Advanced Marine Structures
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Lecture - 1
Introduction and Scope

Welcome to the course on advance marine structures. I am Dr.Srinivasan Chandrasekaran from IIT madras; I will be the coordinator for this course. This course comprises of interesting topics as we discussed here, the course title has got advanced in its title, and we say that we will talk about marine structures.

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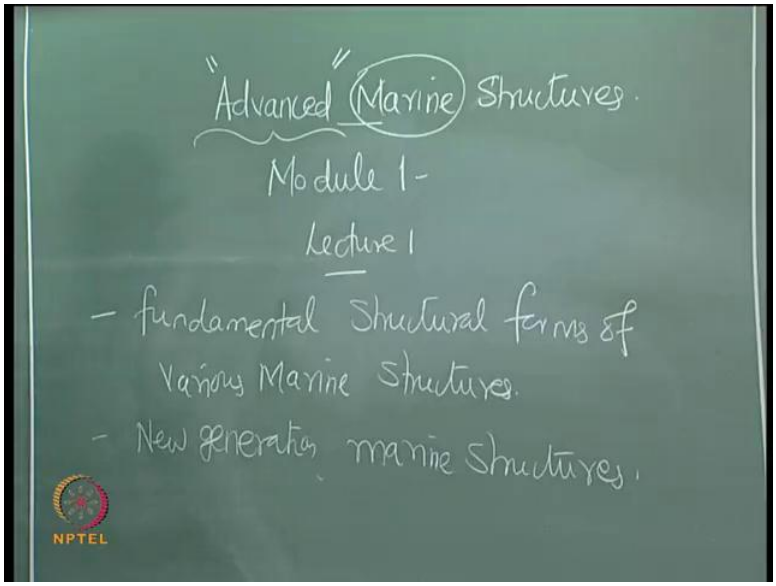

So obviously, we will discuss about some of the fundamental forms of various marine structures in this course. Now, you may ask me that how the word advance is associated with this particular course content. We will also talk about some new generation marine structures. So some part of the advancement comes from the new generation concept, which we will discuss in this course.

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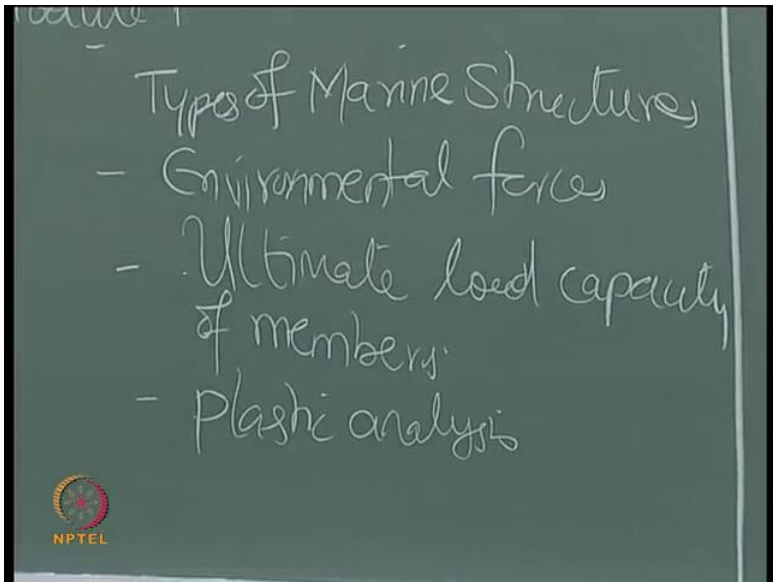

In addition to this, there are some classical and advanced studies, which are required to understand the response behavior of marine structures , for example in this course, we will talk about the reliability of marine structures. Reliability analysis is one of the advanced techniques of understanding performance of any existing structure. We will talk about fatigue and fracture damages caused to marine structures because of various sources; this again is another level of advancement which is not classically and conventionally discussed in other courses.

So as you see here this course, we will have four modules. I will discuss about these modules in the PPT few minutes from now. Module one, will focus on different types of marine structures, various environmental forces acting on marine structures; we will also talk about the ultimate load carrying capacity of members and about their plastic analysis.

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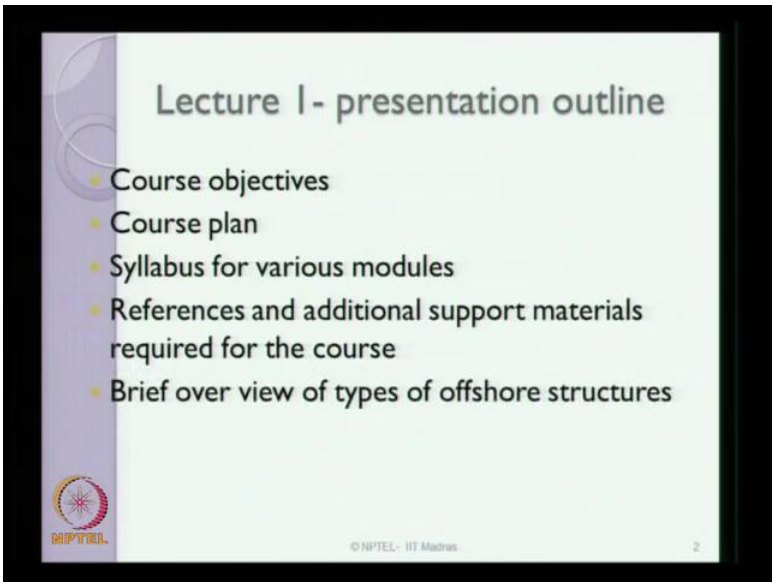

So, let us see the presentation outline for this lecture. So we will talk about the course objectives and about the course plan in this lecture. I will discuss the detail syllabus for various modules, as I just now hinted to you. We will also talk about many references and additional support materials, which are required to understand this course in detail. We will talk about brief overview on different types of offshore structures in this lecture.

