Geosynthetics Engineering: In Theory and Practices

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Lecture - 1
Introduction

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. You may contact me through my E mail ID, cejnm@civil.iitb.ac.in or you can visit to my site URL - http://WWW.civil.iitb.ac.in/~cejnm. The name of the course Geosynthetics Engineering in Theory and Practice, this lecture number 1 Introduction.

Geosynthetics has been internationally while establish and potentially very versatile material in the field of civil engineering for many years. It is hot and emerging area, it is one of the most significant construction material for design and construction problems, independent of geographic, climatic or technological differences. The uniqueness of geosynthetics are simple in their various application and offer multi functional performance while providing most important economical advantages.

There is no other construction material available in the entire construction industry be it concrete, steel or wood or bamboo or jute or any combination thereof, which offers such variety of sound solution to construction problem has does the geosynthetics in civil engineering. In general, these solution refer to foundation stabilization, erosion protection, drainage, slope civilization, lining protection as per ((Refer Time: 02:57)) and ceiling reinforced soil, retaining wall reinforced soil, slope and so on.

The revolutionary development of geosynthetics begin in the early 1970s in road construction. The name of the course is geosynthetics engineering in theory and the practice, we now address the module of and the content of the course. The name of the course geosynthetics engineering in theory and practice, you can contact me through my Email ID cejnm@civil.iitb.ac.in or you can visit to my website URL - http//WWW.civil.iitb.ac.in/~cejnm.

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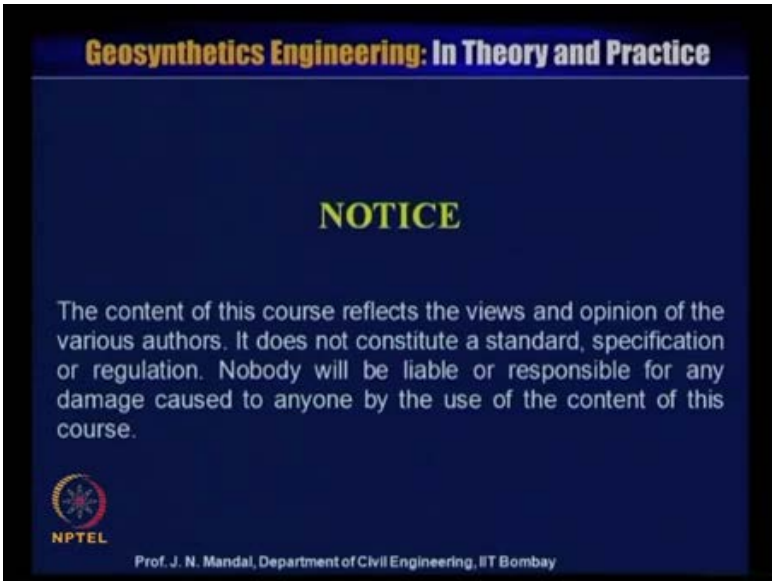

Notice, the content of this course reflect the views and opinion of the various authors, it does not constitute a standard specification or regulation. Nobody will be liable or responsible for any damage caused to anyone by the use of the content of this course. Next, I will address the content of the course on geosynthetics engineering in theory and practice, there are 13 module.

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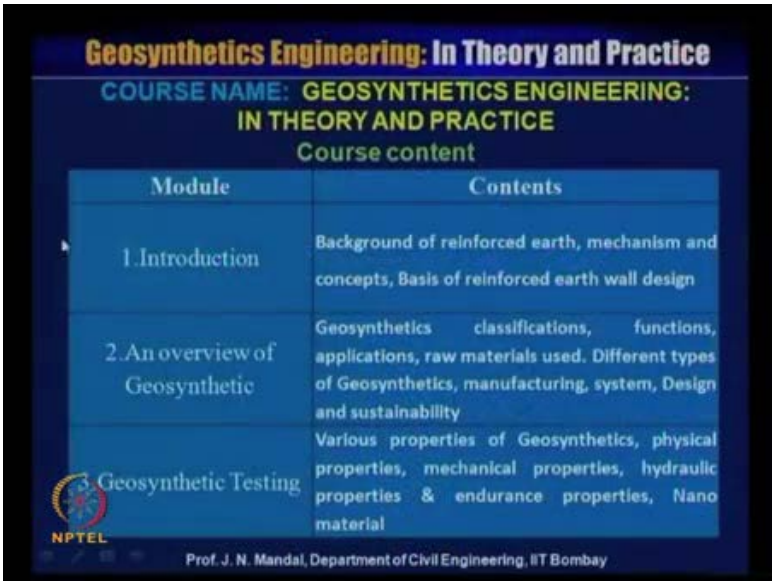

Module 1, the introduction, it contain background of reinforced earth, mechanism and concept, basis of reinforced earth wall design. Module 2, an overview of geosynthetics,

geosynthetics classification, function, application, raw materials used, different types of geosynthetics manufacturing system, design and sustainability. Module 3 geosynthetics testing, various properties of geosynthetics, physical properties, mechanical properties, hydraulic properties and endurance properties, and nano material.

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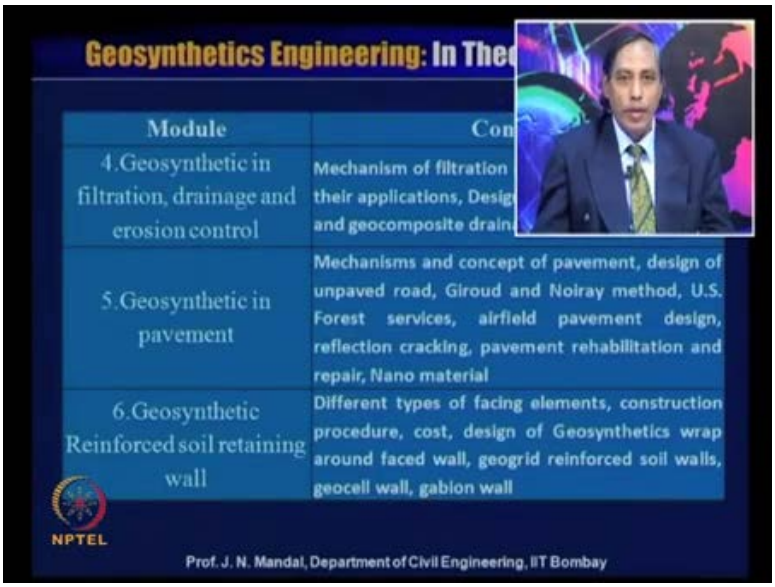

Module 4 is geosynthetics in filtration, drainage and erosion control, it cover mechanism of filtration and drainage function and their application, design step for erosion control and geocomposite drainage. Module 5, geosynthetics in pavement, mechanism and concept of pavement, design of unpaved road, Giroud and Noiray method, U.S. forest services, airfield pavement design, reflection cracking, pavement rehabilitation and repair and nano material. Module 6, geosynthetics reinforced soil retaining wall, it contain different types of the facing element, construction procedure, cost, design of geosynthetics wrap around face wall, geogrid reinforced soil wall, geocell wall and gabion wall.

