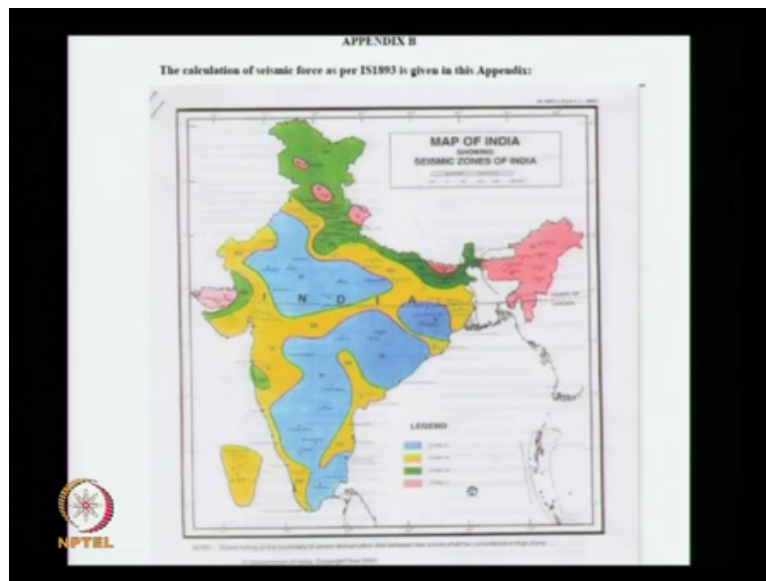


**Port and Harbour Structures**  
**Prof R Sundaravadivelu**  
**Department of Ocean Engineering,**  
**Indian Institute of Technology Madras**  
**Module 4, Lecture 23**  
**Estimation and Seismic Forces**

This class we will be discussing about Seismic force calculation. This will be calculated as per this IS code.

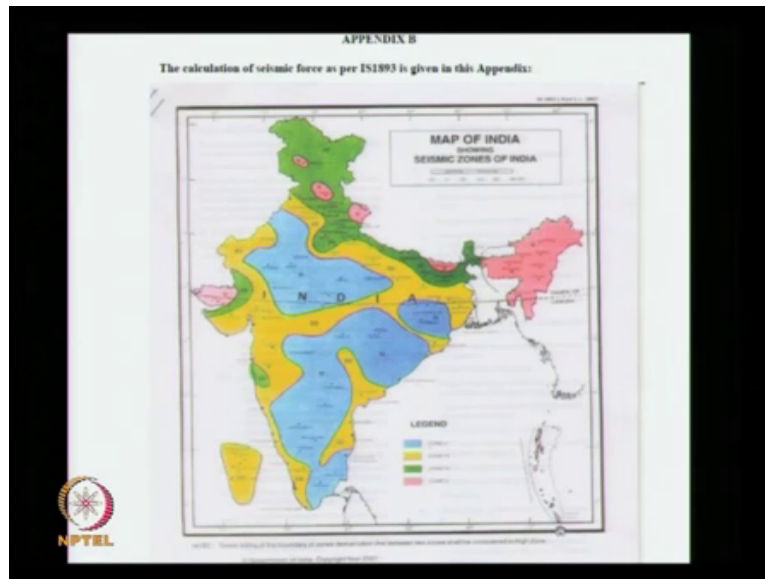
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This IS code number is 1893 eighteen ninety three is revised in 2002. There is a appendix B in which this figure is given. How many of you have seen this map before? Civil engineering students, hmm nobody has seen this map, how many of you have seen India map? I am really asking, have you seen India map? Ok what is this part? What is this, hmm? This one these are also part of India. So there are different colours given. Can you identify the colour? Blue then yellow then green then pink. Is really pink here? Light pink, ok. What does it mean?

Which is very severe earth quake? I do not know whether you are able to see this, you are able to see what is this zone? Zone 5 it starts from zone 2. So you have a earlier fear 1893 I will show it towards the end of my power point presentation where we have zone 1, zone 2, zone 3, zone 4, zone 5. India is divided into 5 zones, right? But now India is divided into 4 zones. The zones are zone 2, zone 3, zone 4 and zone 5. You can compare and see that most of the zones are most of the places upgraded to 1 zone above.

