IIT BOMBAY

NPTEL

NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

CDEEP
IIT BOMBAY

Geotechnical Engineering Laboratory

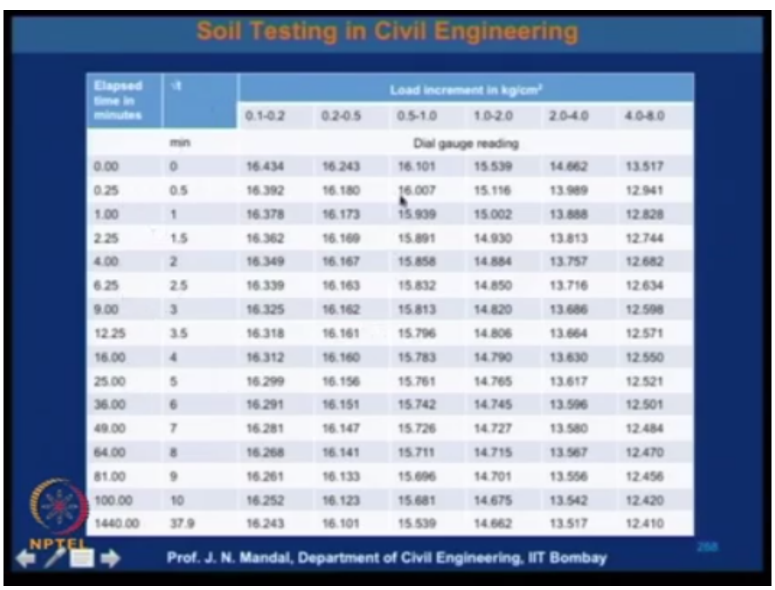
Prof. Jnanendra Nath Mandal
Department of civil engineering, IIT Bombay

Lecture No – 21

Consolidation

Welcome, I am Prof. J.N. Mandal, department of civil engineering in an institute of technology Bombay. I will now show that how you can take the reading in a consolidated meter and you have to take the reading after elapse time, let us see that.

(Refer Slide Time: 00:47)



Elapsed time in minutes	√t	Load increment in kg/cm²					
		0.1-0.2	0.2-0.5	0.5-1.0	1.0-2.0	2.0-4.0	4.0-8.0
	min	Dial gauge reading					
0.00	0	16.434	16.243	16.101	15.539	14.662	13.517
0.25	0.5	16.392	16.180	16.007	15.116	13.989	12.941
1.00	1	16.378	16.173	15.939	15.002	13.888	12.828
2.25	1.5	16.362	16.169	15.891	14.930	13.813	12.744
4.00	2	16.349	16.167	15.858	14.884	13.757	12.682
6.25	2.5	16.339	16.163	15.832	14.850	13.716	12.634
9.00	3	16.325	16.162	15.813	14.820	13.686	12.598
12.25	3.5	16.318	16.161	15.796	14.806	13.664	12.571
16.00	4	16.312	16.160	15.783	14.790	13.630	12.550
25.00	5	16.299	16.156	15.761	14.765	13.617	12.521
36.00	6	16.291	16.151	15.742	14.745	13.596	12.501
49.00	7	16.281	16.147	15.726	14.727	13.580	12.484
64.00	8	16.268	16.141	15.711	14.715	13.567	12.470
81.00	9	16.261	16.133	15.696	14.701	13.556	12.456
100.00	10	16.252	16.123	15.681	14.675	13.542	12.420
1440.00	37.9	16.243	16.101	15.539	14.662	13.517	12.410

Here I am showing that 00.25 like that 1.09, 2.48 and you continue take the reading like that upto 14.40 minutes and this is the root T time in minutes, so this is for root this value is also given that is 0 this is 0.5 this is 1, 1.5 like that you continue upto 14.40 that is it will be about 17.9 and this is the root of T value, so you have to apply the load and initial load in a consolidate meter is 0.12, 0.2 kg/cm^2.

