Soil Mechanics
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Lecture – 28
Stress Distribution in soils

Students, you have already undergone a series of lectures on the topic of soil mechanics. I presume that you already have a good idea of what are soils, how they are formed, what they consist of, what are there general properties for example known as index properties. And how they are useful in practice as materials of construction. Today we shall see a different topic; you can see the name of the topic here which is stress distribution in soils. This topic of stress distribution in soils is a very important topic, as an engineer you can easily understand that every engineer has to ultimately deal with forces, mechanics, stresses, strains and deformation. This is true of soils as well, not only of man made materials like concrete or steel. Therefore stress distribution in soils is a topic which needs to be understood very well in order to design a safe structure. We shall study this topic through a series of questions and answers. Let us take a look at some of these questions.

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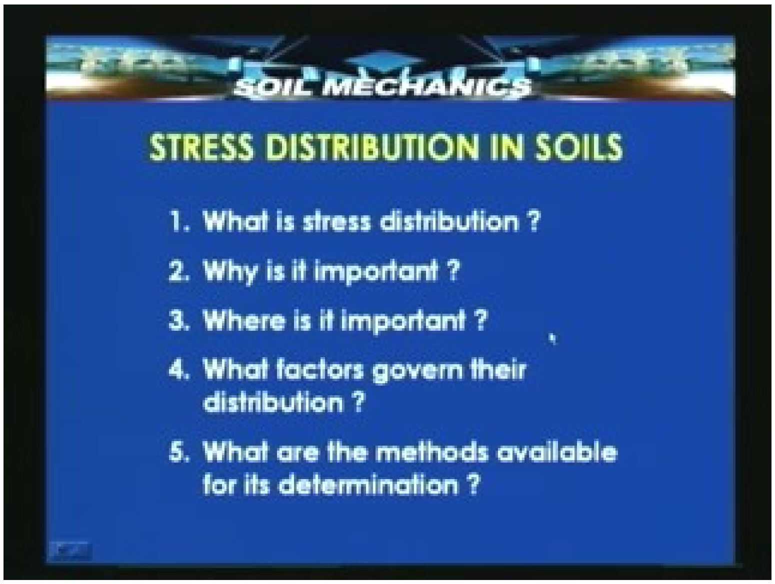

In the slide here, I have listed five questions. There could always be more. These five questions are what is stress distribution? Why is it important? Where is it important? What are the factors which govern the distribution of stresses? In soils what are the methods which are available for determination of the stress distribution? We shall take these questions up one by one and try to analysis the questions, understand them and then look for answers. So the first question is what is stress distribution. For this let us imagine a structure. A structure could be a chimney, could be a multistoried building, could be a tower, and could be any civil engineering structure like a dam for example.

All these have foundations. All these have weights of their own, these weights serve as loads and these loads act on the foundations. When these loads act on the foundations, the foundations in turn transmit these loads to the soil below because these foundations are resting on soils. When the loads from the foundations are transmitted to the soil below, the soil experience stresses. These stresses have to be well within the capacity of the soil to withstand the stresses without causing distress to the foundation. And therefore it is very important to know how these stresses are distributed in the soils due to the loads which are transmitted by the foundations from the structures.

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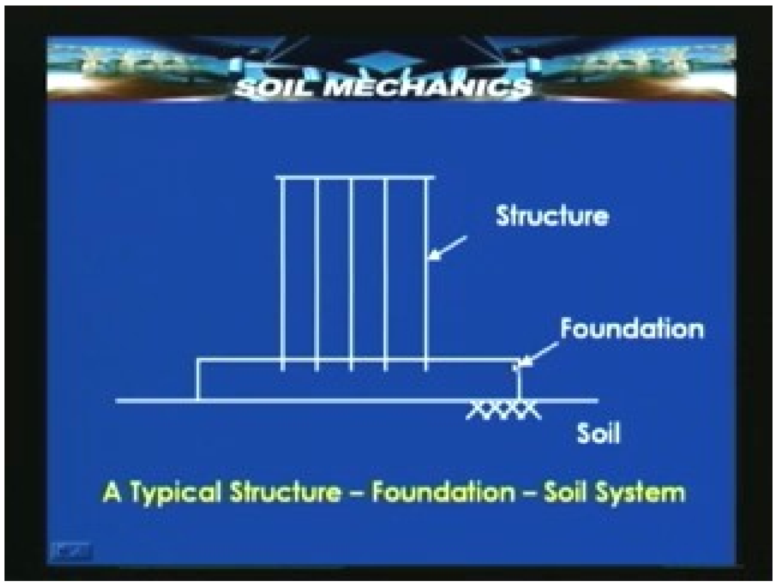

So we can understand the important of these like this. Suppose there is a typical structure, I have drawn a multistoried structure a frame structure for example. This is resting on a foundation; I have depicted the foundation by a combined foundation but it could also be individual foundations under each one of these columns. In any case this structure has certain weight, this weight is transmitted to this foundation and this foundation finally transmits the loads to the soil and the soil experiences stresses. It is a typical structure foundation soil system that we are really interested in. Given a structure, given a soil, as a soil mechanics engineer we would like to design the foundation such that it is same. In order to do that we need to know how this stresses are distributed inside the soil.

So if you want to look for a formal definition of what is stress distribution, then we can say when a structure is erected on a soil it transmits its weight as a load to the foundation. The foundation in turn imposes the loads on to the soil; these loads induce stresses inside the soil. The distribution of these stresses is what referred to as stress distribution. What we shall be doing during the course of this lecture is to see what are the different types of foundations, what are the different types of loads that might come that can generalize them, can divide them into different categories. And then see what could be the possible stress distributions inside the soil. So coming back to the slides once again, we go to the next question.

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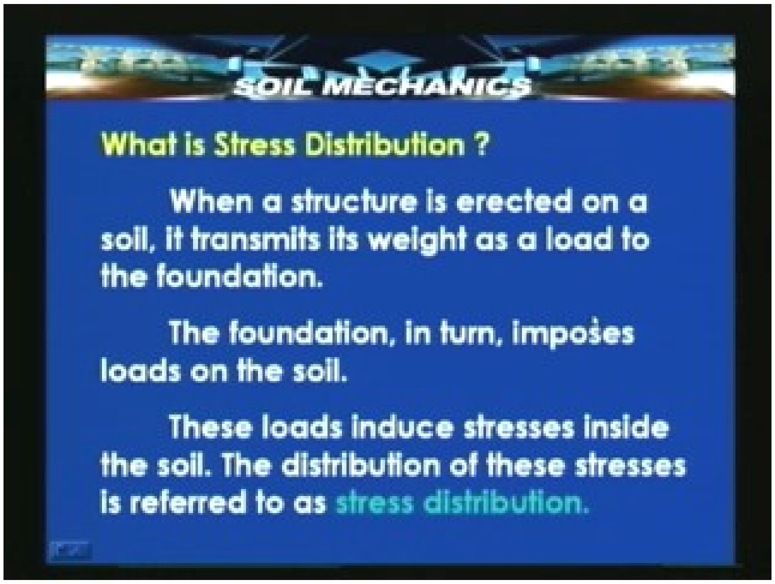

Why is stress distribution important? As I just mentioned stress distribution is important because the structure has to be safe. The structure is safe only when the load transmitted by it to the foundation is withstood by the foundation. The foundation can withstand only if the soil does not give way. Therefore stress distribution in soil is important, if you see this slide to understand the stability of the foundation and the safety of the structure. As these depend upon the stress distribution. The next question is where is this important? Is it important in all kinds of situations? In what kind of situations is this important? For this if you look at this slide it is important for all structures. But in today's context, it is especially important because we are constructing larger and large structures. Consider for example a small single storied residential structure.