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So this blue colour you can see these are all the zone 2 where the intensity is less. And the pink colour intensity is high. Where are the pink colours in India, Gujarat North east and hmm? Andaman Nicobar islands you are missing the important thing pink colour is shown elsewhere also what is it? Not only north east that is a Himalayan belt hmm this all these locations na is that all part of Himalayas, ok. And green colour is zone 4 is all Himalayan ranges only.

So there it is as I have told to lot of Seismic activities. Then we have the yellow colours. Mostly yellow colour is in the coastal region and there is a connection here between these two. Yellow colour is zone 3 actually (03:18) is in zone 3 not in zone 5. So this seismic force controls the design of the structure if it is in zone 5 or zone 4. So where we have earth quake which port we had earth quake? Recent times? What are the two earth quakes that has occurred very recently. Earth quake is occurring every day, every year also it may be there.

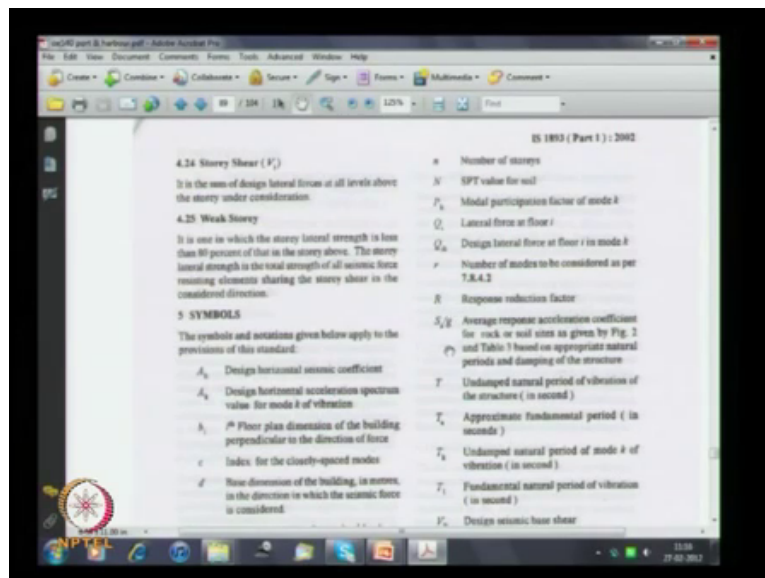
Two severe earth quakes in this decade what are they? Bhuj earth quake, then another earth quake. You know Tsunami right? When did it happen? 2006, Why it happened? 2006, 2004 why it happened? Bhuj when it has happened Bhuj earth quake. 2001, ok. When did it happened? Jan 26. What about Tsunami? December? I do not know, hmm ok. Tsunami why did it happened? Hmm? It also happened because of earth quake only what intensity? 8.1 hmm? 9.2 or 9.3 what is the maximum value? Bhuj earthquake 7.2, 7.3.

See this Tsunami has taken place in Indonesia that island is very close to this the tip of Indira point. There is a point here which is called as Indira point tip of Nicobar island. That earth quake occurred all along this plane also. There is a spot line which goes like this, it happened all along this. Earth quake happened not only at Indonesia or the tip of Indonesia It has happened in Port Blair also. You are aware of this or you do not know that. Major earth quake has happened in recent times.

Whenever you see the code you will be getting this information you have to read, how many of you have read any code? Hmm? Any code what code you have read? IS456 You have not studied IS 890 1893. How to get these codes? You know how to get? Please try to use it if you are going outside may not be able to get all these codes. There is list of IS codes which are to be used I saw it today somewhere which are useful please download and put it in the memory stage.

