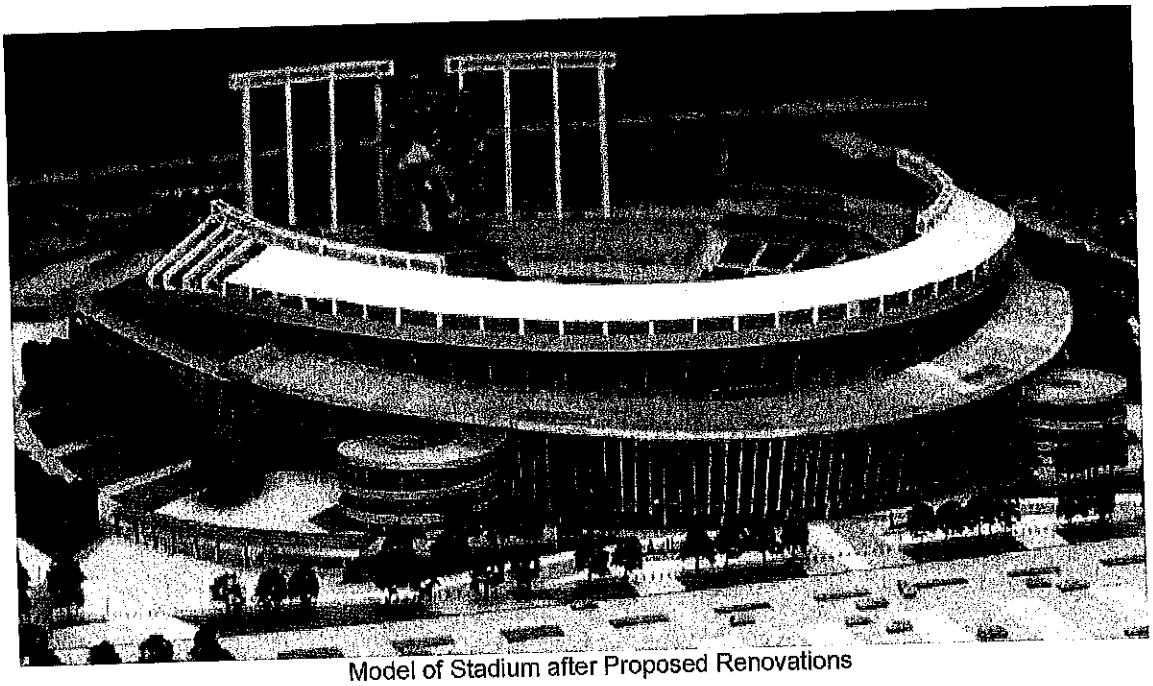
Concrete Materials Testing of
Kauffman Stadium
Kansas City, MO



Model of Stadium after Proposed Renovations

Prepared For:

Kansas City Royals Baseball Corporation and
Jackson County Sports Complex Authority and
One Royals Way
Kansas City, MO 64129

December 19, 2007

Prepared By:

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Limited Liability Statement

Tourney Consulting Group, L.L.C. is a consulting firm focused on the durability aspects of reinforced concrete. The basis of the present assessment is strictly upon the condition of the facility from a reinforced concrete materials perspective. The condition appraisal provided in this report by no regards constitutes a structural engineering condition appraisal or analysis. If obvious serious structural concerns are present at the time of field evaluation and are observed, Tourney Consulting Group, L.L.C. will immediately bring these potential issues to the owner.

The analysis, results, and recommendations only reflect the condition of the sites tested and may not be representative of all locations throughout the structure.

The value of durability analysis, as used in this report, rests on the client's ability to relationally compare the condition of the studied structure under various maintenance, corrosion protection, and restoration alternatives. Typically, the comparison of alternatives is based on a net present value analysis. This approach is used to establish the relative cost associated with alternatives that have variable duration expectations. Any relative cost estimates provided are only intended to be "ballpark" estimates, and are not intended to be precise estimates of cost.

Any repair recommendations provided are based on materials performance data from manufacturer's publications. Tourney Consulting Group does not offer any implied or expressed warranty of material performance.

Project Description

Tourney Consulting Group (TCG) was contracted to conduct concrete materials testing of Kauffman Stadium for the Kansas City Royals Baseball Corporation and the Jackson County Sports Complex Authority as outlined in the "Request for Material Testing Services Proposal" dated May 14, 2007.

The objectives of this assessment were:

1. To assist Thornton-Tomasetti determine the type and extent of immediate repairs that should be recommended to the Owner.
2. To perform life-cycle analysis on major stadium areas and draw conclusions with regard to frequency and costs of future repairs in order to achieve a 30 year life span.
3. To assist Thornton-Tomasetti with preparation of reports and construction drawings for the stadium by providing recommendations with respect to concrete repair materials and treatments.

TCG performed a limited visual assessment, conducted concrete sampling and patching, corrosion testing, concrete cover measurements, and reinforcement location at three locations using ground-penetrating radar in accordance with the requested scope of services in "Table 1: Royals Stadium: Materials Testing Summary" during the KC Royals away-stand from August 15 through August 21, 2007. Additional tests were conducted on cores extracted from the View seating roof pedestals along with hardened air void analysis on all cores receiveing petrographic examination. The quantity of tests performed is detailed in Table 1.

Table 1 – Schedule of Tests Performed

Test Method	Required No. Tests	Actual No. Tests
Acid-soluble chloride ASTM C 1152	218	254
Acid-soluble chloride ASTM C 1218	108	98
Petrographic Examinations ASTM C 856	50	64
Hardened air-void system parameters ASTM C457		64
Thin-section analysis ASTM C 856		9
Compressive Strength	40	44
Concrete Cover Profiles	80	79
Half-cell Potential Measurement ASTM C 876	10 areas	10 areas
Ground Penetrating Rebar	3 areas	3 areas

Visual Observations

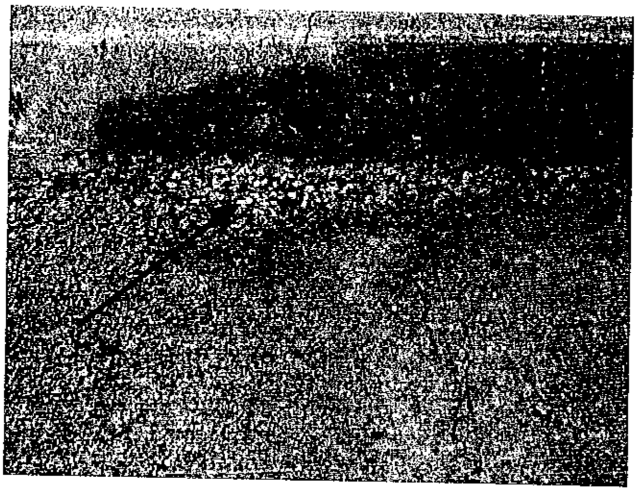
Key issues related to the durability of the concrete elements under investigation were documented with photographs. TCG was contracted to help Thornton-Tomasetti in this regard, so this report contains only general features that TCG identified as indicators of distress to assist the visual assessment work by Thornton-Tomasetti's personnel.

It should be noted that the following photographs are intended to show the observed distress, and are not intended to represent typical conditions throughout the structure. Overall, the concrete is in pretty good shape. These photos are intended to help Thornton-Tomasetti characterize the various levels of distress observed.

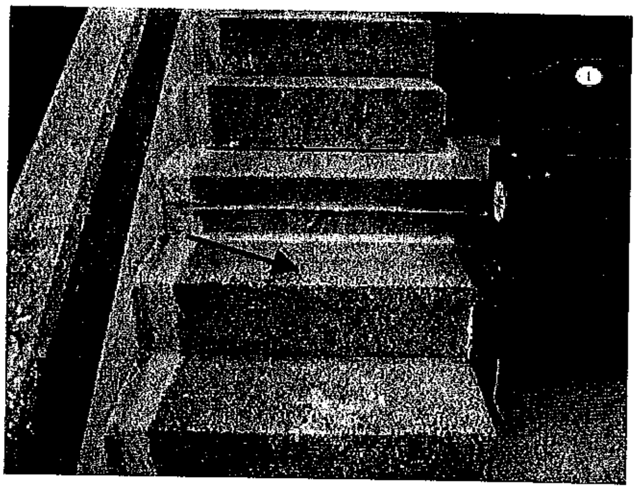
Photographs of Typical Observations

1. Freeze-thaw scaling distress is prevalent along the aisles in the Field seating bowl.

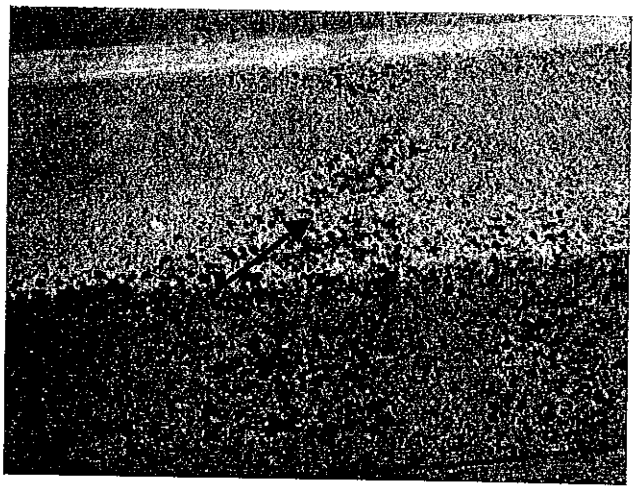
2. Close-up of severe scaling showing complete loss of cement paste and exposed coarse aggregate. Repair of this condition will require partial-depth repair, because water ponds in this location accelerating the deterioration.



3. Moderate to advance scaling distress on precast stair blocks

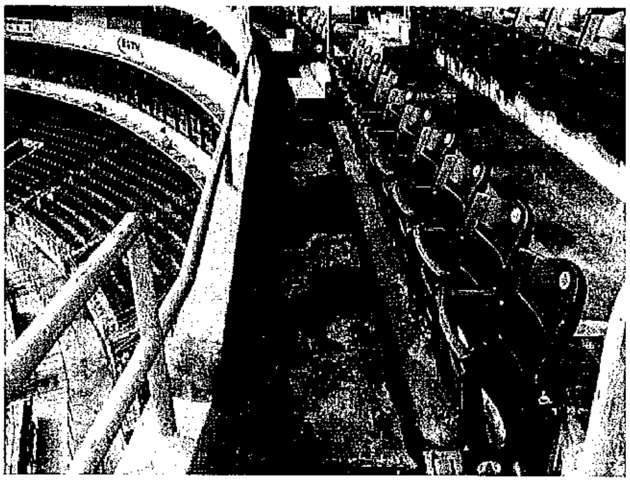


4. Close-up of scaling distress on precast step in the View Seating Bowl. This stair is still functional so replacement at this time is not necessary. However, scaling will continue to degrade the step so future replacement is expected.

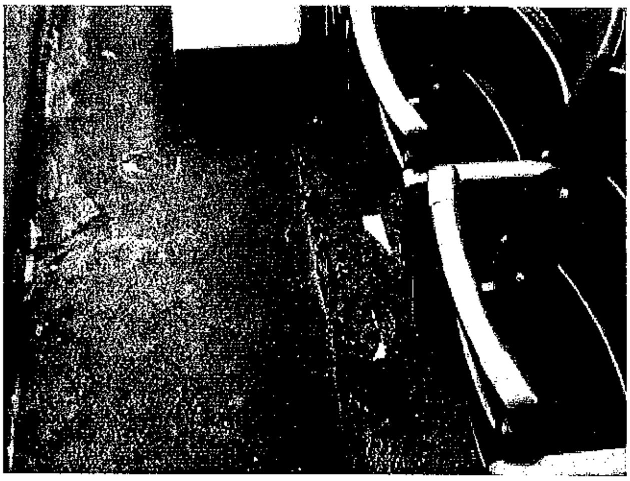


5. Failed "cosmetic" feather-edge surface patch of scaling distress at Section 135 Field Level Seating Bowl. Scaling has continued under the patches.

6. Failed coating along row A of View Seating Bowl. The failed coating covers a delaminated topping mortar and structural slab under the seats. The topping was used to create a trough under the seats. The sealant along the edge of the trough has deteriorated and allows water under the topping and coating, which contributes to premature coating failure.

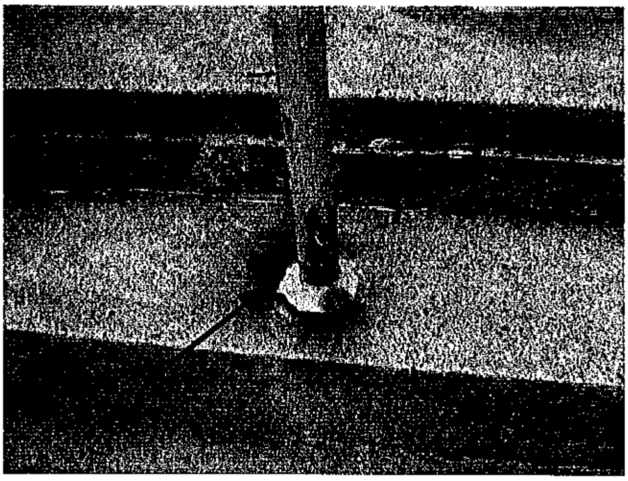


7. Poor drainage allows water to pond in the trough and seep under the mortar and coating.



8. Corrosion induced distress from handrail posts embedded into the portal walls is common.

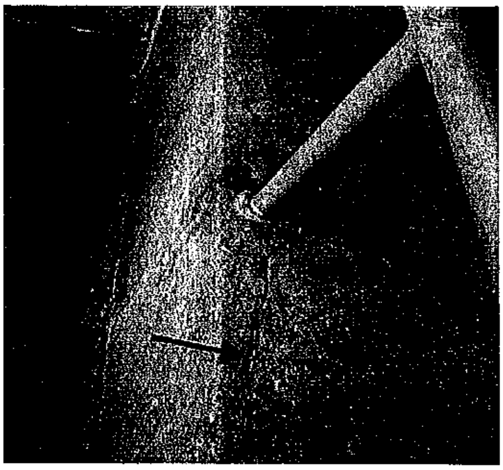
9. Replacement of handrails with excessive corrosion is required.



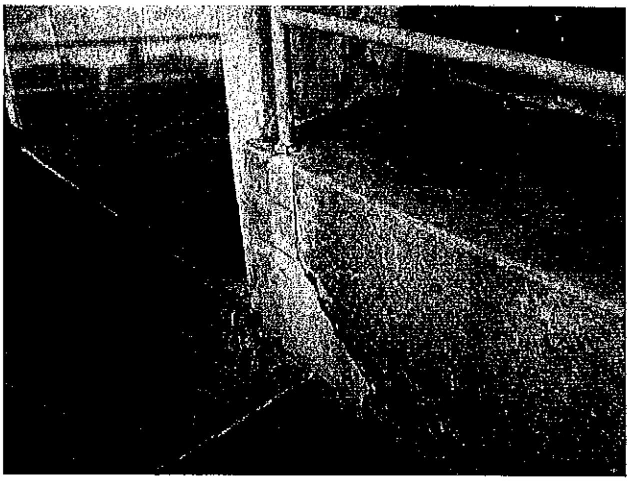
10. Cracking from pipe corrosion inside the concrete. This handrail and concrete should be repaired. (Typical condition)

11. Failure of previous "cosmetic" surface patch with cracking distress at handrails.

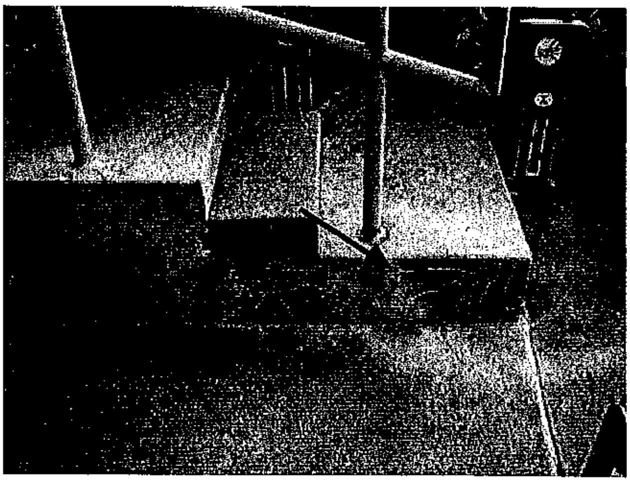
12. Handrail corrosion-related cracking along the wall between the Field Level and Plaza Level seating areas. Partial-depth wall repair behind reinforcing and handrail pocket is required at several locations.



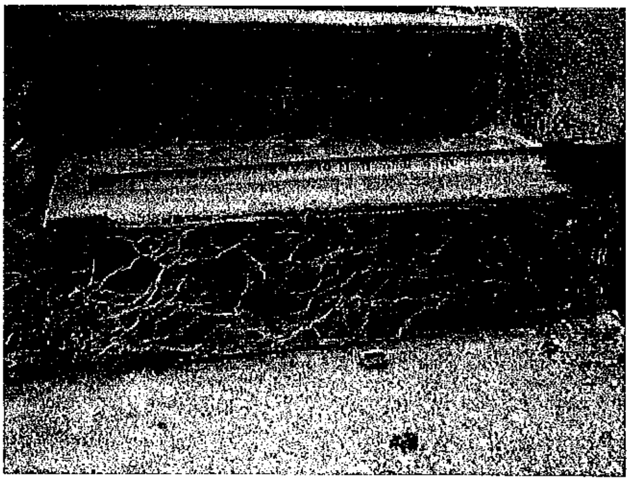
13. ASR-related cracking at handrail along the wall between the Field Level and Plaza Level seating areas. Previous repairs show signs of adjacent ASR distress. Also note ASR cracking distress adjacent to and reflecting through walkway patch repair at arrow. This corner and slab should be replaced within 5 years.



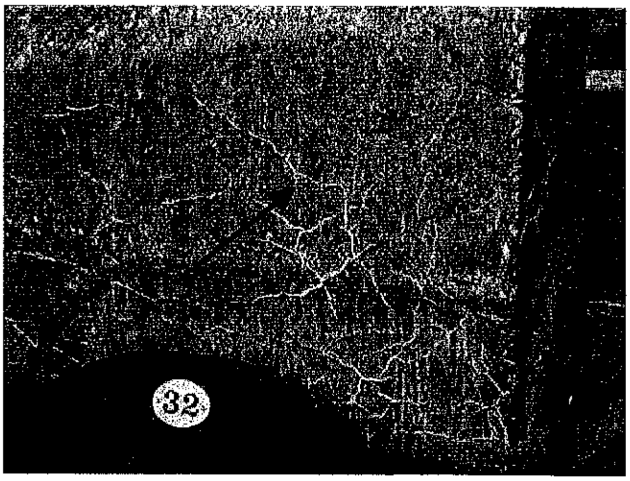
14. ASR cracking distress in slab on grade at Section 139 railing. This slab and stair should be replaced.



15. Severe ASR distress of stair at Section 343. Note tightly spaced cracks with exudation. Removal and replacement of concrete in this condition is recommended at this time. When repairing ASR distressed concrete, topical application of 30% lithium nitrate solution to the interface between existing and replaced concrete is recommended.

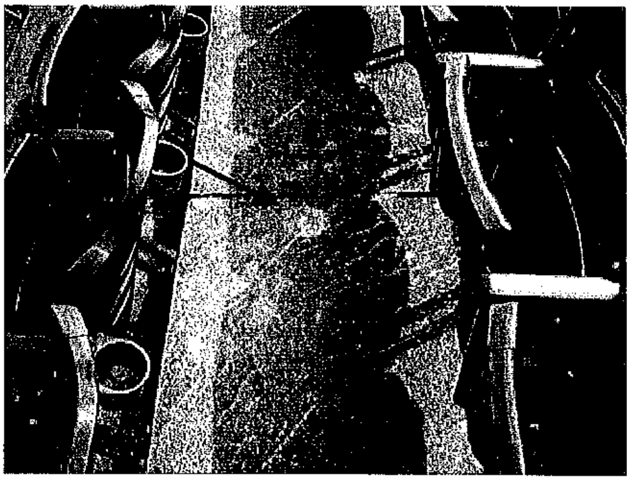


16. Advanced ASR distress of wall adjacent to stair at Section 343. Removal and replacement is recommended.

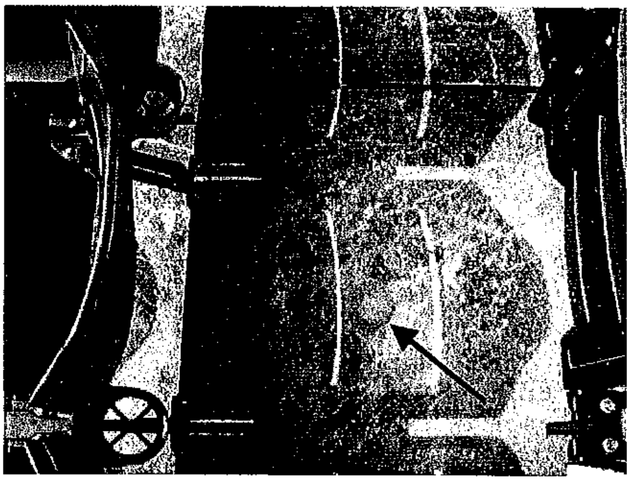


17. Core from step at Section 343 crumbled during coring operation. Core can be broken by hand.

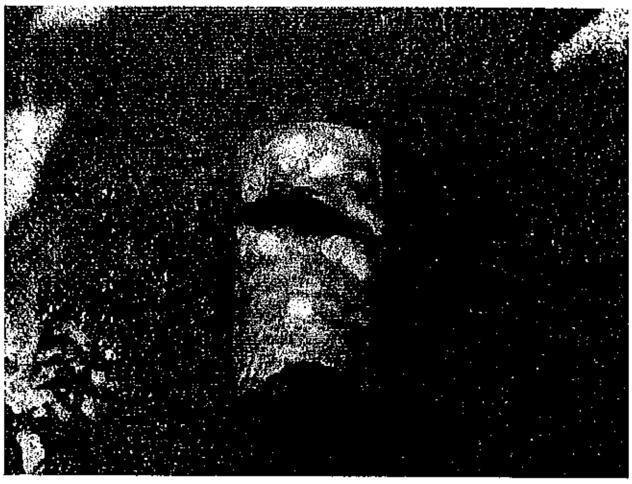
18. Advanced ASR distress along construction joint in Field Level seating Section 130 slab on grade. Note cracking pattern with ASR gel exudation and core 130P2 location. Concrete in this condition will probably need to be replaced in 5 to 10 years.



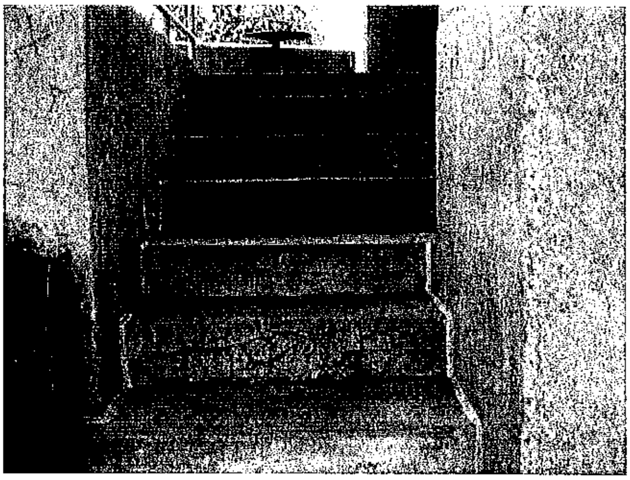
19. Advanced ASR distress along construction joint in field level seating Section 127 slab on grade. Note cracking pattern with exudation and core 127P1 location away from expansion joint.



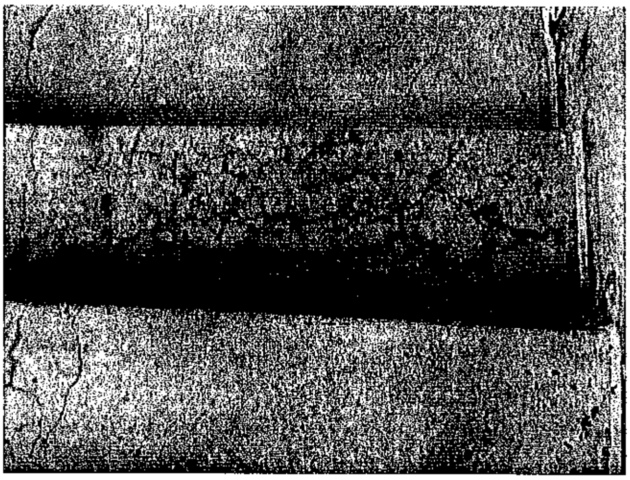
20. Core removed from Section 130 adjacent to construction joint.



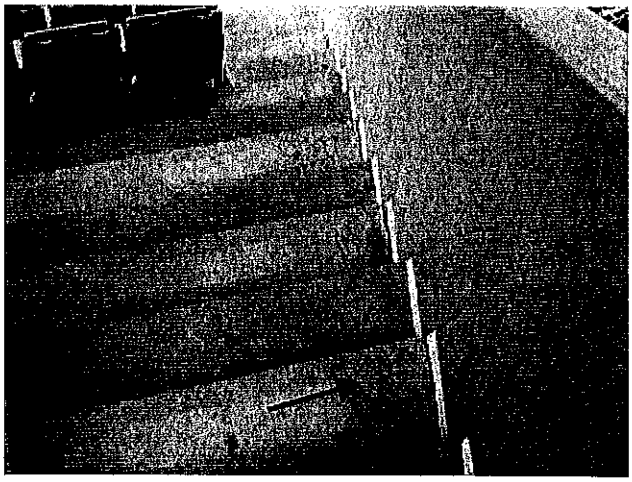
21. Advanced ASR of stairs from Club Concourse to right field Section 238. It is likely that the stairs will need replacement within 5 to 10 years.



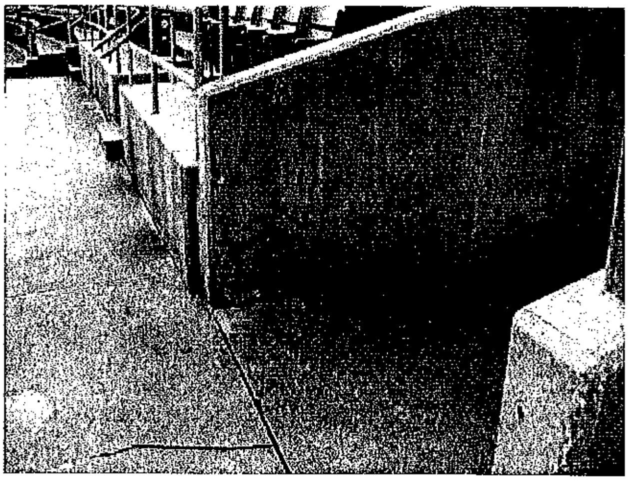
22. Close-up of Section 238 step that was cored for petrographic examination. Note close spacing of interconnected cracks. Concrete in this condition is probably too far gone to treat effectively.



23. Stairs along the wall in Section 238 Club Level right field. Note Moderate ASR cracking distress adjacent to failed sealant.

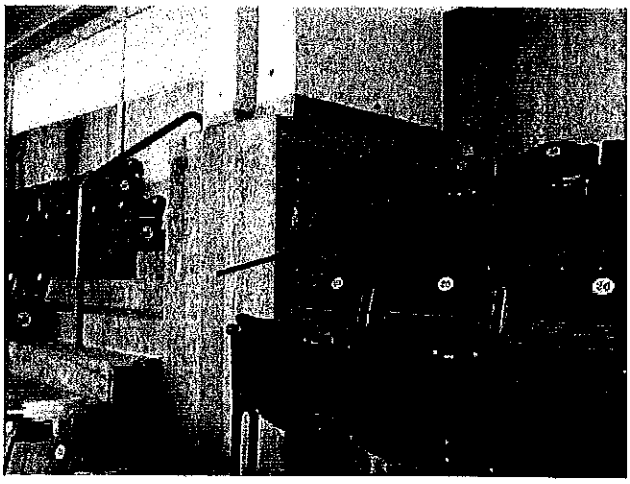


24. Moderate ASR distress of portal wall in right field. Note cracking pattern at base of the wall where the exposure to moisture is greatest. This wall is a candidate for lithium nitrate treatment, as replacement within the next 20 years is likely.

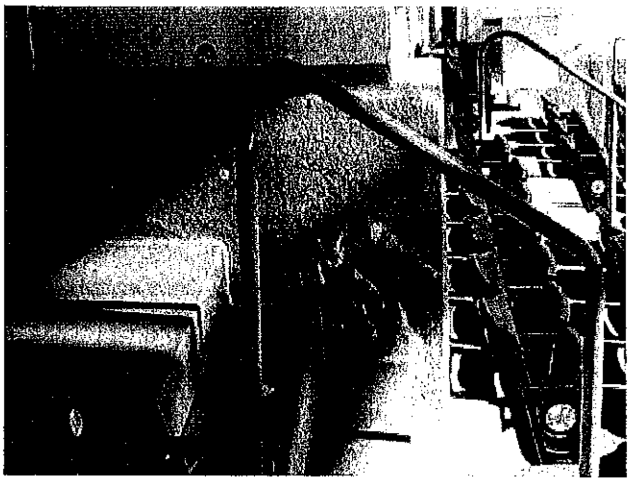


25. Advanced ASR Cracking with exudation along Portal wall on View Level. Cores for petrographic examination were taken from this location. Replacement of this concrete will be necessary within 5 years.

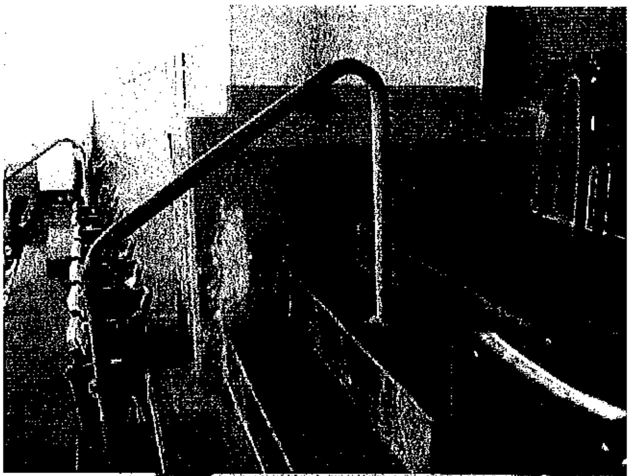
26. Severe ASR distress of the expansion joint pedestals supporting the View Roof at Section 423. Cores were taken from this pedestal for petrographic examination and compressive strength. Core strength was approximately 6000 psi.



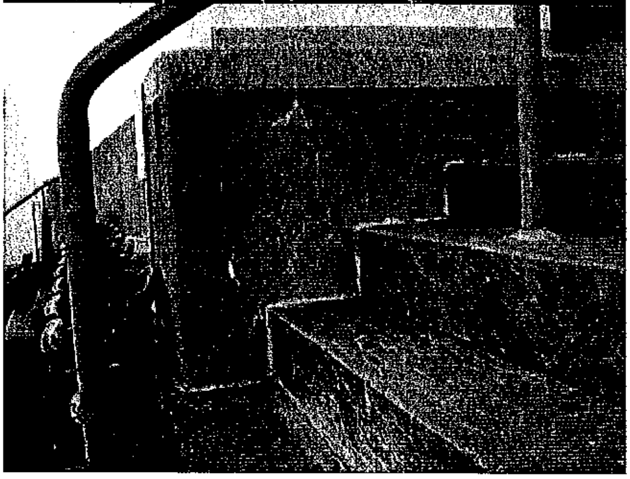
27. Advanced ASR distress of left field pedestal. Note exudation and cracking below the top 12 inches of the pedestal. This indicates that the concrete below the steel tube is of questionable quality.



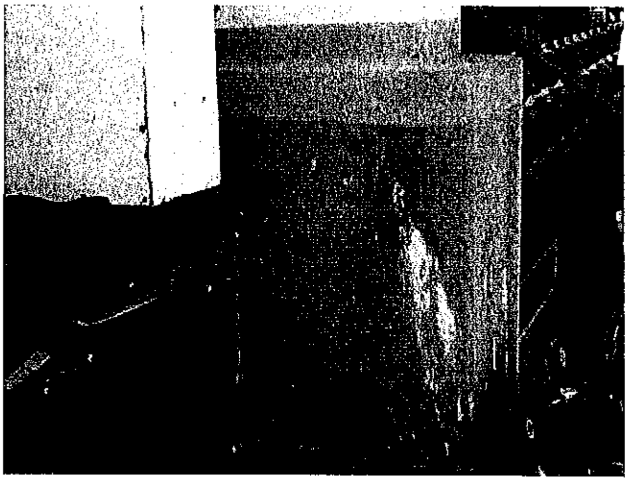
28. Advanced ASR distress of View Roof pedestal in Section 428. Note exudation and cracking below the top 12 inches of the pedestal. This indicates that the concrete below the steel tube is of questionable quality.



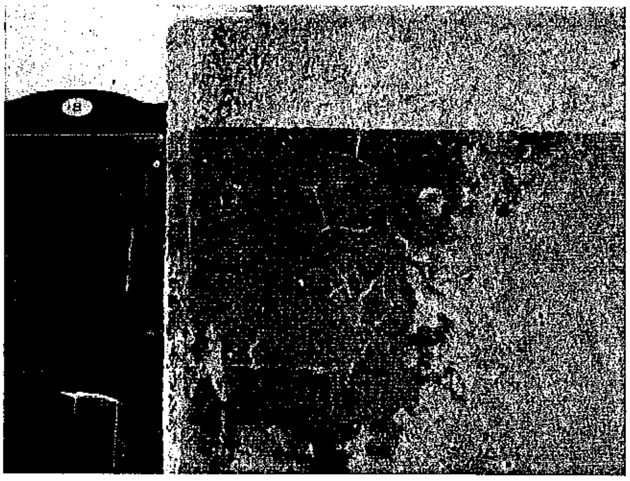
29. Advanced ASR distress of View Roof pedestal and stair in Section 432.



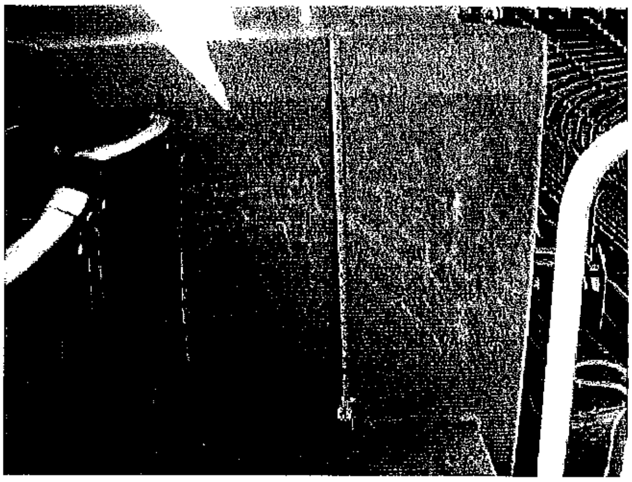
30. Advanced ASR distress of View Roof Pedestal in Section 428. Note close crack pattern at base of pedestal with gel exudation.



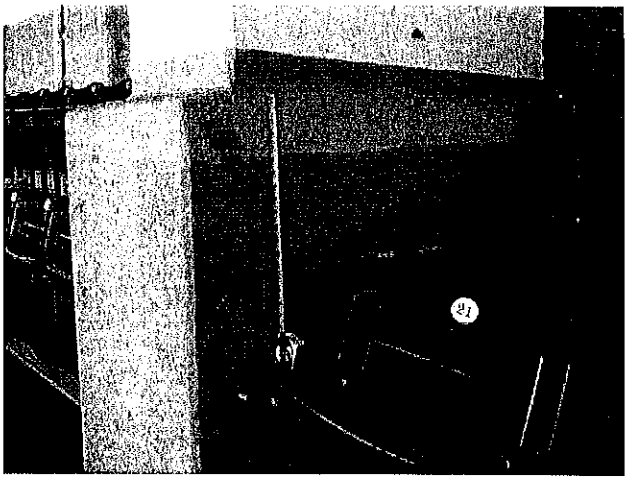
31. Moderate ASR distress of View Roof Pedestal. This condition shows the typical "Y" cracking damage has begun, but replacement at this time is not mandatory because the concrete strength has probably not begun to deteriorate. Strength deteriorates when the "Y" cracks coalesce, additional intermediate cracks form, and exudation is prevalent.



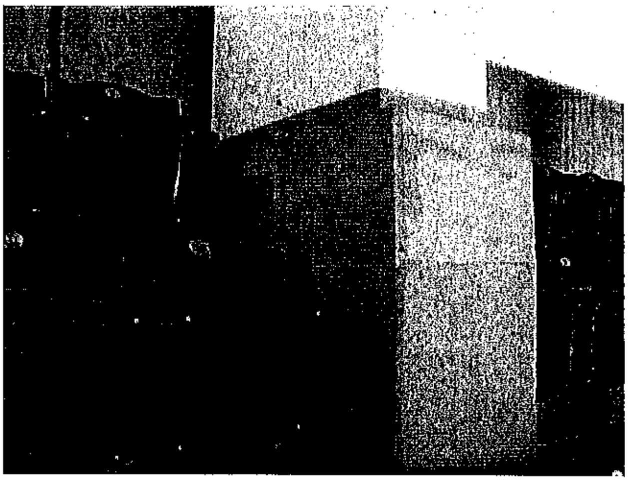
32. Moderate ASR distress of pedestal from Section 424 that was sampled. ASR cracking is visible above the point where the steel tube stops (~12 in. on tape). Cores were extracted below this zone to avoid the tube and reinforcing. The compressive strength was in excess of 10,000 psi.



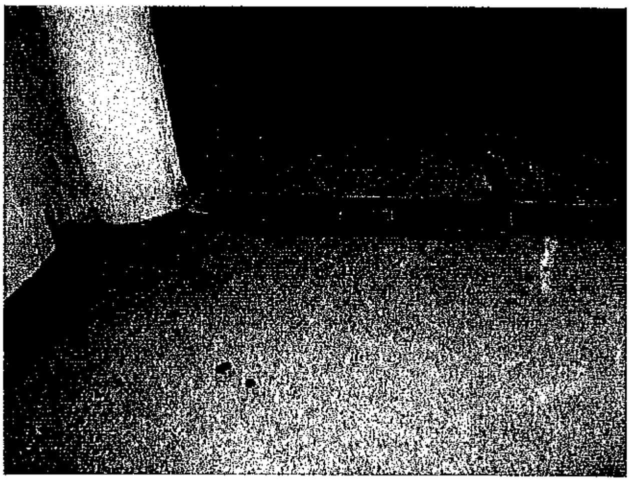
33. Minimal ASR distress observed at pedestal from Section 400 that was sampled. Core compressive strength exceeded 10,000 psi, and petrographic examination identified internal ASR distress. Future replacement is expected in approximately 10+ years.



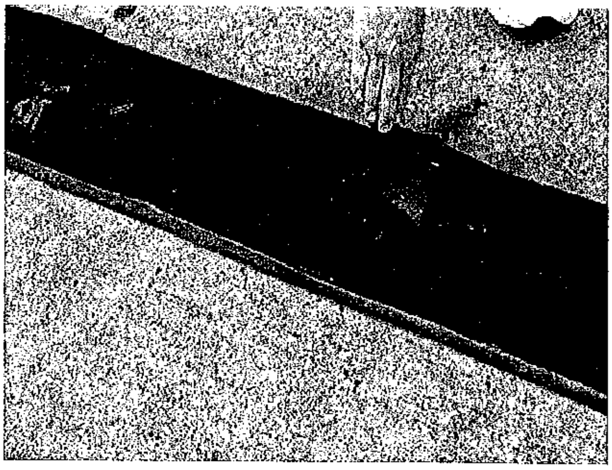
34. Previous View Pedestal patch repair. Visual inspection should include looking for signs of ASR distress along the interface between existing concrete and patch concrete.



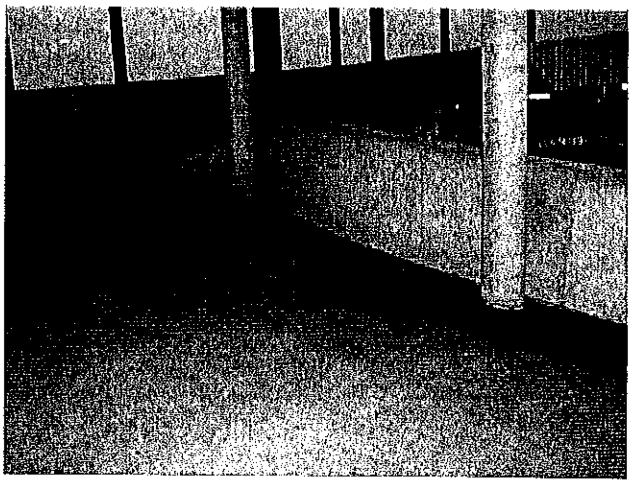
35. Many expansion joint seals on Pedestrian ramps need to be repaired or replaced. Note water stream along the interior ramp wall.



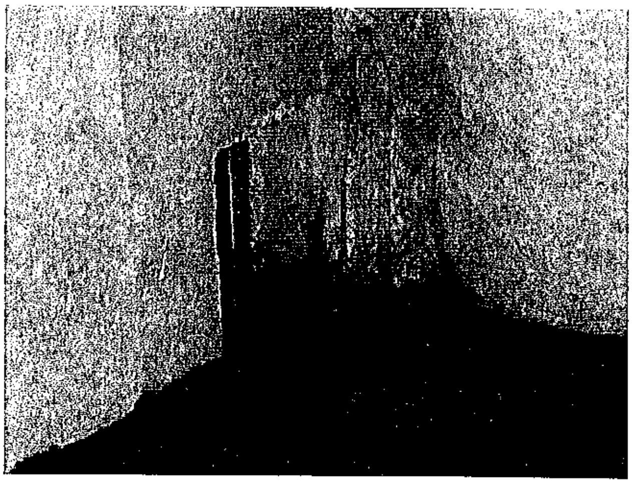
36. Damaged expansion joint seals should be replaced.



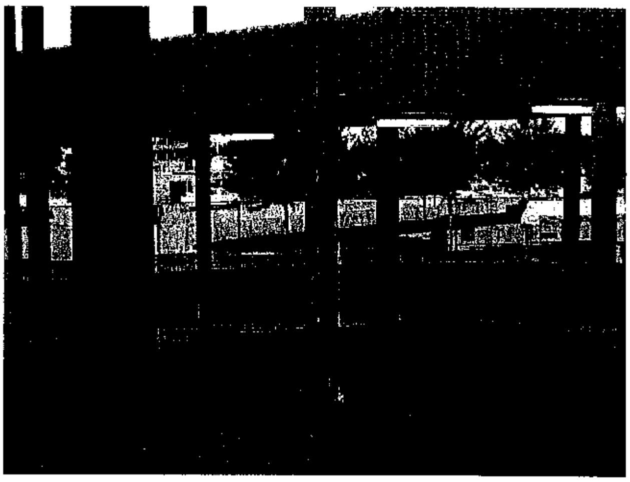
37. Typical drainage pattern of the Pedestrian Ramps.



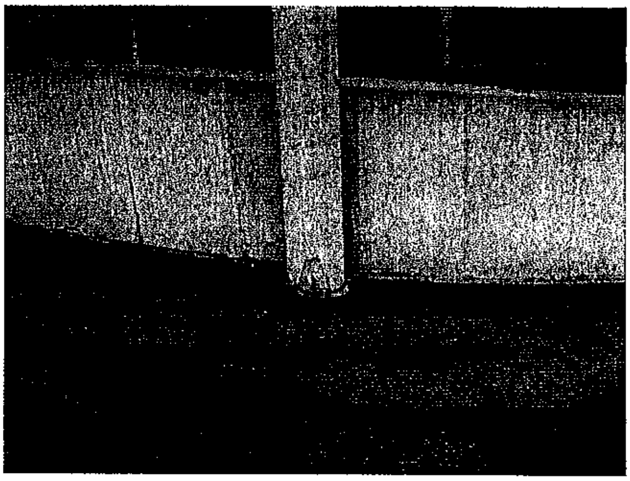
38. Close-up of pedestrian ramp scupper showing rust stains from reinforcement that is too close to the surface.



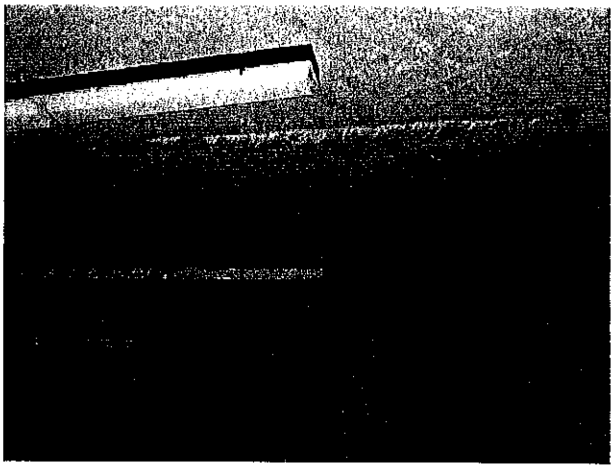
39. Drainage of ramp running along an expansion joint column. This condition should be remedied so that water is directed away from the columns.



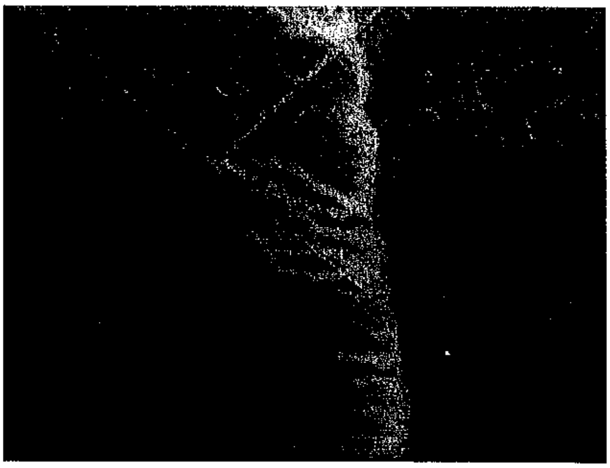
40. Corrosion of a pedestrian ramp column with less than adequate concrete cover over the reinforcing. Low concrete cover is common throughout the building.



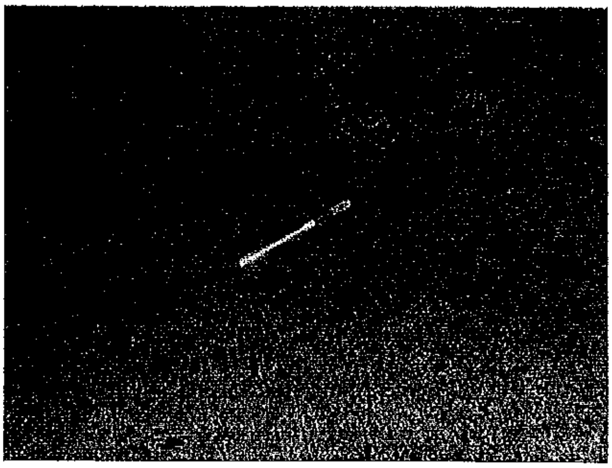
41. Radial cracks in the pedestrian ramp slabs allow seepage that decalcifies the concrete adjacent to the crack and allows corrosion to initiate.



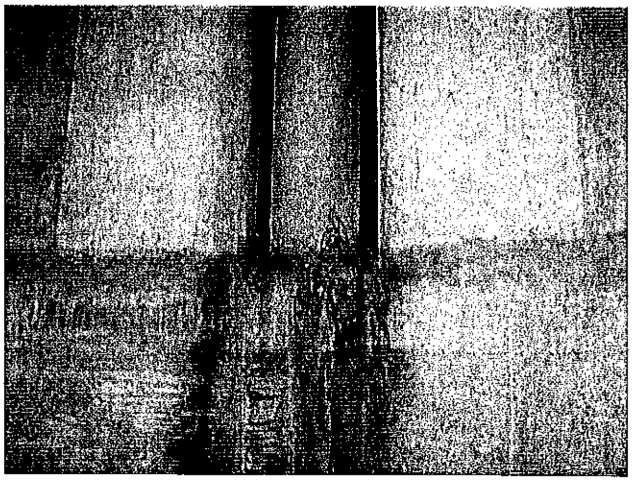
42. Corrosion stains indicate corrosion has initiated on the reinforcing crossing this crack. Intervention at this time is necessary to minimize future corrosion damage.



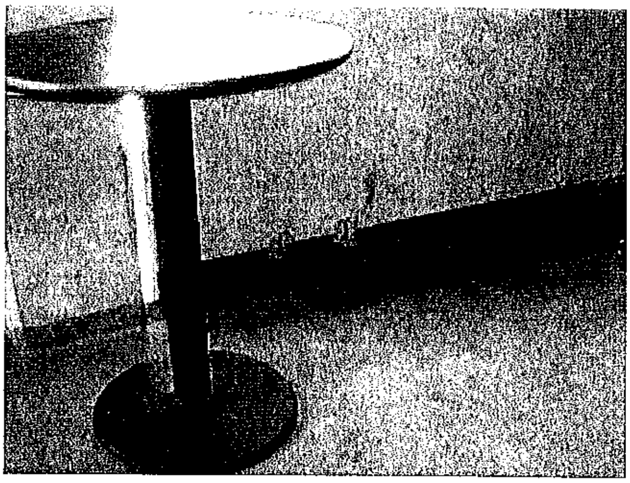
43. Top side appearance of typical leaking radial crack in pedestrian ramps. These cracks should be routed and sealed to minimize corrosion of reinforcing steel.



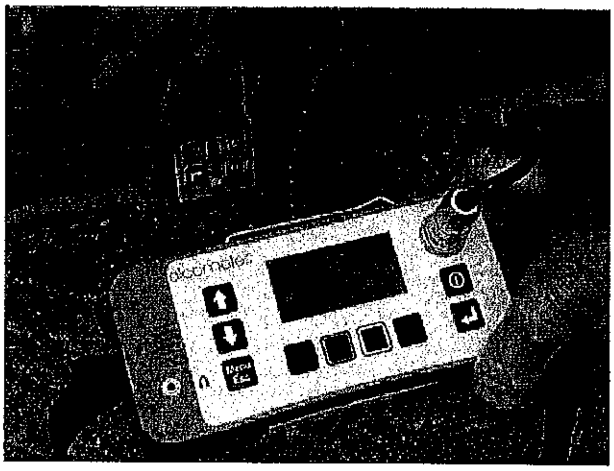
44. Corrosion of column base on top of retaining wall below Plaza Level on right field Pedestrian Ramp. Note stains from salts running along wall.



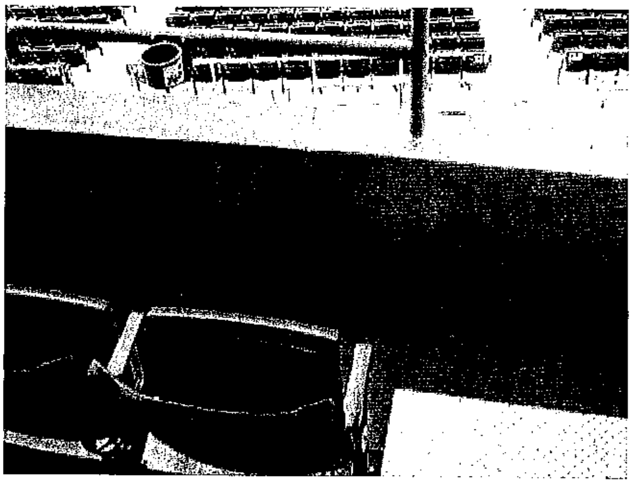
45. Corrosion popouts along Club Level wall near Section 234. Low concrete cover is the most typical cause for this type of distress.



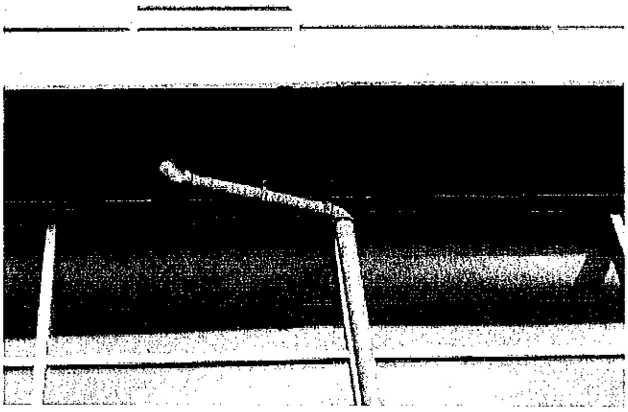
46. Non-destructive concrete cover measurement.



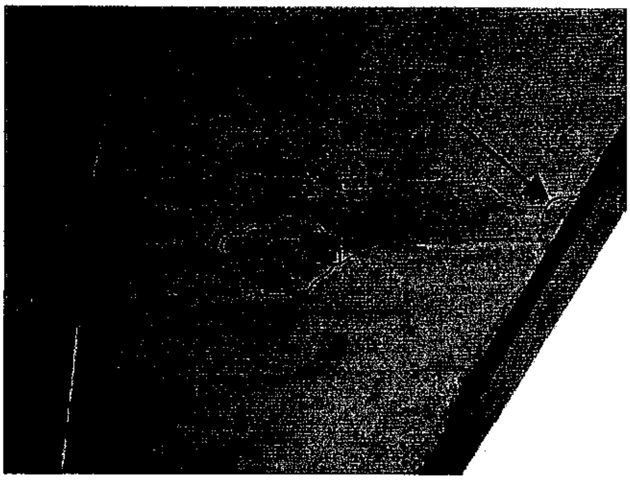
47. Corrosion popout from low concrete cover along a construction joint in right field Club Level Row A.



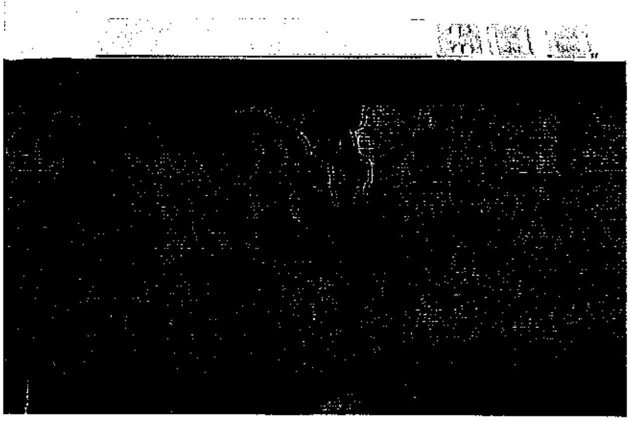
48. Corrosion of the 300 Level Row A slab soffit over the Stadium Club. Beam reinforcing was located against the forms when cast.



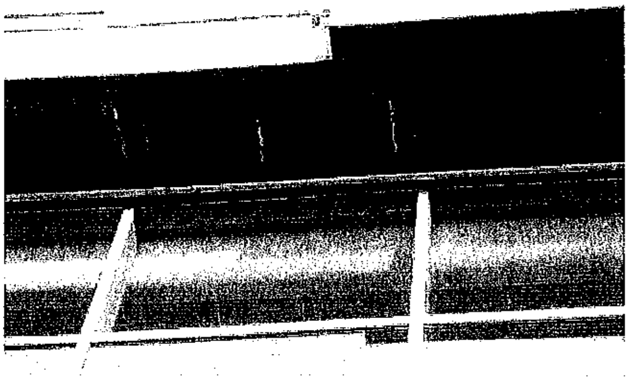
49. Concrete spall of 300 Level Row A soffit. Spall removal is recommended. Corrosion mitigation will be necessary to minimize continual maintenance of this potentially hazardous area. It appears that this condition is most frequently associated with the beam locations.