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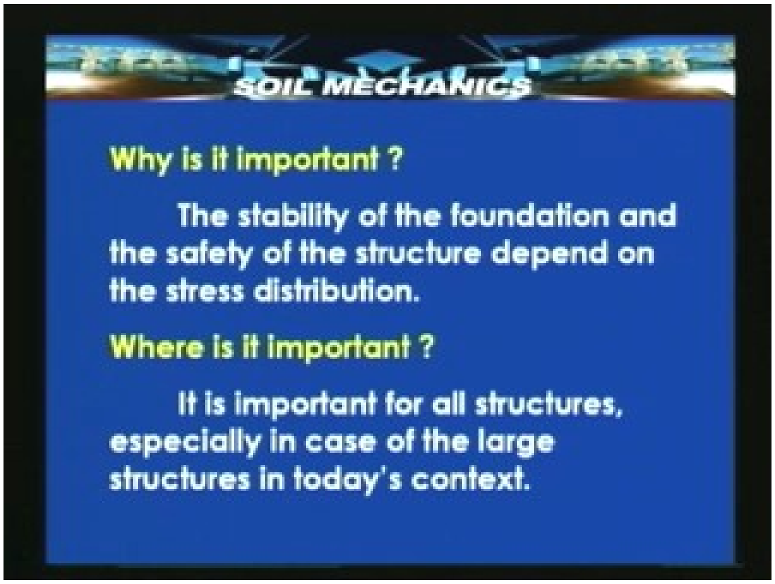

This single storied residential structure is unlikely to impose heavy loads on the soil. You will even find that some of the elementary simple single storied structures like lightweight houses or founded directly on soil, there is no foundation even. Whereas slightly larger structures so called engineer built structures require foundations and if we go one step higher we could have several storied tall structures. We could have different type of structures like chimney, we could have structures like dams, and we could have any number of structures of different types. But all of them will have some foundation and stress distribution is important in all those, where the weight is likely to cross stresses which are likely to exceed the capacity of the soil.

Therefore it is important we can say in all situations where the stress imposed is likely to be more than the stresses that the soil can safely withstand. And therefore it is very important in today's context, particularly in the case of large structures as more and more large structures are being built. Large structures are being built because there is a shortage of space available, there is pressure on space and therefore there is consequent raise in cost of building of the structure. All these contribute to higher and higher structures being built in very congested areas. And this therefore accentuates or in fact increases the importance that we need to attach to this topic of stress distribution.

Now let us see the next slide. The next question I have listed here is what are the factors which affect the stress distribution. Let us analysis this question before we read further. This question tries to identify the factors which are responsible for stress distribution because if we can understand these factors which are responsible for stress distribution, we can arrive at a suitable method not only to calculate these stresses but also to limit these stresses within the capacity of the soil. As I have pointed out just now that is the ultimate purpose. What are these factors which can possibly affect the stress distribution? Obviously number one should be the type of load, the nature of the load. I have mentioned sometime back, a number of different types of structures varying from multistoried tall building to dams.

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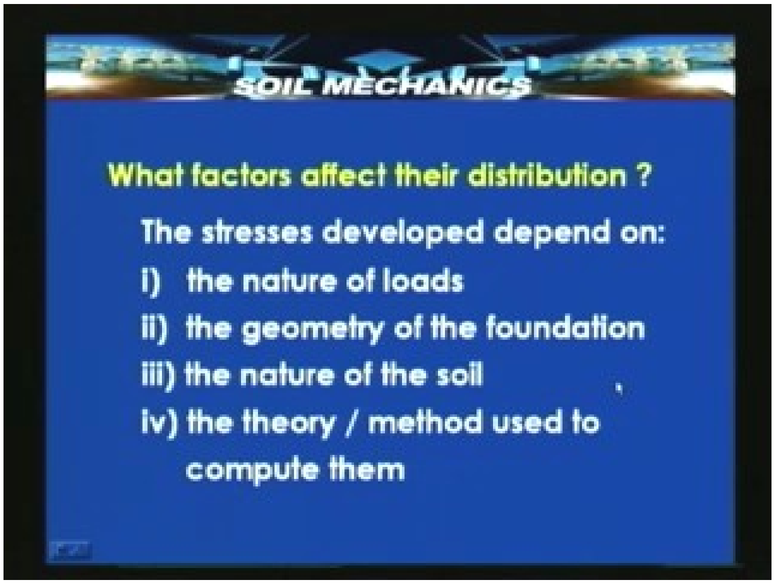

Each structure has its own geometry, each structure has its own material, its own shape and therefore it imposes a different load. Each structure imposes a different type of load and even the load which is created by these is not uniform. It may vary within the structure as well. Therefore the nature of these structures, the nature of the load that it causes and the nature of variation of the load within the structure, these are all important factors related to the structures which are needed to be understood first. Therefore let us go back to this slide. The first item, the most important item that I have mentioned here is the nature of loads. Next comes the geometry of the foundation.

Let us take a look at this topic, the geometry and try to analysis this. A foundation can have a shape which need not remain constant for all structures. Every structure has its own peculiarities or specific features and therefore the foundation that is used for a structure will depend upon the nature of the structure itself. The nature of the foundation can vary in terms of shape, in terms of size, in terms of the depth at which it is founded. All these factors have a barring on, how the load coming from the structure on to the foundation is distributed within the foundation and then transmitted to the soil.

So the second aspect if you take a re-look is the geometry of the foundation and this includes size and shape of the foundation and also where and how it is laid. For example once again, a foundation could be what is known as a simple footing or it could be a deep foundation like that of a bridge or a building. The so called simple footing or shallow foundations will be found near to the surface and not so at greater depth. Whereas the deeper foundations could go tens of meters below the ground. Obviously the transmission of stresses will take place closer to the surface in the shallower foundations and deep within the soil in the case of the tall structures or structures which have deep foundations.

Therefore the nature of the foundations should also include the depth at which the foundation is laid, because the depth up to which the stresses will be transmitted into the soil depends very much on that.

Let us come back to the slide. The third and equally important aspect is the nature of the soil. Let us analyze this. The nature of the soil means whether the soil is clayey, silty, sandy or gravel. I am sure that you have already studied soil classifications. So you know precisely what the word clay means, what the words silt, sand and gravel mean. For engineering purposes in soil mechanics we have assigned specific size ranges to these soils. And these soils can therefore be distinguished very well from each other. And once you distinguish them easily, you can even understand how they will possibly behave when they are subjected to some stresses.

It is easy to imagine for example, if you have a clayey or marshy soil close to a marine location, you can easily see that the soil will be weak cannot withstand heavy loads. Whereas if you go further deeper into the land and meet with harder ground may be sand or gravel or even rock, you can build much taller structures and much heavier structures. Therefore the nature of the soil which of course includes rock also place a very important role on how the stress is going to be distributed inside it. Greater the strength more can be the stresses that can be imposed on it and therefore a nature of this soil is very important.

Let us come back to the slide. The third aspect that is the nature of the soil therefore needs a close look always. Lastly the stress distribution surprisingly would also depend upon the method or the theory that we used for computing. Not only it depends upon these physical aspects mentioned here but it also depends upon the mathematical aspect relating to the theory or the method that is used for computing the stress distribution. Let us look into this a little bit deeply. The theory or the method that may be used for stress distribution will depend upon the ease with which we can make the computations. For example, soil is a particulate material. It consists of a number of grains. If you visualize that you are applying a load to one grain, that load will get distributed to two or three grains or more which are supporting this single grain.

Each one of these supporting grains will in turn take part of the load applied. They in turn will transmit that is each one of those will transmit their share of the load to other particles which are below them which are supporting them. Thus the load goes on getting dissipated or distributed into the soil as we go deeper and deeper. We therefore need a method ideally speaking to compute how the load is transmitted from grain to grain to grain and deep into the soil. But then it has its own complexity and therefore as you will see later we will idealize this and we will develop an ideal theory and an ideal method to compute these stresses which may not reflect the exact complexity of the grained nature of the soil. But we will also see that this does not introduce serious error in practical computations.

Let us take a look at this slide again. Therefore to sum up the factors which affect the distribution of stresses in soil are the nature and type of loads and their distribution, the geometry shape, size and depth of founding of a foundation, the nature of the soil whether it is silt, sand, gravel or clay or a mixture and the theory or the method which is used for computing the stress distribution.

