup> .s
Waves < 1.5 m	No protection required. AOS $\leq D_{50}$ fill, $q_{n,100} \geq 30$ L/m <sup>2</sup> .s	No protection required, but change in shape may occur over time. AOS $\leq D_{50}$ fill, $q_{n,100} \geq 30$ L/m <sup>2</sup> .s
Waves $\geq 1.5$ m	No protection required, but considerable change in shape may occur after repeated events. AOS $\leq D_{50}$ fill, $q_{n,100} \geq 30$ L/m <sup>2</sup> .s	Protection required and change in shape may occur. AOS $\leq D_{50}$ fill, $q_{n,100} \geq 30$ L/m <sup>2</sup> .s

Note: AOS = apparent opening size of the geotextile tube skin;  $q_{n,100}$  = volume flow rate at 100 mm constant head through the geotextile tube skin. (Lawson, 2006)



Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

So, this is the chart which is given by Lawson in 2006, this is the hydraulic regime. This is the period of exposure to hydraulic regime. This is intermittent and this is continual. Now, when the hydraulic regime is still or slow moving water so intermittent, no

protection required and apparent opening size of the geotextile should be less than 0.5 millimeter. And  $q_n$  100 should be greater than equal to 10 liter per meter square second. If it is a continual, no protection is required. The A O S value should be less than or equal to 0.5 millimeter and  $q_n$  100 should be greater than equal to 10 liter per meter square second. If the water current is less than 1.5 meter per second so intermittent, that is no protection required and A O S should be less than or equal to D 85 fill, and  $q_n$  100 should be greater than equal to 10 liter per meter square second.

So, no protection required in case of continual and A O S should be less than equal to D 85 fill and  $q_n$  100 should be greater than equal to 30 liter per meter square second. When the water current is greater than equal to 1.5 meter per second, then intermittent no protection required, but some change in shape may occur after the repeated event. That is A O S should be less than equal to D 85 fill and  $q_n$  100 should be greater than or equal to 30 liter per meter square second. Now, continual protection required and some change in shape may occur, that means A O S should be less than equal to D 50 fill and  $q_n$  100 should be greater than equal to 30 liter per meter square second.

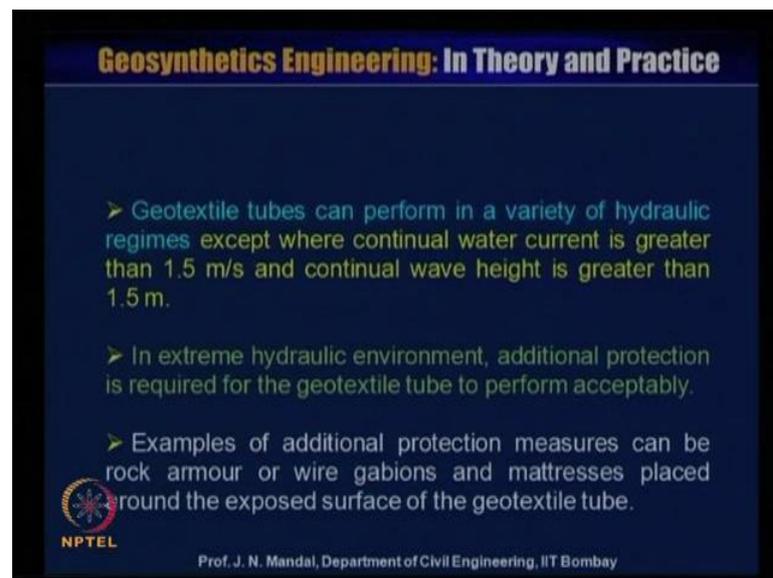
Now, when the hydraulic regime wave is less than 1.5 meter for intermittent no protection required, A O S should be less than equal to D 50 fill and  $q_n$  100 greater than equal to 30 liter per meter square second. And in case of continual no protection require, but change in shape may occur over time. So, A O S less than equal to D 50 fill and  $q_n$  100 greater than equal to 30 liter per meter square second when the hydraulic regime wave greater than equal to 1.5 meter.

