Pavement Materials
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Lecture 55
Mix Design of PQC- Examples (Part-2)

Hello everyone, in the last class we were discussing about, we solved a problem related to the mix design of PQC, and we solve the problem for the design flexural strength. So, as I mentioned that today also we will solve two problems. The first problem will be similar to what we have done in the last class, but today we will try to see the solution corresponding to the design compressive strength and we will also solve a problem to produce a high strength concrete mix.

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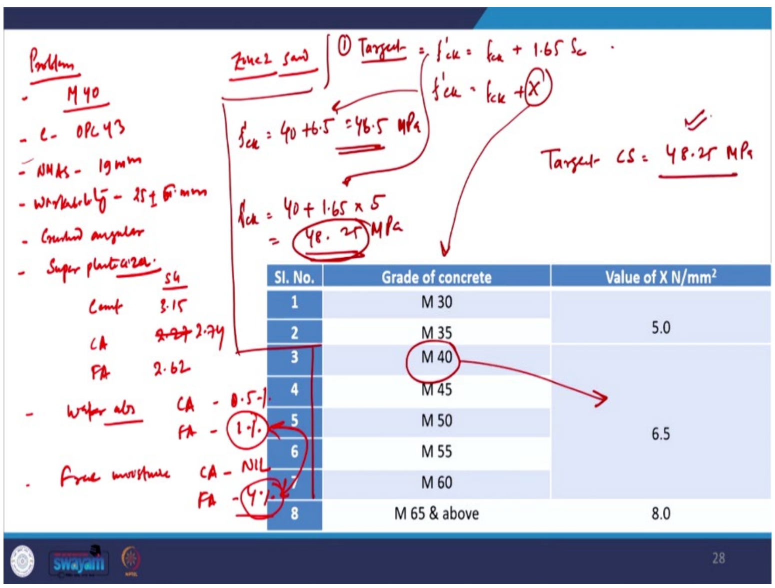

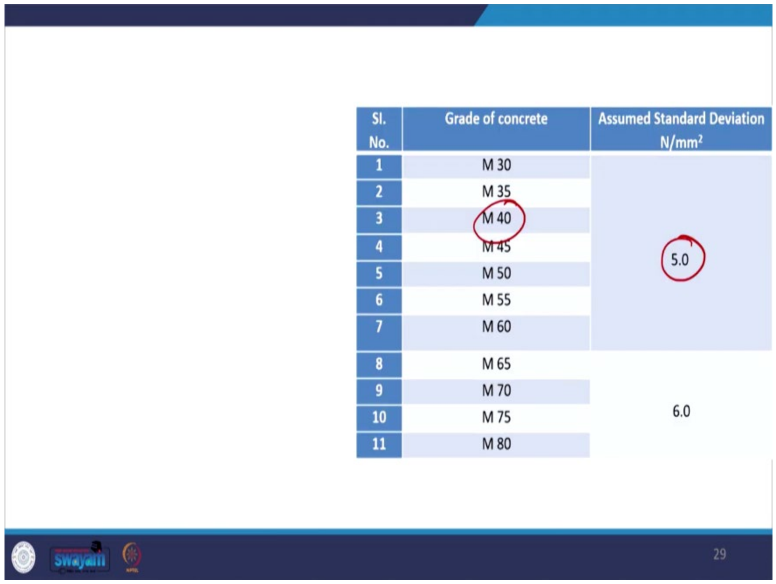

Sl. No.	Grade of concrete	Assumed Standard Deviation N/mm^2
1	M 30	5.0
2	M 35	
3	M 40	
4	M 45	
5	M 50	
6	M 55	
7	M 60	
8	M 65	6.0
9	M 70	
10	M 75	
11	M 80	

So, let me first write down the problem here, what are the inputs given in the design problem. So, we have to design a M 40 concrete here, the type of cement which we are using is OPC 43. The nominal maximum aggregate size is different in this case. So, the nominal maximum aggregate size is 19 mm. Minimum cement content and the maximum water cement ratio criteria remains the same.