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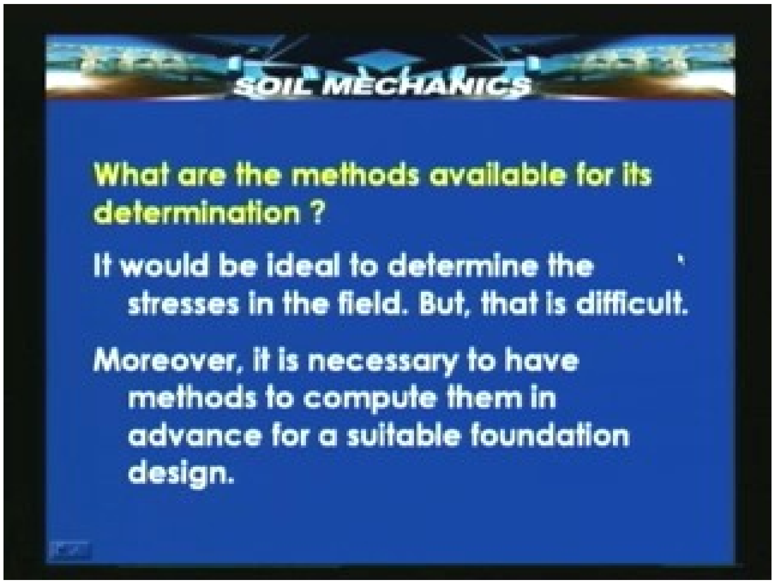

Let us go further. What are these methods which are available for the determination of the stresses? Ideally if you see this, it would be good to determine the stresses directly in the field. Is it possible? Can we possibly determine these stresses directly in the field? In certain situations it is possible but imagine a situation where we have to erect a building. We can not possibly erect the building and then measure the stresses. We need to have a method to compute the stresses in advance and not to construct the building and then measure the stresses. And so in-situ measurement is a difficult task and also that is not what we need in the initial stages of planning and designing the structure.

So coming back to this slide, we can see that moreover it is necessary to have methods to compute them in advance, before we actually construct the structure. So that we can have a suitable design for a foundation. Although it will be ideal to determine the stresses in the field, we would rather like to determine them on paper in the lab or in the office using some theoretical technique or a mathematical technique. So that we can design a stable and safe foundation. In understanding the methods which are available for determination of stresses, as I cautioned we must remember that soil is a discontinuous medium. It is a particulate material and not only that; if you look at the soils in nature in-situ, it can be present in different conditions depending upon the presents of moisture. In the very early chapter on unit weights or index properties of soils, you would have learnt that there are several unit weights which can be defined for a soil.

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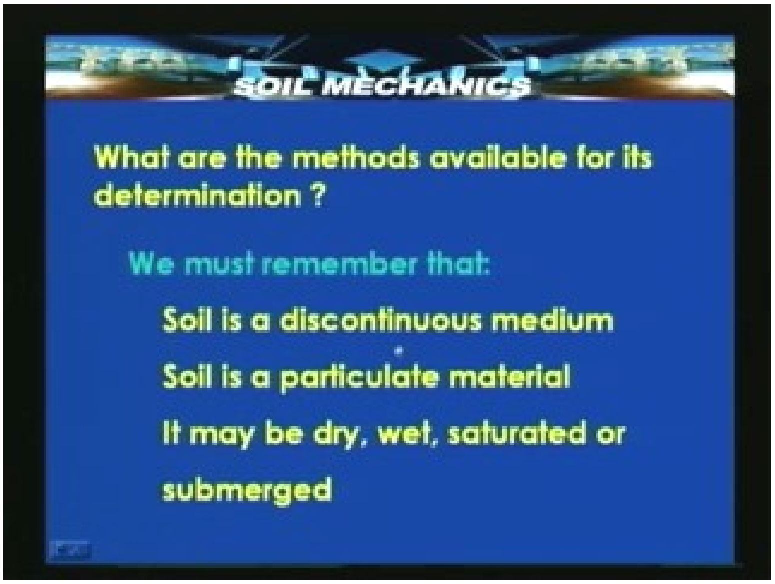

When a soil is in dry condition it has a unit weight which is called the dry unit weight. When it becomes wet, it will then have the effect of water added to its weight and then will have a weight per unit volume or the unit weight which is known as wet unit weight or moist unit weight. Suppose the water in the soil increases to such as extend, has to fill up all the voids and saturate the soil then the unit weight becomes a wet unit weight which corresponds to the saturated value. That unit weight is known as the saturated unit weight.

It can also have yet another unit weight, when it is completely under water, submerged and or inundated during flooding for example. Then the soil particles experience buoyant forces from below, the unit weight then becomes the so called buoyant unit weight. All these unit weights and then all these terminologies are quite familiar, so I will not repeat their formal definitions. We must remember therefore that the soil may be dry or wet, saturated or submerged and this also plays a very important role. And the method that we use for computing the stresses should take account of the nature of the soil, particularly with respect to the presence of moisture in it.

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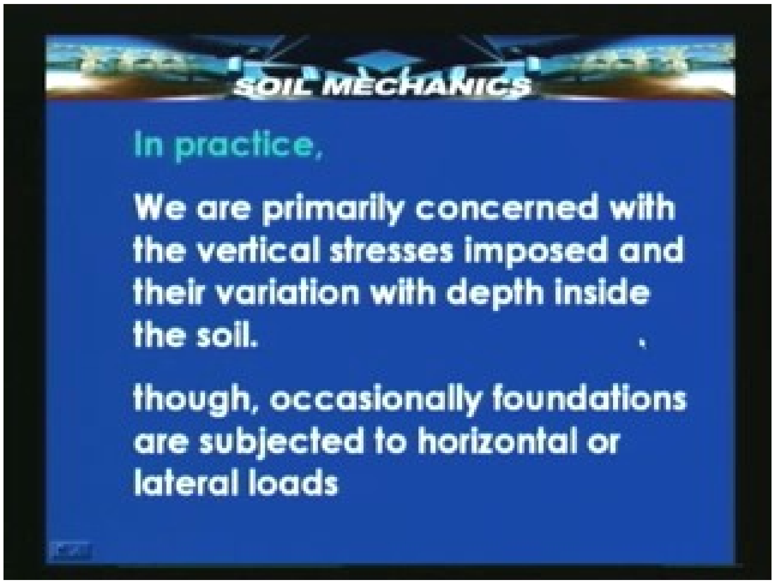

In practice we are primarily concerned only with the vertical stresses imposed. That is because all these structures normally have their weights and as we know the weights are transmitted vertically down. Therefore primarily the stresses imposed on the soil are also vertical and we are therefore generally interested in the vertical stresses inside the soil. Of course there can be structures, take for example a tall tower like structure, a transmission tower for example or a big chimney or even a multistoried building say 40 or 30 storied building. They will all be subjected to wind forces. That is a lateral load. A structure might also experience earthquake force that again would be a lateral force. Therefore during the life time of a structure there could be some lateral loads which arise. In big structures these are significant, in many ordinary structures these are not that much significant. Therefore generally speaking we are interested primarily in vertical stresses inside the soil but however if we need to compute the shear stresses or the stresses arising due to lateral loads, that is also possible.

Although we are primarily concerned with vertical stresses imposed and their variation with depth, we would occasionally be interested in lateral loads and the stress distribution arising out of those. With this introduction, let us define the scope of this lecture. In this particular lecture which of course is an introductory lecture basically, wherein I am not going to deal with mathematical details of the methods of computation of stresses yet.

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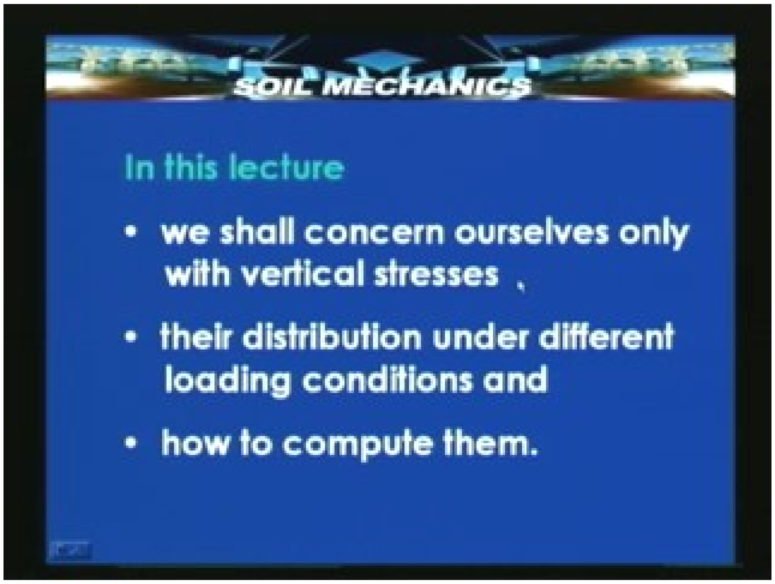

If you see this slide we shall concern ourselves only with vertical stresses during the course of this lecture and the computation of these vertical stresses. We will also be interested in their distribution under different loading conditions and how to compute them. These are the three aspects that we shall be dealing with, during the course of this lecture. So before we proceed further into one of these aspects, let us have an overview of what to expect in the whole lecture.