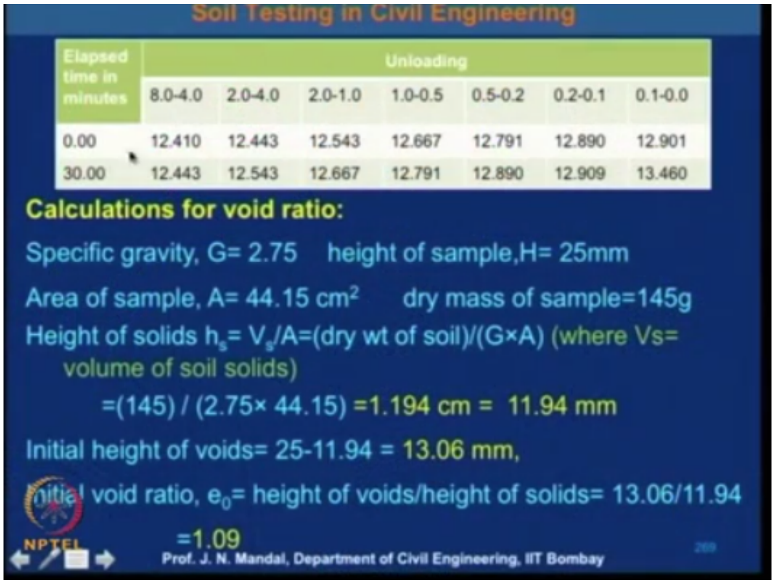
You apply the load o.1 to 0.2 kg/m^2 and it keep on take the reading in a dial gauge reading, so this is the dial gauge reading starting from 16.634 then at a time of 0.2^5 then your dial gauge reading is 16.392 like that you continue after the different elapse time you take the dial gauge reading or a loading of 0.12 to 0.2 kg/cm^2, if take the reading and this last reading is about what 16.243, okay.

Then again you start from the beginning that is next after the 14.40 hour and you in case that load that is 0.2 to 0.5 kg/cm^2 and then you are taking the reading or the different time okay let us say 0.254 you are taking the reading about 16.180 okay, it keep on reading like that under the different elapse time upto 14.40 okay. And then at a load of increment of 0.2 to 0.5 kg/cm and this lasted in his 16.101, so this was the 16.101 again then again you are engage the loading, okay.

That is 1. 0.5 to 1.0 then you take the reading again that initial reading is 16.601 and under the different elapse time you keep on take the reading and the after the 14.40 hour that is load of 0.5 to 0.10 you are having a dial gauge reading about over 15.539 then again you apply the load increment 1 to 2 then keep on reading like that from 0 to 49 to put your, then again you increase the load from 2.0 to 4.0kg/cm^2 and under the different elapse time you take the reading like this.

And then again finally 4.0 to 8. 0 kg/cm^2 increment loading then you take the reading, okay under the different elapse time. So you know that how to take the reading with the incremental of the load and after the loading again you require for unloading, so we can unload this.

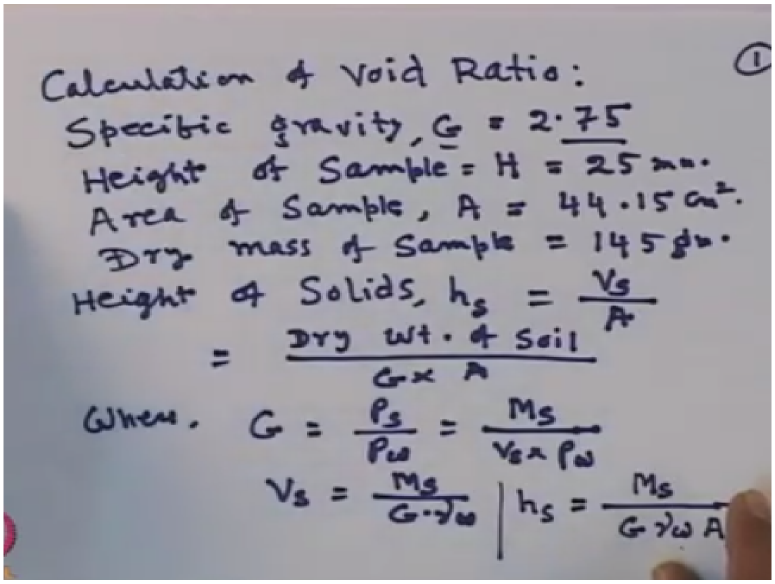
(Refer Slide Time: 05:26)



So this is the unloading let us say 0.0 and then at a time of 30 minutes you can see this was the initial loading under the load of initially 8 to 4 kg/cm^2 then you unload it at particular time you are having this targets reading 12.443 when you are unloading, then from 2 to 4 kg/cm^2 and after 30 minutes 12.543 then 2 .0 to 1.0, 1.0 to 0.5, 0.5 to 0.2, 0.2 to 1.00 and then 0.1 to 0.0 and ultimately you can have this dial gauge reading in 30 minutes, okay.

Then this is the unnecessary unloading condition, the earlier one it was the loading condition and from this reading you can calculate the different value, I am showing that I have to calculation of the void ratio right so that calculation.