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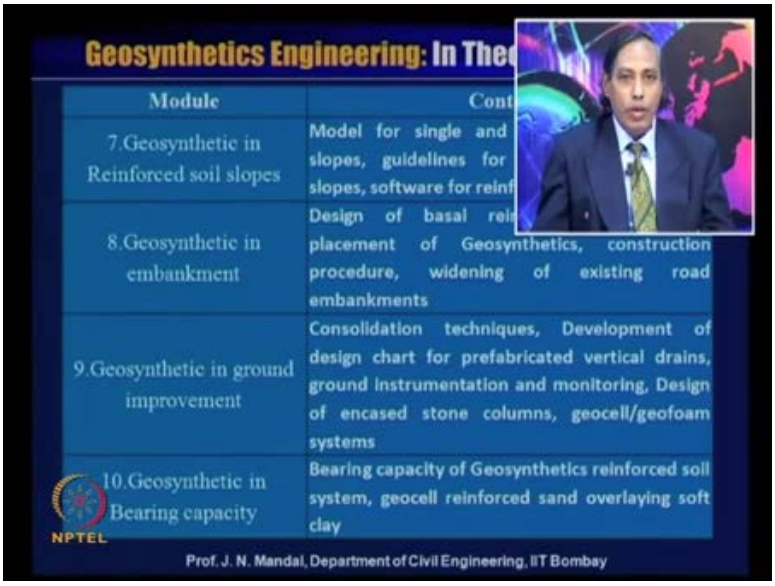

Module 7, geosynthetics in reinforced soil slope, it cover model for single and multi layer reinforced slope, guidelines for design of reinforced slope, software for reinforced soil slope. Module 8, geosynthetics in embankment, design of basal reinforced embankment, placement of geosynthetics, construction procedure, widening of existing road embankment.

Module 9, geosynthetics in ground improvement, it cover consolidation technique, development of design chart for prefabricated vertical drain, ground instrumentation and monitoring, design of encased stone column, geocell geofoam system. Module 10, geosynthetics in bearing capacity, it cover bearing capacity of geosynthetics reinforced soil system, geocell reinforced sand overlaying soft clay.

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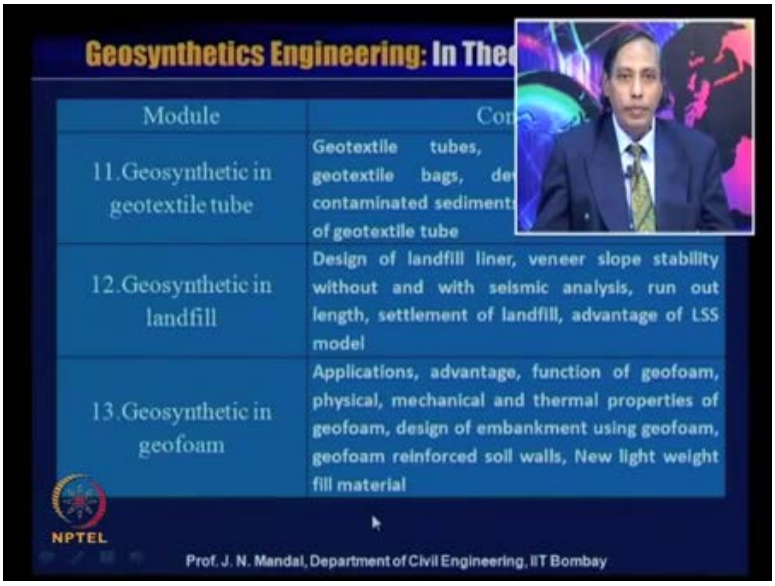

Module 11, geosynthetics in geotextile tube, it contain geotextile tube, geotextile container, geotextile bag, dewatering waste and contaminated sediment, installation and design of geotextile tube. Module 12, geosynthetics in landfill, design of landfill liner, veneer slope stability without and with seismic analysis, run out length, settlement of landfill, advantages of LSS model.

And last module 13, geosynthetics in geofoam, it cover application, advantage, function of geofoam, physical, mechanical and thermal properties of geofoam, design of embankment using geofoam, geofoam reinforced soil wall, new light weight fill material. So, we will cover the 13 module and you known that, what are the content of this module and then, as the name of the course on geosynthetics engineering and theory and practice, I will now address some of the important reference, which you can follow up during this course.

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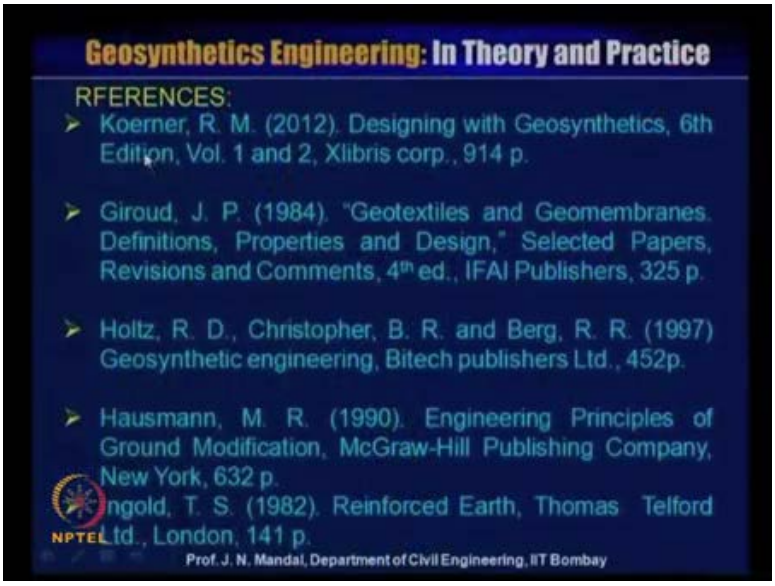

First text book, Koerner. R. M. that is, 2012, Designing with Geosynthetics, 6th edition volume 1 and 2. Xlibris corp, this book is very popular, I always recommended this book to study. You can have detail about the designing with geosynthetics material, I highly recommend this book for you. Giroud. J. P. 1984, Geotextile and Geomembrane, definition, property and design, selected paper, revision and comment that is, 4th edition IFAI publisher, this book contain the series of the paper.

So, you can have the very basic function and their different application and also other related material and how you can design and how you can conduct the test, so you can have some idea from this book written by Dr. J. P. Giroud. Next book Holtz. R. D., Christopher. B. R. and Berg. R. R. 1997, Geosynthetics Engineering, Bitech publisher, this is also very good books, you can go for the design and analysis and specimen of the geosynthetic related material.

You will be knowing that, what kind of the design, what kind of the application, you can have some idea about this geosynthetics material and other related system. Next book Hausmann. M. R. 1990, Engineering Principles of Ground Modification, this is McGraw hill publishing company, New York. This is also one of the interesting book, you can have the basic idea of the reinforced earth system, for some design also has been done by the using the metallic reinforcement, this book is very popular and you can make use of this book.

Next Ingold. T. S. 1982, Reinforced Earth, Thomas Telford Limited, London, this is the very basic book of the reinforced earth system, in this book you can have details about the metallic reinforcement, how it has been used, what is the basic concept and the mechanism of the reinforced earth system, this is also good book.