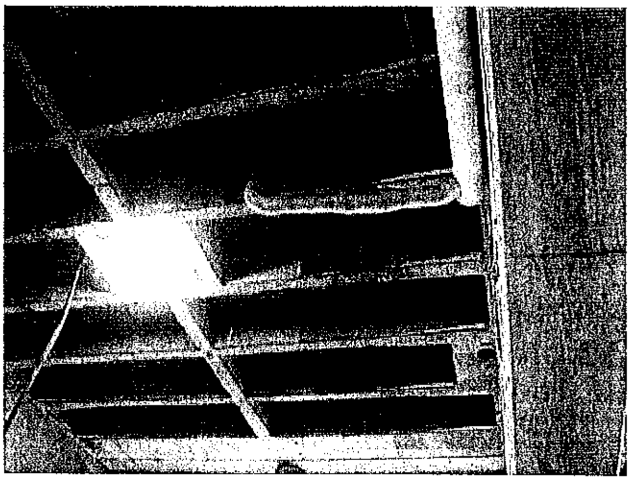
50. Corrosion spall of left field Level 300 Row A slab soffit and staining from Row B void drain hole. The outlined area is loose concrete over corroding reinforcement that should be removed to mitigate the potential for a falling object hazard.



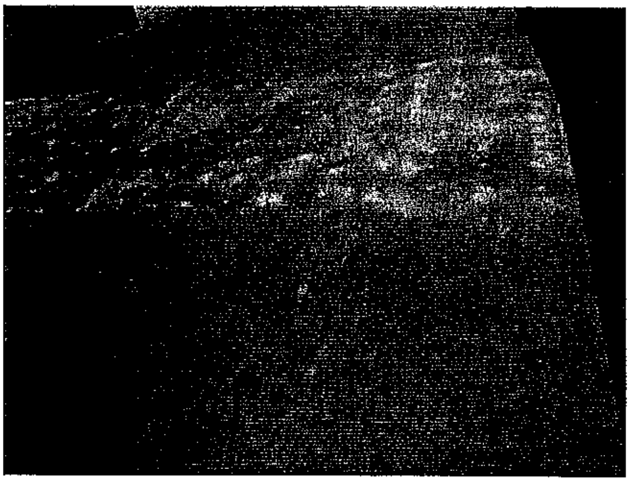
51. Cracks in the 300 Level Row A slab soffit with efflorescence. This condition indicates water movement through the cracks which can lead to corrosion and accelerate ASR distress.



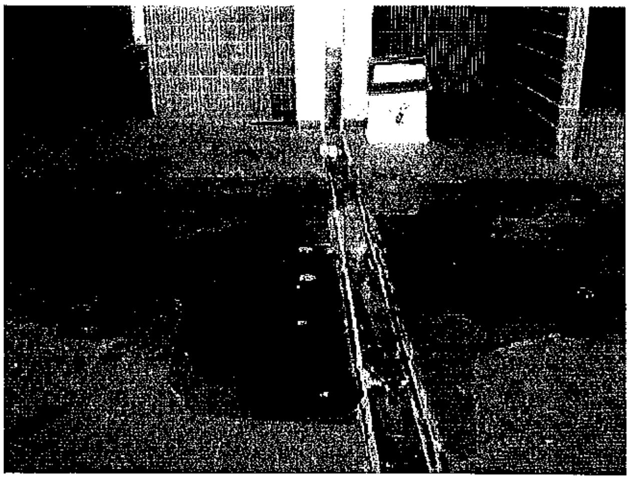
52. Leaking crack in Club Level slab along joist. Note reinforcing wire grid impression on the slab soffit, indicating minimal concrete cover over the wire.



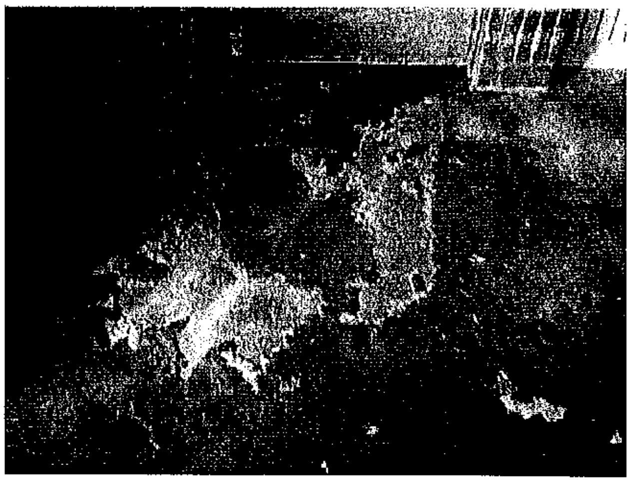
53. Corrosion potential and coring location on View Concourse at Section 303. Note damaged area (arrow) and drill marks at corrosion potential grid locations (Corrosion Test Areas 8 and 9)



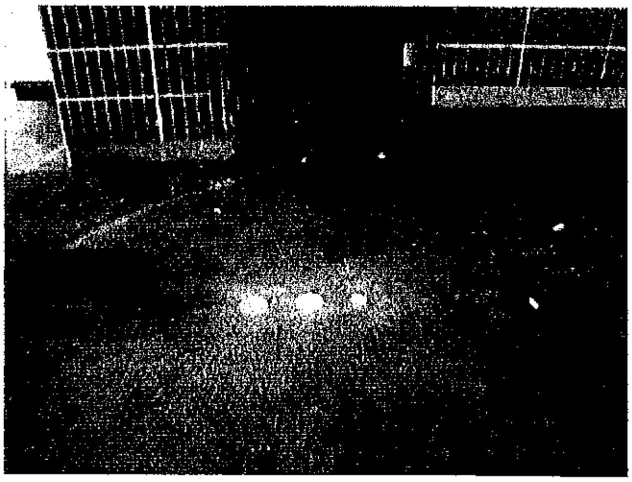
54. Damaged membrane coring locations at the View Concourse expansion joint near Section 323.



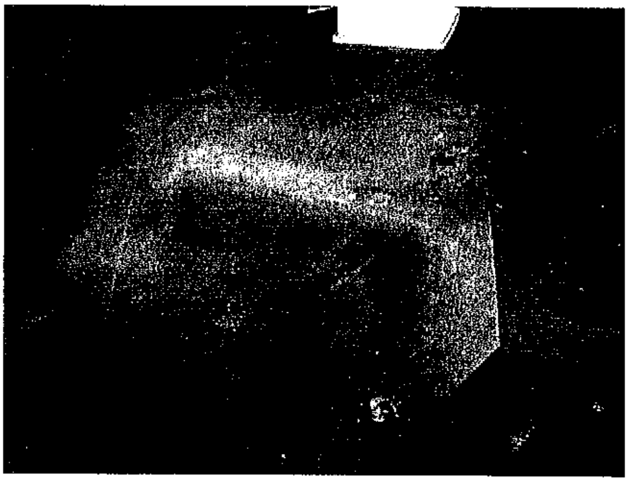
55. Pedestrian coating damage on Plaza level adjacent to food service door ways.



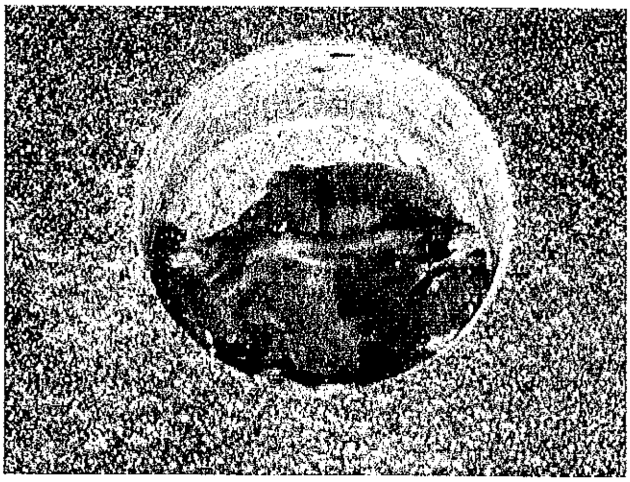
56. Undamaged membrane coring site on the Plaza Concourse at Section 130 food service.



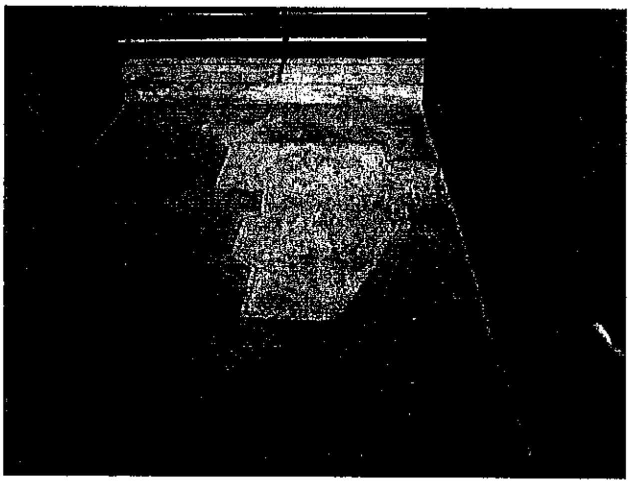
57. Damaged membrane coring site on the Plaza Concourse in the food court behind Section 116.



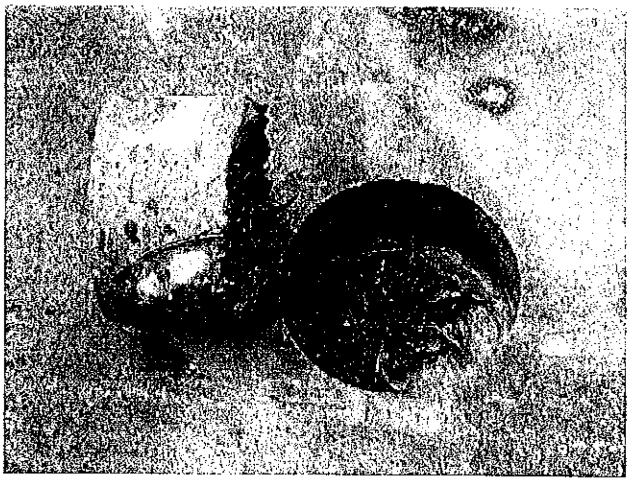
58. Core from damaged membrane area of View Concourse near Section 333 showing rubber membrane below topping slab over Stadium Club. The combination of an external coating with an intermediate waterproof layer traps moisture in the topping concrete that can accelerate coating failure.



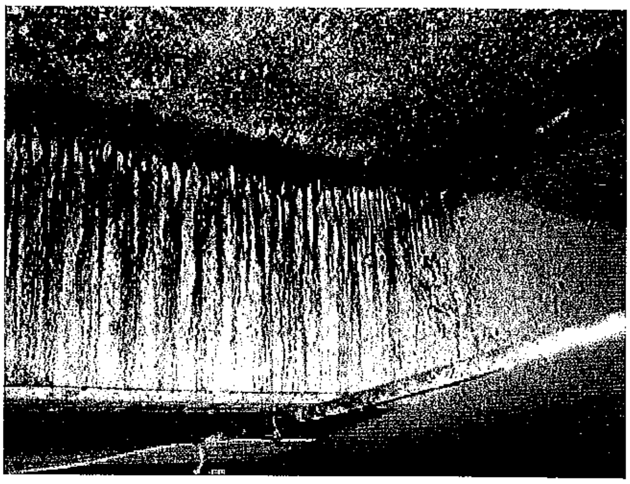
59. Damaged and undamaged membrane coring site on the View Level Concourse in Section 333 portal. This location is a patch repair over the Royals Club. This repair was a steel fiber reinforced topping slab over a polymer coating.



60. Core removed from the 333 portal damaged membrane area. Coring was halted when the intermediate membrane was encountered.



61. Ceiling of food storage room 014 with black staining below concession area. TCG attempted to remove a core from this ceiling for examination, but failed because the core snapped off at ¾ inches at two locations. Coring was halted when the coring bit overheated. The concrete was not carbonated. Close examination indicates that the stain is a loose scale that is probably of organic origin. The scale can be removed by hand brush or pressure washing.



Concrete Cover Measurements

Concrete cover measurements were taken at representative locations around Kauffman Stadium using the non-destructive test device "Protovale 331" manufactured by Elcometer. This cover meter operates uses the "state-of-the-art" pulse-induction eddy-current conductivity technique that allows relatively quick and reliable assessment of existing as-built concrete cover values. Concrete covers were determined at core sampling locations and additional randomly selected areas spread throughout the ballpark.

The values in the following tables were obtained by scanning a representative area with the equipment and recording the highest value, the lowest value and estimating the median value displayed. Each test area consisted of at least 10 ft² for raker columns, and seating areas; pedestrian ramp and concourse locations consisted of larger areas that were at least 25 ft² each. Yellow highlighted areas indicate concrete covers less than recommended for exterior exposure.

Design concrete cover values.

Exposed to soil = 3 in.
Slabs (top and bottom) = ¾ in.
Joists = 1 in.
Columns and Beams = 1-½ in.
Foundation walls and other = 2 in.

Findings:

- Concrete cover varies widely throughout the stadium.
- The most frequent areas with inadequate concrete cover are columns, beam bottoms, and walls.

Table 2 - Upper Deck Back Panel Cover Measurements, in.

Section	Min	Max	Median
442	1.75	6.00	3.10
436	<0.45	4.35	2.10
428	2.15	3.00	2.65
420	1.00	3.00	1.25
404	<0.45	3.60	1.60
407	1.65	2.85	2.10
423	0.70	3.00	1.65
441	<0.45	3.00	2.00

Table 3 – Field Level Seating Cover Measurements, in.

Section	Min	Max	Median
136, 130	1.1	2.5	1.5
110, 105	1.25	3	1.6
127, 135	2.3	2.8	2.5

Note: Minimum @ nosings reinf. approx. 15 in.O.C., > 7 in between bars

Table 4 – Plaza Level Seating Cover Measurements, in.

Section	Min	Max	Median
130	4.35	6.35	5.15
104	4.35	8.0	5.8

Table 5 – Club Level Seating Cover Measurements, in.

Section	Min	Max	Median
208	1.45	2.5	2.2
209	1.8	2.6	2.2

Table 6 – View Level Seating Cover Measurements, in.

Section	Min	Max	Median
436			1.5
424			1.5
412			1.5
415			1.5

Note: WWF in 3-in. precast riser consistently placed.
WWF cover not consistent in stair blocks – many exposed wires

Table 7 – Plaza Level Concourse Cover Measurements, in.

Section	Min	Max	Median
130	1.45	3.25	2.2
116 food court	1.75	4.6	2.8
106	2.1	4.35	2.8

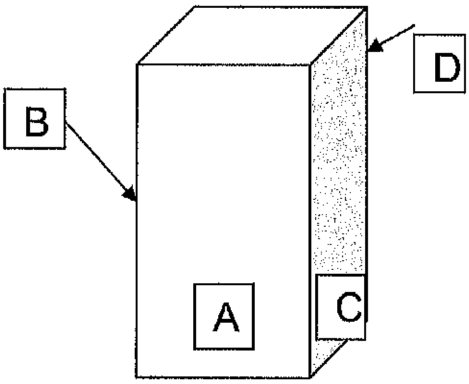
Table 8 – Club Level Concourse Cover Measurements, in.

Section	Min	Max	Median
236	1.5	2.45	1.8
200	1.75	2.9	2.1
207 in front of ramp	1.75	2.4	2.0
Stadium club entrance around drain	1.3	2.3	1.6

Table 9 – View Level Concourse Cover Measurements, in.

Section	Min	Max	Median
400	1.8	2.3	2
411	2.4	2.8	2.5
419	2.15	2.65	2.2
427	1.55	2.4	2.2
439	0.8	1.5	1.1
404	2.8	3.15	2.45
412	1.7	2.45	1.95
424	2.25	2.7	2.35
432	2.15	3	2.35
440	1.1	1.9	1.55

Table 10 - View Level Raker Cover Measurements, in.



- Side A always faces away from the field
- No measurement = blocked side of column

View Level Raker Cover Measurements, in												
	A			B			C			D		
Location	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median
C – 38	2.10	2.95	2.60	1.25	2.35	2.60	2.35	3.15	2.70	0.90	2.60	2.10
C – 26	<0.45	2.50	1.00	1.20	3.20	1.50	1.90	4.20	3.60			
C – 13	1.20	2.20	1.40	2.35	3.10	1.80	1.85	3.10	2.30	1.20	2.20	1.70
C – 7	2.10	2.50	2.40	2.65	3.20	2.80	1.60	3.10	1.90	1.10	1.90	1.40
C – 32	0.45	2.05	0.90	2.95	4.65	3.60	0.80	2.45	1.60	2.95	3.50	2.50
C – 18	1.35	2.50	1.60	2.05	5.05	3.65	2.65	6.00	3.80	1.55	2.30	1.80
A – 48	<0.45	3.35	2.10	<0.45	3.05	0.90						
A – 1	<0.45	3.00	1.35	<0.45	3.00	0.90						

View Level Raker Columns A – 48, A – 1

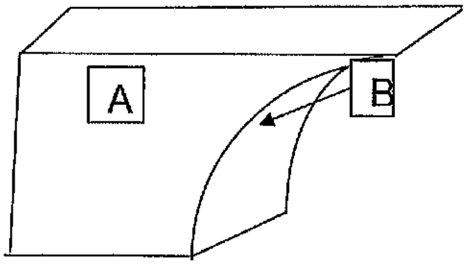
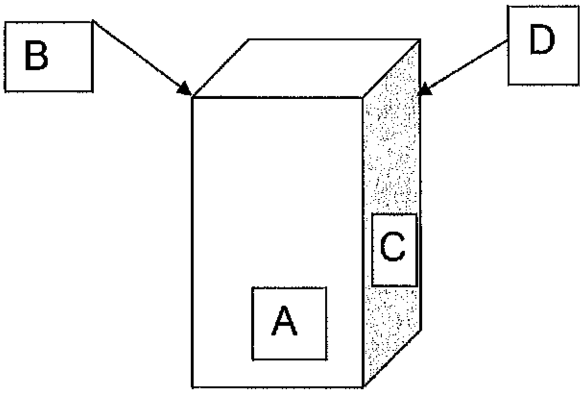


Table 11 - Club Level Raker Cover Measurements, in.



- Side A always faces away from the field
- No measurement = blocked side of column

Club Level Raker Cover Measurements, in

	A			B			C			D		
Location	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**
C - 12	2.45	5.05	4.20				1.25	2.25	1.60	2.60	5.30	3.40
B - 10	<0.45	4.55	3.10									
C - 3	1.70	5.70	3.30	<0.45	5.10	2.50	<0.45	3.65	2.35	<0.45	2.35	1.70
A - 8							2.35	3.60	2.60			
B - 36							1.65	3.75	2.80	1.75	2.65	2.00
A - 46				2.30	4.80	3.40						
C - 47	2.05	3.05	2.60	0.70	2.40	1.40	0.75	1.85	1.10	<0.45	1.00	0.70
B - 6	<0.45	2.45	1.60				2.20	3.70	3.30	1.70	3.00	2.80

Table 12 – Right Field Inner Pedestrian Ramp Cover Measurements, in.

Element ->	Ramp			Walls			Columns		
Level	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**
View	1.65	3.1	2.1	2.0	2.5	2.2			
Club	1.45	3.3	2.0	1.5	2.5	2.0	0	2.5	shifted
Plaza	1.75	2.8	2.1	1.45	2.5	2.1	0.75	2.5	shifted
Field	1.85	3.2	2.3						

Table 13 – Left Field Inner Pedestrian Ramp Cover Measurements, in.

Element ->	Ramp			Walls			Columns		
Level	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**
View	2.0	3.0	2.25	0.5	2.0	1.5			
Club	1.9	3.0	2.0	1.25	2.0	1.65	0	2.5	shifted
Plaza	1.75	2.5	2.1	1.0	1.75	1.5	0.5	2.5	shifted
Field							0.75	2.0	shifted

Compressive Strength:

Concrete compressive strength was verified in accordance with ASTM C 42 procedures by extracting 3.25 inch diameter cores throughout the structure. Most locations are represented by individual cores as described in the following graphs and core log. All compressive strength cores were extracted from areas of sound concrete.

The original specified concrete strengths (1973) reported by Thornton-Tomasetti in a preliminary report dated November 28, 2006 were:

- Piers and foundations = 4,000 psi
- Structural rakers, floor framing, and slabs on grade = 4,000 psi
- Precast seating risers = 5,000 psi

Findings:

Compressive strength test results indicate that the concrete strength meets or exceeds the original specified strength.

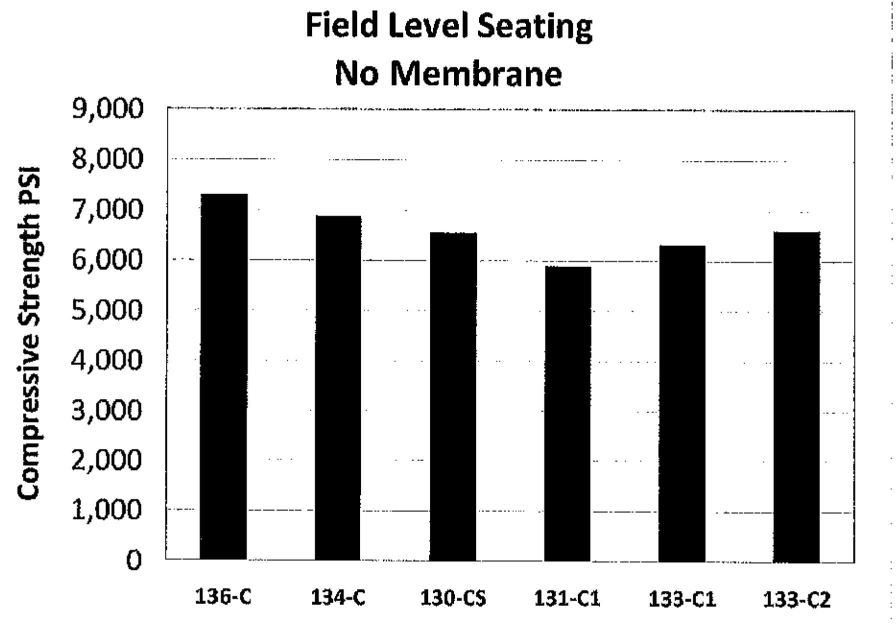


Fig. 1 – Field level seating compressive strength (slab-on-grade)

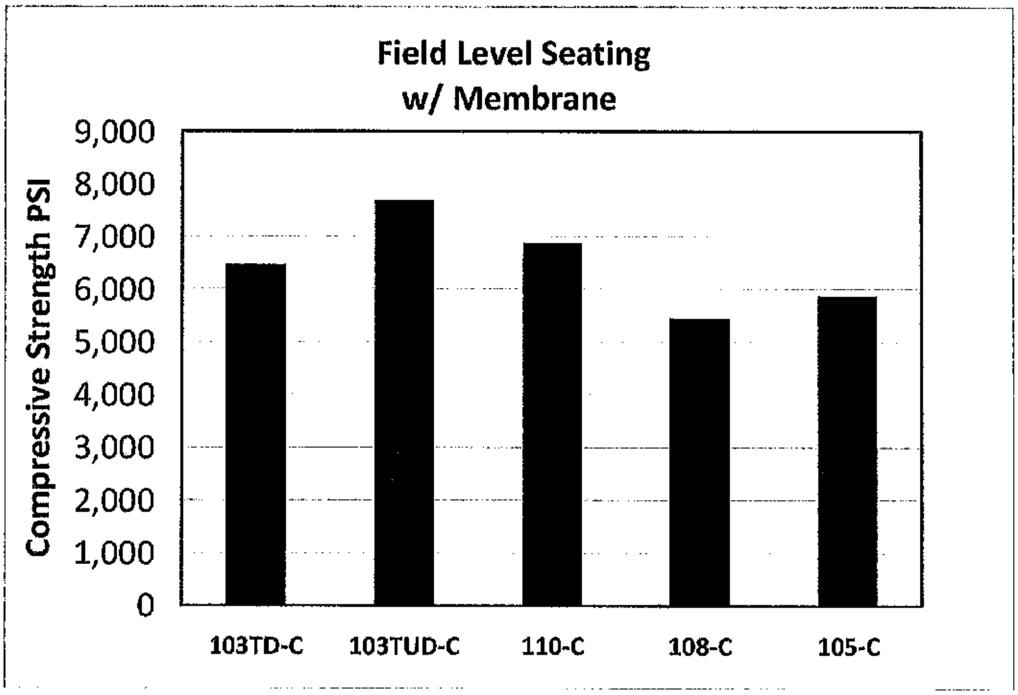


Fig. 2 – Field level seating compressive strength (1998 renovation)

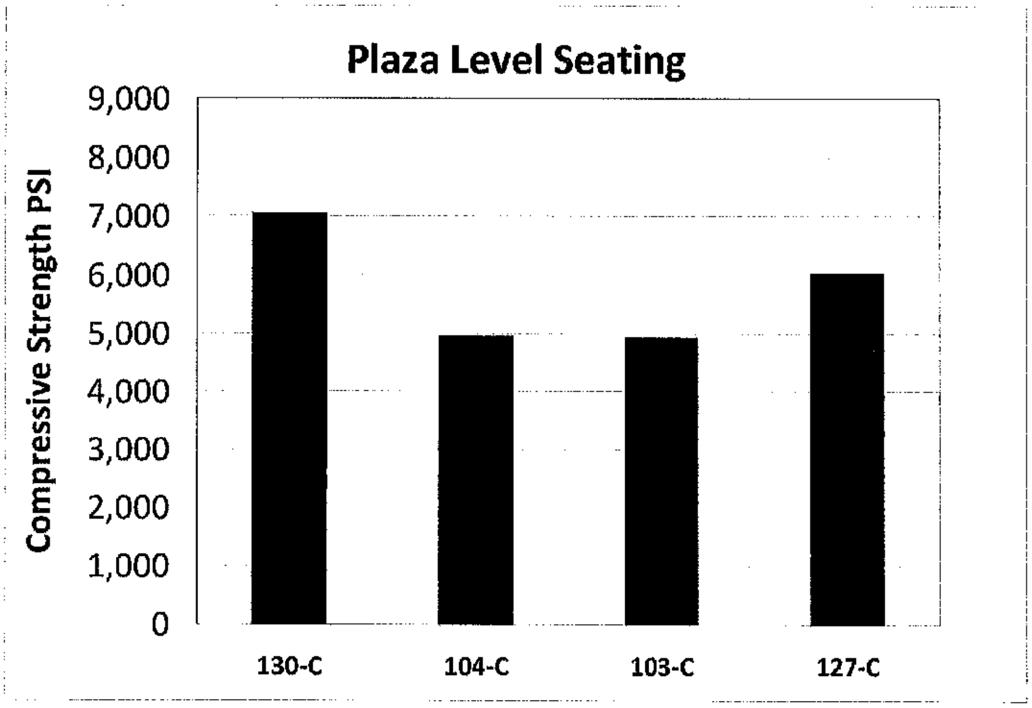


Fig. 3 – Plaza level seating compressive strength

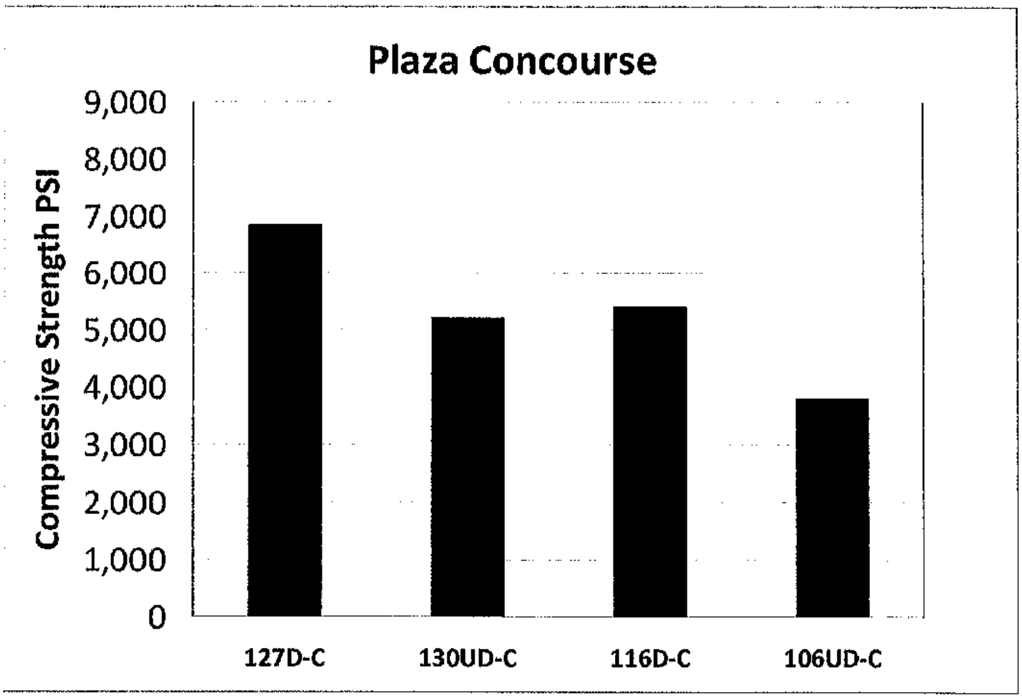


Fig. 4 – Plaza concourse compressive strength

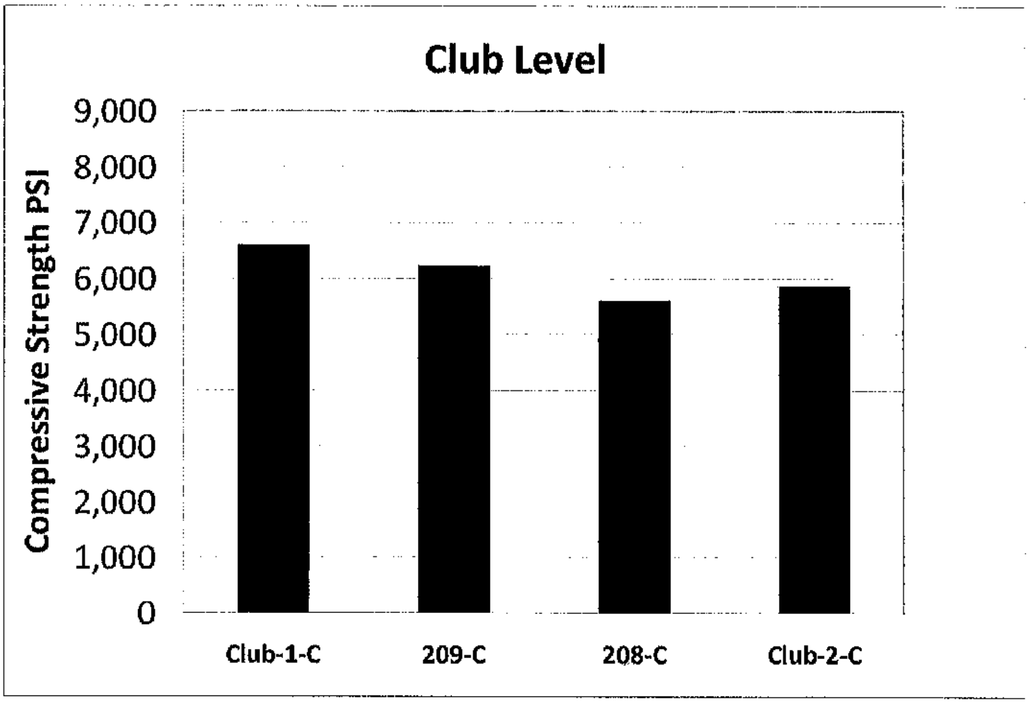


Fig. 5 – Club level compressive strength

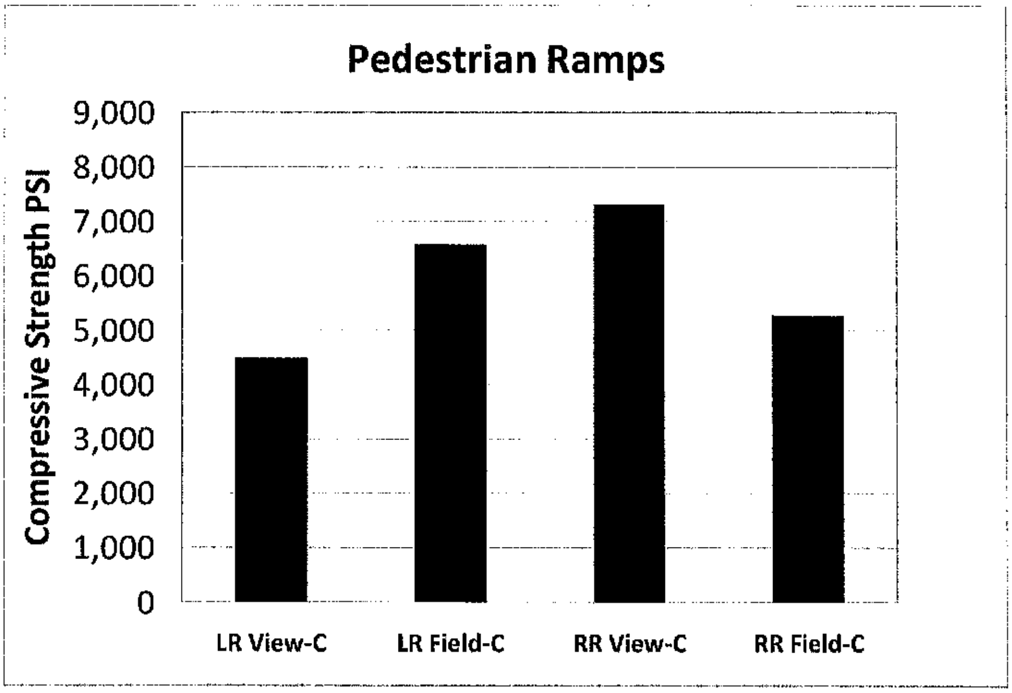


Fig. 6 – Pedestrian ramp compressive strength

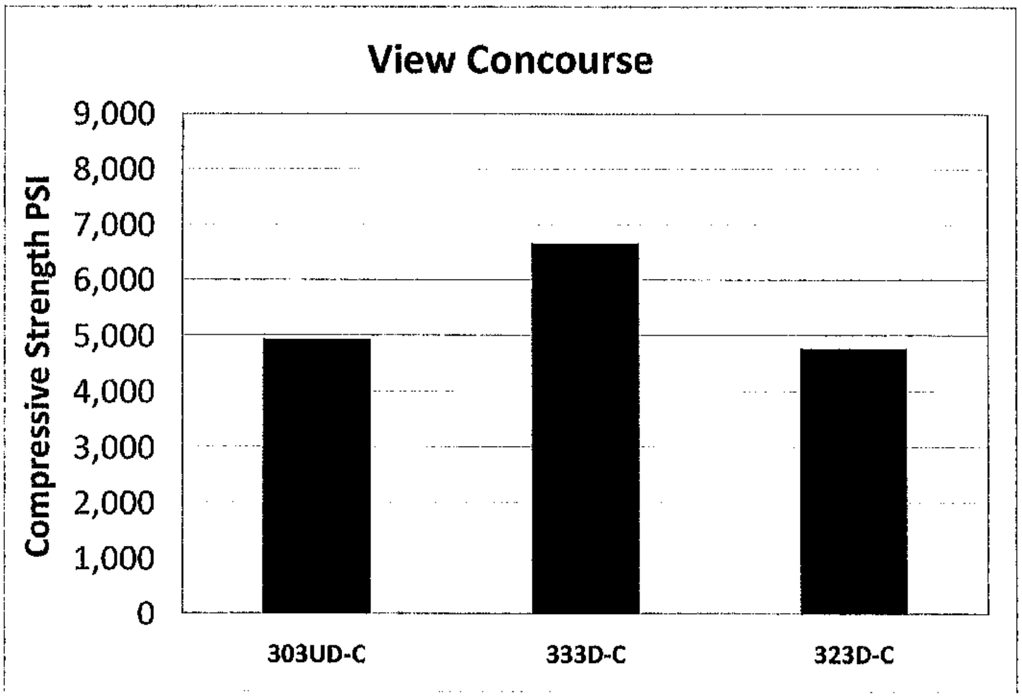


Fig. 7 – View concourse compressive strength

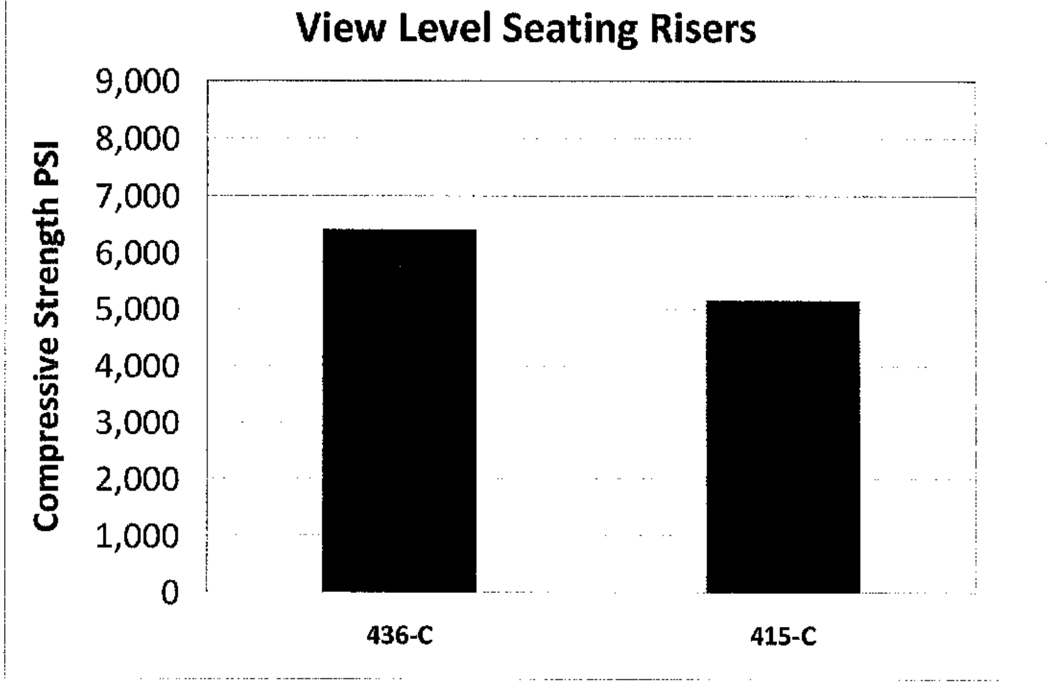


Fig. 8 – View level seating compressive strength

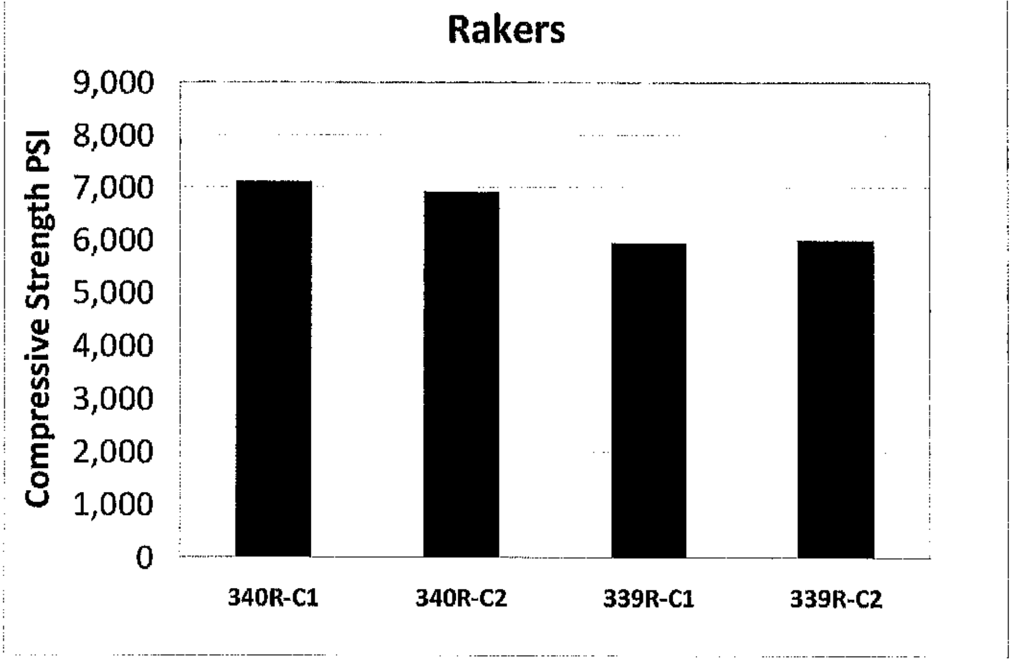


Fig. 9 – View level raker column compressive strength

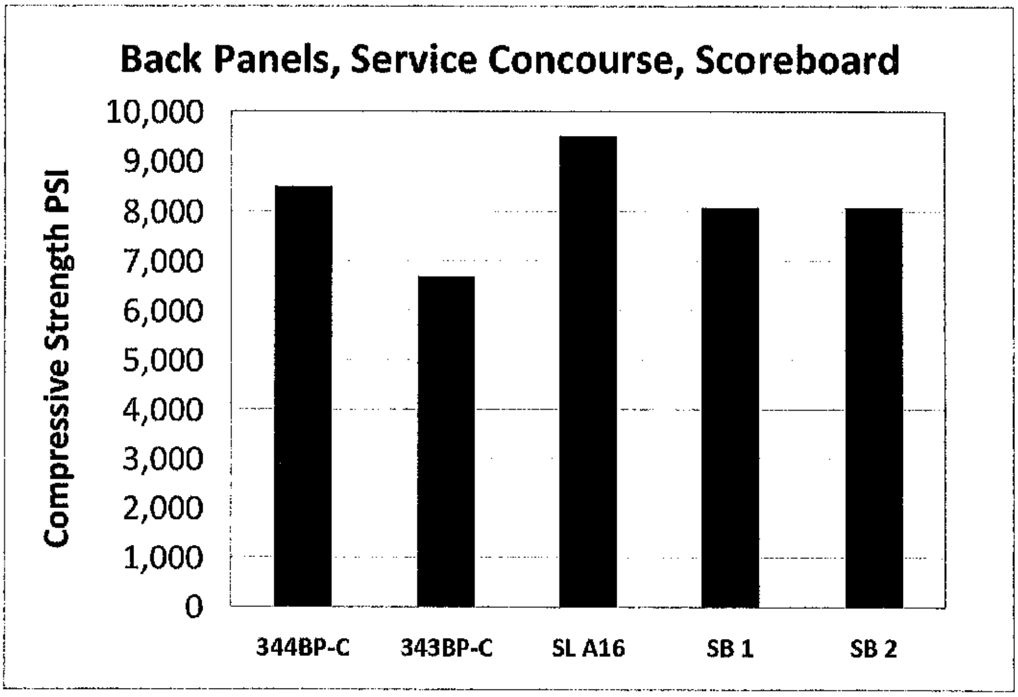


Fig. 10 – Back panel, service concourse, and scoreboard compressive strength

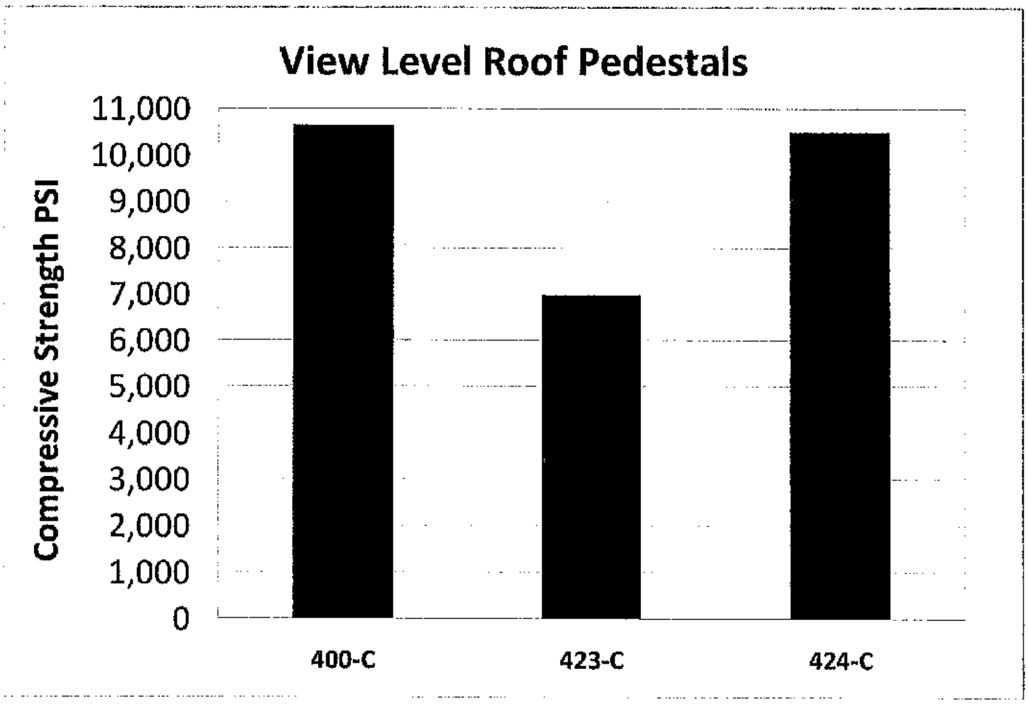


Fig. 11 – View roof pedestal compressive strength

Table 14 - ASTM C 42 Compressive Strength Core Log

TCG Project No. 0756
Project Name: Kansas City Royals Kauffman Stadium
Location: Kansas City, MO
Report Date: November 23, 2007

			Core Size Measurements																Compressive Strength			
Date Sampled	Date Treated	Core ID	Diameter @ Top			Avg Diam Top	Diameter @ Bottom			Avg Diam Bot	Length Before Capping			Avg Length Before Capping	Length After Capping	Avg Diam	L/D	L/D Factor	Area Sq In	Total Load lb	Strength PSI
FIELD LEVEL																					
8/15/2007	9/21/2007	136-C	2.751	2.750	2.740	**2.747**	2.757	2.759	2.760	**2.759**	5.519	5.505	5.503	**5.509**	**5.760**	**2.753**	2.001	**1.000**	6.0	43500	**7310**
8/15/2007	9/21/2007	134-C	2.756	2.752	2.755	**2.754**	2.757	2.763	2.757	**2.759**	5.474	5.474	5.468	**5.472**	**5.740**	**2.757**	1.985	**1.000**	6.0	41000	**6870**
8/15/2007	9/21/2007	130-CS	3.220	3.220	3.220	**3.220**	3.225	3.225	3.222	**3.224**	5.825	5.740	5.840	**5.802**	**6.035**	**3.222**	1.801	**1.000**	8.2	53500	**6560**
8/15/2007	9/21/2007	131-C1	3.227	3.225	3.227	**3.226**	3.224	3.226	3.224	**3.225**	4.493	4.430	4.465	**4.463**	**4.777**	**3.226**	1.384	**0.946**	8.2	51000	**5900**
8/15/2007	9/21/2007	133-C1	3.222	3.220	3.220	**3.221**	3.220	3.220	3.221	**3.220**	5.705	5.752	5.835	**5.764**	**6.125**	**3.221**	1.790	**1.000**	8.1	51500	**6320**
8/15/2007	9/21/2007	133-C2	3.228	3.228	3.225	**3.227**	3.225	3.228	3.229	**3.227**	5.376	5.337	5.400	**5.371**	**6.064**	**3.227**	1.664	**0.973**	8.2	55500	**6600**
8/19/2007	9/21/2007	103TD-C	3.228	3.238	3.235	**3.234**	3.235	3.230	3.233	**3.233**	4.762	4.746	4.753	**4.754**	**5.046**	**3.233**	1.470	**0.956**	8.2	55500	**6470**
8/19/2007	9/21/2007	103TUD-C	3.240	3.233	3.233	**3.235**	3.232	3.232	3.232	**3.232**	4.520	4.494	4.587	**4.534**	**4.899**	**3.234**	1.402	**0.948**	8.2	66500	**7680**
8/15/2007	9/21/2007	110-C	3.222	3.220	3.225	**3.222**	3.221	3.223	3.225	**3.223**	5.208	5.133	5.125	**5.155**	**5.470**	**3.223**	1.600	**0.968**	8.2	58000	**6880**
8/15/2007	9/21/2007	108-C	3.222	3.225	3.227	**3.225**	3.225	3.222	3.224	**3.224**	5.153	5.165	5.153	**5.157**	**5.423**	**3.224**	1.599	**0.968**	8.2	46000	**5450**
8/15/2007	9/21/2007	105-C	3.220	3.223	3.225	**3.223**	3.222	3.222	3.224	**3.223**	5.618	5.566	5.633	**5.606**	**5.907**	**3.223**	1.739	**0.979**	8.2	49000	**5880**
PLAZA LEVEL																					
8/19/2007	9/21/2007	127D-C	3.239	3.237	3.232	**3.236**	3.237	3.240	3.242	**3.240**	6.027	6.045	6.144	**6.072**	**6.333**	**3.238**	1.875	**1.000**	8.2	56500	**6860**
8/19/2007	9/21/2007	130UD-C	3.230	3.232	3.231	**3.231**	3.231	3.230	3.229	**3.230**	5.332	5.317	5.288	**5.312**	**5.646**	**3.231**	1.644	**0.972**	8.2	44000	**5220**
8/19/2007	9/21/2007	116D-C	3.235	3.230	3.240	**3.235**	3.230	3.230	3.232	**3.231**	5.730	5.757	5.752	**5.746**	**6.036**	**3.233**	1.777	**1.000**	8.2	44500	**5420**
8/19/2007	9/21/2007	106UD-C	3.230	3.255	3.230	**3.238**	3.240	3.240	3.242	**3.241**	5.096	5.193	5.218	**5.169**	**5.530**	**3.240**	1.596	**0.968**	8.2	32500	**3820**
9/20/2007	9/21/2007	130-C	3.222	3.221	3.218	**3.220**	3.230	3.230	3.229	**3.230**	5.527	5.508	5.523	**5.519**	**5.813**	**3.225**	1.711	**0.977**	8.2	59000	**7060**
8/19/2007	9/21/2007	104-C	3.232	3.231	3.233	**3.232**	3.240	3.235	3.238	**3.238**	5.223	5.297	5.264	**5.261**	**5.557**	**3.235**	1.626	**0.970**	8.2	42000	**4960**
8/19/2007	9/21/2007	103-C	3.242	3.240	3.233	**3.238**	3.240	3.232	3.242	**3.238**	5.625	5.672	5.650	**5.649**	**5.960**	**3.238**	1.745	**0.980**	8.2	41500	**4940**
8/19/2007	9/21/2007	127-C	3.232	3.232	3.226	**3.230**	3.226	3.240	3.232	**3.233**	6.125	6.156	6.125	**6.135**	**6.375**	**3.231**	1.899	**1.000**	8.2	49500	**6040**

Table 14 - ASTM C 42 Compressive Strength Core Log

TCG Project No. 0756
Project Name: Kansas City Royals Kauffman Stadium
Location: Kansas City, MO
Report Date: December 19, 2007

			Core Size Measurements														Compressive Strength			
Date Sampled	Date Tested	Core ID	Diameter @ Top			Avg Diam. Top	Diameter @ Bottom			Avg Diam. Bot.	Length Before Capping			Avg Length Before Capping	Length After Capping	Avg Diam.	L/D	L/D Factor	Area sq. in.	Total Load lb	Strength psi
CLUB LEVEL																					
8/16/2007	9/21/2007	Club-1-C	1.822	1.826	1.823	**1.824**	1.822	1.830	1.823	**1.825**	3.240	3.273	3.246	**3.253**	**3.591**	**1.824**	1.783	**1.000**	2.6	17250	**6600**
8/16/2007	9/21/2007	209-C	1.822	1.822	1.823	**1.822**	1.822	1.822	1.825	**1.823**	3.433	3.426	3.418	**3.426**	**3.694**	**1.823**	1.880	**1.000**	2.6	16250	**6230**
8/16/2007	9/21/2007	208-C	1.822	1.825	1.827	**1.825**	1.820	1.826	1.830	**1.825**	2.703	2.749	2.760	**2.737**	**3.961**	**1.825**	1.500	**0.960**	2.6	15250	**5600**
8/16/2007	9/21/2007	Club-2-C	1.825	1.831	1.829	**1.828**	1.822	1.822	1.836	**1.827**	3.445	3.405	3.473	**3.441**	**3.751**	**1.828**	1.883	**1.000**	2.6	15400	**5870**
VIEW SEATING RISERS																					
8/17/2007	9/21/2007	436-C	1.804	1.803	1.804	**1.804**	1.803	1.806	1.805	**1.805**	2.932	2.906	2.926	**2.921**	**3.195**	**1.804**	1.619	**0.970**	2.6	16900	**6410**
8/17/2007	9/24/2007	415-C	1.803	1.807	1.810	**1.807**	1.803	1.805	1.803	**1.804**	2.346	2.385	2.450	**2.394**	**2.683**	**1.808**	1.931	**1.000**	2.6	13250	**5160**
VIEW LEVEL ROOF PEDESTALS																					
9/13/2007	9/21/2007	400-C	2.305	2.305	2.304	**2.305**	2.306	2.306	2.307	**2.306**	4.551	4.571	4.561	**4.561**	**4.832**	**2.306**	1.978	**1.000**	4.2	44500	**10660**
9/13/2007	9/21/2007	423-C	2.304	2.304	2.304	**2.305**	2.304	2.307	2.305	**2.305**	3.758	3.763	3.763	**3.761**	**4.039**	**2.305**	1.632	**0.971**	4.2	30000	**6980**
9/13/2007	9/21/2007	424-C	2.309	2.309	2.310	**2.309**	2.308	2.308	2.309	**2.308**	4.562	4.571	4.571	**4.568**	**4.855**	**2.309**	1.978	**1.000**	4.2	44000	**10510**
VIEW CONCOURSE																					
8/16/2007	9/21/2007	303UD-C	3.228	3.232	3.233	**3.231**	3.236	3.233	3.232	**3.234**	5.545	5.546	5.520	**5.537**	**5.893**	**3.232**	1.713	**0.977**	8.2	41500	**4940**
8/16/2007	9/21/2007	333D-C	3.230	3.230	3.230	**3.230**	3.225	3.230	3.225	**3.227**	3.639	3.659	3.655	**3.651**	**4.123**	**3.228**	1.131	**0.901**	8.2	60500	**6660**
8/16/2007	9/21/2007	323D-C	3.233	3.231	3.233	**3.232**	3.230	3.232	3.225	**3.229**	5.550	5.646	5.584	**5.593**	**5.837**	**3.231**	1.731	**0.979**	8.2	40000	**4770**

Table 14 - ASTM C 42 Compressive Strength Core Log

TCG Project No. 0756
Project Name: Kansas City Royals Kauffman Stadium
Location: Kansas City, MO
Report Date: December 19, 2007

			Core Size Measurements															Compressive Strength			
Date Sampled	Date Tested	Core ID	Diameter @ Top			Avg Diam Top	Diameter @ Bottom			Avg Diam Bot	Length Before Capping			Avg Length Before Capping	Length After Capping	Avg Diam	L/D	L/D Factor	Area sq in	Total Load lbs	Strength PSI
BACK PANELS																					
8/17/2007	9/21/2007	344BP-C	1.799	1.799	1.803	**1.800**	1.798	1.799	1.802	**1.800**	3.513	3.518	3.507	**3.513**	**3.756**	**1.800**	1.951	**1.000**	2.5	21600	**8490**
8/17/2007	9/21/2007	343BP-C	1.803	1.805	1.803	**1.804**	1.805	1.816	1.802	**1.808**	3.438	4.460	3.457	**3.785**	**3.799**	**1.806**	2.096	**1.000**	2.6	17100	**6680**
COLUMNS/RAKERS																					
8/17/2007	9/21/2007	340R-C1	3.225	3.225	3.224	**3.225**	3.223	3.224	3.224	**3.224**	5.675	5.650	5.772	**5.699**	**6.075**	**3.224**	1.768	**1.000**	8.2	58000	**7100**
8/17/2007	9/21/2007	340R-C2	3.220	3.220	3.223	**3.221**	3.225	3.232	3.235	**3.231**	6.045	6.122	6.060	**6.076**	**6.375**	**3.226**	1.883	**1.000**	8.2	56500	**6910**
8/17/2007	9/21/2007	339R-C1	3.220	3.225	3.220	**3.222**	3.223	3.225	3.225	**3.224**	5.815	5.902	5.843	**5.853**	**6.134**	**3.223**	1.816	**1.000**	8.2	48500	**5940**
8/17/2007	9/21/2007	339R-C2	3.225	3.222	3.223	**3.223**	3.228	3.225	3.226	**3.226**	5.838	5.752	5.835	**5.808**	**6.105**	**3.225**	1.801	**1.000**	8.2	49000	**6000**
PEDESTRIAN RAMPS																					
8/16/2007	9/21/2007	LR View-C	3.250	3.220	3.217	**3.229**	3.225	3.220	3.225	**3.223**	5.132	5.106	5.092	**5.110**	**5.355**	**3.226**	1.584	**0.967**	8.2	38000	**4490**
8/16/2007	9/21/2007	LR Field-C	3.222	3.220	3.220	**3.221**	3.226	3.228	3.231	**3.228**	5.134	5.175	5.132	**5.147**	**5.410**	**3.225**	1.596	**0.968**	8.2	55500	**6580**
8/16/2007	9/21/2007	RR View-C	3.229	3.250	3.231	**3.237**	3.233	3.235	3.240	**3.236**	5.620	5.625	5.625	**5.623**	**5.910**	**3.236**	1.738	**0.979**	8.2	61500	**7320**
8/16/2007	9/21/2007	RR Field-C	3.227	3.225	3.229	**3.227**	3.226	3.232	3.220	**3.226**	5.113	5.252	5.252	**5.206**	**5.495**	**3.227**	1.613	**0.969**	8.2	44500	**5270**
FEILD LEVEL CONCOURSE SLAB ON GRADE																					
8/19/2007	9/21/2007	SL A16	3.243	3.245	2.238	**2.909**	3.240	3.240	3.240	**3.240**	6.001	6.025	6.030	**6.019**	**6.283**	**3.074**	1.958	**1.000**	7.4	70500	**9500**
SCOREBOARD FOUNDATION																					
12/3/2007	12/17/2007	SB 1	3.660	3.662	3.663	**3.662**	3.660	3.662	3.663	**3.662**	7.250			**7.250**	**7.500**	**3.662**	1.980	**1.000**	10.5	85000	**8070**
12/3/2007	12/17/2007	SB 2	3.660	3.660	3.665	**3.662**	3.661	3.662	3.662	**3.662**	7.250			**7.250**	**7.500**	**3.662**	1.980	**1.000**	10.5	85000	**8070**

Chloride Content Tests:

Chloride ion contamination of the concrete was determined by extracting cores throughout the stadium at representative sampling locations. Once extracted, the cores were individually labeled and sealed in plastic bags for transport to TCG's laboratory in Kalamazoo, MI. In the laboratory, the cores were photographed, measured, sliced into ½ inch thick disks, oven dried, and then pulverized into a powder passing the No. 20 sieve prior to chemical analysis in accordance with ASTM C 1152 and ASTM C1218.

