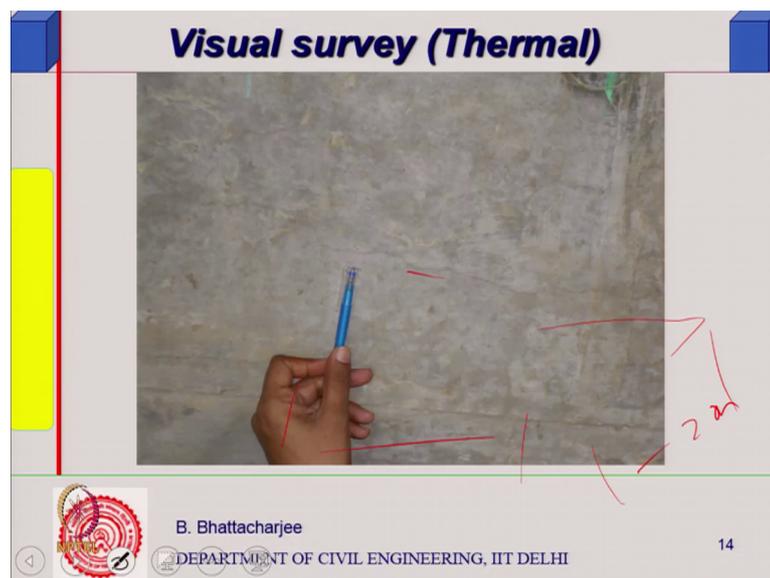


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Lecture – 46
Case studies of visual survey

So, having looked at some of those intrinsic crack related to shrinkage let us look at some thermal cracks. Now, one set you know this is again a massive concrete right, now you can you can see the cracks possibly something like this you know you can see this cracks, some cracks here this is the is not easy the pen shows those, the pen here now this cracks is of a bridge pier, bridge pier is actually approach to the bridge right.

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Now, the dimensions were too large, something like you know I exactly do not remember, but the width is 2 meter pier and the span you know length is because of 6 lanes. So, I think it was a continuous; it was continuous, but this width was not less than 2 meter it was width was more than that so, depth is 2 metre height is; obviously, high.

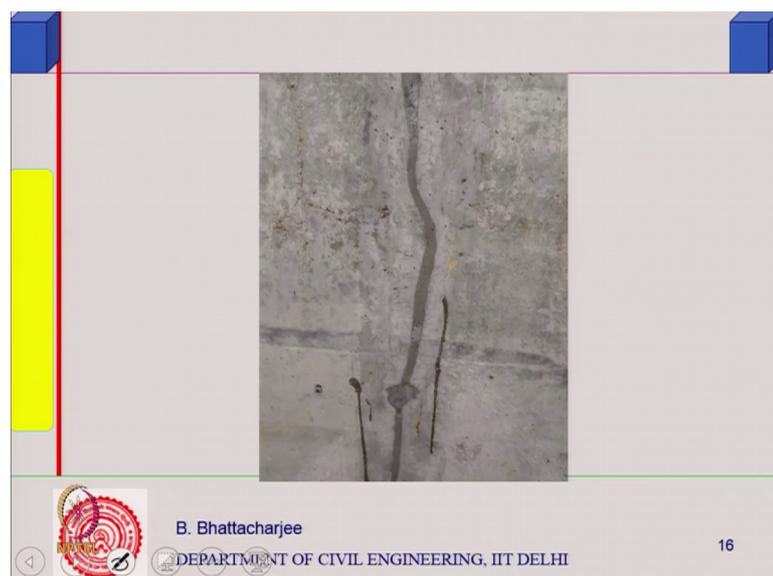
Now, is this such kind of a thick concrete volume to surface area ratio is very large is almost like mass concrete, the grade of concrete was I think 35 or 40 or something of that kind relatively high grade used a 53 grade of cement right use 53 grade of cement which actually produces more heat of hydration early and concrete grade was quite high so, cement content was also very high.

So, this developed this kind of thermal so, thermal cracks do come in large structures, you know where you have a like a thick craft thin sections usually you should be one should be careful about shrinkage, thick sections very thick section thermal cracks are the once which are likely to come. So, this is what the case was this is the same place same bridge it is showing further cracks somewhere you know somewhere these are the piers, these are the you know these are the these are beam which is supported on piers.

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So, is the approach this is the approach basically you know there is a approach and then here the gardens are supposed to come but, the cracks the cracks thermal cracks of this form. But one of that the filled it in with some sort of.

