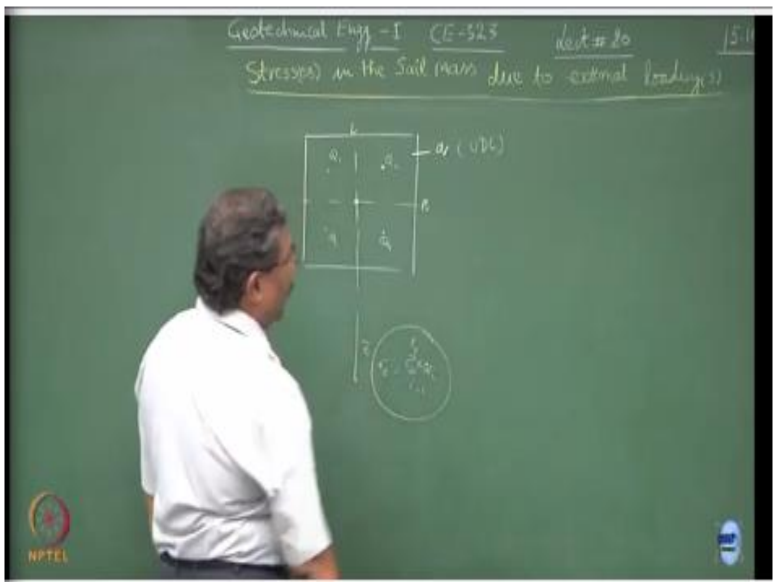
Geotechnical Engineering I
Prof. Devendra N. Singh
Department of Civil Engineering
Indian Institute of Technology-Bombay

Lecture-24
Stresses in the Soil mass due to External Loadings-II

So until now we have discussed about the superimposition principle and where we have superimpose the loads, there are few more techniques of superimposing the loads.

(Refer Slide Time: 00:29)

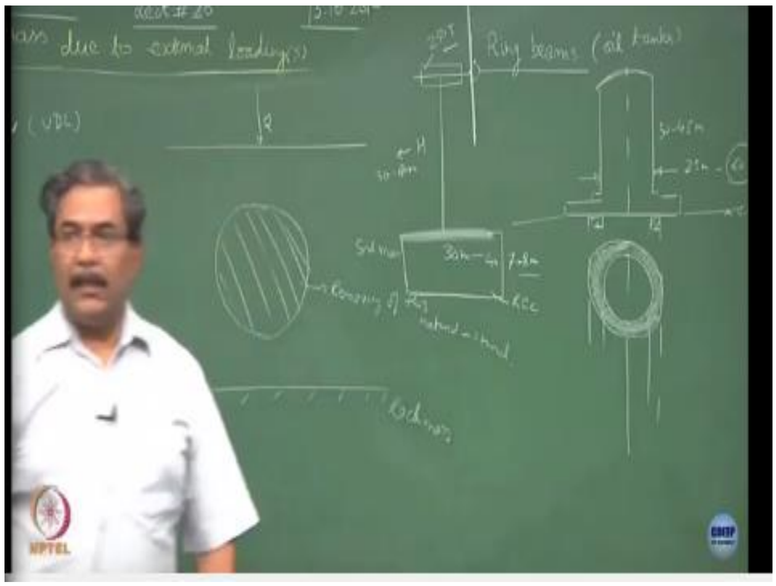


Suppose if I have a uniformly distributed loading on this area of l and b it is something known as equivalent point loads you know we are going now reverse from a uniformly distributed load we are coming back to the point loads. So for the sake of convenience I can break this in 4 parts and I can assume that the equivalent of q is acting at this cg, so this becomes Q 1, Q 2, Q 3, Q 4 alright.

And then I might be interested in finding out what is the state of stress at this point at a given z, so this can also be solved very easily, I hope you can realize this alright. So this is a reverse way from Q we have converted into equivalent point loads. And then for equivalent point load I know what is the state of stress at a given point, I can sum with sum this up and I can write the total sigma z would be summation of sigma z coming out of 1 to 4.