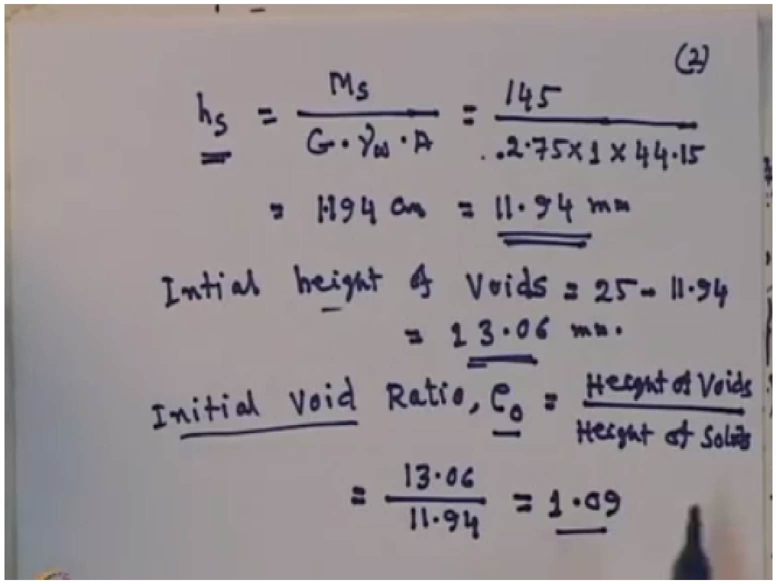
(Refer Slide Time: 06:30)



Calculation of void ratio, so this calculation of void ratio to calculate the void ratio you should know what is specific gravity so let us say specific gravity of soil is G = 2.75 and you know that height of the sample in a consolidate meter that is height of the sample let us say that is is equal to H = 25mm then area of the sample that designated at A = 44.15 cm^2 you can calculate that what should be the dry mass of the sample so let us say dry mass of the sample = 145 gram, then you can calculate what should be the height of solid which is designated at $h_s = V_s /A$ that means this is dry weight of soil this divided by G x A so for whereas you know that $G = \rho_s / \rho_w = M_s/V_s \times \rho_w$ so you can write that $Vs = M_s / G \gamma_w$ so you know the V_s.

So $V_s = M_s / G \gamma_w \times A$ okay so just like we can write that dry weight of the soil that what will be the dry weight of the soil/ G x A, so this you can write you know that what is that M_s you know that what will be G value you know that this is $\gamma_w = 1$ so in place of V_s you can write $Vs = M_s / G \gamma_w$, so that means height of the solid that means h_s we can write $Vs = M_s / G \gamma_w$, okay. That means you can write what will be the weight of the solid this divided by G and this is γ_w x this is A.

So now if you substitute the value that diverse of the solid of the soil so this is $M_s = 145$ and G value is given 2.75, γ_w is 1 and A value is given 44.15, so we can write that h_s that means.
(Refer Slide Time: 11:03)

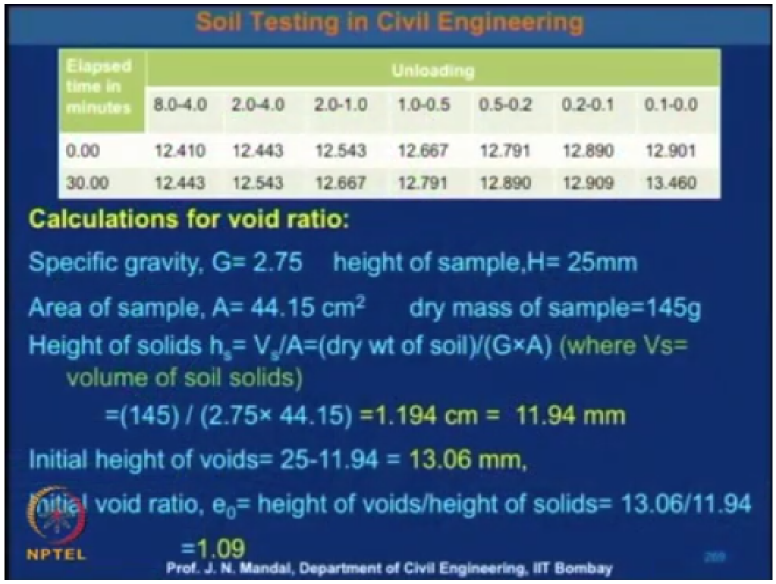


H_s is a M_s / G γ_w x A so this is solid is 145 okay so you can write 145 this divided by and G value is given 2.75 so this is. While next we can write that h_s = M_s / G x γ_w or ρ_w x A so you know that M_s we have calculated dry mass weight 145 so you can write 145 this divided by G value is 2.75 so G value is 2.75 or a γ_w or ρ_w = 1 x the area 44.15 this is 44.15 okay. Now if we calculate then we can write that height of the solid will be equal to 11 or 1.194 cm or is equal to 11.94 mm.