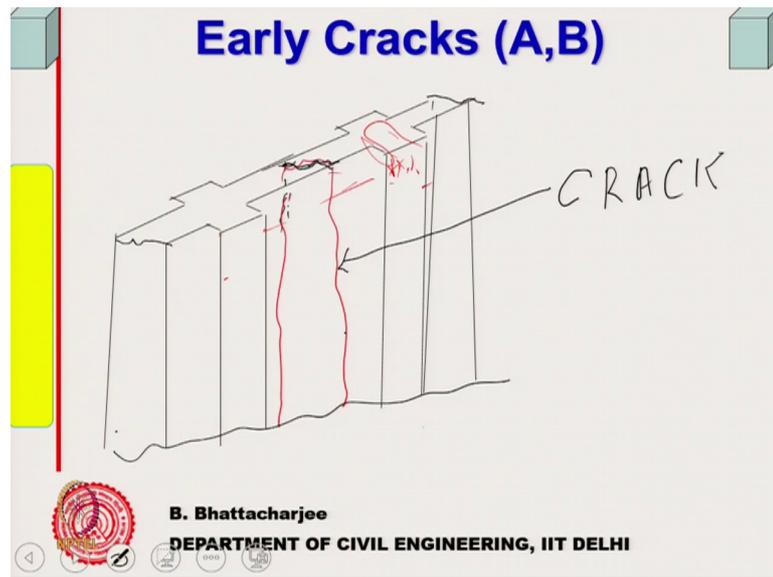
Student: (Refer Time: 02:48).

Yeah some sort of polymer modified system, but the main cause was the high relatively higher grade concrete, relatively higher grade concrete with a high you know early strength cement 53 grade which would not have been the case and heat of hydration resulted in such crack formations.

So, one has to be careful, you know the heat of hydrations the of cement should be low, if you request friend and then this you know I mean the section everything should be taken into account heat of hydration, the rate of strength development required and the structural requirement. So, I think here structural requirements were satisfied with the thickness, when it came to strength development I am not sure because this was lying you know lying unloaded for so long time; that means, the time was not a constraint here.

So, strength development was not a constraint, but then peoples you know I was told the structural designer insisted on 53 grade of cement and the high strength. So, actually that cause it is sort of crack, although these are intensive crack, but they have their long term effect anyway.

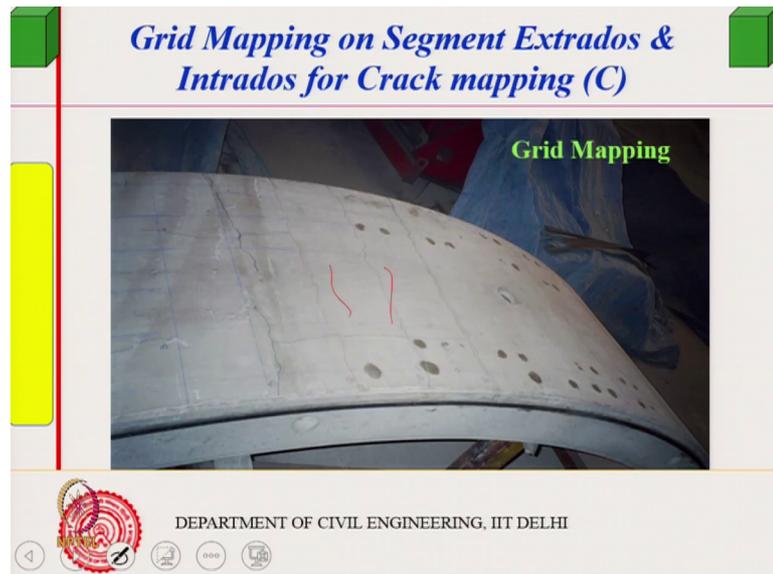
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So, this was the cracks so, case A and B early cracks there was something of this kind, these are the vertical cracks you have seen between the kind of you know plasters I mean there are higher thickness case A and B as I mentioning the shrinkage cracks earlier in the previous lecture. So, the between you know there are kind of bar process you can say right extended section here.

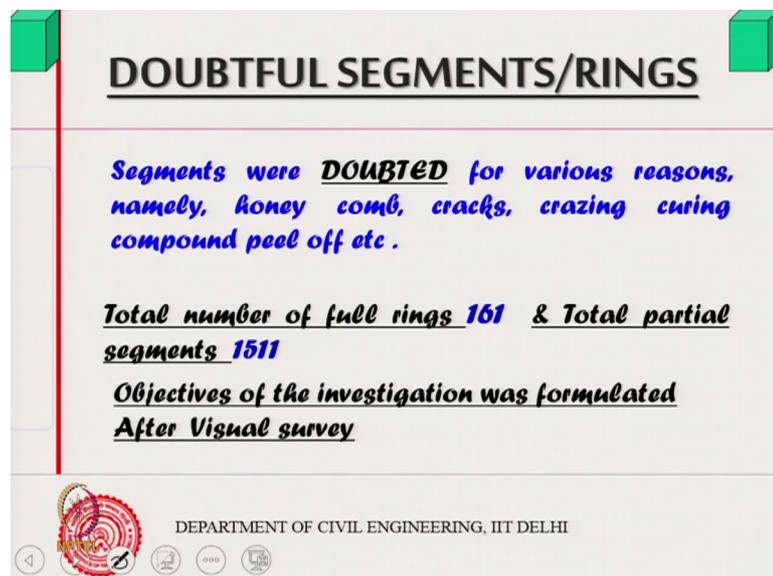
So, exactly near the centre of this one, because this is restrained here. This is shrinking, this is thicker do not shrink you know not allowing it and the cracks were almost equally spaced on in each of these between these two you know between the two bar process sort of thing.