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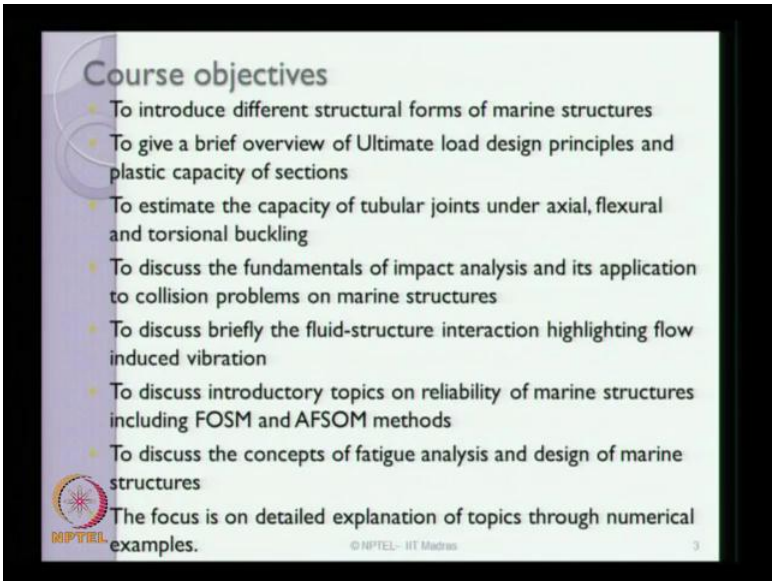

Now let us quickly understand, what are the course objectives of advanced marine structures course, under the braces of NPTEL IIT Madras? We would like to introduce

different structural forms of marine structures to the readers. We will also try to give a brief overview of ultimate load design principles and estimating plastic capacity of sections. We will talk about the methods to estimate the capacity of tubular joints under axial, flexural and torsional buckling, which are common load combinations of any members in marine structures.

We will also discuss the fundamentals of impact analysis and its application examples, the collision problems on marine structures , the fluid structure interaction, highlighting the flow induced vibration, which is one of the critical areas in marine structural analysis and design. We will discuss introductory topics on reliability of marine structures including first order second moment method and advanced first order second moment methods, applicable to marine structures. We will also discuss the concepts of fatigue analysis and design of marine structures, as one of the course objective.

Most importantly the focus will be on detailed explanation of topics through many numerical examples, which will help you to understand the topics under coverage in detail.

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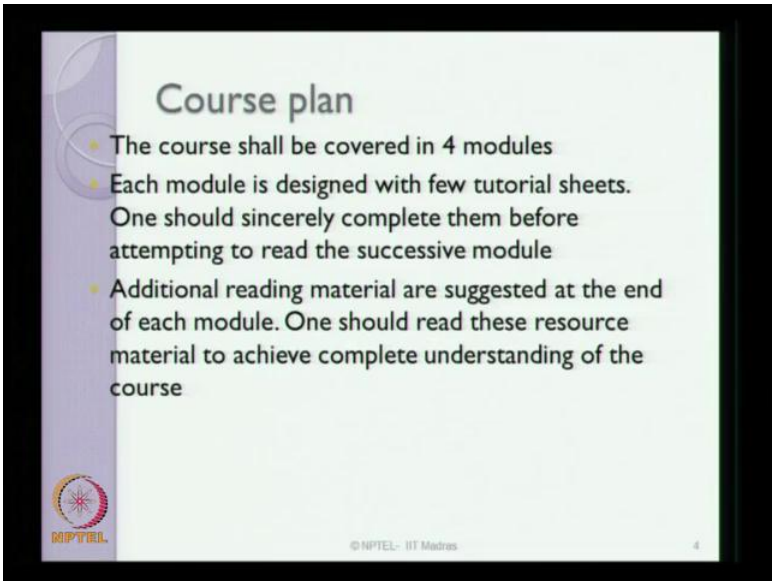

Let us quickly look at the course plan, how do we proceed with this course on advanced marine structures. The course as I told you shall be covered in four modules, each module will be designed with few tutorial sheets. I request that you should sincerely complete them before attempting to read the successive module for better understanding.

Additional reading material referred from research papers, will also be suggested at the end of each module. So, one can read these resource materials to achieve a better understanding of topics of the course covered in the lectures.

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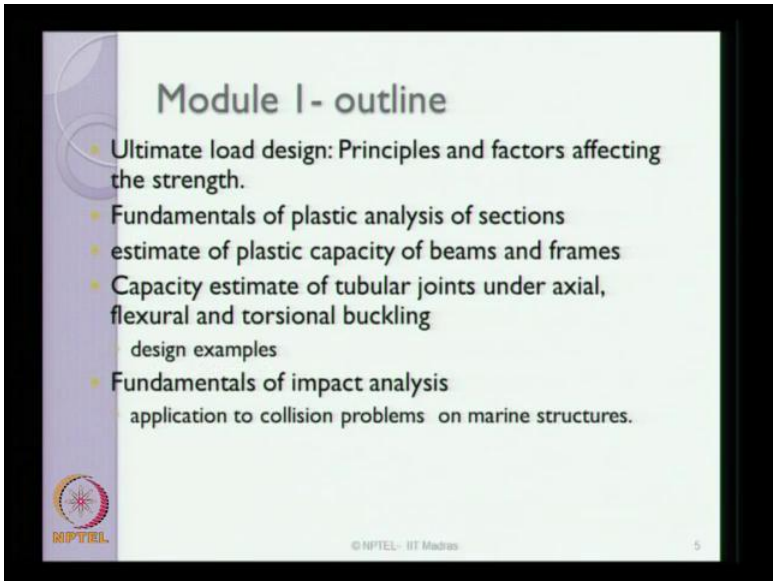

In module one, we will talk about ultimate load design techniques, the principles and factors affecting strength of members. We will talk about fundamentals of plastic analysis of sections, estimate of plastic capacity of beams and frames. We will talk about capacity estimates of tubular joints under axial, flexural and torsional buckling through some design examples. We will also talk about fundamentals of impact analysis looking at the application to collision problems on marine structures.

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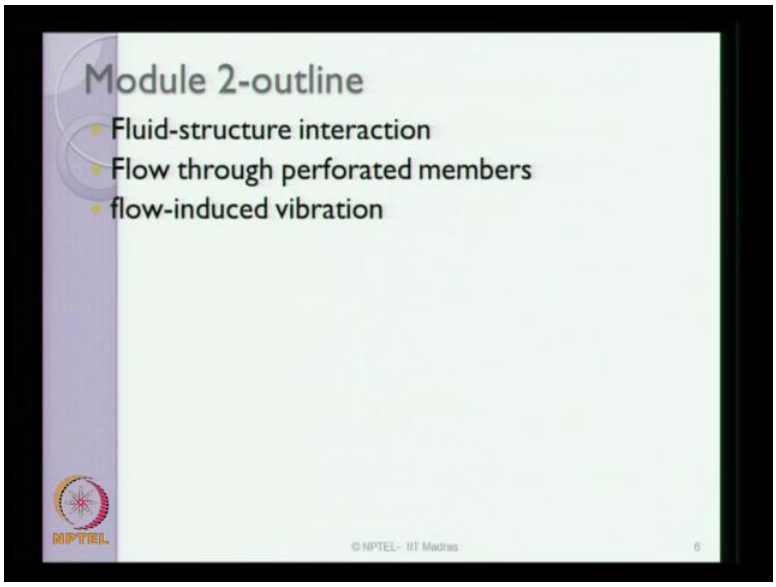

In module two, we will talk about the fluid - structure interaction, its flow through perforated members and will also introduce flow induced vibrations to the listeners.