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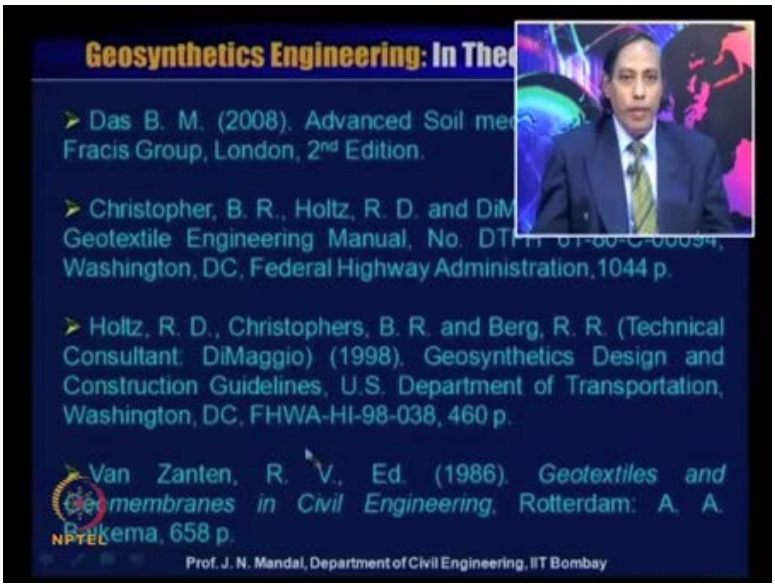

Next book Das. B. M. 2008, Advanced Soil Mechanics, Taylor and Fracis group, London this is also basic soil mechanics book and part of this also geosynthetics or reinforced soil systems also have cover. But, to understand these geosynthetics engineering material, you should know also the basic soil mechanics, in that sense this book is also very popular.

Christopher. B. R., Holtz. R. D., DiMaggio. J. A. 1984, Geotextile Engineering Manual, NO DTFH 61-80-C-00094, Washington DC, Federal Highway Administration. This also book will cover the entire geosynthetics design system and their various application and this will also cover some standard and specification, this is also very good book, you should follow it.

Holtz. R. D., Christopher. B. R. and Berg. R. R. Technical Consultant, Dr. DiMaggio 1998, Geosynthetics Design and Construction Guidelines, U.S. Department of Transportation, Washington DC, FHWA-H1-98-038, this is also very good report similar to that earlier books. So, you can have also more detail about the construction system and

the implementation of the geosynthetics material and their property, this is also very good popular.

Next, Van Zanten. R. W., this 1986, Geotextile and Geomembrane in Civil Engineering, Rotterdam, A.A. Bulkema this also book consist of many many case history and the design. Lot of case history has been covered in this book, so you can have more detail idea about the case history of geosynthetics material and their system.

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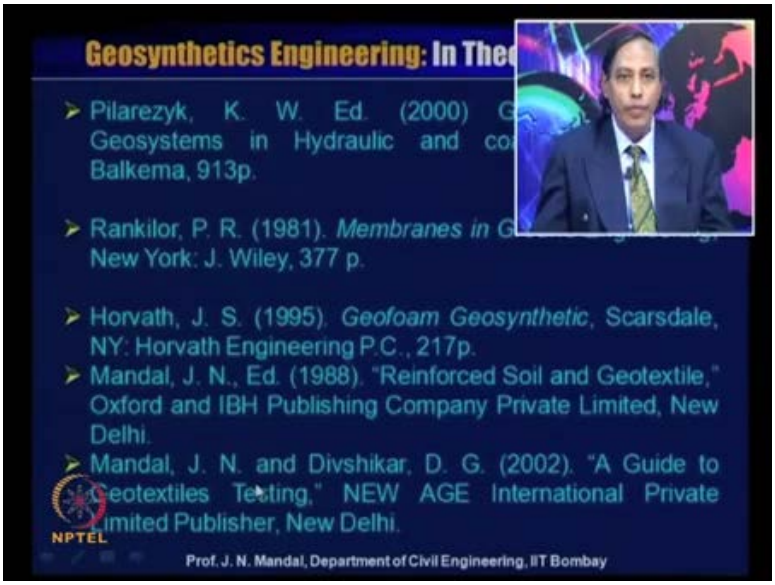

Pilarezyk. K.W., that is 2000, Geosynthetics and Geosystem in Hydraulic and Coastal Engineering, Balkema, this is one of the edited book is very popular in case that, if you wanted to use geosynthetics material for hydraulic and coastal engineering. There are many many application for, you can use this geosynthetics material in hydraulic and coastal related problem, so these book also very popular written by Dr. K. W. Pilarezyk.

Next, Rankilor. P. R., 1981, Membrane in Ground Engineering, New York, J. Wiley, this book also will give you the basic concept of the geosynthetics material, one can go through this book to understand the basic mechanism of reinforcing system. Next, Horvath. J. S. 1995, Geofoam Geosynthetics, Scarsdale, New York, Horvath Engineering PC. Tthis is only one of the book written on the geofoam material, which is very exciting material and this material is very popular, this is only one book related with the geofoam is written by doctor J.S. Horvath, so one can also follow this book.

Mandal. J. N. 1988, Reinforced Soil and Geotextile, Oxford and IBH publishing company private limited, New Delhi. This also cover the number of the paper, so one can go through this book and he can idea even then, one specific natural material like jute has been covered, so this also very useful to you. Mandal. J. N. and Divshikar. D. G., 2002, A Guide to Geotextile Testing, this is NEW AGE international private limited publisher, New Delhi.

Only we should know the properties of the soil and at the same time, we should know that, what will be the properties of the geotextile and related material. So, this book will help you to perform all kind of testing related with the geotextile, so this book also very helpful to understand their basic properties.

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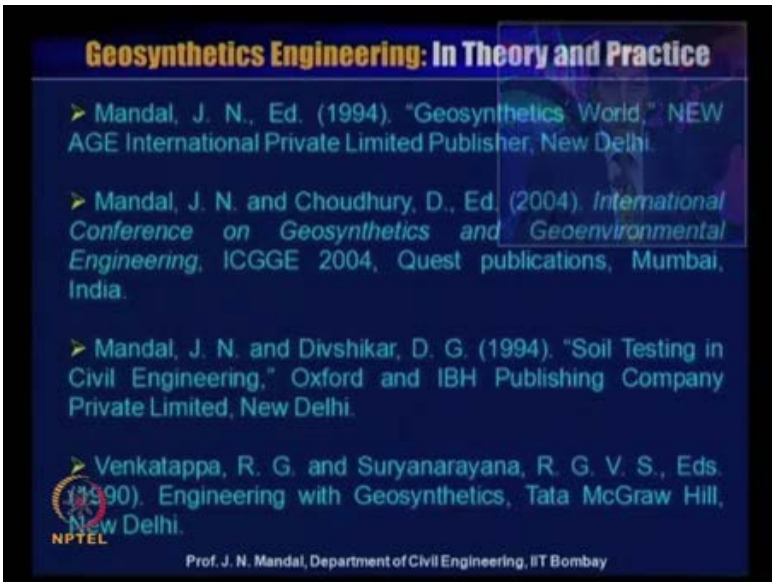

Mandal. J. N. Ed 1994, Geosynthetics World, NEW age international private limited publisher, New Delhi. This book consist of a number of very good paper, so this also reflect the geotextile in India, you can also have the idea about the use of the natural material and jute and coir. Apart from that, you can obtain the various design method given by the various renowned people in the world. Mandal. J. N. and Choudhury. D, Ed 2004, International Conference on Geosynthetics and Geoenvironmental Engineering, ICGGE 2004, Quest publication, Mumbai, India.

This is the international conference organized in IIT, Bombay and in this proceeding, you can have a number of the international paper, this also will be very useful to you.