The first slide here shows the variation of the vertical stress with depth. This horizontal axis depicts the vertical stress in kilo Newton per meter square units. The vertical axis represents the depth inside the soil in meters and the graph shown that is the curve which is shown here shows the variation of the vertical stress denoted as sigma z.

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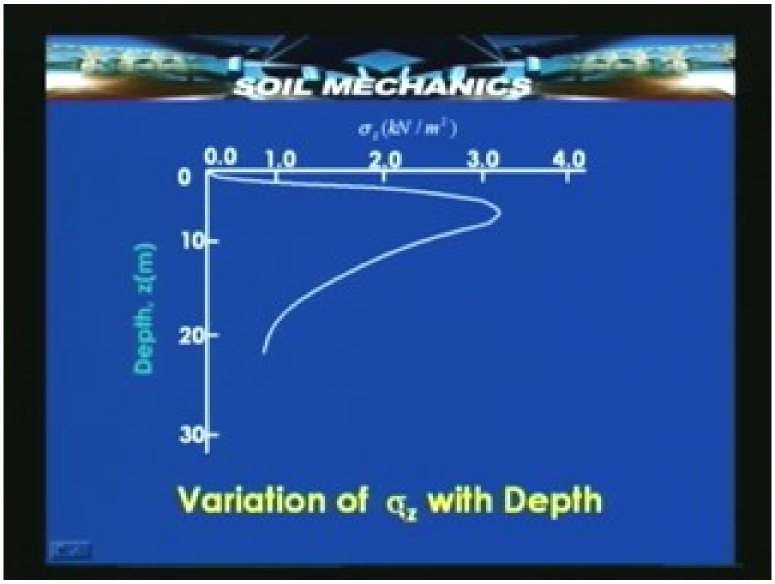

Where sigma standing for stress and z standing for the direction in which the stress is acting and its variation with depth. Now you find here that this curve (Refer Slide Time: 25:30) is showing a general increase in the stress with depth up to some point and then a decrease. So if you try to understand this, you will find that it is very easy to understand. Suppose a load is applied on a soil, the stress is arising due to that, obviously have to decay with depth at some point. The load cannot go on indefinitely increasing with depth of the soil. It has to therefore after some time go on decreasing, as the influence of the load goes on decreasing with depth, the stresses also have to decrease. Initially close to the surface therefore where there was no stress at all, when a building is erected the load due to that increases a stresses at all points very close to the surface. That is what you see in this slide as well.

In this slide close to the surface in this specific instance, up to a depth of about 7 or 8 meters the stresses are going on increasing. Whereas if we look at distances or depths more than these 8 meters, as the points under consideration goes farther and farther for the load applied, the effect of the load at this point is definitely going to decrease as the distance increases. And that is what you find in the slide, beyond 8 meters the stresses show a gradual degrees and almost even a steady value is reached beyond a depth of about 20 meters. This is a very important point and the method that we use for computing the stresses should be able to predict this accurately.

Let us take the variation as the vertical stress once again, but now in the horizontal direction or the x direction. Consider for example a distributed load over an area with width B is equal to 2 m, just as an example. And let us say a load of 100 kilo Newton per meter square is applied in the vertical direction on the surface of the soil. You will find this caching here is a typical method for representing the soil surface. The x denotes the x-coordinate and this denotes the vertical coordinate which is depicted as z. This is a center of the load and therefore directly below the center of the load we experience maximum stresses.

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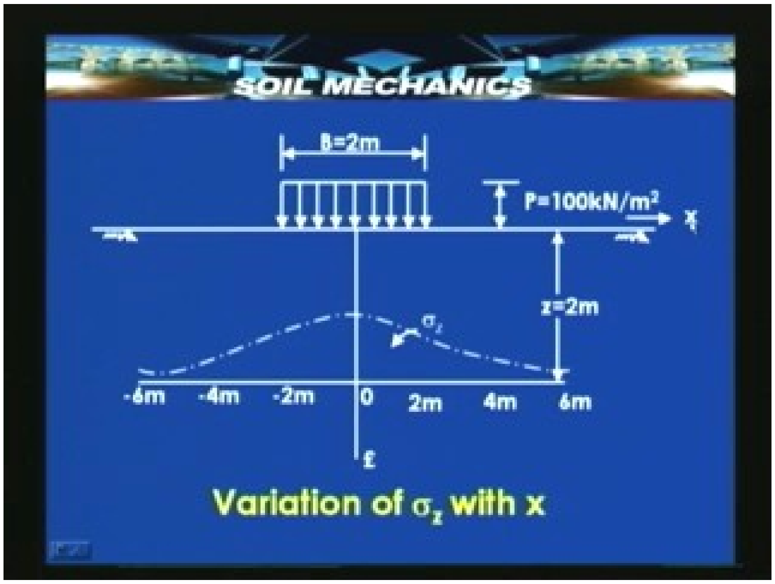

But as we go away, the influence of this load goes on decreasing and that is easily visualizable and you find therefore that the vertical stress sigma z goes on decreasing as you go away from the center to the lateral direction either here or here (Refer Slide Time: 28:35). But this is valid at one particular depth, at any other depth you may still find the same trend but the magnitude and the rate of variation will be different. Our method of computing stresses must therefore be capable of computing stresses in such a way as to depict this phenomenon. That is the variation of sigma z with depth as well as laterally at any given depth.

In order to understand the stress distribution we need to understand the behavior of a typical soil element. Let us take a two dimensional problem for convenience and take a look at it typical soil element. Let us see this slide, as I said this is the ground level or the soil surface, this is the z coordinate. Let us take a typical rectangular element one dimension of which is parallel to the x-axis, another dimension of which is parallel to the z-axis. This soil element which is a typical two dimensional soil element will experience vertical stresses due to the weight of the soil above it, as well as due to any load that may be applied on the surface. This in turn will lead due to lateral stresses as shown here which are depicted as sigma h, h standing for horizontal.

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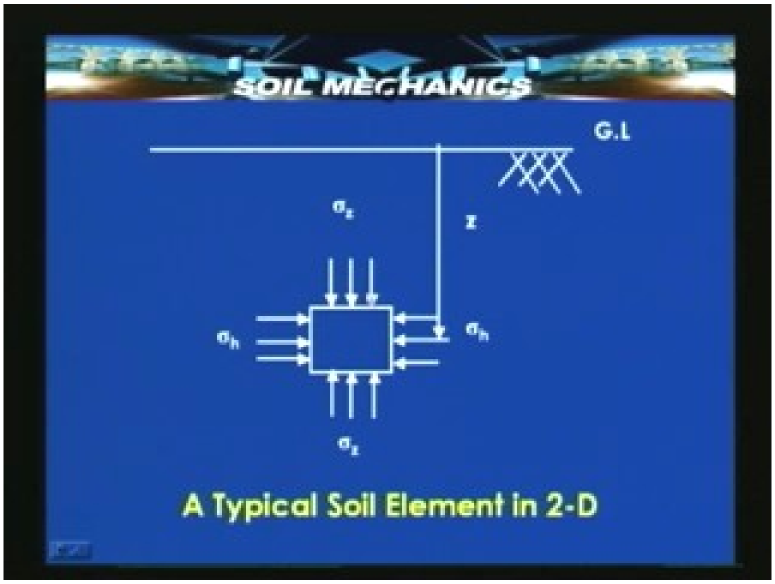

These lateral stresses or the so called confining stresses which arise due to the confining effect of the surrounding soil or surrounding elements of soil and their magnitude depends upon its usual fraction of the vertical stress sigma z. Therefore the lateral stress can be computed if you know the vertical stress. There are instances of course where the lateral stress could be not just a fraction of sigma z but could be even more than sigma z. Such situations are very rare and there is an explanation for this which we might see later. This is a typical two dimensional element and any method to compute stress distribution should be capable of computing the stresses around this element. The stresses around this element have to be searched as to keep the soil element in equilibrium. Therefore equilibrium is an important consideration that should be taken into account in the method that is used for computing the stresses.

Let us define a coordinate system so that we are capable of expressing these stresses unambiguously. For this purpose we normally use the so called x y z axis system which is shown, the rectangular coordinate system which is shown here. This is the general three dimensional cases that are shown. This is the x-axis, this is the y-axis at right handed straight and this is the z-axis. And you know that as you move from x to y, a right handed screw will tend to penetrate this way into the soil and therefore the positive z direction will be directed downwards into the soil. If there is a load capital P at this origin (0, 0, 0) it will cause stresses in a typical soil element.

