AN INVESTIGATION OF DEFECTS IN REPAIR WORK OF ROOF SLAB OF ACADEMIC BLOCK AT JUIT, HP, INDIA

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Abstract: *Jaypee University of Information Technology is located at Waknaghat; in district Solan of Himachal Pradesh state, India. It is situated in hilly area and due to orographic precipitation the weather here is rainy. Therefore buildings may face problem of dampness and water leakage. Due to large diurnal temperature variation and alternate wetting and drying conditions, cracks appear on the surface of concrete. A crack was observed at the time of placement of conduits pipe after casting of the slab. Pipe was concealed using a rich mix of mortar. Here the defect has been appeared due to the internal cracks in concrete slab. Water percolating from this crack is creating appearance of white scales on the repair work and this is ruining the appearance of slab too. This defect on the slab was due to calcium carbonate efflorescence. In this paper, remedies for the presented calcium carbonate efflorescence are suggested.*

Keywords - *Carbonation, Alkalinity, Efflorescence.*

I. INTRODUCTION

The internal cracks in concrete slab are believed to be the prime cause of this type of defects. In hilly area, due to orographic precipitation, moisture content in this region is high and the buildings here may face the problem of dampness and water leakage. A white scaling with percolating water is observed under roof slab in the academic block (5th floor) of JUIT, Waknaghat. The prime cause of white scaling (as shown in Figure 1 and 2) defect was a chocking of conduits pipe after casting of slab due to any weight and at the time of wiring these chocked pipes are replaced by new ones. It is observed that during the chiseling of concrete slab for replacement of conduits pipe, the internal cracks has been appeared in the slab. On that repair position a whitish material (lime) appeared.

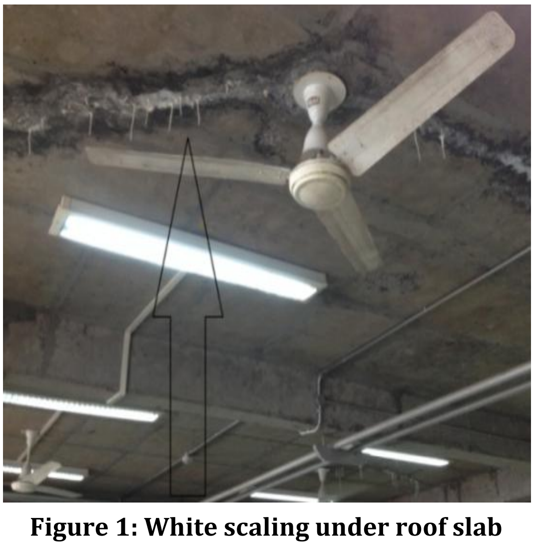

Figure 1: White scaling under roof slab

Figure 2: Prime cause of white scaling

It may be due to any type of efflorescence. Due to water percolating under roof slab, reinforcement may be corroded. Carbonation test was performed to rule out corrosion. The white scaling rose on the surface due to presence of some water soluble salts in water, cement, sand, lime or clay, if used. Even rain water carry dissolved sulphates from the air which may percolate into concrete or plaster. These salts get dissolved in moisture present in mass of concrete, plaster or masonry. The water serves as carrying agent for the salt to bring them to the surface of concrete.

At the surface of concrete, the water evaporates into air but salt cannot vaporize under normal conditions hence it gets deposits onto the surface which causes these white spots on the surface. From Figure1 and Figure 2 the slab defects are clearly visible; the whitish bloom material has appeared on the repaired position of slab. Dropout of whitish bloom material on floor due to continue water leakage in slab are shown in Figure 3. To find out the type of material which has appeared on the surface of defective slab, alkalinity test of material was performed.