So we calculate the height of the solid is 11.94 mm, now you should know what will be the initial height of void, okay. Initial height of void we know that in the beginning that height of the sample was 25 mm so initial height of the void 25 mm – 11.94mm this is height of the solid, so this if you subtract you can have the initial height of the void that is 13.06 mm, okay. So from this you can calculate the, what should be initial void ratio.

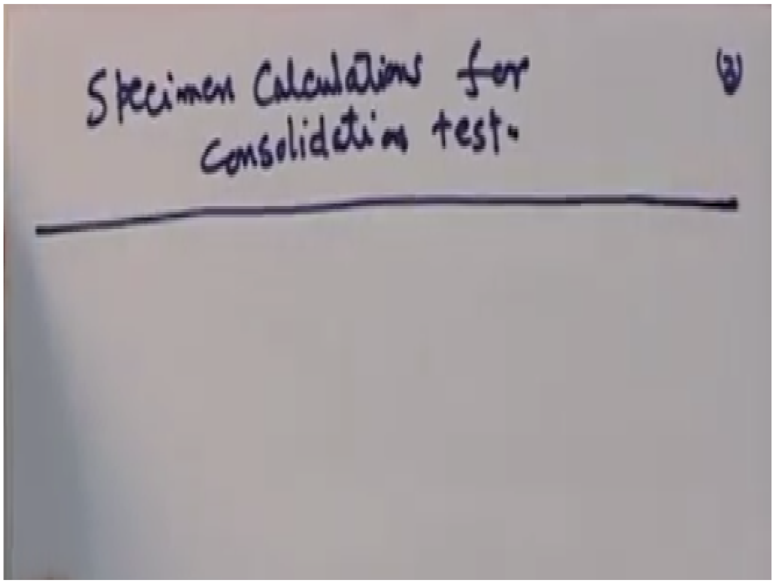
And this is designated at e_0 so e_0 will be what will be the height of the void this divided by height of solid, so what is the height of the void, height of the void 13.06 so you can write 13. 06/ height of the solid so here we calculate height of the solid 11.94 so this is 11.94. So if you calculate then you can have the initial void ratio e_0 that is will be 1.09, so you can calculate that what will be the initial void ratio that is 11.09.

(Refer Slide Time: 15:26)



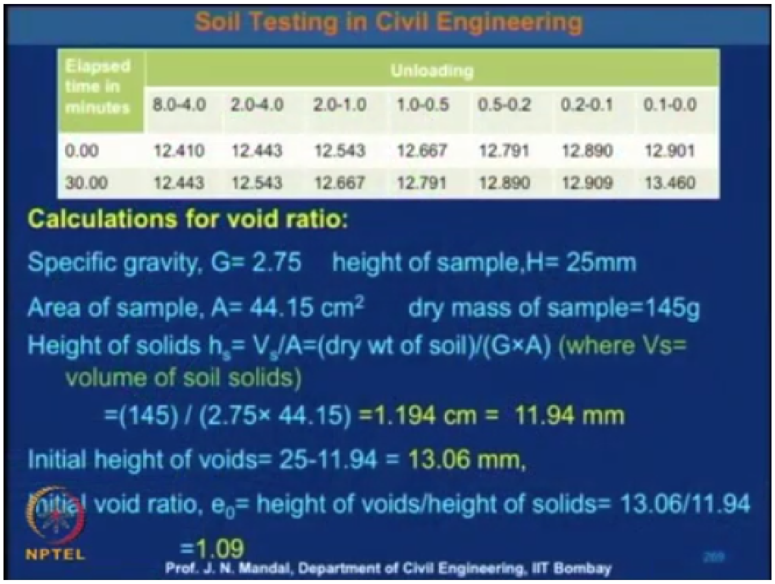
Now I will show you some specimen.

(Refer Slide Time: 15:29)