Mandal. J. N. and Divshikar. D. G. 1994, Soil Testing in Civil Engineering, Oxford IBH publishing company private limited, New Delhi. So, apart from the geotextile testing, you also recall proper kind of the soil testing, so this book also will be very helpful to the readers. Venkatappa. R. G. and Suryanarayana. R. G. V. S. Eds 1990, Engineering with Geosynthetics, Tata McGraw hill, New Delhi. This a number of the papers are there in this book, so this book also will give you the idea, the overall design of geosynthetics and other related material.

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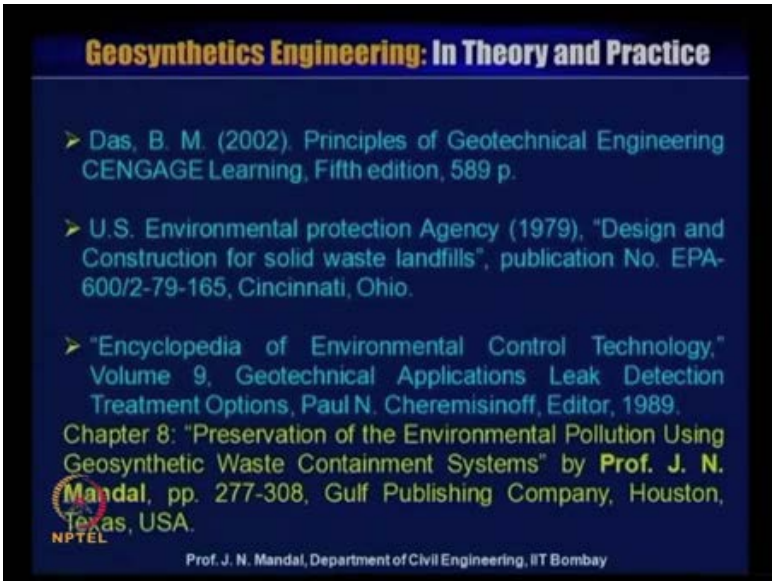

Das. B. M. 2002, Principle of Geotechnical Engineering, CENGAGE learning, 5 th edition, 589 page. So, this book also will give you that, what will be the principle of the soil mechanics and apart from this, you can have some subject area on the reinforced earth soil, this is very very good books, so one can go through this book also. Here, U.S. environmental protection agency 1979, Design and Construction for Solid Waste Landfill, publication number EPA-600/2-79-165, Cincinnati, Ohio.

So, this is the book is very good for any landfill design, any kind of the solid waste landfill, how to design it, how to construct it, so lot of details has been given in this book, so one must read this book, encyclopedia of Environmental Control Technology, volume 9, Geotechnical Application Leak Detection Treatment Option, Paul. N. Cheremisinoff, Editor, 1989.

This chapter 8, Preservation of the Environmental Pollution Using Geosynthetics Waste Containment System by Professor J. N. Mandal, page 277 to 308, Gulf Publishing Company, Houston, Texas, USA. So, in this book and particularly this chapter is very important for the proper preservation of the environmental pollution and how to design this and some computer aided design also has been given in this book, so one must go through this book.

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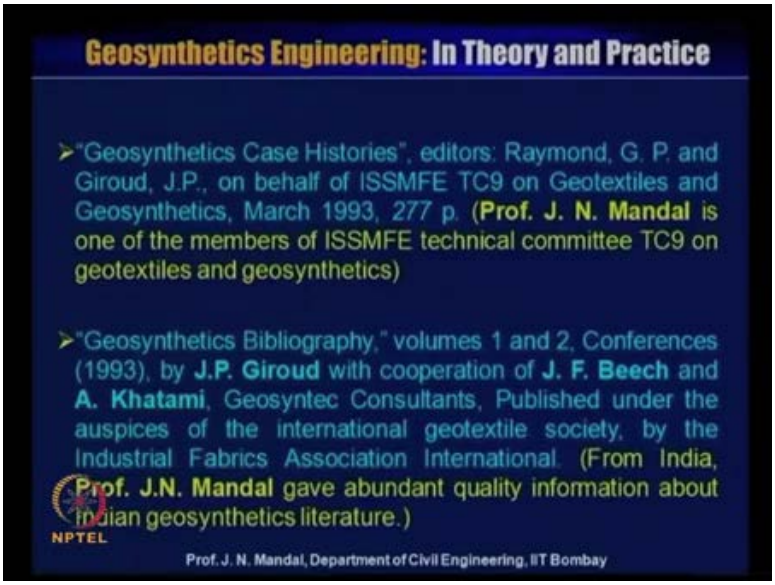

Geosynthetics Case History, editor Raymond. G. P and Giroud. J. P. on behalf of the International society Soil Mechanics and Foundation Engineering, TC9 on Geotextile and Geosynthetics, March 1993, 277 page. Professor J. N. Mandal is one of the member of the International Society for Soil Mechanics and Foundation Engineering technical committee TC9 on geotextile and the geosynthetics.

So, lot of case history across the world has been given in this book, this is very very useful, you can have the different types of the case history, what is happening, how they have designed, how it has been fail, etcetera, this is very very interesting book to you. Geosynthetics Bibliography, volume 1 and 2, Conferences 1993 by Dr. J. P. Giroud with cooperation of Professor J. F. Beech and Professor A. Khatami, Geosyntec Consultant published under the auspices of the international geotextile society by the Industrial Fabrics Association International.

From India, Professor J. N. Mandal gave abundant quality of information about Indian geosynthetics literature. So, you can have many many references from Indian side and other related across the world, is given in this geosynthetics bibliography, so you must go through this book also.

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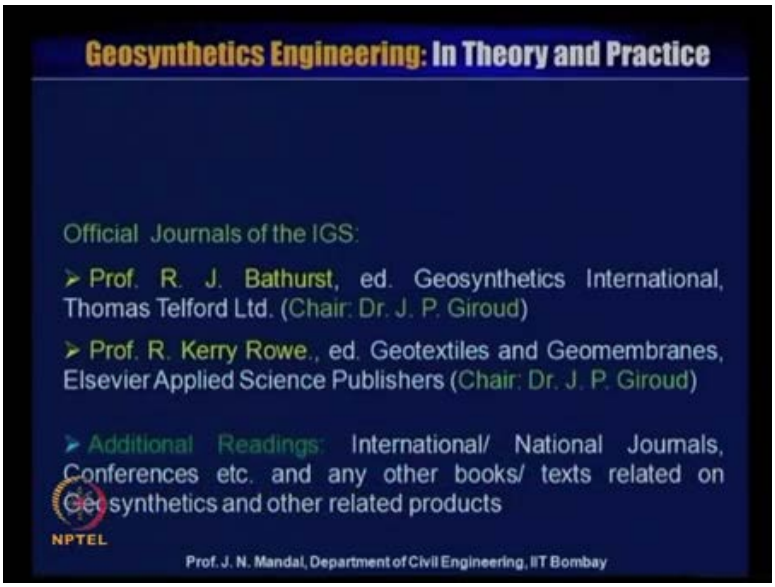

Now, apart from this book also, we have a couple of international journal that is, official journal of the international geosynthetic society. And Professor R. J. Bathurst is the editor of Geosynthetic International, Thomas Telford limited and chaired by Dr. J. P. Giroud and Professor R. Kerry Rowe editor, Geotextile and Geomembrane, Elsevier Applied Science Publisher and Chair Dr. J. P. Giroud. These are the two international journal on the geosynthetics, this is very very useful, I recommended to you to go through this international journal.