So, in case of intermittent no protection required, but considerable change in shape may occur after the repeated event or A O S less than equal to D 50 fill and  $q_n$  100 greater than equal to 30 liter per meter square second. And in case of continual protection required and change in the shape may occur. So, A O S should be less than equal to D 50 fill and  $q_n$  100 greater than 30 liter meter square second. So, here A O S is equal to apparent opening size of the geotextile tube skin, and  $q_n$  100 is the volume of flow rate at 100 millimeter constant head through the geotextile tube skin.

So, this is the nice design chart is reported by Lawson, 2006 and this chart give a good indication of the hydraulic regime. And also is very important, because you should know what should be the water current. You should know what would be the wave, what will

be the height of the wave, what will be the current, what velocity. And then what will be the period of expert for hydraulic regime is required, either in case of intermittent or the continual case. So, from this good design chart, so you can also design and consider this parameter.

(Refer Slide Time: 32:20)



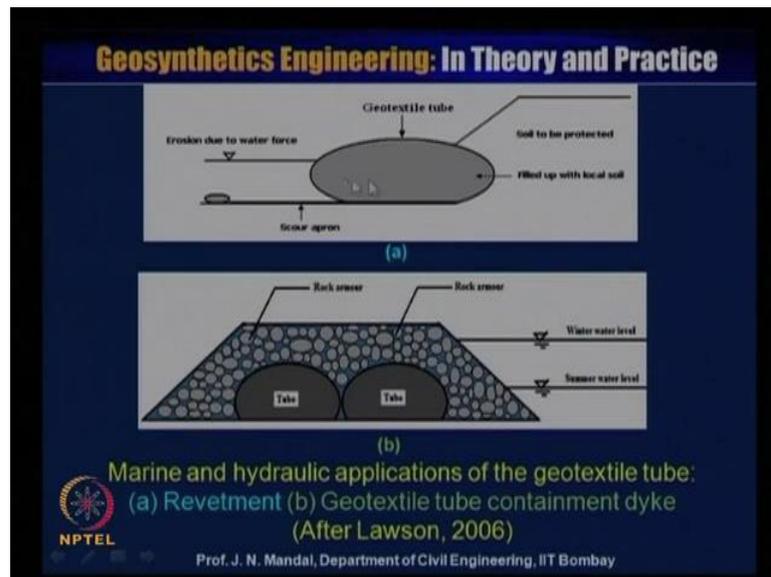
**Geosynthetics Engineering: In Theory and Practice**

- Geotextile tubes can perform in a variety of hydraulic regimes except where continual water current is greater than 1.5 m/s and continual wave height is greater than 1.5 m.
- In extreme hydraulic environment, additional protection is required for the geotextile tube to perform acceptably.
- Examples of additional protection measures can be rock armour or wire gabions and mattresses placed around the exposed surface of the geotextile tube.

 NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

So, geotextile tube can perform in a variety of hydraulic regime, except where the continual water current is greater than 1.5 meter per second and continual wave height is greater than 1.5 meter. In extreme hydraulic environment, additional protection is required for geotextile tube to perform acceptability. Example of additional protection measure can be rock armour or wire gabion and mattresses placed along the exposed surface of the geotextile tube.