Acid-soluble, or total chloride ion content was determined in accordance with ASTM C 1152 for all concrete test locations. Chloride profiles were obtained by slicing six one-half inch thick increments from each core. The water-soluble chloride ion content was determined in accordance with ASTM C 1218 for select cores in accordance with the distribution of tests contained in Table 1 from the request for proposals dated May 14, 2007.

Determination of the chloride content profile through the depth of the concrete is an important step in determining the source for chloride contamination, the cause for corrosion activity, and developing appropriate maintenance procedures.

Findings:

- Chloride contamination varies throughout the structure.
- Where chloride contamination was found it appeared to be relatively constant through the depth of the concrete, which is indicative of admixed chloride set accelerators.
- Background chloride levels (chloride ion contributed by the concrete ingredients) were relatively low, approximately 50 parts per million, ppm, or 0.005% by mass of concrete powder.
- Areas with chloride levels in excess of the industry accepted corrosion threshold range (350 to 500 ppm) at the reinforcing level were:
    - Upper back panels (1 of 2),
    - View Concourse (3 of 7),
    - Pedestrian ramps (4 of 8), and
    - Plaza Level (4 of 8).
- Water-soluble chloride contents were consistently lower than companion acid-soluble chloride tests by approximately 100 to 300 ppm. A few individual water-soluble data points exceeded companion acid-soluble values.

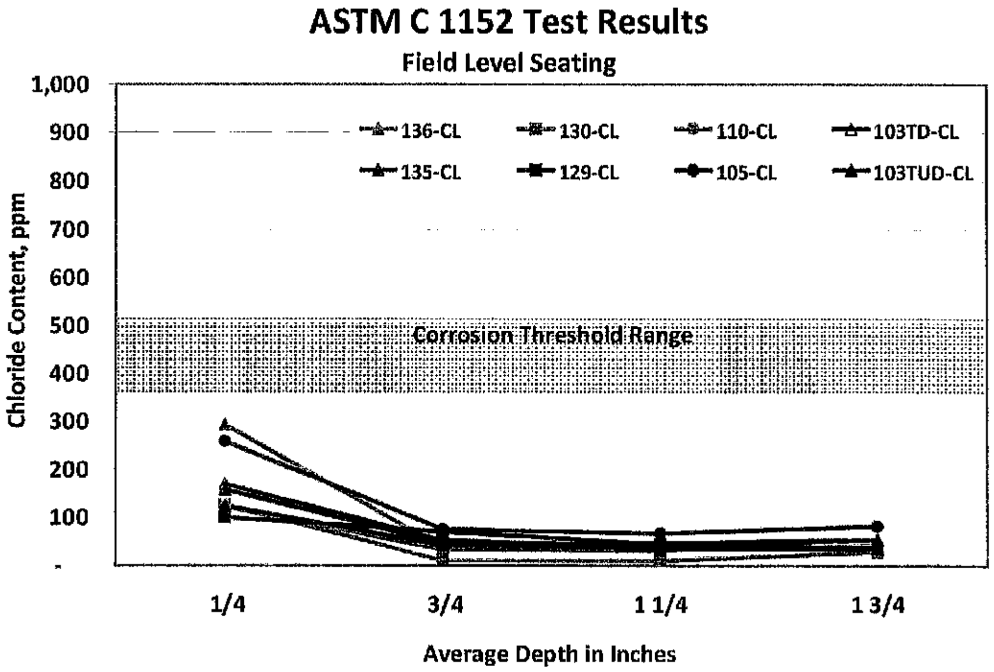


Fig. 12 – Field level acid-soluble chloride content

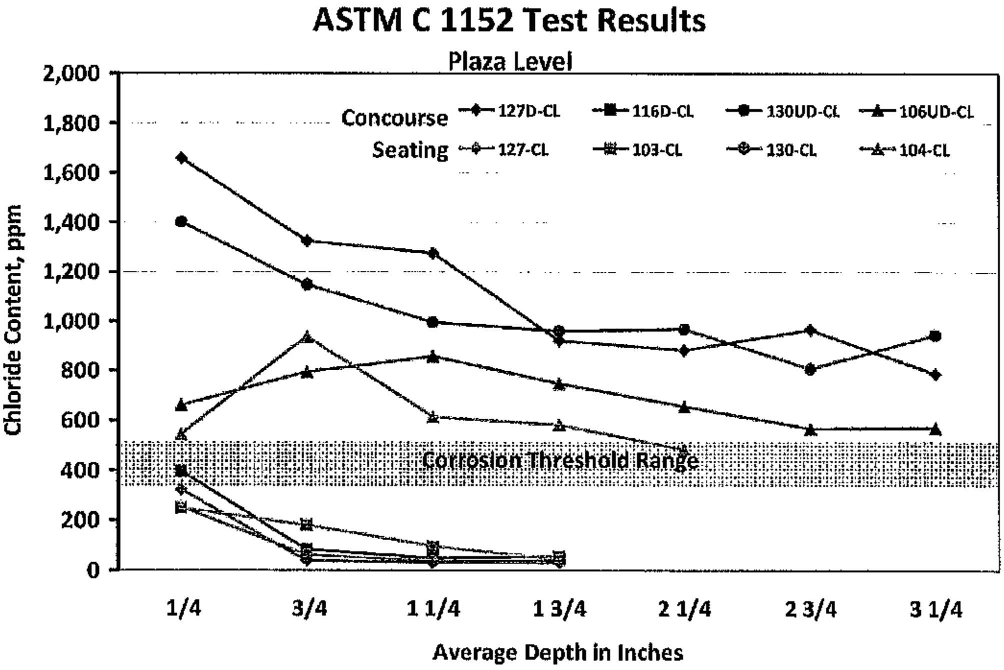


Fig. 13 – Plaza level seating acid-soluble chloride content

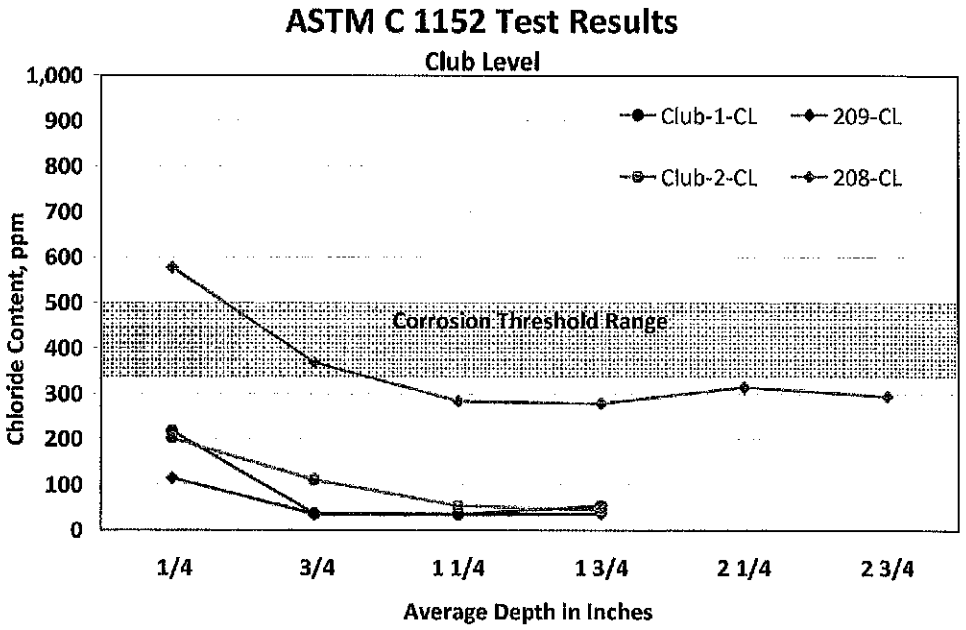


Fig. 14 – Club level acid-soluble chloride content

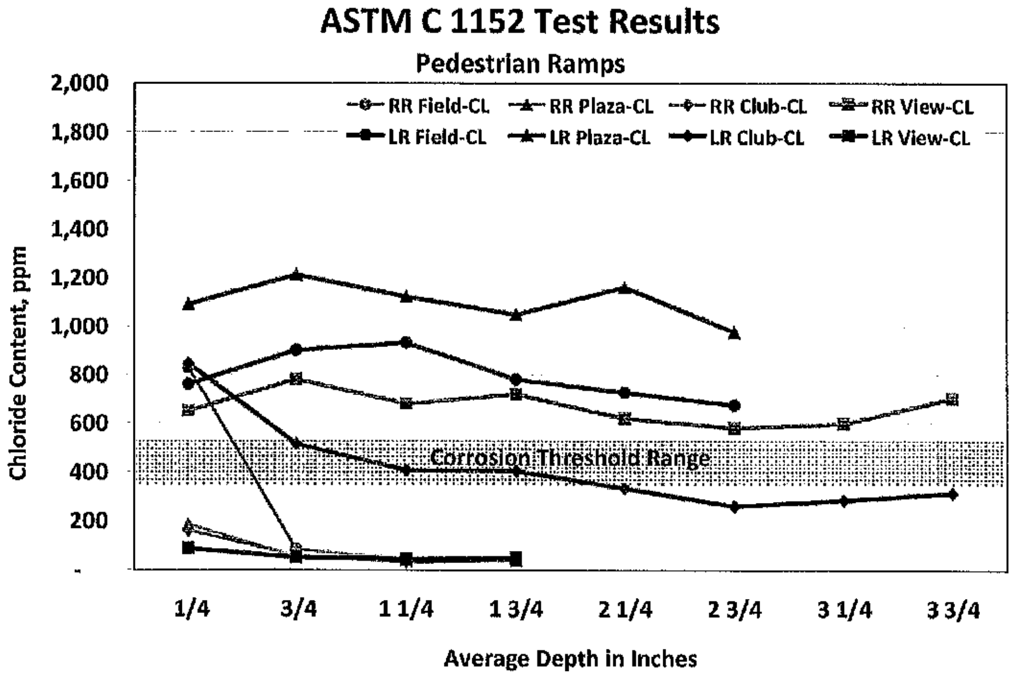


Fig. 15 – Pedestrian ramp acid-soluble chloride content

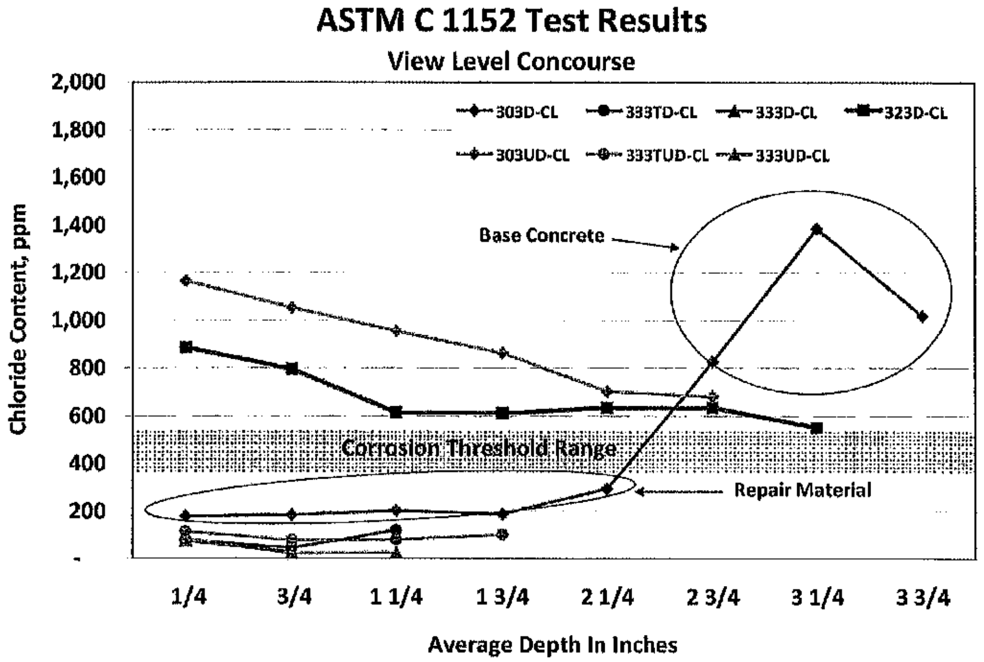


Fig. 16 – View concourse acid-soluble chloride content

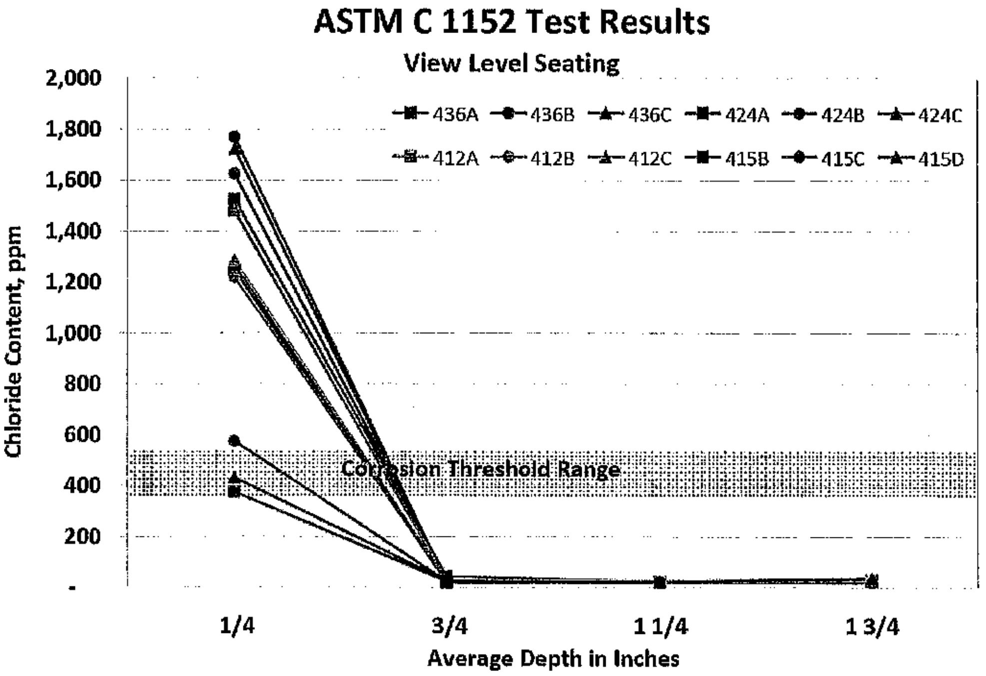


Fig. 17 – View seating acid-soluble chloride content

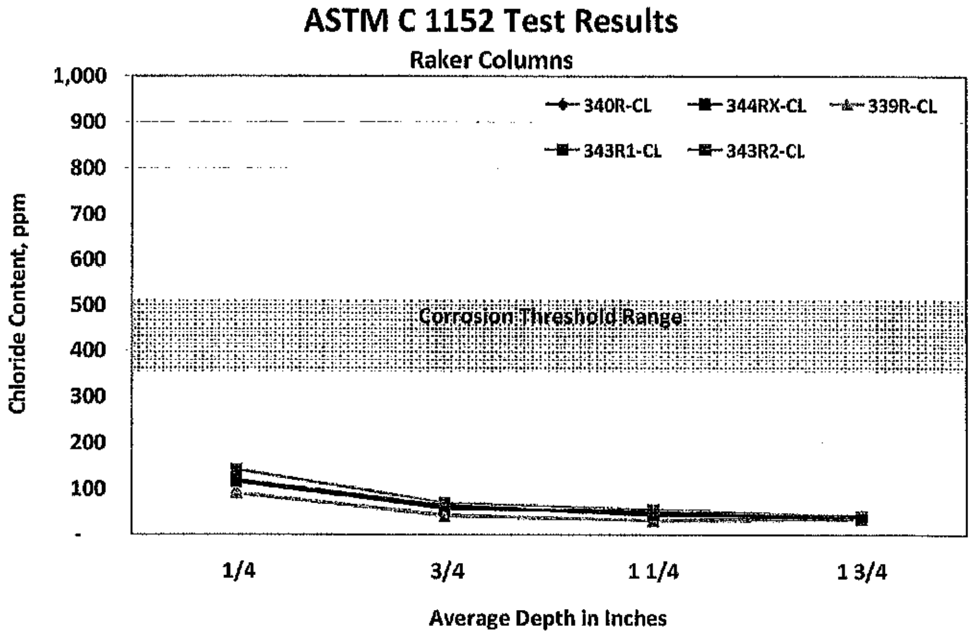


Fig. 18 – View level raker column acid-soluble chloride content

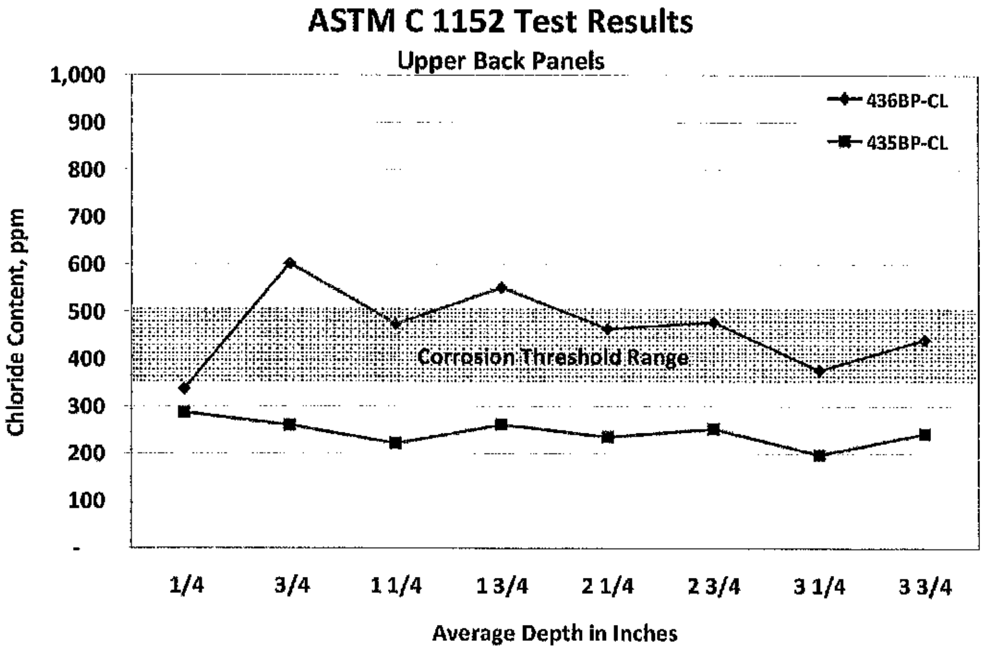


Fig. 19 – Upper back panel acid-soluble chloride content

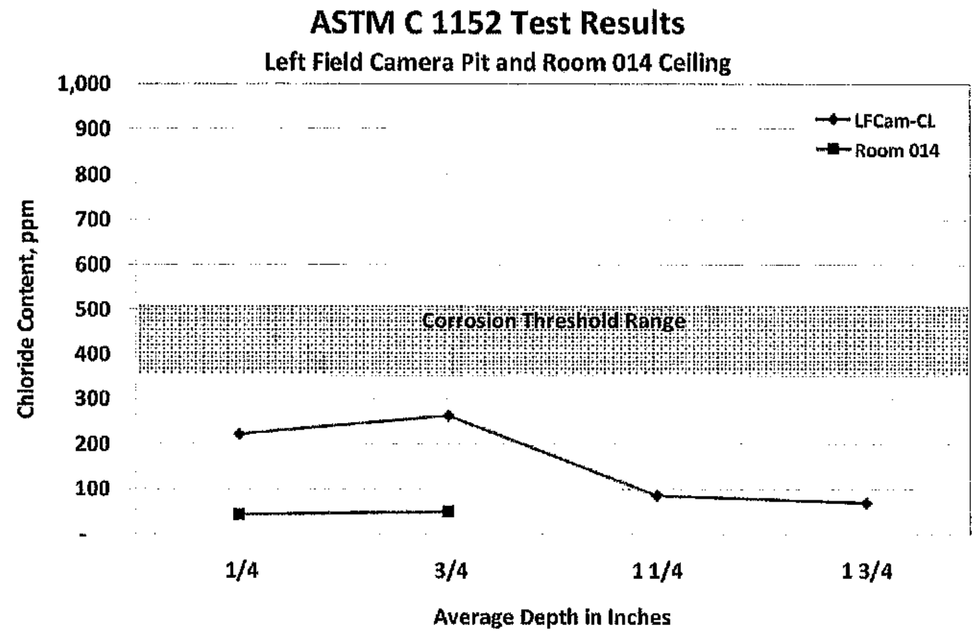


Fig. 20 – Left field camera pit acid-soluble chloride content

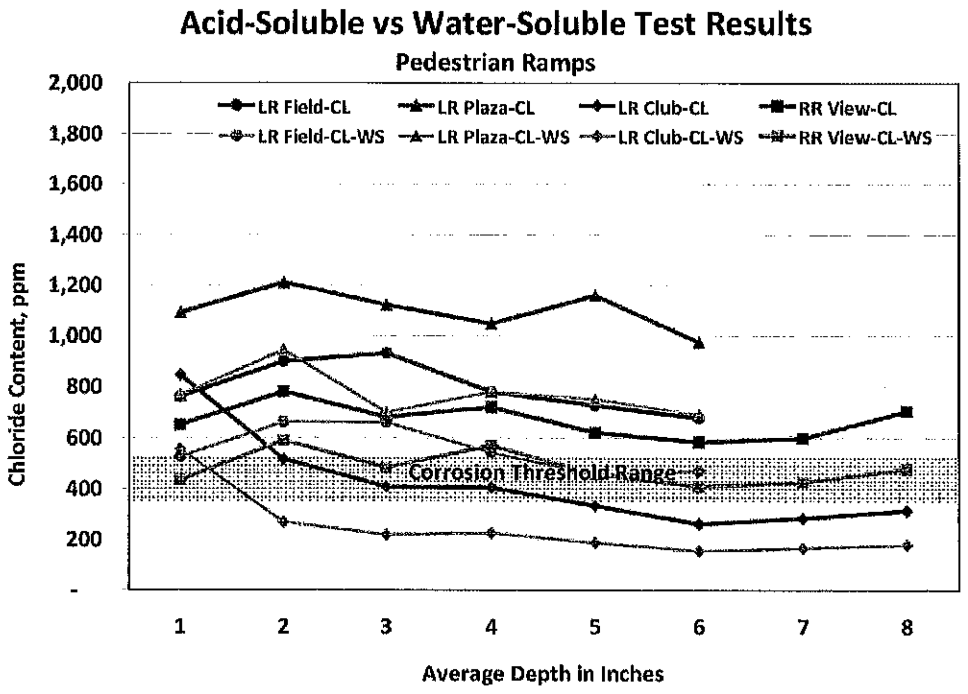


Fig. 21 – Comparison of acid-soluble and water-soluble chloride content

Table 15 - ASTM C 1152 Acid-Soluble Chloride Data

TCG Project No. 0756
Project Name: Kansas City Royals Kauffman Stadium
Location: Kansas City, MO
Report Date: November 23, 2007

Core ID	Location Details	Center of 1/2 in Thick Slice from Core (in.)							
		1/4	3/4	1 1/4	1 3/4	2 1/4	2 3/4	3 1/4	3 3/4
FIELD LEVEL									
103TD-CL	Tunnel on Field Level @ Col line 28 in damaged membrane	170	52	40	54				
103TUD-CL	Tunnel on Field Level @ Col line 28 in undamaged membrane	124	42	47	55				
130-CL	Right Field - Field Level Seating Row M/Seat 3	127	10	10	28				
136-CL	Right Field - Field Level Seating Row H/Seat 3	294	37	36	34				
105-CL	Field Level Seating w/ membrane Row L/Seat 5	259	76	67	82				
110-CL	Field Level Seating w/ membrane Row L/Seat 5	122	33	32	42				
129-CL	Left Field - Field Level Seating Row K/Seat 4	100	70	45	36				
135-CL	Left Field - Field Level Seating Row K/Seat 1	158	46	35	36				
Room 014	Under food service area (ceiling below)	43	50						
PLAZA LEVEL SEATING									
130-CL	Right Field Plaza Level Seating Row NN/Seat 6 (No Membrane)	252	63	36	38				
104-CL	Right Field Plaza Level Seating Row NN/Seat ? (Membrane over Tunnel)	545	938	614	582	485			
103-CL	Left Field Plaza Level Seating Row NN/Seat 17 (Membrane over Tunnel)	249	181	97	43				
127-CL	Left Field Plaza Level Seating Row NN/Seat 4 (No Membrane)	323	38	31	31				
PLAZA CONCOURSE									
130UD-CL	Rt Field Plaza Concourse @ B7 (Undamaged Membrane)	1401	1147	997	960	970	807	944	
116D-CL	Rt Field Plaza Concourse @ BM Line 13 Food Court (Damaged Membrane)	397	83	49	55				
106UD-CL	Rt Field Plaza Concourse @ BM Line 19 (Undamaged Membrane)	661	795	858	749	657	568	570	
127D-CL	Lt Field Plaza Concourse @ B42 (Damage Membrane)	1658	1324	1276	922	884	966	787	
CLUB LEVEL									
Club-2-CL	Rt Field Club Level Concourse @ C13	203	111	54	45				
208-CL	Rt Field Club Level Seating Row B/Seat 2	577	369	284	279	316	295		
Club-1-CL	Lt Field Club Level Concourse @ D33	218	36	35	54				
209-CL	Lt. Field Club Level Seating Row B/Seat 4	115	35	34	37				

Table 15 - ASTM C 1152 Acid-Soluble Chloride Data

TCG Project No. 0756
Project Name: Kansas City Royals Kauffman Stadium
Location: Kansas City, MO
Report Date: November 23, 2007

Core ID	Location Details	Center of 1/2 in. Thick Slice from Core in.							
		1/4	3/4	1 1/4	1 3/4	2 1/4	2 3/4	3 1/4	3 3/4
	PEDESTRIAN RAMPS								
LR Field-CL	Left Field Ramp Field Level	761	900	932	780	727	676		
LR Plaza-CL	Left Field Ramp Plaza Level	1092	1211	1123	1049	1161	976		
LR Club-CL	Left Field Ramp Club Level	846	516	408	405	334	262	285	314
LR View-CL	Left Field Ramp View Level	87	51	46	50				
RR Field-CL	Right Field Ramp Field Level	829	84	44	44				
RR Plaza-CL	Right Field Ramp Plaza Level	185	56	38	38				
RR Club-CL	Right Field Ramp Club Level	161	59	32	39				
RR View-CL	Right Field Ramp View Level	651	781	681	721	621	583	599	704
	RAKER COLUMNS								
340R-CL	Upper Rakers Adjacent to RF stair @ last portal	89	43	31	41				
344RX-CL	Upper Rakers Adjacent to RF stair @ last portal	115	57	50	33				
339R-CL	Upper Rakers Adjacent to LF stair @ last portal	91	41	31	33				
343R1-CL	Upper Rakers Adjacent to LF stair @ last portal	119	63	43	40				
343R2-CL	Upper Rakers Adjacent to LF stair @ last portal	142	69	55	40				
436BP-CL	Upper Back Panel adjacent to pedestal	338	602	474	551	464	478	376	441
435BP-CL	Upper Back Panel adjacent to pedestal	287	260	222	262	236	253	198	243

Table 15 - ASTM C 1152 Acid-Soluble Chloride Data

TCG Project No. 0756
Project Name: Kansas City Royals Kauffman Stadium
Location: Kansas City, MO

Report Date: November 23, 2007

Core ID	Location Details	Center of 1/2-in. Thick Slice from Core, in.							
		1/4	3/4	1 1/4	1 3/4	2 1/4	2 3/4	3 1/4	3 3/4
VIEW CONCOURSE									
303D-CL	View Level Concourse Damaged Membrane Area	179	184	202	188	295	827	1385	1018
303UD-CL	View Level Concourse Undamaged Membrane Area	1164	1051	954	863	703	681		
333D-CL	View Level Concourse Damaged Membrane Area	76	26						
333UD-CL	View Level Concourse Undamaged Membrane Area	81	22	26					
333TD-CL	View Level Tunnel Damaged Mem. Area	78	45	120					
333TUD-CL	View Level Tunnel Undamaged Mem. Area	114	77	81	102				
323D-CL	View Level Concourse Damaged Membrane Area	886	795	615	611	635	635	551	
VIEW SEATING									
412A	P/C Riser @ Row J/Seat 27	1480	25	25	30				
412B	P/C Riser @ Row J/Seat 27	1219	25	20	19				
412C	P/C Riser @ Row J/Seat 27	1287	23	22	31				
415B	P/C Riser @ Row J/Seat 27	374	24						
415C	P/C Riser @ Row J/Seat 27	574	24	21					
415D	P/C Riser @ Row J/Seat 27	431	25	21	37				
436A	P/C Riser @ Row G/Seat 27	1526	42	23	24				
436B	P/C Riser @ Row G/Seat 27	1770	22	25	29				
436C	P/C Riser @ Row G/Seat 27	1722	20	24	33				
424A	P/C Riser @ Row J/Seat 27	1248	19	21					
424B	P/C Riser @ Row J/Seat 27	1625	25	19	25				
424C	P/C Riser @ Row J/Seat 27	1275	21	22					
LFCam-CL	Left Field Camera Platform	221	263	86	69				

Table 16 - ASTM C 1218 Water-Soluble Chloride Data

TCG Project No. 0756
Project Name: Kansas City Royals Kauffman Stadium
Location: Kansas City, MO
Report Date: December 19, 2007

Core ID	Location Details	Center of 1/2-in. Thick Slice from Core, in.							
		1/4	3/4	1 1/4	1 3/4	2 1/4	2 3/4	3 1/4	3 3/4
127D-CL-WS	Plaza Concourse over BM line 42	**1273**	**1196**	**1006**	**748**	**647**	**687**	**562**	
130UD-CL-WS	Plaza Level Concourse Pan Joist	**1007**	**682**	**745**	**701**	**712**	**813**	**629**	
104-CL-WS	Plaza Level Seating Area	**405**	**713**	**396**	**431**	**325**			
106UD-CL-WS	Plaza Level Concourse over BM line Food Court	**405**	**888**	**549**	**488**	**461**	**429**	**359**	
208-CL-WS	Club Level Seating Area 3	**453**	**491**	**166**	**168**	**169**	**175**		
LR Club-CL-WS	Left Field Ramp Club Level	**556**	**269**	**218**	**225**	**188**	**156**	**167**	**179**
LR Field-CL-WS	Left Field Ramp Field Level	**525**	**662**	**660**	**542**	**456**	**469**		
LR Plaza-CL-WS	Left Field Ramp Plaza Level	**766**	**944**	**700**	**781**	**751**	**690**		
RR View-CL-WS	Right Field Ramp View Level	**434**	**590**	**484**	**571**	**458**	**409**	**426**	**478**
303D-CL-WS	View Level Concourse Damaged Membrane Area	**119**	**122**	**108**	**106**	**179**	**498**	**846**	**718**
303UD-CL-WS	View Level Concourse Undamaged Membrane Area	**887**	**780**	**646**	**589**	**439**	**425**		
323D-CL-WS	View Level Concourse Damaged Membrane Area	**664**	**551**	**450**	**378**	**417**	**535**	**303**	
436BP-CL-WS	Upper Back Panel Adjacent to pedestal	**220**	**302**	**284**	**291**	**252**	**254**	**184**	**235**
435BP-CL-WS	Upper Back Panel Adjacent to pedestal	**137**	**106**	**94**	**95**	**58**	**71**	**78**	**95**

Highlighted test result exceeds companion acid-soluble test result

Corrosion Potential Survey:

Corrosion half-cell potentials were determined for the equivalent of ten 40 SF areas. Unless other wise noted, corrosion potentials were obtained on a 1 ft grid pattern. TCG's minority subcontractor, Concorr, Inc. performed the corrosion potential testing. The test areas are listed below and identified on the core and test location drawings located in Appendix A.

1. View Level Concourse column at C45
2. View Level Concourse back panel at C46
3. View Level Concourse expansion joint column at C43
4. Right Field Ramp interior column between View and Club Levels
5. Right Field Ramp interior column between View and Club Levels
6. Right Field Ramp along a slab crack near the Field Level portal
7. View Level Concourse back panel at C3
8. View Concourse slab from C26 to D26
9. View Concourse slab from C26 to D26
10. Left Field TV camera platform

Corrosion potential measurements are used to estimate the probability of corrosion activity on reinforcing steel inside concrete. Corrosion potentials were determined in accordance with ASTM C876 "Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete", using a copper/copper-sulfate ($Cu/CuSO_4$) reference electrode and a hand-held multimeter. In this procedure, the common lead from the multimeter is connected to the reference electrode, and the other lead is connected to the reinforcing steel. The measurement is taken by placing the reference electrode against the surface of moist concrete using a wet sponge and recording the voltage difference between the reinforcing steel and the reference electrode.

The voltage difference between the reinforcing steel and the reference electrode placed on the concrete surface indicates the probability for corrosion activity. In areas where the structure was coated, small indentations were made in the coating using a rotary drill at the test locations. All such indentations were cleaned and filled with self-leveling polyurethane sealant upon completion.

The following table has been developed for evaluating $Cu-CuSO_4$ half-cell potentials. Corrosion potential measurements are displayed in a table format using the green-yellow-red color code.

Reading ($Cu-CuSO_4$ Half-cell)	Corrosion Condition
> -200 mV	Low (< 5% probability of corrosion)
-200 to -350 mV	Uncertain (50 % probability of corrosion)
[illegible]	High (> 95% probability of corrosion)

Findings:

- Generally, minimal corrosion activity was associated with dry test areas even with low concrete cover. This is common when the environment is hot and dry.
- Localized corrosion activity was identified at the following locations:
    - Location 6 – Right Field Pedestrian Ramp crack.
    - Location 8&9 – View Concourse
    - Location 10 – Left Field Camera Platform
- Visual observation of corrosion spalls along the slab soffit under Row A on the View and Club levels indicates wide spread corrosion activity in the Row A slab.
- Location 8&9 corrosion potentials indicate corrosion well outside the boundary of the previous patch. The previous patch was determined to be delaminated. Chloride contamination tests in this area indicate elevated chloride levels in the sound concrete. This is an indication of corrosion activity in the slab reinforcing below the previous patch.
- Corrosion activity was high in the two coated areas.

Table 17 - Corrosion Potential Data - Location 1

CONCORR, Inc.

CONDITION SURVEY

Location 1

REFERENCE CELL DATA

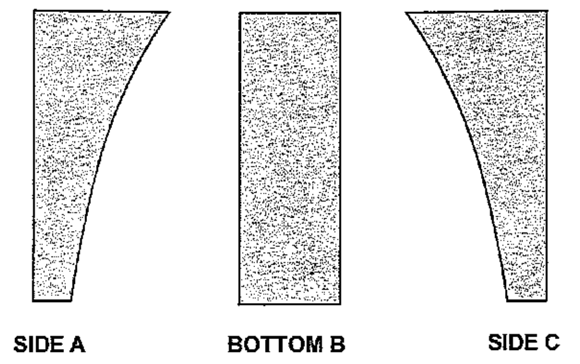
Project: Kauffman Stadium - KC, MO
Project Code: TCG-KC
Weather: SUNNY / HOT
Temperature: 88 F

Date: 08/16/07
Tested by: JPC

Sheet 1 **of** 1

Side A	Side A	Bottom B	Bottom B	Bottom B	Side C	Side C
-67	-106	-97	-68	-74	-65	-41
-84	-101	-78	-52	-66	-66	-52
-67	-100	-50	-15	-55	63	-28
-66	-82	-32	13	-25	-41	-32
-41	-92	17	16	90	-17	-22
-64	-83	-23	7	2	-30	-26
	-84	-12	4	-4	-28	
	-63	-12	25	7	-9	

RAKER BEAM SECTION 435-439



Note: -200 to 0   -201 to -349   -350 or less

Table 18 - Corrosion Potential Data – Location 2

CONCORR, Inc.

CONDITION SURVEY

REFERENCE CELL DATA

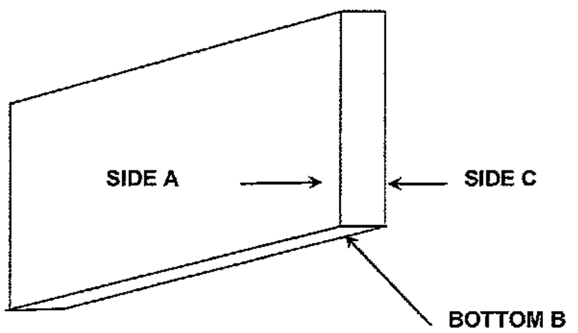
Project: Kauffman Stadium - KC, MO
Project Code: TCG-KC
Weather: SUNNY / HOT
Temperature: ____

Date: 8/16/07
Tested by: JPC

Sheet 1 of 1

SIDE A	0	67	75	71	104	129
SIDE A	35	110	96	103	101	138
CORNER A	-69	-5	105	87	91	104
BOTTOM B	-46	-20	-42	41	32	91
CORNER C	-41	31	53	59	35	51
SIDE C	16	128	39	45	57	62
SIDE C	45	132	38	50	27	78

BACK WALL, SECTION 435 - 439



Note: ____

Table 19 - Corrosion Potential Data – Location 3

CONCORR, Inc.

Location 3

CONDITION SURVEY

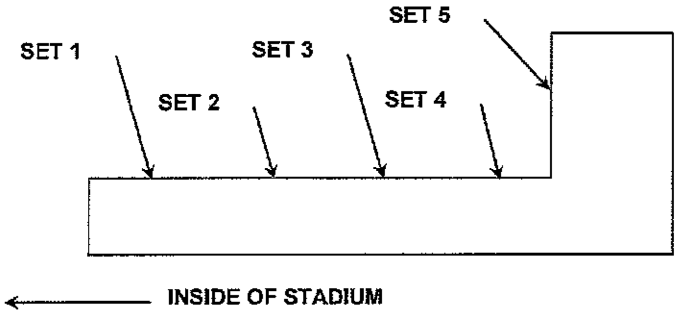
REFERENCE CELL DATA

Project: Kauffman Stadium - KC, MO
Project Code: TCG-KC
Weather: SUNNY / HOT
Temperature:

Date:
Tested by:

Sheet 1 of 1

SET 1	-110	-52	22	28	9	21	18	30	17	48	104	
SET 2	-104	-35	13	13	-52	32	21	-12	-13	55	56	
SET 3	2	12	23	-4	-26	5	17	183	202	79	72	
SET 4	45	46	39	29	23	51	149	185	190	101	90	
SET 5	100	124	71	186	184	175	186	193	222	204	206	



Note:

Table 20 - Corrosion Potential Data – Location 4

CONCORR, Inc.

Location 4

CONDITION SURVEY

REFERENCE CELL DATA

Project: Kauffman Stadium - KC, MO
Project Code: TCG-KC
Weather: SUNNY HOT
Temperature: 96.6 F

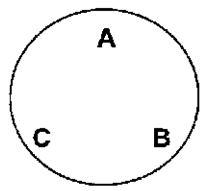
Date: 8/16/07
Tested by: JPC

Sheet 1 of 1

OUTER A	CLOCKWISE	
A	B	C
196	197	91
189	159	70
182	145	131
157	150	77
184	68	91
184	125	126
183	142	110
11	69	82

OUTER RAMP COLUMN

OUTSIDE EDGE OF RAMP



CROSS SECTION

Note:

Table 21 - Corrosion Potential Data – Location 5

CONCORR, Inc.

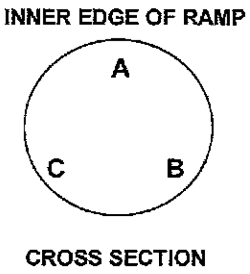
CONDITION SURVEY

REFERENCE CELL DATA

Project: Kauffman Stadium - KC, MO
Project Code: TCG-KC
Weather: SUNNY HOT
Temperature: 95.8 F

Date: 8/16/07
Tested by: JPC

Sheet 1 of 1

OUTER A	CLOCKWISE			INNER RAMP COLUMN								
A	B	C										
142	115	174										
141	119	173										
135	137	161										
144	111	164										
143	112	155										
106	126	147										
133	112	146										
91	77	126										

Note:

Table 22 - Corrosion Potential Data – Location 6

CONCORR, Inc.

CONDITION SURVEY

REFERENCE CELL DATA

Project: Kauffman Stadium - KC, MO
Project Code: TCG-KC
Weather: SUNNY /HOT
Temperature: 94.6 F

Date: 8/16/07
Tested by: JPC

Sheet 1 **of** 1

		RT FIELD RAMP SLAB - FIELD LEVEL										
				CRACK								
INNER COLUMN		SET 1	SET 2	SET 3	SET 4	SET 5						
		-113	-68	-185	-198	5						
		3	-26	-230	-82	19						
		20	26	-164	-25	38						
		-1	-14	-138	-59	-10						
		2	-38	-176	46	-1						
		15	20	-161	-15	-41						
		-43	-85	-229	-87	-40						
		7	-19	-212	-64	7						
		32	1	-74	-97	10						
		-28	-47	-53	-87	-38						

Note: 2 FOOT GRID

Table 23 - Corrosion Potential Data – Location 7

CONCORR, Inc.

CONDITION SURVEY

REFERENCE CELL DATA

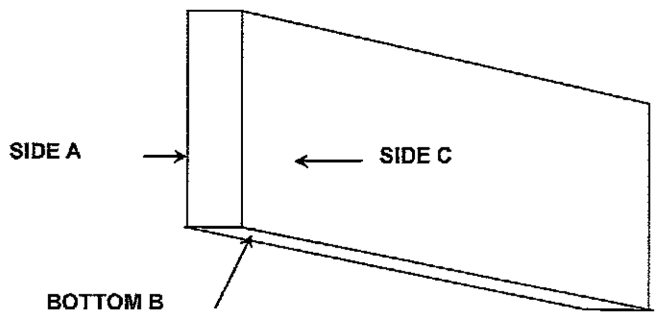
Project: Kauffman Stadium - KC, MO
Project Code: TCG-KC
Weather: OVERCAST
Temperature: 76.9 F

Date: 8/17/07
Tested by: JPC

Sheet 1 **of** 1

SIDE A	70	68	71	94	63	72	76	70	77			
SIDE A	62	66	72	99	71	85	66	59	69			
CORNER A	52	36	64	61	59	60	35	58	90			
BOTTOM B	70	93	100	99	82	48	25	46	47			
CORNER C	N/A *	N/A *	N/A *	125	110	92	93	122	34			
SIDE C	N/A *	N/A *	N/A *	124	104	110	107	108	138			
SIDE C	N/A *	N/A *	N/A *	109	11	115	115	93	148			

BACK WALL, SECTION 440 - 442



Note:

Table 24 - Corrosion Potential Data – Location 8 and 9

CONCORR, Inc.

CONDITION SURVEY

REFERENCE CELL DATA

Project: Kauffman Stadium - KC, MO
Project Code: TCG-KC
Weather: 0
Temperature: 0

Date: 8/17/07
Tested by: JPC
Sheet 1 of 1

VIEW CONCOURSE SECTION 303 - NEAR ELEVATORS												
				OUTSIDE WALL								
SET 1	SET 2	SET 3	SET 4	SET 5	SET 6	SET 7	SET 8	SET 9	SET 10			
-70	-65	-51	-55	-69	-65	-68	60	-70	-20			
-70	-50	-56	-41	-40	-64	-63	43	-55	-26			
-77	-42	-72	-44	-45	-69	-67	47	-61	-25			
-33	-78	-77	-68	-77	-68	-69	-67	-48	19			
-56	-85	-39	67	-74	-64	74	-70	-26	86			
-59	-89	-60	-37	-75	-68	-63	-38	11	170			
-37	-103	-71	-77	-81	-64	-62	-41	41	30			
-40	-79	-39	-102	-104	-82	-88	-193	-103	-72			
-56	-104	-169	-246	-206	-143	-108	-123	-127	11			
-69	-100	[illegible]	[illegible]	[illegible]	-276	-180	-157	-149	72			
-104	-125	[illegible]	[illegible]	[illegible]	[illegible]	-216	-175	-170	31			
-124	-173	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-225	DRAIN	-254			
-103	-166	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-224	-188	-239			
-83	-70	-185	[illegible]	-309	-257	-234	-204	-168	-139			
-170	-34	-173	-224	-234	-244	-93	-211	-139	133			
-182	-191	-196	-210	-215	-106	-53	30	-132	131			
-185	-187	183	-189	-110	-115	-78	58	-110	133			
-173	-172	-174	-178	-110	-113	-68	-24	-62	-110			
-171	-174	-171	-165	-89	-54	-79	-31	-98	-112			
-171	-171	-170	-87	-52	-54	-77	-151	-114	112			
-32	-48	-61	-72	GND	-142	-130	-209	-104	-106			
-60	-84	-70	-93	-101	-110	-125	-133	-115	-108			
-60	-84	-70	-93	-101	-101	-96	-105	-113	-90			
68	64	-117	-67	-132	-85	-68	4	-77	13			
69	-104	-117	-30	-94	-91	-94	13	7	2			
SET 1	SET 2	SET 3	SET 4	SET 5	SET 6	SET 7	SET 8	SET 9	SET 10			
LADIES ROOM - INNER PART OF STADIUM												

Note: 1 FOOT GRID

-1 to -200

-201 to -349

-350

POSITIVE

PATCH

Table 25 - Corrosion Potential Data – Location 10

CONCORR, Inc.

CONDITION SURVEY

REFERENCE CELL DATA

Project: Kauffman Stadium - KC, MO
Project Code: TCG-KC
Weather: SUNNY / HOT
Temperature: 95.5 F

Date: 8/17/07
Tested by: JPC

Sheet 1 of 1

RAILING FACING INSIDE THE STADIUM												
WALL 1	25	44	-125	-269	-315	20	32					
WALL 2	142	50	-104	-256	-262	-109	23					
CORNER 3	-163	-151	-132	-285	[illegible]	-153	-120					
SLAB 4	-158	-122	-139	-268	-233	-106	-125					
SLAB 5	-124	116	-124	-295	-294	-152	-140					
TOWARDS THE SEATS AND BACK WALL												

Note: 1 FOOT GRID, AREA LOCATED NEAR THE CAMERA STAND AREA

Ionic Transport Properties:

Sixteen concrete cores were extracted from four locations to determine ionic transport properties. Ionic transport properties are used as input data for service-life modeling. Typically, service life modeling is used to estimate future chloride ingress to predict when corrosion will initiate.

The sampling locations were.

1. Field Seating (Labeled 130T)
2. Right Field Pedestrian Ramps on the Club Level (Labeled RRClubT)
3. View Concourse at undamaged coating area (Labeled 303UDT)
4. Plaza Level food court in a damaged coating area (Labeled 116DT)

Three test procedures were conducted to determine the ionic transport properties of the concrete:

porosity (ASTM C 642)
pore solution extraction on saturated and virgin samples
ion migration test

Porosity

Porosity measurements were performed in accordance with ASTM C642 - 06: *Standard Test Method for Density, Absorption, and Voids in Hardened Concrete.* A minimal volume of concrete of 350 cm^3 is required to perform this test. Results for (porosity and absorption) are given in the table below. Each result is the average of 2 individual results.

Table 26 – ASTM C 642 Test Results

Core ID	Absorption after boiling (%)	Porosity (%)
130T	4.4	10.0
RRClubT	7.4	16.0
303UDT	6.8	15.0
116DT	6.2	13.8

The results vary from one location to another suggesting that it is not the same concrete, as expected. For comparison, a good quality concrete with water to cement ratio of 0.45, the typical porosity range is from 11% to 12%; and the typical absorption range is from 5 to 6 %. The Field Seating concrete appears to be of better quality than the concrete from the other three elevated slabs.

Pore Solution Extraction

Information on pore solution chemistry of concrete is obtained by performing a pore solution extraction based on the procedure described in Barneyback and Diamond[1]. Concrete samples were broken into small pieces and placed in a cell to be subsequently crushed at a pressure of approximately 72,500 psi (500 MPa). The solution "squeezedout" from the concrete was analyzed to measure the concentration of the various ionic species (i.e. OH_{-}, Cl_{-}, Na_{+}, K_{+}, Ca_{2+} and $SO4_{2-}$) present in the pore solution. Typically, 2 to 5 ml of pore solution is extracted. The solution was delivered through a drain ring and channel, and recovered with a syringe in order to limit exposure to the atmosphere. Pore solution analyses were carried out shortly after the extraction test by means of atomic adsorption spectroscopy and potentiometric titration.

Extractions were performed on vacuum-saturated sample in a 300 mmol/l NaOH solution, which is similar to the sample preparation for the ion migration test. This pore solution was used for the determination of ionic diffusion coefficients. (see the following section).

Table 27 - Expressed Pore Solution Chemistry for Ionic Diffusion

Ionic Species	Concentration (mmol/L)			
	130T	RRClubT	303UDT	116DT
OH^-	263.1	272.3	290.3	239.5
Na^+	242.4	247.2	242.6	207.9
K^+	38.4	46.0	59.9	38.4
SO_4^{2-}	6.4	8.8	6.4	3.4
Ca^+	0.5	0.5	1.4	2.7
Cl^-	5.9	4.2	2.1	5.5

Pore solution was also extracted from a second sample after soaking in distilled water (virgin sample) for each location to measure the actual pore solution in the structure. For example ASR activity is related to the internal pH of the concrete, which can be calculated from the OH^- concentration. The calculated pH and pore solution chemistry for these concretes indicates ample alkali hydroxide is available to support ASR.

Table 28 - Virgin Pore Solution Chemistry

Ionic Species	Concentration (mmol/L)			
	130T	RRClubT	303UDT	116DT
OH^-	187.7	122.4	183.5	174.4
Na^+	122.0	77.4	86.8	103.6
K^+	84.9	66.5	108.6	76.7
Cl^-	7.5	4.8	1.8	4.7
pH	13.27	13.09	13.26	13.24

Chloride Ion Migration Test

The ionic diffusion coefficients (Di) of the main ionic species (Cl^-, K^+, SO_4^{2-},Ca^{2+}, Na^+, and OH^-) involved in the chemical degradation of concrete were determined using a modified and improved version of the ASTM C1202-(05) – *Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration* test method. The test consists in measuring the transport of ions through a saturated concrete disk under an external electrical potential applied to the system. The current (electrical charge) passing through the concrete specimen over a given period of time (typically 10-14 days) is measured periodically. Analysis of the current data with STADIUM® yields the diffusion coefficients of all ionic species present in the pore solution. Tests are run in duplicate. The procedure used is described in Samson et al[2].

Table 29 – Ionic Diffusion Properties

Ionic Species	Ionic Diffusion Coefficients x 10^{-11} m^2/s							
	130T		RRClubT		303UDT		116DT	
	#1	#3	#1	#3	#2	#4	#1	#2
OH^-	1.5	1.4	3.8	3.7	4.6	3.5	3.6	2.4
Na^+	0.4	0.3	1.0	0.9	1.2	0.9	0.9	0.6
K^+	0.6	0.5	1.4	1.4	1.7	1.3	1.3	0.9
SO_4^{2-}	0.3	0.3	0.8	0.8	0.9	0.7	0.7	0.5
Ca^+	0.2	0.2	0.6	0.6	0.7	0.5	0.5	0.4
Cl^-	0.6	0.5	1.4	1.4	1.8	1.4	1.4	0.9

A higher diffusion coefficient indicates that ion will diffuse faster through concrete. The ionic diffusion coefficients correlate with the porosity results. For high porosity concrete, the diffusion coefficient is usually high. The typical range for the OH^- diffusion coefficient ranges from 1 to 2 x 10^{-11} m^2/s for a concrete with water to cement ratio (w/c) of 0.45. By comparison, the concrete for the Field Level seating (130T) appears to be comparable to w/c = 0.45 concrete, whereas the elevated slabs were probably cast at a higher water content.