The workability to be achieved is similar to what we have used in the last case, 25$\pm$5 mm. The type of aggregate is again crushed angular and here also we are using super plasticizer. So, now, the specific gravity of the individual material is similar to what we have used in the last example. So, for cement the specific gravity is 3.15, for coarse aggregate it is 2.74, for fine aggregate it is 2.62.

let us take similar water absorption, but we will change the free moisture present in the surface. So, water absorption for coarse aggregate is given to be 0.5 percent and for fine aggregate it is given to be 1 percent. And free moisture is present in this problem, coarse aggregate is 0 percent free moisture, but in fine aggregate we have 4 percent free moisture.

So, therefore, the total moisture content in fine aggregate becomes equal to 4+1 that is 5 percent out of which 4 percent is in the surface and 1 percent is corresponding to the water absorption. Here also, we are using zone 2 sand. So, let us now try to, with these inputs, we can start solving the problem start completing the mix design and we will use similar steps what we have seen in the last class.

So, the first step is to calculate the target strength. So, for the target strength here also we have two formulas. So, the first formula is that f'ck = $F_{ck} + 1.65 \times S_c$and again f'ck = $F_{ck} + x$. Here the value of x is a function of the grade of the concrete, in our case it is M40, so the value is 6.5. So, f'ck = $40 + 6.5$ which is 46.5 MPa.

And in this formula, we have to know the value of Sc. So, if you see here the value of Sc four M40= 5. So, we will use this value here. So, this becomes equal to f'ck = $40 + 1.65 \times 5$, so this becomes equal to 48.25 MPa. So, out of these two values 48.25 is maximum. So, the target compressive strength is equal to 48.25 mPa. This is what we will consider in the design, 48.25.

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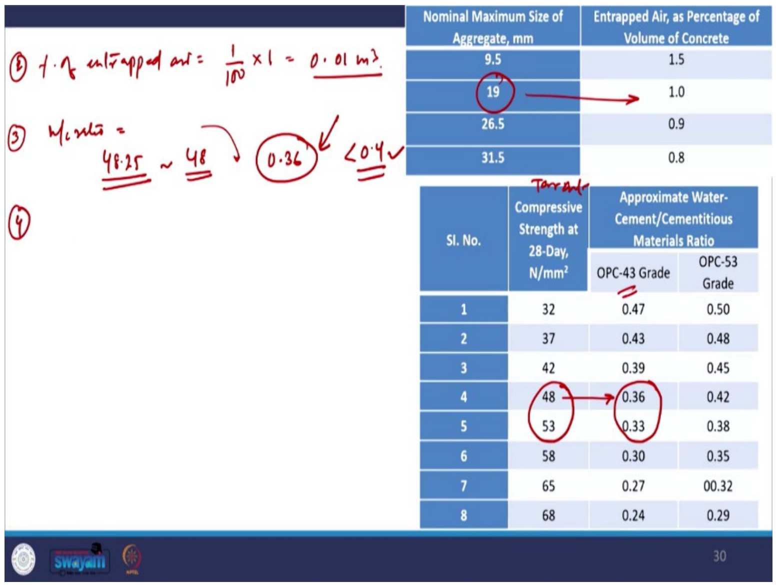

In the second step what we will do we will see the amount of entrapped air. So, entrapped air is a function of the nominal maximum aggregate size, which you see here. So, it is 1 percent. So, percentage of entrapped air is equal to $\frac{1}{100} \times 100$, so this is 0.01 m^3. So, and this we will use at the end when we are calculating the proportion by volume, or we are calculating the total volume of the concrete. So, this is the second step.

Then we will go to this third step of selecting the water cement ratio. So, water cement ratio is a function of the target compressive strength and the grade of the cement, our target compressive strength is equal to 48.25 so it is somewhere between 48 and 53. And, which means the water cement ratio we have to interpolate between 0.36 and 0.33. So, since our target grade is 48.25, it is very similar very close to 48.

So, let us not do any interpolation here rather take the direct value. So, we can take the water cement ratio to be approximately 0.36. If you remember, we have to apply a check here. So, this 0.36 is less than 0.4. So, it is fine, we can proceed to the next step. In the next step, we have to select the water content.