Until now we have discuss anything related to the negative loading, is it not, we have been talking about always positive loading. So negative loading comes in the form of when you create a intrusion. Suppose there is a soil mass and if I remove this much of the soil to create what, suppose this is the rock hard strata, this is a soil mass alright. And there is a load which is acting on the top of this, now what we have done by removing this material we are creating a tunnel.

(Refer Slide Time: 02:53)



So this becomes a state of material this is a intrusion, now suppose if I ask you to find out these state of stresses at different points going to be difficult, you cannot use this concepts share now business theory. Because this much of the soil mass has been removed alright, so you have to adopt to some FA model or finite difference model or whatever, advance computation techniques.

But suppose if I say that we were talking about the ring beam if you remember for the oil tanks. So in plant the oil tanks would like this you must have seen I am sure, they normally rest on a big pad and this happens to be the ground surface. Normally we put a lid on the top of this, these are typically 30 to 45 meter high huge structures. And the diameters could be depending upon your requirements 25 meter to 60 meter to whatever.

Now as I said that most of the time these systems are going to be sitting on a ring beam alright. So in plant the ring beam would like and so you say annulus, this is the portion on which the tank is resting. Next time when you get a chance please go to see the foundations of a wind turbine. So wind turbines are normally you must have seen Sahara and maybe some parts of Madhya Pradesh and Rajasthan and Karnataka then the coastal areas, you have seen a wind turbine or not.

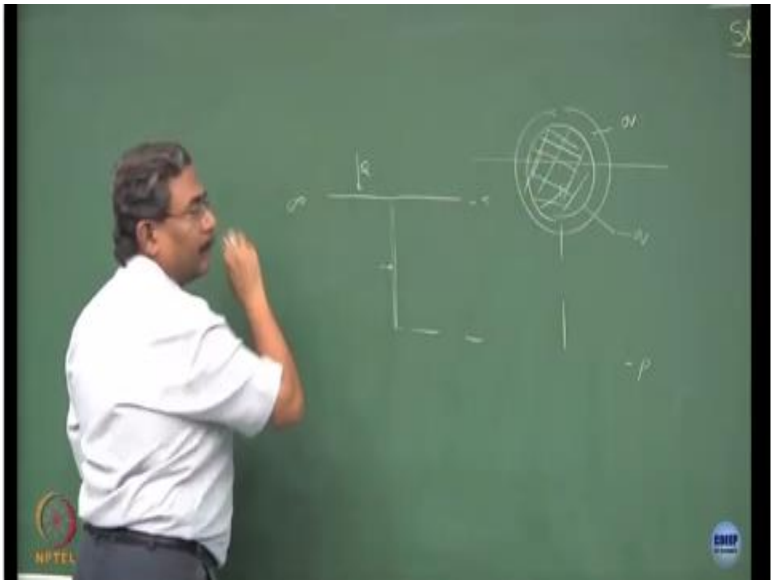
So there will be a big room half of this maybe there will be a rotor here and this rotor will be containing a fan. So this is what is going to rotate and then you generate electricity because of the rotation of the blades, design of foundations is interesting. Because heights are approximately 50 to 80 meters, payloads are 250 tons, imagine, I am not doing any mistake, clear. And is a sort of a fan which you pedestal fans in your domestic uses alright.

Huge fan, what type of foundation would be required here, massive foundations 30 meter diameter, 40 meter diameter, rafts, thick units you know this will about 7 to 8 meters thick monolith RCC. Then this fan is going to stand there, what is approximately 7 to 8 meter thickness of the raft, any idea close your eyes. Normal room is 2 and half to 3 meters, so at least 2 times the size of the height of the room clear, this is what the foundation size would be raft.