So, you will get all the current information about the wall on the geosynthetics material and other related product. It is also required some additional reading that, international, national journals, conferences, etcetera and any other book or texts related on geosynthetics and other related product.

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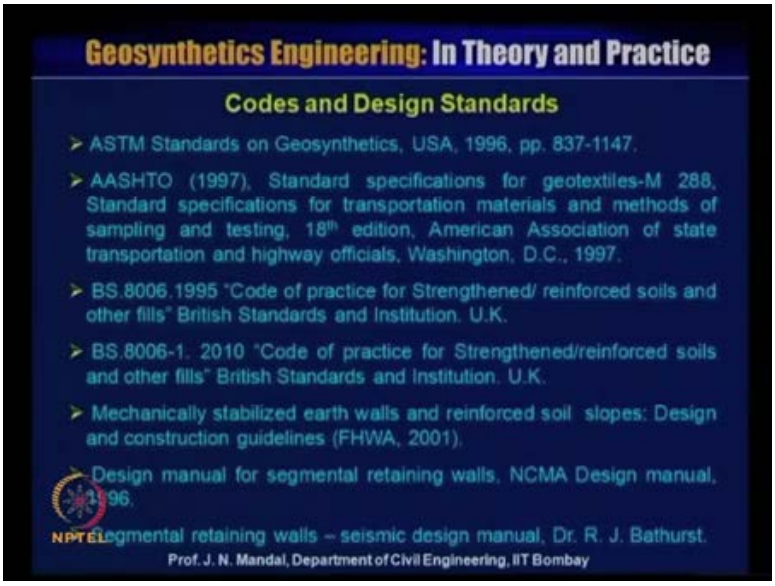

Apart from this book, in our course it is also require some codes and designed standard, because you have made some design and some example based on certain code and the design standard. Here, I am focusing some of the code and the design standard, it is ASTM standard on Geosynthetics, USA, 1996, page 837 to 1147. So, you can have all the testing procedure about the ASTM system, which generally we follow up for our design purpose.

Then, AASHTO, AASHTO 1997 that is, standard specification for geotextile-M 288, standard specification for transportation material and method of sampling and testing, 18 th edition, American Association of state transport and highway official, Washington DC, 1997. So, this specification also exclusively used for the design of mechanically stabilized reinforced soil wall and the slope. Similarly, BS 8006, 1995 Code of Practice for Strengthened reinforced soil and other fills, British Standard and Institution, UK, and BS 8006-1 2010, Code of Practice for Strengthened reinforced soil, and other fill, British Standard and Institution, UK.

So, these are the BS code 8006 is exclusively used for the design of the reinforced soil wall. And this code also exclusively used in various any type project in India and also you can have, how to design the geosynthetics reinforced soil slope, this is very useful code or design standard, mechanically stabilized earth wall and reinforced soil slope, design and construction guideline, FHWA 2001.

So, this also the code and design standard, also very useful for the design of geosynthetics reinforced soil wall and slope. Design manual for segmental retaining wall, NCMA design manual, 1996, this is another code or design standard for the segmental retaining wall. So, if you want to construct the segmental retaining wall, so you can adopt this NCMA design manual. So, these are the, mainly this code and the design standard for the FHWA or AASHTO or BS or the NCMA.

It is also require to design the seismic aspect, so segmental retaining wall seismic design manual is by Dr. R. J. Bathurst. So, you know that, most of the cases in various zone of India, that is under the seismic condition, so one has to also include the seismic aspect design, so this book also will be very helpful. Audience target group, this course will be very useful to undergraduate and the post graduate student of civil engineering. Now, with this all the books and the journal and the code and specification, we will now address that audience and the target group.

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This course will be very useful to undergraduate and post graduate student of civil engineering. Geosynthetics, geotechnical, textile, polymer, consulting, practicing engineers, government official, policy and the decision maker, implementation, NGOs, because this is a multi disciplinary area. So, it will be very useful for this textile and the polymer people, consultant people also should know about this new material, how to use it.

And at the same time, government official, this is not only use that some policy and the decision maker for the application of geosynthetics in various application, at the same time it is most important that, whether it has been implemented properly or not, that also one has to take care for this. So, this course also very useful that way for the policy and decision maker and implementation. And particularly, also for the NGO, because for the NGO, people they are very much sometimes very useful.

I have also come in contact with some NGO, for that I have to talk about the four item, one is the low cost housing, another is for the erosion control and the low cost road and also the landfills system. There is always some kind of the social and the political problem also, that way it will be very useful this course for the NGO people. Apart from this, Professor as well as specifier, project designer, distributor, contractor and the manufacturer, those will specify a kind of the product or kind of the system, so they should go through this course.

And how to design this project, also they should go to this course, and also contractor, how to use how to implement these geosynthetics material in the field, and at the same time, these geosynthetics material have been manufactured by different company. So, they should know that, what is the actual requirement for civil engineering for the application of geosynthetics material, so they should manufacture as per require from the civil engineering.

To understand this course, one should go for prerequisite, so they should undergo some basic course or the mere knowledge of the basic soil mechanics and foundation engineering or geotechnical engineering. Not only that it is all the time require, because this is multidisciplinary, so one can think about this people on the area of textile, polymer or any other chemical engineering, mechanical engineering, material science, environmental engineering, also can go through this course, which will be helpful for them.

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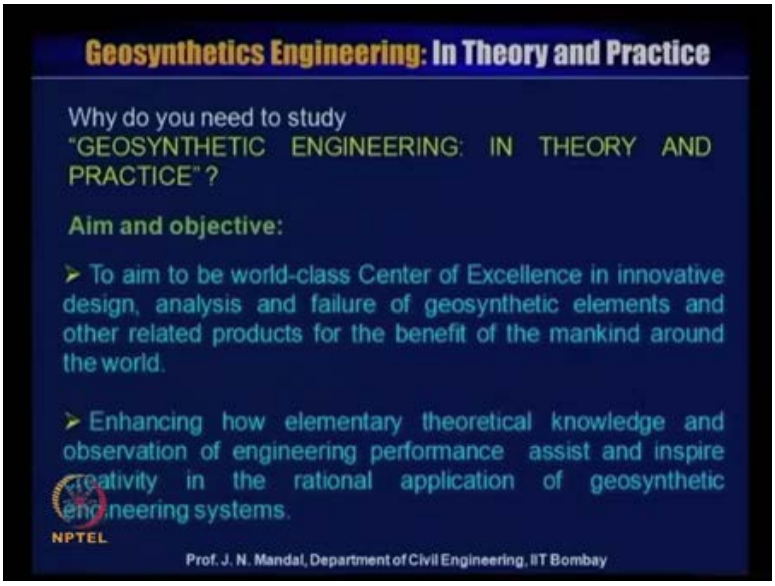

Now, why do you need to study geosynthetics engineering in theory and practice, what is aim and objective. To aim to be World Class Center of Excellency in innovative design, analysis and failure of geosynthetics element and other related product for the benefit of the mankind around the world. Enhancing, how elementary theoretical knowledge and observation of engineering performance assist and inspire creativity in the rational application of geosynthetics engineering systems.