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So, this was the case A and B both A and B show this, C should this is a I was talking about the segment you know 280 mm thickness you can see the cracks the red, blue etcetera. Because it classified them, you know you can see the cracks like this there are lot of cracks on this convex side there are nothing on the concave side so, convex side there are plenty of cracks.

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So, basically this where since the cracks k just started doubting the segments you know segments quality. So, they are thought there could be one is a cracks, but there are a honeycomb somewhere else you know once it is under scanner this can they started looking to every details. So, some places honeycomb.

And it is for an important structure as you can say it is a tunnel structure. So, honeycomb, cracks, crazing, curing, they start looking at everything, curing peeled off started looking at it and then they there is something like 1511 segments where doubtful. You know comprising of full 161 you know, full 161 rings and some more part of the rings you know all that. So, you see to use a huge number of them and the cost involved will be pretty high so, the objective of this investigation is then one has to formulate.

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GROUPING OF SEGMENTS FOR THE PURPOSE OF INVESTIGATION

- **Gr. I: No observed Cracks, but honeycombing or damaged during demoulding.**
- **Gr. II: Mould Measurements doubtful.**
- **Gr. III: No observed Cracks, Curing not up to the mark.**
- **Gr. IV: Post Casting Chloride bearing water for Segment humidification**
- **Gr. V: Observed Cracks,**

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So, visual survey was done, then it was decided that you can group the cracks into 5 groups, for example, group 1: no observe cracks, but honeycombing or damaged during moulding. So, then is it would be treated in a different manner. So, honeycombing or damaged during the moulding so there can be treated in a different manner you know because while you are handling them there might be some corner broken and all and these are respected and therefore, standard procedure one would lay down in contract sort of situation.

Then some others they started doubting the doubt because one sits on the scanner everything is on the scanner measurement sizes because, it is precast element has to go to the right place. So, therefore, there were measurements doubts were they are all some of them. 3rd variety in observe cracks curing, but then curing was not up to the mark you know it was felt that it peeled off early although the cracks is not come.

Then somewhere very surprisingly; somewhere the use a curing water which had chloride. So, this is also you know it is an example how investigation I mean the how the real situation comes into being so, the case study explains the visual survey part is important here, we will come to the other parts later on anyway. So, post they are there the use some chloride bearing water for curing and that is for they say that this are the set up segments where that water has been used which is not tested water, possibly chloride bearing and therefore, you know you have to investigate upon them also.

The last variety is the cracks observed, observed cracks where observed and this variety was most important because, we would like to keep the cracks away or rather either throw them away or repair them.

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GROUPING OF SEGMENTS FOR THE PURPOSE OF INVESTIGATION

- ✘ **Gr. I: Standard procedure existed for repair.**
- ✘ **Gr. II: Control Assembly.**

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So, since in the first case where you have honeycombing, small honeycombing when always come depending upon several situations the mould dwell has not been applied properly. The you know the concrete is grid dry compaction does not gone properly small honeycombing can come even in an kind of an casting here which is buy and large industrialize production as I mentioned.

So, they it was envisage I mean it was seen earlier for seen earlier so, standard procedure was laid down. So, group I those ones we said that you just follow the standard procedure and can be passed. Group II dimensional problem, they had a control assembly system; that means, since it was tunnel segment.

So, they had you know Moc tunnel line you Moc tunnel was there on the ground. So, control assembly so, you have 1 segment next segment coming in, 6 segment should be there 1 segments come in next segment comes in etcetera then there is a key segment last one. So, all the segments you put in position and if they are fitting in so, your things are so, this is control assembly.

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GROUPING OF SEGMENTS FOR THE PURPOSE OF INVESTIGATION

- ✘ **Gr. I: Standard procedure existed for repair.**
- ✘ **Gr. II: Control Assembly.**
- ✘ **Gr. III: Investigation required for quality of concrete and durability.**
- ✘ **Gr. IV: Test for Chloride at rebar level.**
- ✘ **Gr. V: Investigation required for quality of concrete and durability, crack depth progress of crack etc**

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Then, since curing was improper little bit of sub durability tests where necessary for those concrete and where chloride was used for you know curing. So, what was done is test for chloride at rebar level. Now, we see it also gives an idea what tests are selected and how it is selected.