So I am sure you must be realizing that the foundations are going to be extremely expensive part of the structures, clear. And apart from the time you require lot of material and lot of money to construct this. So why I am linking these 2 things is this is a tank unit hydrostatic pressures are going to act and hydrostatic pressures are going to act which going to be dissipated in the whoop stress of the steel R theta component, sigma R theta component clear.

So a better way of doing this would be rather than spending more money and more time if I eliminate this much portion from the foundation system and if I create a annulus on which I will put the foundation which I would use as a foundation for the tank, I am not going to lose anything. Now how I am going to link this to the analysis which we have doing by Boussinesq method.

(Refer Slide Time: 08:05)



So what is happened is you had a circular area of intensity Q from which I have eliminated this much of the loading. Now I think you understood how to do this, so this becomes - q correct, you can find out these stress at a given point p because of the whole system. And plus minus q of the stresses which have been relived because of this agreed, that is it. So here I will introduce the concepts of negative loading, got it.

The same thing can be done in case of excavations also, remember, if I want to excavate something over here. And if this was the loading Q and for some purpose I want to find out what is the state of stress acting at this point, this could be a sheet pile, this could be RCC pile whatever. So because of this I want to find out the state of stress at this point where I have done excavation here, technically I cannot use Boussinesq theory, why, it is not a semi infinite soil mass, agreed.

So what it should have been if you have to apply Boussinesq theory this would have been a semi infinite – infinity to + infinity clear. So because of removal of the soil mass what we might do is we might apply a – q over here and superimpose this with the stresses which are going to come are you getting this point. So this is again a case of excavation, this is a case of creation of annular space this is the case of creation of a cavity through which my metros will pass and so on, is this concept clear.

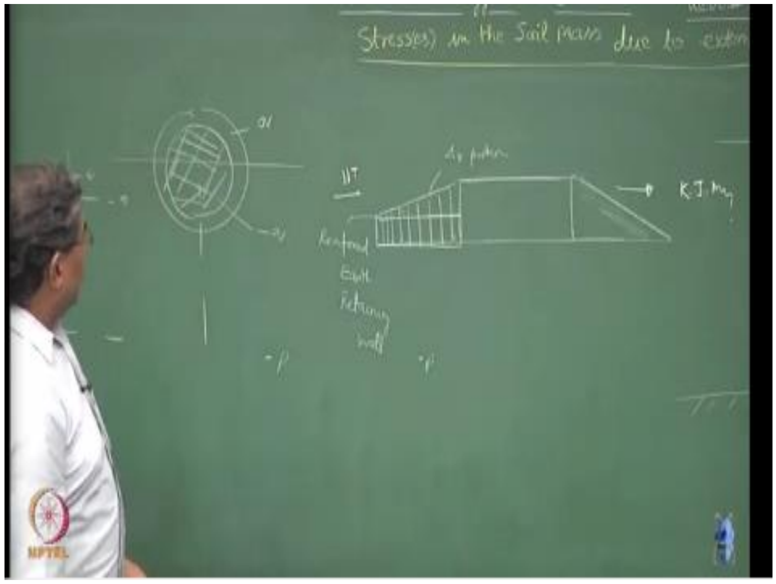
(Refer Slide Time: 10:12)

Suppose if I want to design pipes which are conveying water, can use your data cables, fiber optic cables, petroleum and so on. Later on we will realize that these type of systems are either flexible or rigid. Now this is because of the material and the thickness of the wall of the pipe which you have considered. So if thickness of the pipe is too small and let us say it is made up of PVC, it becomes a flexible pipe.

If the thickness is too much and if it is made up of RCC it becomes a rigid pipe, what stress is going to do, this loading could be because of railways, it could be because of you know traffic, it could be because of aircrafts, I know the value of Q which is coming to the tire, getting transmitted over here. What is going to happen is depending upon the flexible or rigid nature of the pipe, the deformation is going to be different.

A rigid system will not deform, a flexible will deform, clear, the state of stress I have to compute. So this part we will discuss again in the second course strength of the materials, shear strength theory. But the way the stresses are going to be computed the concept remains same, is this part ok. So I have talked about several issues, several problems I hope you can now solve this, few more complicated situations. Every time when you climb on a bridge or a ROB you must have noticed like our Kanjurmarg bridge.