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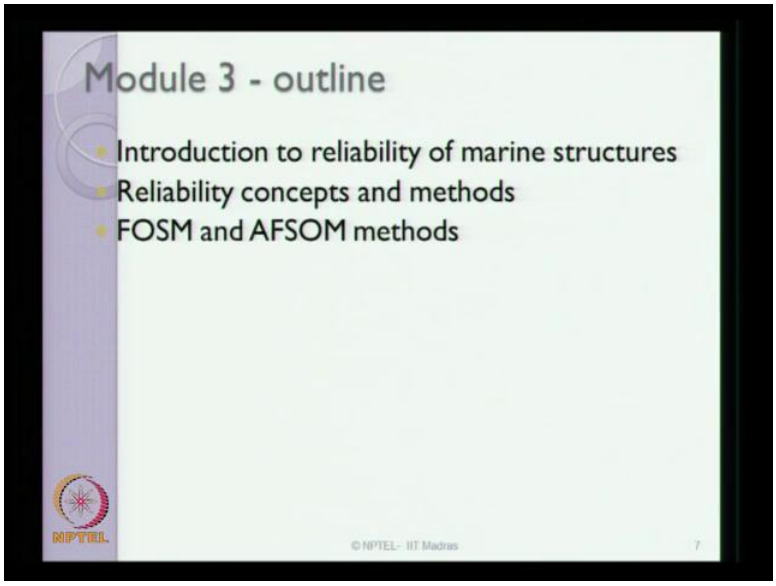

In module three, we will talk about introduction concepts to reliability analysis of marine structures. We will also talk about the concepts of reliability and various methods of reliability studies as applied to marine structures; and about the first order second moment methods and advanced first order second moment methods of reliability studies and examples applicable to marine structures.

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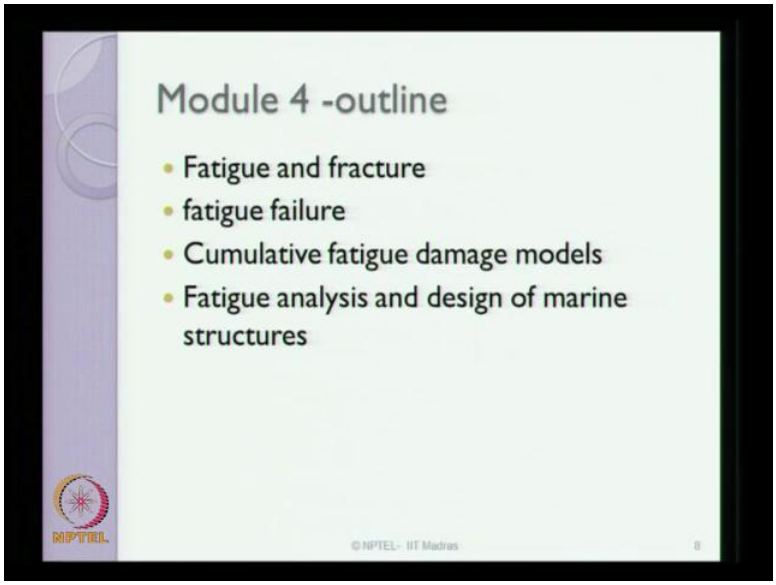

In module four, we will talk about fatigue and fracture; will talk about fatigue failure and causes and solutions of fatigue failure as applicable to members on marine structures. We will also discuss cumulative fatigue damage models, and fatigue analysis and design of marine structures as a part of the fourth module of this course.

Ladies and gentlemen, as I told you, the course will be distributed in four modules. Each module will have different topics of interest as we discussed.

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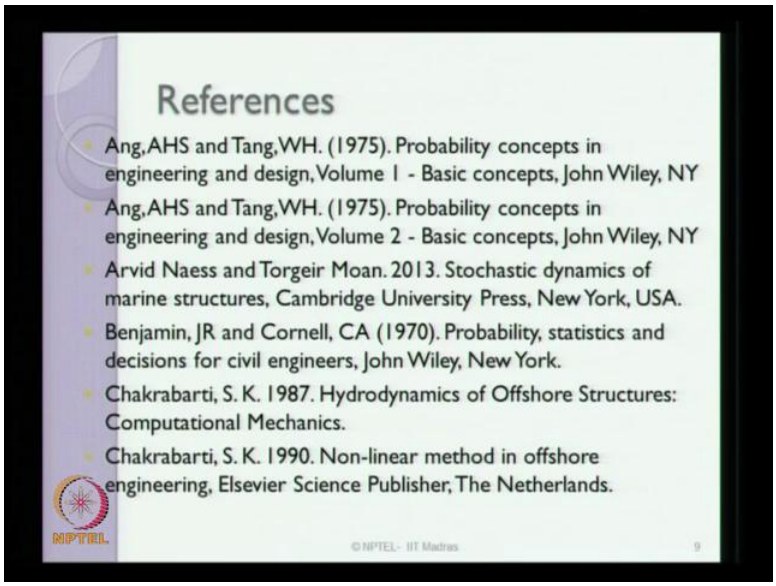

Now interestingly, there are many references sighted in the website of this NPTEL of this course for the benefit of the readers, let me quickly highlight these references. There are different books and research papers, text books available in the open source literature, which I request that the audience should try to refer the original copies of these, and try to read them parallel as they follow this course, probability concepts are very important.

Therefore, you try to study Ang's and Tang's book on probability concepts, Talk about Stochastic Dynamics of Marine Structures by Arvind Naess and Torgeir Moan. Benjamin and Cornell discuss probability statistics and decision for civil engineers, which is one of the very good books for engineering graduates to follow this course.

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There are good books on hydrodynamics of offshore structures as discussed by Chakrabarti including the non-linear methods. So I argue to follow these books as important references, in addition to the books which I am showing now. There are different books available for construction techniques of offshore structures, introduction to offshore structures, design fabrication and installation given by Graff.