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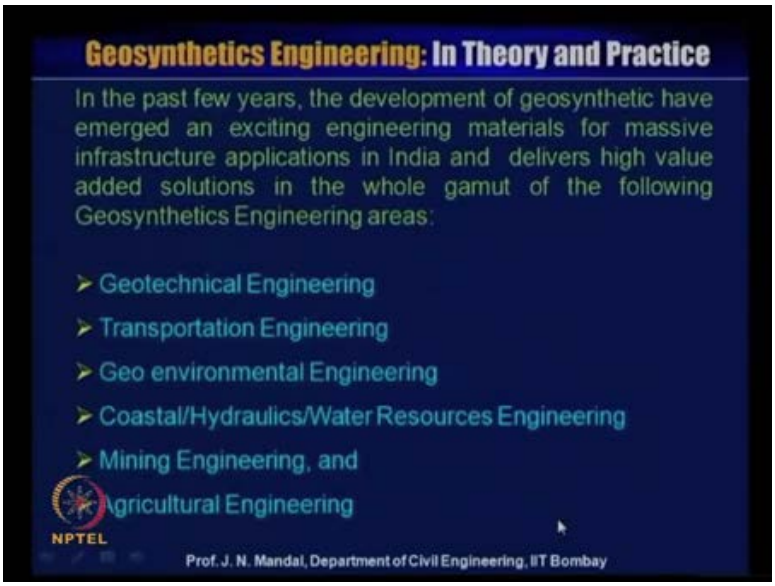

In the past few years, the development of geosynthetics have emerged an exciting engineering material for massive infrastructure application in India and deliver high value added solution in the whole gamut of the following geosynthetics engineering area. You can see that, how the geosynthetics material has been used in the different area, it can be used for the Geotechnical Engineering, Transportation Engineering, Geo environmental Engineering, Coastal Hydraulics and Water Resources Engineering, Mining Engineering and Agricultural Engineering. So, you can see that, how this product can be used for these different application.

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The next slide you see that some picture, the left hand side of the picture, it is a very soft soil and already stagnant. We need the three things in our life, a house for the shelter and food for survival and for cloth to wear. If this ground is very soft, water is very stagnant, the conventional geotechnical engineering system will be very expensive and time consuming. Alternative to the geotechnical engineering system, we can use this geosynthetics engineering system, which could be the economical and also you can have less time for the construction of the house on this soft soil.

So, we can construct a house on the soft soil easily by the introduction of these geosynthetics material. One side you can see the water is stagnant, so we can use geosynthetics material here as a filtration and the drainage, and also can be improve the soil by the introduction of the reinforcing material like geosynthetics. You can look at

the right hand side of this picture, this is absolutely dry soil, you can see farmer is looking for the rain water for the cultivation for the land for the crops.

But, you can excavate the soil and you can place the important material like the geomembrane or geosynthetics clay liner then, you can preserve the water and can make use for that water for the crops and also for the drinking water. You can also cover this reservoir with the geomembarane material from the sunlight, you know it is about 23 percents of the water is lost due to the evaporation. So, we can make use of the geosynthetics material for saving the farmer and at the same time, we can produce the crops.

So, we can have the food, where there is a problem, where there is a dry kind of the soil and it is very difficult to have to control that water in this locality. So, you can make use of this geomembrane or geosynthetic clay liner to protect the water and produce the crops. This slide shows that, all kind of the geotextile material or it is the fabrics, so we will introduce this kind of the fabrics material to this kind of the related problem, where water is stagnant, where the land is very dry.

So, I remember, when we produce one of the film in IDC sometimes in 1987 and the title of that film was geosynthetics age. And I remember one of the words is the mother earth and how you can make use of this geosynthetic material into this earth to serve the society of the world. I remember one of the project site, where this geosynthetic material has been used for the erosion control and the contractor is used this fabrics onto the slope. And on the top of the fabric, they just place some stone or armour stone to protect the slope and the remaining portion of the fabrics is as it is.

And the next day, suppose the contractor should come and to fill up with this aggregate material. But, when the contractor came in the next day, he found there is no fabric onto the slope and the local people have cut it and wear it, so how this geosynthetic material also can be used to wear for the people also and also for our mother earth.

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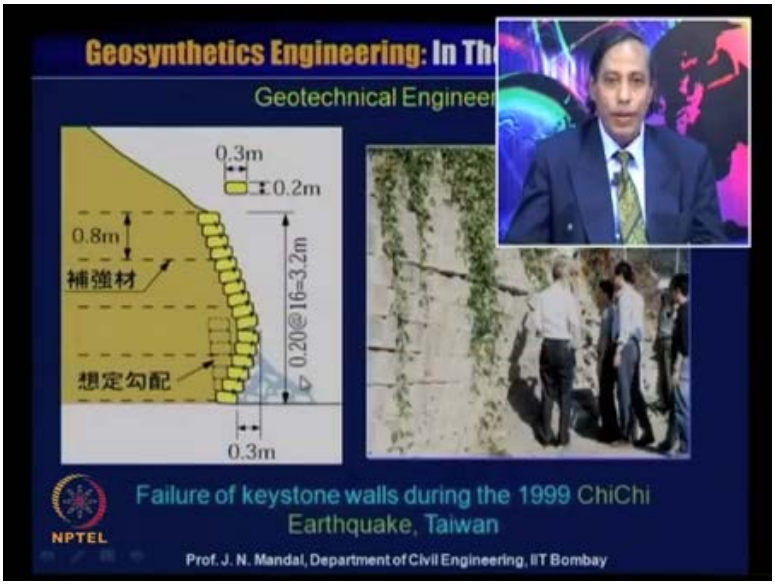

I will show you some of the case history and because this geosynthetic material has been used in the different area, I just talk about in the geotechnical engineering area. You can see here that, how the failure has occur. The failure of the keystone wall and this happened during 1999 in ChiChi earthquake in Taiwan. So, if you do not do proper kind of the design, so you can see that, how the facing element has bulged and fell. So, it is necessary that, to understand that what kind of the material, what kind of the facing element, what kind of their properties of the material should use it.

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This some of the slides you can see, the failure of the reinforced soil for this metallic reinforcement has been used here. This is near to the Kolkata and this is the facing element and the back of the facing element is metallic reinforcement, it is the same picture you can see that, how the structure collapsed. So, if you do not provide proper kind of the design, so you can see that, how the structure fell and this happen after one month of the construction.

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You can see here also some failure of the, this is the geogrid material, this is reinforced soil wall, you can see how this also material have fell. This is also another structure, this is near to Sahara Mumbai and where the gabion, this is the gabion has been used and you can see that, how this gabion fell and there is a permission of huge hip. So, it is required for all the material, whether it is a metallic reinforcement or the geogrid reinforcement or the gabion wall, you need proper kind of the design and the construction, and at the same time, proper kind of the quality control and the quality assurance.