(Refer Slide Time: 12:16)

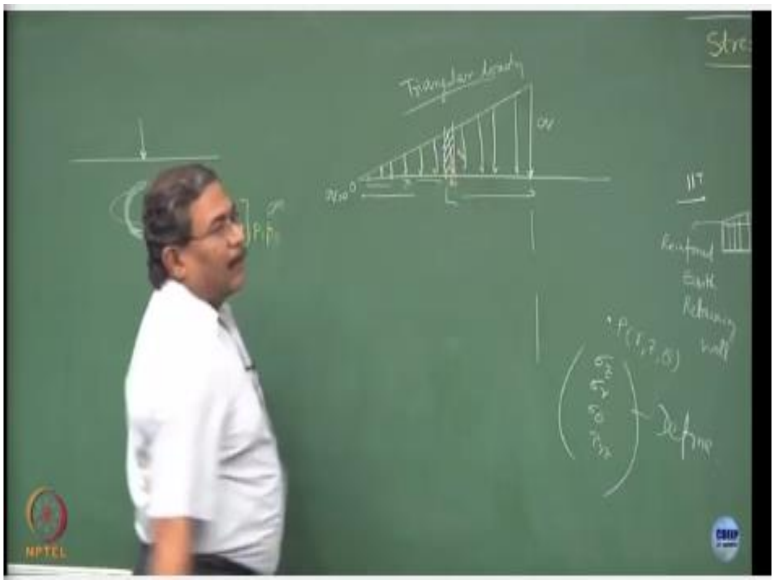


So these bridges are you know this is the Kanjurmarg junction, this is on the IIT side let us say and this is towards the Gandhi nagar or let us say Kanjurmarg bridge. So what you have observed is they have created a retaining wall over here which gives you the elevation to come to the deck of the bridge. And again there is a retaining value cannot be so steep this is a distorted scale there walls the roads cannot be done like this.

So what I am trying to emphasize here is the moment this happens to be a RE wall reinforced earth retaining wall, what will happen. This is how the pressure will get executed of the soil mass itself and then I am interested in finding out the pressure at this point. I can have 2 components of this one is going to be the loading which is coming because of the rectangular section and the second is the loading which is coming because of the triangular portion.

So is for importance academic importance that people should know how to find out the state of stress in the soil mass when the loading intensity is varying linearly ok.

(Refer Slide Time: 14:05)

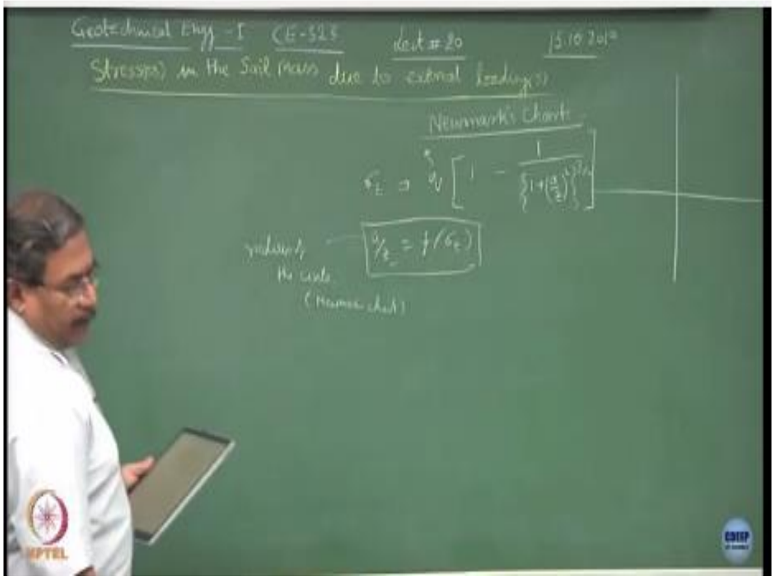


So this is a similar situation as the one which I created over here starting from value of Q = 0 over a length of L, I achieve a maximum value of q. So would you be able to solve this any problems, now this is what is known as the triangular loading. And the statement of the problem remains same, find out the stress at a point p this could be anywhere, coordinates are known r, z theta and find out the state of stress at this point.