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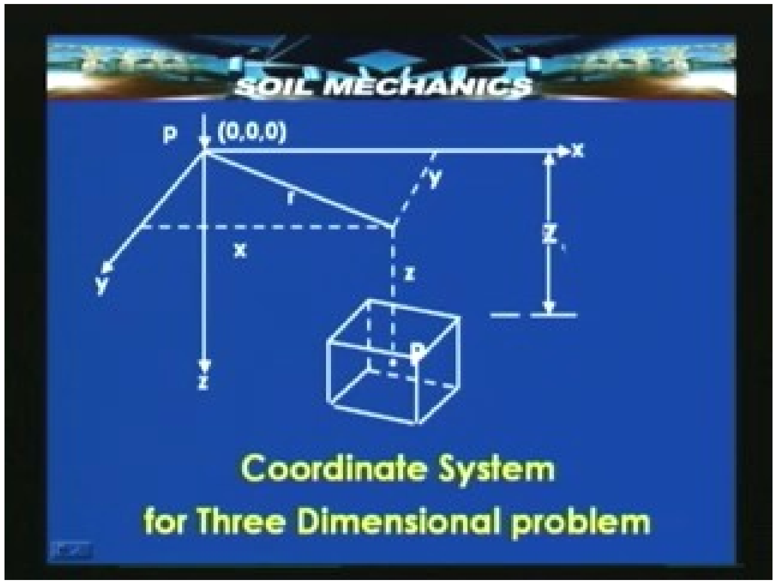

We now have a three dimensional system and therefore a three dimensional element and these three dimensional element is commonly known as a parallelepiped. This parallelepiped has its center at this point P which has coordinate, which can be depicted or represented as x, y and z. If you know x, y and z with respect to any given well defined rectangular coordinate system you will know where this point is and you can compute the stresses at this point due to a load applied on the surface. This is a three dimensional problem, soil stress distribution really is a three dimensional problem and this is the generalized coordinates system that can be used for the three dimensional problem and this is a Cartesian coordinate system.

In general a three dimensional stress system will consist of stresses on each one of the phases of the parallelepiped. This parallelepiped element which we are considering in three dimensional situations will have how many phases. It will have 6 phases, 2 phases each will be parallel to each of the coordinate’s planes and each one of these phases will experience stresses. In a very general sense, any phase would experience a stress in some arbitrary direction due to the complex or the combination of loads which are imposed on the soil. On each surface the direction of this stress may vary. Therefore we need a method by which we can generalize this stress on each phase.

For this purpose we use this coordinates system. This coordinates system tells us that any stress that is acting on any surface of the parallelepiped can always be resolved into components. One of them will be normal to the surface; the remaining two will be parallel to the surface. Let us take the normal once first and take a look at this slide. This slides shows what are the typical normal stresses which will be acting on each one of these phases. We use notations such as sigma one, sigma two and sigma three to represent the normal stresses on these phases.

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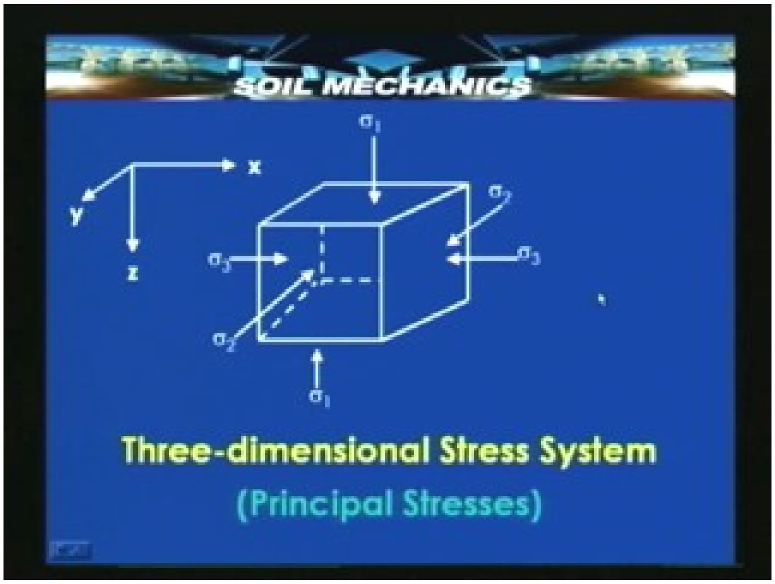

Sigma one is usually called the major principals stress and the plane on which it acts is known as the major principal plane. The other two stresses, normal stresses each one of them acting on perpendicular planes, sigma two acts on the plane xz and sigma three acts on the plane yz. Generally sigma one is the maximum stress, sigma two is an intermediate value and sigma three is the least possible principal stress. These are a system of normal stresses, known therefore as principal stresses. But in a general problem where there would be any arbitrary loading. There will be not only these normal stresses or the principal stresses on a parallelepiped. But each phase will also experience stresses parallel to the phase. Let us take a look at that.

This is the most generalized stress system, again a three dimensional system and again for Cartesian coordinates. You find here that in addition to the vertical stress sigma z, the horizontal stresses sigma x and sigma y, we also have shear stresses. It is worth mentioning here, the notation that one uses normally for the depiction of stresses or for denoting the stresses. The normal stresses are depicted or denoted by a notation sigma with a subscript which defines the direction in which it is acting. For example sigma z would mean a normal stress acting in this z-direction, similarly sigma x and sigma y. The shear stresses on the other hand will slightly need more elaborate definition. On the phase parallel to y z, for example on the plane parallel to y z, that is this plane the normal stress is sigma x.

There will be two shear stresses, one parallel to the direction y and another parallel to the direction z. The one which is parallel to the direction z is denoted as dow x z because this shear stress acts on a plane whose normal is in the x direction and the shear stress itself is directed in this z direction. And this is taken as positive if the outward normal is positive. In this case the outward normal of this surface is in the positive x-axis direction and therefore this stress dow x z is a positive shear stress in this z direction. And similarly the stress dow x y is a positive shear stress in the y direction.

It is interesting to see that the two similar stresses will also act on this phase for example in the phase x y. And those stresses will be dow z y and dow z x respectively. It can be shown by simple considerations of moment and equilibrium, that this dow z x must be numerically equal to dow x z but apposite in sense as we can see from the direction of the arrows here. These are known as conjugate shear stresses, it can be shown that the conjugate shear stresses a pair of them are equal always, dow x z is equal to dow z x, dow x y will be equal to dow y x and so on. This is the most general stress system in the case of Cartesian coordinates. But some times we may also need to use the so called cylindrical coordinates in which case a typical general stress system would be something like this.

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Here now the stresses will not be represented in terms of sigma x, sigma y and sigma z. They will rather be represented in terms of radial stresses, tangential stresses and shear stresses. Sigma r for example is a typical radial stress. If from this point P, from the origin if you draw a radial line normal to this element this new parallelepiped, then sigma r will represent the normal stress. And a plane which is perpendicular to this will experience these stress which is called sigma theta because it acts in the theta direction. Whereas a shear stress acts on each one of these planes, parallel to the plane itself. For example dow r z here is one such shear stress and a conjugate shear stress here would be dow z r.

This becomes a generalized stress system and this can be related to the Cartesian system through a simple relationship. That is this radio specter r of this parallelepiped is equal to square root of the coordinates x and y, squared and added. This is a typical cylindrical coordinate system in three dimensions. Let us see in what kind of problems this might be useful. A cylindrical coordinates system is often required in problems, where the geometry of the foundation or the geometry of this structure and therefore the consequent load distribution is not on rectangular surfaces.