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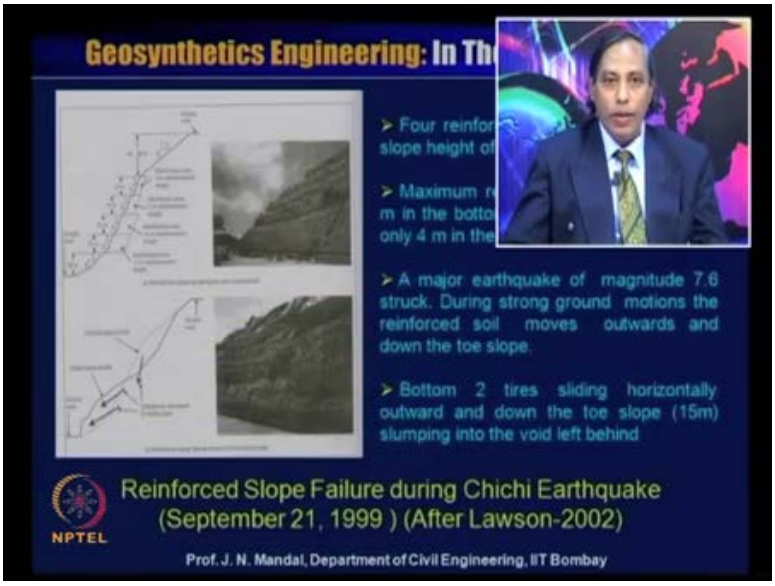

Now, this is also another interesting slide, which you can see here, the reinforced slope that failure during the ChiChi earthquake that is, in September 21, 1999 and this reported by Lawson in 2002. You can see here that, 4 reinforce star, 1 2 3 4 reinforced star and which is about 40 meter in height, each star is 10 meter, this is 40 meter height and all the slope height is maximum is about from 80 meter, which is from the bottom to the top, it is about 80 meter.

And maximum reinforcement zone that width is about 13 meter at the bottom tire and then, gradually it is decreasing to only that 4 meter at the top. A major earthquake of magnitude 7.6 struck during the strong ground motion, the reinforced soil moves outward and down to the toe slope. The bottom two tires sliding horizontally outward and down the toe slope about 15 meters slumping into the void left behind, see you can think about the kind of the failure. So, you require proper kind of the design in case of the reinforced soils of system, what should be their correct length of the reinforcing material and what should be the spacing and what should be the slope you should maintain.

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Now, apart from geotechnical engineering, we will talk about some transportation engineering, which most of the time we feel some kind of the problem. You can see, the truck is very difficult, it is very soft soil and the truck cannot move, so you require proper kind of use of the geosynthetics material and this is a unfit road. So, how you can tackle this kind of this problem or you can see, a kind of the formation of the huge rut and you can provide a kind of the geosynthetics material and can design for the unpaved road. We will also follow up into this course in transportation engineering, how you can prevent the Latin system, how you can improve the bearing capacity of the soil and how you can reduce the settlement of this kind of the problem.

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This is another area the pot hole and the reflection cracking, this is very common, you can see in Mumbai, there are many places on pot hole. This may be in the longitudinal like this kind of the train, you can have a lot of pot hole like this, also like this and apart from that, you can have also see some alligator cracking. So, when you can face this kind of the pot hole or the alligator cracking or the reflection cracking, so why do we do year after year, we go out for the as per yearly and cover it.

But, geosynthetics material can help you, how you can control these pot hole, so we will also cover in our course about, how to rectify this kind of the pot hole, what system you should adopt. That is more important that, you should initially study that, what kind of the cracking pattern and what kind of the geosynthetic material you should select and what is made of. So, these also will be very useful for the transportation engineering.

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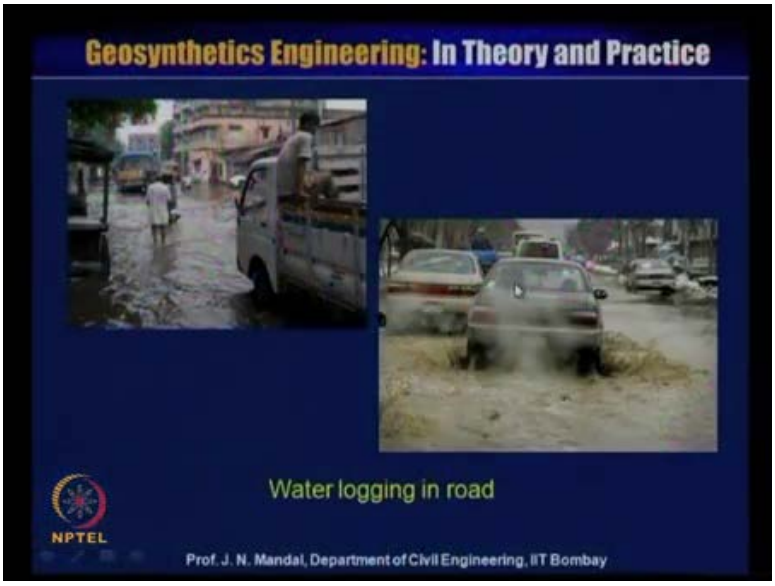

You can see that, water logging in the road during rainy season, this is also of drainage problem, this is all about the wall, you can find that, a kind of the drainage problem. Majority of the structure fell due to the drainage, because we do not provide proper kind of the drainage system, we do not maintain some kind of the system, in which that drainage system can be properly maintained. So, you can use proper kind of the geosynthetics material to drain the water from this locality.

So, it may be the road, it may be the railway, it may be the airport, so depending upon the quantity of the water passing through that area. So, you can design and you can select the proper kind of the geosynthetics material and make use of it and you can control it the water logging in the road or the pavement.

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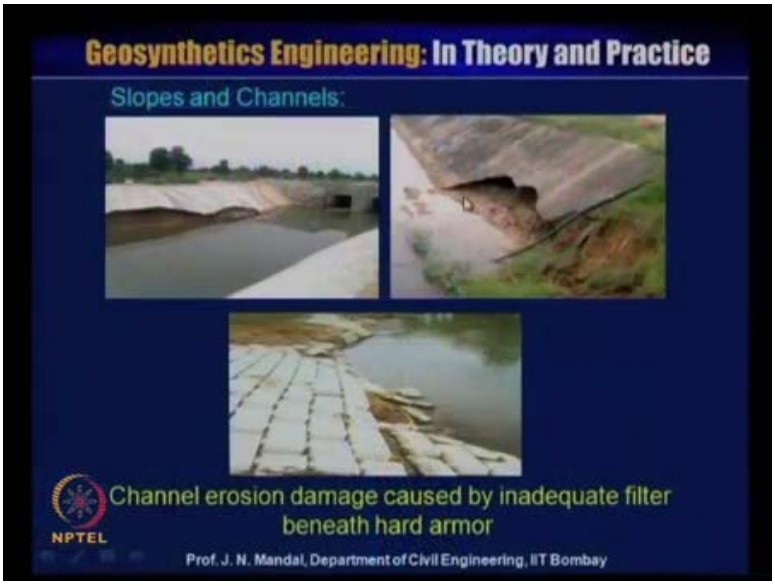

Sometimes we can see, there also in the slope and the channel, you can see that, what kind of the failure. Channel erosion damage, this is caused by the inadequate filter beneath the hard armour. You require proper kind of the geosynthetics material, which is to be placed below this stone, because there is a development of the excess hydrostatic pressure and it fell. You can see that, how the concrete crack, so all kind of the problem, you require proper kind of the geosynthetics system.

For example, you require for slope stability here, you require to protect the water, you can use the geomembrane, you can use the GCL. So, it depend upon that, what you are looking for, for the channel you wanted to control the seepage, you can use the geomembrane material. You wanted to control the drainage and filtration, you can use the proper kind of the geosynthetics material. Otherwise, you can see that, what kind of the failure have occurs in different types of the application in the channel.

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Some also for tunnel rehabilitation, this is you can see, how the excessive leakage and which cause the instability of the soil. The water is seepage throughout the dam, you require proper kind of the geomembrane material, which can be protected this from this preventing from the seepage here. You can see that, San Fiorano Italy that is, the tunnel and in this tunnel, also there is a kind of the problem for the seepage. So, you can provide with the proper a kind of the geosynthetics system, while you can use the geomembrane and the geotextile material.