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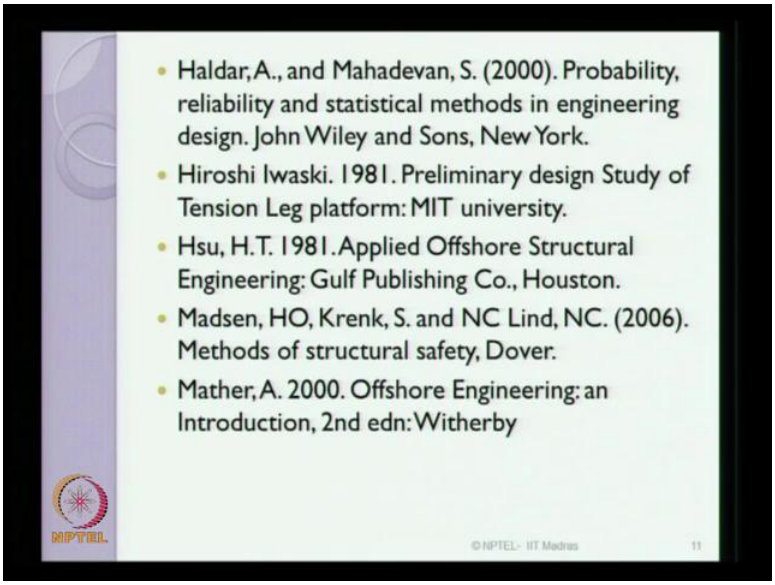

There are good books available which talks about the concepts of marine structures which you must understand. There are also good books available on preliminary design study on exclusive complain structures like TLPs. So try to acquire and access to these, so that you understand the topics better on various structural forms of marine structures as you go through these books.

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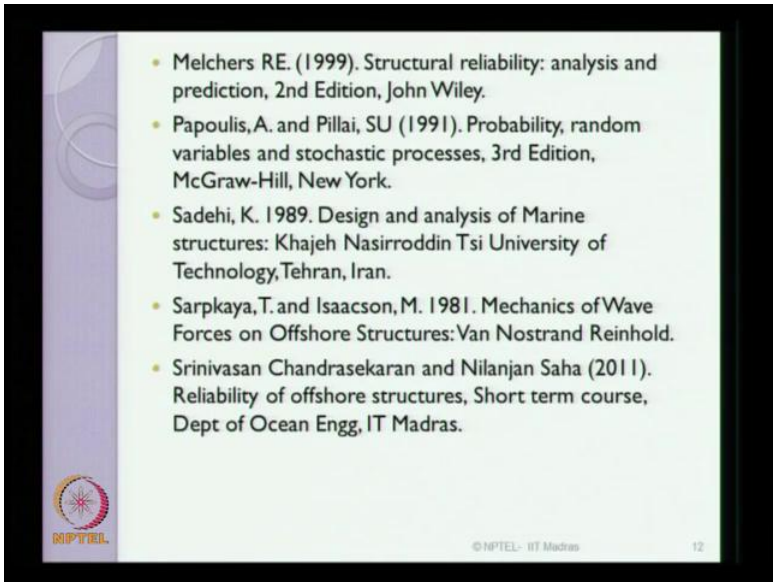

There are good books available on structural reliability, analysis and prediction by Melchers. So I want you to understand reliability concepts as applicable to marine structures following these books. Papoulis and Pillai is another book, where people talk about probability and random variables applicable to stochastic process, which is important. Analysis and design of marine structures is a very important book available by Sadehi, which one can follow, whereas Sarpkaya and Issacson talks about the mechanics of wave force on offshore structures, where the fluid structure interaction is explained in a very nice manner.

So there are books available from my side as I have co-authored with Nilanjan Saha- one of the short term course, what we organized in IIT Madras on reliability of offshore structures is a publication. You can write to me to acquire a copy of the short term course notes, available on reliability of offshore structures.

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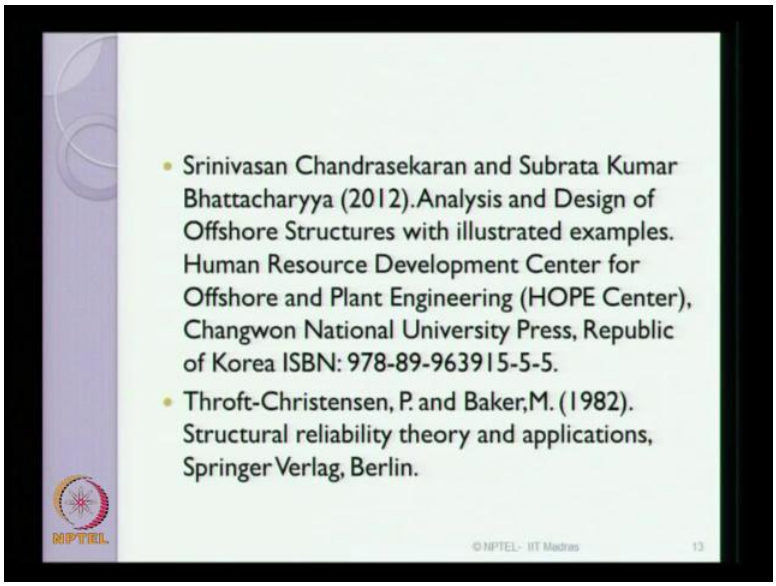

There are books available talking about analysis and design of offshore structures with many illustrated examples which is written by me and my colleague S.K. Bhattacharya of IIT Madras which is available in the literature. So I would request that you procure these books and try to read them parallelly as we proceed with the course.

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Now interestingly, the fundamental question comes, before we understand different advancements happened in marine structures, let us look at the history. Let us look at the origin from where these kinds of marine structures started . Ladies and gentlemen, this portion of the lecture will have a common repetition of many kinds of courses, which address offshore portion structures and materials. So this is mandatory because, I wish the readers to understand these fundamentals of one goal. Therefore, there is a small lap of repetition of this part of the lecture, which you must have heard or might have studied earlier on different kinds of offshore structures.

Nevertheless, this is important because this will give you a full understanding of different evolution strategy of offshore structures from the pre-historic period to the advanced levels. Let us talk about the history of offshore industry, as you can see the photograph taken on Huntington beach in California in 1900s where you can see there are lot of offshore derricks, which has been placed all along the coast where people have started exploring oil. It is interesting for you to understand that oil was available in 1900s at a very close to above twenty meters. So people started using these kinds of structures for exploring oil in the initial stage, it started off from 1900 in Huntington Beach in California.

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Further which, we can see the Summerland, California also showed off many derricks, which you can see here in a black and white photograph.