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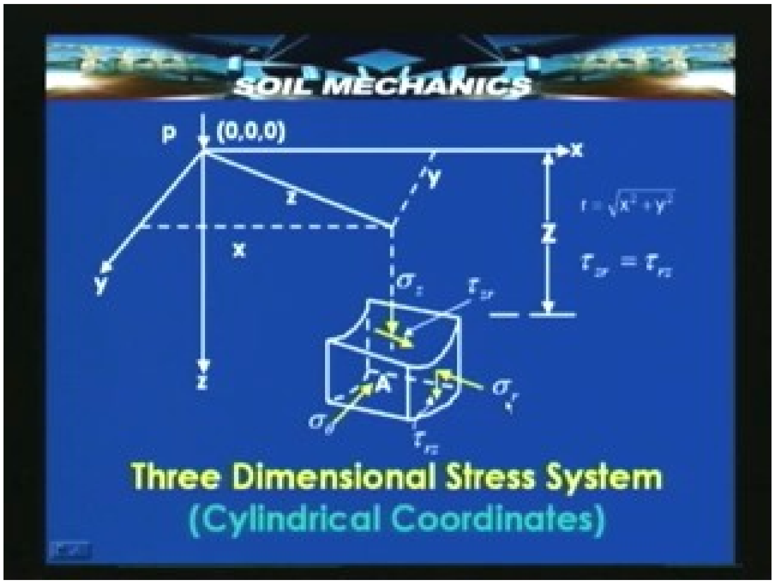

If the geometry of a foundation or a bridge for example is considered. It could be circular, it could be ellipsoidal, and it need not be rectangular. For such instances it is very convenient to use a cylindrical coordinates system defined by the coordinate's r theta and z. The oil storage tanks is usually cylindrical in shape, it will also have a cylindrical foundation sum.

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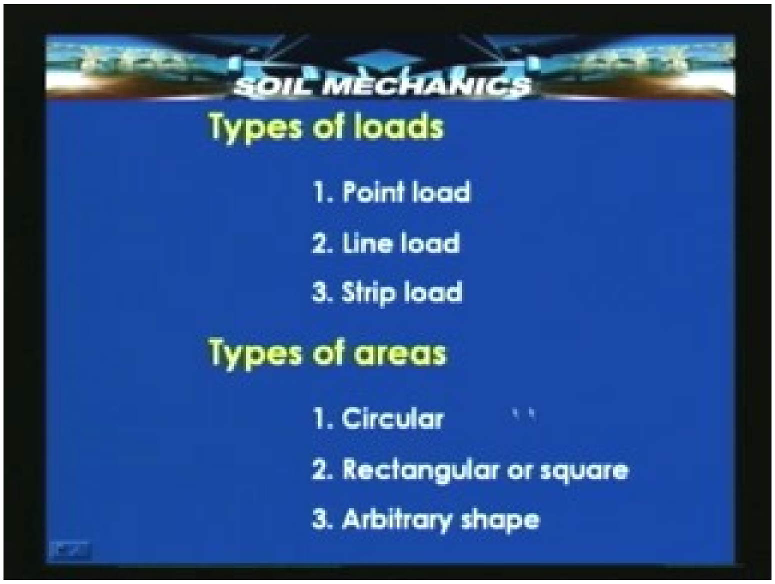

Let us see that the cylindrical coordinates are useful in certain specific instances. Here is a list in the above slide for different types of loads and the different types of foundation areas or loaded areas which one could come across. The types of loads that can arise due to different structures are point load, line load and strip load. And the types of areas of foundation or the loaded areas could be circular, rectangular or square or any arbitrary shape. If it is circular we use the cylindrical coordinates system, if it is rectangular or square we use the Cartesian coordinates system, if it is an arbitrary shape also we use a Cartesian coordinates system.

Let us see what are these different types of loadings. I have listed it here by simple diagrams, the point, line and strip loading. It is not difficult to understand them, let us see what these loadings mean. A point load is one which is acting at a point, a concentrated load for example. A concentrated load arises due to any object which is resting on, for example the floor of a building. That concentrated object will induce a load which again may be coming as a point load ultimately on the foundation. There could also be strip loads, consider for example the foundation of a compound wall of a building.

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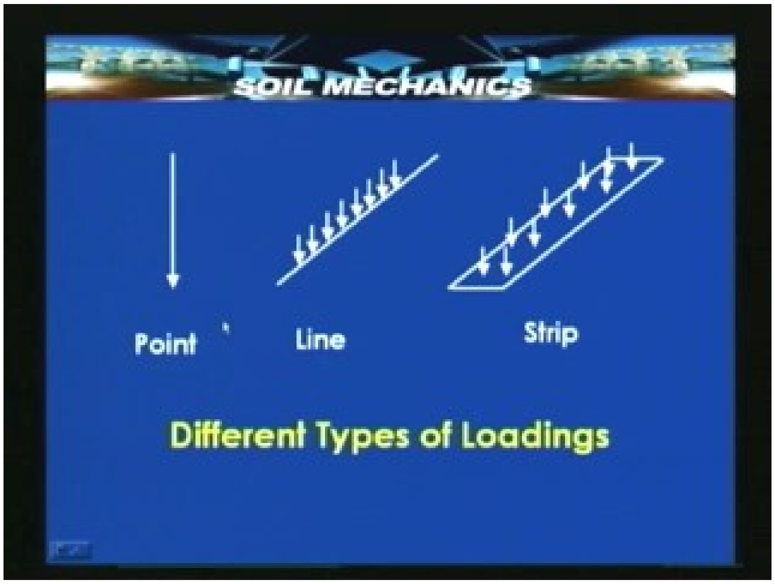

It is a linear structure; the compound wall of a building will have a foundation which is long in length, very large in length but small in cross sectional dimensions. It will experience a series of loads along its length and this kind of loading is known as a strip load and that is what depicted here. This kind of a loading is known as a line load and that is what depicted here by means of a series of arrows on a line. In general case, if a series of line loads act over a definite area then it becomes strip load. So these are the different possible types of loadings which can arise. The area may vary in shape and size but the nature of the loads by enlarge will remain the same.

Let us see the areas: The types of areas one can come across, types of areas means areas of loading or the shapes of the foundations could be circular. For example piers of bridges, storage tanks as I mentioned some time back will have circular shapes and their foundation will also be circular or cylindrical in shape. Whereas normal buildings will generally have rectangular or square foundations and there are always special situations not conforming to any one of these standard shapes which will require a foundation of an arbitrary shape.

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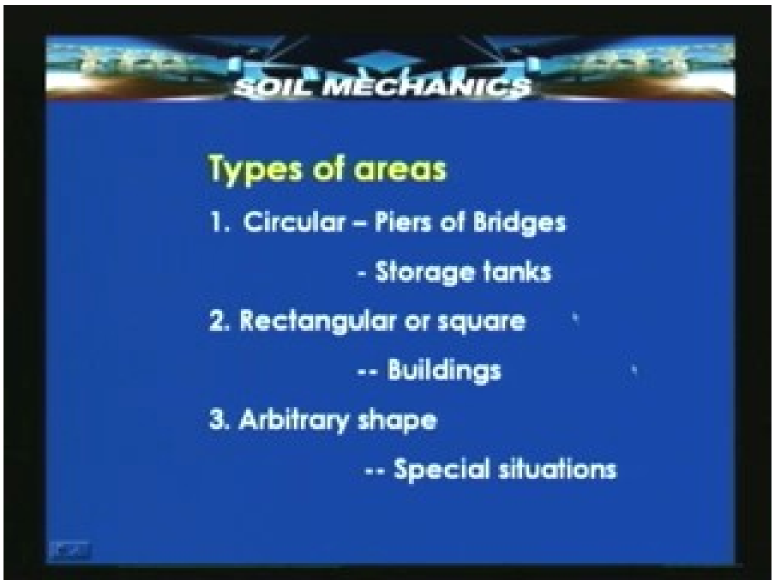

The stresses due to a point load can be computed using a Cartesian coordinates system and suppose this P is a point or a concentrated load acting here. We need a method to compute the stress at point P using this coordinate system where P is now defined by a set of coordinates x y z.

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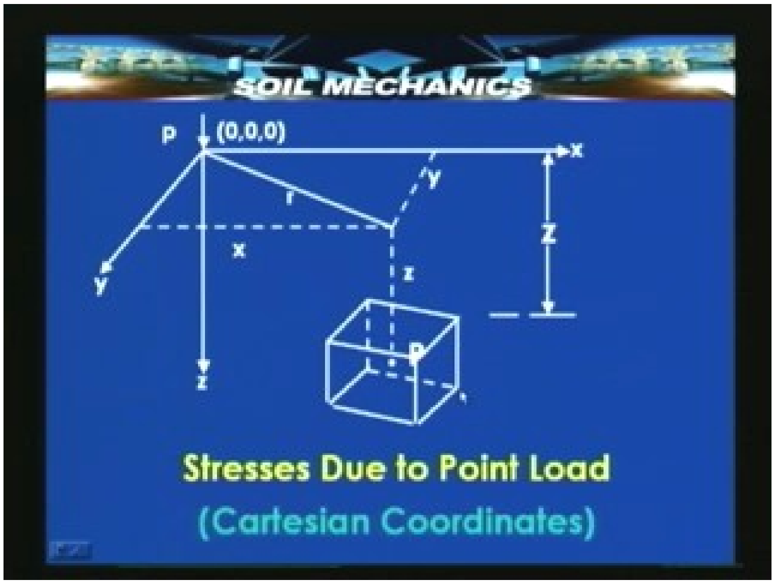

Knowing the load P and the position of the point P we should be able to compute the stresses due to this load at any position or any location of this point P given by any combination of the coordinates x y and z. In terms of cylindrical coordinates once again, if this is a point load, the stress arising due to this point load inside this element at the center for example should be calculated in terms of the coordinates x y z or r theta z and the cylindrical coordinates system and the corresponding method should be able to give this.