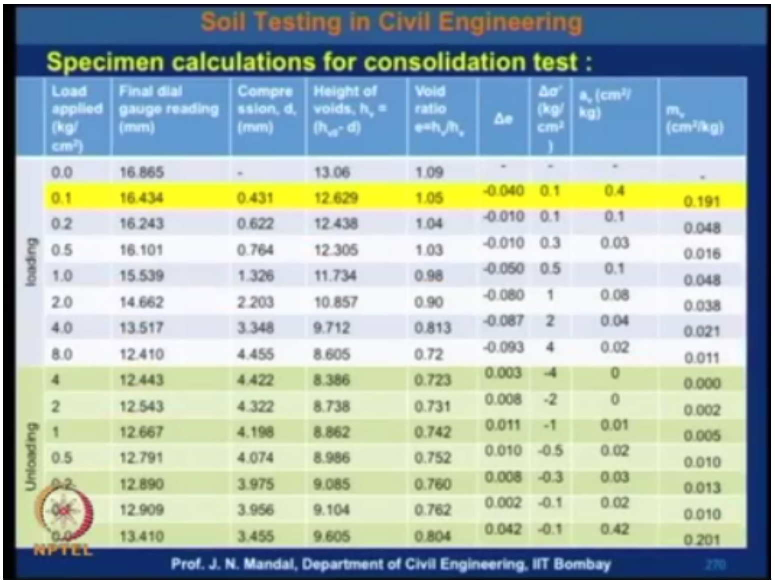


Specimen calculation for consolidation test, some specimen calculation I am showing here that.

(Refer Slide Time: 15:59)



(Refer Slide Time: 16:02)



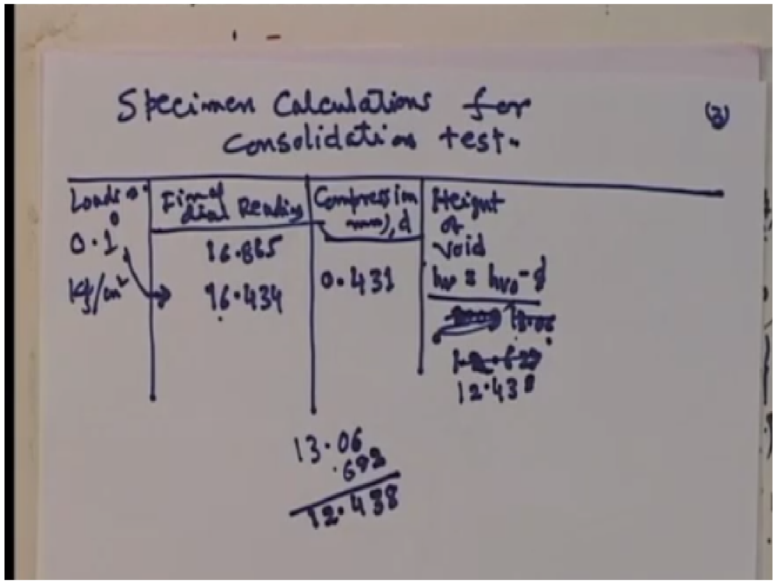
	Load applied (kg/cm²)	Final dial gauge reading (mm)	Compression, d, (mm)	Height of voids, $h_v = (h_{v0} - d)$	Void ratio $e = h_v/h_s$	Δe	Δσ' (kg/cm²)	a_v (cm²/kg)	m_v (cm²/kg)
loading	0.0	16.865	-	13.06	1.09	-	-	-	-
	0.1	16.434	0.431	12.629	1.05	-0.040	0.1	0.4	0.191
	0.2	16.243	0.622	12.438	1.04	-0.010	0.1	0.1	0.048
	0.5	16.101	0.764	12.305	1.03	-0.010	0.3	0.03	0.016
	1.0	15.539	1.326	11.734	0.98	-0.050	0.5	0.1	0.048
	2.0	14.662	2.203	10.857	0.90	-0.080	1	0.08	0.038
	4.0	13.517	3.348	9.712	0.813	-0.087	2	0.04	0.021
	8.0	12.410	4.455	8.605	0.72	-0.093	4	0.02	0.011
Unloading	4	12.443	4.422	8.386	0.723	0.003	-4	0	0.000
	2	12.543	4.322	8.738	0.731	0.008	-2	0	0.002
	1	12.667	4.198	8.862	0.742	0.011	-1	0.01	0.005
	0.5	12.791	4.074	8.986	0.752	0.010	-0.5	0.02	0.010
	0.2	12.890	3.975	9.085	0.760	0.008	-0.3	0.03	0.013
	0.1	12.909	3.956	9.104	0.762	0.002	-0.1	0.02	0.010
	0.0	13.410	3.455	9.605	0.804	0.042	-0.1	0.42	0.201

This is the table for specimen calculation so initially we have to apply the load 0.1 kg/cm^2 to upto 8kg/cm^2 in to the soil sample okay. The you unload the sample that is 4 then 2, 1 then 0.5, 0.2, 0.1 and 0 so this part is the loading okay this is the load gap light in kg/cm^2 from 1 to 8 kg/cm^2 you unload the sample that is 4kg/cm^2 to 0.1 kg/cm^2 then you take the final dial gauge reading so you are starting reading is initially it is 16.68 this is 16.865 then 16.434 like that you are taking this dial gauge reading.