References:

1) Barneyback R.S., & Diamond S. (1981). Expression and analysis of pore fluids from hardened cement
pastes and mortars. *Cement and Concrete Research 11*, pp. 279-285.

2) E. Samson, J. Marchand and K.A. Snyder, *Calculation of ionic diffusion coefficients on the basis of migration test results*, Materials and Structures, Vol. 36, April 2003, pp 156-165.

Petrographic Analysis:

Petrographic analysis is the interpretation of observations from various microscopy, physical, and chemical evaluation techniques to determine the cause for concrete distress. Three petrographic techniques were used to examine concrete cores from Kauffman Stadium: ASTM C 856 general petrographic examination, ASTM C 856 thin-section examination, and ASTM C 457 hardened air-void system parameters.

A general petrographic examination involves cutting a slab of concrete from the center of the core and polishing the cut surface, then observing the polished surface under a microscope. Visual observations are complimented with chemical and physical tests to quantify characteristics such as: overall description; coarse and fine aggregate type, size and quality; cement paste color, hardness and quality; depth of carbonation; presence of fillers or supplementary cementitious materials; presence of consolidation voids and entrained air; presence of microcracking; and the condition of the paste-to-aggregate interface. Analysis of this thorough examination allows the petrographer to identify/determine the cause for distress in most situations.

A thin section is a piece of concrete mounted on a glass slide that is so thin that light can pass through. This technique is often used to compliment a general petrographic examination. Thin section microscopy using polarized light provides the petrographer a technique to confirm the presence of mineral inclusions within aggregates, confirm the presence of chemical reaction products such as ASR gel and to observe the components within hydrated cement paste.

A hardened air-void parameter analysis is a specialized technique that involves quantification of the size and spacing of voids in the paste portion of the concrete. This technique uses observations at more than 1000 locations per core followed by mathematical calculation to determine the following parameters:

- Paste content by volume, P, %
- Air content by volume, A, %
- Paste to air ratio, P/A
- Void frequency, n
- Average chord length, $\bar{l}$, in.
- Specific surface, α, in^2/in^3
- Spacing factor, $\bar{L}$

<u>Air-void parameter criteria for concrete with compressive strength ≥ 4000 psi:</u>

1. If the air content exceeds 3.0%, the concrete is considered air entrained.
2. If the specific surface is less than 500, the voids are probably too large to effectively act as air entrainment.

3. if the spacing factor, $\overline{L}$, is less than 0.008 in., the concrete is considered to be properly air entrained for freeze thaw durability in a saturated environment.
4. If the spacing factor, $\overline{L}$, is greater than 0.009 in. the concrete air-void system is considered to be inadequate for freeze-thaw durability in a saturated environment.
5. For spacing factors between 0.008 and 0.009, the air void system is considered to be marginal for freeze-thaw durability in a saturated environment.

In Kauffman Stadium, the only location where the concrete would classify as a saturated freeze-thaw environment would be the slabs on grade. All other locations can be classified as partially saturated or moist.

Air voids act as pressure relief valves for ice formation inside concrete. Freeze-thaw distress in concrete is a phenomenon that cracks and weakens the cement paste, or causes some aggregates to fail. Typical signs of freeze-thaw distress are exposed aggregate from the loss of cement paste at the concrete surface, and crumbling corners or joints. Air voids also serve as pressure relief valves and reservoirs for the expansive gel formed by alkali-silica reaction, ASR.

Detailed descriptions of each petrographic examination are enclosed in Appendix B.

Findings:

- The air-void system was insufficient for freeze-thaw durability for the majority of the concrete cores examined.
- The aggregates used to make the concrete are reactive. The limestone has inclusions of microcrystalline quartz, and the sand contains reactive chert particles. Thin-section analysis provided confirmation of these findings.
- Alkali-silica reaction was identified in 57 out of 59 cores examined.
- Concrete extracted from visibly distressed areas contained voids that were completely filled with ASR gel.
- Voids partially filled with ASR gel were observed in all cores except the two extracted from Section 105 and 110 that were cast in 1998.
- Field seating sections built in 1998 behind home plate can be characterized as having **minimal** ASR distress. It is expected that the concrete in this area will require minimal maintenance over the next 30 years.
- The majority of the structure can be characterized as having **moderate** ASR distress. The rate of ASR propagation is most uncertain in this category. It is expected that this concrete will last 10 to 20 years before distress accelerates to a point where replacement becomes necessary. Treatment

with lithium nitrate coupled with monitoring should be seriously considered for critical areas as a means to mitigate/prevent distress in the hope that replacement is not required within the remainder of the 30 year design life.

- Cores from locations characterized as having **moderate to advanced** ASR distress include:
    - Scoreboard foundation
    - View Roof pedestals
    - View Concourse portal at Section 416
    - Field level seating slabs on grade

  Concrete characterized as moderate to advanced ASR distress are near the tipping point where the rate of degradation accelerates. These areas are expected to be candidates for replacement in less than 10 years. Treatment may possibly extend the life of the concrete in these areas, but it is unlikely that they will last 30 years.

- Cores from locations characterized as having **advanced or severe** ASR distress include:
    - View Roof Pedestals
    - Stair at section 238
    - Stair and wall at section 343
    - Field level step and seating area at section 137 Row Y
    - Field level seating slabs on grade

  Locations characterized as having advanced or severe ASR distress are candidates for concrete replacement at this time.

Table 30 - Petrographic Examination Summary Table

TCG Project No. 0756
Project Name: Kansas City Royals Kauffman Stadium
Location: Kansas City, MO
Report Date: November 24, 2007

Petrographic Examination Notes
1 secondary deposits of ettringite
2 alkalic gel deposits in microcracks and voids
3 Gel-filled voids
4 Reaction rims on aggregate
5 fractured aggregate
6 cracking through agg and paste
7 aggregate/paste separation

					Tests Performed			ASTM C856 Examination Summary							ASTM C457 Air Void System Parameters			
Core ID	Dia	Length	Row/Seat	Comment	ASTM C856	ASTM C457	Thin Section	Overall Ranking	Carbonation	Coating	Pozz?	ASR?	AGG TYPE	Notes	Air	Sp. Surf.	Sp. Factor	FT Ranking
								FIELD LEVEL SEATING - GROUP 1										
105P	3.25	5.25	L/5	Lt. field - behind home plate - membrane circa 1997	1	1		Fair	veneer	POLYMER	NO	NO	LS/nat.sand	1,5	4.55	514.3	0.0088	MARGINAL
110P	3.26	4.25	L/7	Rt. field - behind home plate - membrane circa 1997	1	1	1	Fair	1/8	POLYMER	NO	NO	LS/nat.sand	1,5,6	4.89	358.9	0.0143	POOR
127P1	3.25	6.00	K/7	Lt. field - at distressed constr. jt.	1	1		Poor	1/4	NONE	NO	YES	LS/nat.sand	1,2,3,4,5,6	3.24	419.6	0.013	POOR
127P2	3.25	4.00	K/10	Lt. field - adj. to distressed constr. jt.	1	1		Fair/Poor	3/32	SEALER	NO	YES	LS/nat.sand	1,4,5	2.66	822.1	0.0072	NOT AIR-ENTRAINED
130P1	3.25	4.38	L/3	Rt. field - adj. to distressed constr. jt.	1	1		Poor	1/16	SEALER	NO	YES	LS/nat.sand	1,2,4,5	6.71	364	0.0077	MARGINAL
130P2	3.25	5.00	L/6	Rt. field - at. distressed constr. jt.	1	1	1	Poor	1/8	NONE	NO	YES	LS/nat.sand	1,2,4,5,6	4.58	272.8	0.0179	POOR
134P	3.25	5.25	H/8	Rt. field - no distress	1	1	1	Fair	veneer	SEALER	NO	YES	LS/nat.sand	1,2,3,4,5,6	5.62	429.2	0.0096	POOR
135P	3.25	6.50	K/1	Lt. field - no distress	1	1	1	Fair	1/16	SEALER	NO	YES	LS/nat.sand	1,2,3,4,5	4.15	559.7	0.0082	MARGINAL
				Group 1 Totals	8	8	4											
								PEDESTRIAN RAMPS - GROUP 2										
LRViewP	3.25	5.00		Lt. Field - minor distress	1	1		Poor	1/8	NONE	NO	YES	LS/nat.sand	2,4,5	9.65	359.9	0.0047	MARGINAL
LRClubP	3.25	5.00		Lt. Field - minor distress	1	1		Fair/Poor	1/16	NONE	NO	YES	LS/nat.sand	2,4,5	5.95	550.5	0.0061	OK
LRFieldP	3.25	5.25		Lt. Field - minor distress	1	1		Poor	1/16	NONE	NO	YES	LS/nat.sand	2,4,5,7	4.44	329.4	0.0123	POOR
RRViewP	3.25	5.38		Rt. Field - minor distress	1	1		Poor	1/16	NONE	NO	YES	LS/nat.sand	2,4,5	5.46	380.8	0.0108	POOR
RRClubP	3.25	5.75		Rt. Field - minor distress	1	1		Poor	1/8	NONE	NO	YES	LS/nat.sand	2,4,5	8.22	332.2	0.0062	MARGINAL
RRFieldP	3.25	5.00		Rt. Field - minor distress	1	1		Poor	3/32	NONE	NO	YES	LS/nat.sand	2,4,5	8.33	295.3	0.0092	POOR
				Group 2 Totals	6	6	0											
								PLAZA LEVEL SEATING - GROUP 3										
103P	3.25	5.50	NN/17	Lt. field - under cover - membrane circa 1997	1	1		Poor	1/8	POLYMER	NO	YES	LS/nat.sand	2,4,5	3.11	581	0.0093	POOR
104P	3.25	6.00	NN/16	Rt. field - under cover - membrane circa 1997	1	1		Poor	1/8	POLYMER	NO	YES	LS/nat.sand	2,4,5	5.33	352.9	0.0122	POOR
127P	3.25	6.25	NN/4	Lt. field - under cover - no membrane circa 1973	1	1	1	Poor	1/32	SEALER	NO	YES	LS/nat.sand	2,4,5	6.17	340.9	0.01	POOR
130P-Plaza	3.25	5.75	NN/6	Rt. field - under cover - no membrane circa 1973	1	1		Poor	NONE	NONE	NO	YES	LS/nat.sand	2,4,5	3.11	265.4	0.0182	POOR
				Group 3 Totals	4	4	1											
								PLAZA LEVEL CONCOURSE- GROUP 3B										
106UD-P	3.25	4.75		Rt. field - undamaged membrane over beam 19b to 19c	1	1		Poor	1/8 to 1/4	7 layer	NO	YES	LS/nat. sand	2,4,5	8.92	342.3	0.0061	MARGINAL
116D-P	3.25	5.75		Rt. field - damaged membrane over beam 13b to 13c	1	1		Poor	NONE	NONE	NO	YES	LS/nat. sand	2,4,5,7	7.82	468.5	0.0067	MARGINAL
127D-P	3.25	5.75		Lt. field - mild damage to membrane over beam at 42b	1	1		Poor	NONE	4 layer	NO	YES	LS/nat. sand	2,4,5,7	6.26	498.5	0.0064	MARGINAL
130UD-P1	3.25	2.75		Rt. field - undamaged membrane over pan at 6b	1	1		Poor	1/8	3 layer	NO	YES	LS/nat. sand	2,4,5,7	10	346	0.006	MARGINAL
130UD-P2	3.25	3.00		Rt. field - undamaged membrane over beam at 7b	1	1		Poor	NONE	3 layer	NO	YES	LS/nat. sand	2,4,5,7	6.7	440	0.007	MARGINAL
				Group 3B Totals	5	5	0											

Table 30 - Petrographic Examination Summary Table

TCG Project No. 0756
Project Name: Kansas City Royals Kauffman Stadium
Location: Kansas City, MO
Report Date: November 24, 2007

Petrographic Examination Notes
1 secondary deposits of ettringite
2 alkalic gel deposits in microcracks and voids
3 Gel-filled voids
4 Reaction rims on aggregate
5 fractured aggregate
6 cracking through agg and paste
7 aggregate/paste separation

					Tests Performed			ASTM C856 Examination Summary							ASTM C457 Air Void System Parameters			
Core ID	Dia	Length	Row/Seat	Comment	ASTM C856	ASTM C457	Thin Section	Overall Ranking	Carbonation	Coating	Pozz?	ASR?	AGG TYPE	Notes	% Air	Sp. Surface	Sp. Factor	F/T Ranking
UPPER RAKER COLUMNS AND VIEW ROOF PEDESTALS - GROUP 4																		
339R-P1	3.25	6.50		Lt. field - adj. to tunnel	1	1		Poor	3/8	NONE	NO	YES	LS/nat. sand	2,4,5	6.21	130.5	0.0146	POOR
339R-P2	3.25	6.75		Lt. field - adj. to tunnel	1	1		Poor	5/8	NONE	NO	YES	LS/nat. sand	2,4,5	2.81	418.7	0.014	NOT AIR-ENTRAINED
340R-P1	3.25	5.38		Rt. field - adj. to tunnel	1	1		Poor	3/8	NONE	NO	YES	LS/nat. sand	2,4,5,7	3.7	574.4	0.0091	POOR
340R-P2	3.25	4.50		Rt. field - adj. to tunnel	1	1		Poor	7/8	NONE	NO	YES	LS/nat. sand	2,4,5,7	2.91	641	0.0067	NOT AIR-ENTRAINED
400Ped	2.25	6.75		Full width pedestal behind home plate - mild distress	1	1		Poor	NONE	EPOXY	NO	YES	LS/nat. sand	2,4,5	6.47	332.7	0.0157	POOR
423Ped	2.25	6.75		Exp. joint pedestal - very distressed	1	1		Very Poor	VENEER	EPOXY	NO	YES	LS/nat. sand	1,2,3,4,5,6	5.99	294.5	0.0153	POOR
424Ped	2.25	8.00		Full width pedestal - moderate distress	1	1		Poor	NONE	EPOXY	NO	YES	LS/nat. sand	2,4,5	3.39	440.3	0.0077	MARGINAL
				Group 4 Totals	7	7	0											
VIEW CONCOURSE - GROUP 5																		
303UD-P	3.25	6.25		Central area - undamaged membrane - corrosion site	1	1		Fair/Poor	NONE	3 layer	NO	YES	LS/nat. sand	2,4,5	6.56	332.8	0.0128	POOR
323D-P	3.25	6.00		Lt. field - damaged membrane at expansion joint	1	1	1	Poor	NONE	6 layer	NO	YES	LS/nat. sand	2,4,5	8.6	330.2	0.0062	MARGINAL
333D-P1	3.25	1.75		Lt. field - topping slab w/ damaged membrane	1	1		Poor	NONE	5 layer	NO	YES	Nat. pearock	2,4,5	4.08	476.2	0.0107	POOR
333D-P2	3.25	1.50		Lt. field - topping slab w/ damaged membrane	1	1					NO	YES						
333UD-P1	3.25	1.75		Lt. field - topping slab w/ undamaged membrane	1	1		Fair/Poor	NONE	4 layer	NO	YES	Nat. pearock	2,4,5	2.2	611	0.011	NOT AIR-ENTRAINED
333UD-P2	3.25	1.50		Lt. field - topping slab w/ undamaged membrane	1	1					NO	YES						
333TD-P1	3.25	1.75		Sec. 333 tunnel - topping slab repair area - stl fibers	1	1		Fair	NONE	NONE	FLYASH	YES	Nat. pearock	4,5	6.93	143.4	0.0276	POOR
333TD-P2	3.25	1.50		Sec. 333 tunnel - topping slab repair area - stl fibers	1	1					NO	YES						
333TUD-P1	3.25	2.25		Sec. 333 tunnel - topping slab w/membrane - stl fibers	1	1		Poor	NONE	3 layer	NO	YES	Nat. pearock	1,2,4,5	4.5	161.7	0.0363	POOR
333TUD-P2	3.25	2.25		Sec. 333 tunnel - topping slab w/membrane - stl fibers	1	1					NO	YES						
				Group 5 Total	10	10	1											
VIEW LEVEL SEATING - GROUP 6																		
412P	1.75	6.50	H/27	Precast riser - horizontal core	1	1		Fair/Poor	1/8	NONE	NO	YES	Exp. Shale/Nat. sand	2,4,5 Stain	4.03	438.4	0.0111	POOR
416P1	1.75	3.75	D	Portal wall with visible signs of distress	1	1		Poor	veneer	NONE	NO	YES	LS/nat. sand	1,2,3,4,5,6,7	1.66	425.6	0.0162	NOT AIR-ENTRAINED
416P2	1.75	4.38	D	Portal wall with visible signs of distress	1	1												
424P	1.75	3.00	H/27	Precast riser - horizontal core	1	1		Fair/Poor	veneer	NONE	NO	YES	Exp. Shale/Nat. sand	2,4,5 Stain	4.1	392	0.012	POOR
436P	1.75	6.00	F/27	Precast riser - horizontal core	1	1	1	Fair/Poor	1/16	NONE	NO	YES	Exp. Shale/Nat. sand	2,5 Stain	5.35	306.4	0.0154	POOR
343 Step	3.25	4.00		Crumbled core - questionable value for examination				Very Poor		NONE	NO	YES	LS/nat. sand	could not prep				
				Group 6 Totals	5	5	1											

Table 30 - Petrographic Examination Summary Table

TCG Project No. 0756
Project Name: Kansas City Royals Kauffman Stadium
Location: Kansas City, MO
Report Date: December 20, 2007

Petrographic Examination Notes
1 secondary deposits of ettringite
2 alkalic gel deposits in microcracks and voids
3 Gel-filled voids
4 Reaction rims on aggregate
5 fractured aggregate
6 cracking through agg and paste
7 aggregate/paste separation

[illegible]	[illegible]	Length	Row/Sect	Comment	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ASR	AGG TYPE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CLUB LEVEL CONCOURSE AND SEATING - GROUP 7																		
Club1P1	1.75	4.50		Lt field concourse with membrane near column C33	1	1		Poor	NONE	4 layer	NO	YES	LS/nat. sand	1,2,4,5,7 stain	4.7	373	0.012	POOR
Club1P2	1.75	3.50		Lt field concourse with membrane near column C33	1	1												
Club2P1	1.75	5.13		Rt field concourse with membrane near column C13	1	1		Poor	1/6	5 layer	NO	YES	LS/nat. sand	1,2,4,5 stain	5.31	351.4	0.013	POOR
Club2P2	1.75	4.75		Rt field concourse with membrane near column C13	1	1	1											
208P1	1.75	5.50	B/5	Rt. Field seating area	1	1		Poor	NONE	3 layer	NO	YES	LS/nat. sand	2,4,5,7 stain	4.7	393	0.012	POOR
208P2	1.75	3.50	B/5	Rt. Field seating area	1	1												
209P1	1.75	5.00	B/2	Lt. Field seating area	1	1		Poor	1/16	3 layer	NO	YES	LS/nat. sand	2,4,5 stain	4.42	532.3	0.0052	POOR
209P2	1.75	5.00	B/2	Lt. Field seating area	1	1					NO							
238P	3.25	4.63	Step	Rt. Field seating area near column C3	1	1		Very poor	3/16	NONE	NO	YES	LS/nat. sand	1,2,3,4,5,6	6.54	391.9	0.0088	POOR
				Group 7 Totals	9	9	1											
UPPER BACK PANELS AND SCOREBOARD FOUNDATION - GROUP 8																		
343BP-P	1.75	5.25		Lt field view level - adj. to tunnel - cracked/twice cored	1	1		Poor	NONE	3/4" sealer	NO	YES	LS/nat. sand	2,4,5,7 stain	1.9	736	0.009	NOT AIR-ENTRAINED
344BP-P	1.75	6.50		Rt field view level - adj. to tunnel	1	1		Poor	NONE	1/4" sealer	NO	YES	LS/nat. sand	2,4,5,7 stain	1.1	1136	0.007	NOT AIR-ENTRAINED
435BP-P	1.75	4.00		Lt field view seating - Adj. to awning outrigger	1	1		Poor	1/8	NONE	NO	YES	LS/nat. sand	2,4,5, stain	5.1	222	0.017	POOR
436BP-P	1.75	5.75		Rt field view seating - Adj. to awning outrigger	1	1		Poor	3/16	NONE	NO	YES	LS/nat. sand	2,4,5,7 stain	6.8	466	0.007	MARGINAL
Scoreboard P1	3.25	5.75		Vertical core at entrance	1	1	1	Poor	1/6	NONE	NO	YES	LS/nat. sand	2,3,4,5,7 stain	1.94	265.9	0.0235	NOT AIR-ENTRAINED
Scoreboard P2	5.63	9.00		Vertical core at base of foundation	1	1		Poor	NONE	NONE	NO	YES	LS/nat. sand	1,2,3,4,5	2.14	197.9	0.0306	NOT AIR-ENTRAINED
				Group 8 Totals	6	6	1											
Field Level Concourse - Group 9																		
103TD-P	3.25	4.75		Tunnel @ Section 103 damaged membrane	1	1		Poor	NONE	5 layer	FLYASH	YES	LS/nat. sand	1,2,4, 5	8.04	376.7	0.0075	MARGINAL
103TUD-P	3.25	3.50		Tunnel @ Section 103 undamaged membrane	1	1		Poor	NONE	2 layer	FLYASH	YES	LS/nat. sand	1,2,3,4,5	6.65	286	0.0082	MARGINAL
SL-A16-P	3.25	7.00		Corridor slab @ entrance to Section 112 Tunnel	1	1		Poor	3/8	Wax	NO	YES	LS/nat. sand	1,2,4,5	8.51	384.6	0.0073	MARGINAL
SL-B25-P	3.25	3.25		Corridor pan joist slab over Visitors locker room	1	1		Poor	3/8	NONE	NO	YES	LS/nat. sand	2,4,5	4.44	470.2	0.0092	POOR
				Group 9 Totals	4	4	0											

Note: Pairs of cores (P1, P2) were examined and reported as one.

Summary of Findings

Concrete Cover:

- Concrete cover varies widely throughout the stadium.
- The most frequent areas with inadequate concrete cover are columns, beam bottoms, and walls.

Compressive Strength:

- Compressive strength test results indicate that the existing concrete meets or exceeds the original specified strength.
- All compressive strength cores were extracted from areas of sound concrete.
- No compressive strength cores were intentionally taken from distressed areas.

Chloride Contamination:

- Chloride contamination varies throughout the structure.
- Where chloride contamination was found it appeared to be relatively constant through the depth of the concrete, which is indicative of admixed chloride set accelerators.
- Background chloride levels (chloride ion contributed by the concrete ingredients) were relatively low, approximately 50 parts per million, ppm, or 0.005% by mass of concrete powder.
- Areas with chloride levels in excess of the industry accepted corrosion threshold range (350 to 500 ppm) at the reinforcing level were:
    - Upper back panels (1 of 2),
    - View Concourse (3 of 7),
    - Pedestrian ramps (4 of 8), and
    - Plaza Level (4 of 8).
- Water-soluble chloride contents were consistently lower than companion acid-soluble chloride tests by approximately 100 to 300 ppm. A few individual water-soluble data points exceeded companion acid-soluble values. This finding is consistent with experience.

Corrosion Potentials:

- Generally, minimal corrosion activity was associated with dry test areas even with low concrete cover. This is common when the environment is hot and dry.
- Localized corrosion activity was identified at the following locations:
    - Location 6 – Right Field Pedestrian Ramp crack.
    - Location 8&9 – View Concourse
    - Location 10 – Left Field Camera Platform
- Visual observation of corrosion spalls along the slab soffit under Row A on the View and Club levels indicates wide spread corrosion activity in the Row A slab (tub section).
- Location 8 & 9 corrosion potentials indicate corrosion activity well outside the boundary of the previous patch on the view concourse. The previous patch was determined to be delaminated. Chloride contamination tests in this area indicate elevated chloride levels in the sound concrete. This is an indication of corrosion activity in the slab reinforcing below the previous patch.
- Corrosion activity was high in the two areas that had a polymer coating. This corrosion activity is most likely caused by moisture trapped under the membrane.

Concrete Transport Properties:

- The ionic diffusion coefficient determined for the concrete from elevated slabs are comparable and are indicative of relatively porous concrete with a water-to-cement ratio greater than 0.45.
- The ionic diffusion coefficient determined for the concrete used to construct the field seating was higher quality, with properties indicative of a concrete water-to-cement ratio of 0.45.
- The pore solution chemistry indicates sufficient alkali hydroxides are available to promote ASR.

Petrographic Examination:

- The air-void system was insufficient for freeze-thaw durability for the majority of the concrete cores examined.
- The aggregates used to make the concrete are reactive. The limestone has inclusions of microcrystalline quartz, and the sand contains reactive chert particles. Thin-section analysis provided confirmation of these findings.
- Alkali-silica reaction was identified in 57 out of 59 cores examined.

- Concrete extracted from visibly distressed areas contained voids that were completely filled with ASR gel.
- Voids partially filled with ASR gel were observed in all cores except the two extracted from Section 105 and 110 that were cast in 1998.
- Field seating sections built in 1998 behind home plate can be characterized as having **minimal** ASR distress. It is expected that the concrete in this area will require minimal maintenance over the next 30 years.
- The majority of the structure can be characterized as having **moderate** ASR distress. The rate of ASR propagation is most uncertain in this category. It is expected that this concrete will last 10 to 20 years before distress accelerates to a point where replacement becomes necessary. Treatment with lithium nitrate coupled with monitoring should be seriously considered for critical areas as a means to mitigate/prevent distress in the hope that replacement is not required within the remainder of the 30 year design life.
- Cores from locations characterized as having **moderate to advanced** ASR distress include:
    - Scoreboard foundation
    - View Roof pedestals
    - View Concourse portal at Section 416
    - Field level seating slabs on grade

  Concrete characterized as moderate to advanced ASR distress are near the tipping point where the rate of degradation accelerates. These areas are expected to become candidates for replacement in less than 10 years. Treatment may possibly extend the life of the concrete in these areas, but it is uncertain if treatment will extend the life for the full 30 years. Monitoring and future treatment may be required.
- Cores from locations characterized as having **advanced or severe** ASR distress include:
    - View Roof Pedestals
    - Stair at section 238
    - Stair and wall at section 343
    - Field level step and seating area at section 137 Row Y
    - Field level seating slabs on grade

  Locations characterized as having advanced or severe ASR distress are candidates for concrete replacement at this time.

This report was developed and written by:

Matt Miltenberger

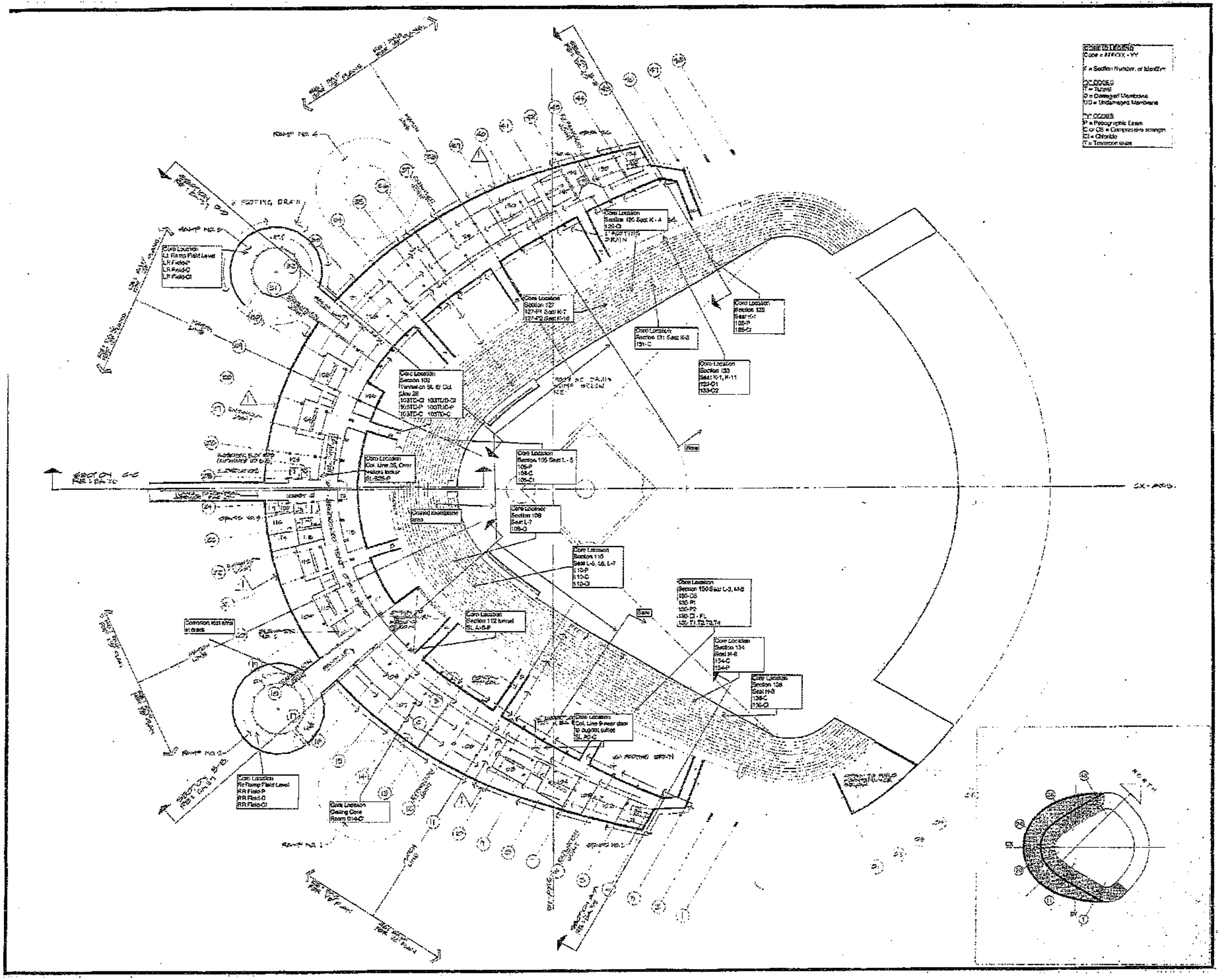
Matthew Miltenberger, P.E.

Tourney Consulting Group, L.L.C.

Date: December 19, 2007

APPENDIX A

CORROSION POTENTIALTEST SITES
CORING LOCATIONS



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CHARLES DEATON, ARCHITECT
DESIGN ASSOCIATE
TEN MAIN CENTER KANSAS CITY, MISSOURI

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X-12

CONTRACTOR SHALL CHECK AND VERIFY A
DIMENSIONS AT THE SITE

DRAWN BY PWS JOB NO. 3710-B
CHECKED BY [illegible] DATE 9 APRIL 1[illegible]
8 MAY 1[illegible]

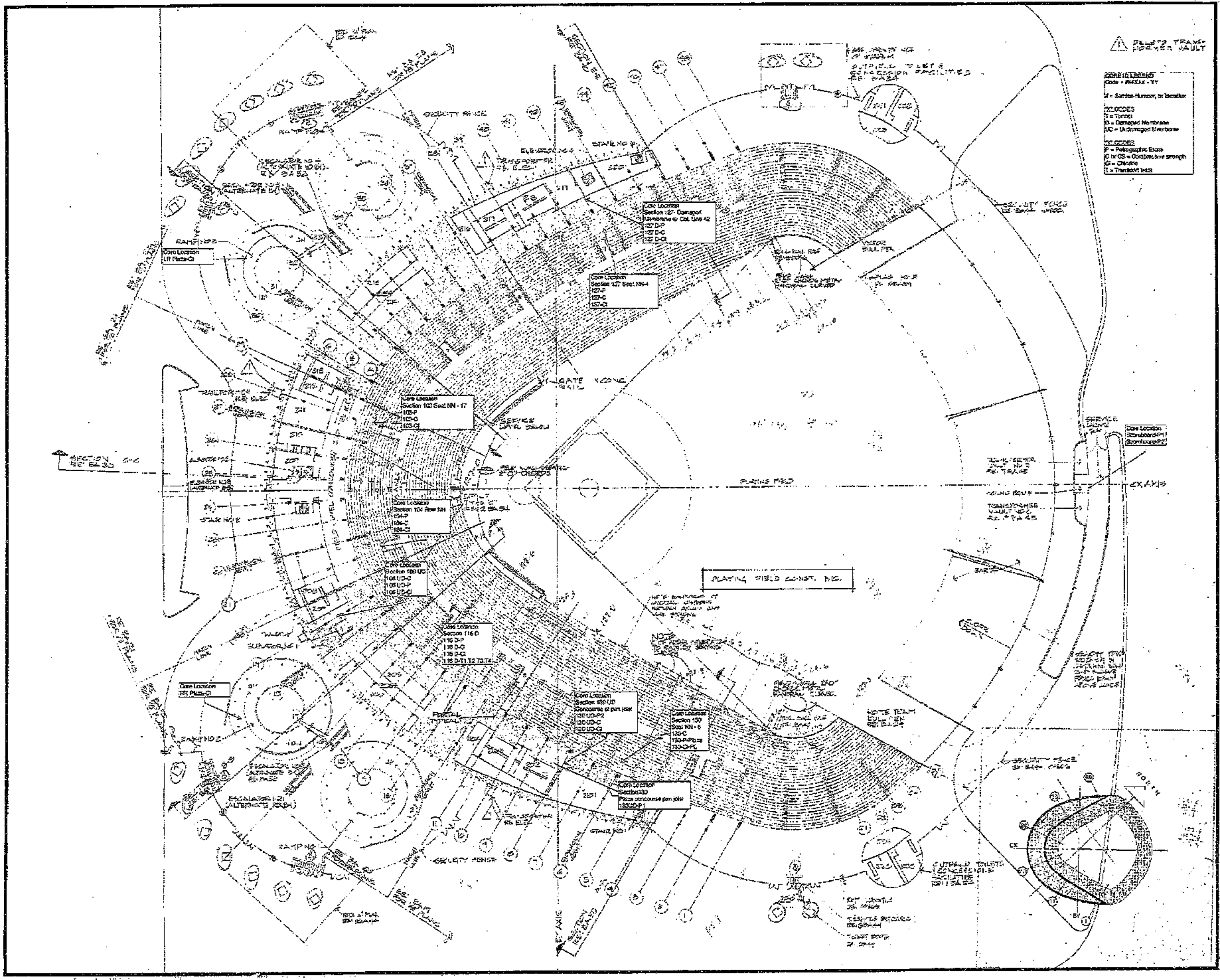
JACKSON COUNTY CONTRACT NO. 1[illegible]

BASEBALL STADI

LOWER FIELD LEVEL
CONCOURSE

1[illegible]

BA



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CONCRETE CONSULTANTS

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DRAWN BY JOB NO. 67-045
CHECKED BY SCH DATE APRIL
SHT

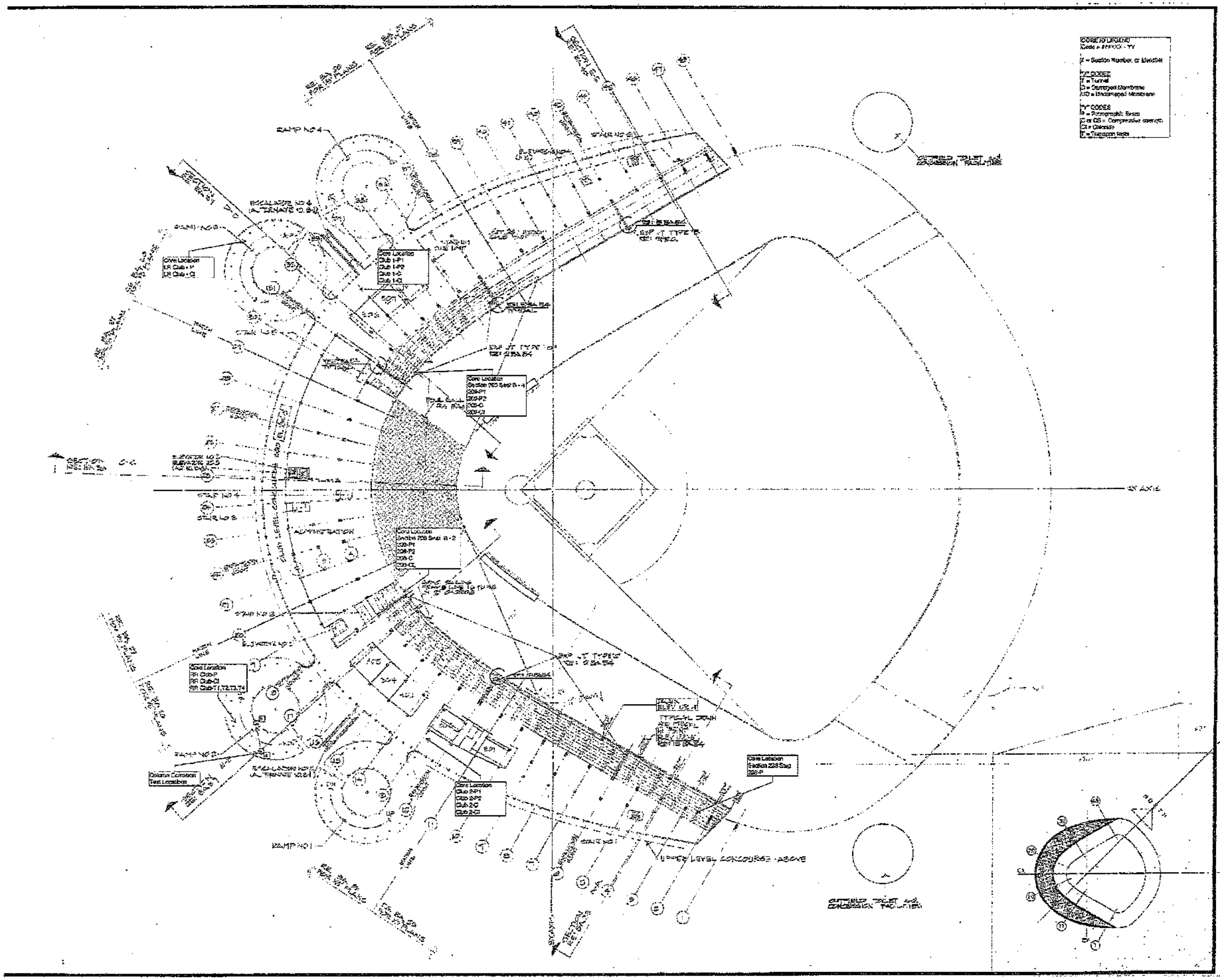
JACKSON COUNTY CONTRACT NO. 1

BASEBALL STADIU

FIELD LEVEL CONCOURS
& SEATING

1/32 = 1'-0"

B.A.4



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CONTRACTOR SHALL CHECK AND VERIFY ALL DIMENSIONS AT THE SITE

DRAWN BY JOB NO. 67104
CHECKED BY DATE APRIL 1969
5 MAY 1969

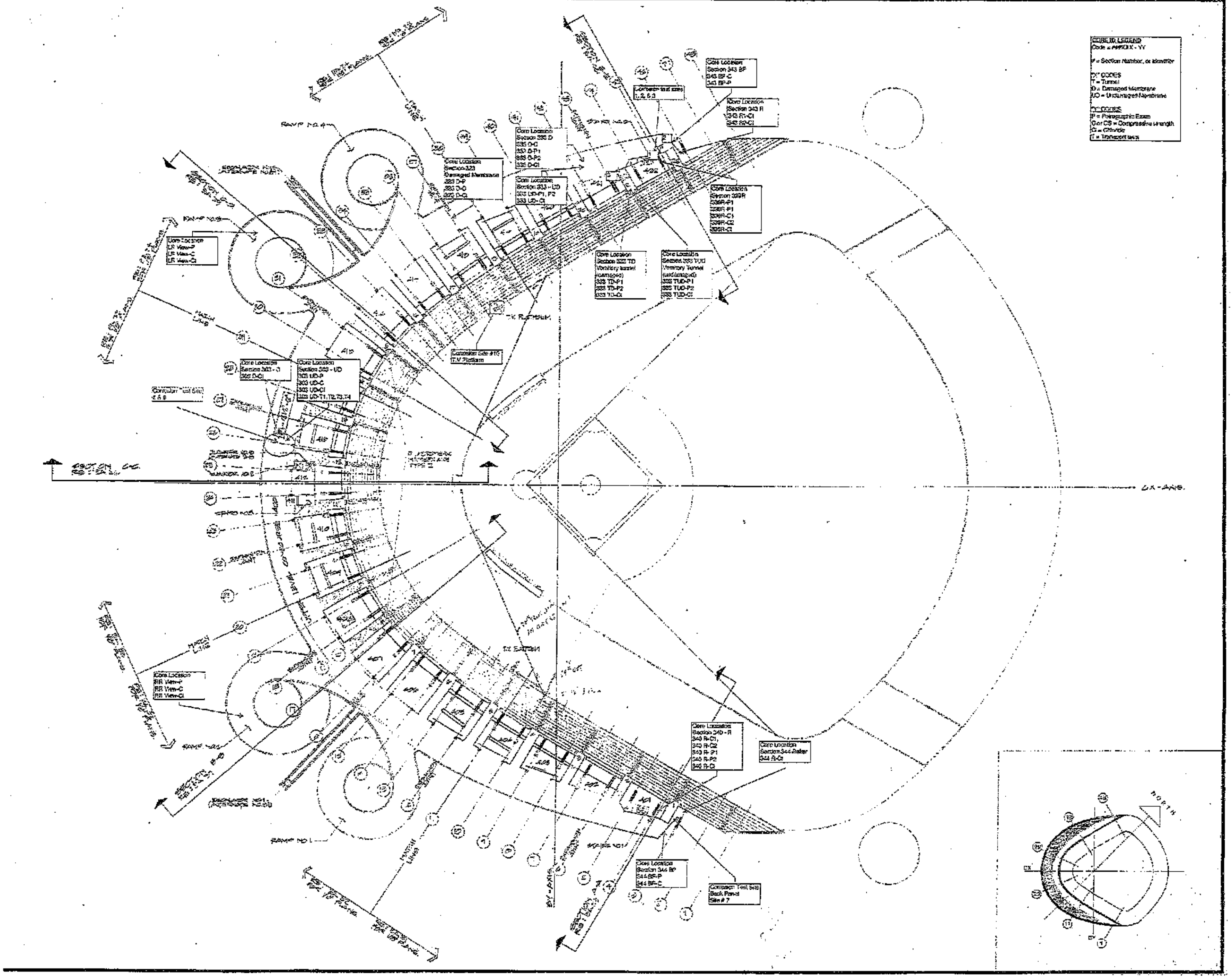
JACKSON COUNTY CONTRACT NO. 1106

BASEBALL STADIUM

CLUB LEVEL CONCOURSE & SEATING

1/32" = 1'-0"

BA5



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CONSULTANTS, INC.
CONCRETE CONSULTANTS

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CONTRACTOR SHALL CHECK AND VERIFY A
DIMENSIONS AT THE SITE

DRAWN BY GHC JOB NO. 6710-B
CHECKED BY BDW DATE APRIL 1
2 MAY 19

JACKSON COUNTY CONTRACT NO 11

BASEBALL STAD

UPPER LEVEL CONCOURS
& SEATING

1/32 = 1'-0"

BA(

JACKSON
COUNTY
SPORTS
COMPLEX

JACKSON COUNT
KANSAS CITY, MISSOU

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PROJECT ARCHITECT, WIT
CHARLES DEATON, ARCHITE
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CONSULTANTS, INC.
CONCRETE CONSULTANTS

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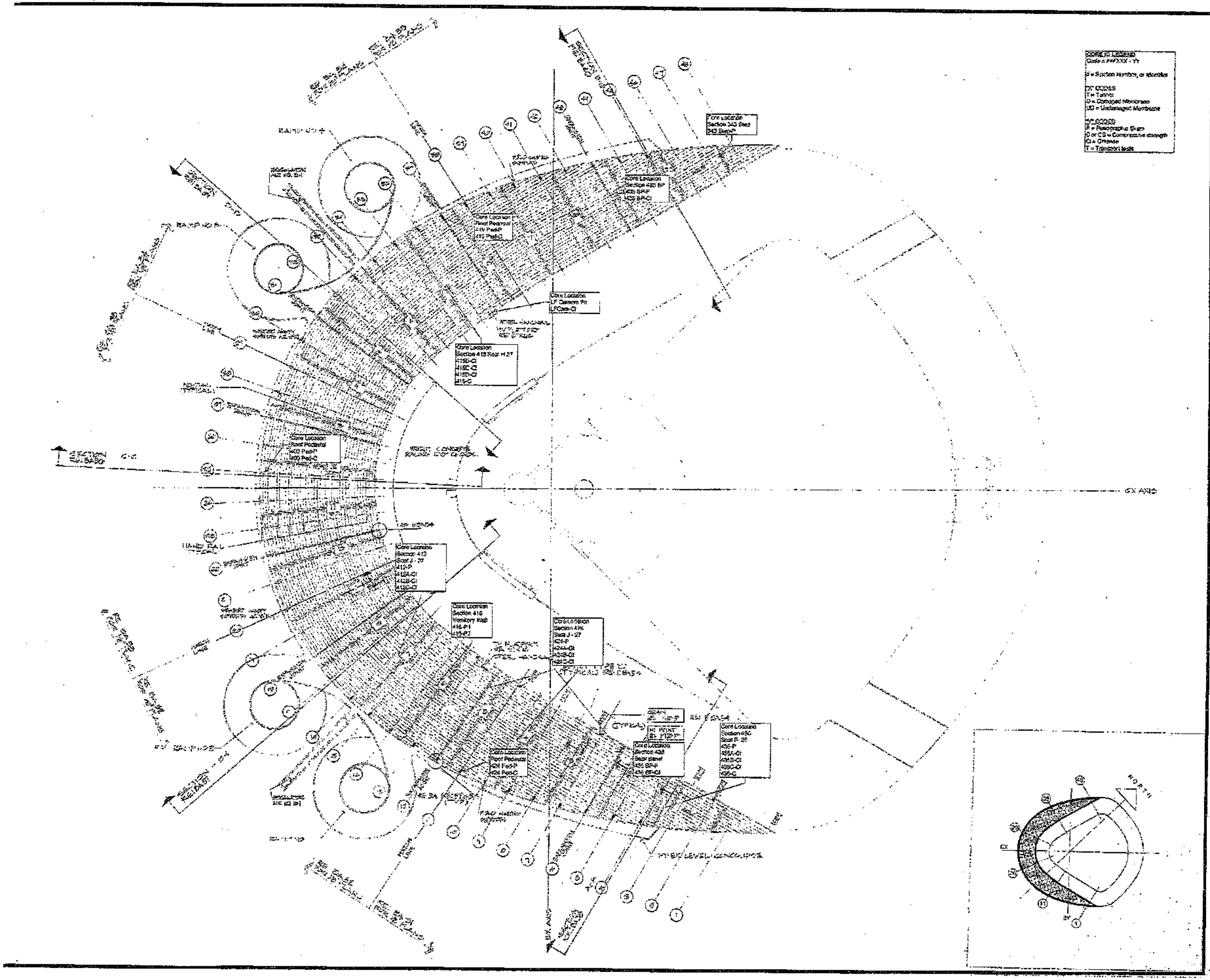

CORE ID LEGEND
Code = ##XXX - YY

= Section Number, or Identifier

XX CODES
T = Tunnel
D = Damaged Membrane
UD = Undamaged Membrane

YY CODES
P = Petrographic Exam
C or CS = Compressive strength
CI = Chloride
T = Transport tests

CONTRACTOR SHALL CHECK AND VERIFY
DIMENSIONS AT THE SITE

DRAWN BY D-D JOB 20.2-70-D
CHECKED BY BON CDS DATE APRIL

JACKSON COUNTY CONTRACT NO. 1:

BASEBALL STADIU

UPPER LEVEL SEATING

1/32" = 1'-0"

BA7

APPENDIX B
PETROGRAPHIC EXAMINATION REPORTS

THE ROCK DOCTOR
CONCRETE SOLUTIONS FOR CONCRETE PROBLEMS

PETROGRAPHIC REPORT

DATE:	September 7, 2007
WORK ORDER:	07-08-31-01 / Group I
CLIENT:	Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY:	Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received eight core portions of hardened concrete to determine the general condition of the concrete(s). The core portions were marked **"105P"**, **"110P"**, **"127P1"**, **"127P2"**, **"130P1"**, **"130P2"**, **"134P"**, and **"135P"**. The core portions measured, in length, approximately 5-1/2, 4-3/4, 6-1/4, 4-1/2, 4-1/2, 5-1/2, 5-1/4 and 6 inches, respectively. The core portions were approximately 3-1/8 inches in diameter, except Sample **"134P"**, which measured approximately 2-3/4 inches in diameter.

It was reported that the submitted samples were taken from field level seating areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Several digital photographs were also submitted. Mix designs were not available at the time of this writing.

SAMPLE PREPARATION AND METHODS

The core samples were cut in half, approximately perpendicular to the top surfaces. The cut surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were determined following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters.

The unprepared samples were partially immersed in water for at least three days to mobilize any alkalic gels present. The cut surfaces of the core portion samples were not immersed in water.

The prepared and unprepared samples were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

"105P"

GENERAL CONDITION: (See PLATES 1-3) The top surface exhibited a generally flat, soft, mostly elastic, membrane/coating that was mottled in color from gray to dark gray. Water readily beaded on this surface. Many, partially exposed fine quartz aggregate particles and many air-void septa were present at the exposed surface. The observed darker gray-colored portions at the exposed surface were generally stiffer/less flexible than the lighter gray-colored portions and exhibited very fine cracks as well. Very small amounts of yellow-colored material, presumed to be used for marking purposes, were also present at the exposed surface.

In section, the observed membrane/coating was approx. 1/16 of an inch thick and was composed of two apparent layers. The layer at/adjacent to the exposed surface was approx. ¼ of the total coating thickness and exhibited a small amount of small voids and several fine aggregate particles. At the interface between the two apparent coating layers, no voids, separations, or cracks were observed. The underlying layer (approx. ¾ of the total topping thickness) exhibited many small air-voids. The bottom surface of this layer exhibited an almost continuous, adhered layer of paste/mortar from the base concrete. A continuous separation/crack was present at or near the interface of the topping system and the base concrete. A discontinuous veneer of carbonated paste was observed at the top surface of the base concrete. A very small amount of microcracking was observed throughout the sample. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and variegated from gray-light brown with a small-moderate amount of unhydrated cement particles to light brown-dull gray in color, with a very small-small amount of unhydrated cement particles. The lighter colored paste areas were softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 1:

TABLE 1

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	I in.	α in.$^{-1}$	L in.
"105P"	21.65	2,023	99.70	4.55	4.76	5.9	.0078	514.3	.0088

The inhomogeneously distributed voids were mostly small in size and spherically shaped with larger, spherical to irregularly shaped voids also observed. A small amount of clusters of voids was observed throughout the sample. In several smaller voids, secondary, internal deposits were observed as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\ H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Several particles exhibited internal fractures. Small amounts of microcracks were observed at a few aggregate peripheries as well as small discontinuous zones of lighter-colored paste. In addition, discontinuous veneers of markedly darker gray colored paste and mortar were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, claystone, limestones, mica flakes and books, and microcrystalline quartz chert particles. Although cherts are considered to be, at least, potentially reactive with cement alkalis, no such reaction was observed.

"110P"

GENERAL CONDITION: (See PLATES 4-6) The top surface exhibited a generally flat, soft, mostly elastic, membrane/coating that was mostly gray in color with smaller area exhibiting a dark gray color. Water readily beaded on this surface. Many, partially exposed fine quartz aggregate particles, several aggregate sockets, and many air-void septa were present at the exposed surface. The observed darker gray-colored portions at the exposed surface were generally stiffer/less flexible than the lighter gray-colored portions and exhibited very fine cracks as well. Very small amounts of yellow-colored material, presumed to be used for marking purposes, were also present at the exposed surface.

In section, the observed membrane/coating ranged from approx. 1/32 up to 1/16 of an inch thick and was composed of two apparent layers. The layer at/adjacent to the exposed surface ranged from a very thin film up to approx. ½ of the total coating thickness and exhibited a small amount of small voids and several fine aggregate particles. At the interface between the two apparent coating layers, no voids, separations, or cracks were observed. The underlying layer (from approx. 1/2 of the total topping thickness to almost full topping thickness) exhibited many small air-voids. The bottom surface of this layer was underlain by an 1/8 of an inch thick mortar. No voids, separations, or cracks were observed at this interface. The mortar layer exhibited variable carbonation up to full mortar thickness. At the interface of this mortar layer and the base concrete, no voids, separations, or cracks were observed. The upper surface of the base concrete exhibited a continuous veneer of carbonated paste. A very small amount of microcracking was observed throughout the sample. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and variegated from gray-light brown with a small-moderate amount of unhydrated cement particles to light brown-dull gray in color, with a very small-small amount of unhydrated cement particles. The lighter colored paste areas were softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 2:

TABLE 2

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"110 P"	26.53	2,024	99.75	4.89	5.43	4.1	.0119	336.9	.0143

The inhomogeneously distributed voids were spherically shaped and ranged in size from small to large with fewer, larger, irregularly shaped voids also present. A small amount of clustering of voids was observed throughout the sample. In several smaller voids, secondary, internal deposits were observed as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\,H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Several particles exhibited internal fractures. Small amounts of microcracks were observed at a few aggregate peripheries as well as small discontinuous zones of lighter-colored paste. In addition, discontinuous veneers of markedly darker gray colored paste and mortar were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, claystone, limestones, and microcrystalline quartz chert particles. Although cherts are considered to be, at least, potentially reactive with cement alkalis, no such reaction was observed.

"127 P1"

GENERAL CONDITION: (See PLATES 7-10) Upon receipt, the sample consisted of two heavily fractured core portions that were taped together. A horizontally oriented fracture plane was present approx. 1-3/4 inches below the top surface. At this fracture surface and at the fracture surface of the bottom surface of the sample, many coarse aggregate particles were observed with reaction rims and "halo-like", fine, white deposits within the respective particles adjacent to aggregate edges. These white deposits exhibited the optical properties if alkalic gels and carbonated alkalic gel. The top surface was generally flat and exhibited numerous partially exposed, fine aggregate particles in a recessed paste matrix. Loosely adhered, very fine, light brown "dust" as well as small amounts of small fragments of soft, rubbery black material were also present. Most of the light brown "dust" (presumed to be debris from the coring procedure) and some of the black material was easily washed from the surface. After washing, two fine cracks were observed at the top surface. These cracks were infilled with a light brown-dull white material with some properties of alkalic gel and carbonated alkalic gel. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a continuous zone of carbonated paste was present and ranged in thickness from approx. 1/16 up to ¼ of an inch(coinciding with a fine surface crack). A moderate-abundant amount of microcracking was observed throughout the sample. Some of these microcracks were partially to completely infilled with clear-off white material with similar optical properties of alkalic gel and carbonated alkalic gel. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and variegated from pale brown with a very small amount of unhydrated cement particles to dull white with very little, if any, unhydrated cement particles. The lighter colored paste areas were softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 3:

TABLE 3

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"127 P1"	23.31	2,008	98.95	3.24	7.19	3.4	.0095	419.6	.0130

The inhomogeneously distributed voids were spherically shaped and ranged in size from small to large with fewer, larger, irregularly shaped voids also present. A small amount of clustering of voids was observed throughout the sample. In numerous voids, secondary, internal deposits were observed. Partial to complete infillings of clear-white material with similar optical properties of alkalic gel and coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\ H_2O$ were observed. Some of these deposits appeared to be concentrated within voids on void surfaces closest to the top surface, that is, on "upper" portions of the voids with respect to the top surface of the sample.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Many particles exhibited internal fractures as well as reaction rims. Moderate amounts of microcracks were observed at a few aggregate peripheries and in the adjacent paste. Small, discontinuous-to-continuous zones of lighter-colored paste were also observed at aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, siltstone, and microcrystalline quartz chert particles. Some of the microcrystalline quartz chert particles exhibited reaction rims and internal fractures.