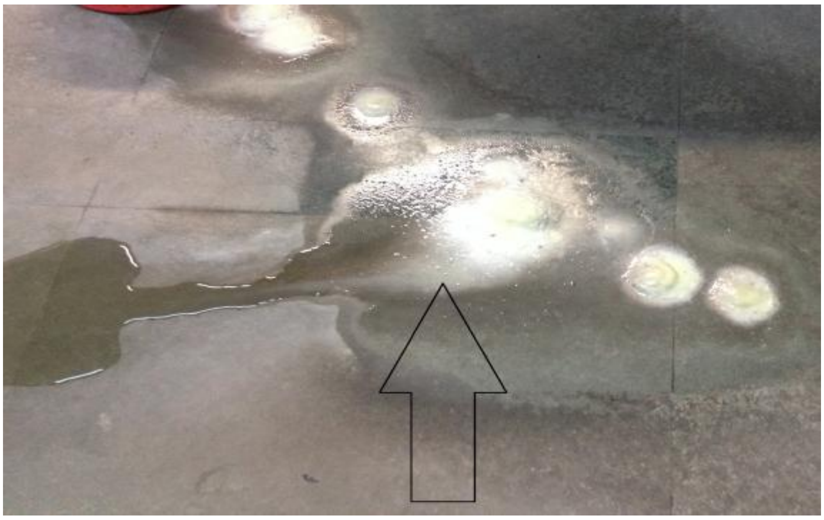

Figure 3: Dropout of whitish bloom material on floor

II. EXPERIMENTATION

2.1 Carbonation [1]

When calcium hydroxide chemically reacts with carbon dioxide and is converted into calcium carbonate this chemical process is known as carbonation. It occurs not only at the surface, but also deep within the concrete. It generally occurs during cold weather. Its reaction with these hydroxides causes chemical reaction as under (Equation 1 and 2):

$CO_2 + H_2O = H_2CO_3$ (Acid) ... (1)

$Ca\,(OH)_2 + H_2CO_3 = CaCO_3 + 2H_2O$ ... (2)

(Alkali) (Acid) (Salt) (Water)

Because of these reactions, the alkalinity of concrete gets reduced. This process is called Carbonation of concrete and leads to corrosion of reinforcement. It can be a problem in areas where the concentration of CO_2 is high and relative humidity is moderate (50-60%). Permeable concrete made with low cement content, high water-cement ratio, and inadequately moist-cured tend to suffer from serious carbonation even due to diurnal or seasonal temperature variations.

2.2 Carbonation Test

This test is carried out to determine the depth of concrete affected due to combined attack of atmospheric carbon dioxide and moisture causing a reduction in level of alkalinity of concrete. A spray of 0.2% solution of phenolphthalein is used as pH indicator of concrete. The change of colour of concrete to pink indicates that the concrete is in the good health, where no change in colour takes place; it is suggestive of carbonation-affected concrete. The test is conducted by drilling a hole on the concrete surface to different depths up to cover concrete thickness, removing dust by air blowing, spraying phenolphthalein with physician's injection syringe and needle on such freshly drilled concrete and observing the colour change. This test was performed on the defected part of the slab and on white deposits as well. The colour turned pink in both the cases. Therefore, it means the concrete is in good health and not affected by carbonation.

Figure 4: Pink colour after spraying of phenolphthalein

From Figure 4 it can be seen that after spraying of phenolphthalein indicator in cracks and in drilled hole, appearance of pink colour is observed. It shows the concrete is not affected by carbonation.

2.3 Alkalinity [2]

The alkalinity reserve of concrete is a function of proportions of hydroxides of Calcium, Potassium and Sodium present in the hardened concrete matrix, which in turn is directly related to quantity of cement. Higher the cement content, higher the reserve pH of concrete due to increased quantity of such hydroxides of Calcium, Potassium and Sodium. It is observed that excessive quantities of cement content also lead to other related problems due to heat of hydration, shrinkage etc. For this Reason, in the codes, the requirements on durability are expressed in terms of minimum cement content, maximum water/cement ratio, and minimum grade of concrete and minimum cover to reinforcement.

The total alkalinity consists of alkalinity caused by CO_3^-, alkalinity caused by HCO_3^-, and by OH^-. A very little negative alkalinity is also caused by H^+.

$$\text{Total alkalinity} = CO_3^- + HCO_3^- + OH^- - H^+ \quad \cdots \quad (3)$$

2.4 Alkalinity test

100 ml distilled water was taken and it mixed with 0.2309 gm sample. After that 1 drop of sodium thiosulfate and 2 drops of phenolphthalein indicator was mixed with

contents, then it gave pink colour. Now the burette was filled with sulphuric acid and titrate the contents with it till the colour changed to colour less. Measure the amount of sulphuric acid was consumed. Further 2 drops of methyl orange indicator added with the contents, it gave yellow colour then again titrate it with sulphuric acid till the colour changed to red and again measure the amount of sulphuric acid that was consumed and calculate the alkalinity of the sample.