And dial gauge reading you can say it is decreasing then at the load of 8 it is 12.410 so then you have to determine that what will be the compression in mm, okay. I will show you one of the under the loading of 0.1 kg/cm^2 and this is the dial reading 16.434 then what should be the compression, okay under the loading of 0.16/cm^2 this I will only show you and then accordingly you can also calculate what the other loading and also reloading, unloading.

So this is 16.43 so compression your d in(mm) is 16.865 – 16.434s okay, so you can have the compression value 0.431 I am showing here that you are calculating that compression so okay.

(Refer Slide Time: 19:11)

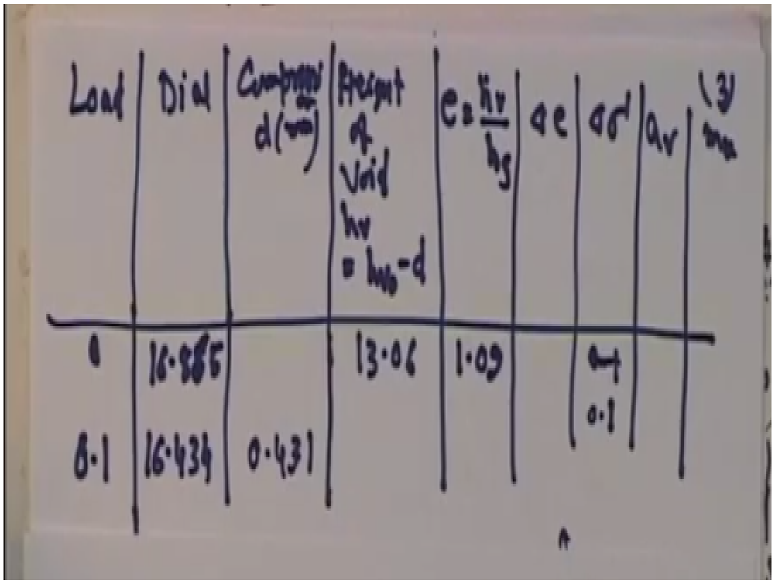


So let us say that at a particular loading when loading is 0.1 kg/cm^2 this is kg/cm^2 and then you are taking what will be the final dial reading and let us say that at the 0 loading so you are having the dial gauge is 16.865 and for this one loading you are having 16.434, so then you calculate what is the compression okay in mm so compression will be 16.865 – 16.434 so this will give you 0.431mm.

So you can calculate that what will be the compression, okay. That is compression is d. Now you can calculate the, what should be the height of void, okay. Height of void that means $h_v = h_{v0} – d$ this is d, so what is the h_{v0}? So h_{v0} initially we take the reading and for 0 it is your 1.09 okay and for a load of $1kg/cm^2$ then height of void will be equal to let us say that this is height of void during is equal to $h_{v0} – d$.

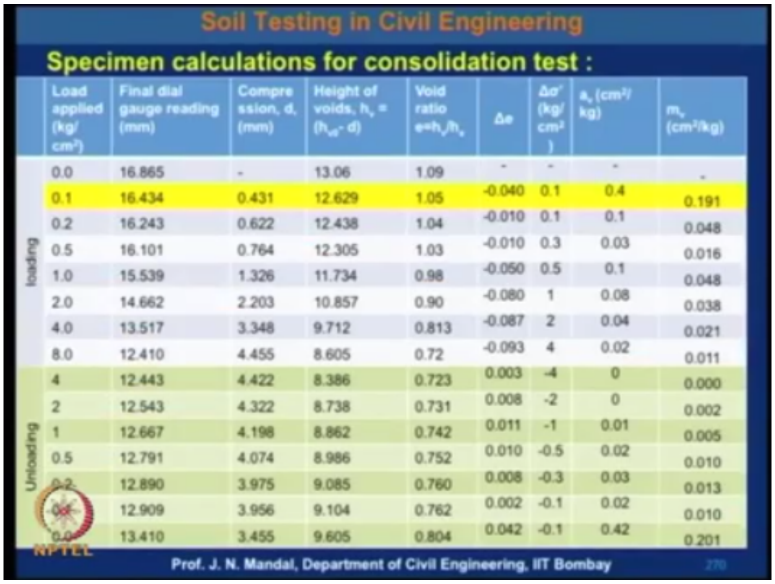
That means initial void will be the 13.06 and then under the load of $1kg/cm^2$ this is 16 point 12.629, okay. So this is the $h_v = hv_0 –d$ so what is h_{v0}? H_{vo} is 13.06 that means if I write 13.06 h_{v0} and this minus that 0.692 this one 692, 0.69 this is 2 so this will give you the value of 12.438 so this value h_0 $V_0 – d$ will be equal to your 12.438 weight.