"127 P2"

GENERAL CONDITION: (See PLATES 11 and 12) The top surface was generally flat and exhibited numerous partially exposed, fine aggregate particles in a recessed paste matrix. Loosely adhered, very fine, light brown "dust" as well as a moderate amount of small fragments of soft, rubbery black material were also present. Most of the light brown "dust" (presumed to be debris from the coring procedure) and some of the black material was easily washed from the surface. An approx. 1-inch diameter semi-circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a continuous zone of carbonated paste was present and ranged in thickness from a veneer up to approx. 3/32 of an inch. A very small amount of microcracking was observed. A zone at/near the top surface (approx. 1/8 up to approx. 3/8 of an inch thick) was markedly less water absorptive than the bulk paste and did not readily wet-out when water was applied. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light brown-pale gray to light brown with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 4:

TABLE 4

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"127 P2"	22.65	1,996	98.40	2.66	8.52	5.5	.0049	822.1	.0072

The inhomogeneously distributed voids were mostly spherically shaped and small in size with fewer, larger, spherical to irregularly shaped voids also present. A small amount of clustering of voids was observed throughout the sample. In several voids, secondary, internal deposits were observed as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\ H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subangular in shape with an observed topsize of 1-1/4 inches. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. A few particles exhibited small amounts of internal fractures as well as reaction rims. One coarser aggregate particle exhibited cracks that paralleled the aggregate periphery. Several paste portions adjacent to several aggregate particles exhibited lighter-colored paste.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, siltstone, claystone, and microcrystalline quartz chert particles. Although cherts are considered to be, at least, potentially reactive with cement alkalis, no such reaction was observed.

"130 P1"

GENERAL CONDITION: (See PLATES 13 and 14) The top surface was generally flat and exhibited numerous partially exposed, fine aggregate particles in a recessed paste matrix. Loosely adhered, very fine, light brown "dust" as well as a moderate amount of small fragments of soft, rubbery black material were also present. Most of the light brown "dust" (presumed to be debris from the coring procedure) and some of the black material was easily washed from the surface. An approx. 1-inch diameter semi-circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a continuous zone of carbonated paste was present and ranged in thickness from a veneer up to approx. 1/16 of an inch. A small amount of microcracking was observed. A zone at/near the top surface (approx. 3/8 up to approx. 3/4 of an inch thick) was markedly less water absorptive than the bulk paste and did not readily wet-out when water was applied. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and variegated from pale gray with a small amount of unhydrated cement particles to light brown with a very small amount of unhydrated cement particles. Lighter-colored areas appeared to be softer as compared to darker-colored areas of the paste. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 5:

TABLE 5

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"130 P1"	18.89	2,028	99.95	6.71	2.82	6.1	.0110	364.0	.0077

The inhomogeneously distributed voids were mostly spherically shaped and ranged from small to large in size with fewer, larger, irregularly shaped voids also present. A moderate amount of clustering of voids was observed throughout the sample. In several smaller voids, secondary, internal deposits were observed as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26 H_2O$. A small amount of clear-white material deposits with the optical properties of alkalic gel were observed as partial linings and coatings in several voids.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subangular in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Many particles exhibited small amounts of internal fractures as well as reaction rims. Several paste portions adjacent to several aggregate particles exhibited lighter-colored paste.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, siltstone, and microcrystalline quartz chert particles. Several particles exhibited internal fractures.

"130 P2"

GENERAL CONDITION: (See PLATES 15-17) Upon receipt, the sample consisted of two heavily fractured core portions that were taped together. A horizontally oriented fracture plane was present approx. 2 inches below the top surface. At this fracture surface and at the fracture surface of the bottom surface of the sample, a few coarse aggregate particles were observed with reaction rims and "halo-like", fine, white deposits within the respective particles adjacent to aggregate edges. These white deposits exhibited the optical properties if alkalic gels and carbonated alkalic gel. The top surface was generally flat and exhibited numerous partially exposed, fine aggregate particles in a recessed paste matrix. Loosely adhered, very fine, light brown "dust" as well as a moderate amount of small fragments of soft, rubbery black material were also present. Most of the light brown "dust" (presumed to be debris from the coring procedure) and some of the black material was easily washed from the surface. After washing, a few, fine cracks were observed at the top surface. These cracks were partially infilled with a light brown-dull white material with some properties of alkalic gel and carbonated alkalic gel. Small amounts of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a continuous zone of carbonated paste was present and ranged in thickness from a veneer up to approx. 1/8 of an inch. An abundant amount of microcracking was observed throughout the sample transecting paste and aggregate particles. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light brown-pale gray with a small amount of unhydrated cement particles to light brown with a very small amount of unhydrated cement particles. Lighter-colored areas appeared to be softer as compared to darker-colored areas of the paste. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 6:

TABLE 6

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	ℓ in.	α $in.^{-1}$	L in.
"130 P2"	25.60	2,051	100.85	4.58	5.59	3.1	.0147	272.6	.0179

The inhomogeneously distributed voids were mostly spherically shaped and ranged from small to large in size with fewer, larger, irregularly shaped voids also present. A moderate amount of clustering of voids was observed throughout the sample. In several smaller voids, secondary, internal deposits were observed as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\ H_2O$. A small amount of clear-white material deposits with the optical properties of alkalic gel were observed as partial linings and coatings in several voids.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subangular in shape with an observed topsize of 1-1/8 inches. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Several particles exhibited small amounts of internal fractures as well as reaction rims. Several paste portions adjacent to several aggregate particles exhibited lighter-colored paste.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, siltstone, and limestone particles. Several particles exhibited internal fractures.

"134 P"

GENERAL CONDITION: (See PLATES 18 and 19) The top surface was generally flat and exhibited numerous partially exposed, fine aggregate particles in a recessed paste matrix. Loosely adhered, very fine, light brown "dust" as well as small amounts of small fragments of soft, rubbery black material were also present. Most of the light brown "dust" (presumed to be debris from the coring procedure) and some of the black material was easily washed from the surface. After washing, one fine crack were observed roughly bisecting the top surface. This crack was infilled with a light brown-dull white material with some properties of alkalic gel and carbonated alkalic gel. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface. An approximately ½ X ¾ of an inch portion of the top surface adjacent to the core edge was a fractured surface.

In section, a veneer of carbonated paste was observed with a localized, V-shaped zone of carbonated paste adjacent to a vertically oriented crack from the top surface to an approx. depth of ½ of an inch. A zone at/near the top surface (approx. 3/8 up to approx. 5/8 of an inch thick) was markedly less water absorptive than the bulk paste and did not readily wet-out when water was applied. A small amount of microcracking was observed throughout the sample. Some of these microcracks were partially to completely infilled with clear-off white material with similar optical properties of alkalic gel and carbonated alkalic gel. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and variegated from light brown-pale gray with a small-moderate amount of unhydrated cement particles to light brown with a very small to small amount of unhydrated cement particles. The lighter colored paste areas were slightly softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 7:

TABLE 7

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"134 P"	23.13	2,010	98.80	5.62	4.12	6.0	.0093	429.2	.0096

The inhomogeneously distributed voids were spherically shaped and ranged in size from small to large with fewer, larger, irregularly shaped voids also present. A small amount of clustering of voids was observed throughout the sample. In several voids, secondary, internal deposits were observed. Partial to complete infillings of clear-white material with similar optical properties of alkalic gel were observed as well as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26 H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Several particles exhibited reaction rims. A few particles exhibited internal fractures. Small, discontinuous-to-continuous zones of lighter-colored paste were also observed at a few aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, siltstone, limestone, and microcrystalline quartz chert particles. Several particles exhibited internal fractures.

"135 P"

GENERAL CONDITION: (See PLATES 20 and 21) The top surface was generally flat and exhibited a few fine aggregate sockets, numerous partially exposed, fine aggregate particles in a recessed paste matrix. Loosely adhered, very fine, light brown "dust" as well as small amounts of small fragments of soft, rubbery black material were also present. Most of the light brown "dust" (presumed to be debris from the coring procedure) and some of the black material was easily washed from the surface. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present in the central portion of the top, exposed surface.

In section, a veneer up to approx. 1/16 of an inch zone of carbonated paste was observed. A zone at/near the top surface (approx. 3/32 up to approx. 3/8 of an inch thick) was markedly less water absorptive than the bulk paste and did not readily wet-out when water was applied. A small amount of microcracking was observed throughout the sample. Some of these microcracks were partially to completely infilled with clear-off white material with similar optical properties of alkalic gel and carbonated alkalic gel. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and variegated from light brown-pale gray with a small amount of unhydrated cement particles to light brown with a very small amount of unhydrated cement particles. The lighter colored paste areas were slightly softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 8:

TABLE 8

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"135 P"	20.48	2,070	102	4.15	4.94	5.8	.0071	559.7	.0082

The inhomogeneously distributed voids were spherically shaped and ranged in size from small to large with several, larger, irregularly shaped voids also observed. A small amount of clustering of voids was observed throughout the sample. In several voids, secondary, internal deposits were observed. Partial to complete infillings of clear-white material with similar optical properties of alkalic gel were observed as well as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26 H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Many particles exhibited reaction rims. A few particles exhibited internal fractures. Small, discontinuous-to-continuous zones of lighter-colored paste were also observed at a few aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, siltstone, limestone, and microcrystalline quartz chert particles. Several particles exhibited internal fractures.

DISCUSSION & CONCLUSION

We received eight core portions of hardened concrete to determine the general condition of the concrete(s). It was reported that the submitted samples were taken from field level seating areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Several digital photographs were also submitted. Mix designs were not available at the time of this writing.

The air-void system parameters for all samples are listed below in TABLE 9:

TABLE 9

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"105P"	21.65	2,023	99.70	4.55	4.76	5.9	.0078	514.3	.0088
"110 P"	26.53	2,024	99.75	4.89	5.43	4.1	.0119	336.9	.0143
"127 P1"	23.31	2,008	98.95	3.24	7.19	3.4	.0095	419.6	.0130
"127 P2"	22.65	1,996	98.40	2.66	8.52	5.5	.0049	822.1	.0072
"130 P1"	18.89	2,028	99.95	6.71	2.82	6.1	.0110	364.0	.0077
"130 P2"	25.60	2,051	100.85	4.58	5.59	3.1	.0147	272.6	.0179
"134 P"	23.13	2,010	98.80	5.62	4.12	6.0	.0093	429.2	.0096
"135 P"	20.48	2,070	102.00	4.15	4.94	5.8	.0071	559.7	.0082

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi.

- The examined samples are considered to be air-entrained except **"127 P2"**.
- Overall, the observed coarse aggregate exhibited reaction rims (except in Samples **"105P"**and **"110 P"**) and internal fractures. Alkalic gel deposits were observed in Samples **"127 P1"**, **"130 P1"**, **"130 P2"**, **"134 P"**, and **"135 P"**. Sample **"127 P1"** exhibited fine aggregate particles with reactions rims. Internal fractures were observed in the finer aggregate portions of Samples **"127 P1"**, **"130 P1"**, **"130 P2"**, **"134 P"**, and **"135 P"**. These features strongly suggest that the collective aggregates should not be considered "durable" due to susceptibility to alkali-silica reactivity.
- The determined spacing factors for Samples **"127 P2"** and **"130 P1"** were under (acceptable) the recommended, industry standard limit maximum of 0.0080 inches, are are considered to be adequate for exposure in a water-saturated, cyclic, freeze-thaw environment. The determined spacing factor for Samples **"135 P"**and **"105 P"** are marginal, that is, slightly over the recommended, industry standard limit maximum of 0.0080 inches. The remaining samples exhibited spacing factors over the recommended, industry standard limit maximum of 0.0080 inches, and should not be considered to be adequate for durability in a water-saturated, cyclic, freeze-thaw environment.
- The compressive strength(s) of the concrete represented by this sample/mix design is unknown and

comments regarding this will not be made.

All Portland cement based concretes will carbonate over time. When carbonation occurs early in the life of the concrete, the strength development of the affected area can be compromised. The samples exhibited various depths of carbonated paste. However, the carbonated zones and the respective bulk pastes exhibited similar hardnesses. This suggests that the carbonation had occurred over the service lives of the concretes.

The presence of ettringite is commonly associated with the occurrence of ASR. The presence of ettringite that has formed due to DEF is associated with precast members that have been exposed to high curing temperatures. It should be noted that ettringite is common in Portland cement based concretes and its presence alone is not indicative of sulfate attack. It must be chemically established that the sulfate content of the concrete is greater than would be supplied by the original sulfate content of the cement.

Based on this examination, the most possible cause of the reported distress, as represented by the submitted samples, is active alkali-aggregate reactivity. Based on this examination and observations including aggregate features and the presence/degree of observed microcracking, the general conditions deemed:

Poor – Samples **"127P1"** and **"130P2"** (Companion Samples **"127P2"** and **"130P1"** exhibited markedly lower amounts of microcracking. Differences in exposure conditions, especially exposure to water, can account for these apparent physical changes in condition.)

Fair/Poor – Samples **"134P"**, and **"135P"** exhibited small amounts of microcracking and fewer aggregate particles exhibiting reaction characteristics.

Fair – Samples **"105P"**and **"110P"** exhibited very small amounts of microcracking and fewer aggregate particles exhibiting reaction/distress characteristics.

Inadequate air-void systems can be likely contributing factors to deficiencies or potential failure and/or further degradation.

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (e.g., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur. Differences in exposure conditions, especially exposure to water, can account for apparent physical changes in condition of the examined samples.

RECOMMENDATIONS

1) Replace existing concrete with new concrete – likely the most expensive and time consuming alternative. Possibly the most effective way of controlling expansion due to ASR is to design mixtures specifically to control ASR, preferably using locally available materials. The use of newer, faster test methods can be utilized for initial screening to qualify concrete mixtures. Current practices include the use of a supplementary cementing material or blended cement proven by testing to help control ASR or limiting the alkali content of the concrete. Supplementary cementing materials include fly ash, ground granulated blast-furnace slag, silica fume, and natural pozzolans. Blended cements use slag, fly ash, silica fume, and natural pozzolans to help control ASR. Low-alkali Portland cement with an alkali content of not more than 0.60% (equivalent sodium oxide) can be used to help control ASR. When pozzolans, slags, or blended cements are used to control ASR, expansion usually decreases as the dosage of the pozzolan or slag increases. Lithium-based admixtures are also commercially available to

help control ASR. Manufacturers of these admixtures can be very helpful in designing/testing new concrete mixtures.

2) Treat/repair in-place slabs to get more service life from the existing concrete. There are some techniques available that can help extend the service life of the ASR affected structure. To aid in minimizing future damage/reaction to the slab:

- Provide adequate or improved drainage (to minimize availability of moisture).
- Apply claddings or coatings to further limit moisture ingress.
- Treat existing cracks to minimize future expansion (and direct moisture ingress).
- Avoid future use of deicing salts/alkali solutions that will increase alkali content of the concrete.
- Restrain or confine expansion of structural element.
- Chemically suppress ASR using lithium compounds

If the ASR is left unchecked, expansion will continue until moisture is removed, the source of alkalis is depleted, or the reactive silica components are consumed. Treatment(s) of serviceable base concretes (after proper surface preparations) with a lithium-based product, such as lithium nitrate, to mitigate, slow, and chemically suppress ASR is recommended. It is not completely known or understood why lithium works in combating ASR. It is believed that lithium forms a gel that is non-expansive, i.e. does not absorb water.

Techniques used achieve enhanced penetration of lithium compounds into the concrete matrix and effectively reduce the potential for further ASR are listed below. Common application methods to chemically suppress ASR using lithium compounds in existing structures are:

- Electrochemical injection
- Pressure Injection
- Vacuum impregnation
- Topical applications by spraying and/or ponding. This method is usually the least expensive. Repeated applications to insure adequate penetration of the solution is common.

Once a mitigation solution has been applied, then patching and repairs can be conducted using traditional concrete repair technologies. Traditional repairs using Portland cement based materials may fail by enhancing or increasing ASR distress in the hardened concrete by supplying a fresh source of alkali. Better results are usually obtained when the cementitious systems used in the repair also incorporates a lithium nitrate admixture.

JR Varga

J. R. Varga, Concrete Petrographer
The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_1.pdf

- Online version of Plates 1-10 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_1_10.pdf
- Online version of Plates 11-17 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_11_17.pdf
- Online version of Plates 18-21 report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_18_21.pdf

W.O.#: 07-08-31-01 / TCG 0756

SAMPLE "105P"

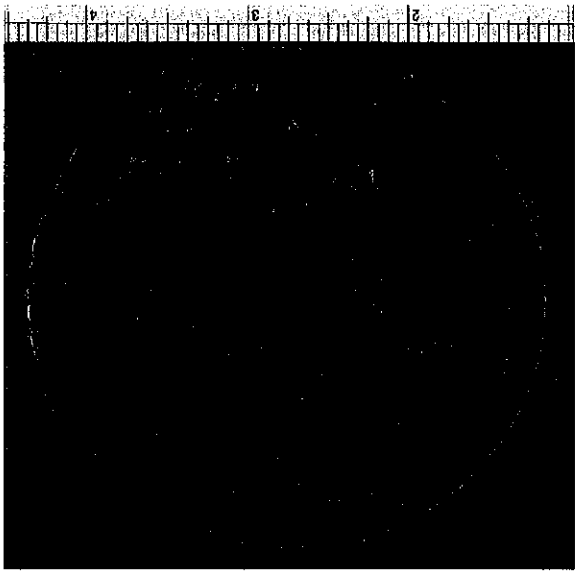

PLATE 1
TOP SURFACE

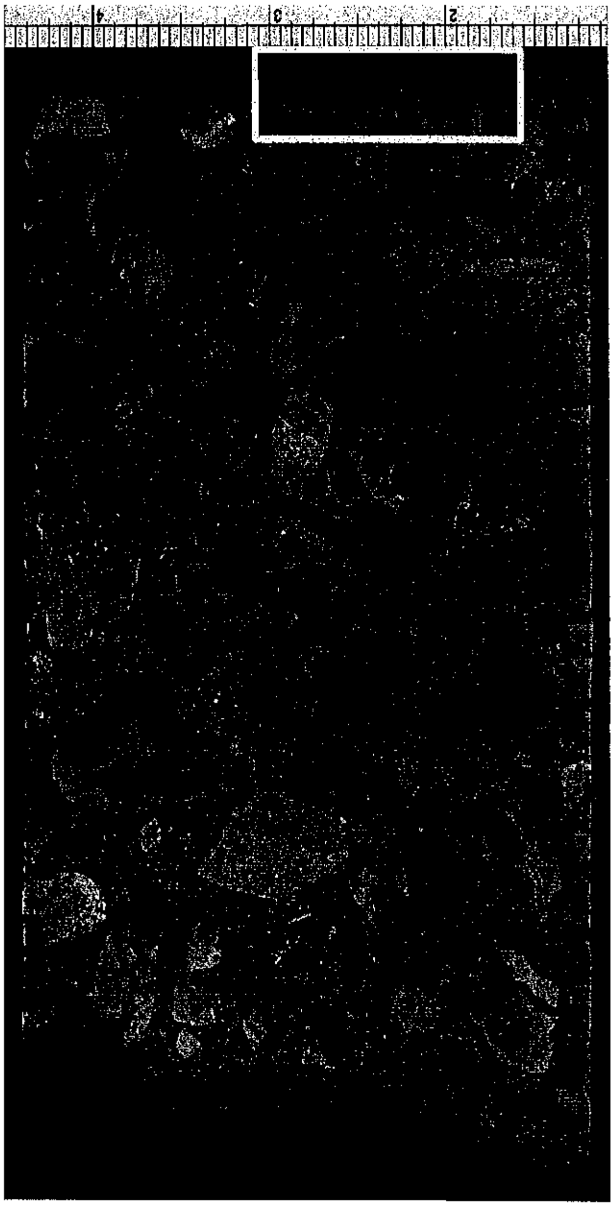

PLATE 2
PREPARED SURFACE
YELLOW BOX SHOWN IN PLATE 3

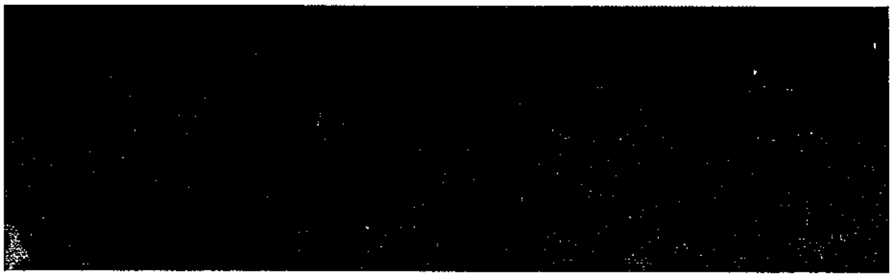

PLATE 3
PREPARED SURFACE SHOWING FINE, CONTINUOUS CRACK AT TOPPING SYSTEM:BASE CONCRETE INTERFACE

W.O.#: 07-08-31-01 / TCG 0756

SAMPLE "110P"

PLATE 4
TOP SURFACE

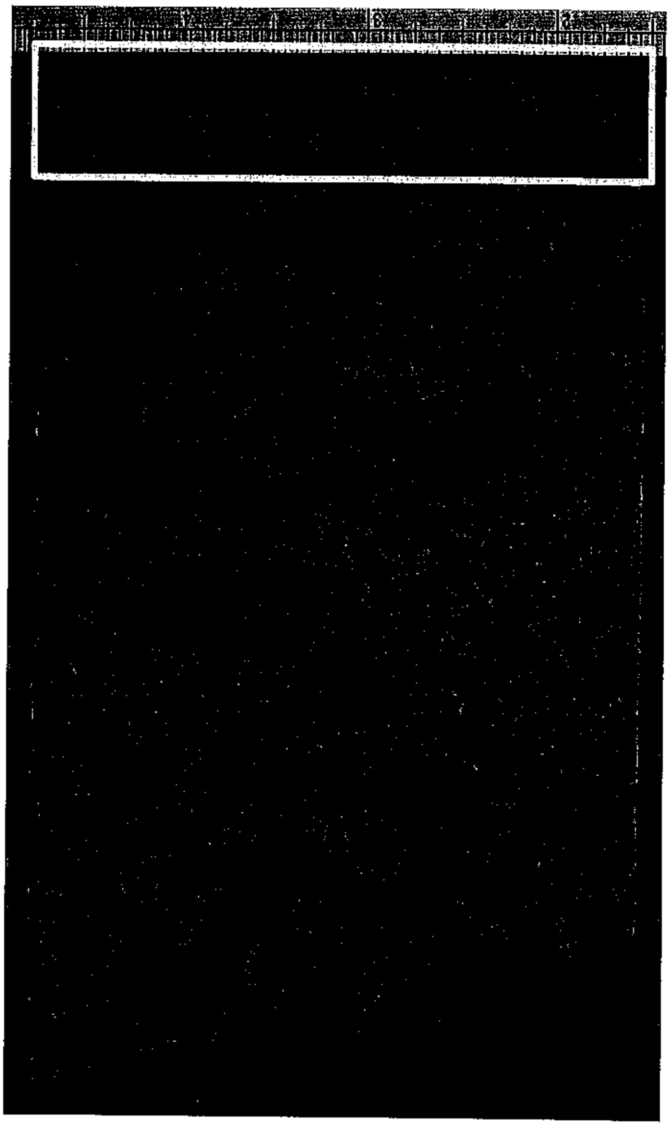

PLATE 5
PREPARED SURFACE
YELLOW BOX SHOWN IN PLATE 6

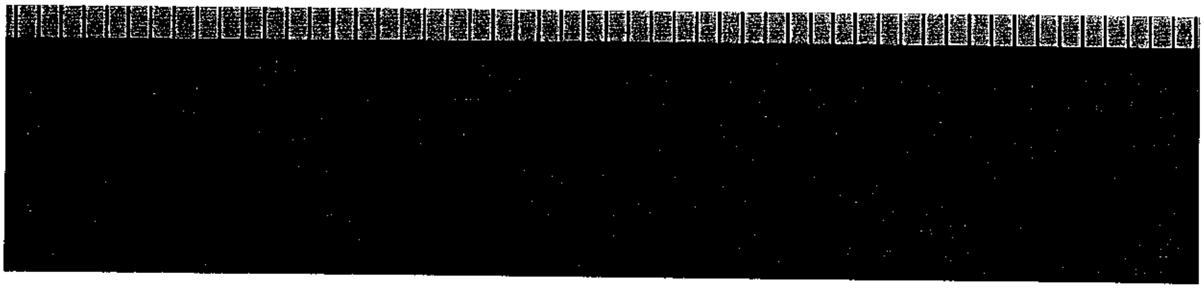

PLATE 6
PREPARED SURFACE SHOWING INTERFACES OF TOPPING: MORTAR AND MORTAR:BASE CONCRETE

W.O.#: 07-08-31-01 / TCG 0756
SAMPLE "127 P1"

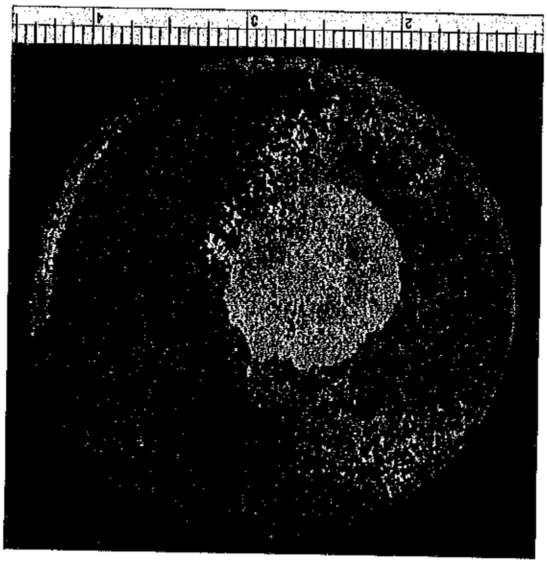

PLATE 7
TOP SURFACE

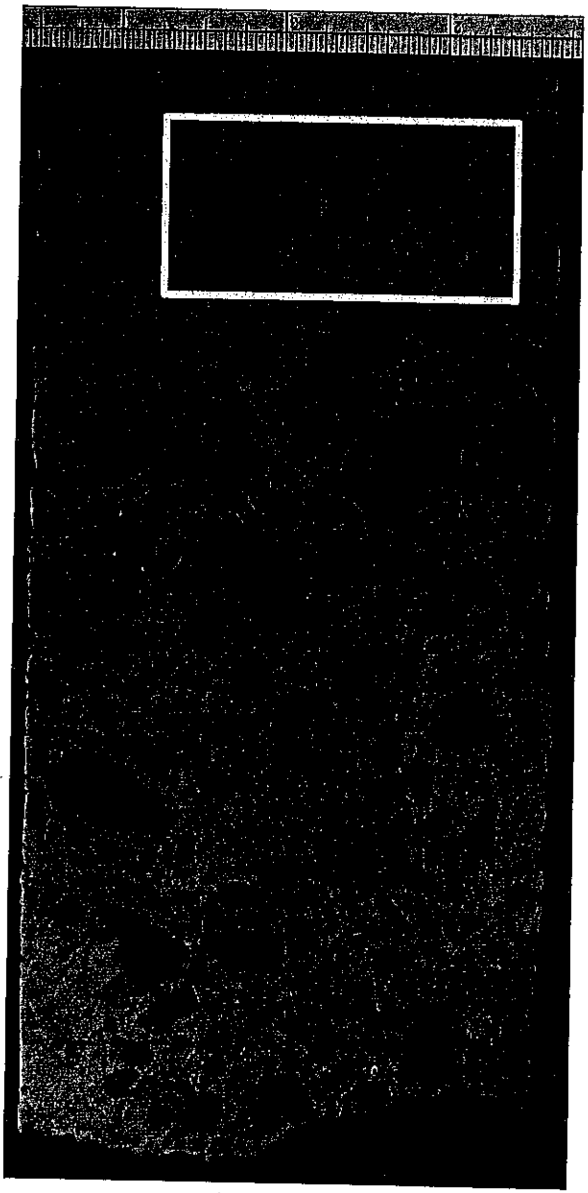

PLATE 8
PREPARED SURFACE
YELLOW BOX SHOWN IN PLATE 10

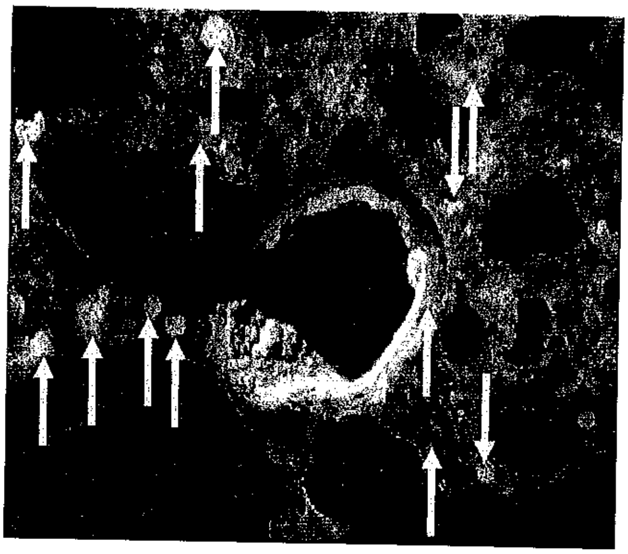

PLATE 9
ALKALIC GEL DEPOSIT IN LARGER VOID
SOME VOID INFILLINGS SHOWN BY
YELLOW ARROWS

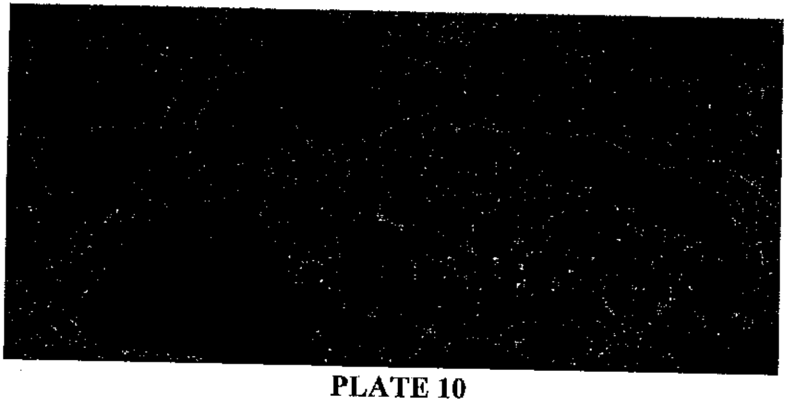

PLATE 10
PREPARED SURFACE SHOWING LOCALIZED CRACKS AND
DISTRESS IN AGGREGATES AND ADJACENT PASTE

W.O.#: 07-08-31-01 / TCG 0756

SAMPLE "127 P2"

PLATE 11
TOP SURFACE

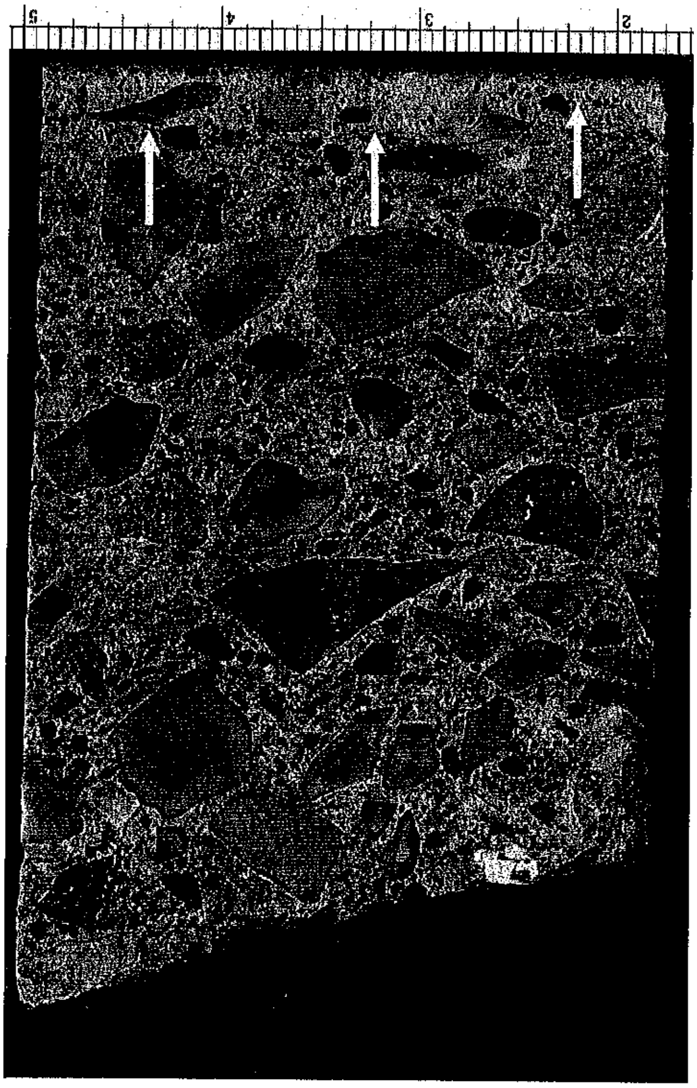

PLATE 12
PREPARED SURFACE
YELLOW ARROWS SHOWN PENCIL LINE THAT DENOTES LESS WATER ABSORPTIVE PORTION OF SAMPLE ADJACENT TO TOP SURFACE

W.O.#: 07-08-31-01 / TCG 0756

SAMPLE "130 P1"

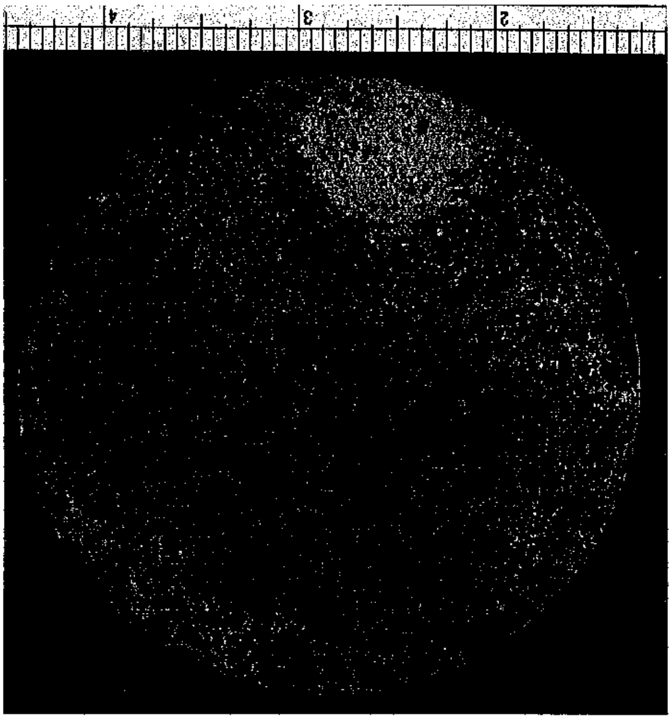

PLATE 13
TOP SURFACE

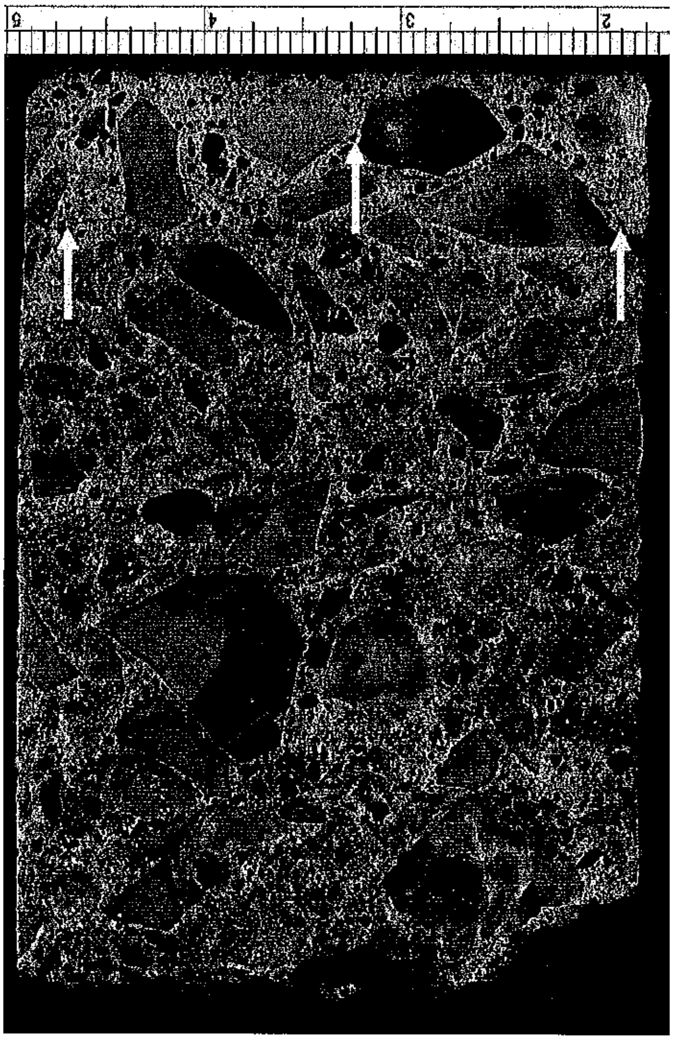

PLATE 14
PREPARED SURFACE
YELLOW ARROWS SHOWN PENCIL LINE THAT DENOTES LESS WATER ABSORPTIVE PORTION OF SAMPLE ADJACENT TO TOP SURFACE

W.O.#: 07-08-31-01 / TCG 0756

SAMPLE “130 P2”

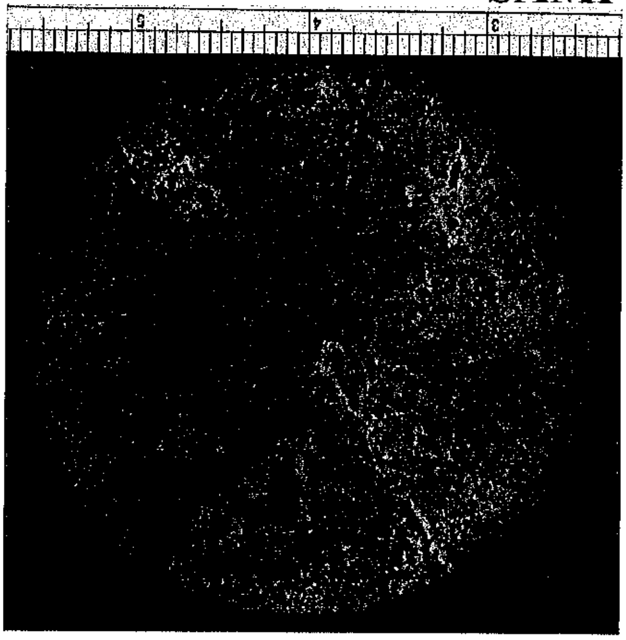

PLATE 15
TOP SURFACE

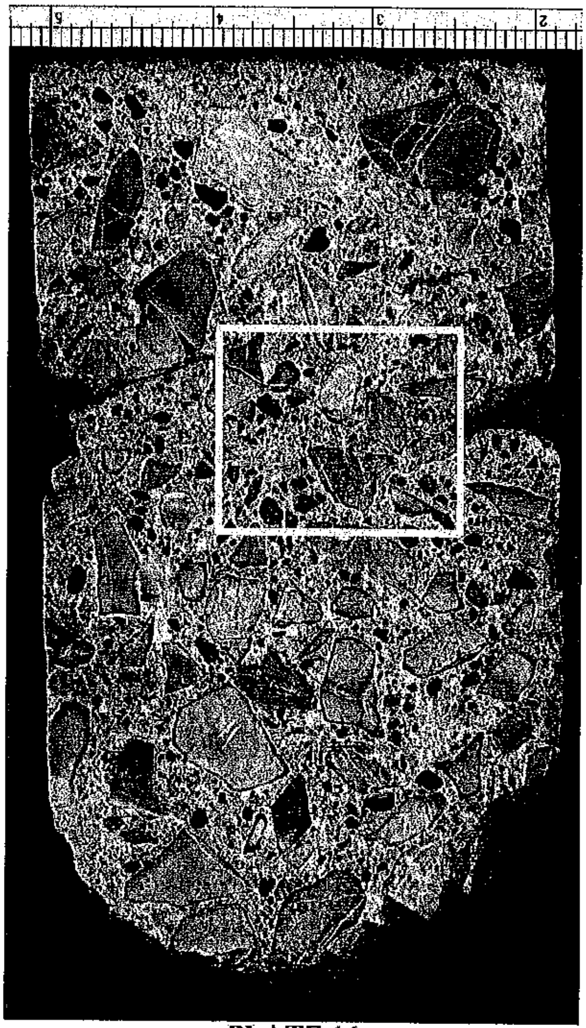

PLATE 16
PREPARED SURFACE
YELLOW BOX SHOWN IN PLATE 17

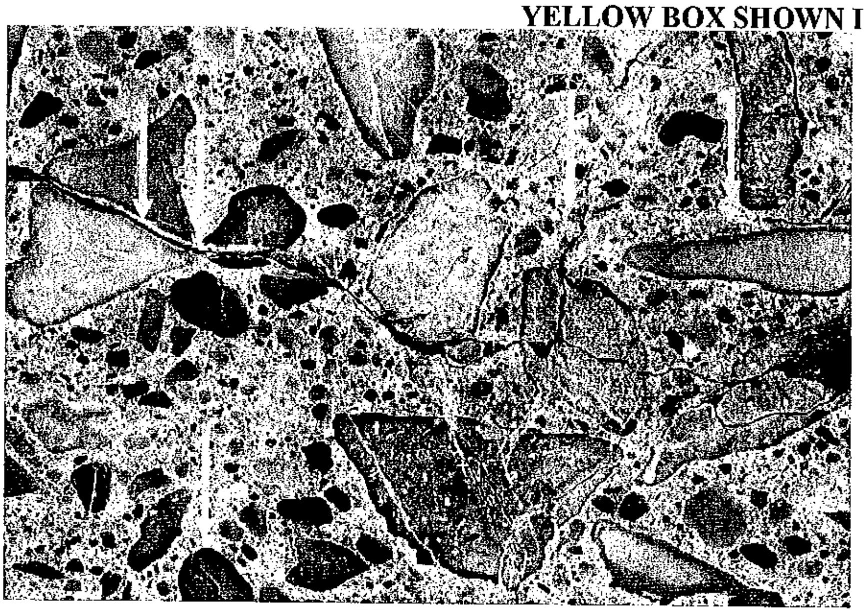

PLATE 17
PREPARED SURFACE SHOWING CRACKING/MICROCRACKING
SOME ALKALIC GEL DEPOSITS S SHOWN BY YELLOW ARROWS
NOTE: MANY VOIDS INFILLED WITH ALKLAIC GELS AND/OR ETTRINGITE

W.O.#: 07-08-31-01 / TCG 0756

SAMPLE "134 P"

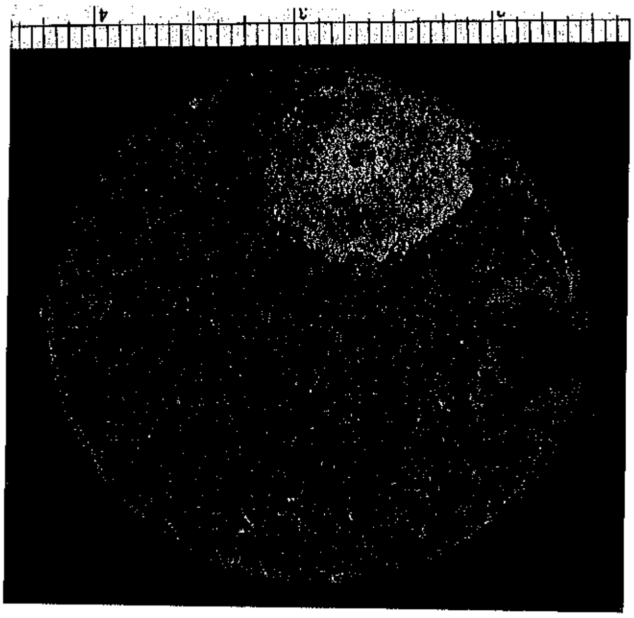

PLATE 18
TOP SURFACE

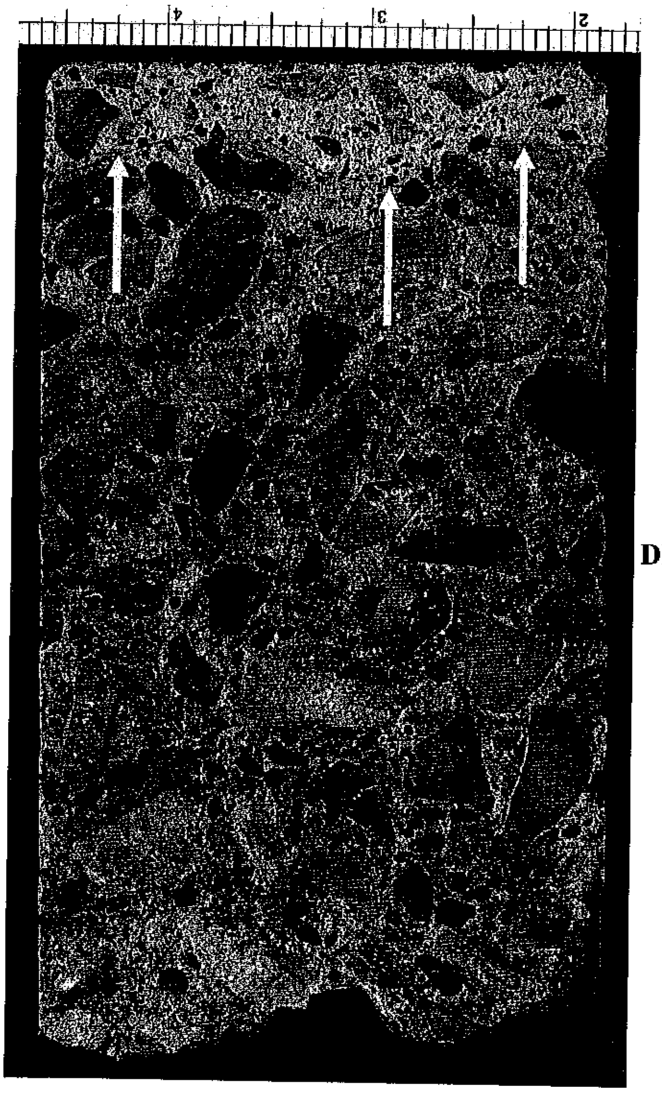

PLATE 19
PREPARED SURFACE
YELLOW ARROWS SHOWN PENCIL LINE THAT
DENOTES LESS WATER ABSORPTIVE PORTION OF
SAMPLE ADJACENT TO TOP SURFACE

W.O.#: 07-08-31-01 / TCG 0756

SAMPLE "135 P"

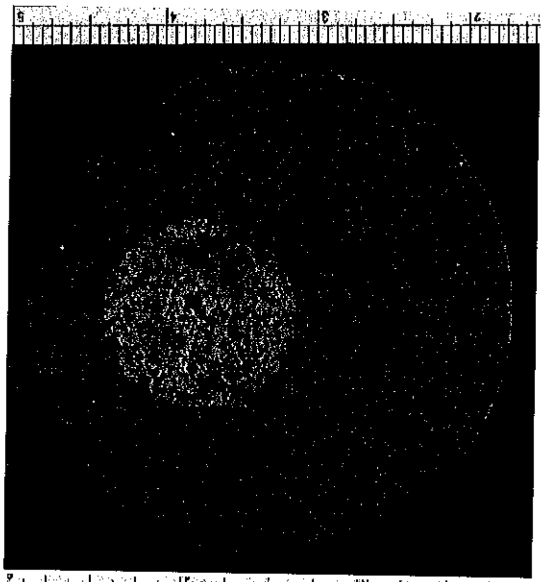

PLATE 20
TOP SURFACE

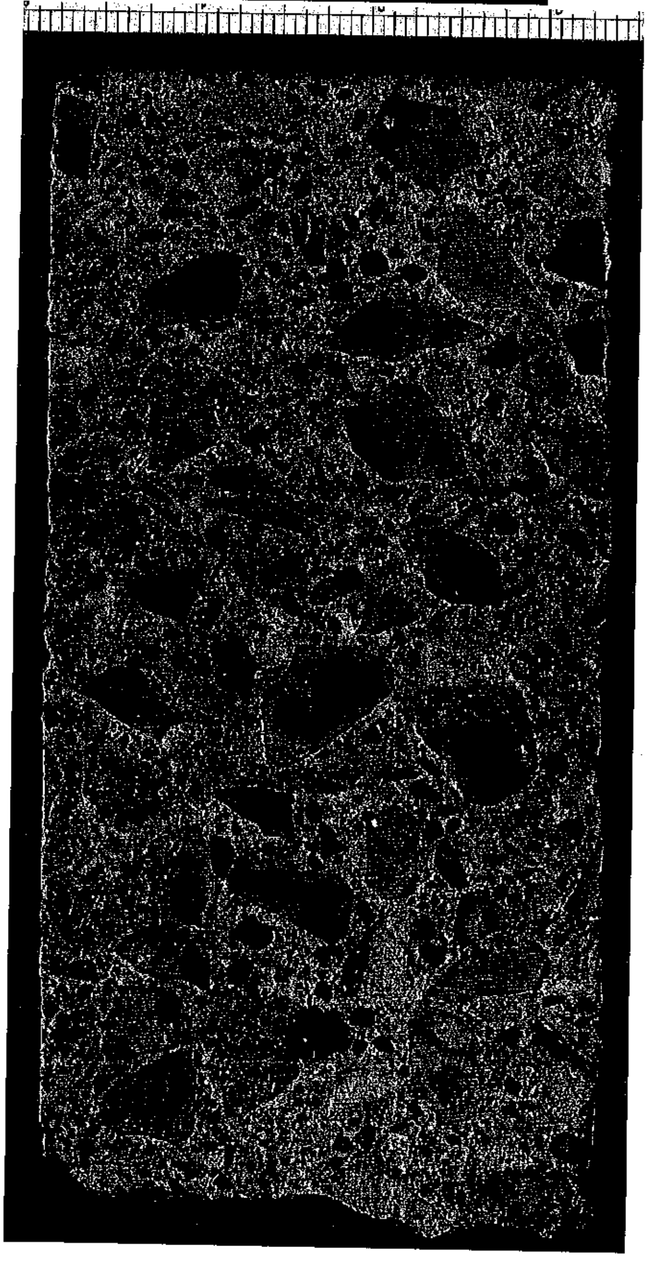

PLATE 21
PREPARED SURFACE

W.O.#: 07-08-31-01 / TCG 0756
GROUP 1 STAINED SAMPLES

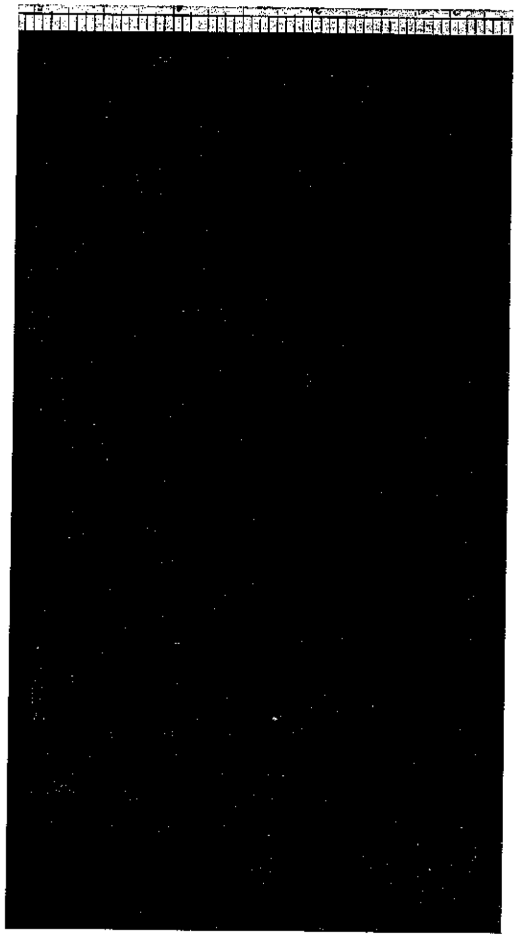

PLATE 1
PREPARED SURFACE OF SAMPLE “105 P”
SHOWING YELLOW STAINING IN PASTE AND
WITHIN AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING

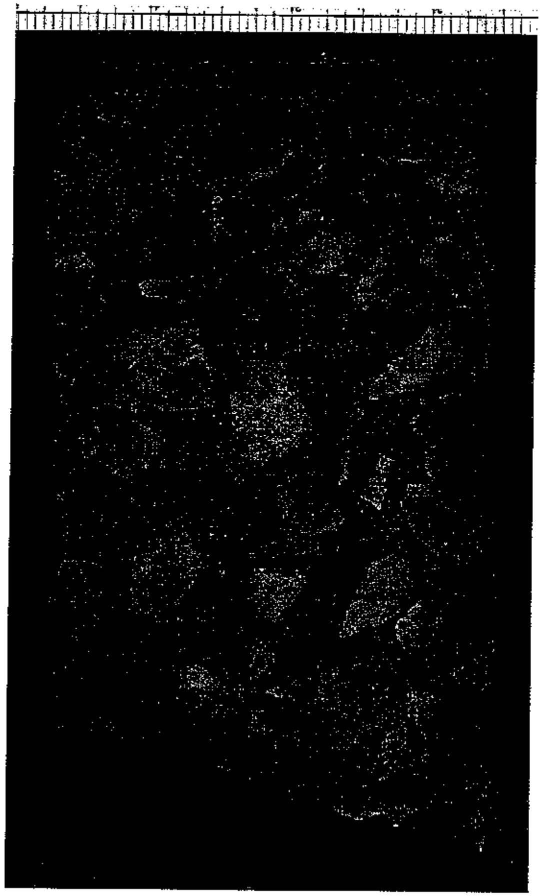

PLATE 2
CUT SURFACE OF SAMPLE “110 P”
SHOWING MARKED YELLOW STAINING IN PASTE AND
WITHIN AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING
NOTE: UPPER PORTION SHOWS PURPLE STAINING FROM
pH INDICATOR WITHIN THE PASTE