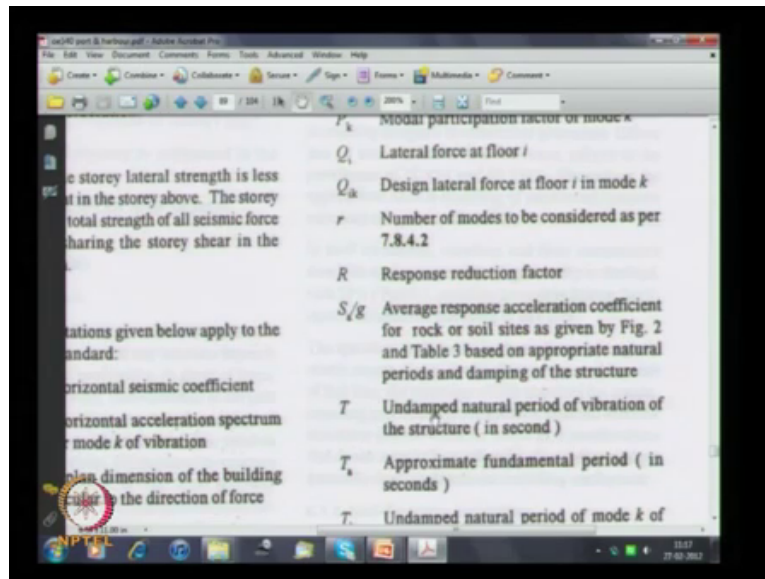
Then download no all the IS codes. Please do it, if you go outside if you are going for a software company their management do not do it. IF you want to do core engineering you please download. Mechanical engineering also there are lot of codes which you can get it from IIT very difficult to get outside. When I said it I bought all these codes paying money.

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There is a parameter given here S A B Y G Average response acceleration coefficient this we will be using or is the response reduction factor. This also we will be using the design.

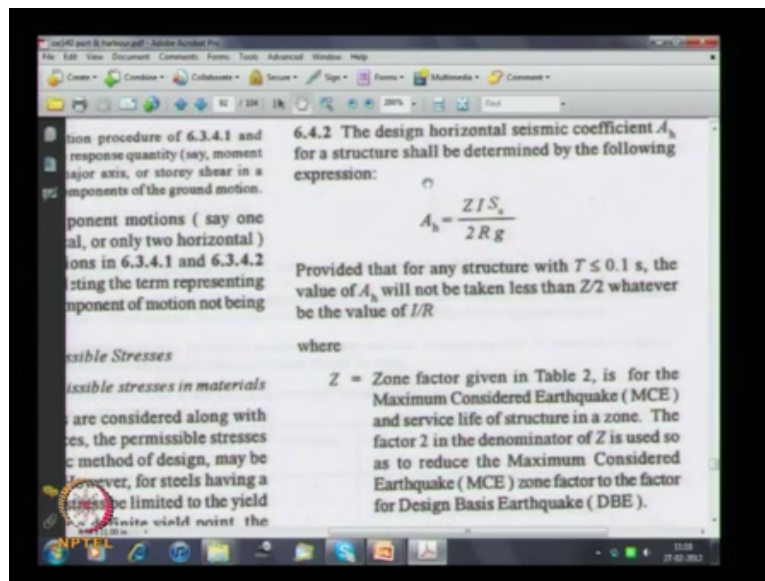
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This  $T$  is given is called as Undamped natural period of vibration of the structure in second. What is natural period? You know what is natural period. You say yes or know only one answer is there. Hmm? I think you are keeping quite means you know something and you do not know completely. You have not studied what is natural period. Omega is equal to root of  $k$  by  $m$ . How many of you know? Hmm? All are civil engineers, mechanical engineers should also know how many mechanical engineer raise your hand.

You also should know. You have not studied Omega is equal to root of  $k$  by  $m$ , hmm? Studied or not studied? Studied sir, mechanical? Yes sir. What is omega? Natural period, what is  $k$ ? Stiffness  $m$  is mass. The frequency omega is equal to  $2\pi$  by  $T$  the  $T$  is equal to natural period. I will tell you after some time how to calculate that for a cantilever. For a cantilever how to calculate a natural period have you written any problem not done I will tell.