(Refer Slide Time: 23:26)



Repeat so here I am showing one that calculation for the load increment called 0.1 kg/cm^2 or 0.0 this is the final dial gauge region that is 16.865 and for 1th loading is 16.434, okay.

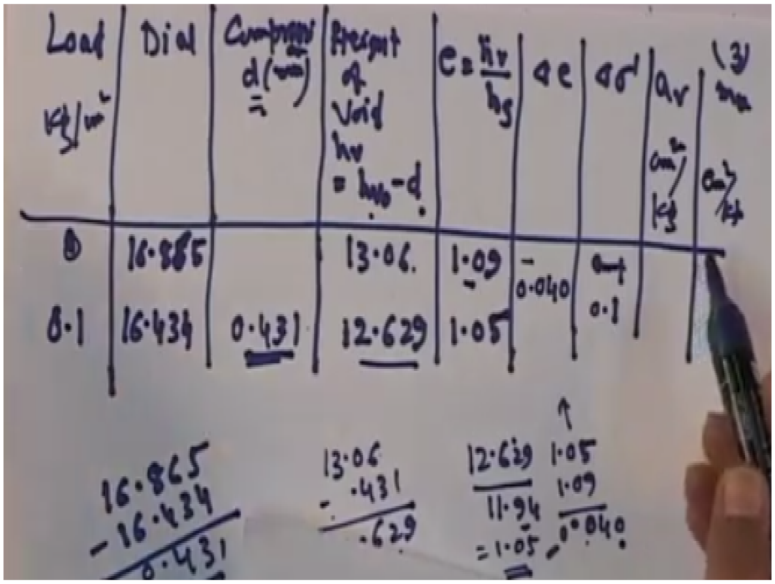
(Refer Slide Time: 24:09)



	Load applied (kg/cm²)	Final dial gauge reading (mm)	Compression, d, (mm)	Height of voids, $h_v = (h_{vo} - d)$	Void ratio $e = h_v/h_s$	Δe	$\Delta\sigma'$ (kg/cm²)	a_v (cm²/kg)	m_v (cm²/kg)
loading	0.0	16.865	-	13.06	1.09	-	-	-	-
	0.1	16.434	0.431	12.629	1.05	-0.040	0.1	0.4	0.191
	0.2	16.243	0.622	12.438	1.04	-0.010	0.1	0.1	0.048
	0.5	16.101	0.764	12.305	1.03	-0.010	0.3	0.03	0.016
	1.0	15.539	1.326	11.734	0.98	-0.050	0.5	0.1	0.048
	2.0	14.662	2.203	10.857	0.90	-0.080	1	0.08	0.038
	4.0	13.517	3.348	9.712	0.813	-0.087	2	0.04	0.021
	8.0	12.410	4.455	8.605	0.72	-0.093	4	0.02	0.011
Unloading	4	12.443	4.422	8.386	0.723	0.003	-4	0	0.000
	2	12.543	4.322	8.738	0.731	0.008	-2	0	0.002
	1	12.667	4.198	8.862	0.742	0.011	-1	0.01	0.005
	0.5	12.791	4.074	8.986	0.752	0.010	-0.5	0.02	0.010
	0.2	12.890	3.975	9.085	0.760	0.008	-0.3	0.03	0.013
	[illegible]	12.909	3.956	9.104	0.762	0.002	-0.1	0.02	0.010
	0.0	13.410	3.455	9.605	0.804	0.042	-0.1	0.42	0.201

So here I am showing for 1kg.

(Refer Slide Time: 24:16)

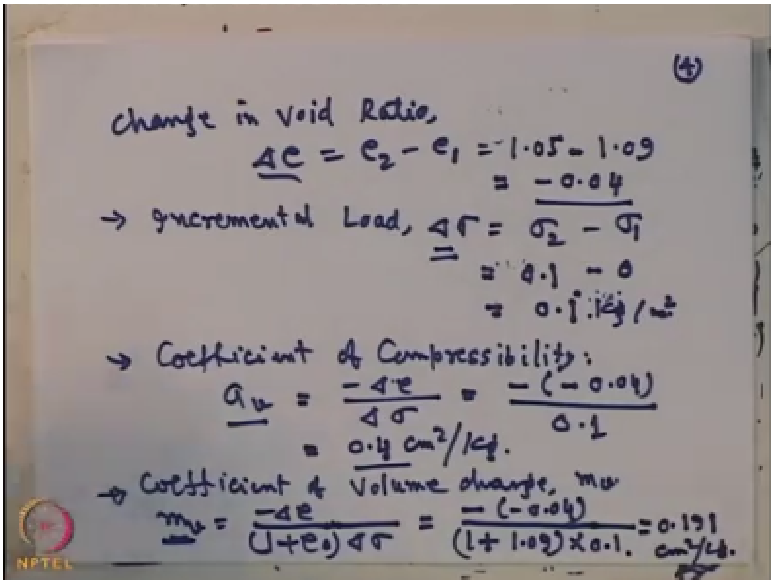


Loading that is loading is kg/cm^2 you are having the dial gauge reading 16.434 so compression that is d in mm will be 16.865 – 16.434 so if you deduct you can have 0.431 so this is 0.431 that is d compression, now height of the soil under o load it was 13.06 so height of the void is equal to h_{vo} – d so initially we have calculated that what is h_{vo} so initial height h_v , h_{v0} will be equal to here that initial height of the void 13.06 so initial height is 13.06.