For example there why just I am quite happy to select only durability related test, I do not I am not going to look at this strength. In this case I will not do neither any other durability test I will take samples and measure the chloride and if the chloride is within permissible limit I am fine if it is not then you start you know you particular work then the additional tests if we done right, maybe you have to do some protection. So, that there is already internal chloride is there so, either you know have to at decision has to be taken.

But, fortunately in this particular case when test at none of the case showed chloride level high you know you can do chloride testing by silver nitrate test, standard titration procedures are there make powder grind it, pass it through 150 mm same powder

dissolve it in. If your testing for free chloride, dissolved it in distilled water for half an hour take an extract of those you know soluble chloride or if it is total chloride I am not go into the details of this total and free chloride, but total chloride is even chemically bound chloride in the concrete system. And that also get dissolved when you test it under 6 normal you know you saw dissolved it in 6 normal nitric acid. So, the grinded concrete powder then dissolved in 6 normal nitric acid test for chloride by first you know adding silver nitrate and precipitate etcetera doing it iteration you can find it out. So, fortunately in this case nothing showed up chloride so every, you know it was all.

Now, last one is the most important one because there are cracks observed so, there was a you know you need to have test first of all the whether this cracks are acceptable or not whether there is a problem related to strength every details 1 or 2 find out. So, quantity of quality of concrete durability and even strength was a requirement and depth of crack you know how much is the depth of crack whether it has gone through and through that is what was.

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Diagnosis during visual survey

- Diagnosis of causes of cracks is complex in some cases, can be diagnosed through visual observation
- ❖ A, B, C: Plastic settlement
- ❖ D, E, F: Plastic Shrinkage
- ❖ L: Rebar corrosion
- ❖ M: Alkali agg. Reaction
- ❖ H, G thermal construction
- ❖ I Long term (months) drying shrinkage in thin section
- ❖ J, K Crazing

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So, first a visual survey diagnosis as I said we used this right, from the look of it we identify using the same diagram which I used earlier which I showed earlier we could diagnose that this is possibly drying shrinkage in thin section, because 280 mm was thickness and curing was not proper.

So, drying would have occur and the cracks did not come immediately within 48 hours or something and later on when one would put glass still tale as it call it, it did not crack as if the cracks where all dead. So, therefore, from this we could looking at cracks everything first stage was we thought this was drying shrinkage cracks right, because of poor curing scenario.

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CRACKS IN GR. V SEGMENTS

- **Crazing are hairline cracks < 0.08 mm (003 in) wide, CAN BE left un-repaired.**
- ✳ **For cracks > 0.8mm (0.035 in) transfer of stress across the crack is not possible, is a candidate for repair.**

The slide includes a hand-drawn diagram in red ink showing a rectangular cross-section of a concrete member with a vertical crack. Two downward-pointing arrows are positioned above the crack, representing an applied load. The crack is shown as a vertical line with a jagged, irregular edge, indicating a significant structural discontinuity.

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So, there are some crazing and hairline cracks were also there you could see that. Now crazings are defined as something less than 0.08 millimeter width right and this can be left unrepaired according to American concrete institute ACI you know guidelines and all that you can leave it un you know it is 0.08 millimeter thickness 8 percent of an millimetre thickness. So, we can see what small it is, but you can you can measure them on the magnifying glass and scale there are ways there maybe some class I will show you how crack can be measured sometime I will show you. So, you can you have scales actually through which you can measure.

And if it is less than that well it is you know it can be left un repaired, for cracks greater than 0.8 millimeter that was 0.08 and this is 0.8 millimeter. Essentially, you know transfer of stress cracks transfer of stress across the crack that could be may not be possible. Because, if I have a crack something of this kind right I apply a load here now if there is a gap is sufficiently large this load will not be transferred to the other side right.

What causes this, if there is interlocking of the aggregates even after crack then load will be transferred because, through the interlock locks it will be transferred. So, it is the sand which protruding out the sand allows crack I meant stress to be transferred therefore, 0.8 millimeter is the, you know 0.8 millimetre is guidelines. In existing structure if the crack is more than 0.8 millimetre then it you know you go to think about that there may not be a possibility of load transfer. So, accordingly one has to identify them you know identify them.