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So this  $A_h$  is called as the seismic coefficient this is called as the design horizontal seismic coefficient. Seismic coefficient you know horizontal means in the horizontal direction. What is design? Always we use what is design. This design means want to use it for the purpose. It can be more than the probability of a currents or less than the probability of a currents. In this case we use  $E_z$  by 2,  $E_z$  is a son factor that divided by 2 is what we use.

This is design basis earth quake,  $E_z$  by 2. It is likely that the maximum earth quake coefficient can be  $E_z$ . But we are using only  $E_z$  by 2. So the structure files do not go and kill the engineer (10:30). We do not design, is it clear we do not design it for the maximum credible earth quake. Maximum credible earth quake is equivalent to  $E_z$ . What we are doing is for  $E_z$  by 2. (10:45) power plant is designed for  $E_z$  or they might have designed even more than  $E_z$ .

Most of the temples which have survived so many earth quakes and Tsunamis in India they are all designed for very high earth quake coefficients. So if you see the palaces of south Indian princess now no palace is available except this Thirumalai nayakar mahal. Whereas most of the temples are existing because they have assumed a very high factor of safety. Eye is a important factor here only it comes into picture. Important factor can be 1 or 1.5. So if it is a very important structure we use important factor of 1.5.

What is the response reduction factor it depends on the ductility of the system.  $S_A$  BY  $G$  is the seismic coefficient that depends on the natural period of the system.  $S_A$  is Seismic

Acceleration and is normalized with the acceleration due to gravity. Son factor is given in table 2. This is for the maximum considered as I said credible that is not correct. Maximum considered earth quake and service life of structure in a zone the factor 2 in the denomination of wizard is used first to reduce the maximum considered earth quake son factor to the factor of design basis earth quake.

I will ask these questions. What is MCE and what is DBE? You have to explain. What is MCE and What is DBE? Importance factor I already applied it is depending on the hazardous consequences of its failure. Water tanks are designed for very high importance factor, schools, public buildings, libraries, temples, common markets, we have to design for malls also (( ))(12:50) in the mall. Hazardous consequence of its failure means dams. There is a failure of a dam it will create lot of problem, so these things we have to see.

Post earth quake functional needs. What do you need after earth quake what building you need after earth quake? What building you need to survive after an earth quake. Hmm? Hospital, Hospital is correct so hospital is to be designed for historical value. What is a historical value? How many monuments are there in Chennai? Historical value, hmm? Have you seen any historical building in Chennai? Hmm? No building is there? All of you made a pass through that building, hmm? Centre station? Centre station is a historical building, any other building?

Recently there was a fire accident which building? Chennai there was a fire accident in one of the building which building it was? [Ezhilagam](#), You do not read news paper and all [Ezhilagam](#) have you seen where it is? See there are many buildings with just opposite our IIT campus there is a historical building, what is that? Anna university, Guindy Engineering college building is one of the historical buildings. This, this there is a footnote which you should see the ratio of IBR shall not be greater than one, ok. This you have to see do not substitute some values and get IBR greater than 1.

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values of Importance Factor  $I$ , Response Reduction Factor  $R$ , and damping values are given in the respective parts of this standard. The method (empirical or otherwise) to calculate the natural periods of the structure to be adopted for evaluating  $S_a/g$  is also given in the respective parts of this standard.

**Table 2 Zone Factor,  $Z$**   
(Clause 6.4.2)

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
$Z$	0.10	0.16	0.24	0.36

6.4.3 Where a number of modes are to be considered for dynamic analysis, the value of  $A_h$  as defined in 6.4.2 for each mode shall be determined using the following provisions:

For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15T; & 0.0 \\ 2.50 & 0.1 \\ 1.00/T & 0.4 \end{cases}$$