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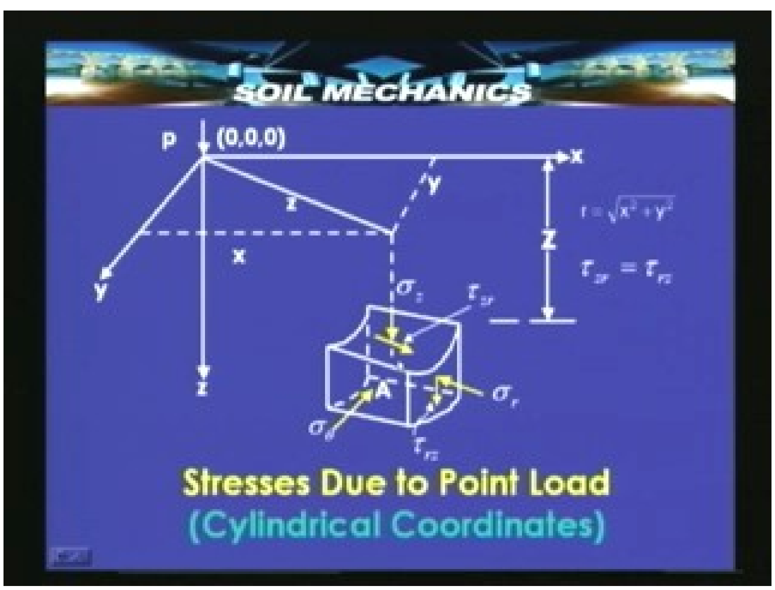

If we have a line load for example as depicted here, a line load is nothing but a series of loads arising as in the case of a compound wall. You find a series of concentrated loads depicted by P kilo Newton per meter. Since this is a load which is distributed over a length, the units for the load will be kilo Newton per unit length of loading that is kilo Newton per meter.

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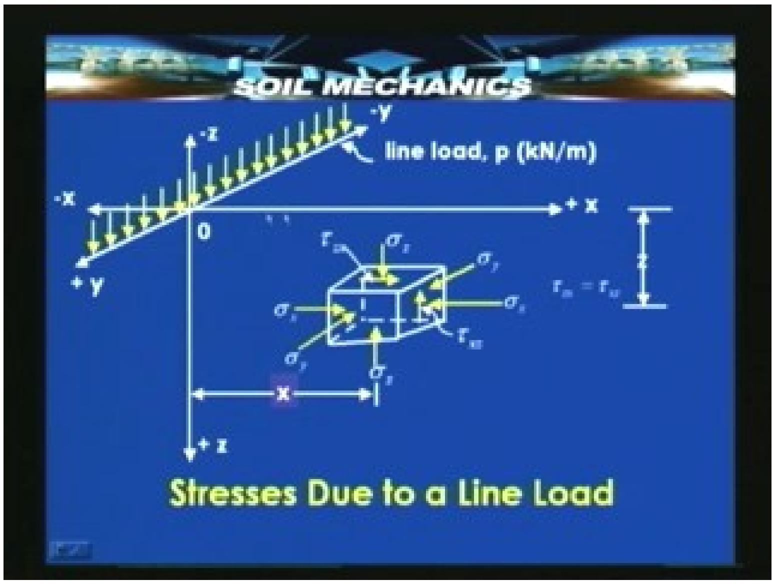

If I take the coordinates directions x and z and consider a three dimensional element, this three dimensional element will have stresses normal and shear on each one of these phases. And we should be able to calculate the stress due to each one of these point loads which comprise this line load and get the stresses at this point. There are methods available for integrating the effects of each one of these point loads and getting the total effect of the line load.

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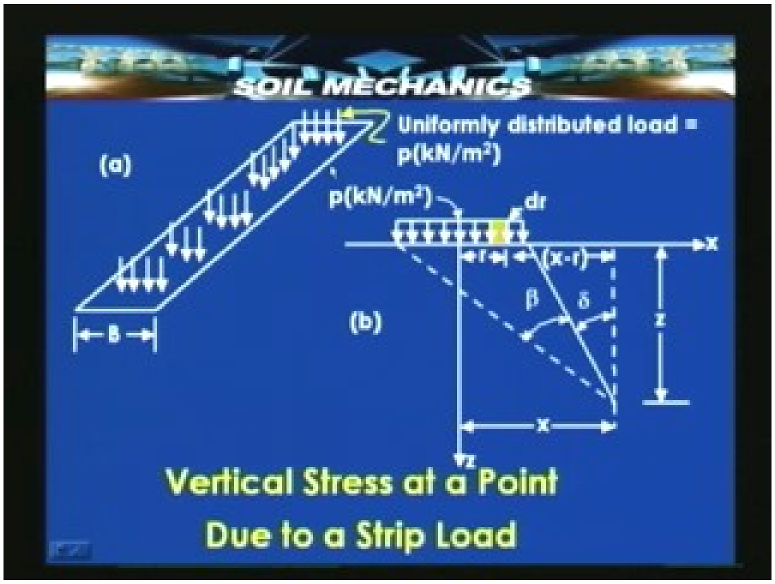

We also could have strip loading areas, for example here is a rectangular foundation which is experiencing a strip load or a uniformly distributed load of P kilo Newton per meter square. This being a load distributed over an area, it is depicted as kilo Newton per meter square and on the other hand a line lode was represented as kilo Newton per meter. The vertical stress arising due to this kind of loading at any point with coordinates x and z must also be computed using an appropriate method.

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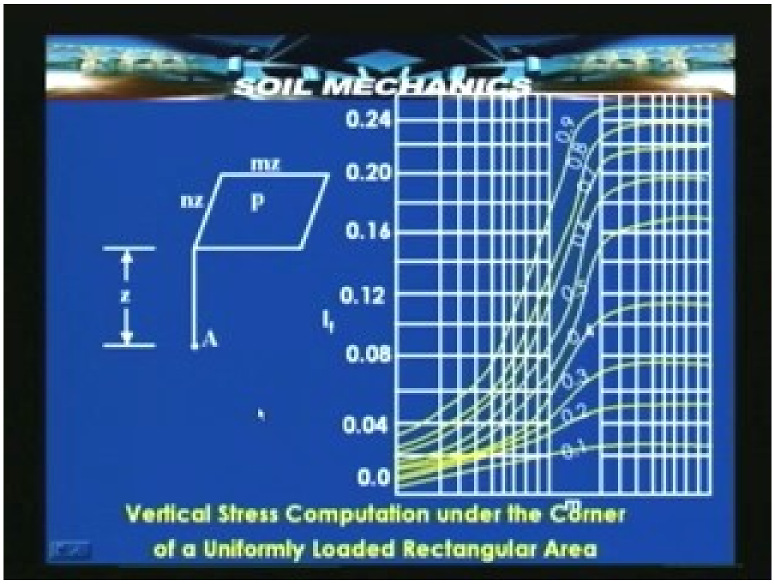

There are methods available for computing the vertical stress at any point due to a strip load. We shall be seeing these methods as well. For a rectangular area for example we have a method which helps us to compute the stress at any point below its corner. Once we have a method to compute this stresses at any point below the corner with the help of a chart, then we can extend this for computing this stresses at the center of the loaded areas as well or any other point by using an extension of this method.