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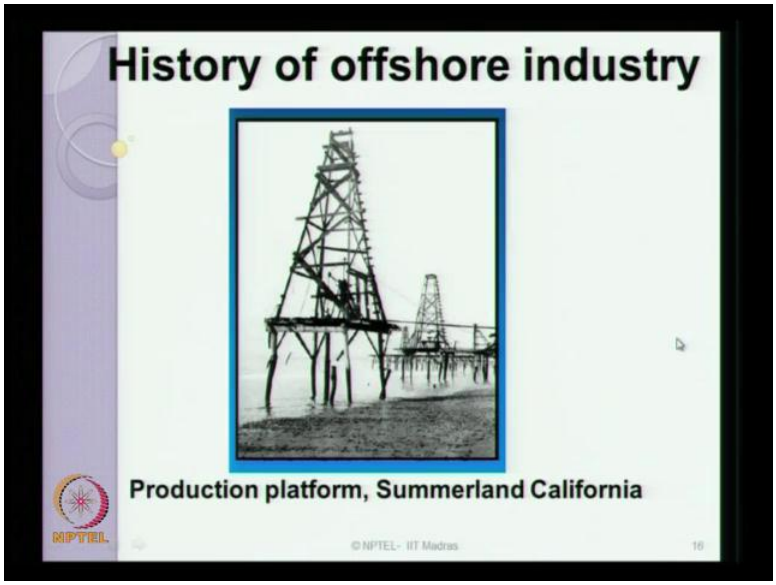

Successively, different elemental production platform are constructed essentially can see that truss type structure, which has been constructed in the early stages. The structures look very simple, resting on four or six columns, which are simply diagonally braced and they were the structures required in initial stage, when the water depth of exploration was very shallow. We can see there are series of structures, so offshore industry on the

marine structures were not constructed in earlier years. It has got a very old historical development which we must understand to realize how advancements took place in this industry.

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So you can also see the lake Maracaibo, Venezuela where complicated tall, strong and stiff structures are constructed for greater water depths gradually. So ladies and gentlemen, one can realize that the structural form started getting upgraded from a simple form to a complex geometry, as the water depth of exploration started increasing from shallow to medium to deep and today, we are at ultra deep of oil exploration.

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Similarly, in Caspian Sea Soviet Era up to 100 kilometer offshore, we can see there are lots of derricks constructed and an approach load has been made to transport the oil explored in these sides to an onshore area.

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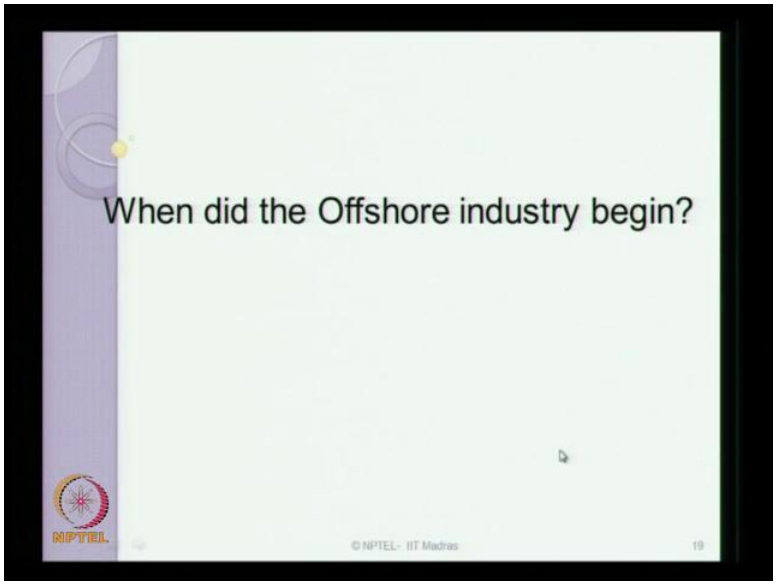

Now a fundamental question comes, when did actually this industry begin? What was the origin of this industry?

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Interestingly, in 1891, the first oil well was drilled at Grand lake St. Mary's, Ohio. Subsequently in 1896, the first submerged oil well in salt water, were drilled in summer field, summer land field extending under the Santa Barbara channel in California. The simple structure which has been used for exploring oil in the specific channel was shown to you in the previous slide.

In 1900, early submerged drilling activity started. This started occurring on the Lake Erie on the Canadian side. In 1910, Caddo Lake in Louisiana shows some exploration activity. In 1920, Lake Maracaibo in Venezuela started constructing concrete platforms for drilling or oil exploration. In 1923, one of the oldest subseas well recorded in the infields's off shore in Bibi Eibat well in Azerbajjan was reported in the literature. In 1930, Texas Company developed the first mobile steel barges for drilling.

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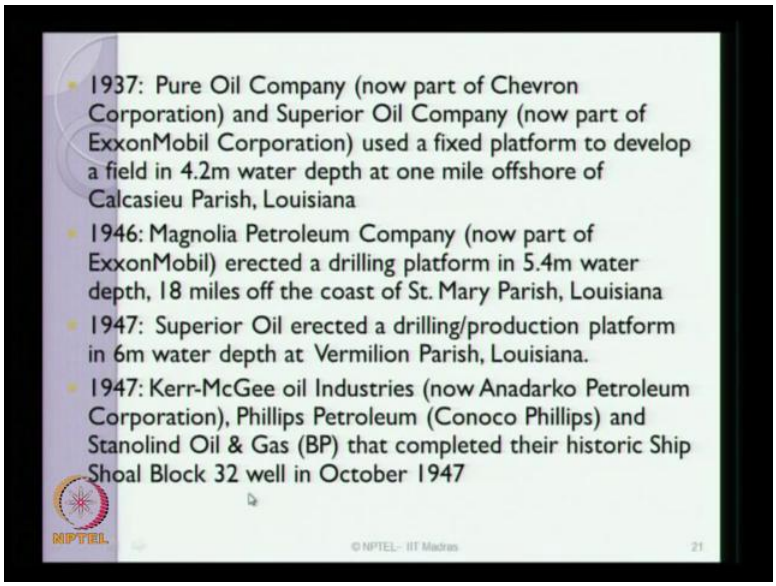

So subsequently, you can see that the historical developmentof marine structures started in 1895 and continued to grow in 1937, the Pure Oil Company, which is now the part of Chevron Corporation and Superior Oil Company, which is now the part of ExxonMobil Corporation used first a fixed platform to develop a field in about 4.2 meter water depth at one mile offshore near Louisiana. In 1946, the Magnolia Petroleum Company, which is now the part of ExxonMobil, erected a drilling platform at a depth of 5.4 meter, 18 miles off the coast in Louisiana again.

In 1947, the Superior Oil Company, which is now the part of ExxonMobil, erected a drilling production platform at a depth as shallow as 6 meter in the same area for oil exploration. In 1947, the Kerr-McGee Oil Industries, which is now the part of Anadarko Petroleum Corporation and Philips Petroleum, which is now the part of Conoco Philips and Stanolind Oil and Gas company, which now the part of BP at completed historic ship shore block 32 well in October 1947. So it is about 150 to 180 years down the line, when the marine structures were started constructed, because of specific purpose for which they have been built.