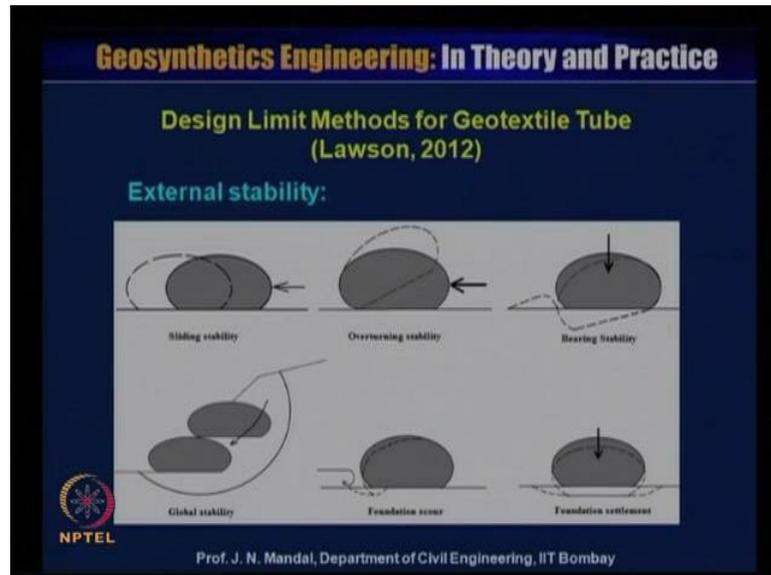
(Refer Slide Time: 33:03)



You can see here the marine and hydraulic application of geotextile tube, this is for revetment. So, this is the geotextile tube and this is the erosion due to the wave forces, and this is the filled up with the local soil and this is you can see scour apron. This is the anchor and this side the soil is to be protected. So, you can provide with the geotextile tube and you can fill up with the local soil material.

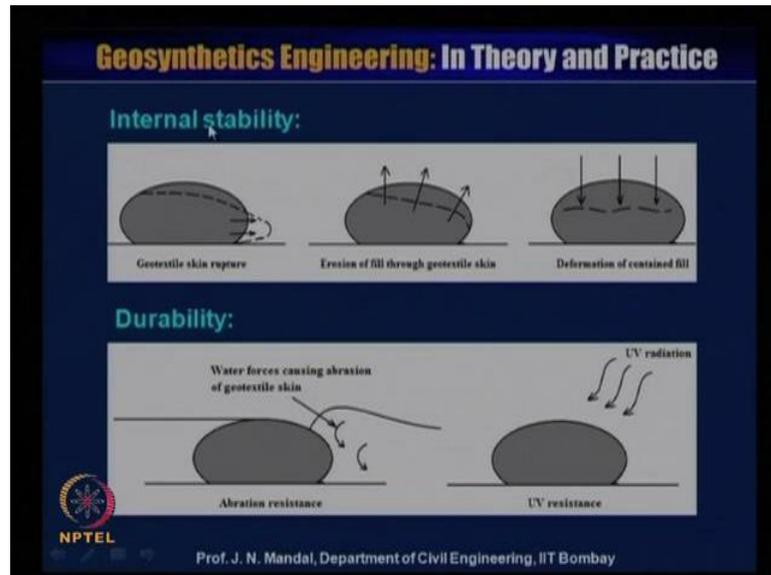
So, this is a one kind of the application in the revetment for marine or hydraulic application of geotextile tube. Now, also here is another kind of the application of geotextile tube in the containment dyke. So, here is the geotextile tube and this is rock armour, and you can see here the variation in the water level. During the summer the water level in the lower side and during the winter water level is on the higher side. And this geotextile tube is covered with the rock of armour. So, this also the marine and hydraulic application of geotextile tube when is the for the containment dyke.

(Refer Slide Time: 34:47)



Now, some design limit method by geotextile tube, Lawson given by 2012, that is for external stability. So, for external stability there is a possibility for sliding stability. So, geotextile tube may slide or here is the overturning, the overturning stability and here that bearing stability. You can see that how the bearing stability may occur in a geotextile tube or you can place the one geotextile tube with the on the another geotextile on the top of this geotextile tube. And there is possibility for the global stability failure or you have to check the foundation scour may occur here, or this foundation may be settlement may occur. So these are the some of the external stability which you have to take into consideration in the design limit.

(Refer Slide Time: 36:11)



Now, for internal stability this is a geotextile tube. So, geotextile skin rupture there is a possibility for rupture of the geotextile tube or erosion of fill through the geotextile skin. And also there is a deformation of contained fill due to this load. So, there is a deformation of the geotextile tube. So, these are the internal stability of the geotextile may occur and third durability. Now, this is a geotextile tube, it is the abrasion resistance because water force causing the abrasion of the geotextile tube.