W.O.#: 07-08-31-01 / TCG 0756
GROUP 1 STAINED SAMPLES

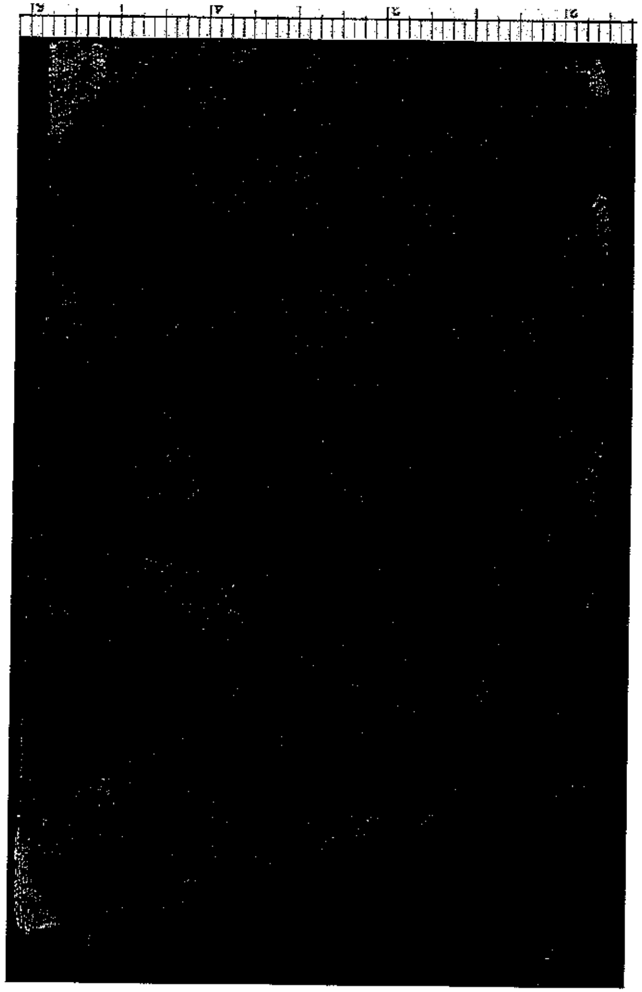

PLATE 3
PREPARED SURFACE OF SAMPLE "127P2"
SHOWING SMALL AMOUNT OF LOCALIZED YELLOW
STAINING IN PASTE AND WITHIN AGGREGATE PARTICLES
AFTER COBALTINITRITE STAINING

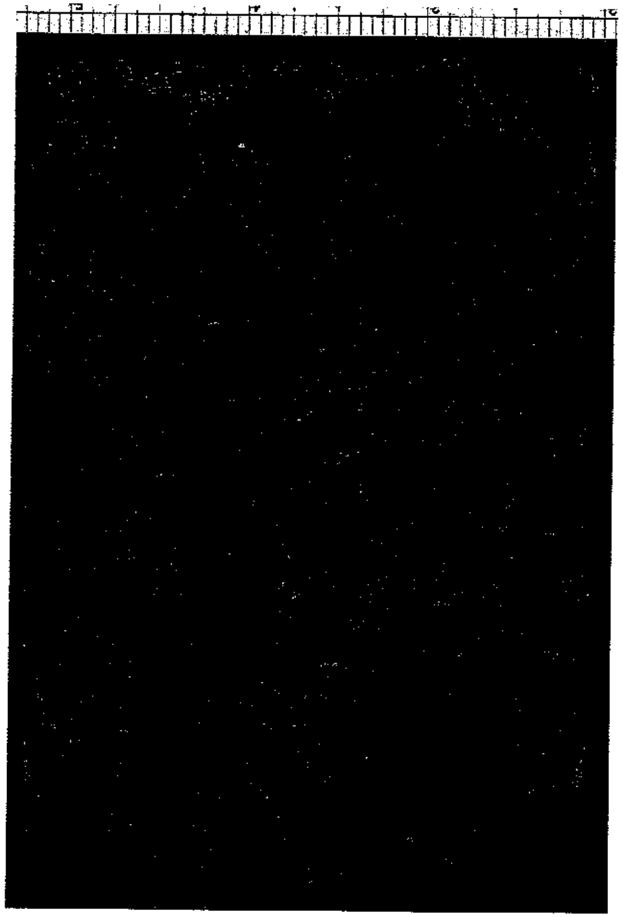

PLATE 4
PREPARED SURFACE OF SAMPLE "130P1"
SHOWING YELLOW STAINING IN PASTE AND WITHIN
AGGREGATE PARTICLES AFTER COBALTINITRITE
STAINING

W.O.#: 07-08-31-01 / TCG 0756
GROUP 1 STAINED SAMPLES

PLATE 5
UPPER PORTION OF PREPARED SURFACE OF SAMPLE "134P"
SHOWING YELLOW STAINING IN PASTE AND WITHIN AGGREGATE
PARTICLES AFTER COBALTINITRITE STAINING
NOTE: STAINED SAMPLE APPROX. 1 MONTH OLD SHOWS A LESS
DRAMATIC, MUTED STAINING

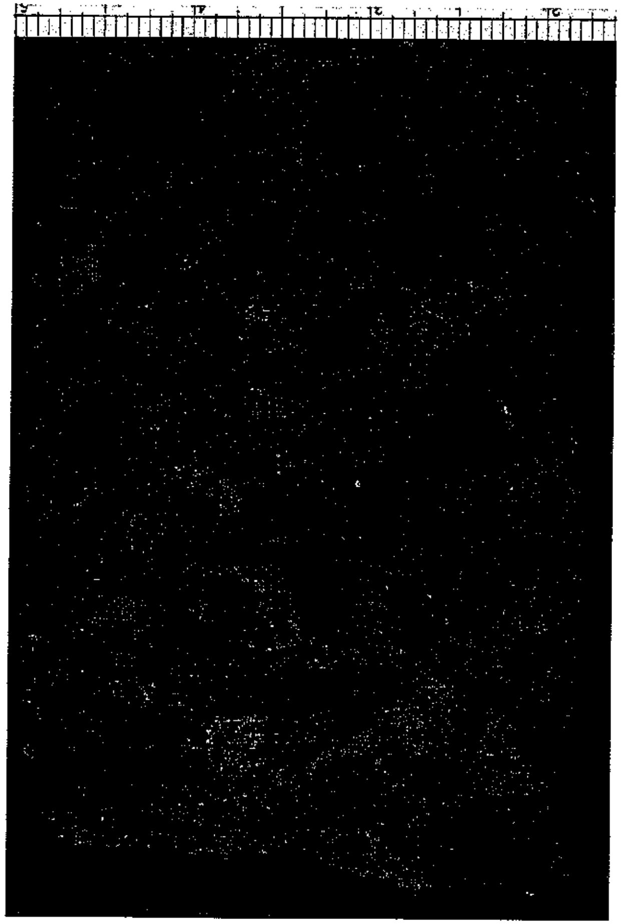

PLATE 6
LOWER PORTION OF PREPARED SURFACE
OF SAMPLE "134P"
SHOWING YELLOW STAINING IN PASTE AND WITHIN
AGGREGATE PARTICLES AFTER COBALTINITRITE
STAINING
NOTE: STAINED SAMPLE APPROX. 1 MONTH OLD
SHOWS A LESS DRAMATIC, MUTED STAINING

W.O.#: 07-08-31-01 ADDENDUM

YELLOW STAINED AREAS OF INTEREST ARE SHOWN BY WHITE ARROWS

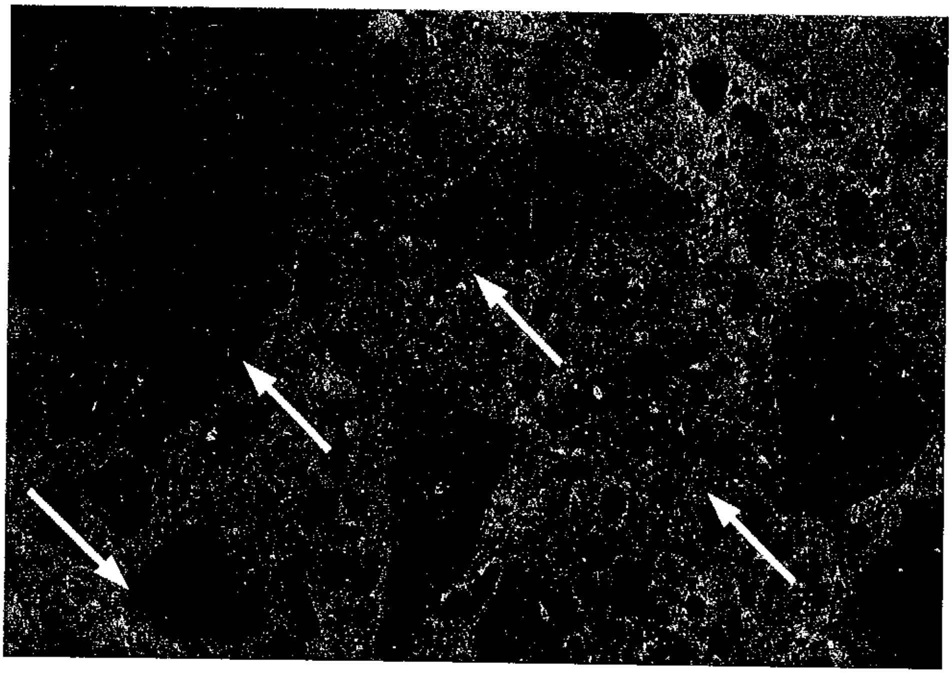

PLATE 1
SAMPLE "134 P"

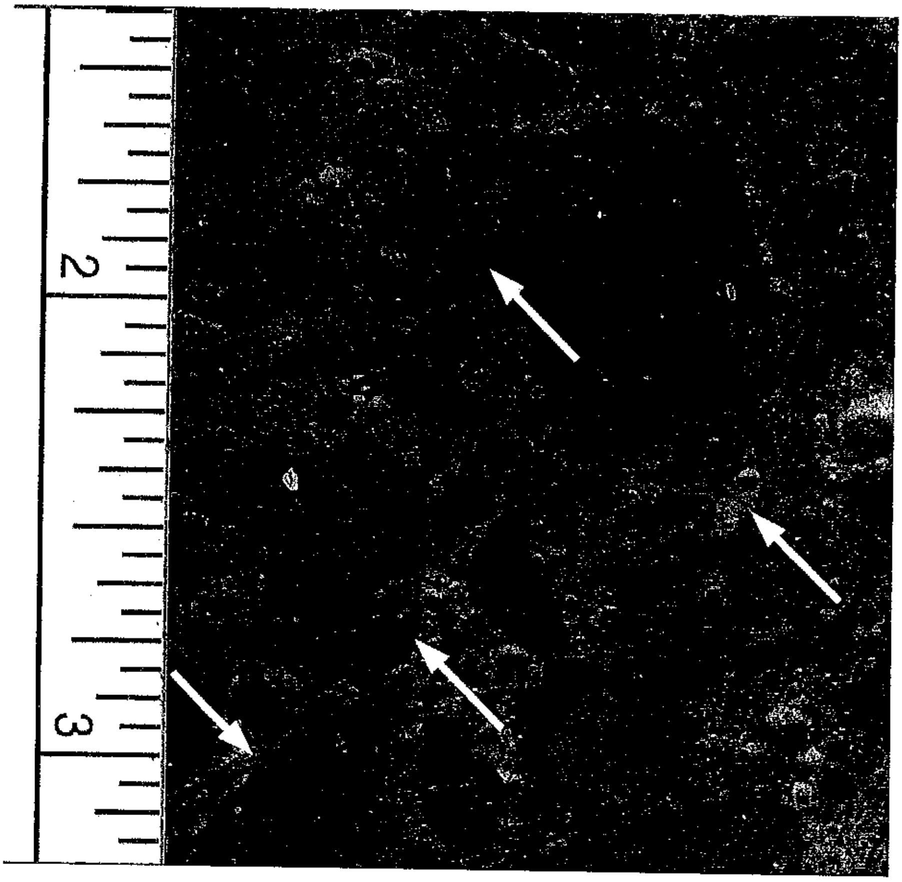

PLATE 2
SAMPLE "135 P"

W.O.#: 07-08-31-01 ADDENDUM

THIN SECTION VIEWS OF PORTIONS OF COARSE AGGREGATE PARTICLES UNDER CROSSED NICOLS

YELLOW ARROWS SHOW MICROCRYSTALLINE SILICA

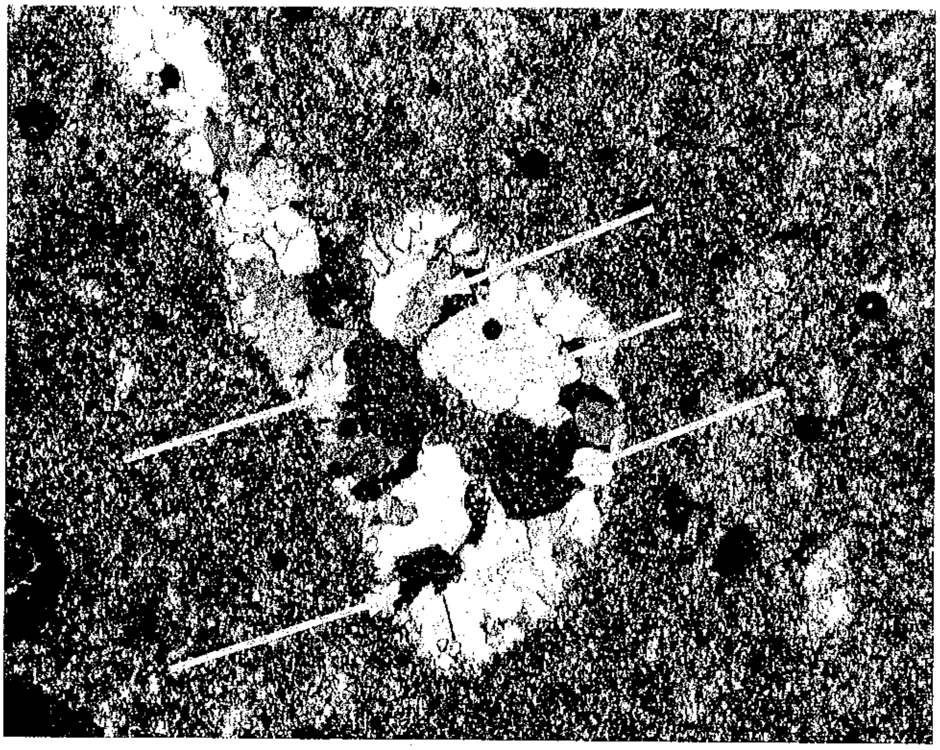

PLATE 3

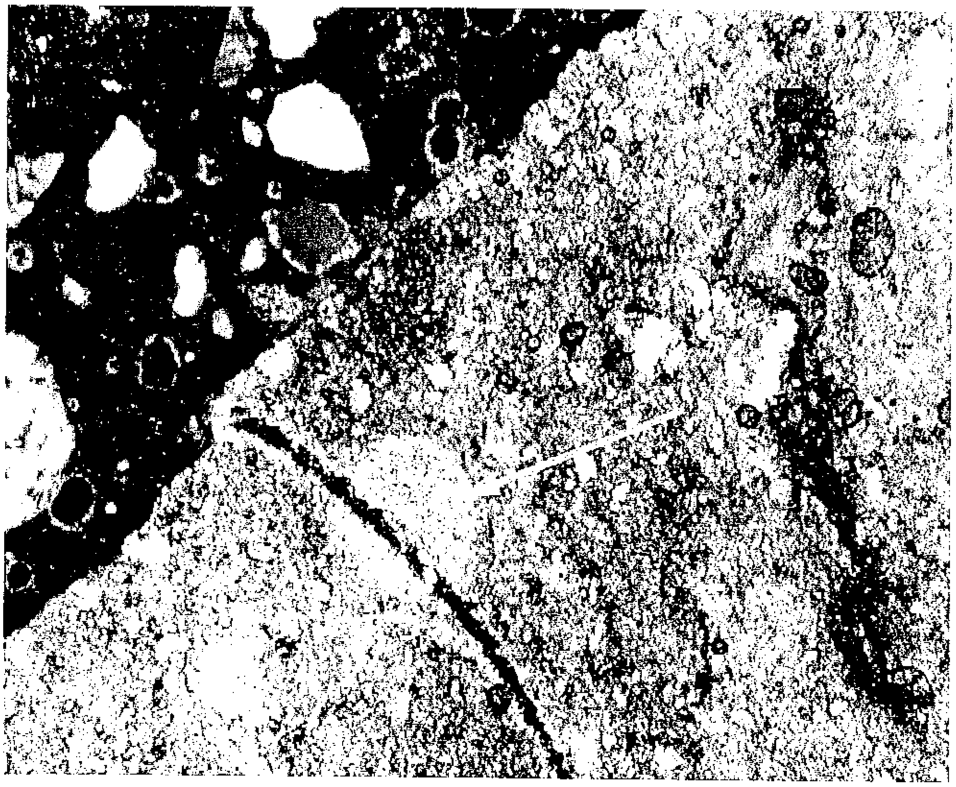

PLATE 4

W.O.#: 07-08-31-01 ADDENDUM

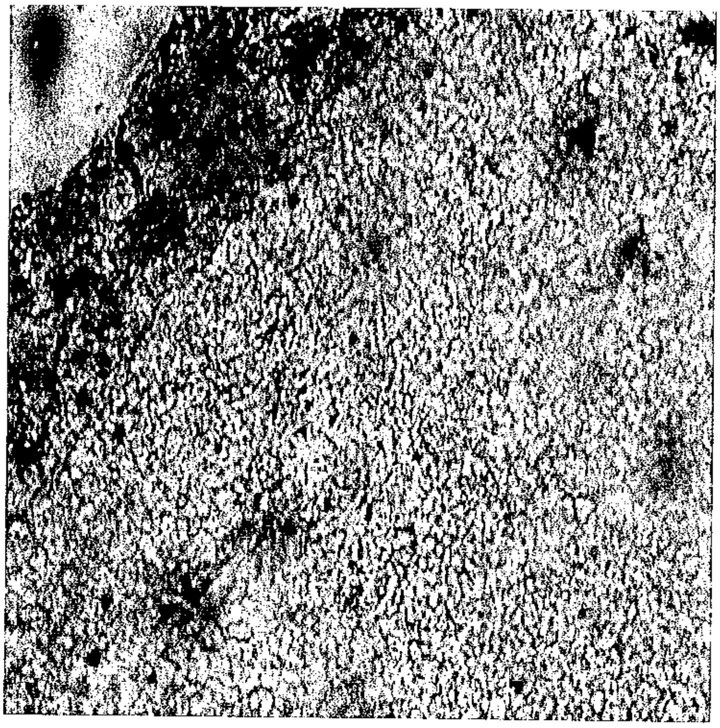

PLATE 5
THIN SECTION
VIEW OF PORTION OF COARSE
AGGREGATE PARTICLE
UNDER PLANE POLARIZED LIGHT

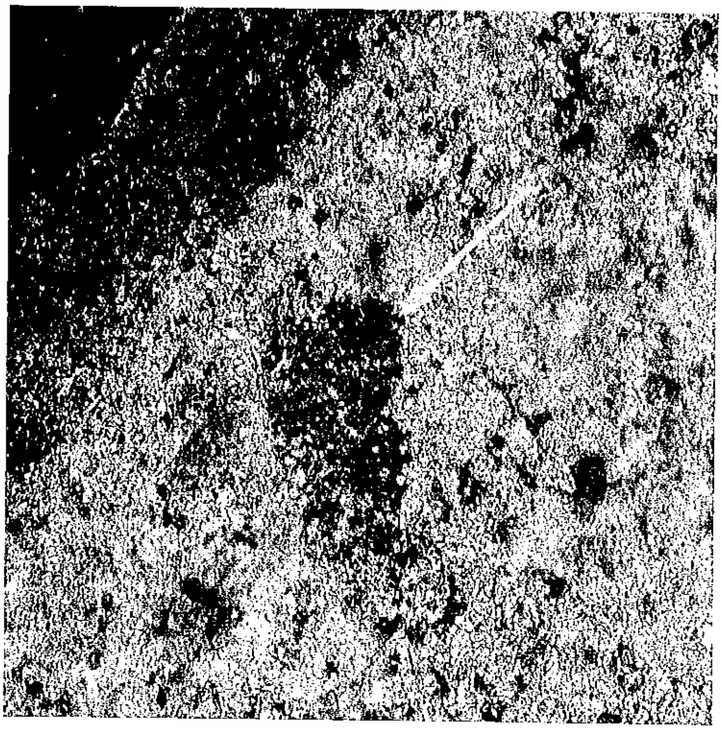

PLATE 6
THIN SECTION
VIEW OF PLATE 5
UNDER CROSSED NICOLS
YELLOW ARROW SHOWS
MICROCRYSTALLINE SILICA

THE ROCK DOCTOR
CONCRETE SOLUTIONS FOR CONCRETE PROBLEMS

PETROGRAPHIC REPORT

DATE:	September 14, 2007
WORK ORDER:	07-08-31-01 / Group 2 Pedestrian Ramps
CLIENT:	Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY:	Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received six core portions of hardened concrete to determine the general condition of the concrete(s). The core portions were marked **"LR FIELD P"**, **"RR FIELD P"**, **"RR CLUB P"**, **"LR CLUB P"**, **"RR VIEW P"**, and **"LR VIEW P"**. The core portions measured, in length, approximately 5-3/4, 5-1/4, 6, 5-1/4, 5-1/2, and 5-1/2, inches, respectively. The core portions were approximately 3-1/8 inches in diameter.

It was reported that the submitted samples were taken from pedestrian ramp areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

SAMPLE PREPARATION AND METHODS

The core samples were cut in half, approximately perpendicular to the top surfaces. The cut surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were determined following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters.

The unprepared samples were partially immersed in water for at least three days to mobilize any alkalic gels present. The cut surfaces of the core portion samples were not immersed in water.

The prepared and unprepared samples were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

"LR FIELD P"

GENERAL CONDITION: (See PLATES 1 and 2) The top surface was generally flat and exhibited a rough broomed finish with numerous partially exposed, fine aggregate particles in a slightly recessed paste matrix. Moderate amounts of small fragments of soft, rubbery black material were also present. Some of the black material could be easily washed from the surface. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a continuous zone of carbonated paste up to approx. 1/16 of an inch was observed. A small amount of microcracking was observed throughout the sample. Most of these microcracks were partially to completely infilled with white material with similar optical properties of alkalic gel and carbonated alkalic gel. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light brown-pale gray in color with a small amount of unhydrated cement particles to dull white-light brown with a very small amount of unhydrated cement particles. The lighter colored paste areas were slightly softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 1:

TABLE 1

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	I in.	α in.$^{-1}$	L in.
"LR FIELD P"	18.01	2,049	100.90	4.44	4.06	3.7	.0121	329.4	.0123

The homogeneously distributed voids were small in size and spherically shaped with larger, spherical-irregularly shaped voids also present. A small amount of clustering of voids was observed throughout the sample. In numerous voids, secondary, internal deposits were observed as thin coatings of clear-white material that exhibited optical properties similar to alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. A few particles exhibited internal fractures and several fossiliferous limestone particles exhibited reaction rims with localized light brown staining in the adjacent cement paste at aggregate peripheries. One separation/crack was observed at a paste:aggregate interface.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, limestone, and microcrystalline quartz chert particles. A continuous separation was observed at the paste:aggregate interface of one fine limestone particle.

"RR FIELD P"

GENERAL CONDITION: (See PLATES 3-6) The top surface was generally flat and exhibited a shallow broomed finish with numerous partially exposed, fine aggregate particles in a recessed paste matrix. Abundant amounts of small fragments of soft, rubbery black material were also present. Some of the black material could be easily washed from the surface. Loosely adhered, very fine, light brown "dust" (presumed to be debris from the coring procedure) was also present and was easily washed from the surface. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a continuous zone of carbonated paste that ranged from approx. 1/16 of an inch up to approx. 3/32 of an inch was observed. A small-moderate amount of microcracking was observed throughout the sample. Most of these microcracks were partially to completely infilled with white material with similar optical properties of alkalic gel and carbonated alkalic gel. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from-pale gray-light brown in color with a small amount of unhydrated cement particles to light gray-dull white with a very small amount of unhydrated cement particles. The lighter colored paste areas were slightly softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 2:

TABLE 2

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"RR FIELD P"	22.55	2,004	99.00	8.33	2.71	6.2	.0135	295.3	.0092

The inhomogeneously distributed voids were mostly small in size and spherically shaped with fewer, larger, spherical-irregularly shaped voids also present. A small amount of clustering of voids was observed throughout the sample. In numerous voids, secondary, internal deposits were observed as partial coatings/linings of clear to dull white material that exhibited optical properties similar to alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. A few particles exhibited reaction rims.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and limestone particles. A few chert particles exhibited reaction rims, internal fractures, and localized, clear alkalic gel exudations.

"RR CLUB P"

GENERAL CONDITION: (See PLATES 7-9) The top surface was generally flat and exhibited a very shallow broomed finish with numerous partially exposed, fine aggregate particles in a recessed paste matrix. Small amounts of small fragments of soft, rubbery black material were also present. Some of the black material could be easily washed from the surface. Loosely adhered, very fine, light brown "dust" (presumed to be debris from the coring procedure) was also present and was easily washed from the surface. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a continuous zone of carbonated paste that ranged from a veneer up to approx. 1/8 of an inch was observed. A small-moderate amount of microcracking was observed throughout the sample. Most of these microcracks were partially to completely infilled with white-light brown material with some optical properties of alkalic gel and carbonated alkalic gel. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and pale gray-light brown in color with a very small-small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 3:

TABLE 3
AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	I in.	α in.$^{-1}$	L in.
"RR CLUB P"	16.83	2,044	100.80	8.22	2.05	6.8	.0120	332.2	.0062

The inhomogeneously distributed voids were mostly small in size and spherically shaped with larger, spherical-irregularly shaped voids also present. Fewer, larger, irregularly shaped voids were also observed. A moderate amount of clustering of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as partial coatings/linings of dull white material that exhibited optical properties similar to alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. A few particles exhibited reaction rims as well as internal fractures.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, limestone, and microcrystalline quartz chert particles. A continuous separation was observed at the paste:aggregate interface of one fine limestone particle. A few limestone particles exhibited reaction rims and internal fractures. Adjacent to one finer limestone particle, a separation at the paste:aggregate interface was observed around the entire particle. A few chert particles exhibited reaction rims.

"LR CLUB P"

GENERAL CONDITION: (See PLATES 10 and 11) The top surface was generally flat and exhibited numerous partially exposed, fine aggregate particles in a recessed paste matrix. Moderate amounts of small fragments of soft, rubbery black material were also present. Some of the black material could be easily washed from the surface. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a continuous zone of carbonated paste that ranged from a veneer up to approx. 1/16 of an inch was observed. A small amount of microcracking was observed throughout the sample. Most of these microcracks were partially to completely infilled with dull white-light brown material with some optical properties of alkalic gel and carbonated alkalic gel. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and light gray-pale brown in color with a small-moderate amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 4:

TABLE 4

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"LR CLUB P"	20.03	2,052	101.20	5.95	3.67	8.2	.0073	550.5	.0061

The inhomogeneously distributed voids were mostly small in size and spherically shaped with larger, spherical-irregularly shaped voids also present. A moderate amount of clustering of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as partial coatings/linings of white material that exhibited optical properties similar to alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 1-1/8 inches. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. A few particles exhibited reaction rims as well as internal fractures.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, granites, feldspar, and microcrystalline quartz chert particles. Several particles exhibited internal fractures.

"RR VIEW P"

GENERAL CONDITION: (See PLATES 12-15) The top surface was generally flat and exhibited numerous partially exposed, fine aggregate particles and one coarser limestone aggregate particle in a recessed paste matrix. Very small amounts of adhered gray material (presumed to be from a previously applied coating/membrane) were also present at the exposed surface. Loosely adhered, very fine, light brown "dust" as well as a small-moderate amount of soft, rubbery black material fragments were also present. Most of the light brown "dust" (presumed to be debris from the coring procedure) and some of the black material was easily washed from the surface. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a discontinuous veneer of carbonated paste was observed ranged up to approx. 1/16 of an inch thick. A small amount of microcracking was observed throughout the sample. Most of these microcracks were partially to completely infilled with dull white material with some optical properties of alkalic gel and carbonated alkalic gel. After immersion in water, the sample trimming exhibited alkalic gel exudations on the core edge as well as on the cut surface over a fine aggregate particle. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light brown-pale gray in color with a small amount of unhydrated cement particles to light brown-dull white in color with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 5:

TABLE 5

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"RR VIEW P"	22.39	2,014	99.25	5.46	4.10	5.2	.0105	380.8	.0108

The inhomogeneously distributed voids were small to large in size and spherically shaped with fewer, larger, irregularly shaped voids also present. A small-moderate amount of clustering of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as partial coatings/linings of dull white material that exhibited optical properties similar to alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. A few particles exhibited reaction rims as well as internal fractures. A few fossiliferous limestone particles exhibited reaction rims with localized light brown staining in the adjacent cement paste at aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, granites, feldspar, microcrystalline quartz chert, and claystone particles. Several particles exhibited internal fractures and a few exhibited reactions rims.

"LR VIEW P"

GENERAL CONDITION: (See PLATES 16 and 17) The top surface was generally flat and exhibited numerous partially exposed, fine aggregate particles and a few partially exposed, coarser limestone aggregate particles in a recessed paste matrix. Loosely adhered, very fine, light brown "dust" as well as a small amount of soft, rubbery black material fragments were also present. Most of the light brown "dust" (presumed to be debris from the coring procedure) and some of the black material was easily washed from the surface. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a continuous zone of carbonated paste was observed up to a maximum thickness of approx. 1/8 of an inch. A moderate amount of microcracking was observed throughout the sample. Most of these microcracks were partially to completely infilled with light brown-dull white material with some optical properties of alkalic gel and carbonated alkalic gel. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and light brown-pale gray in color with a very small-small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 6:

TABLE 6

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"LR VIEW P"	16.16	1,980	97.60	9.65	1.68	8.7	.0111	359.9	.0047

The inhomogeneously distributed voids were mostly small in size and spherically shaped with fewer, larger, spherical-irregularly shaped voids also present. A moderate-abundant amount of clustering of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as partial coatings/linings of dull white material that exhibited optical properties similar to alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. A few particles exhibited reaction rims as well as internal fractures. A few fossiliferous limestone particles exhibited reaction rims with localized light brown staining in the adjacent cement paste at aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, granites, feldspar, microcrystalline quartz chert, and claystone particles. A few particles exhibited internal fractures and reactions rims.

DISCUSSION & CONCLUSION

We received six core portions of hardened concrete to determine the general condition of the concrete(s). It was reported that the submitted samples were taken from pedestrian ramp areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

The air-void system parameters for all samples are listed below in TABLE 7:

TABLE 7

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"LR FIELD P"	18.01	2,049	100.90	4.44	4.06	3.7	.0121	329.4	.0123
"RR FIELD P"	22.55	2,004	99.00	8.33	2.71	6.2	.0135	295.3	.0092
"RR CLUB P"	16.83	2,044	100.80	8.22	2.05	6.8	.0120	332.2	.0062
"LR CLUB P"	20.03	2,052	101.20	5.95	3.67	8.2	.0073	550.5	.0061
"RR VIEW P"	22.39	2,014	99.25	5.46	4.10	5.2	.0105	380.8	.0108
"LR VIEW P"	16.16	1,980	97.60	9.65	1.68	8.7	.0111	359.9	.0047

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi.

- The examined samples are considered to be air-entrained.
- Overall, the observed fine and coarse aggregates exhibited reaction rims and internal fractures. Alkalic gel deposits were observed in all samples as well as marked gel exudations after water immersions for samples with the **"RR"** designation (Samples **"RR FIELD P"**, **"RR CLUB P"**, **"RR VIEW P"**). These features strongly suggest that the collective aggregates should not be considered "durable" due to susceptibility to/ongoing alkali-silica reactivity.
- The determined spacing factors for Samples **"RR CLUB P"**, **"LR CLUB P"**, and **"LR VIEW P"** were under (acceptable) the recommended, industry standard limit maximum of 0.0080 inches, are are considered to be adequate for exposure in a water-saturated, cyclic, freeze-thaw environment. The remaining samples exhibited spacing factors over the recommended, industry standard limit maximum of 0.0080 inches, and should not be considered to be adequate for durability in a water-saturated, cyclic, freeze-thaw environment.
- The compressive strength(s) of the concrete represented by this sample/mix design is unknown and comments regarding this will not be made.

All Portland cement based concretes will carbonate over time. When carbonation occurs early in the life of the concrete, the strength development of the affected area can be compromised. The samples exhibited various depths of carbonated paste. However, the carbonated zones and the respective bulk pastes exhibited similar hardnesses. This suggests that the carbonation had occurred over the service lives of the concretes.

Based on this examination, the the general condition of the concrete(s), including aggregate features and the presence/degree of observed microcracking, were deemed:

"LR FIELD P" - Poor - exhibited small amounts of microcracking and relative highest level of aggregate distress

"RR CLUB P" - Poor - exhibited small-moderate amounts of microcracking and aggregate distress

"LR VIEW P" - Poor - exhibited moderate amounts of microcracking and aggregate distress

"RR VIEW P" - Poor - exhibited small amounts of microcracking and aggregate distress

"RR FIELD P"- Poor - exhibited small-moderate amount of microcracking with observed lower levels of aggregate distress

"LR CLUB P" - Fair/Poor - exhibited small amounts of microcracking with observed lower levels of aggregate distress

The most possible cause for observed distress, as represented by the submitted samples, is active alkali-aggregate reactivity. Differences in exposure conditions, especially exposure to water, can account for these relative, different physical conditions. Inadequate air-void systems can be likely contributing factors to deficiencies, potential failure, and/or further degradation under similar exposure conditions. However, no marked evidence of freeze-thaw distress was observed.

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (e.g., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur. Differences in exposure conditions, especially exposure to water, can account for apparent physical changes in condition of the examined samples. If the ASR is left unchecked, expansion will continue until moisture is removed, the source of alkalis is depleted, or the reactive silica components are consumed.

JR Varga

J. R. Varga, Concrete Petrographer
The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_2.pdf
- Online version of Plates 1-10 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_2_1_9.pdf
- Online version of Plates 11-17 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_2_10_17.pdf

W.O.#: 07-08-31-01 GROUP 2/ TCG 0756
SAMPLE "LR FIELD P"

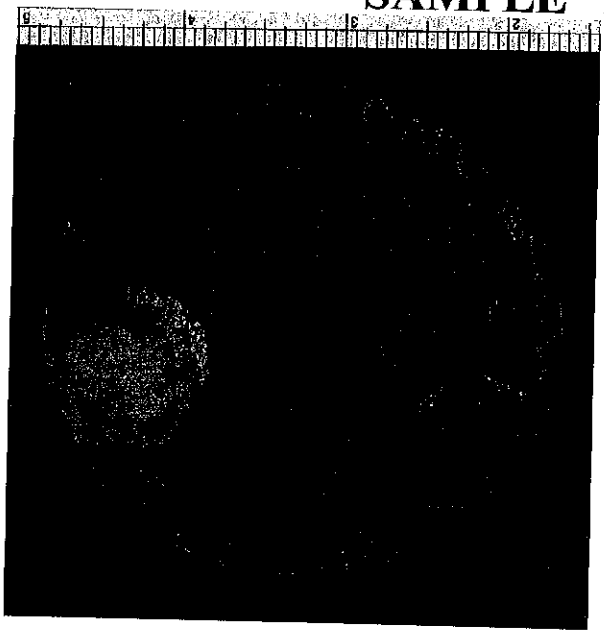

PLATE 1
TOP SURFACE

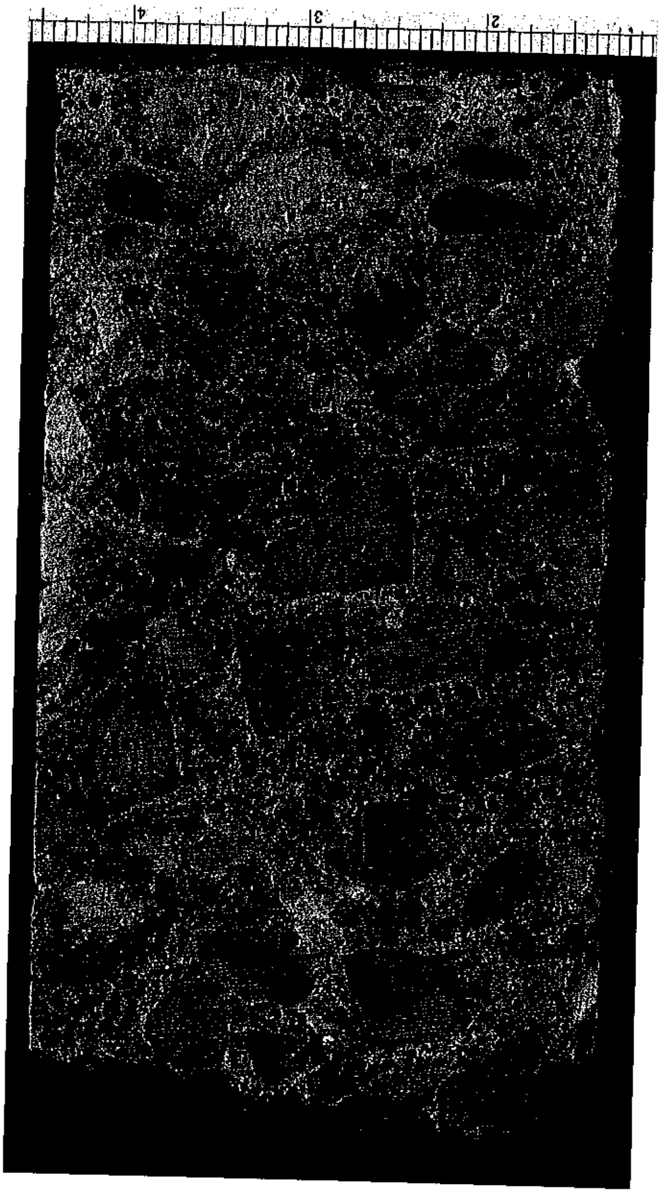

PLATE 2
PREPARED SURFACE

W.O.#: 07-08-31-01 GROUP 2/ TCG 0756

SAMPLE "RR FIELD P"

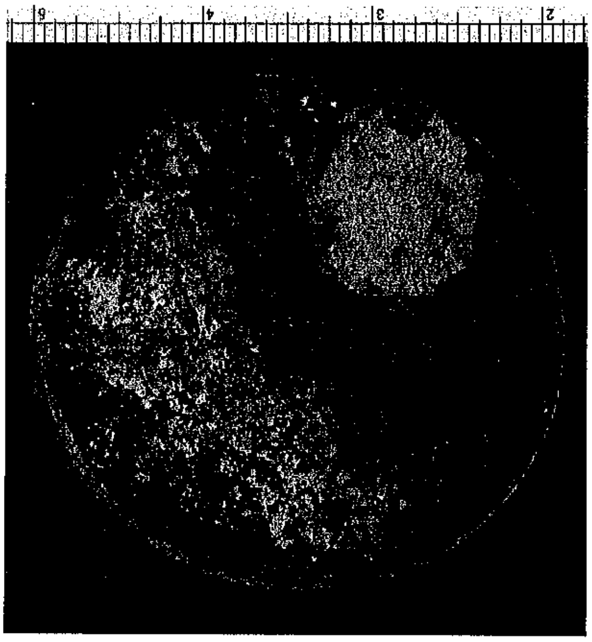

PLATE 3
TOP SURFACE

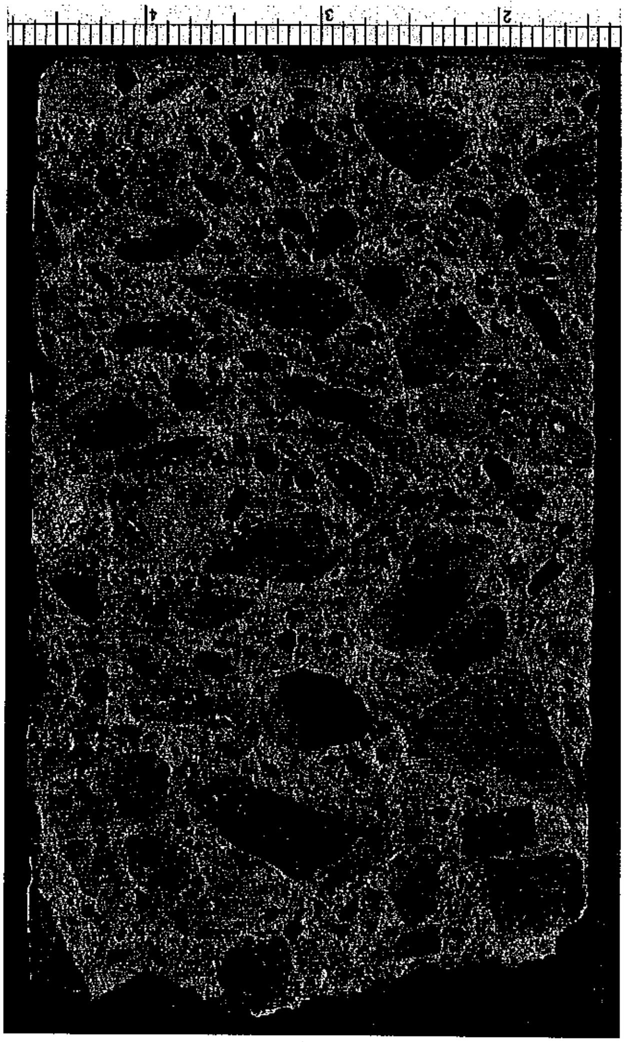

PLATE 4
PREPARED SURFACE

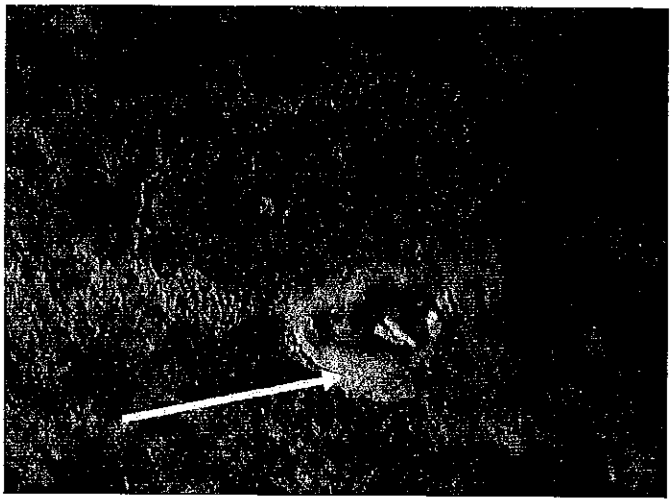

PLATE 5
CUT SURFACE SHOWING ALKALIC GEL EXUDATION AND FRACTURED CHERT PARTICLE

PLATE 6
CORE EDGE SURFACE SHOWING PARTIALLY CRACKED ALKALIC GEL EXUDATIONS

W.O.#: 07-08-31-01 GROUP 2/ TCG 0756
SAMPLE "RR CLUB P"

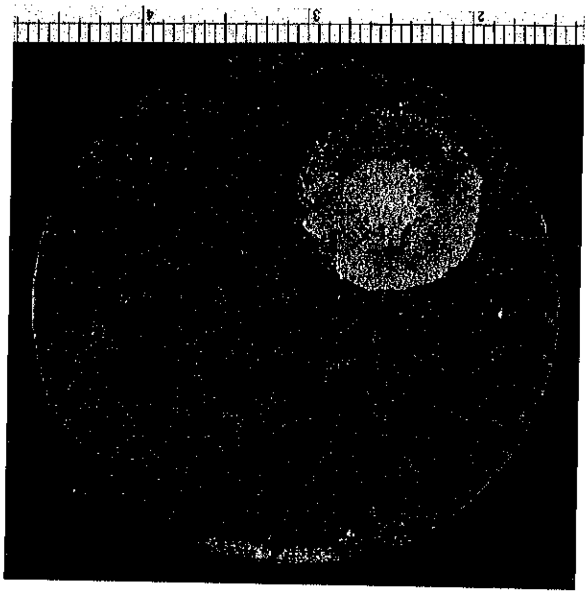

PLATE 7
TOP SURFACE

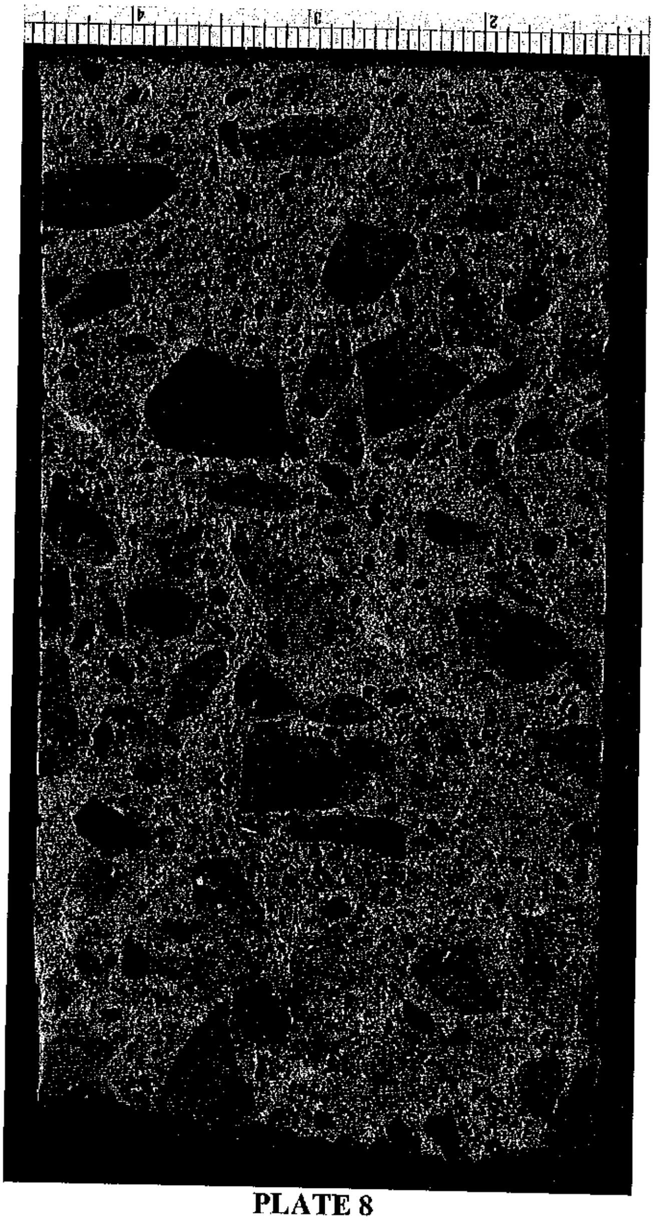

PLATE 8
PREPARED SURFACE

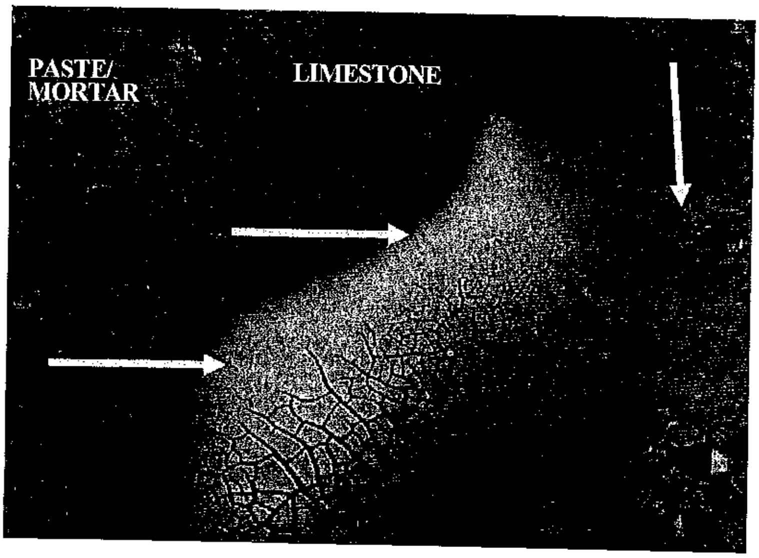

PLATE 9
CUT SURFACE SHOWING ALKALIC GEL EXUDATION (YELLOW ARROWS) ON LIMESTONE SURFACE AS A "SHEET-LIKE" DEPOSIT

W.O.#: 07-08-31-01 GROUP 2/ TCG 0756

SAMPLE "LR CLUB P"

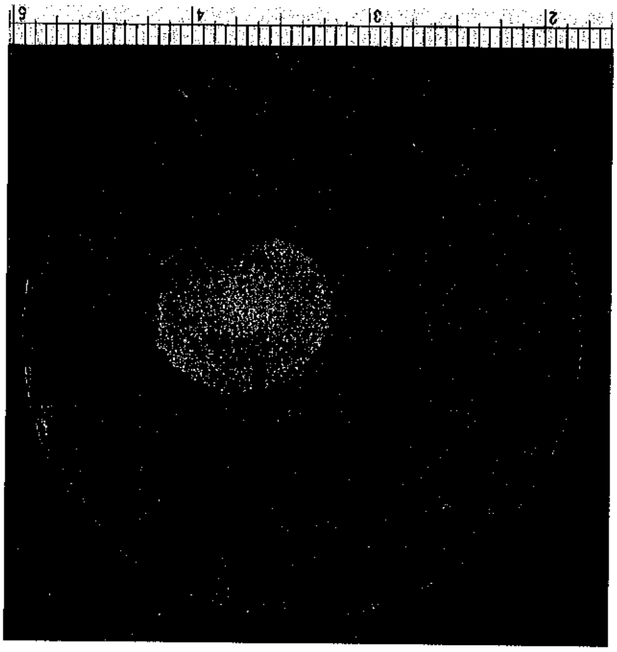

PLATE 10
TOP SURFACE

PLATE 11
PREPARED SURFACE

W.O.#: 07-08-31-01 GROUP 2/ TCG 0756

SAMPLE “RR VIEW P”

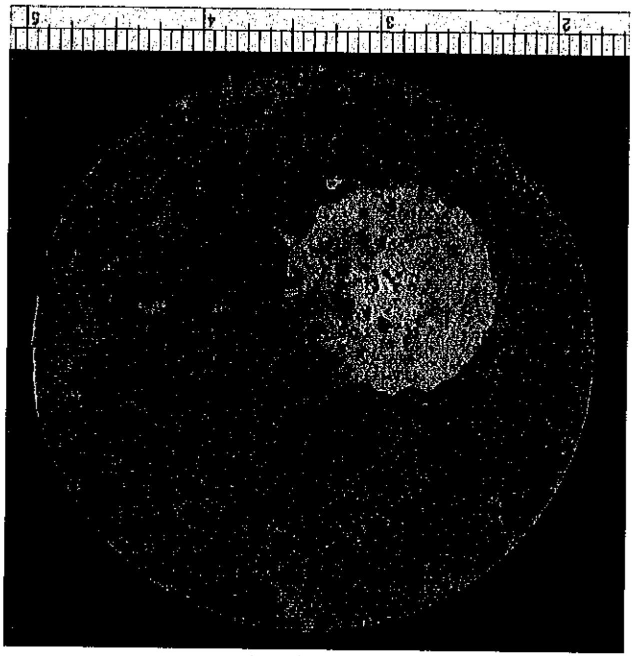

PLATE 12
TOP SURFACE

PLATE 13
PREPARED SURFACE

PLATE 14
CUT SURFACE SHOWING ALKALIC GEL EXUDATION OVER FINE AGGREGATE PARTICLE

PLATE 15
CORE EDGE SURFACE SHOWING ALKALIC GEL EXUDATION

W.O.#: 07-08-31-01 GROUP 2/ TCG 0756

SAMPLE "LR VIEW P"

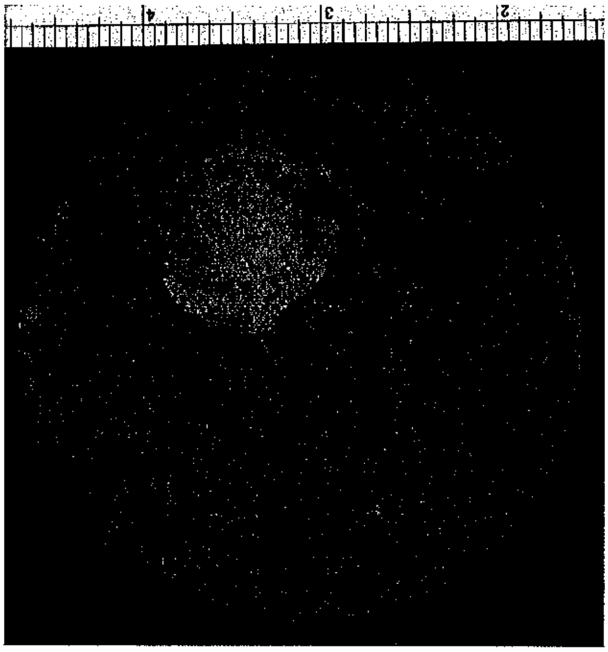

PLATE 16
TOP SURFACE

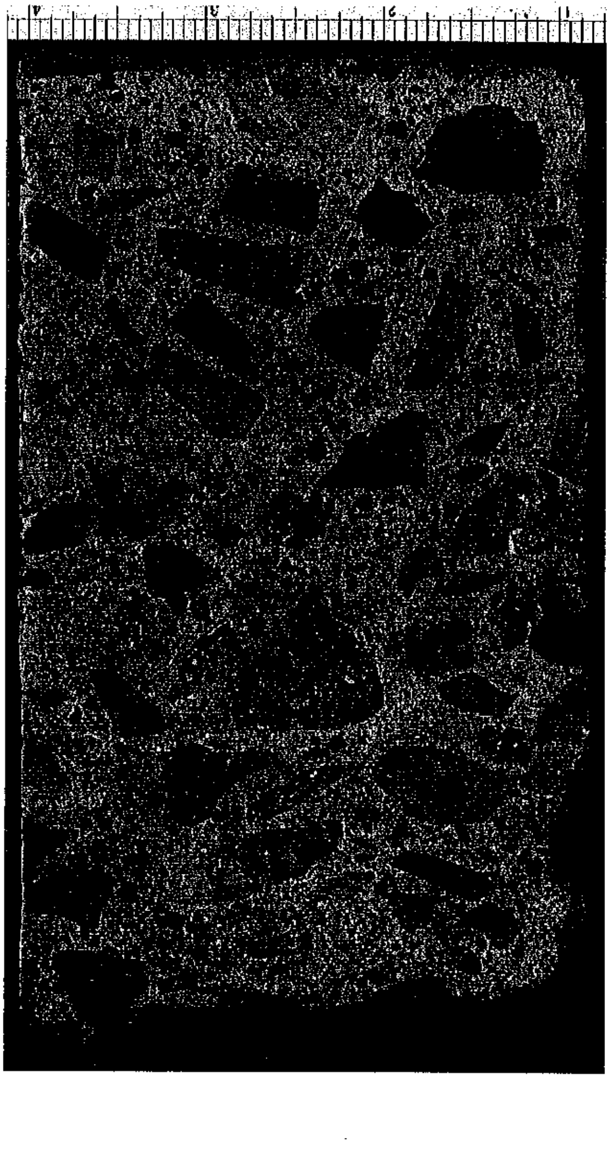

PLATE 17
PREPARED SURFACE

W.O.#: 07-08-31-01 / TCG 0756
GROUP 2 STAINED SAMPLES

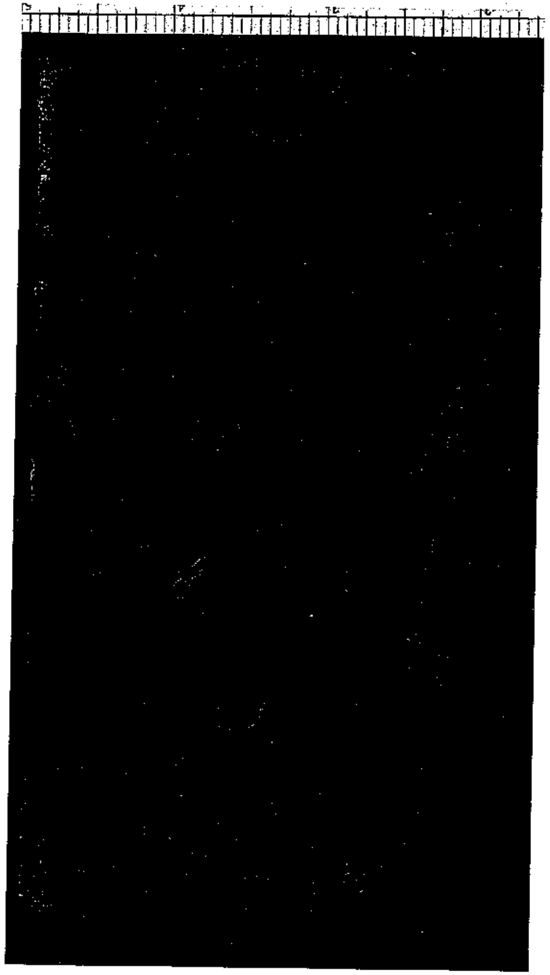

PLATE 1
PREPARED SURFACE OF SAMPLE "LRVIEW P"
SHOWING A VERY SMALL AMOUNT YELLOW
STAINING IN PASTE AND WITHIN AGGREGATE
PARTICLES AFTER COBALTINITRITE STAINING