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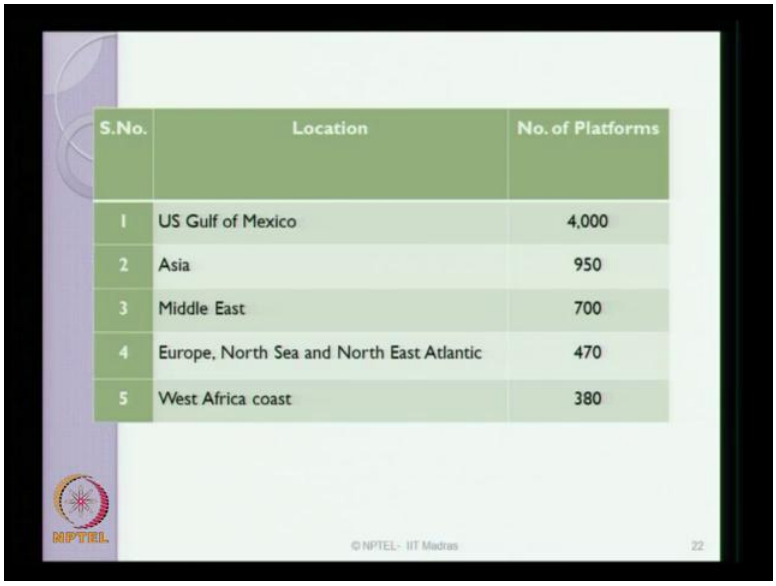

So if you look at the brief summary of different kinds of platforms, as on December 2012, we have in U.S. in Gulf of Mexico, approximately about 4000 platforms wherein Asia, we have got about 950 platforms. In middle east in Europe north east and north east Atlantic and west African coast, we have got 700, 470 and 380 odd numbers, which has summarized as total number of platforms so for constructed around the world. All these are different types of marine structures constructed by various sources; various sites specific regions for only one purpose, where people wanted to explore oil. Because of this, they constructed different kinds of marine structures.

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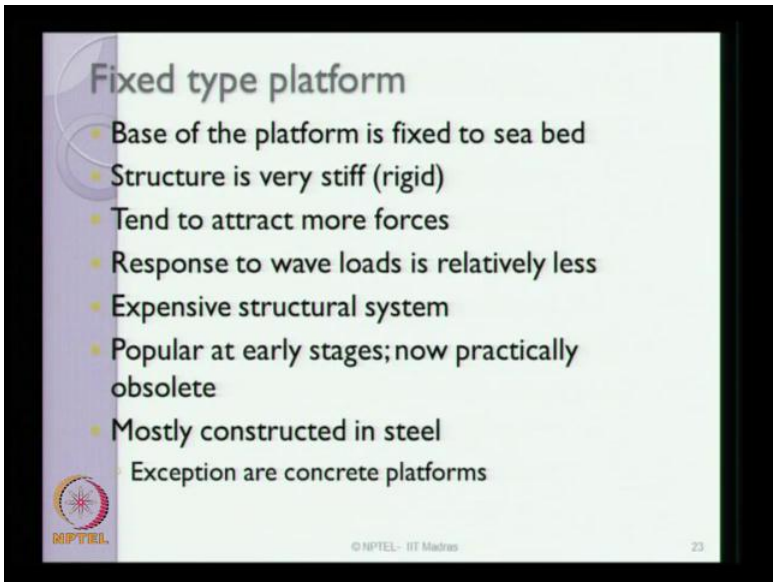

Amongst these, the original evolution started from fixed type of offshore platforms or the marine type structures. Fixed type platforms actually has the base of the platform, which is fixed to the sea, it is because of this reason, the term associated fixed to that of the platform is seen in the literature. The structure is generally very stiff, constructed by rigid type structure; therefore it has a tendency to attract more forces. The response to the lateral loads acting on structure is relatively less because of structure is very stiff. It is an expensive structural system; people realized that the cost involvement in this kind of structures proportionate to the water depth is very high.

On the other hand, people never thought of carrying these kind of forms structural form to deeper waters, because as these structures are moved from shallow to deeper waters, the cost of the structural system seem to be very expensive. They were popular at early stages of oil exploration but now, these kinds of structures are practically obsolete, because we are talking about oil exploration in deeper-in ultra deep waters, where fixed type platforms will become highly un-economical. So these kinds of structures are mostly constructed in steel of course, they have got expectance where people constructed them in concrete as well.

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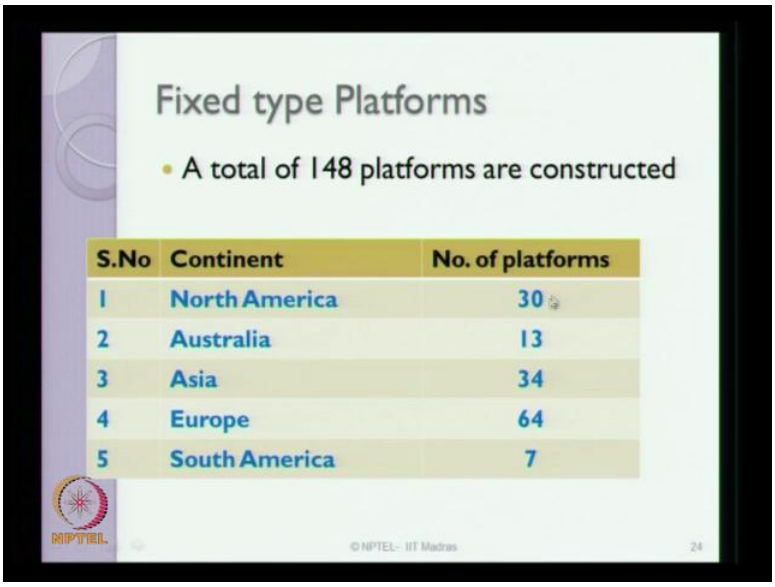

About 148 platforms are fixed type were constructed around the world, can see North America has 30, whereas Asia and Europe put together had lot of investment on the fixed type structures. Intelligently, you could see that in North America, people started moving from fixed type to other type of semi-compliant type in earlier stages. Therefore, the initial investment in these kind of platform constructed in North America, where much lower than they have invested in Asian and European sectors.