So, when there is a water force which attack this geotextile tube, and there will be interaction between the geotextile tube and the water, and there is a possibility for the abrasion resistance, of course that UV radiation, ultraviolet radiation due to sun light. So, you cannot keep open the geotextile tube, always you require some kind of the cover. Otherwise, there is a possibility for the ultraviolet radiation into the geotextile tube. So these are the design aspect limit which we should consider geotextile container.

(Refer Slide Time: 38:06)

**Geosynthetics Engineering: In Theory and Practice**

**GEOTEXTILE CONTAINERS**

Geotextile container is made of woven (450 gm/m<sup>2</sup>) and/or nonwoven geotextile (650 gm/m<sup>2</sup>).

The tensile strength of geotextile is generally greater than 60 kN/m.

The length of geotextile tube is unlimited and circumference varies from 1m to 15 m.

Normally, volume of geotextile container is about 450 m<sup>3</sup> and depth is about 25 m.

 NPTEL

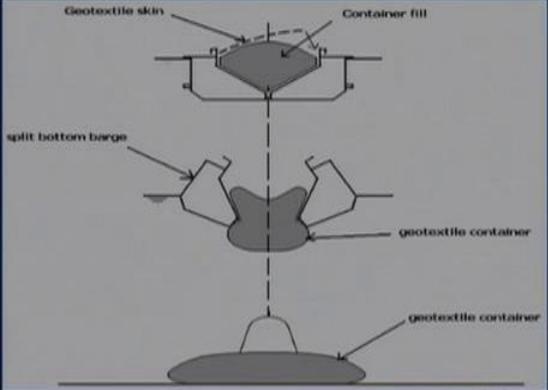
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Now, this container is made of woven or nonwoven geotextile material. In case of woven 450 gram per meter square and the nonwoven geotextile is 650 gram per meter square. Also you require that tensile strength of the geotextile is generally greater than 60 kilo Newton per meter. And the length of the geotextile tube is unlimited and circumferential varies from 1 meter to 15 meter. Normally, volume of geotextile container is about 450 meter cube and depth is about 25 meter.

(Refer Slide Time: 39:01)

**Geosynthetics Engineering: In Theory and Practice**

**Installation of geotextile container (After Pilarczyk, 2000)**



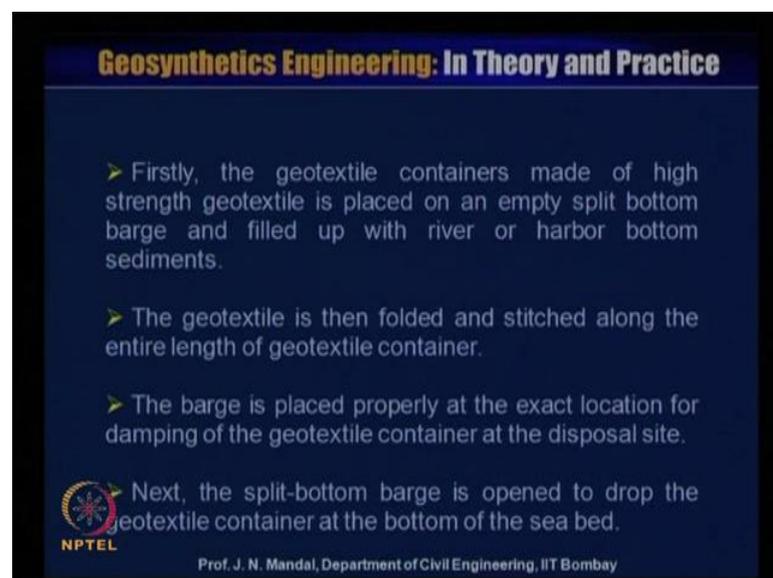
 NPTEL

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

So, here you can see that how the geotextile container is placed on to the seashore, and this involve the removal of the river and the harbor bottom sediment from the shipping channel or navigable water ways. So, you require the woven high strength geotextile material. And this geotextile material you have to put in an empty barge and then you fill with the bottom sediment, and then you have to fold it over with the top and then seen together. And then this barge is to be towed to the disposal area. So, proper position is very important, where you wanted to place this geotextile container, and then you can split the of the barge is open. When you split this, the barge will be open and the sediment fill container drop to the bottom.