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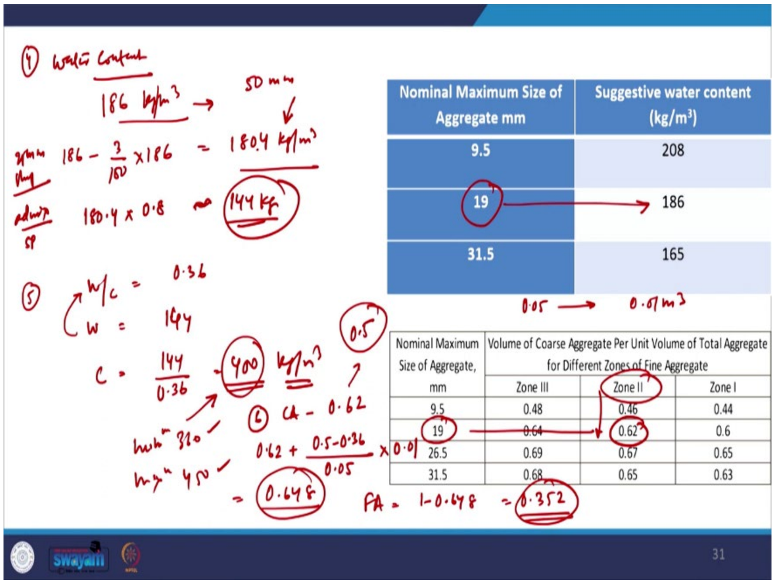

Again, we have a suggestive table corresponding to the NMAS. So, the nominal maximum aggregate size is 19. So, the suggestive water content is 186 Kg/m^3, but this has some conditions. For example, this is for a slump of 50 mm. And this is without any admixture. So, similar to what we did in the last problem, our design slump is 25. So, we have to reduce 3 percent.

Today I am doing the calculation, the speed of doing the calculation is more considering that we have already completed this discussion in the last class. So, it will be easy for you to follow this particular lecture. So, this is 180.4 kgs per meter cube corresponding to 25 mm slump. And corresponding to the admixture we are using super plasticizer, so 20 percent reduction in this particular water content, so 180.4 $\times$ 0.8.

So, this becomes equal to approximately 144 kg. So, 144 kg is the amount of water which we have to take. So, now, we know the water cement ratio, now we know the water content. So, wc ratio is 0.36, water content is 144, just put it here to get the cement content which is equal to $\frac{144}{0.36} = 400$. Same value which we got the last time. Again, we will apply two checks here, the minimum is 360, so it satisfies the minimum criteria.

The maximum is 450, it satisfies this criteria also. So, we are good to go ahead. Now, the next step is to take the proportion of the coarse aggregate, we are here, we are here, so our value will be 0.62. So, the amount of course, aggregate that we have to use is equal to 0.62. But the condition here is again related to the required water cement ratio of 0.5. So, we have to do the adjustment.

Now, how to do the adjustment? We know that for every decrease in water cement ratio by 0.05 we have to increase this value. So, for every decrease in the water cement ratio by 0.05 we have to increase the volume by 0.01 m^3. So, that is what we are going to do here also. So, this will be equal to $62 +$

$\frac{0.5-0.36}{0.05} \times 0.01$. So, if we do this calculation you get the value as 0.648 which means 64.8 percent by the volume of total aggregate will be coarse aggregate.

So, therefore, fine aggregate becomes equal to (1-0.648) which is equal to 0.352 per unit volume of total aggregates. So, this is the proportion which we have got. Now, the next step is checking the gradation so that we have to ensure that for the given coarse aggregate blend and the zone 2 fine aggregate which we are using we are able to reach the combined gradation which we have already discussed in the last class.