For geotextile material, we will act as a filtration and the drainage, and the geomembrane will act as a barrier, so you can control it. So, this is after Koerner. R. M. GSI and GRI, so you can see that, what kind of the problem and what way we can control with the use of this material.

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Some of the disaster management flood, you can see that, what kind of the flood, you can see how the people are surviving, how the people are moving and you can see that, there is a reinforced soil house, but it is intact condition. So, you can control the flood, you can use proper kind of the geosynthetics system to control the flood for the disaster management.

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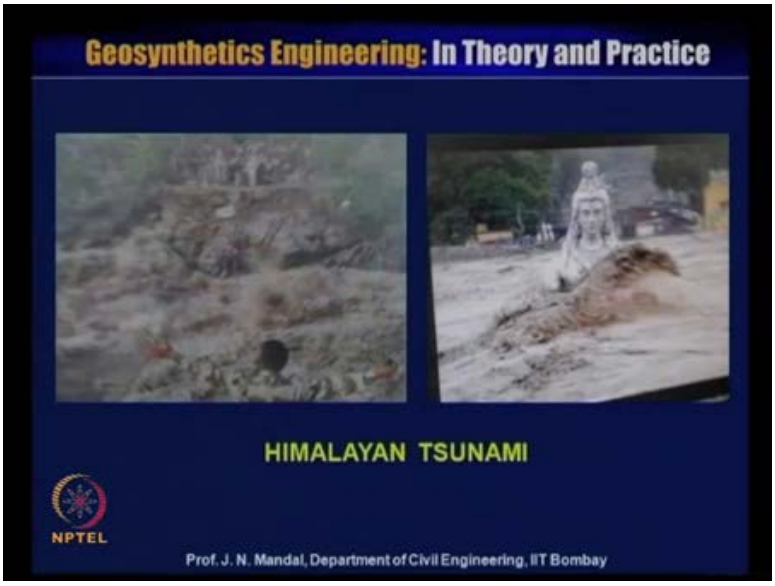

We know that, recently there is a Himalayan Tsunami, there is a huge land slide and also there is erosion control, because there is no proper design for the drainage and the

filtration and the slope stability analysis. Now, these geosynthetics material will be very useful to control this kind of the land slide systems, susceptibility problem and also for the filtration and drainage.

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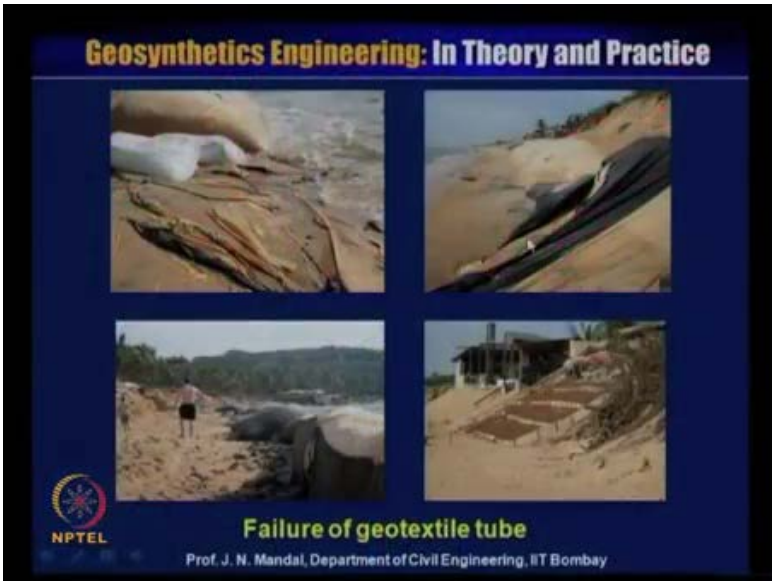

Some of the structure, which has been used in the Goa and you can see, to control the seashore for the erosion control, you can see how the geotextile tube has been fell, because it is not properly designed, it is not properly estimated that wave. So, you should control, you could think about the many many parameter and then, you should properly design for the geotextile tube. So, we will cover some part of also geotextile tube in our course.

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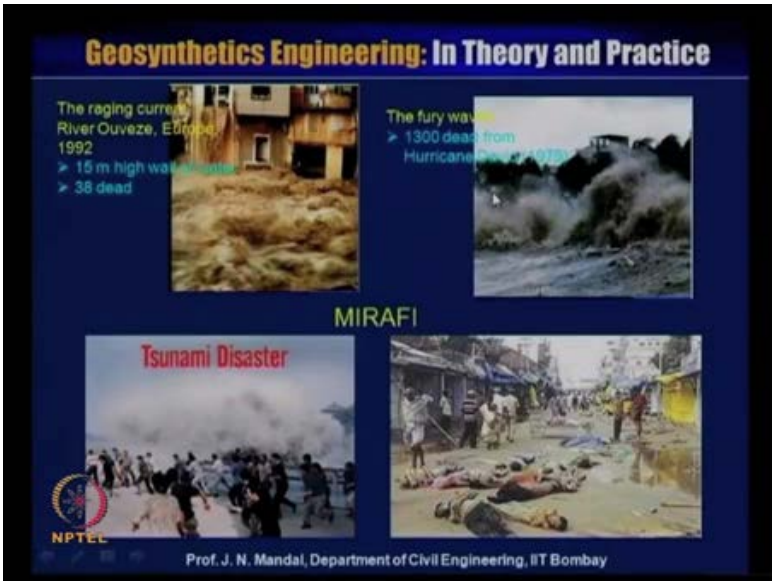

This is the raging current, you can see river Ouveze, Europe 1992 and this is about 15 meter high wall water and 38 people dead. You can see that, how the fury wave that is, 1300 dead from the Hurricane flood in 1979. You can see in the Bangkok, how the Tsunami disaster, people are running for saving their life, you can see this picture how the people died due to the Tsunami.

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So, you require proper kind of the geosynthetic material to control the Tsunami disaster, the next I will just address some of geoenvironmental engineering. You can see that, a

kind of the landfill, this is open sanitary landfill in Okhla, huge landfill, it is open, it contaminated the ground surface. So, you require proper kind of covering, proper kind of scientific landfill systems should be, otherwise you can see, what is the kind of the problem, it is absolutely open.

You can see some Mumbai in the Devanar landfill, here the water is stagnant and the ground is contamination. You require proper kind of the protection and proper kind of the landfill designing, I will show you some more slide.

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Also you can see in Mumbai, Mulund landfill and you can see a kind of the municipal waste material and there is no proper scientific installation, they are all kind of the waste material. In this slide, it has shown that, how the geomembrane fell into the slide slope, so if you do not do proper kind of the design, this kind of failure may occurs. So, today we cover that different types of the failure and also you will be knowing more about, how we can rectify this kind of the problem.

We talk about the different types of the books and their code and the specification and what are the kind of the international journal are available for the design and construction of the geosynthetics reinforced soil system, and how it has been exclusively used in the different area like transportation engineering, geotechnical engineering, hydraulics or water resources engineering or agricultural engineering or mining engineering. So, I conclude here that, there are lot of potential application of

geosynthetics material in various area. It is a multidisciplinary; it will be very useful for the most economical design and also to, how you can save the time and the money. With this, I finish today's lecture, please let us hear from you any question.

Thank you very much for listening.