So, sub surface embankment are formed, and if sediment is any containment is there and you never leave to the history for the or any other place. It will be remain as it is, that is one of the most significant advantage that this geotextile container, will never leave the history. So, this is very important where you can place this geotextile container and how you can place this geotextile container. You require the proper position and proper depth and proper placement of the geotextile tube. If you do not properly place then there is a possibility for the failure of the geotextile container.

(Refer Slide Time: 41:45)



**Geosynthetics Engineering: In Theory and Practice**

- Firstly, the geotextile containers made of high strength geotextile is placed on an empty split bottom barge and filled up with river or harbor bottom sediments.
- The geotextile is then folded and stitched along the entire length of geotextile container.
- The barge is placed properly at the exact location for dumping of the geotextile container at the disposal site.

Next, the split-bottom barge is opened to drop the geotextile container at the bottom of the sea bed.

**NPTEL**  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

So, here I am showing that firstly, that geotextile container made of high strength geotextile is placed on the empty split bottom barge, here empty split bottom barge you have to place and fill up with river or harbor bottom sediment. The geotextile is then

folded and stitched along the entire length of the geotextile container. The barge is placed properly at the exact location for dumping of the geotextile container at the disposal site. Next, the split bottom barge is opened, here this split bottom split bottom barge is open to drop the geotextile container at the bottom of the sea bed. So, you can place the sea bed.

(Refer Slide Time: 42:36)

**Geosynthetics Engineering: In Theory and Practice**

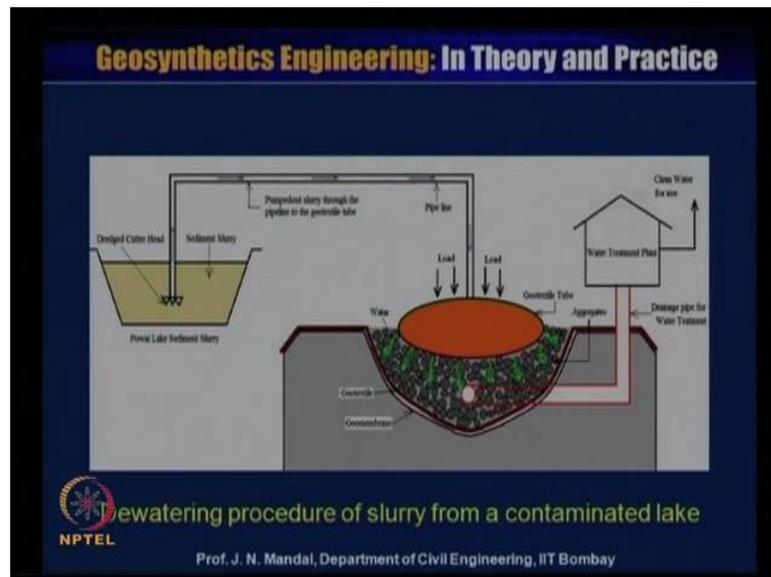
**DEWATERING OF WASTE AND CONTAMINATED SEDIMENTS**

- ❑ Fowler et al. (1996) used geotextile tube for dewatering of the municipal sewage sludge.
- ❑ In lake or river side, the geotextile tube can be used for dewatering the contaminated sediments
- ❑ Apart from contaminated lake side, the dewatering process can be applied to municipal waste sludge and water treatment, mining waste, industrial waste, agricultural farm waste, organic compounds and heavy metal, pesticides e.g. lead, zinc, mercury, copper, arsenic etc.

NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

So, dewatering of the waste and contaminated sediment, Fowler et al 1996 used geotextile tube for dewatering for the municipal sewage sludge. In lake or river side, geotextile tube can be used for dewatering the contaminated sediment. Apart from contaminated lake side, the dewatering process can be applied to municipal waste sludge and the water treatment, mining waste, industrial waste, agricultural farm waste, organic compound and heavy metal, pesticides, that is lead, zinc, mercury, copper, arsenic, etcetera.

(Refer Slide Time: 43:30)



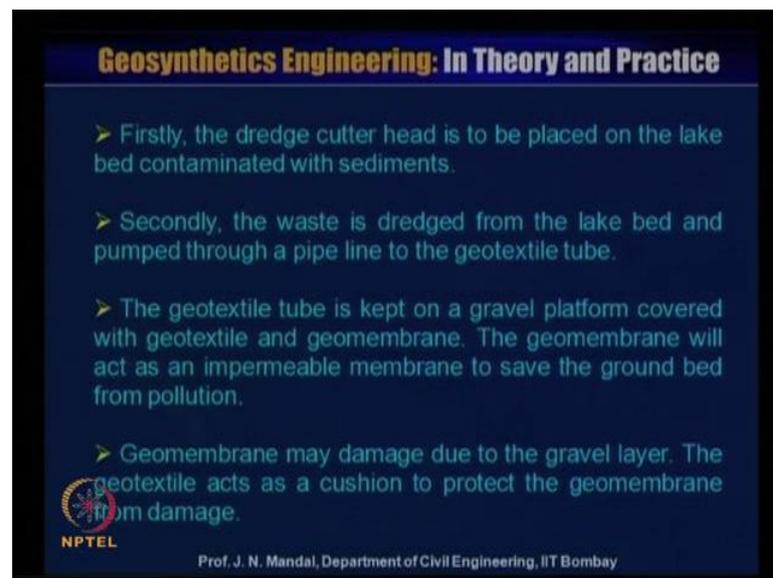
So, here we are showing one the dewatering procedure of a slurry from a contaminated lake. For an example, here for an example this is Powai lake, where there is a sedimentary slurry and this is the geotextile tube. And this geotextile tube is placed on a impermeable X, the geotextile this is a impermeable. You can place the geomembrane, then you can place the geotextile material and then you place the aggregate, on the top of the aggregate you can place the geotextile tube. Now, there is a let us say Powai lake and this is the sedimentary slurry and this sedimentary slurry which can be dredged by the cutter head.

So, there is a machinery which can cut all the dredged and then pump it out slurry through the pipe line to the geotextile tube. So, this is the pipe line then this all the sedimentary slurry can be directly inserted into the geotextile tube, then you are applying the load. And what will happen? The water will exert out from the geotextile tube and then this water will as a drainage pipe here for water treatment. So, you send it to the water treatment plant. So, you can have a clean water after processing, you can have a clean water for the use.

So, this kind of the system is very simple, even then you can construct this embankment using this geotextile tube in Powai lake surrounding. You can place the geotextile tube, you can excavate all the sedimentary slurry in to the tube and then you can place the another geotextile tube on the place of the existing geotextile tube. And then you can

slurry can be pump it out and water can be pump it out from the geotextile tube with this geotextile tube. You can construct an embankment and also you can provide with the different the drainage. So, all the water in this Powai lake should be the clean and it should be the discharge is out with this cutting edge technology.

(Refer Slide Time: 46:29)



**Geosynthetics Engineering: In Theory and Practice**

- Firstly, the dredge cutter head is to be placed on the lake bed contaminated with sediments.
- Secondly, the waste is dredged from the lake bed and pumped through a pipe line to the geotextile tube.
- The geotextile tube is kept on a gravel platform covered with geotextile and geomembrane. The geomembrane will act as an impermeable membrane to save the ground bed from pollution.
- Geomembrane may damage due to the gravel layer. The geotextile acts as a cushion to protect the geomembrane from damage.

**NPTEL**  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

So, firstly the dredge cutter head to be placed on the lake bed contaminated with sediment and this kind of machinery is available. Secondly, the waste is dredged from the lake bed and pumped through a pipeline to the geotextile tube. The geotextile tube is kept on a gravel platform covered with geotextile and geomembrane. The geomembrane will act as an impermeable membrane to save the ground bed from pollution. The geomembrane may damage due to the gravel layer. Therefore, the geotextile act as a cushion to protect the geomembrane from damage.