So I think simple way you can take a small element the way we did it for the circular case at a X distance, if I know d x, if I know this q x. I have a geometrical relationship between q x upon x = q upon L clear and then you integrate it over and get the effect at this point, that is it fine. So this finishes most of the situations which I wanted to discuss in the class. Now until now we have and this is the last thing which I want to discuss today.

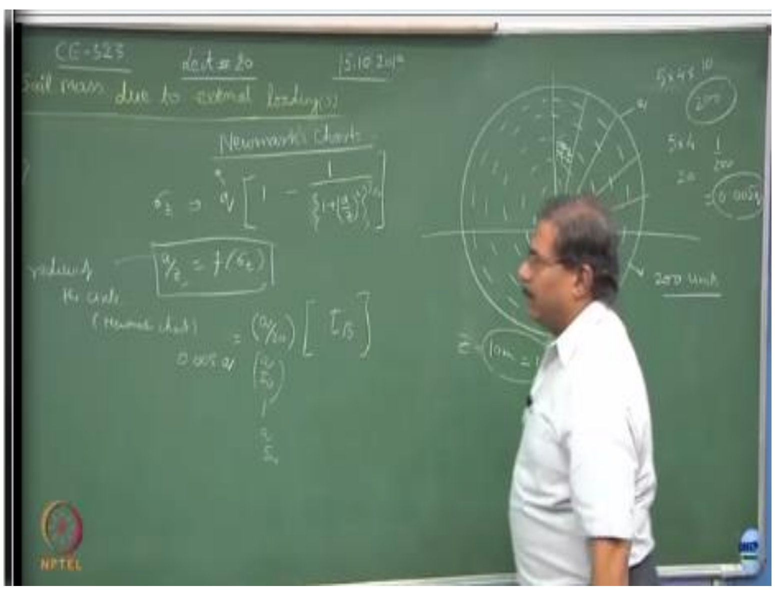
So until now we have talked about the geometrically well defined shapes which most of the time you would not find in the regular practice. Mostly the structures are irregular, foundation systems are irregular. So how to deal with those situations this is where people use the concept of Newmark's chart.

(Refer Slide Time: 16:15)



It is a simple philosophy what we do is we define the state of stress sigma z as q 1 – 1 upon 1 + a by z the square to the power 3 by 2 alright. And what this gives you is a by z as a function of sigma z. Now a is the radius of the area of the circle which is the Newmark's chart, depth remains same, what we know, q is the pressure intensity, what we do is here.

(Refer Slide Time: 17:57)



Suppose this is the whole area which is defined by this equation, now I can this is uniformly distributed let us say with the loading q. I can create here 4 radials 1, 2, 3, 4, 5 sectors, so 5 sectors 4 radials give me 20 units, fine. That means I am assuming that each of this unit corresponds to the equal concentration of q. So what I can do is this q gets replaced by q by 20, this remains as influence factor I B ok.