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CRACKS IN GR. V SEGMENTS

- **Crazing are hairline cracks < 0.08 mm (003 in) wide, CAN BE left un-repaired.**
- ✘ **For cracks > 0.8mm (0.035 in) transfer of stress across the crack is not possible, is a candidate for repair.**
- **crack width shall be sufficiently small to protect the rebar from corrosion. [w < 0.3mm (0.012 in) for moderate condition].**

ACI 224R-90 ✓

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So, identify the size of the crack according to the width crack width should be sufficiently small to protect the river from corrosion, because if the crack progresses up to the river, something can come from outside the moisture; obviously, and if there is any other things or even carbonation would follow that crack.

So, corrosion could be a thing and therefore, you need some protection, now that size is less than 0.3 millimeter right for moderate condition and all these are given in ACI 224 R 90 guideline. So, therefore, we followed that, by following that classify the cracks according to their width.

Student: Indian.

No not yet, not in Indian code, this is a best guideline because this is also based on a little bit of experience right. So, we do not have Indian guidelines on existing structure their crack width how do we classify or where what should shown.

Student: (Refer Time: 16:12).

We have used this and I think is a good one to use, after it is based on international experience.

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VISUAL SURVEY

Table . Colour coding scheme used in recording the cracks in visual observation

Colour	w = width of the crack
Green ✓	w < 0.08 mm
Blue ✓	0.08 mm ≤ w < 0.2 mm ✓
Red ✓	0.2 mm ≤ w < 0.4 mm ✓
Double Black ✓	0.4 mm ≤ w < 0.8 mm ✓
Double Red ✓	w ≥ 0.8 mm ✓

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So, based on this what was done was used a colour coding, used colour coding for the cracks all the cracks are mm all over all the segments this is an example how one does visual survey thoroughly right, there are some more examples I might look into. So, green, if the colour is green the crack is marked with green marker pen you know first all the elements well laid down with their convex side on the surface. The doubtful cracks one by one, batch by batch something like maybe 16, 8 or 16 you take today look at them mark them and then identify etcetera. Green colour means width less than 0.08 mm, this you know is as I said you can measure them I will next time I think I will bring that and I will show you there is the small scale, but there are better methods of then measurements are also crack with measurement.

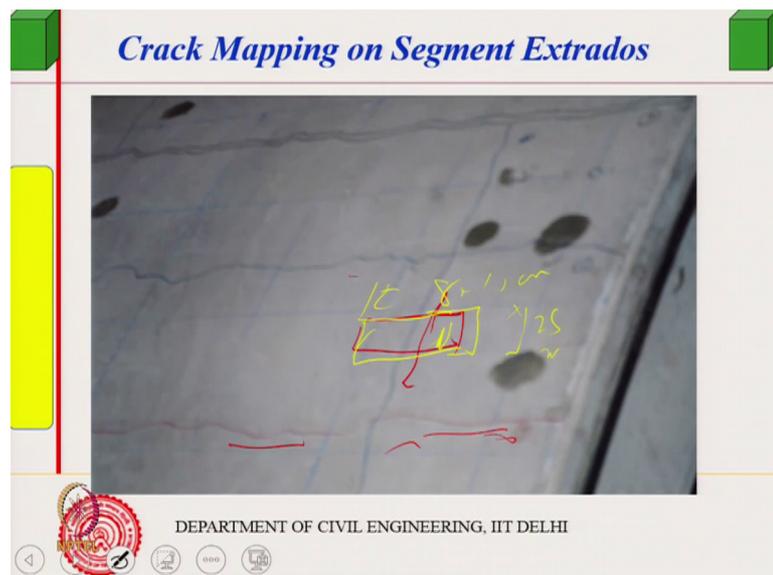
Blue colour between 08 to 0.2 millimeter, actually 0.3 could have been there, but we decided to put in into 0.2 and 0.4 red, double black is 0.4 to 0.8 and double red a so 2 red

lines would show that the crack is more than 0.8 millimeter. Which means that stresses transfer for such a segment could be problematic, you know if the stress comes on one side of the segment may not the other side may not be you know they will act independently. So, effective size of the crack for stress transfer might be reduced. So, that is why it was you know colour coding was done this manner.

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And this is how somebody is doing it, visual inspection has been done is being done and this shows the colour coding you can see that these are all blue, this is blue this is red,

single line red, blue colour, blue, red some more big green double red perhaps were not there. At all you know you can see that there is a red fine red line going on above my red, my green line these are all blue mark you can see that so, all cracks were actually colour coded and marked right.

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INVESTIGATION & TESTS

- **Test for Uniformity and strength**
 - **Rebound hammer, USPV & Core test**
- **Progress of Cracks through Tell-tale strips**
- **Crack depth through USPV**
- **Durability quality through absorption test/ ISAT/ Permeability**

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And then tests are suggested, you know the tests are first because you know strength was not a serious issue, but we definitely wanted to look into the quality of concrete. So, two tests which we will discuss some time later on, a hardness test called rebound hammer test. And this is the ultrasonic pulse velocity test and core test was done to look at the strength for some other course at least which are actually badly damaged.