For medium soil sites

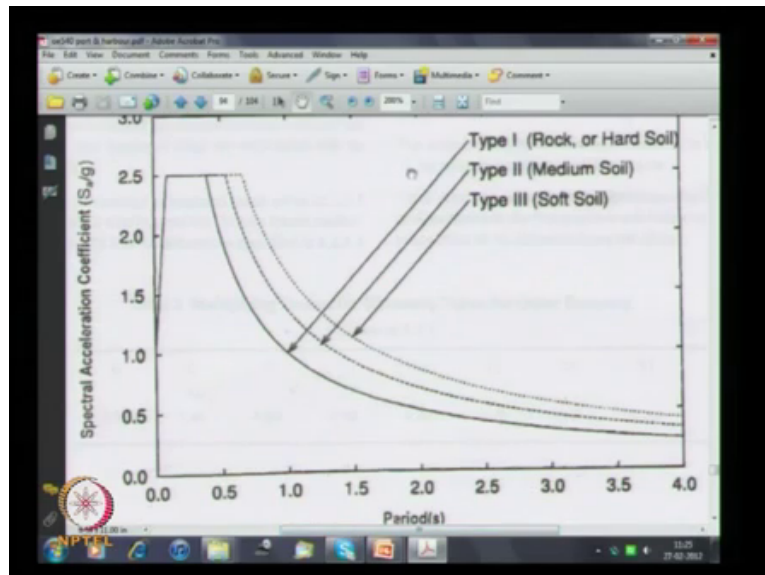
$$\frac{S_a}{g} = \begin{cases} 1 + 15T; & 0.0 \\ 2.50 & 0.1 \\ 1.36/T & 0.5 \end{cases}$$

motions, when required, may be of the design horizontal acceleration in 6.4.2.

Figure 2 shows the proposed 5 rocky and soils sites and Table 3 g factors for obtaining spectral value dampings.

This is a zone factor  $z$ , zone factor  $z$  is zone 2, zone 3, zone 4, zone 5 values varies from 0.1, 0.16, 0.24 and 0.36, these are the values.

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Then we use this graph whenever you want to present a graph you will be making some presentation in future also. Whenever you do you define what is the x axis? What is x axis? Period means natural period of a structure in seconds. What is a range given? What is the natural period range given. What is a range? 0 to 4 second most of our berthing structure will be very close to one second. What is the natural period of Jacket platform.

M Tech Engineering you have studied no what is natural period? 2 to 4 second, if it is very close to 4 second then we have to consider dynamics most of the platform are between 1 and 2 second only. With increase in  $(\omega)$ (16:57) what will happen to natural period, hmm? It will increase Omega is equal to root of k by m. So it will discuss later. What is the maximum? What is y axis ? It is called as petrol acceleration coefficient S A BY G

What is the maximum value? 2.5 this spectral acceleration can be 2.5 times the acceleration due to gravity. We need very less value, suppose somewhere here we are it is better. They do not give more than 4 that does not mean your natural period will not be more than 4. It means it is asymptotic the value will not increase further. The (maximum) the minimum value will be somewhere around 0.2. What are these three curves? These three curves are depending on the type of soil. If the soil is rock, medium soil, or soft soil depending on the curve will change.

Where do you want the natural period of structure? Where do you do not want the, where do not you want the natural period of the structure? We do not want the natural period of the structure somewhere here. Then we will have a very high Seismic Acceleration coefficient, so we do not want to have it here. So if the soil is a soft soil it has a suppose you take 1 as a period you go vertically here what happens, if it is a rock it is near about 1. If it is soil it is near about 1.8, so the better the soil your seismic acceleration coefficient will be lesser.