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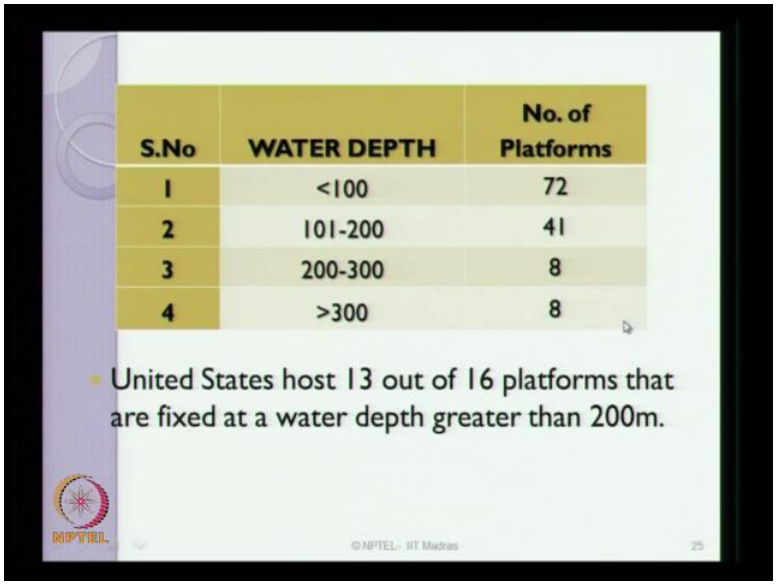

Looking at the water depth as the fixed type platforms proportion, you will see that United States hosts about 13 out of 16 platforms, which are fixed at a water depth greater than 200 meters because, you can see lesser than 100 meters, there were 72 platforms whereas, as the water depth keeps on increasing the number of fixed type platforms is on the declining side, because as you keep on increasing the water depth, the cost of construction installation and exploration of using fixed type platform at greater water depth becomes very expensive.

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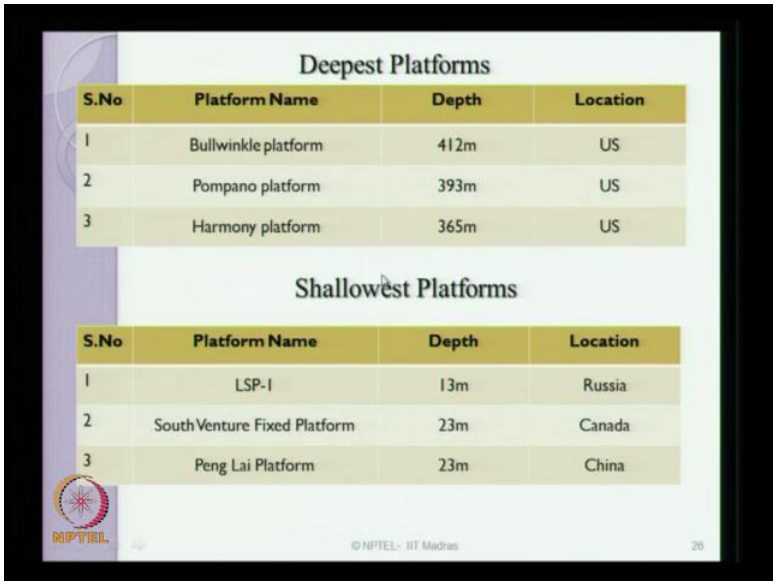

For statistical information, let us try to understand what are the deepest and shallowest platforms constructed. The deepest platform is constructed at a depth of 412 meter, which is a Bullwinkle platform in Gulf of Mexico at United States whereas; the shallowest platform is constructed at just 13 meter depth which is called LSP-1 in Russia.

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Let us quickly see the statistical information as applicable to Bullwinkle platform. This is the photograph of the Bullwinkle platform, which is a fixed type offshore structure constructed for oil exploration located in Manatee Field in Gulf of Mexico about 260 kilometers south west of New Orleans. The cost of this particular project is about five ten power eight US dollars, where we convert this into Indian rupees; this comes to around approximately 2500 crores as on today. This was constructed to be Heerema marine contractors then in that year at a depth of 412 meters, the total height of the platform is about 529 meters and constructed at 1988. It took about three years for constructing this platform during that period.

The total weight of the topside structure is about 77000 tons made out of steel. It has a capacity of 59000 BOPD. So one can be interested to know what you understand by BOPD. BOPD is defined as number of barrels per day; one barrel is approximately equal to 158.98 liters. In that case, one BPD will be about 50 tons per year considering the production rate, and in the present price, we can imagine the revenue what one can earn from one platform is about six million US dollars per day.

So, that is the strategical and very interesting for which one has to understand as an engineer, the revenue given by this kind of marine structures are phenomenally high. Therefore, these structures should be designed to an utmost care with a good level of

surveillance as well as good level of reliability and confidence applied design and analysis stage.

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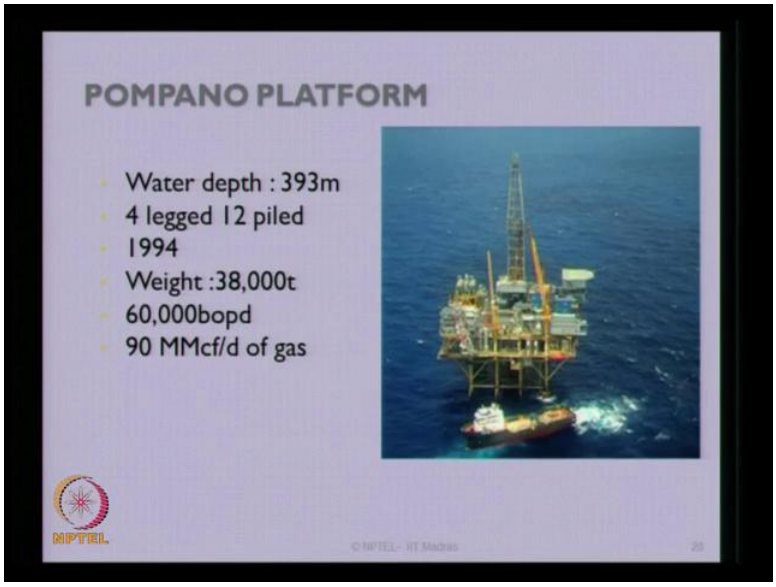

Let us talk about another kind of platform strategical information constructed in Pompano. This is the photograph of the Pompano platform constructed at a depth of 393 meters. It is a four legged platform with 12 piled free on each group constructed in the year 1994, weighs about 38000 tons. The production capacity of this platform is closed to around 60000 BOPD, which has got about 90 MMcf/d of oil, in case of the production rate.