You know which I cannot use because, I am damaging the by making the you know cutting the course. So, we do we know we try to establish the strength somewhere from those kind of because across the concrete is same so, that is what it.

Then, we one would place you know it was actually tell tale strips we are place that is that I think the diagram is there, perhaps the diagram is there not here it is not diagram is here. So, you put a glass strip small glass strip around that, small glass strip you know put a small glass strip around here on both sides of the crack. Now, after sometime if the strips you know this glass strip is nothing the kind of thin about 2 millimetre or 3 millimeter or thick glass rectangular piece, maybe about 8 to 10 centimetre 8 centimetre or so 80 mm. And this side maybe about 25 mm or 20 mm rectangular piece bonded here

with epoxy or something on both sides of the crack and if the crack is live that it this is expanding then glass being brittle and if this bond is proper it will stop the crack after sometime.

So, this is standard procedure followed to find out whether a crack is live or it is dormant you know it is not it is not really expanding dead or dormant as we call it. So, this is this was put in many of them, especially the width where we know red one surely because we thought that might increase so, that is what is that is was done.

This is the one test and only that since during handling the there can be problem. So, this segments were Moc handle after putting those glass they have taken by the crane and taken to the stacking here and put them there. So, if you take you the stacking here these the handling or load to the truck. So, a Moc handling was done and seen during the Moc handling process did it crack.

Then, this is of course, the test then of course, just for uniformity and strength as I said then progress of crack was done this and also crack depth through ultrasonic pulse velocity. Now, this I will explain some time later on because, once I explain ultrasonic pulse velocity tests itself you can measure crack depth to that. But there are other measures of measuring crack depth as well today there are other measures available, but this you can use this to find out the cack depth we will see that right.

Then sum of those segments you know some of the segments you wanted to do some durability test. So, which are in-situ so, what do you do is on the segment itself one can do initial surface absorption test again I will describe the sometime later on again I will talk about this sometime later on right.

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INVESTIGATION & TESTS

- **Test for Uniformity and strength**
 - **Rebound hammer, USPV & Core test**
- **Progress of Cracks through Tell-tale strips**
- **Crack depth through USPV**
- **Durability quality through absorption test/ ISAT/ Permeability**

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Because I have not mentioned what is ISAT test some permeation quality tests, absorption test would require a sample of code to be taken BS absorption test or EN it is now EN so, absorption test we will require some code to be taken. So, we were avoiding code taking, but ISAT and some other permeability tests one could have done.

So, this is the example of how one goes about visual inspection and then follows up some tests, maybe some more of it will come not exactly because, the some cases I have discussed one case I discussed elaborately because this is an important case where we looked into several things. So, this also tells you how one can go about you know investigating.

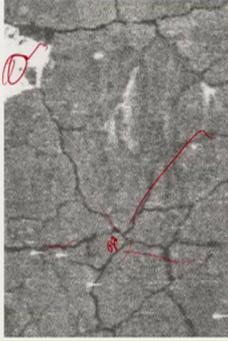
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Alkali Aggregate reaction

$$\text{Ca(OH)}_2 + \text{H}_4\text{SiO}_4 \rightarrow \text{Ca}^{2+} + \text{H}_2\text{SiO}_4^{2-} + 2 \text{H}_2\text{O}$$

$$\rightarrow \text{CaH}_2\text{SiO}_4 + 2 \text{H}_2\text{O}$$

- Typical alkali aggregate reaction cracks. (Map cracking)
- Often cracks can appear late from larger aggregate particles



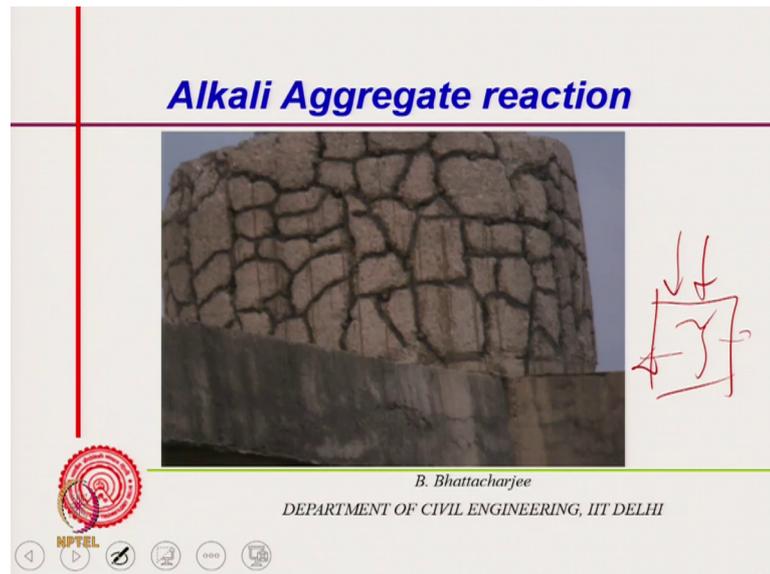
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NPTEL