(Refer Slide Time: 47:13)

**Geosynthetics Engineering: In Theory and Practice**

- During dewatering, the excess water drains out from the tube and sent to the water treatment plant for further treatment. The treated water may be recycled to the lake.
- After completion of dewatering, the volume of geotextile tube gets reduced. The tube is cut, opened as well as the solid is collected.
- The solid waste can be recycled or disposed of the landfill or can be used for land development or as fertilizer for crops.

The dewatering process is one of the best methods for quick removal of solids from waste slurry.

NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

During dewatering, the excess water drained out from the tube and sent to the water treatment plant for further treatment. The treated water may be recycled to the lake. After completion of dewatering, the volume of geotextile tube get reduced. The tube is cut, opened as well as solid is collected. Now, this the solid waste can be recycled or disposed of the landfill or can be used for the land development or as a fertilizer for crops.

So, depending upon the type of the material, so you can send it for the recycling. You can send it for the use of as a fertilizer also, if it is a contaminated then entire geotextile tube you can be placed to the landfill, or you can make that material. You can produce the bricks or you can make use for the any road construction for any stabilization purpose also can be used. So, dewatering process is one of the best method for quick removal of solid from waste slurry, Kutay and Aydilek, 2004.

(Refer Slide Time: 49:01)

**Geosynthetics Engineering: In Theory and Practice**

**Kutay and Aydilek (2004):**

- Geotextile dewatering performance is independent of AOS and permittivity
- Higher slurry water content and higher fines results in more piping
- Use of double layer of geotextiles can increase retention and enhance dewatering

**Koerner and Koerner (2003 and 2006):**

- AOS is a poor predictor of geotextile tube dewatering performance
- Flow rate was found to be proportional to sediment permeability
- Hanging bag test was recommended to determine dewatering performance with in-situ sediments

NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Geotextile dewatering performance is independent of apparent opening size and permittivity. Higher slurry water content and higher fine result in more piping. Use of double layer of geotextile can increase the retention and enhance the dewatering. Koerner and Koerner, 2003 and 2006, apparent said opening size of geotextile is a poor predictor of geotextile tube dewatering performance. Flow rate was found to be proportional to sediment permeability. Therefore, hanging bag test was recommended to determine dewatering performance with in-situ sediment.

(Refer Slide Time: 50:04)

**Geosynthetics Engineering: In Theory and Practice**

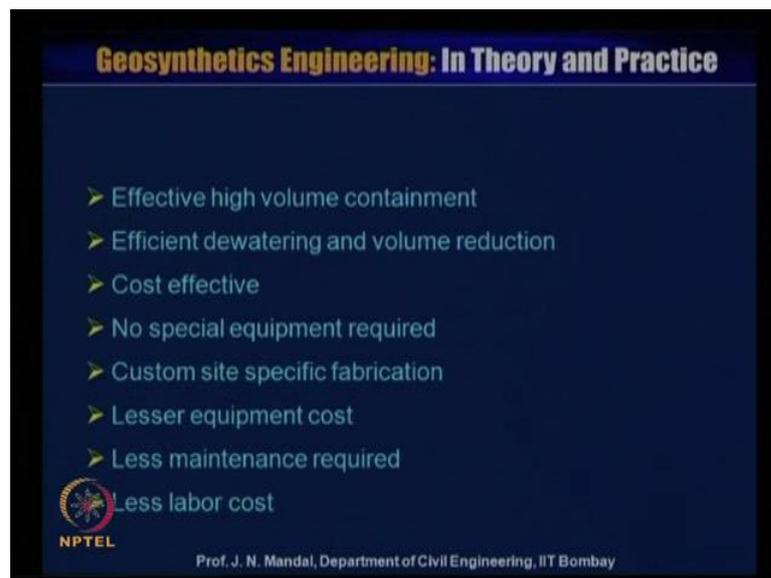
**Some major benefits of geotextile tube:**

- Geotextile tube has suitable apparent opening sizes and is very good as a permeable filtration material.
- It can contain huge volume waste slurry or bio-solids as well as dewatering of the slurry can be very fast.
- Geotextile tube can be cut to remove and dispose the solid particles to the construction site for land development or in the landfill.