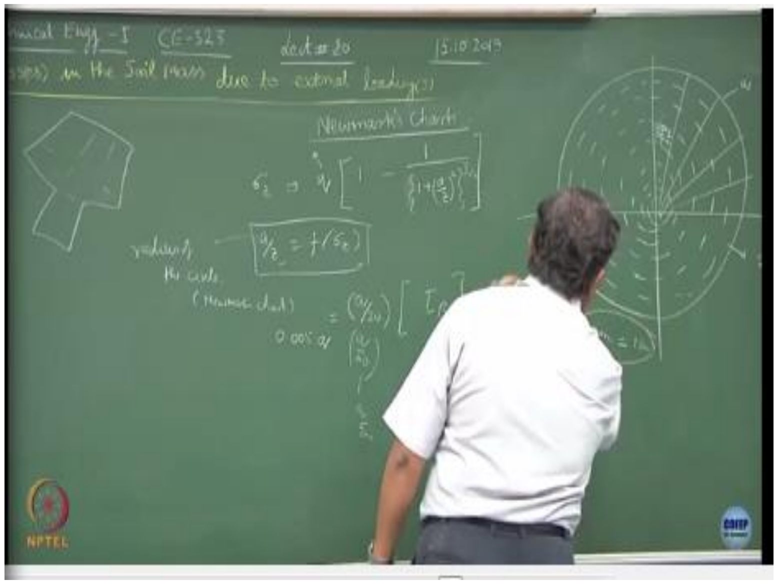
Now normally these type of graphs are plotted for 200 units, that means I have to draw now 10 circles, is this ok. So if you draw the 10 circles, how many elements I have created, so that means now I have created from the 1 circle 1, 2, 3, 4, 5 into 4 into 10 that is 200 units, fine. So I have done is, I have now dissipate to the pressure in q upon 200. So this becomes equal to 0.005 times q, have you understood this thing, each element in this chart is going to contribute equally, fine.

So now suppose if I say this element, this is what the total intensity of the pressure would be. So that means your sigma z value is 0.005 times q, this is a standard value. That means the guy who created this charts assume the whole procedure like this, fine. You have choice, if you are very particular if you are want to refine the things much more, you are free to go for 2000 units it takes lot of time but yes it is going to precise.

So accordingly then this will become 1 upon 2000 and this pressure term will become that much, this will become equal number of drops or the deltas. Now the logic is compute the a value corresponding to the number of circles which you have drawn and plot them over here, is this fine. So your charts are ready, what I have written over here is a by z is a function of sigma z, so the moment I go from q by 20 to q by 40 I have drawn the second circle.

The moment I go from q by 40 to q by 80 to q by 200 that means outermost circle is also ready, so one each of this get the value of a if z is known fine.

(Refer Slide Time: 22:20)

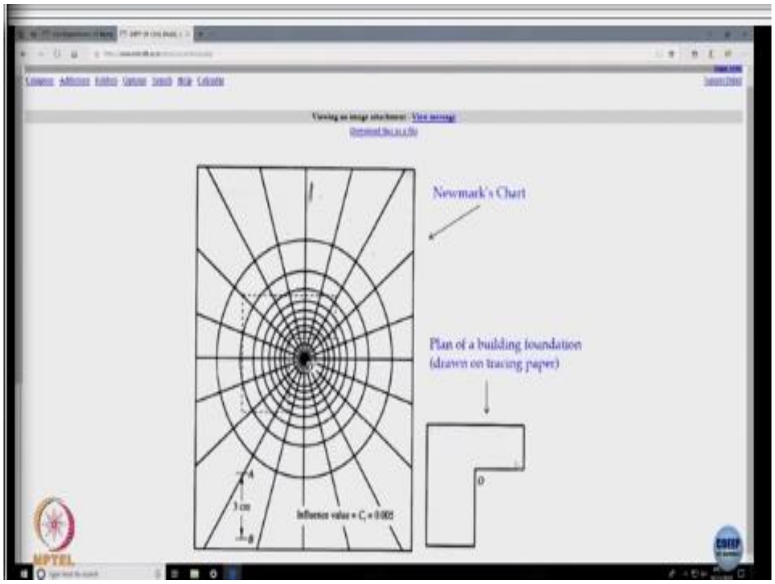


Now where and how to use this suppose if I have a plan of like this, you can still debate that I can discretize in small, small parts. And I can use either Boussinesq equation yes you are free to do that, no issues. So you can discretize in small, small parts you can treat this as a segment, you can treat this as a segment, you can again do whatever we have done, very complicated procedures particularly when you are doing big buildings, clear.