Now, the visual survey alkali aggregate reaction, basically alkali aggregate reaction involves some silica, which forms H is this acid, you know silica in some aggregates right and they can react with the alkalis of cement sodium hydroxide and potassium hydroxide. So, we you know we it can react I mean a am not interested in the reaction part of it, but what I am interested in how the cracks will look like.

Now, this is from literature, typical alkali aggregate reaction cracks would look something like this they would look something like this right alkali aggregate reaction would like this. And they might appear from large aggregate here so, typical alkali aggregate cracks what you will call map cracking you might see and if you delay it for quite some time some chance might even come out.

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Now, yeah this one is a real case of an alkali aggregate reaction in Indian scenario northeast, you know after sometime say basically support for tower support for tower right. So, they use aggregates which you are not tested really because the finished off their earlier aggregates and it give up cracks of this kind. So, they are not very sure why it is happened, well us you know somebody can be jolly well diagnostic as possible because, the load that can, but load internal pressure was you know there will be no internal pressure, If I put some load on to a pedestal you know it would bulge along this direction.

So, I will have cracks, but why horizontal cracks so, this was actually you know, you have to use your common sense of load flow as well, visualised how the load flow is taking place this was an cracks which came after about 10 years in service.

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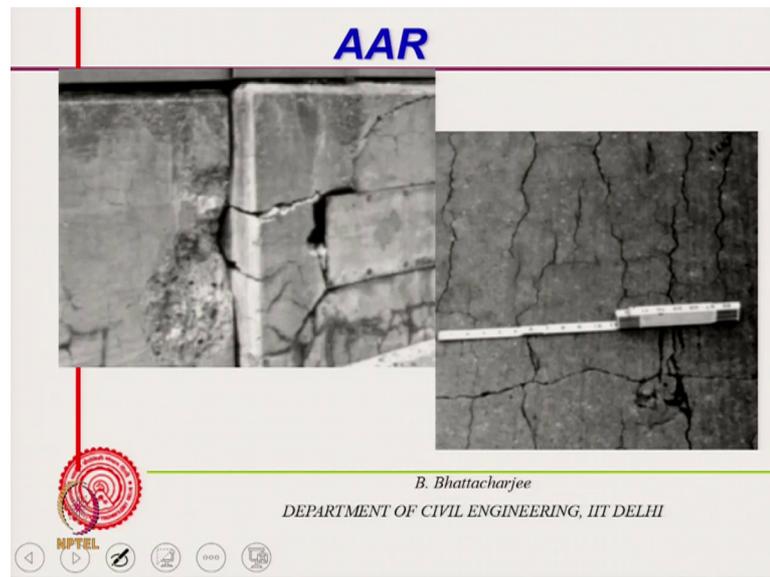


So, because they use an aggregate and this is an example of alkali aggregate reaction now how do I so, I am so, confirm. Because we when we take out the aggregate from the same one I find the aggregate and then the white alkali silica gels were silica gels were very much there right.

And many other parts of the structures whether cracks are not so, much one can see cracks like this, one can see map cracking all over the place you know all over the place they cracks. So, this was the case of an alkali because of some of the piers, it is piers of tower supporting structures wells well this is well that was the pedestal.

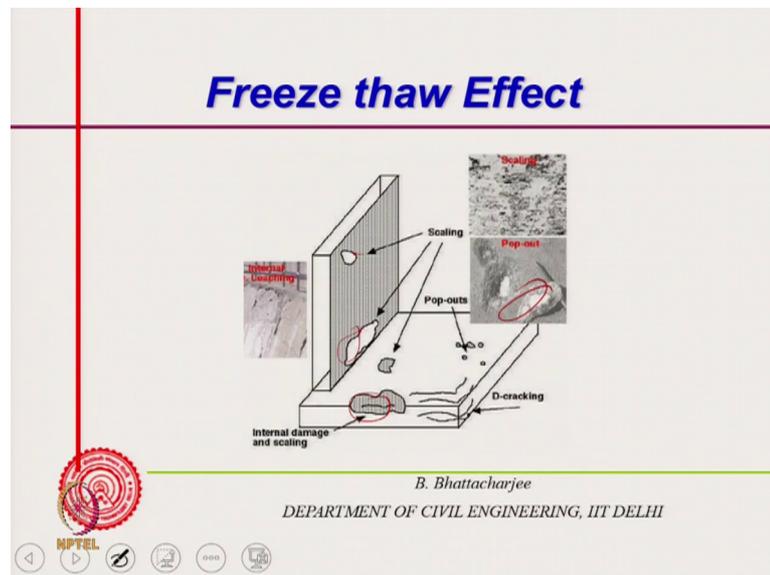
So, they use aggregates which you are not really tested over time and did not do test for alkali aggregate reaction, you will see white patches like this. And there are other additional test, to take the samples chemical test you can do or petrographic analysis you can do to find out on those aggregates what are the minerals presents.