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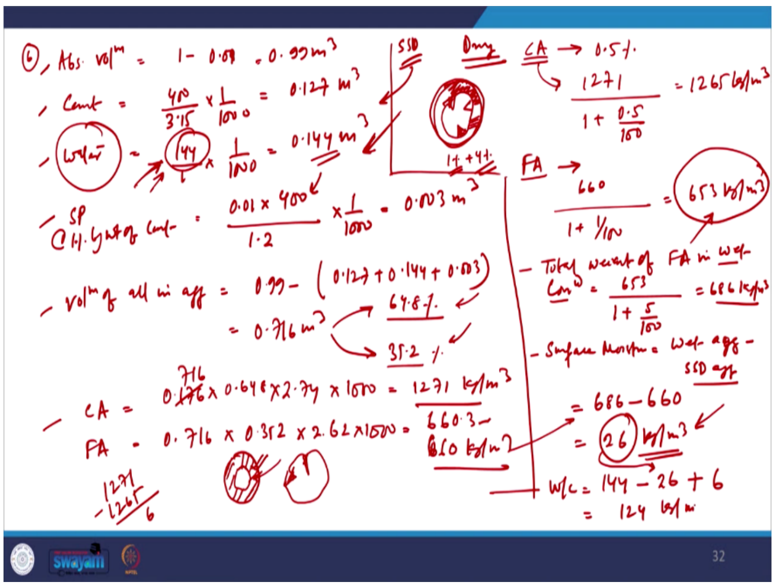

And then finally, we will have the proportions with us. So, let me write down the proportion. Now, in this problem the absolute volume of concrete becomes equal to (1-0.01). So, this is 0.99 m^3. Then we have cement, we know the specific gravity, we know the mass, so we can calculate the volume which will be equal to 0.127.

Then, similarly, we can calculate the volume of water, weight of water was given, specific gravity we know, this becomes equal to 0.144 m^3, then we have super plasticizer let us say we are using at the rate of 1 percent by weight of cement. So, this becomes equal to 0.01 × 400 this is the weight and then we have to divide by the specific gravity $1.2 \times \frac{1}{1000}$, this becomes equal to 0.003 m^3.

Now, we have all the proportions, so the volume of all in aggregate becomes equal to 0.99 minus the summation of all the other volumes. So, this becomes equal to 0.716 m^3. Now, a part of this volume will be occupied by the coarse aggregates. So, 64.8 percent of this volume belongs to the coarse aggregate whereas, 35.2 percent of this volume belongs to the fine aggregate.

So, now, we have to calculate the weight of the coarse aggregate and fine aggregate using these proportions because we know the specific gravity of coarse aggregate and fine aggregate. So, the weight of coarse aggregate becomes equal to 0.716, 64.8 percent of this volume, 0.648. Specific gravity is 2.74 in 2000. So, Kg/m^3 this becomes equal to 1271 Kg/m^3.

So, fine aggregate becomes equal to again $0.716 \times 0.352 \times 2.62 \times 1000$. So, this becomes equal to 660.3 or let us say 660 Kg/m^3. So, now, we have all the mixed proportion. Again, this is by SSD. If I want to do it in dry condition, then I have to know the water absorption and the presence of free moisture also. In case of coarse aggregate, we did not have any free moisture but the water absorption is 0.5 percent.

So, similar to what we did in the last class that now the changed value of course, aggregate will be = $\frac{1271}{1+\frac{0.5}{100}}$. So, this becomes equal to 1265 Kg/m^3. Now, in case of fine aggregate, we have two cases one is the water absorption and the other is the presence of free moisture. Remember this was an SSD condition, and in this condition, we have not considered the presence of free moisture, we have only considered the presence of the absorbed moisture in the fine aggregate.

So, first let us find out the dry mass of the fine aggregate corresponding to the water absorption. So, this becomes equal to = $\frac{660}{1+\frac{1}{100}}$, so this is equal to 653 Kg/m^3. Now, this is the dry mass and now we have to calculate the free surface moisture corresponding to this particular dry mass.

So, if I want to find out total weight of fine aggregate in wet condition. When I say wet condition it includes this is the aggregate. So, we have some absorbed water and then we have some surface water. So, total weight in wet conditions should include both the surface water and the absorbed water. So, in that case it will be equal to the total moisture which is equal to 1 percent which is inside the pores plus 4 percent which is on the surface, so 5 percent.

So, if I want to calculate the total weight it will be equal to 653 the dry weight divided by (1 + total moisture)= $\frac{5}{100}$,. So, this value will be equal to 686 Kg/m^3. And therefore, what is the weight of surface moisture, surface moisture is equal to the wet aggregate minus the SSD aggregate, is not it, because this total weight aggregate minus the SSD aggregate will give me the value of the total surface moisture.