So rather than doing all these things what people do is suppose if z is defined as 10 meters, I will take this equal to some unit of let us say 1 centimeter on the graph, I will scale down the entire plan of the building to 110th, my plan is ready. Suppose if I wanted to find out the state of stress at a given point in this building, I will lift it and I will superimpose it over here in such a manner that the point where I wanted to find out the stress matches with the center of this Newmark's chart ok.

The last step is count the number of sectors which are included in this plan when you have superimpose it over here ok. Number of units multiplied by 0.005 times q is going to give you the total state of stress, is this ok, I will show you typically how this is done.

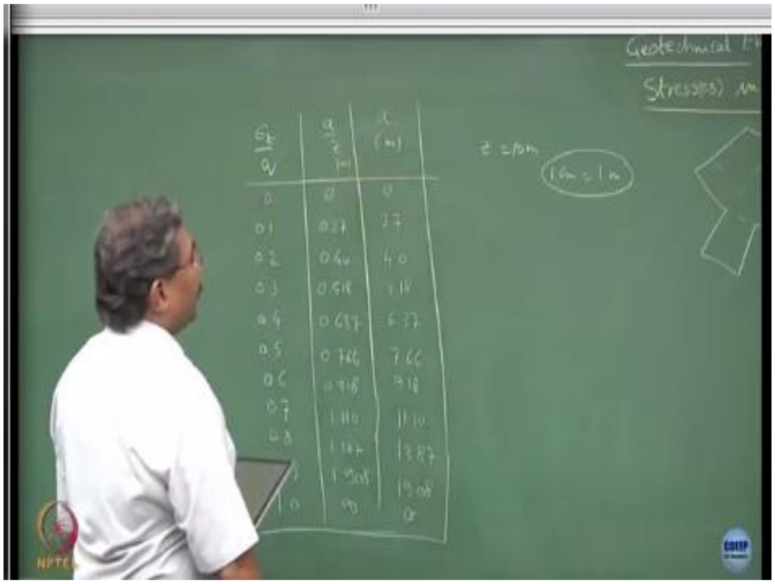
(Refer Slide Time: 24:02)



So these are typical Newmark’s chart, very useful for irregular shape buildings, this is the plan of the foundation which I have plotted on a tracing paper on a scale. This thing has been divided into 200 units, so influence value or the I B value becomes 0.005 times q. If z is known what I can do is this whole thing which is to the scale can be shifted over here and find out what is the state of stress at a point o of your interest as simple as this.

I will just write down few steps, you just follow them you should be aware of you know how these type of things are computed. But in competitive exams yes they will ask these type of questions, so you should practice. So the steps involves are, so suppose if I write down the steps for you, sigma z by q and a by z and a.

(Refer Slide Time: 25:01)



So normally we do it for steps of 0.1, I hope you understand the decimals place indicates I think you are asking this question 0.1 sigma z is 10% of q, 20% of q, 30%, 40, 50, 60, 70, 80, 90 and 100% alright. So in this expression sigma z upon q we have define, so each circle which you have plotting over here corresponds to 10%, 20%, 30%, 40%, 50%, 60%, 100% in the reverse order because this shows that as a increases your sigma z value is going to decrease, so this is 0% and so on.

So suppose if I assume z as 10 meters which is equal to 1 centimeter = 1 meter on a graph plane, I can compute the values of a by z using this expression and this I will be getting as 0.27, 0.40, 0.518, 0.637, 0.766, 0.918, 1.110, 1.387, 1.908 and what about 1, any guess. The moment you substitute the value of a by z = 1, sigma z upon q 100% what is going to happen, this will be tending to infinity.

And then you compute a values from here, so this will be 0, 2.7, 4.0, 5.18, 6.37 these are the radius of the concentric circles. The moment this thing is done it is in meters because z is in meters 1 meter is equivalent to 1 centimeter and hence you can draw the circles. And you can compute the value of sigma z, is this part ok.