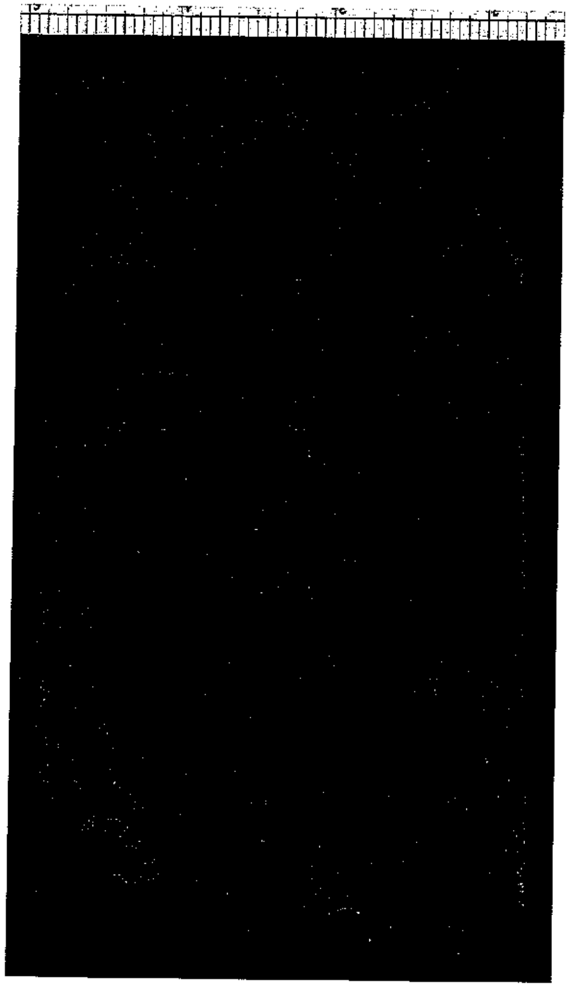

PLATE 2
PREPARED SURFACE OF SAMPLE "LRCLUB P"
SHOWING MODERATE YELLOW STAINING IN PASTE AND
WITHIN AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756

GROUP 2 STAINED SAMPLES

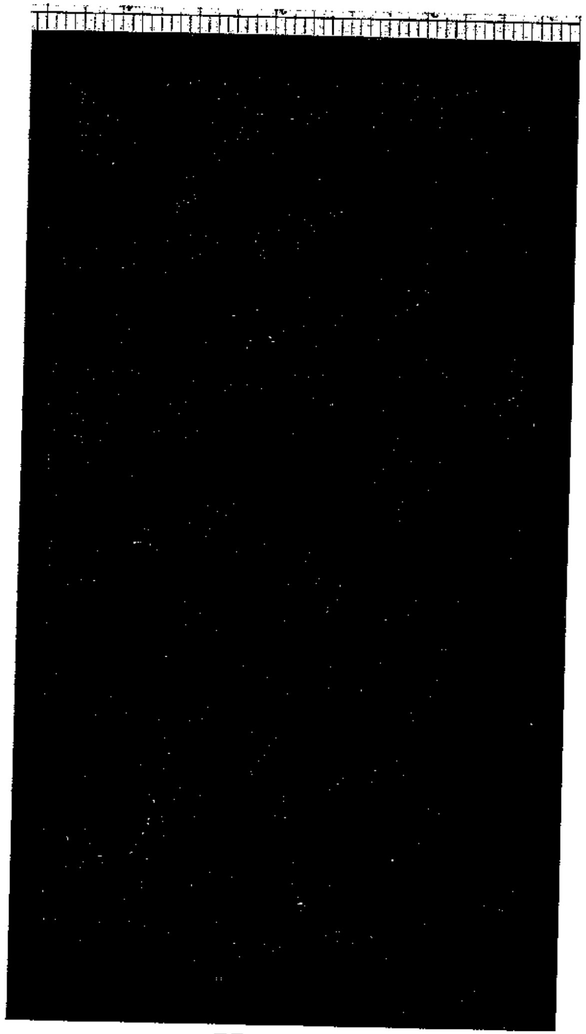

PLATE 3
PREPARED SURFACE OF SAMPLE "LRFIELD P"
SHOWING SMALL AMOUNT OF LOCALIZED YELLOW
STAINING IN PASTE AND WITHIN AGGREGATE PARTICLES
AFTER COBALTINITRITE STAINING

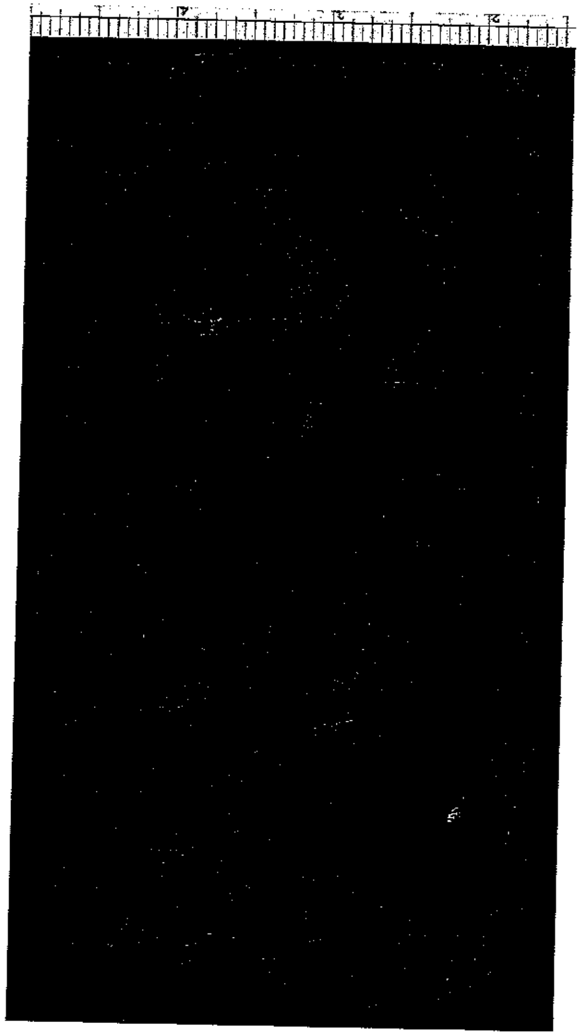

PLATE 4
PREPARED SURFACE OF SAMPLE "RRVIEW P"
SHOWING YELLOW STAINING IN PASTE AND WITHIN
AGGREGATE PARTICLES AFTER COBALTINITRITE
STAINING

W.O.#: 07-08-31-01 / TCG 0756
GROUP 2 STAINED SAMPLES

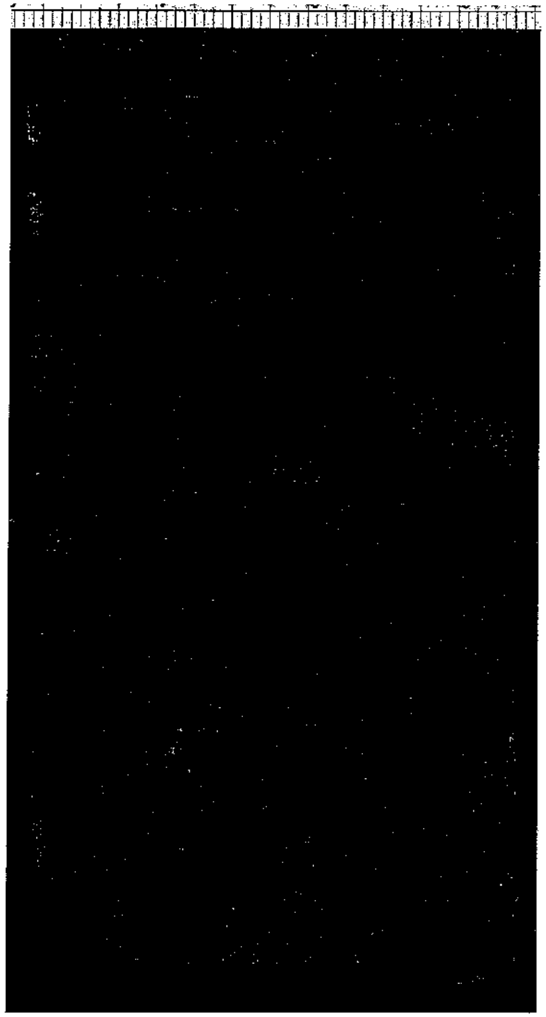

PLATE 5
PREPARED SURFACE OF SAMPLE “RRCLUB P”
SHOWING SMALL AMOUNT OF YELLOW STAINING IN PASTE AND
WITHIN AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

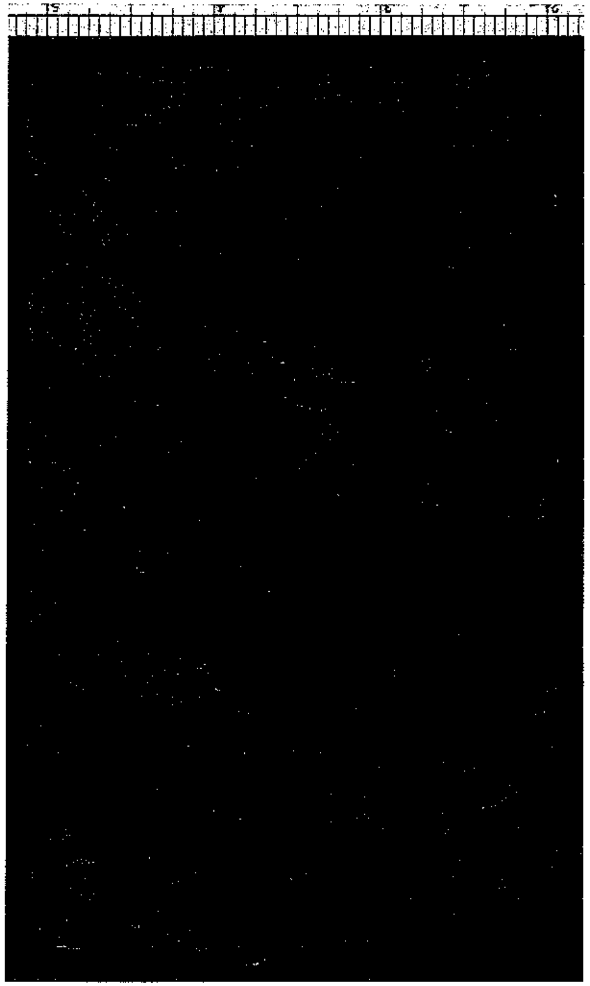

PLATE 6
PREPARED SURFACE OF SAMPLE “RRFIELD P”
SHOWING SMALL-MODERATE YELLOW STAINING IN
PASTE AND WITHIN AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING

PETROGRAPHIC REPORT

DATE:	September 18, 2007
WORK ORDER:	07-08-31-01 ADDENDUM / Thin Sections
CLIENT:	Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY:	Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

It was requested to determine and identify any deficiencies or potential failure/degradation mechanisms via examinations of thin sections of previously examined samples at the above referenced project. Samples of prepared surfaces from Samples **"130 P2"**, **"134 P"**, and **"135P"** were used for this request. Please refer to W.O.#: 07-08-31-01 / Group 1 for further details.

SAMPLE PREPARATION AND METHODS

Representative portions from the examined samples were cut, epoxy-mounted, and prepared as thin sections following our standard techniques and methods.

The portions of the previously prepared surfaces of Samples **"134 P"** and **"135P"** were stained using a saturated, aqueous solution of sodium cobaltinitrite (reacts with soluble potassium to produce a yellow precipitate resulting in staining potassium-rich ASR gel) following the guidelines in a July 1998 report titled *"Geochemical Methods for the Identification of ASR Gel"* by Guthrie and Carey, Los Alamos National Laboratory . In addition, a saturated, aqueous solution of Rhodamine B was similarly used to aid this staining procedure by highlighting (providing a high contrast background) the regions of yellow-stained ASR gel and in part, to identify other degradation products.

The stained samples and prepared thin section slides were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in both stained sample surfaces, PLATES 1 and 2. Yellow staining was observed in both gray-colored, cherty limestone particles as well as light brown, fossiliferous limestone particles in the coarse aggregate, in the secondary, internal deposits a few voids, as paste "halos" at aggregate peripheries, localized paste regions, within internal fractures in aggregate particles, and in microcrystalline quartz chert particles in the fine aggregate portions. Rhodamine B staining resulted in pink colorations.

Thin Section Analyses

The presence of microcrystalline silica within the coarse aggregate limestone particles was confirmed, PLATES 3-6. Microcrystalline silica was observed as discrete nodules, monomineralic fragments, and polycrystalline deposits with calcite.

DISCUSSION

Aggregates unaffected by ASR have been found to not to be susceptible to staining using sodium cobaltinitrite. Distinct and highly localized staining of reactive aggregates and paste regions (as observed and described above) with sodium cobaltinitrite confirms ASR. The extent of yellow staining also correlates to the degree of reactivity. Previous reports have documented physical distress features associated with ASR.

Thin section analyses confirmed the presence of microcrystalline silica within coarse aggregate limestone particles.

The most possible cause for observed distress, as represented by the previously examined samples, is alkali-silica reactivity (ASR). Textural and mineralogical characteristics for rock types susceptible to alkali-carbonate reaction were not observed.

JR Varga

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The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101ADD.pdf

- Online version of Plates 1-6 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101ADD.pdf

THE ROCK DOCTOR
CONCRETE SOLUTIONS FOR CONCRETE PROBLEMS

PETROGRAPHIC REPORT

DATE:	September 20, 2007
WORK ORDER:	07-08-31-01 / Group 3
CLIENT:	Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY:	Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received four core portions of hardened concrete to determine the general condition of the concrete(s). The core portions were marked **"103 P"**, **"104 P"**, **"127 P"**, and **"130 P"**. The core portions measured, in length, approximately 6, 6-1/4, 6-1/4, and 6 inches, respectively. The core portions were approximately 3-1/4 inches in diameter.

It was reported that the submitted samples were taken from plaza seating areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Several digital photographs were also submitted. Mix designs were not available at the time of this writing.

SAMPLE PREPARATION AND METHODS

The core samples were cut in half, approximately perpendicular to the top surfaces. The cut surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were determined following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters.

The unprepared samples were partially immersed in water for at least three days to mobilize any alkalic gels present. The cut surfaces of the core portion samples were not immersed in water.

The prepared and unprepared samples were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

"103 P"

GENERAL CONDITION: (See PLATES 1-3) The top surface exhibited a generally flat, soft, mostly elastic, membrane/coating that was mottled in color from gray to dark gray. Water readily beaded on this surface. Many, partially exposed fine quartz aggregate particles, a few cracks, and a few dimples of harder, less elastic, cracked gray material were present at the exposed surface. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating was ranged in thickness from approx. 1/24 of an inch up to approx. 1/16 of an inch thick and was composed of two apparent layers. The layer at/adjacent to the exposed surface was approx. ¼ of the total coating thickness and exhibited a small amount of small voids and several fine aggregate particles. At the interface between the two apparent coating layers, no voids, separations, or cracks were observed. The underlying layer (approx. ¾ of the total topping thickness) exhibited many small air-voids. At the bottom surface of this layer, a discontinuous, adhered layer of paste/mortar from the base concrete was observed. A continuous separation/crack was present at or near the interface of the topping system and the base concrete. A continuous zone of carbonated paste was observed at the top surface of the base concrete from a veneer up to approx. 1/8 of an inch thick. A small-moderate amount of microcracking was observed throughout the sample. Most of the observed microcracks were infilled with light brown-off white material with similar optical properties of alkalic gel and carbonated alkalic gel. After immersion in water, the sample trimming exhibited white to clear exudations of material with the optical properties of alkalic gel on cut surfaces. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from pale gray-light brown with a small amount of unhydrated cement particles to light brown-dull white in color, with a very small amount of unhydrated cement particles. The lighter colored paste areas were softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 1:

TABLE 1

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	$\bar{l}$ in.	α in.$^{-1}$	$\bar{L}$ in.
"103 P"	21.86	2,059	101.45	3.11	7.03	4.5	.0069	581.0	.0093

The inhomogeneously distributed voids were mostly spherically shaped and ranged in size from small to large with fewer, larger, irregularly shaped voids also observed. A small amount of clusters of voids was observed throughout the sample. Many voids exhibited partial linings and coatings of clear to off white material with similar optical properties of alkalic gel and carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Several particles exhibited internal fractures. A few particles exhibited reaction rims. Small amounts of discontinuous zones of lighter-colored paste were observed at several aggregate peripheries. In addition, discontinuous veneers of darker colored paste and mortar were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, claystone, limestones, and microcrystalline quartz chert particles. Several particles exhibited internal fractures.

"104 P"

GENERAL CONDITION: (See PLATES 4-6) The top surface exhibited a generally flat, soft, mostly elastic, membrane/coating that was mostly gray in color with smaller, linear area exhibiting a dark gray color. Water readily beaded on this surface. A small amount of partially exposed, fine quartz aggregate particles, a few aggregate sockets, and several air-void septa were present at the exposed surface. The observed darker gray-colored linear portions at the exposed surface was slightly stiffer/less flexible than the lighter gray-colored portions and exhibited adhered debris and dirt. Very small amounts of yellow-colored material, presumed to be used for marking purposes, were also present at the exposed surface. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating was ranged in thickness from approx. 1/24 of an inch up to approx. 1/16 of an inch thick and was composed of two apparent layers. The layer at/adjacent to the exposed surface was approx. 1/5- 1/3 of the total coating thickness and exhibited a small amount of small voids and several fine aggregate particles. At the interface between the two apparent coating layers, no voids, separations, or cracks were observed. The underlying layer (approx. 2/3 to 4/5 of the total topping thickness) exhibited a small-moderate amount of small air-voids. At the bottom surface of this layer, a discontinuous, adhered layer of paste/mortar from the base concrete was observed. A continuous separation/crack was present at or near the interface of the topping system and the base concrete. A continuous zone of carbonated paste was observed at the top surface of the base concrete from a veneer up to approx. 1/8 of an inch thick. A zone of paste at/near the top surface (approx. 1/4 of an inch up to approx. 1/2 of an inch thick) was markedly less water absorptive than the bulk paste and did not readily wet-out when water was applied. A small amount of microcracking was observed throughout the sample. Most of the observed microcracks were infilled with light brown-off white material with similar optical properties of alkalic gel and carbonated alkalic gel. After immersion in water, the sample trimming exhibited a localized, clear exudations of material with the optical properties of alkalic gel on the cut surface. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and variegated from dull gray with a small amount of unhydrated cement particles to light brown-dull gray in color, with a very small amount of unhydrated cement particles. The lighter colored paste areas were softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 2:

TABLE 2

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α $in.^{-1}$	L in.
"104 P"	29.96	2,044	100.70	5.33	5.62	5.1	.0104	382.9	.0122

The inhomogeneously distributed voids were mostly spherically shaped and ranged in size from small to large with fewer, larger, irregularly shaped voids also observed. A small amount of clusters of voids was observed throughout the sample. Partial linings/infillings of clear to off-white material with similar optical properties of alkalic gel and carbonated alkalic gel were observed in many voids.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of ¾ of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. A small amount of internal fractures were observed. A few particles exhibited reaction rims. Discontinuous veneers of markedly darker gray colored paste and mortar were observed at several aggregate peripheries as well as softer, light brown-colored "halos" or rims of paste.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, claystone, limestones, and microcrystalline quartz chert particles. Several particles exhibited internal fractures. A few microcrystalline quartz chert particles exhibited reaction rims and a few exhibited darker colored paste portions at aggregate peripheries.

"127 P"

GENERAL CONDITION: (See PLATES 7-9) The top surface was generally flat, slightly rough with a "worn" appearance and exhibited numerous partially exposed, fine aggregate particles in a flat paste matrix. Small amounts of loosely adhered, black material, dirt/debris were also present especially in a localized, apparent fine crack portion at the exposed surface. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a continuous zone of carbonated paste was observed with a thickness of 1/32 of an inch. The upper approx. 1/16 of an inch thick portion at/adjacent to the top surface exhibited a darker colored paste as compared to the bulk paste. A small-moderate amount of microcracking was observed throughout the sample. Most of these microcracks were infilled with light brown-off white material with similar optical properties of alkalic gel and carbonated alkalic gel. A discontinuous zone of paste at/near the top surface (from zero or non-existent up to approx. 3/4 of an inch) was markedly less water absorptive than the bulk paste and did not readily wet-out when water was applied. After immersion in water, the sample trimming exhibited a localized, clear exudations of material with the optical properties of alkalic gel on cut surface. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, soft-moderately hard, and variegated from pale gray-light brown with a small amount of unhydrated cement particles to dull white-light gray with a very small amount of unhydrated cement particles. The lighter colored paste areas were markedly softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 3:

TABLE 3

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"127 P"	21.00	2,042	100.60	6.17	3.40	5.3	.0117	340.9	.0100

The inhomogeneously distributed voids were spherically shaped and ranged in size from small to large with fewer, larger, irregularly shaped voids also present. A small-moderate amount of clustering of voids was observed throughout the sample. In numerous voids, secondary, internal deposits of clear to off-white material with similar optical properties of alkalic gel and carbonated alkalic gel were observed as partial linings and coatings.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Many particles exhibited internal fractures and several particles exhibited reaction rims. Discontinuous zones of darker-colored paste were also observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and claystone particles. Many reactions rims were observed especially associated with microcrystalline quartz chert particles. Many particles exhibited internal fractures.

"130 P"

GENERAL CONDITION: (See PLATES 10-12) The top surface was generally flat, slightly rough with a "worn" appearance and exhibited numerous partially exposed, fine aggregate particles in a flat paste matrix. Small amounts of loosely adhered, black material, dirt/debris were also present. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, no apparent carbonation was observed. A small amount of microcracking was observed. Most of these microcracks were infilled with light brown-off white material with similar optical properties of alkalic gel and carbonated alkalic gel. After immersion in water, the sample trimming exhibited a localized, clear exudations of material with the optical properties of alkalic gel on cut surface. This exudation apparently lifter a small mortar flake from the cut surface. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light gray-light brown in color with a small amount of unhydrated cement particles to light brown-dull white in color with a very small-small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 4:

TABLE 4

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	ı in.	α in.$^{-1}$	L in.
"130 P"	19.86	2,059	101.45	3.11	6.39	2.2	.0140	285.4	.0182

The homogeneously distributed voids were mostly small in size and spherically shaped with fewer, larger, spherical to irregularly shaped voids also present. In numerous voids, secondary, internal deposits of clear to off-white material with similar optical properties of alkalic gel and carbonated alkalic gel were observed as partial linings and coatings.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subangular in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Several particles exhibited small amounts of internal fractures and many exhibited reaction rims. Several paste portions adjacent to several aggregate particles exhibited lighter-colored paste regions. Several other particles exhibited darker-colored paste regions regions adjacent to aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and limestone particles. Several microcrystalline quartz chert particles and a few limestone particles exhibited reactions rims. Small amounts of internal fractures were also observed.

DISCUSSION & CONCLUSION

We received four core portions of hardened concrete to determine the general condition of the concrete(s).

It was reported that the submitted samples were taken from taken from plaza seating areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

The air-void system parameters for all samples are listed below in TABLE 5:

TABLE 5

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"103 P"	21.86	2,059	101.45	3.11	7.03	4.5	.0069	581.0	.0093
"104 P"	29.96	2,044	100.70	5.33	5.62	5.1	.0104	382.9	.0122
"127 P"	21.00	2,042	100.60	6.17	3.40	5.3	.0117	340.9	.0100
"130 P"	19.86	2,059	101.45	3.11	6.39	2.2	.0140	285.4	.0182

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi. The examined samples are considered to be air-entrained with **"103 P"** and **"130 P"** being considered marginally air-entrained. Overall, the observed aggregates exhibited signs or evidence of reactivity including internal fractures and reaction rims. After water immersion, alkalic gel exudations were present in all samples strongly suggesting active/ongoing alkali-silica reactivity. The determined spacing factors were over the recommended, industry standard limit maximum of 0.0080 inches and are considered unacceptable for freeze-thaw durability in water saturated environments. The compressive strength(s) of the concrete represented by this sample/mix design is unknown and comments regarding this will not be made.

All Portland cement based concretes will carbonate over time. When carbonation occurs early in the life of the concrete, the strength development of the affected area can be compromised. The samples exhibited various depths of carbonated paste. However, the carbonated zones and the respective bulk pastes exhibited similar hardnesses. This suggests that the carbonation had occurred over the service lives of the concretes.

Based on this examination, the the general condition of the concrete(s), including aggregate features and the presence/degree of observed microcracking, were deemed:

"103 P" - Poor - exhibited small-moderate amounts of microcracking and moderate aggregate distress

"104 P" - Poor - exhibited small amounts of microcracking and aggregate distress

"127 P" - Poor - exhibited small-moderate amounts of microcracking and relative highest level of aggregate distress

"130 P" - Poor - exhibited small amounts of microcracking and high level aggregate distress

The most possible cause for observed distress, as represented by the submitted samples, is active alkali-aggregate reactivity. Differences in exposure conditions, especially exposure to water, can account for these relative, different physical conditions. Inadequate air-void systems can be likely contributing factors to deficiencies, potential failure, and/or further degradation under similar exposure conditions. However, no marked evidence of freeze-thaw distress was observed.

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (e.g., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur. Differences in exposure conditions, especially exposure to water, can account for apparent physical changes in condition of the examined samples. If the ASR is left unchecked, expansion will continue until moisture is removed, the source of alkalis is depleted, or the reactive silica components are consumed.

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EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_3.pdf

- Online version of this Plates 1-12 report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_3.pdf

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 3

PLAZA SEATING SAMPLE "103 P"

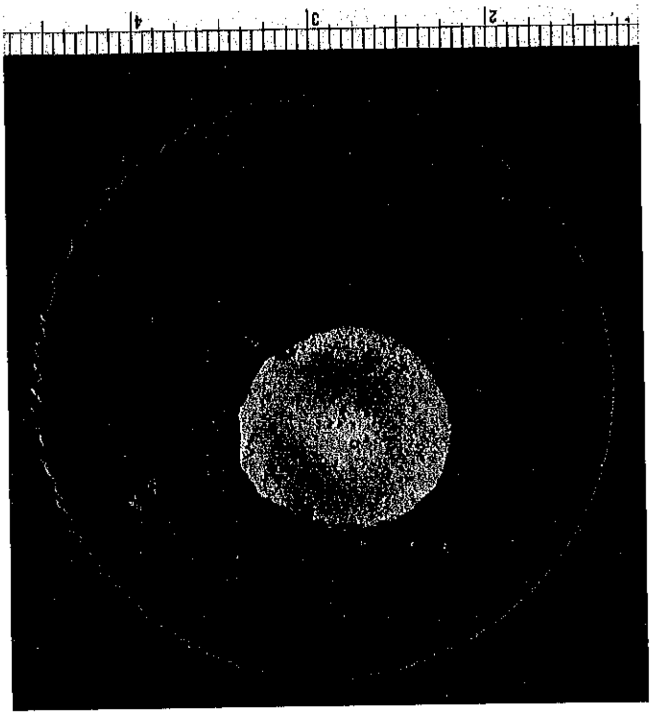

PLATE 1
TOP SURFACE

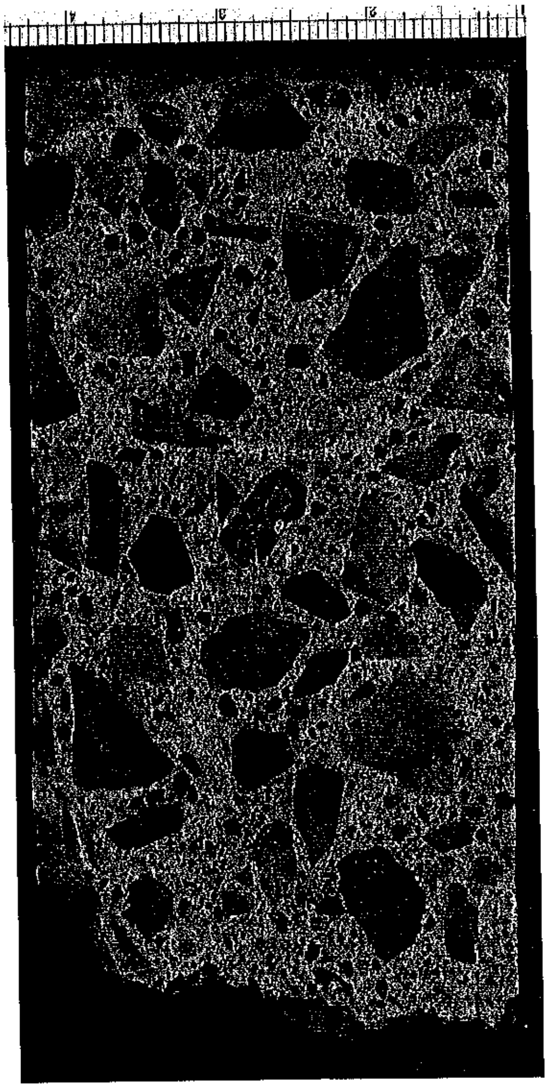

PLATE 2
PREPARED SURFACE

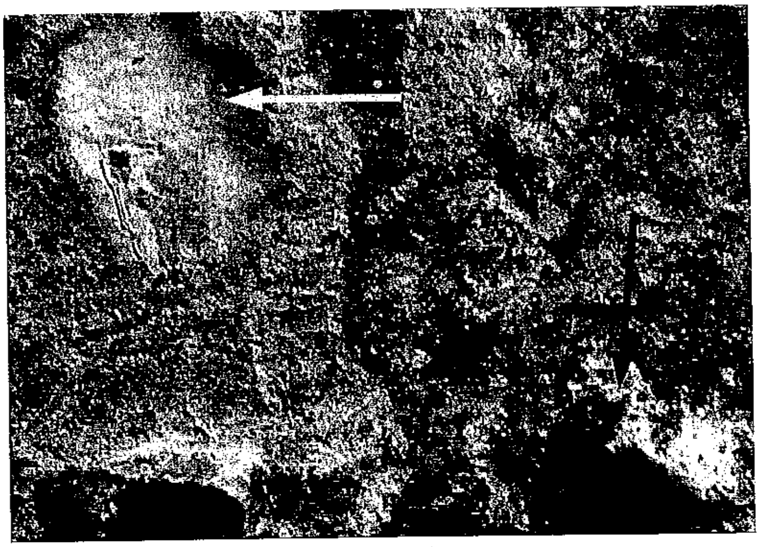

PLATE 3
CUT SURFACE
YELLOW ARROW SHOWING ALKALIC GEL EXUDATION
ON AGGREGATE SURFACE
RED ARROW SHOWS CLEAR ALKALIC GEL EXUDATION
IN ADJACENT VOID

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PLAZA SEATING SAMPLE "104 P"

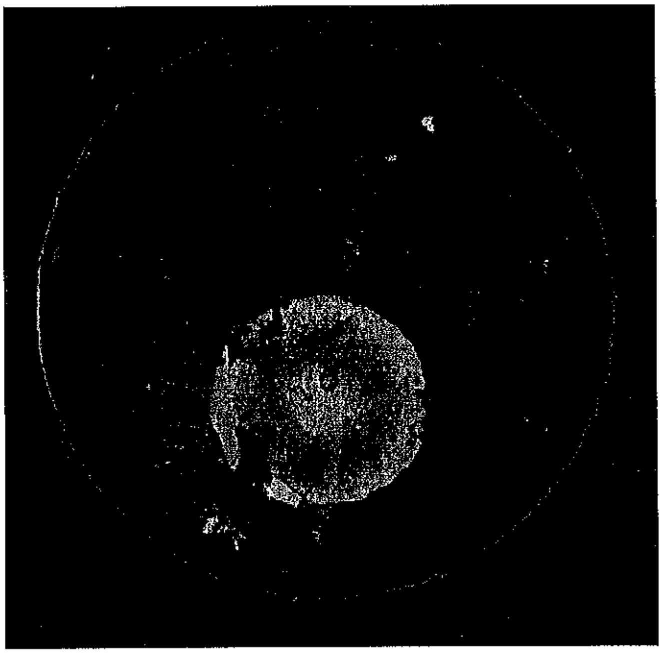


PLATE 4
TOP SURFACE

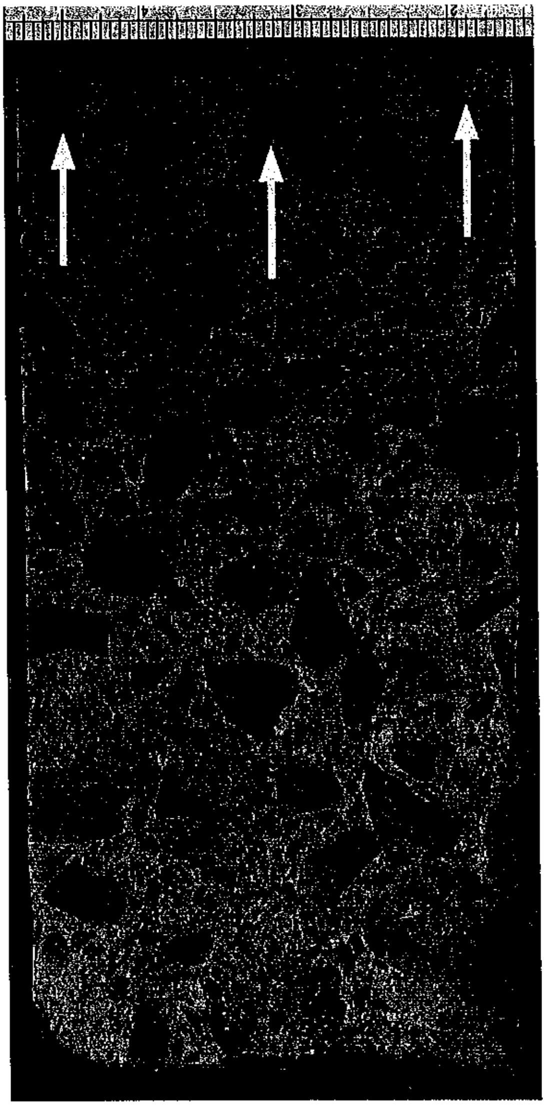


PLATE 5
PREPARED SURFACE
YELLOW ARROWS SHOW PENCIL
LINE DENOTING BOTTOM OF
LESS WATER ABSORPTIVE ZONE
ADJACENT TO TOP SURFACE

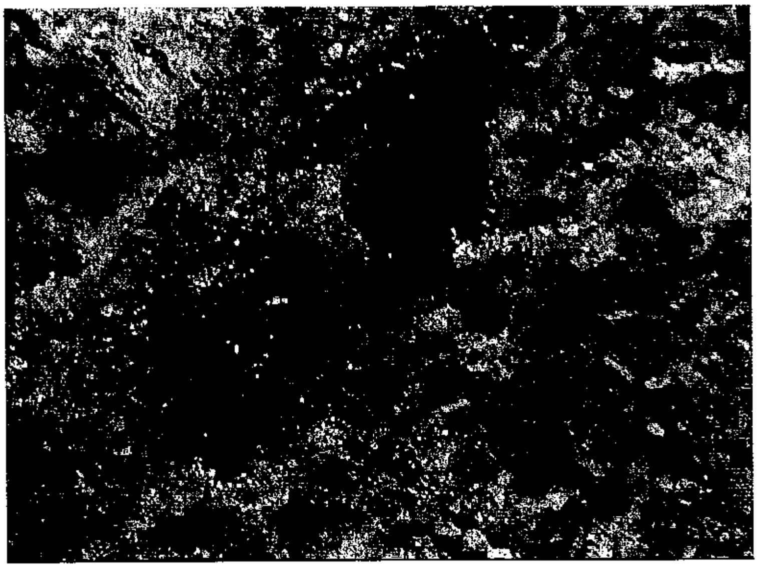


PLATE 6
CUT SURFACE SHOWING CLEAR ALKALIC
GEL EXUDATIONS EMINATING FROM FINE
AGGREGATE PARTICLE

W.O.#: 07-08-31-01 / TCG 0756 /GROUP 3

PLAZA SEATING SAMPLE "127 P"

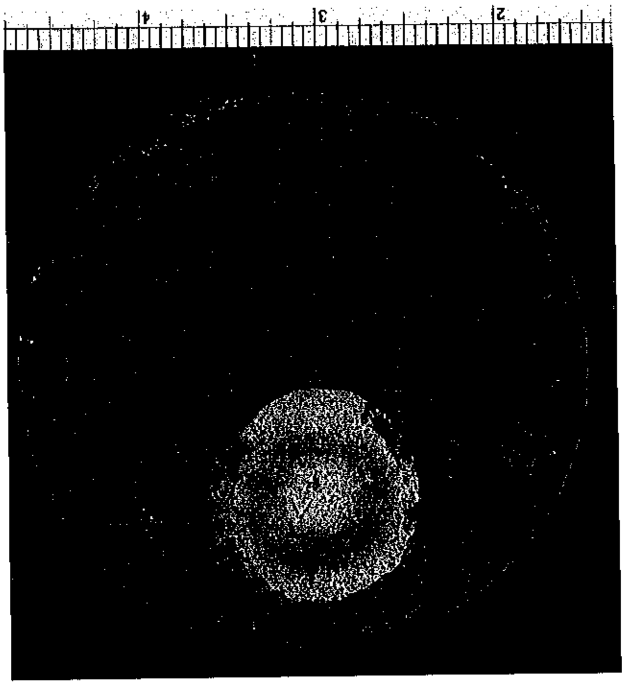


PLATE 7
TOP SURFACE

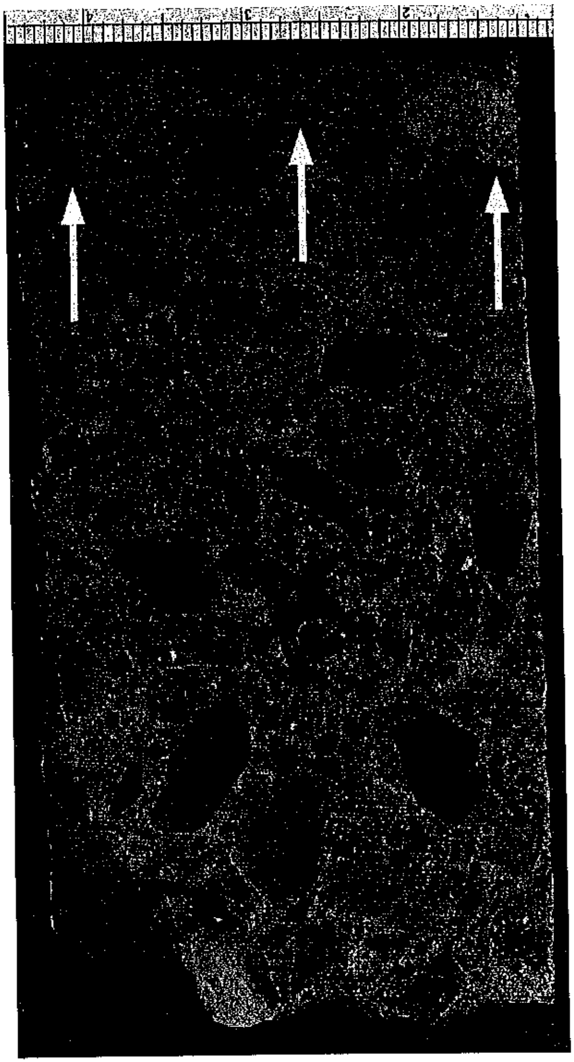


PLATE 8
PREPARED SURFACE
YELLOW ARROWS SHOW PENCIL
LINE DENOTING BOTTOM OF
LESS WATER ABSORPTIVE ZONE
ADJACENT TO TOP SURFACE

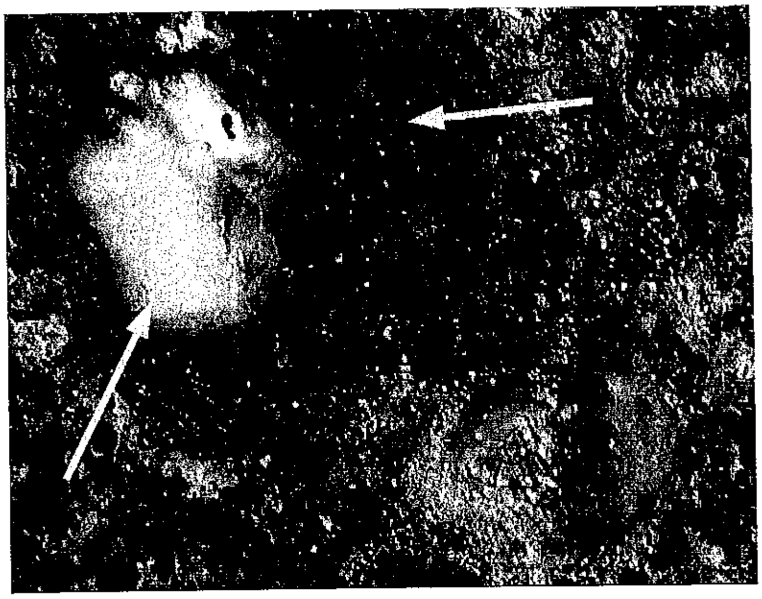


PLATE 9
CUT SURFACE SHOWING ALKALIC GEL EXUDATIONS ON
AGGREGATE PARTICLE (YELLOW ARROW) AND
IN ADJACENT VOID, CLEAR-WHITE CRACKED ALKALIC
GEL LINING (RED ARROW)

W.O.#: 07-08-31-01 / TCG 0756 /GROUP 3

PLAZA SEATING SAMPLE "130 P"

PLATE 10
TOP SURFACE

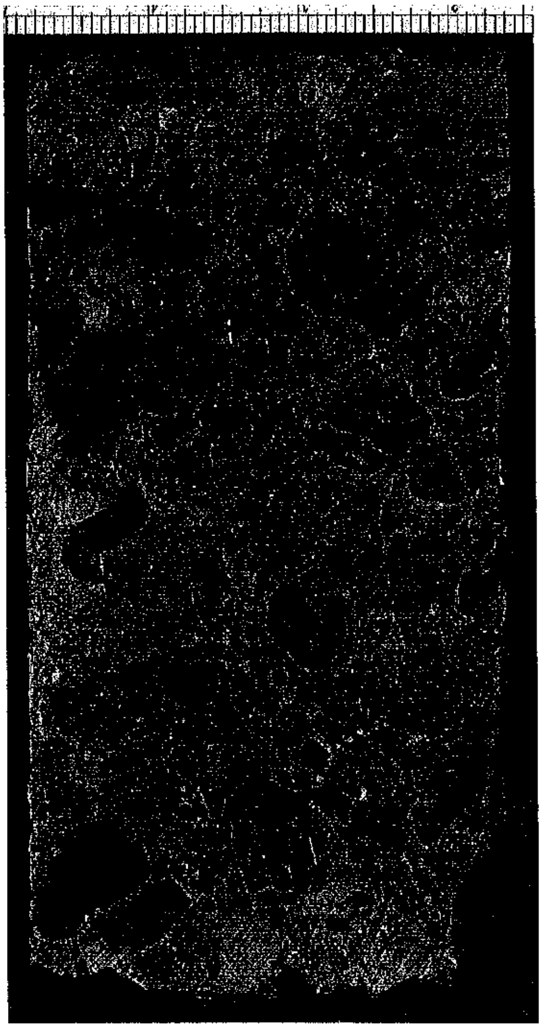


PLATE 11
PREPARED SURFACE

PLATE 12
CLEAR, ALKALIC GEL EXUDATION
(SHOWN BY YELLOW ARROW)
APPARENTLY LIFTING A THIN LAYER OF
MORTAR FROM CUT SURFACE

W.O.#: 07-08-31-01 / TCG 0756
GROUP 3 STAINED SAMPLES

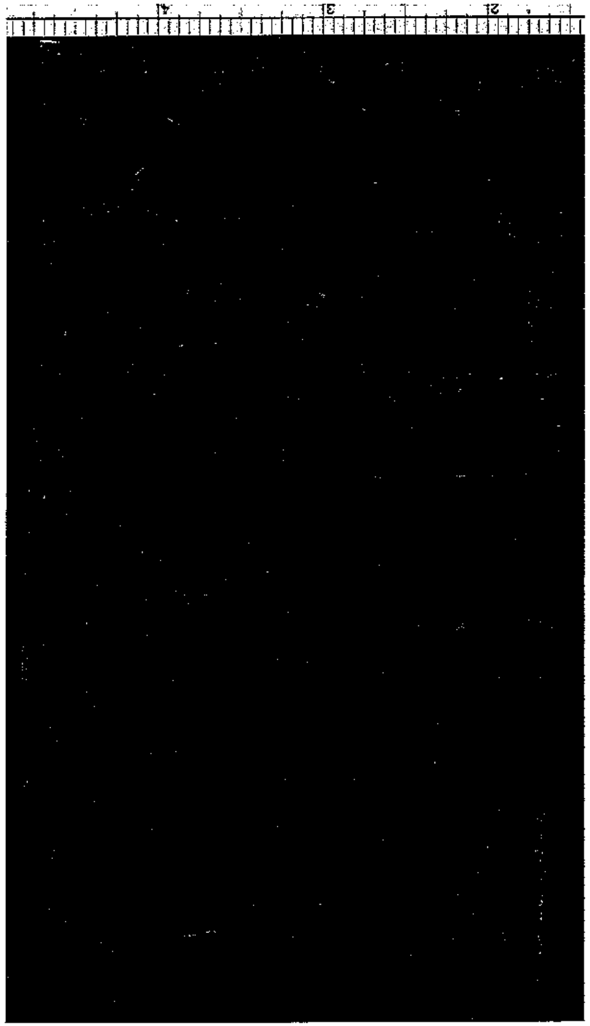


PLATE 1
PREPARED SURFACE OF SAMPLE "103P"
SHOWING VERY SMALL AMOUNTS OF
LOCALIZED YELLOW STAINING IN PASTE AND
WITHIN AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING

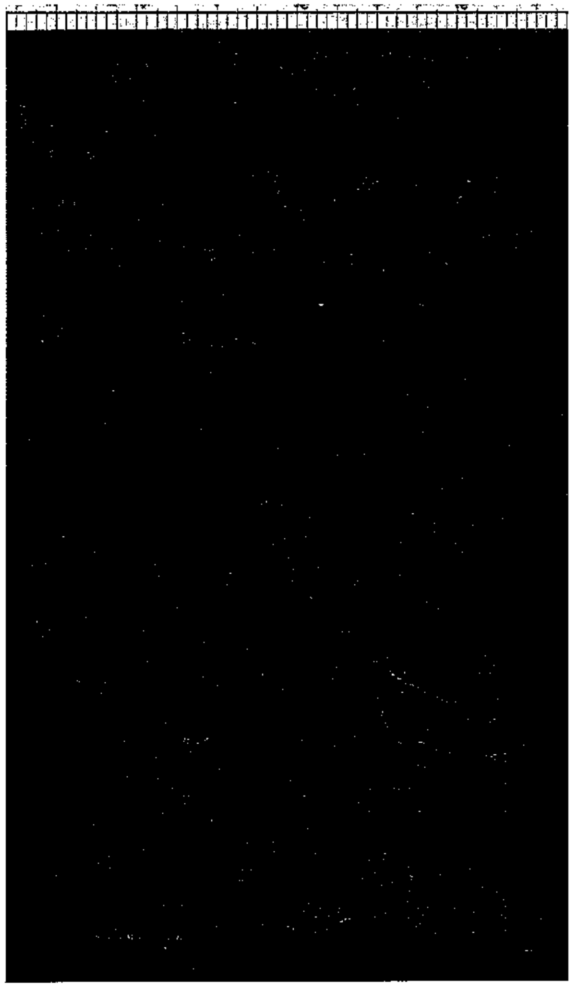


PLATE 2
PREPARED SURFACE OF SAMPLE "104P"
SHOWING MODERATE YELLOW STAINING IN PASTE AND
WITHIN A FEW AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756
GROUP 3 STAINED SAMPLES

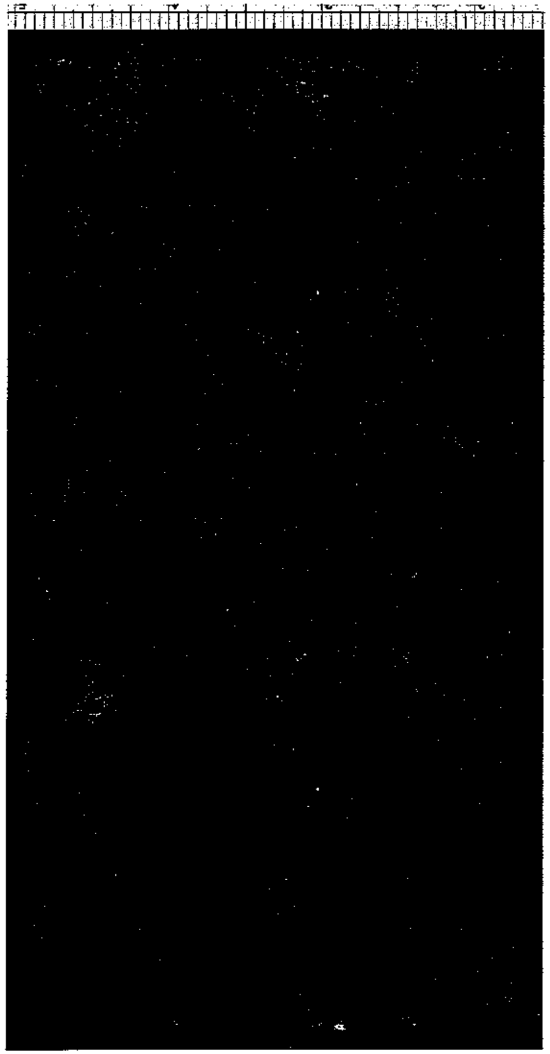


PLATE 3
PREPARED SURFACE OF SAMPLE "127P"
SHOWING MODERATE YELLOW STAINING IN PASTE AND WITHIN AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

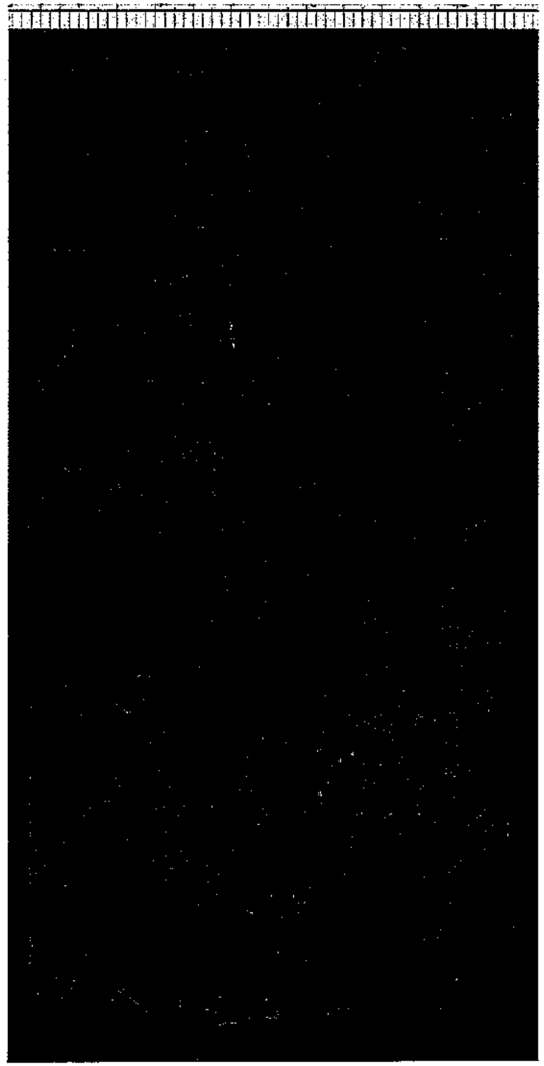


PLATE 4
PREPARED SURFACE OF SAMPLE "130-P-PLAZA"
SHOWING MODERATE YELLOW STAINING IN PASTE AND WITHIN AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

PETROGRAPHIC REPORT

DATE:	October 29, 2007
WORK ORDER:	07-08-31-01 / Group 3B Plaza Level Concourse
CLIENT:	Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY:	Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received five core portions of hardened concrete to determine the general condition of the concrete(s). The core portions were marked **"106UD-P"**, **"116D"**, **"127D-P"**, **"130UD-P1"**,and **"130UD-P2"**. The core portions measured, in length, approximately 4-3/4, 5-3/4, 5-3/4, 2-7/8, and 3-1/4 inches, respectively. The core portions were approximately 3-1/4 inches in diameter.

It was reported that the submitted samples were taken from the plaza level concourse. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

SAMPLE PREPARATION AND METHODS

The examined samples were cut in half, approximately perpendicular to the top surfaces. The cut surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were estimated/determined following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters. Samples **"130UD-P1"**and Sample **"130UD-P2"** did not meet minimum traverse length requirements due to inadequate sample size and the air-void system parameters were estimated.

The unprepared samples were partially immersed in water for at least three days to mobilize any alkalic gels present. The cut surfaces of the core portion samples were not immersed in water.

The prepared surfaces of all examined samples were stained using a saturated, aqueous solution of sodium cobaltinitrite (reacts with soluble potassium to produce a yellow precipitate resulting in staining potassium-rich ASR gel) following the guidelines in a July 1998 report titled *"Geochemical Methods for the Identification of ASR Gel"* by Guthrie and Carey, Los Alamos National Laboratory . In addition, a saturated, aqueous solution of Rhodamine B was similarly used to aid this staining procedure by highlighting (providing a high contrast background) the regions of yellow-stained ASR gel and in part, to identify other degradation products.