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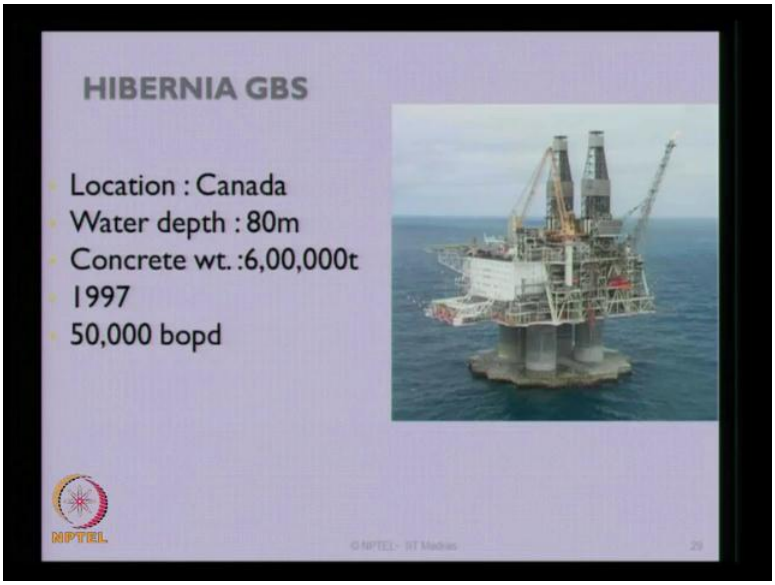

Another important and interesting platform which refers in the literature is Hibernia gravity base structure, which is called Hibernia GBS. The photograph is shown on the right of the slide here. It is located in Canada at a water depth of about 80 meters. Now the difficulty with this kind of platform is that the concrete weight of this platform is around six ten power five metric ton. So, its phenomenally massive structure which rest on gravity that is its called gravity base structure constructed in the year 1997 with a production capacity of about 50000 BOPD.

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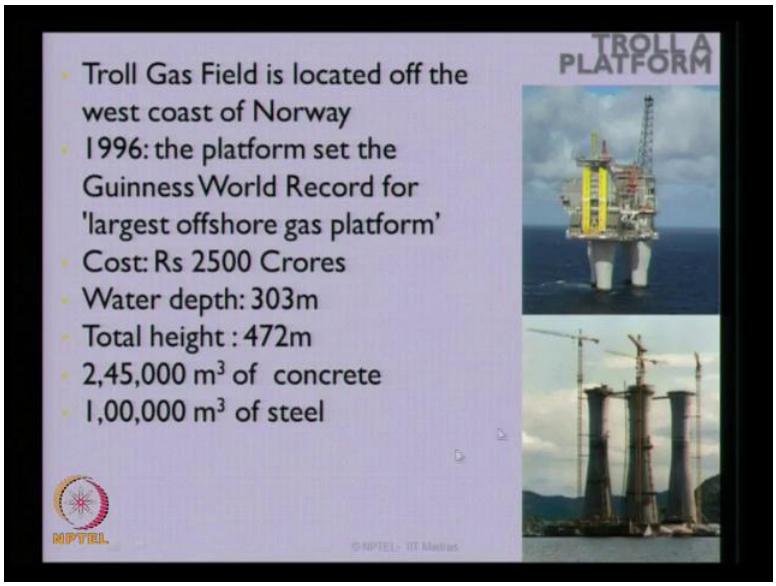

The other interesting platform, which is constructed in series, is a troll. A platform as you see here, troll gas field is located off coast of Norway in 1996, the platform actually constructed set the Guinness of world record for the largest offshore gas platform then being constructed in the year of 1996. It casted about 2500 crores then at that time in Indian rupee; the water depth at which this platform is installed is about 303 meters, the total height of the platform as you see here is about 472 meters, and it has got about 2,45,000 metric cube of concrete as a volume of concrete put in this platform.

Equivalently, one ten power of five cubic metric of steel has been used to construct this kind of platform can see a very clear view of another picture of this platform as you see here in this slide.

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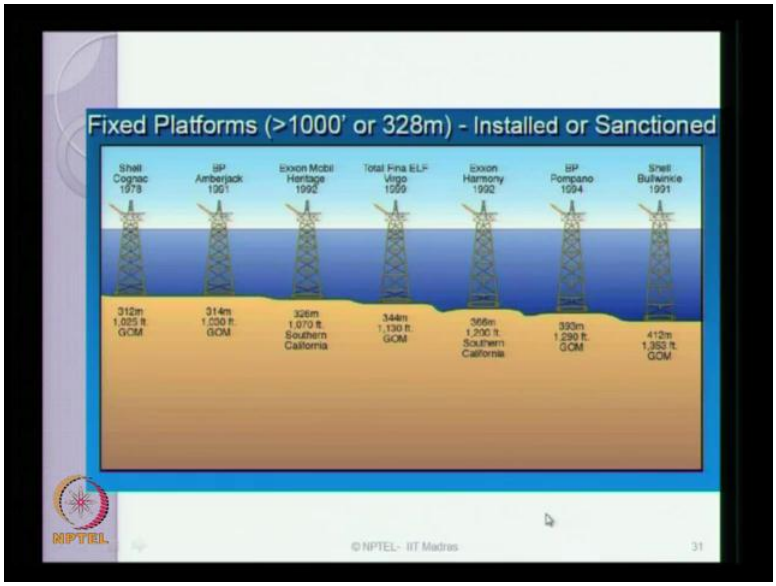

Now, let us look at the summary of fixed type offshore platforms which are generally recommended and installed at a depth more than about 100 meters and closed to around 350 meters. The starting from the evolution of shallow water depth in terms of 1025 feet at 1978 moved towards 1992, at an greater depth in Exxon, where we have got about 1200 feet. It means, in the evolution stage of marine structures of these order, when you have got fixed type platforms. These kinds of platforms were never constructed or attempted to be constructed beyond a depth of let us say around 400 meters. Because, as the water depth keeps on increasing, their construction topography or the structural form

which has been used or preferred for these kind of platforms, as you see here are generally becoming very expensive.

So, people never attempted to construct these kinds of platforms at a greater water depths say beyond 400 meters, because you have understood that these kinds of platforms becomes expensive as the oil exploration depth keeps on increasing beyond practically about 350 meters.

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This lecture has got interesting references. I want you to read these references in addition to what they quoted in the website of NPTEL. There are interesting topics covered in this lecture, which has been acknowledged with these authors from the specific books. So, I want you to look at these materials for additional understanding on this specific lecture on introduction to offshore structures, where we talked about introducing different kinds of marine structures with one variety what we call fixed type of the platforms.

So ladies and gentlemen, in the first lecture we discussed about the modules one, two three and four. The course outlines the lecture topics what will be covering in these lectures and we discussed about brief introduction on one of the type of marine structure which is used for oil exploration, which is fixed type platform. So, what I wanted to emphasize is, the historical development of marine structures started very old from 1900s

and people have started still moving on innovative structural forms, which will discuss down the line in this lecture.

We will talk about different advancements happening or happened in this trade of construction of marine structures in the recent times and of course, different analysis and decision methodologies as applied to these kinds of structures in detail through this course.

Thank you very much.