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So, alkali aggregate reactions can be identify in this way, these are some examples of alkali aggregate reaction a broad from literature only. So, visual observation is important if you see this you can actually find out and this is what alkali aggregate reactions would look like some of them right.

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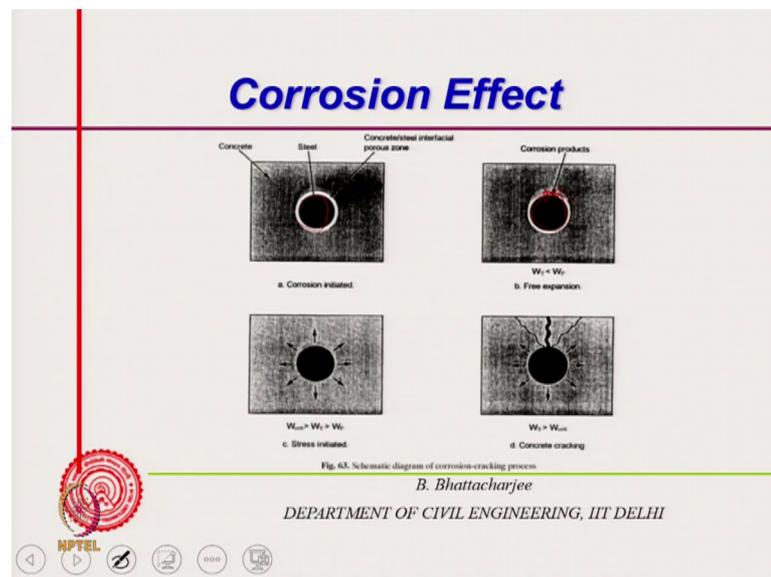


Now, freeze thaw effect is not very common in India, but this is how one it might looked freeze thaw effect might look something like this, some pop out here scaling somewhere you know. So, freeze thaw effect is because of the ice occupies more volume than water.

So, in a saturated concrete if it freezes exerts pressure, ice exerts pressure internally and this can results in sort of you know internal pressure generation and over the years after many cycles I do not think I will go into the concrete science of hit at the moment.

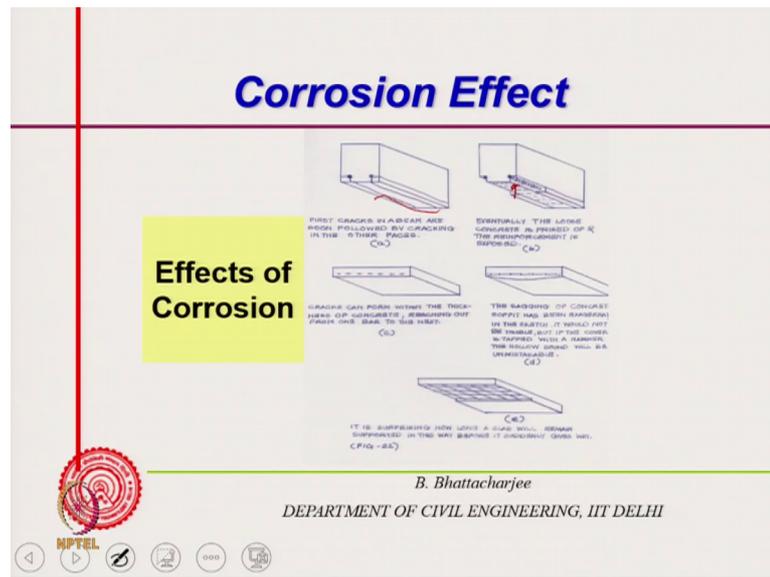
But freeze thaw effect can also be identified kind of popping that you see pop out concrete, scale you know cracks etcetera from the surface deterioration you can actually find out.

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So, similarly corrosion typically corrosion would look like this river corrosion would look like this I showed one example. Initially it is like this, then rust would rust product will occupy the surrounding exerts pressure and finally, the crack comes like this.

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And result should be something like this beam you will see cracks parallel to the line bar like this sometime or later it will simply follow up in slabs you may not see the beginning, but see a sagging and then it will come out like this.