III. RESULTS & DISCUSSIONS

3.1 Calculations

Table 1: Phenolphthalein Alkalinity

S. No.	Volume of sample (ml)	Burette Reading		Volume of Sulphuric acid (ml)
		Initial	Final	
1.	100	1	6	5
2.	100	6	13	7
3.	100	13	19	6

3.1.1 Specimen calculation:

Volume of sulphuric acid (V_1) = 0.6 ml
Normality of sulphuric acid = 0.02 N
Volume of sample = 50 ml
Equivalent weight of $CaCo_3$ = 1000
Phenolphthalein Alkalinity = P

$$P = \frac{\text{Volume of } H_2SO_4\ (V_1) \times \text{Normality} \times 50 \times 1000}{\text{Volume of sample taken}}$$

= 0.6×0.02×50×1000/100

= 6 mg/L as $CaCo_3$ equivalent

Table 2: Methyl orange Alkalinity

S. No.	Volume of sample (ml)	Burette Reading		Volume of Sulphuric acid (ml)
		Initial	Final	
1.	100	0	0.6	0.6
2.	100	0.6	1.1	0.5
3.	100	1.1	1.7	0.6

3.1.2 Specimen calculation:

Volume of sulphuric acid (V_2) = 6 ml
Normality of sulphuric acid = 0.02

Volume of sample = 50 ml
Equivalent weight of $CaCo_3$ = 1000
Total Alkalinity = T

$$T = \frac{\text{Volume of } H_2SO_4\ (V_2) \times \text{Normality} \times 50 \times 1000}{\text{Volume of sample taken}}$$

= 6×0.02×50×1000/100

= 60 mg/L as $CaCo_3$ equivalent.

3.2 Interpretation of Results

- If P = 0, The Alkalinity due to Hydroxyl and carbonate ions was 0 and alkalinity due to bicarbonate ion was equal to the Total Alkalinity i.e. T = 60 mg/L
- If P < 0.5T, then the Alkalinity due to Hydroxyl ion was 0 and the Alkalinity due to carbonate ion is 2P. i.e. 2P = 12 mg/ L. Alkalinity due to Bicarbonate ion is equal to the Total Alkalinity minus 2 times Phenolphthalein Alkalinity i.e. T -2P = 48 mg/L.
- If P = 0.5T then the Alkalinity due to Hydroxyl ion was 0 and the Alkalinity due to carbonate ion was 2P. i.e. 2P = 12 mg/L. Alkalinity due to Bicarbonate ion was equal to 0.
- If P > 0.5T then the Alkalinity due to Hydroxyl and carbonate ions were 2P-T. I.e. 2P-T = -48 mg/L. and alkalinity due to Bicarbonate ion was 0.
- If P = T, The Alkalinity due to Hydroxyl was equal to the Total Alkalinity i.e. T = 60 mg/L. Alkalinity due to carbonate and Bicarbonate ions were 0.

Based on the test results, it was found that the alkalinity of the sample is 60 mg/L. It was found that the alkalinity of sample is within the range.

Table 3: Phenolphthalein Alkalinity

Value of P and T	Alkalinity due to		
	OH^-	CO_3^{2-}	HCO_3^-
P = 0	0	0	T = 60
P< 0.5T	0	2P = 12	T-2P = 48
P = 0.5T	0	2P = 12	T-2P = 48
P > 0.5T	2P-T= -48	2P-T = -48	0
P = T	T = 60	0	0

3.3 Efflorescence [3]

It is a fine, white, powdery deposits of water soluble-salts left on the surface of masonry as the water evaporates. These efflorescence salt deposits tend to appear at the worst times, usually about a month after a building is constructed, and sometimes as long as a year after completion. In this case, the cause of white scaling on repair patch is calcium carbonate efflorescence

3.3.1 Source of Efflorescence

For the process of efflorescence to occur, four things must be present,

- Salts
- Physical forces
- Moisture
- Opening

Salts: - Quantities of water-soluble salts as small as a few tenths of one percent are sufficient to cause efflorescence. The primary source of salts is the calcium hydroxide Ca $(OH)_2$ from hydrated cement. The calcium hydroxide is a by-product of the cement curing process. It can dissolve in water and migrate to the surface of the wall where it remains when the water evaporates. The calcium hydroxide crystals then react with carbon dioxide (CO_2) in the air to form calcium carbonates ($CaCO_3$).