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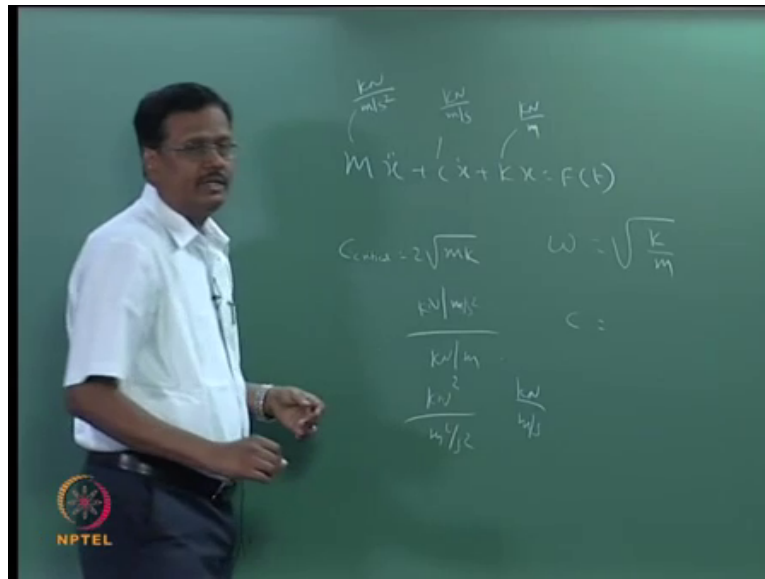
Table 3: Multiplying Factors for Obtaining Values for Other Damping  
(Clause 6.4.2)

Damping Ratio (%)	0	2	5	7	10	15	20	25
Multiplying Factor	1.40	1.00	0.90	0.80	0.70	0.60	0.55	

How many of you know damping? What do you understand by damping?



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How many of you know this equation? Hmm? You have not studied this equation. Mechanical Engineering you have not studied, hmm? Studied or not studied? Studied Sir, everybody has studied. What is M? Mass, what is C? (19:45) What is k? (19:47). What is critical damping? You have studied this equation, critical damping is c is equal to 2 into root of m k, m is mass what is the unit of mass? What is the unit of stiffness? Kilo Newton per meter what is the unit of x hmm? Meter, what is the unit of x dot meter per second unit of x double dot meter per second square.

So c will be kilo Newton divided by meter per second MNB kilo Newton divided by meter per second square. So if we multiply with x double dot it will give kilo Newton multiply with x dot you will get kilo Newton, if you multiply with x you will get kilo Newton. Force also is kilo Newton. What is the unit of this m into k. If you multiply what you will get? What will you get?

You do it yeah simply you have a notebook you write something, you multiply what is the unit for uhh m, m is kilo Newton divided by meter per second square is kilo Newton per meter . So this will be kilo Newton per square by meter square by second square. If we take a root of that it will become kilo Newton by meter per second, whenever you write any derivation or equation you check the units. This is a very simple way of doing it. You do not get it properly then there will be a problem.

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Damping, percent	0	2	5	7	10	15	20	25
Multiplying factors	3.20	1.40	1.00	0.90	0.80	0.70	0.60	0.5

So what is written here is uhh, what is written here damping percent 5 percent damping the factor is 1. So the whatever S A B Y G you got this is for a particular damping that damping is 5 percent. I have derived a curve right? We have shown a curve just now the curve Sa by g values are given for 5 percent damping because the factor is 1. If the damping is less what will happen? Acceleration coefficient will increase; the damping is more the acceleration coefficient will come down. So this percentage is related to the critical damping c is equal to this percentage damping multiplied by critical damping.

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$$c = (\% \text{ damping}) \times C_{crit}$$

Any doubts see what here we have written is  $c$  is equal to some percentage damping multiplied by  $c$  critical. So damping is so low 5 percent damping is normally used. What about offshore structures in water we will have higher damping or lower damping? You have a structure in water which will have more damping water will have more damping. So if the structure is 5 percent damping in water it will be about 10 percent or sometimes some floating platform may have even 20 percent damping.

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The screenshot shows a presentation slide titled "Table 7 Response Reduction Factor  $R$ , for Building Systems (Clause 6.4.2)". The table is as follows:

No.	Lateral Load Resisting System	(2)
<i>Building Frame Systems</i>		
i)	Ordinary RC moment-resisting frame ( OMRF ) <sup>2)</sup>	
ii)	Special RC moment-resisting frame ( SMRF ) <sup>2)</sup>	
iii)	Steel frame with	
	a) Concentric braces	
	b) Eccentric braces	
	Steel moment resisting frame designed as per SP 6 ( 6 )	

So another thing what we have to see is this response reduction factor.