So h_{v0} 13.06 as I showed you –d so h_{v0} 13.06 – 431 that means 12.629 so we can write 12.629. Now you calculate what will be the void ratio that is the e okay so void ratio = e = height of void/ height of solid, okay. So initially this value initial void ratio value we have calculated earlier that is e_0 = 1.09, so it is 1.09, okay. So 1, here 1.09 then next at 0.1 kg/cm^2 of loading so we have to check what will be the void ratio, that means this is h_v = 12.629 here 12.629/ height of the solid. So height of the solid we calculated 11.94 so this is height of the solid 11.94. So 12.629 is the h_v or a load of 0.1kg/cm^2 and height of the solid as I showed you height of the solid is about 11.94, okay.

So 12.629/11.94 it gives 1.05 so here e value will be equal to 1.05 so it will be 1.05 then you calculated Δ(e) okay change in void ratio so change in void ratio 1.05 – 1.049 that means it will give -0.040 so we can write here -0.040 that is change in the void ration. So you can calculate that what will be the change in the void ratio. So similarly you can calculate what will be the Δv does, a_v and the m_v. So a_v can be expressed at cm^2 /kg and m_v also can be expressed as cm^2/kg now how to calculate the a_v value, okay and how to calculate the m_v value?

(Refer Slide Time: 28:43)



I am showing it, let us say change in void ratio that is $\Delta(e) = e_2 - e_1$ that is 1.05 – 1.09 so this will be -0.04 what I showed you in this table that is 0.04 void ration change in void ratio, now incremental, incremental load that is $\Delta \sigma = \sigma_2 - \sigma_1$ what is σ_2 is $0.1 kg/cm^2$ and initial loading = 0 so Δ σ = 0.1 so this Δσ = 0.1 because initial loading is 01 and this is 0, so 0.1 – 0 will give the Δ σ that is 0.1

So this Δ of σ = 0.1 that is kg/cm2 so this Δ σ is kg / cm2, now we have to calculate that a_v that means coefficient of compressible reading so this coefficient of compressibility can be express as a_v = - Δe / Δσ that means – 0.04 this is Δe = - 0.0 this divided by Δ of σ that means this Δ σ = 0.1, so if you calculate we can have the a_v = 0.4cm2 / kg so you can calculate a_v 4 kg/cm2 so we can write this is a_v value = 0.4 a_v / this cm2 / kg so a_v 0.4 kg/ cm2.

Now we have to calculate that what is m_v that means coefficient of volume change, so m_v coefficient of volume change that is m of b so we know that equation m_v = - Δe / 1 + e of 0 into Δσ, so this is – Δ is – 0.04 / 1+ e0 means 1 + 1.09 we have calculated already here and this into Δσ is at a load of 0.1 Δσ. So if you calculate this we can have 0.191 that is cm q/kg so this is coefficient of balloon change m_v = 0.19/ cm2, so we can write here m_v that means 0.191 cm2/kg so you know that e0 this value is known.

That is a 1.09 e_0 and get the σ means increment we have calculated here 0.1kg so 0.1 kg so and Δ you know 0.04 so you can have the value of m_v, so we can calculate in this table all the value what is the a_v what is the m_v value so this value is important.

NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING (NPTEL)

NPTEL
Principal Investigator
IIT Bombay

Prof. R. K. Shevgaonkar

Head CDEEP
Prof. V. M. Gadre

Producer
Arun Kalwankar

Online Editor& Digital Video Editor
Tushar Deshpande

Digital Video Cameraman& Graphic Designer
Amin B Shaikh

Jr. Technical Assistant
Vijay Kedare

Teaching Assistants
Ankita Kumar
Sunil Ahiwar
Maheboobsab Nadaf
Aditya Bhoi

Sr. Web Designer
Bharathi Sakpal

Research Assistant
Riya Surange

Sr. Web Designer
Bharati M. Sarang

Web Designer
Nisha Thakur

Project Attendant
Ravi Paswan
Vinayak Raut

Music
Standard Sandwich- by smilingcynic