Physical Forces: - Efflorescence is particularly affected by temperature, humidity, and wind. These physical forces, as well as others, can increase the absorption of water that leads to efflorescence. For example, wind can force water into a building substrate and its movement over the surface of a building can create pressure differentials that cause the water to move upward. Also, capillary action can cause water to move upward and laterally within a substrate. Hydrostatic pressure present under below-grade slabs and behind below- grade retaining walls can also cause water movement. Additionally, temperature gradients across the wall can drive moisture into or out of the wall.

Moisture: -Water is the vehicle that dissolves and transports the salts to the surface. Possible sources of moisture may include precipitation, water vapor from the interior, poorly aligned sprinklers, or ground water migration.

Opening: - Cement based products such as stucco are naturally porous and thus have numerous capillaries or pathway for water to move through them, these includes hairlines cracks, voids caused by shrinkage, bug holes and improper building designs. Together these four factors result in efflorescence appearing on the surface of a wall, concrete, masonry.

3.4 Remedies of Efflorescence

3.4.1 Theoretical remedies

It is very difficult to remove efflorescence once it appears on concrete, masonry and wall surfaces. It can be controlled to some degree if factors such as moisture and salts ingress are kept in check. Following are some remedial suggestion for efflorescence.

- Once efflorescence appears on the surface in powder form the first step in removing it is to identify the salt causing it. If the salts are water soluble, the best removal method is with a dry brush [4].

- If brushing is not successful, then the stain is probably calcium carbonate efflorescence (which is in this case study). It is more difficult to remove. It usually appears as a white “bloom” and in worst cases forms a hard white crust. To remove calcium carbonate, saturating the wall, slab as thoroughly as possible with water then washing with a diluted acid solution following immediately with an alkaline wash, is a good remedy. The acid recommended is 2-5 parts hydrochloric to 100 parts water or 20 parts vinegar to 100 parts water. A diluted solution of household Ammonia is the recommend alkaline wash.[4]

- The building can be protected against efflorescence by treating the material with an impregnating, hydro-phobic sealer. This is a sealer which repels water and will penetrate deeply enough into the material to keep water and dissolved salts well away from the surface.[5]
- A conventional chemical cleaner (muriatic acid) can be used in a mild solution, usually 1 part muriatic acid to 12 part water. After acid cleaning from the masonry the wall should be sealed.[6]
- If cleaning is not effective in removing, then the wall needs to be fog coated. Fog is the blend of cement, water and dry pigments. It should spray onto the wall but unlike paint, it will not chip, peal or fade.[6]
- All soluble alkali sulphates should be reduced.[6]
- The structure should be enough damp proof.[6]
- The construction technique should be good to eliminate migratory paths for moisture from top surface.[6]
- For the elimination of source of moisture Brush off the surface and apply oil based sealer and paint.[3]
- High pressure steam curing of concrete should be used.[3]
- Efflorescence that is not soluble in water, such as calcium carbonate, may be removed by high pressure water jetting, with possibly adding fine sand to the stream.[5]
- If the composition of the efflorescence is unknown, washing with acid as for insoluble efflorescence is usually effective and it should be preferable to first try dry- or wet-brushing.[7]
- The concrete permeability and concrete's exposure to wetting and drying cycles should be minimized by using specific admixtures.[7]
- Moisture control is the key to reducing efflorescence. Moisture transfer inside and out of the concrete is essential for efflorescence formation. Therefore, concrete should be protected from wetting and drying during construction.[7]
- Care should be taken to assure that the cleaning solution and technique do not physically damage the surface. Improper cleaning procedures can significantly change the appearance and contribute to additional Efflorescence in the future.[7]

3.4.2 Practical remedial steps

- The first step is to removing the tiles from effected area.
- Removing mud plastering from effected area and clean out the surface by steel brushing.
- Treatment of appear hair crack line by making "V" grove and by using Adhesive bonding.
- Apply water proofing over the area by using cico or tapcrete.
- Plastering of the surface of 25 mm thickness over the water proofing area by taking cement-sand ratio of 1:4.

- At bottom level clean out surface and after mud plastering use 2 coat of paint as primer and putty.
- Curing is very important of repaired surface.

IV. CONCLUSION

Efflorescence is ugly in appearance and can readily spoil the looks of mortar, concrete or brickwork, particularly where the decorative properties are very important. However, it is not normally deleterious to long term concrete durability. There are a number of remedial treatments discussed above, which must be applied with great care. Special polyurethane membranes can stop efflorescence from forming in the first instance in both concrete materials and in brickwork, by effectively cutting off the water flow to the surfaces. Waterproofing agents can be applied to bricks, mortars and concretes.

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