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The handwritten equations on the chalkboard are:

$$A_h = \frac{Z}{2} \frac{I}{R} \left( \frac{S_a}{g} \right)$$

$$F_h = A_h (DL + 50\% LL)$$

So we have written that equation.  $A_h$  is equal to  $z$  by  $2 I$  by  $R S_a$  by  $g$ , this  $S_a$  by  $g$  depends on the natural period of the structure depends on what else? Uhh? Percentage of , what is it? Damping  $E z$  is depending on the zone  $I$  is depending on the importance. Now we are seeing this factor  $R$ . So your seismic force horizontal force is given as  $A_h$  multiplied by dead load plus 50 percent of live load. So this is what we have to now see. To calculate the horizontal force due to seismic there is a vertical force also that we will see later. Horizontal force depends on all these factors and you have to calculate that.

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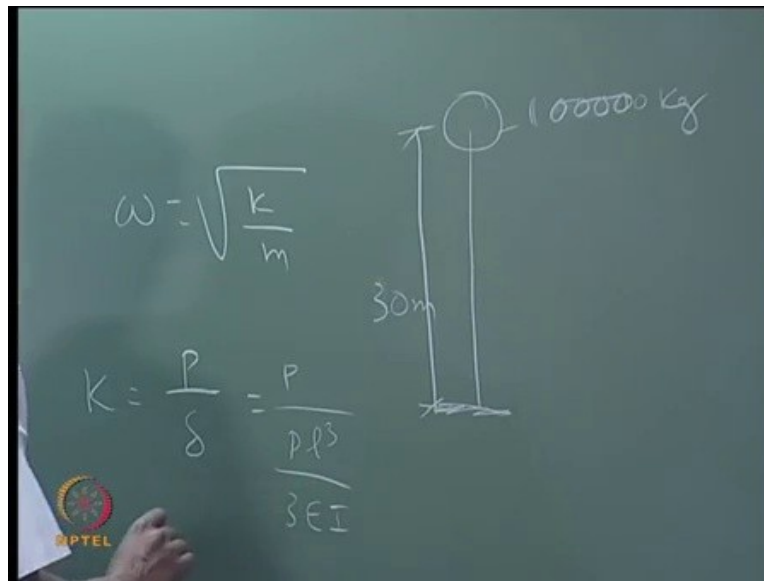
The image shows a screenshot of a PDF document titled 'IS 1893 ( Part 1 ) : 2002'. The table is titled 'Table 7 Response Reduction Factor  $R$ , for Building Systems ( Clause 6.4.2 )'. The table lists various lateral load resisting systems and their corresponding response reduction factors.

No.	Lateral Load Resisting System	R
(1)	(2)	(3)
<i>Building Frame Systems</i>		
(i)	Ordinary RC moment-resisting frame ( OMRF ) <sup>(1)</sup>	3.0
(ii)	Special RC moment-resisting frame ( SMRF ) <sup>(2)</sup>	5.0
(iii)	Steel frame with	
	a) Concentric braces	4.0
	b) Eccentric braces	5.0
(iv)	Steel moment resisting frame designed as per SP 6 ( 6 )	5.0
<i>Building with Shear Wall<sup>(3)</sup></i>		
(v)	Load bearing masonry wall buildings <sup>(4)</sup>	
	a) Unreinforced	1.5
	b) Reinforced with horizontal RC bands	2.5
	c) Reinforced with horizontal RC bands and vertical bars at corners of openings	2.5

So if it is ordinary R c moment resisting factor frame this is 3 special frame means it is 5. Steel frame with a concentric braces 4, Eccentric braces 5. This masonry wall under 1.5 very low and reinforced is 2.5. So this is the intensity which you have to see, if the uniformly distributed floor load is 3 kilo Newton per meter square then we can take 25 percent. If it is more than 3 kilo Newton per meter square it is 50 percent.