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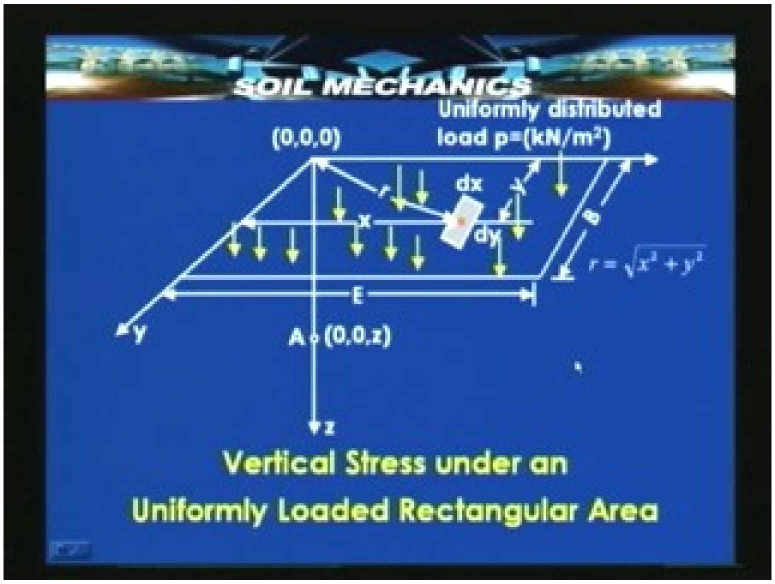

For example here is a rectangular area which is experiencing stress at some point below and we need to calculate the vertical stress at some point other than the corner let us say. Then if you go to the slide, we find that this loaded area can be divided into four parts for example and at the corner of the loaded areas 1, 2, 3 and 4 at the common corner.

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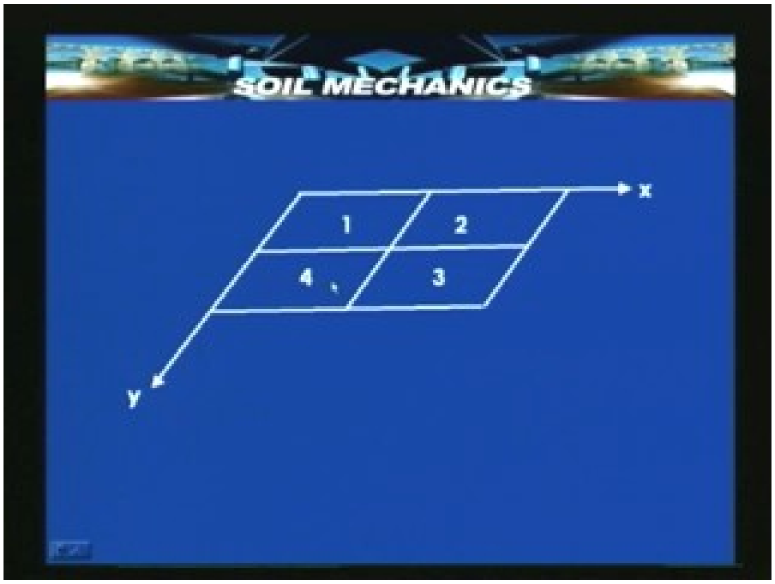

If you can compute the stresses due to each one of these sub areas and add them up or super pose the stresses, we will get the stresses at the center of the loaded area. So this is one of the methods which is based on the principle of super position of stresses at a point, which means the stresses imposed by different loaded units at any given point are super possible, they can be added.

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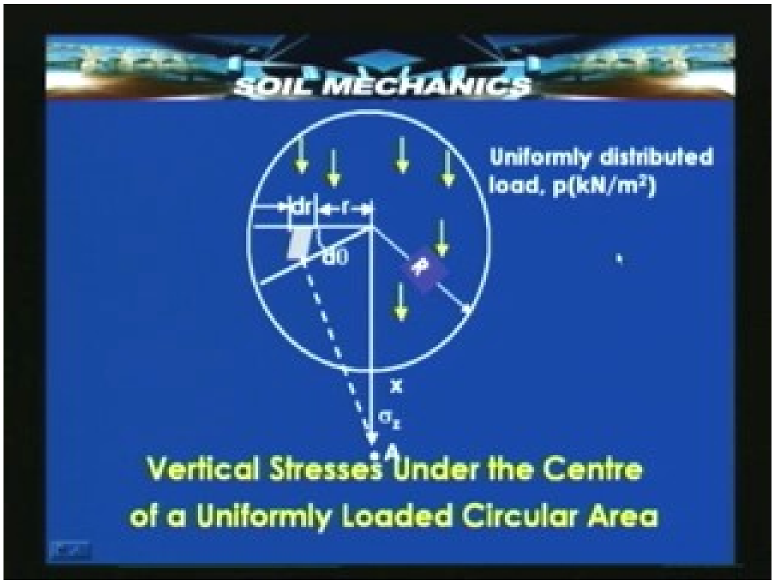

If I have a circular area, we can have once again an appropriate method for calculating this stress at any point below the center of the circular area. This can be extended also to any foundation of any arbitrary shape, there is a method available for computing this stresses below the center or any other point of any arbitrarily shaped area. Here the loaded area is rectangular in shape but this method which is shown here can also be used for any arbitrarily shaped foundation.

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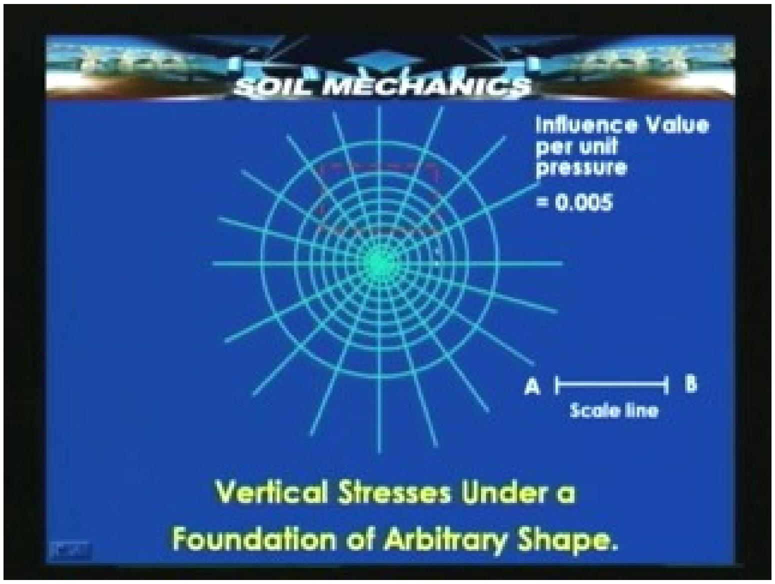

Once we know the stresses on any one phase, it can always be resolved into stresses in any other direction.

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If you know the stresses for example on the plane BC and the plane CA, we can find out this stresses normal and tangential on the plane AB. We shall see some of the details of this computation in the following lectures. Here suppose if to say that there are some methods available for computing these.

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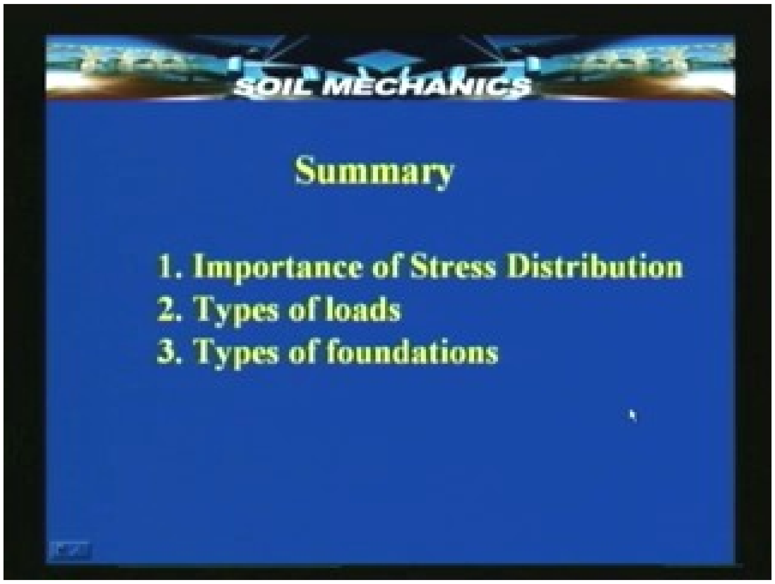

In summary I will say that we have seen in today's lecture, the importance of stress distribution, what are the types of loads and what are the types of foundations. And in the next lecture we shall be seeing what are the methods of determinations of stress distribution, what is the principle, what are the theories which are used and we will also try to see illustration of these with the help of few examples.

Thank you.