NPTEL  
Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

So, some of the major benefit of geotextile tube. So, geotextile tube has suitable apparent opening size and is very good as a permeable filtration material, because it is made of woven and nonwoven geotextile material. It can contain huge volume waste slurry or bio solid as well as dewatering of the slurry can be very fast. Geotextile tube can be cut to remove and dispose the solid particle to the construction site for land development or in the landfill.

(Refer Slide Time: 50:52)



So, what is the effective high volume of containment, efficient dewatering and volume reduction? It is cost effective, no special equipment is required. Custom site specific fabrication, because this is the manmade. So, as you want then manufacturer can produce the geotextile tube as per your requirement, and lesser equipment cost and less maintenance required and less labor cost.

(Refer Slide Time: 51:28)

**Geosynthetics Engineering: In Theory and Practice**

**GEOMEMBRANE DAMS**

- 1) Inflatable dam (open closed type)
- 2) Parachute dams (closed open type)

❖ Inflatable dams can be used for irrigation and water regulation (Tam, 1998).

➤ The inflatable dam is connected with a foundation and fixed with bolts and nuts to a steel frame. It is a cylindrical tube made of synthetic membrane and filled with water, air or combination of both.

The height of the tube can be varied by increasing or decreasing the internal pressure with the aid of a pump

**NPTEL**

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

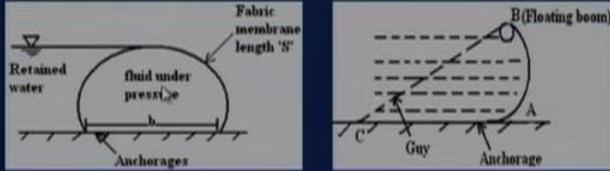
So, this geomembrane dam, this is inflatable dam that is open closed type or parachute dam. This is closed open type, this is very interesting that you can construct a dam. Geomembrane dam and inflatable dam can be used for the irrigation and water regulator dam, 1998. This inflatable dam is connected with a foundation and fixed with bolt and nuts to a steel frame. It is a cylindrical tube made of synthetic membrane and filled with water, air or combination of both. The height of the tube can be varied by increasing or decreasing the internal pressure with the aid of pump.

(Refer Slide Time: 52:32)

**Geosynthetics Engineering: In Theory and Practice**

❖ In parachute dams, the upper end is connected with a floating boom and restrained by guys (Watson, 1985).

- Estuarial lands can be reclaimed by using geomembrane bags filled with inexpensive materials such as dredged soils, cheap rock fill materials.



**Inflatable dam**                      **Parachute dams**

(After Watson, 1985; Tam, 1998 and Pilarczyk, 2000)

**NPTEL**

Prof. J. N. Mandal, Department of Civil Engineering, IIT Bombay

Here, you can see that inflatable dam and the parachute dam. In parachute dam, the upper end is connected with a floating boom and restrained by guys, that is Watson, 1985. The estuarial land can be reclaimed by using the geomembrane bag filled with inexpensive material such as dredged soil, cheap rock fill material. So, this the inflatable dam, this is placed into the anchorage and this is the retained water here, and this is the fabric that membrane this length is S.

So, this is given after Watson 1985, Tam 1998 and the Pilarczyk 2006. So, you can use very easily this kind of the dam. It is very easy to construct and also very easy to use. So, you are just putting the feet under the flexible pressure, you can putting down even then geomembrane dam. You can fill up with the air, you can use to the construction side also, and also it is easy to be the anchor. It can be floated and this is very useful for the irrigation purpose also. With this I finish my lecture today. Let us hear from you any question.

Thanks for listening.