What is the minimum live load on a berthing structure? What is the minimum live load? I have shown a table also. What is the range of live load uniformly distributed in a berthing structure, hmm? 10 kilo Newton to 50 Kilo Newton per meter square. So you have to use this. There are some approximate formulas given here to calculate the natural period that we will see later. So this is how this code has been derived.

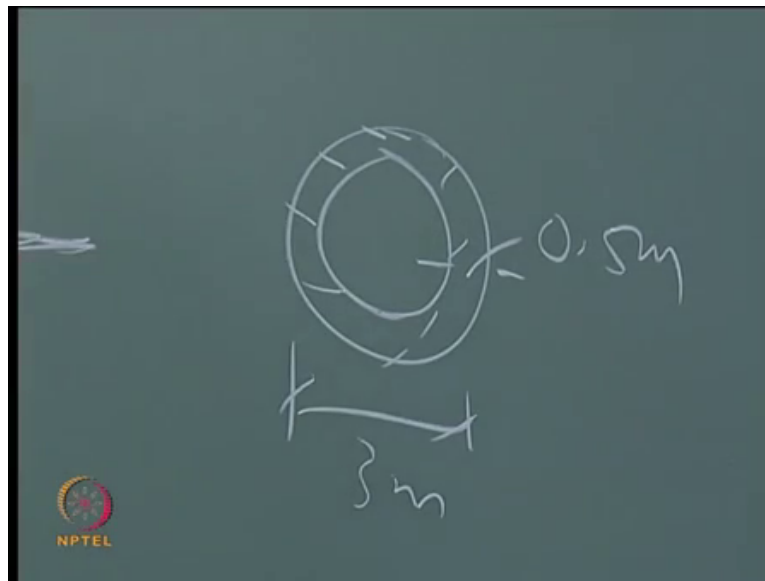
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So you have seen the water tank you have a mass at the top, and the height let us say about 20 meters designed for unlock 100000 litre, 100000 litre means 100000 kg mass. Have you seen water tank in IIT campus? hmm? Where are the water tanks. Near? Jamna hostel, Jamna hostel then hmm? BSB complex so the (( ))(28:31) is something like this. it is a single tower. BSB only you are telling no? It is like this. Height will be 20 metres or more? Take it as 30 meters.

Let us I am assuming it is 100000 litres capacity and the mass is 100000 kg. I have to calculate the stiffness for this, k is equal to p by delta. Suppose you have seen a point load here find out the deflection I will assume unit load divided by delta. What is deflection for a cantilever, l cube by 3E I. So k will be 3E I by l cube. What is E? 5000 root fck. Same that rate of concrete is m 30 and f ck will be 30.

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I means you have to find out this is a shaft when you take the section of the shaft like this may be 3 meter in diameter thickness may be about 0.5 meter or something like this. So from this you can calculate the moment of inertia we substitute  $k$  here  $m$  here. What is the unit of this, this will be kilo Newton per meter mass will be kilo Newton per meter per second square. So if you this will be 1 by second.

Something is wrong here or what, correct only you will get 1 by second  $t$  will be  $2\pi$  by  $\omega$ . This is how you have to calculate the period. Any structure you can calculate like this. So this is what we are doing  $h$  is equal to  $E z$  and  $i E z$  by  $2 i b r$  into  $S a$  by  $g$  average response accuration coefficient. See whatever figure I have given there now I am giving in terms of equation between 0.1 and 0.4 seconds the coefficient is 2.5 less than 0.1 it increases linearly  $1 + 15 t$ , and after 0.4 it reduces  $1$  divided by  $t$ .

Here it is  $1.36$  by  $t$ , here it is  $1.67$  by  $t$ , mostly we will be using these factors. And I was telling about the old zone there it is given zone 1, zone 2, zone 3, zone 4 and zone 5. So the zone 5 remains the same whatever it is all these zone 1 they have become zone 2. There is no zone 1 I think this is zone 2 is given this some portions have become zone 3.

In tomorrow's class we will try to carry out some studies calculations for berthing force mooring force and seismic force for a typical structure I will tell you how to calculate you come to washing in any department, ok.