So, the wet aggregate is equal to 686, SSD aggregate is equal to 660 here from here and this becomes equal to 26 Kg/m^3. So, this we have to again adjust in the total water content. Now, therefore, the change to water content will become equal to earlier it was 144 in SSD condition that we calculated, this is 144 which means we have to subtract the amount of free moisture from here which we are already considering.

Because you see this free moisture is the one which will facilitate workability also, which means this is active water which also reacts with cement and which is also available for workability. But the water which is inside the pores they are not available, which means in the SSD condition whatever we calculated which was you see 144 Kg/m^3this value.

So, this we calculated considering the presence of surface moisture, but again we have some surface moisture in the fine aggregate which means this water content ideally should be reduced because this is the extra water which we are adding, but already in the fine aggregate we have some presence of free moisture which we need to add just in this particular water content. So, for the presence of free moisture we have to first subtract 26, this we will do and then we have to add the additional amount of moisture which is present.

What is that additional amount of moisture which is present, it is equal to 1271 in the coarse aggregate minus 1265. So, this is equal to 6. So, this 6 we have to again add here because that we have not considered in our calculation. The moisture which we have to add becomes equal to 124 Kg/m^3. Similarly, once we have calculated the water cement ratio can be worked out for the given cement content.

So, since we have now discussed the calculation of the proportion of different ingredients or materials that are used to produce the concrete, the other steps are similar to what we have discussed. For example, the next step will be that for these calculated proportions we will have to make trial samples and for those trial samples, we have to ensure that the required slump criteria and the required durability criteria is satisfied.

If they are not satisfied, we can make some adjustments in the proportions and if they do satisfy we will proceed to make further trial samples. Now, the further trial samples will be made considering the calculated water cement ratio and ± 10 percent water cement ratio.

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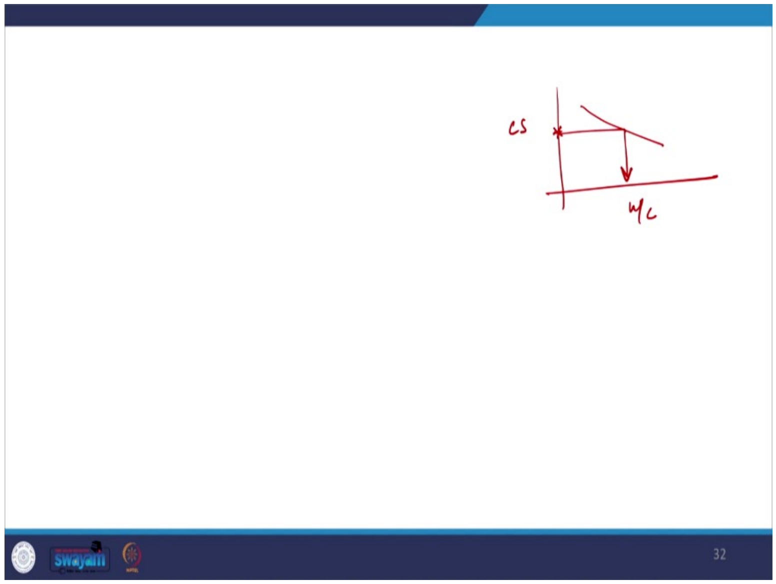

And then we will plot the graph between water cement ratio and the compressive strength or the compressive strength of the concrete. We will draw the graph, we know what is the target strength corresponding to the target strength what is the design water cement ratio we will estimate the same alright and this completes the mix design process as well. We will stop here today and we have discussed or we have solved a problem which is related to the mix design of PQC based on compressive strength.

And by this we have also completed our discussion on the mixed design of concrete in general that we use in pavement construction. And in the next class we will discuss about the mixed design of dryline concrete mixtures that are typically used just below the concrete slab in a usual cross section of concrete pavement that we use in the highways.

After that, we will also discuss about the mixed design of pervious concrete which as I mentioned is a special type of concrete. And we will also discuss in general about its application, about the details and of course the mixed design process. Thank you.