The prepared, unprepared, and stained sample surfaces were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

"106UD-P"

GENERAL CONDITION: (See PLATES 1-4) The top surface exhibited a generally flat, slightly rough surface with mostly smooth, slightly hard, semi-elastic, elastic membrane/coating that was gray to light gray in color. Water initially beaded when applied to this surface and was moderately absorptive. Many, partially exposed fine quartz aggregate particles, a few aggregate sockets, and many fine, cracks were present at the exposed surface. The cracks were mostly located at exposed aggregate peripheries. Small areas exhibited harder, finely cracked, gray coating material. A 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system was approx. 5/32 of an inch thick and appeared to be composed of seven layers of material. The uppermost layer at/adjacent to the exposed surface was dark gray in color, ranged in thickness from a veneer up to approx. 1/32 of an inch, and appeared to be a top coat-type application that filled irregularities present in the underlying layer of material. This uppermost layer exhibited a very few, small voids but did not exhibit any aggregate particles. At the irregular interface between the two uppermost coating layers, no cracks or separations were observed. The second layer below the top surface (up to approx. 1/16 of an inch thick) was moderately soft, semi-elastic, and light gray in color with many fine aggregate particles and a small amount of small air-voids. At the interface between the bottom surface of the second and third layers, a discontinuous fine separation was observed. Immediately below the two upper layers, a gray colored, soft, elastic material was observed with a small amount of air-voids and no aggregate particles. This layer ranged was observed up to approx. 1/32 of an inch thick. At the interface between the bottom surface of the third and fourth layers, a discontinuous fine separation was observed. Below this layer, the fourth layer was light gray in color with a small amount of aggregate particles and a small amount of large air-voids. This layer ranged in thickness from approx. a veneer up to approx. 1/16 of an inch thick. At the interface between the bottom surface of the fourth and fifth layers, a discontinuous fine separation was observed. The fifth layer was semi-elastic, moderately hard, gray colored material with a small amount of aggregate particles and a small amount of small air-voids. At the interface between the bottom surface of the fifth and sixth layers, a discontinuous fine separation was observed. The discontinuous, sixth layer was light gray-dull white in color and moderately hard and inflexible. This layer ranged in thickness from zero up to approx. 1/32 of an inch thick and exhibited very small amounts of aggregate particles and a small amount of small air voids. At the interface between the bottom surface of the sixth and seventh layers, a discontinuous fine separation was observed. The bottommost layer was dark gray-black in color, hard and semi-pliable with many aggregate particles (some which were fractured) and many large, irregularly shaped voids. This layer ranged in thickness from approx. a veneer up to approx. 1/16 of an inch thick.

At the interface of the applied coatings and the underlying base concrete, no cracks or separations were observed. A zone of carbonation was observed from approx. 1/8 up to ¼ of an inch thick. A small amount of microcracking was observed throughout the sample and most were infilled with off-white, fine crystalline material with similar optical properties as alkalic gel/carbonated alkalic gel. Approx. 4-1/8 inches below the top surface, an approx. ¼ of an inch steel bar was observed. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in small localized paste areas especially adjacent to the top surface, within several aggregate particles especially those exhibiting reaction rims, and in chert particles. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft, and subtly variegated from light brown in color with a small-very small amount of unhydrated cement particles to light brown-dull white in color with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The determined air-void system parameters are listed below in TABLE 1:

TABLE 1

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"106UD-P"	18.69	2,017	99.40	8.92	2.10	7.6	.0117	342.3	.0061

The inhomogeneously distributed voids were mostly small and spherically shaped with larger, spherically shaped voids also present. Fewer, larger, irregularly shaped voids were also observed. An abundant amount of clusters of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as coatings/linings and partial linings of clear-off-white material with the optical properties of the alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. A few particles exhibited reaction rims and a few particles exhibited small amounts of internal fractures.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, limestone, quartz sandstone and siltstone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures.

"116D"

GENERAL CONDITION: (See PLATES 5-8) The top surface was slightly rough/worn and generally flat with many, partially exposed fine aggregate particles in a recessed, moderately hard, material that exhibited several, fine cracks. Small amounts of fine cracks and small amounts of fine, loose, black material were also present at the exposed surface. A 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, no carbonation was observed. A small-moderate amount of microcracking was observed throughout the sample and most were infilled with off-white, fine crystalline material with similar optical properties as alkalic gel/carbonated alkalic gel. Approx. 4-1/4 inches below the top surface, an approx. ¼ of an inch steel bar was observed. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in small, localized paste portions. Yellow staining was also observed in the interiors of both coarse and fine aggregate particles, and at reaction rims sites. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and light brown- dull white in color with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The determined air-void system parameters are listed below in TABLE 2:

TABLE 2

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Samples	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
“116 D”	31.78	2,020	99.45	7.82	4.07	9.2	.0085	468.5	.0087

The inhomogeneously distributed voids were mostly small in size and ranged in shape from spherical-irregular. Several, larger, irregularly shaped voids were also present. A small amount of clusters of voids was observed throughout the sample. Numerous voids exhibited secondary, internal deposits as partial coatings/linings and coatings/linings of clear-off white material with the optical properties of the alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The inhomogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 3/4 of an inch. A central portion of the prepared surface exhibited an apparently lower concentration of coarse aggregate particles. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles, and one oolitic limestone particle. Several particles exhibited reaction rims and several particles exhibited small amounts of internal fractures. Also, a few small, irregular separations were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, quartz sandstone and siltstone and claystone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures.

“127D-P”

GENERAL CONDITION: (See PLATES 9-12) The top surface exhibited a dark gray-gray, moderately soft, heavily cracked, coating material with numerous, partially exposed fine aggregate particles. The observed fine cracks were very fine and were present at aggregate peripheries as well as localized areas at the exposed surface. A higher relief, discontinuous layer of similar material was present on a portion of the top surface and exhibited an almost continuous separation/crack at its base. Water initially beaded when applied to this surface and was moderately absorptive. An approx. 1 inch diameter, yellow paint “dot”, presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system was approx. 1/16 up to approx. 3/32 of an inch thick and appeared to be composed of four layers of material. The uppermost layer at/adjacent to the exposed surface was dark gray in color, ranged in thickness from a veneer up to approx. 1/32 of an inch, and appeared to be a top coat-type application that filled irregularities present in the underlying layer of material. This uppermost layer exhibited a very few, small voids but did not exhibit any aggregate particles. At the irregular interface between the two uppermost coating layers, a few very small cracks or separations were observed. Immediately below this layer, a discontinuous, light gray colored, soft, elastic material was observed with many aggregate particles and many air-voids present. This layer was observed from zero up to approx. 1/16 of an inch thick. At the interface with the third layer, no cracks or separations were observed. Both the third and fourth layers exhibited soft, elastic, gray material with many small air-voids. The total thickness of these layers ranged from approx. 1/32 up to approx. 1/16 of an inch. At the interface of these layers, a very faint application “line” was present with no apparent separations. At the bottom surface of the coating, a continuous separation/crack was present at the interface with the underlying base concrete or within the upper portion of the base concrete. Small-moderate amounts of adhered paste/mortar from the base concrete were also observed at/adjacent to the bottom surface of the fourth layer of coating material. No apparent carbonation was observed in the base concrete. A small-moderate amount of microcracking was observed throughout the sample and most were infilled with off-white, fine crystalline material with similar optical properties as alkalic gel/carbonated alkalic gel. A few, small separations were observed at several paste:aggregate interfaces. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in the majority of the paste. Yellow staining was also observed in many aggregate particles, at aggregate peripheries, and in reaction rims. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and light brown- dull white in color with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The determined, air-void system parameters are listed below in TABLE 3:

TABLE 3

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"127D-P"	19.83	2,012	99.05	6.26	3.17	7.8	.0080	498.5	.0064

The inhomogeneously distributed voids were mostly small and spherically shaped with larger, spherically shaped voids also present. Fewer, larger, irregularly shaped voids were also observed. A moderate amount of clusters of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as coatings/linings of clear-off-white material with the optical properties of the alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. A few particles exhibited reaction rims and several particles exhibited small amounts of internal fractures. Also, several, small, irregular separations were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and quartz sandstone particles. A few of the observed microcrystalline quartz chert particles exhibited reaction rims. Several particles exhibited internal fractures.

"130UD-P1"

GENERAL CONDITION: (See PLATES 13-16) The rough top surface exhibited both smooth, semi-elastic gray coating material and portions of moderately hard, dark gray-gray, heavily cracked, coating material with a many, partially exposed fine aggregate particles. In the smooth areas, the observed fine cracks were mostly located at exposed aggregate peripheries. Many aggregate sockets were observed over the exposed surfaces and many were partially infilled with loose, fine, black debris. Water initially beaded when applied to this surface and was slow-moderately absorptive. An approx. 1 inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system was approx. 1/8 of an inch thick and appeared to be composed of three layers of material. The uppermost layer at/adjacent to the exposed surface was dark gray in color, ranged in thickness from a veneer up to approx. 1/32 of an inch, and appeared to be a top coat-type application that filled irregularities present in the underlying layer of material. This uppermost layer exhibited a very few, small voids but did not exhibit any aggregate particles. At the irregular interface between the two uppermost coating layers, no cracks or separations were observed. Immediately below this layer, a discontinuous, light gray colored, soft, elastic material was observed with many aggregate particles and many air-voids present. This layer was observed from zero up to approx. 1/16 of an inch thick. At the interface with the third layer, no cracks or separations were observed. The third layer was soft, elastic, light gray in color and was observed up to approx. 1/16 of an inch thick. At the bottom surface of this layer, an almost continuous, separation/crack was present with small amounts of adhered paste/mortar from the base concrete. A zone of carbonated paste was present in the upper portion of the base concrete from a veneer up to approx. 1/8 of an inch thick. A small-moderate amount of microcracking was observed throughout the sample and most were infilled with off-white, fine crystalline material with similar optical properties as alkalic gel/carbonated alkalic gel. Approx. 1-3/4 and 2-5/8 inches below the top surface, two approx. ¼ of an inch steel bars were observed. The majority of the bottom surface was a smooth and flat formed surface with the remaining portion being a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in several, small portions of the paste. Yellow staining was also observed in several coarse and fine aggregate particles.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from pale brown-light gray in color with a small amount of unhydrated cement particles to pale brown-dull white with a very small-small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 4:

TABLE 4

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			ι	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"130UD-P1"	21.6	1,696	83.50	10.0	2.16	8.7	.012	346	.006

The inhomogeneously distributed voids were mostly small and spherically shaped with small and irregularly shaped voids present. Fewer, larger spherical-irregularly shaped voids also observed. An abundant amount of clustering of voids was observed throughout the sample. Many voids exhibited secondary, internal deposits as coatings/linings of clear-off white material with the optical properties of alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-rounded in shape with an observed topsize of ¾ of an inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. A few particles exhibited reaction rims and several particles exhibited small amounts of internal fractures. Also, several, small, irregular separations were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and quartz sandstone particles. A few particles exhibited reaction rims. Several particles exhibited a small amount of internal fractures.

"130UD-P2"

GENERAL CONDITION: (See PLATES 17-20) The rough top surface exhibited a majority of smooth, semi-elastic gray coating material and smaller portions of moderately hard, dark gray-gray, heavily cracked, coating material with a many, partially exposed fine aggregate particles. In the smooth areas, the observed fine cracks were mostly located at exposed aggregate peripheries. Many aggregate sockets were observed over the exposed surfaces and many were partially infilled with loose, fine, black debris. Water initially beaded when applied to this surface and was slow-moderately absorptive. An approx. 1 inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system was approx. 1/16 up to approx. 3/32 of an inch thick and appeared to be composed of three layers of material. The uppermost layer at/adjacent to the exposed surface was dark gray in color, ranged in thickness from a veneer up to approx. 1/32 of an inch, and appeared to be a top coat-type application that filled irregularities present in the underlying layer of material. This uppermost layer exhibited a very few, small voids but did not exhibit any aggregate particles. At the irregular interface between the two uppermost coating layers, no cracks or separations were observed. Immediately below this layer, a discontinuous, light gray colored, soft, elastic material was observed with many aggregate particles and many air-voids present. This layer was observed from zero up to approx. 1/16 of an inch thick. At the interface with the third layer, no cracks or separations were observed. The third layer was soft, elastic, light gray in color and was observed from 1/32 of an inch up to approx. 1/16 of an inch thick. At the bottom surface of this layer, an almost continuous, separation/crack was present with small amounts of adhered paste/mortar from the base concrete. No apparent carbonation was observed in the base concrete. A small-moderate amount of microcracking was observed throughout the sample and most were infilled with off-white, fine crystalline material with similar optical properties as alkalic gel/carbonated alkalic gel. The bottom surface was a fractured surface with a linear, approx. ¼ of an inch diameter impression present.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in several, small portions of the paste. Yellow staining was also observed in several coarse and fine aggregate particles.

CEMENTITIOUS MATRIX: The highly water absorptive, cement paste matrix was, moderately soft-moderately hard, and variegated in color from light brown-pale gray in color with a small amount of unhydrated cement particles to light brown-dull white with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 5:

TABLE 5

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α $in.^{-1}$	L in.
"130UD-P2"	21.8	1,892	93.20	6.7	3.25	7.4	.009	440	.007

The inhomogeneously distributed voids were mostly small and spherically shaped with fewer, larger, spherical to irregularly shaped voids also present. A moderate-abundant amount of clustering of voids was observed throughout the sample. Many secondary, internal deposits were observed as linings/coatings and partial linings of clear-off white material with similar optical properties of alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-rounded in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. A few aggregate particles exhibited partial reaction rims and several particles exhibited internal fractures. A few, small, irregular separations were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, limestone, quartz sandstone and siltstone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures.

DISCUSSION & CONCLUSION

We received five core portions of hardened concrete to determine the general condition of the concrete(s). It was reported that the submitted samples were taken from the plaza level concourse. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

The determined air-void system parameters are listed below in TABLE 6:

TABLE 6

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α $in.^{-1}$	L in.
"106UD-P"	18.69	2,017	99.40	8.92	2.10	7.6	.0117	342.3	.0061
"116 D"	31.78	2,020	99.45	7.82	4.07	9.2	.0085	468.5	.0087
"127D-P"	19.83	2,012	99.05	6.26	3.17	7.8	.0080	498.5	.0064

The estimated air-void system parameters are listed below in TABLE 7:

TABLE 7

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"130UD-P1"	21.6	1,696	83.50	10.0	2.16	8.7	.012	346	.006
"130UD-P2"	21.8	1,892	93.20	6.7	3.25	7.4	.009	440	.007

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi.

- All samples are considered to be air-entrained.
- Overall, the observed aggregates in each sample exhibited reaction rims and internal fractures. Alkalic gel deposits were observed in all samples. The results of staining using cobaltinitrite showed active gels in paste and aggregates. These features strongly suggest that the collective aggregate should not be considered "durable" due to susceptibility to alkali-silica reactivity.
- The estimated and determined spacing factors were all (except Sample **"116D"**) under (acceptable) the recommended, industry standard limit maximum of 0.0080 inches, and should be considered inadequate for exposure in a water-saturated, cyclic, freeze-thaw environments.
- The compressive strength(s) of the concrete represented by this sample/mix design is unknown and comments regarding this will not be made.

Only small amounts, if any, of carbonation were observed in the examined core samples.

Based on this examination, the most possible cause of the reported distress, as represented by the submitted samples, is active alkali-aggregate reactivity. Based on this examination and observations including aggregate features and the presence/degree of observed microcracking, the general conditions are all deemed "Poor".

Most samples exhibited a small-moderate amount of microcracking (except "small" in Sample**"106UD-P"**), alkalic gel, with roughly equal amounts of aggregate distress. Most samples exhibited small, irregular separations at aggregate peripheries(except in Sample**"106UD-P"**). Cobaltinitrite staining showed yellow staining of the pastes as follows in order of decreasing abundance: **"127D-P"**, **"116D"**, **"106UD-P"**, and **"130UD-P1"/"130UD-P2"**.

An inadequate air-void systems can be likely contributing factors to deficiencies or potential failure and/or further degradation for the concrete represented by Sample **"116 D"** .

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (e.g., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur. Differences in exposure conditions, especially exposure to water, can account for apparent physical changes in condition of the examined samples.

JR Varga

J. R. Varga, Concrete Petrographer

The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_3B.pdf
- Online version of Plates 1-15 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_3B_1_12.pdf
- Online version of Plates 16-24 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_3B_13_20.pdf

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 3B
PLAZA LEVEL CONCOURSE "106UD-P"

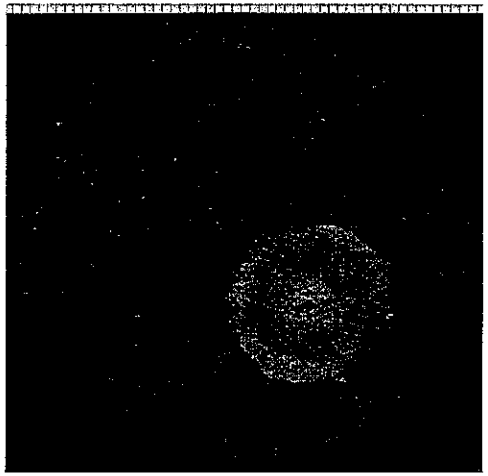


PLATE 1
TOP SURFACE

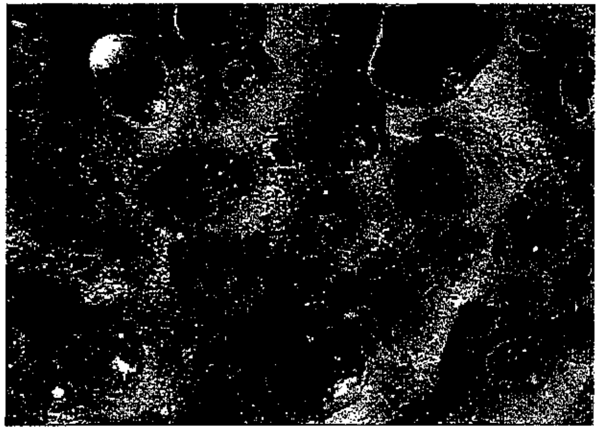


PLATE 2
TOP SURFACE "106UD-P" SHOWING
PARTIALLY EXPOSED AGGREGATES IN
GRAY-LIGHT GRAY MATERIAL

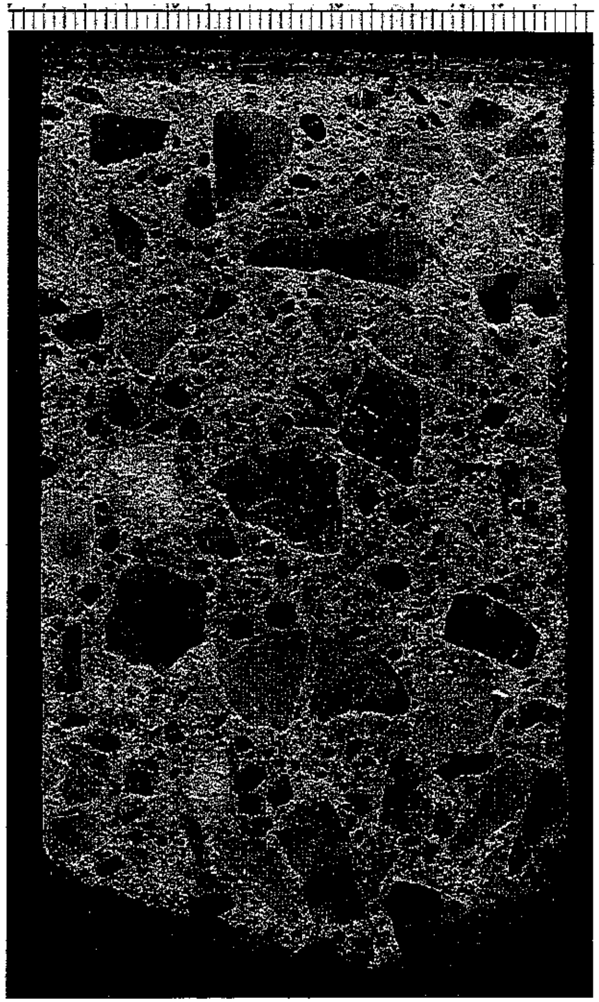


PLATE 3
PREPARED SURFACE
"106UD-P"

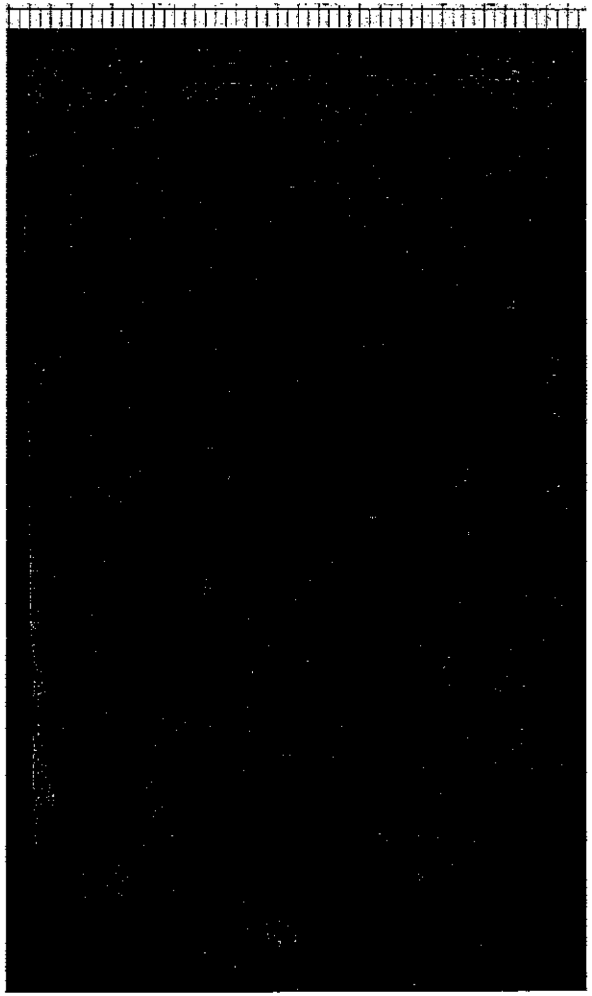


PLATE 4
PREPARED SURFACE "106UD- P"
SHOWING LOCALIZED YELLOW
STAINING IN PASTE AND WITHIN
MANY AGGREGATE PARTICLES
AFTER COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 3B
PLAZA LEVEL CONCOURSE "116D"

PLATE 5
TOP SURFACE

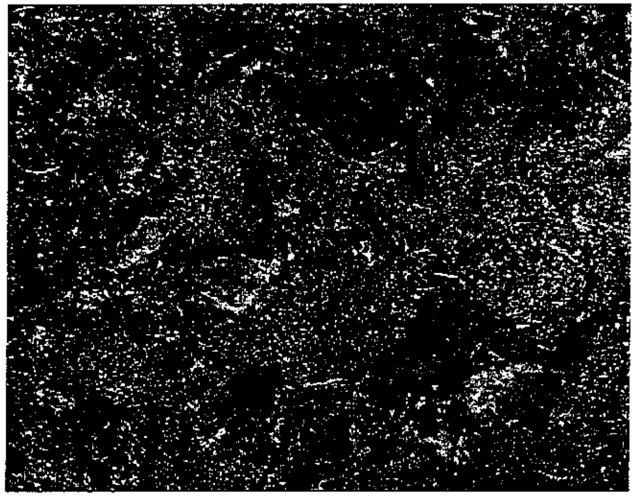


PLATE 6
TOP SURFACE "116D" SHOWING ROUGH TEXTURE
WITH PARTIALLY EXPOSED AGGREGATES

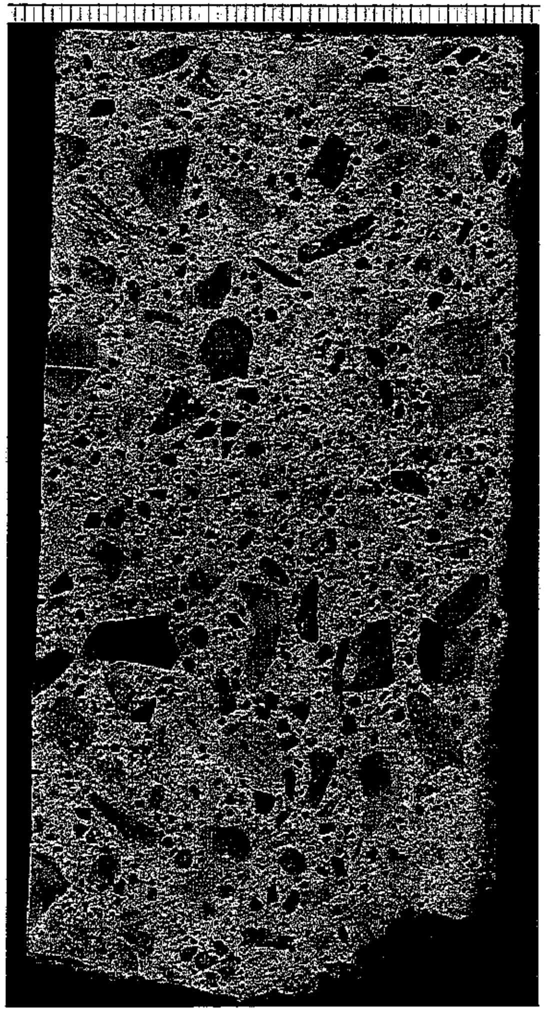


PLATE 7
PREPARED SURFACE
"116D"

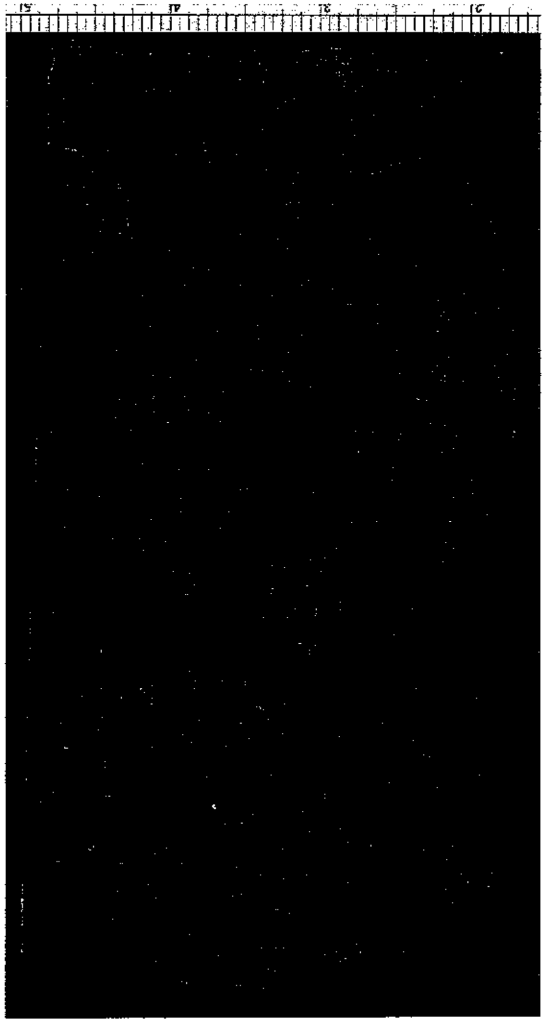


PLATE 8
PREPARED SURFACE "116D"
SHOWING LOCALIZED, YELLOW
STAINING IN PASTE AND WITHIN
MANY AGGREGATE PARTICLES
AFTER COBALTINITRITE
STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 3B
PLAZA LEVEL CONCOURSE "127D-P"

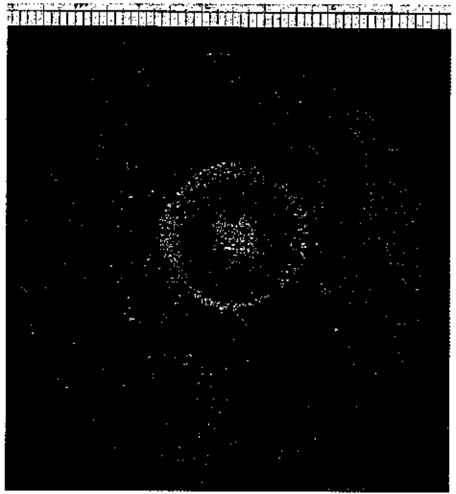


PLATE 8
TOP SURFACE

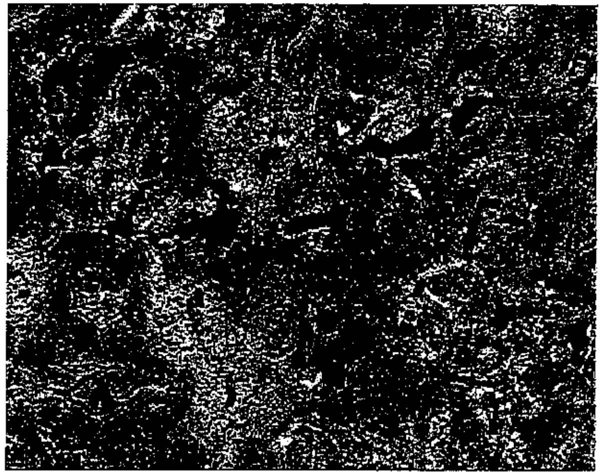


PLATE 9
TOP SURFACE SHOWING HEAVILY
CRACKED DARK GRAY-GRAY
COATING MATERIAL

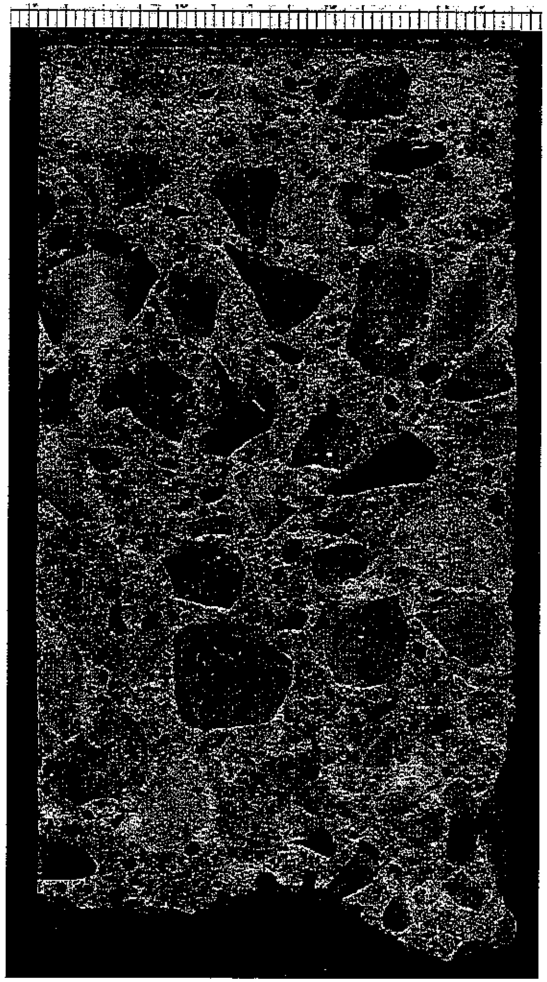


PLATE 10
PREPARED SURFACE
"127D-P"

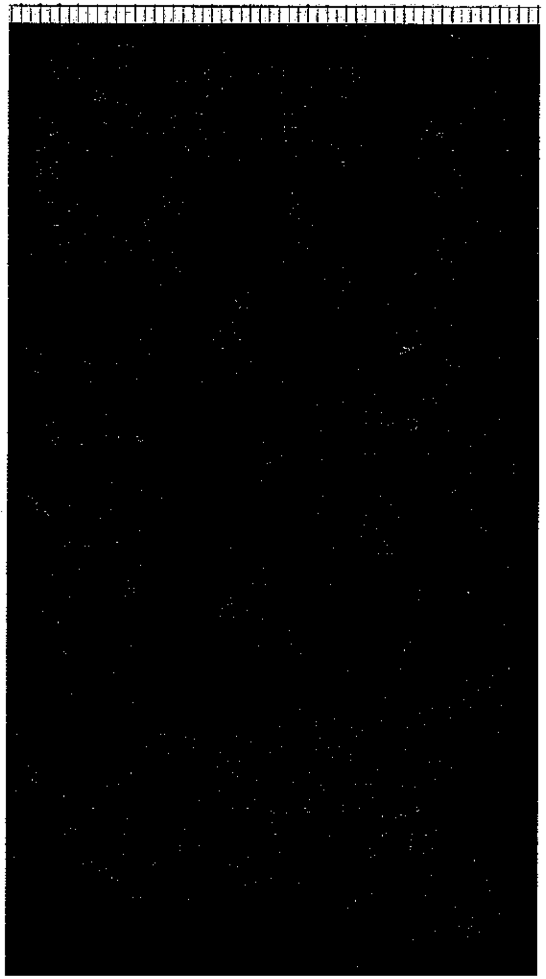


PLATE 11
PREPARED SURFACE "127D-P"
SHOWING YELLOW STAINING IN
MAJORITY OF PASTE AND
WITHIN AGGREGATE
PARTICLES AFTER
COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 3B
PLAZA LEVEL CONCOURSE “130UD-P1”

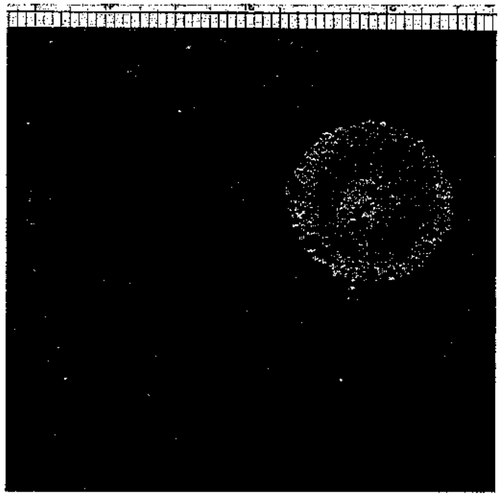


PLATE 13
TOP SURFACE

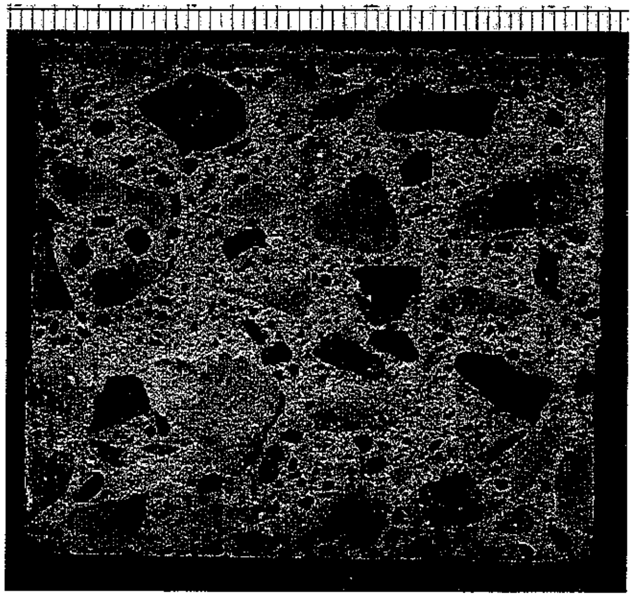


PLATE 15
PREPARED SURFACE
“130UD-P1”

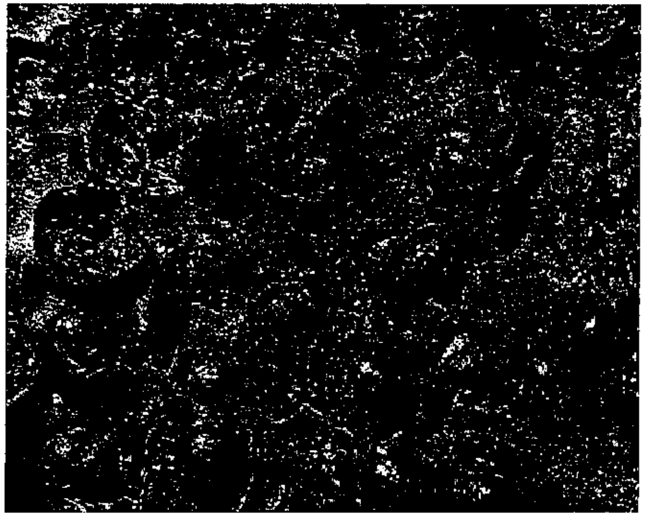


PLATE 14
TOP SURFACE “130UD-P1” SHOWING BOTH HEAVILY CRACKED AND SMOOTH, DARK GRAY-GRAY COATING MATERIALWITH EXPOSED AGGREGATES

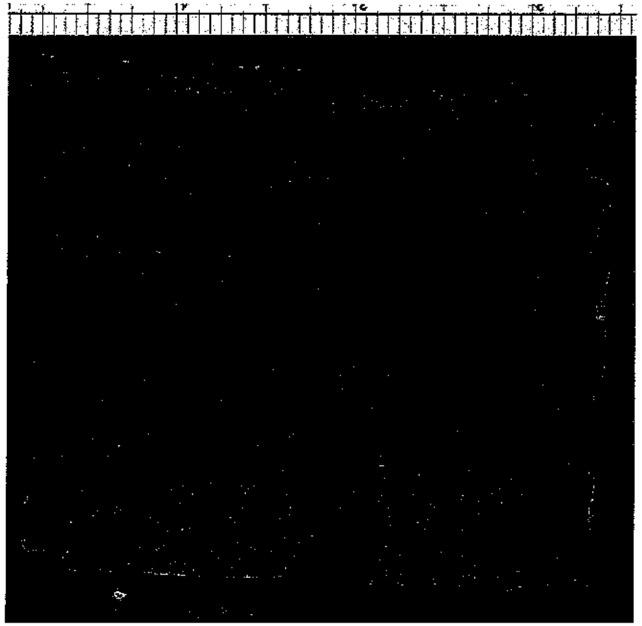


PLATE 16
PREPARED SURFACE “130UD-P1” SHOWING LOCALIZED YELLOW STAINING IN PASTE AND WITHIN MANY AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 3B
PLAZA LEVEL CONCOURSE "130UD-P2"

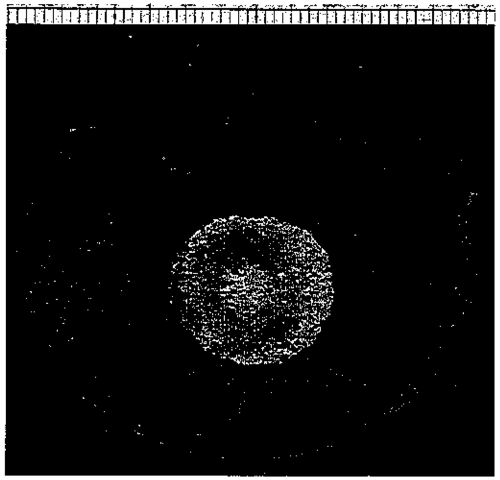


PLATE 17
TOP SURFACE

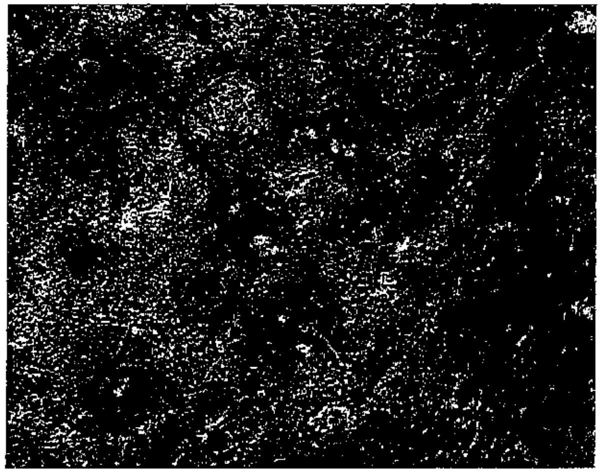


PLATE 18
TOP SURFACE "130UD-P2" SHOWING BOTH FINELY CRACKED AND SMOOTH, DARK GRAY-GRAY COATING MATERIALWITH EXPOSED AGGREGATES

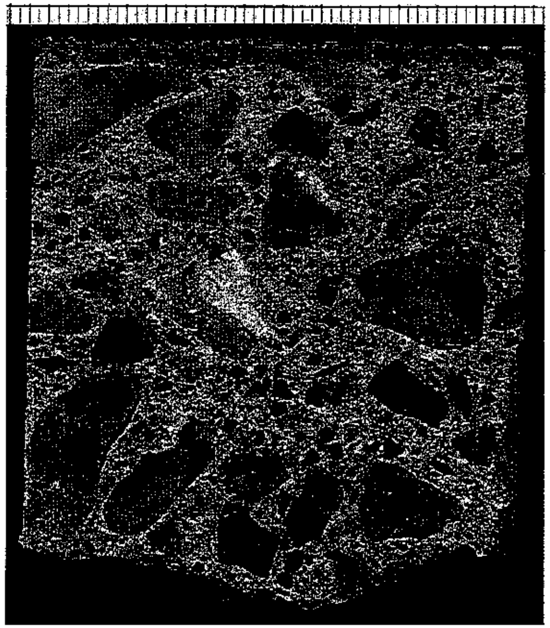


PLATE 19
PREPARED SURFACE
"130UD-P2"

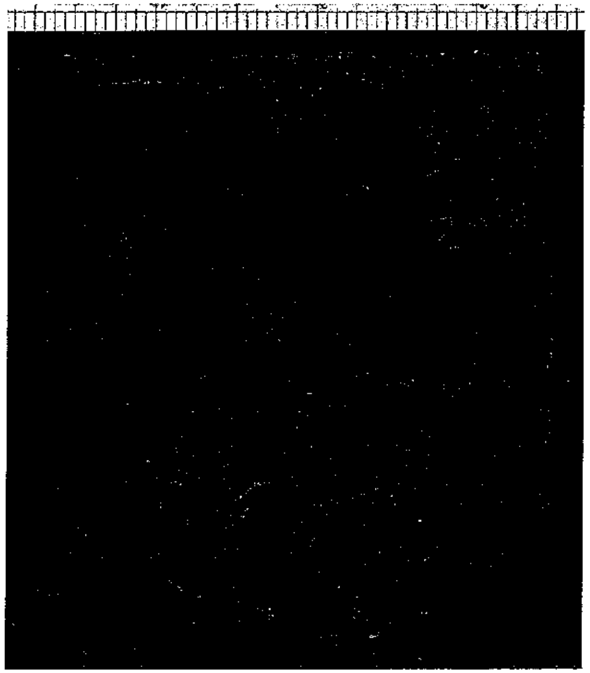


PLATE 20
PREPARED SURFACE "130UD-P2" SHOWING LOCALIZED, YELLOW STAINING IN PASTE AND WITHIN MANY AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

THE ROCK DOCTOR
CONCRETE SOLUTIONS FOR CONCRETE PROBLEMS

INTERIM PETROGRAPHIC REPORT

DATE:	September 24, 2007
WORK ORDER:	07-08-31-01 / Group 4 Pedestal and Upper Raker
CLIENT:	Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY:	Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received three core portions of hardened concrete reported to be from "Pedestals" and four core portions of hardened concrete reported to be "Upper Rakers" to determine the general condition of the concrete(s). The core portions from the "Pedestals" were marked **"423 P"**, **"400 P"**, and **"424 P"**. The core portions measured, in length, approximately 6-3/4, 6-3/4, and 8 inches, respectively. The core portions were approximately 2-1/4 inches in diameter.

The core portions from the "Upper Rakers" were marked **"339R-P1"**, **"339R-P2"**, **"340R-P1"** and **"340R-P2"**. The core portions measured, in length, approximately 6-3/4, 7, 5-1/2, and 4-1/2 inches, respectively. The core portions were approximately 3-1/8 inches in diameter.

It was reported that the submitted sample sets were taken from pedestals and upper raker areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

Results of Petrographic examinations for Samples **"423 P"** and **"339R-P1"** are initially reported in this Interim Report. Results of Petrographic examinations for the remaining samples will follow.

SAMPLE PREPARATION AND METHODS

The core samples were cut in half, approximately perpendicular to the top surfaces. The cut surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were determined following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters.

The unprepared samples were partially immersed in water for at least three days to mobilize any alkalic gels present. The cut surfaces of the core portion samples were not immersed in water.

The unprepared portion of Samples **"423 P"** was stained using a saturated, aqueous solution of sodium cobaltinitrite (reacts with soluble potassium to produce a yellow precipitate resulting in staining potassium-rich ASR gel) following the guidelines in a July 1998 report titled *"Geochemical Methods for the Identification of ASR Gel"* by Guthrie and Carey, Los Alamos National Laboratory . In addition, a saturated, aqueous solution of Rhodamine B was similarly used to aid this staining procedure by highlighting (providing a high contrast background) the regions of yellow-stained ASR gel and in part, to identify other degradation products.

The prepared and unprepared samples were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

"423 P"

GENERAL CONDITION: (See PLATES 1-6) The top surface exhibited a rough, heavily cracked, moderately hard, semi-elastic, membrane/coating that was mottled in color from gray to dark gray. Water readily was moderate-slowly absorptive on this surface. A few, partially exposed fine quartz aggregate particles, and a few fine, Y-shaped cracks were present at the exposed surface. These Y-shaped cracks exhibited light brown material-dull white within the cracks and at crack edges. This material with similar optical properties of alkalic gel and carbonated alkalic gel.

In section, the observed membrane/coating was ranged in thickness from a veneer up to approx. 1/32 of an inch and appeared to be composed of one layer. A small amount of small voids and few fine aggregate particles were observed in this coating material. At the bottom surface of this layer, a discontinuous, adhered layer of paste/mortar from the base concrete was observed. Also, a discontinuous separation/crack was present at or near the interface of the coating and the base concrete. A veneer of carbonated paste was observed at the top surface of the base concrete. A moderate-abundant amount of microcracking was observed throughout the sample. Most of the observed microcracks were infilled with light brown-off white material with similar optical properties of alkalic gel and carbonated alkalic gel. Fine cracks as well as microcracks transected paste and aggregate particles. After immersion in water, the sample trimming was allowed to dry for one day and was then stained using sodium cobaltinitrite and Rhodamine B.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in the paste and a few aggregate particles and associated cracks, PLATE 4. Yellow staining was observed in light brown, fossiliferous limestone particles in the coarse aggregate, in the secondary, internal deposits a few voids, as paste "halos" at aggregate peripheries, within internal fractures in a few aggregate particles, and in microcrystalline quartz chert particles in the fine aggregate portions. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

The bottom surface was a fractured surface and exhibited a few alkalic gel exudations on interior portions of exposed, fractured coarse aggregate surfaces.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light brown with a small amount of unhydrated cement particles to light brown-dull white in color, with a very small amount of unhydrated cement particles. The lighter colored paste areas were softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 1:

TABLE 1

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"423 P"	28.19	2,004	98.00	5.99	4.71	4.4	.0136	294.5	.0153

The inhomogeneously distributed voids were mostly spherically shaped and ranged in size from small to large with fewer, larger, irregularly shaped voids also observed. A very small amount of clusters of voids was observed throughout the sample. Almost all observed voids exhibited infillings, partial linings and coatings of clear to off white material with similar optical properties of alkalic gel and carbonated alkalic gel. Many voids exhibited secondary, internal deposits as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\ H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subangular in shape with an observed topsize of 3/4 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Many particles exhibited internal fractures. An abundant amount of reaction rims were observed. Many particles exhibited both reaction rimming and internal fracturing. Veneers of darker-colored paste and mortar were observed at several aggregate peripheries especially the fossiliferous limestone particles.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, limestones, microcrystalline quartz chert, and siltstone/shale particles. Many particles exhibited internal fractures. Several particles exhibited reaction rims especially microcrystalline quartz chert particles.

"339R-P1"

GENERAL CONDITION: (See PLATES 7-9) The highly water absorptive, top surface was generally flat and smooth and composed mostly of paste with several air-void septa observed. Small, fine, brown-rust-red deposits were also present. An approx. 1-inch diameter circular spot of yellow-colored paint material and "+"-shaped yellow material, presumed to be used for marking purposes, were also present at the exposed surface.

In section, a continuous zone of carbonated paste was observed with a thickness of 1/32 of an inch up to approx. 3/8 of an inch thick. A small amount of microcracking was observed throughout the sample. Most of these microcracks were infilled with light brown-off white material with similar optical properties of alkalic gel and carbonated alkalic gel. After immersion in water, the sample trimming exhibited a localized, clear exudations of material with the optical properties of alkalic gel on cut surface. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, soft-moderately hard, and variegated from pale gray-light brown with a small amount of unhydrated cement particles to dull white with a very small amount of, if any, unhydrated cement particles. The lighter colored paste areas were markedly softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 2:

TABLE 2

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"339R-P1"	15.67	2,023	99.70	8.21	1.91	2.7	.0306	130.5	.0146

The homogeneously distributed voids were spherically shaped and ranged in size from small to large with several, larger, irregularly shaped voids also present. The determined air content and air-void system parameters were likely affected by the presence of these large voids. In many voids, secondary, internal deposits of clear to off-white material with similar optical properties of alkalic gel and carbonated alkalic gel were observed as partial linings and coatings. In most of the larger, irregularly shaped voids, thicker deposits were observed with an apparently, preferred occurrence to the "left"-side of the prepared sample surface. Th core location/orientation is unknown.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subangular in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Many particles exhibited internal fractures and a few particles exhibited reaction rims. A few particles exhibited both reaction rimming and internal fracturing.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and claystone particles. A few reactions rims were observed especially associated with microcrystalline quartz chert particles. Many particles exhibited internal fractures.

DISCUSSION & CONCLUSION

We received seven core portions of hardened concrete to determine the general condition of the concrete(s). It was reported that the submitted samples were taken from pedestals and upper raker areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

Results of Petrographic examinations for Samples **"423 P"**, and **"339R-P1"** are initially reported in this Interim Report. Results of Petrographic examinations for the remaining samples will follow.

The air-void system parameters for all samples are listed below in TABLE 3:

TABLE 3

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	$\bar{l}$ in.	α in.$^{-1}$	L in.
"423 P"	28.19	2,004	98.00	5.99	4.71	4.4	.0136	294.5	.0153
"339R-P1"	15.67	2,023	99.70	8.21	1.91	2.7	.0306	130.5	.0146

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi. The examined samples are considered to be air-entrained. Overall, the observed aggregates exhibited signs or evidence of reactivity including internal fractures and reaction rims. After water immersion, alkalic gel exudations were present in Sample **"339R-P1"**. Distinct and highly localized staining of reactive aggregates and paste regions (as observed and described above for Sample **"423 P"**) with sodium cobaltinitrite confirms ASR. Physical distress features (associated with ASR) strongly suggest active/ongoing alkali-silica reactivity. The determined spacing factors were over the recommended, industry standard limit maximum of 0.0080 inches and are considered unacceptable for freeze-thaw durability in water saturated environments. The compressive strength(s) of the concrete represented by this sample/mix design is unknown and comments regarding this will not be made.

All Portland cement based concretes will carbonate over time. When carbonation occurs early in the life of the concrete, the strength development of the affected area can be compromised. The samples exhibited various depths of carbonated paste. However, the carbonated zones and the respective bulk pastes exhibited similar hardnesses. This suggests that the carbonation had occurred over the service lives of the concretes.

Based on this examination, the the general condition of the concrete(s), including aggregate features and the presence/degree of observed microcracking, were deemed:

"423 P" - Very Poor - exhibited moderate-abundant amounts of microcracking and abundant aggregate distress features

"339R-P1" - Poor - exhibited small amounts of microcracking and aggregate distress

The most possible cause for observed distress, as represented by the submitted samples, is active alkali-aggregate reactivity. Differences in exposure conditions, especially exposure to water, can account for these relative, different physical conditions. Inadequate air-void systems can be likely contributing factors to deficiencies, potential failure, and/or further degradation under similar exposure conditions. However, no marked evidence of freeze-thaw distress was observed.

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (e.g., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur. Differences in exposure conditions, especially exposure to water, can account for apparent physical changes in condition of the examined samples. If the ASR is left unchecked, expansion will continue until moisture is removed, the source of alkalis is depleted, or the reactive silica components are consumed.

JR Varga

J. R. Varga, Concrete Petrographer

The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_4.pdf
- Online version of this Plates 1-9 report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_4_1_9.pdf

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 4
PEDESTAL SAMPLE “423 P”

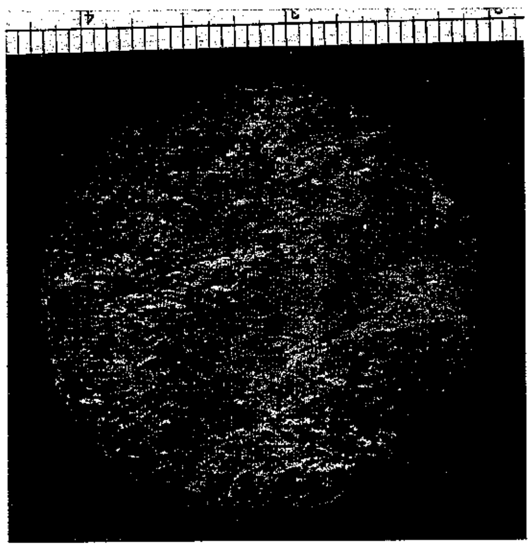


PLATE 1
TOP SURFACE

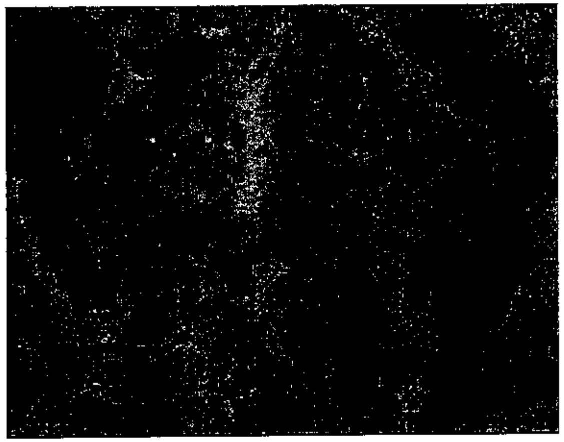


PLATE 2
TOP SURFACE SHOWING HEAVILY
CRACKED GRAY COATING
MATERIAL AND ONE EXPOSED FINE
AGGREGATE PARTICLE

PLATE 3
PREPARED SURFACE

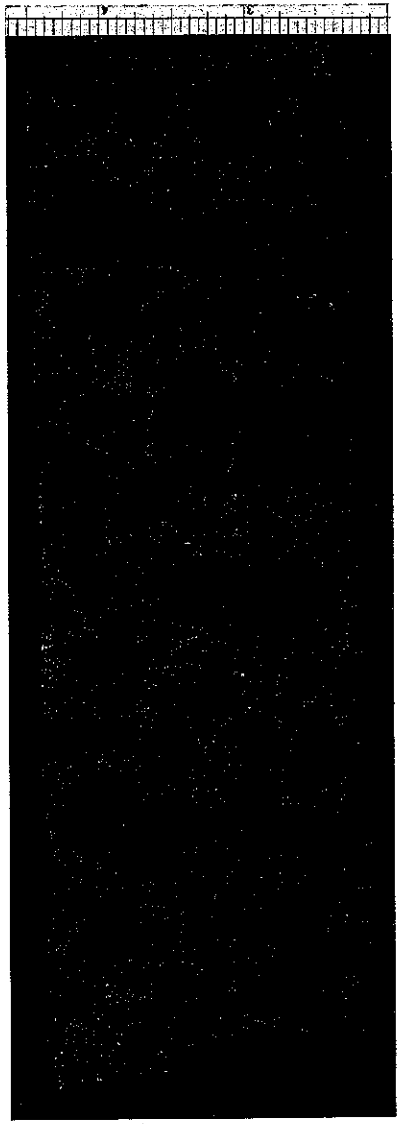


PLATE 4
CUT SURFACE OF SAMPLE TRIMMING AFTER
WATER IMMERSION
WIDESPREAD YELLOW STAINING OF PASTE AND
A FEW AGGREGATE PARTICLES
MAJORITY OF CRACKS EXHIBIT PINK STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 4
PEDESTAL SAMPLE "423 P"

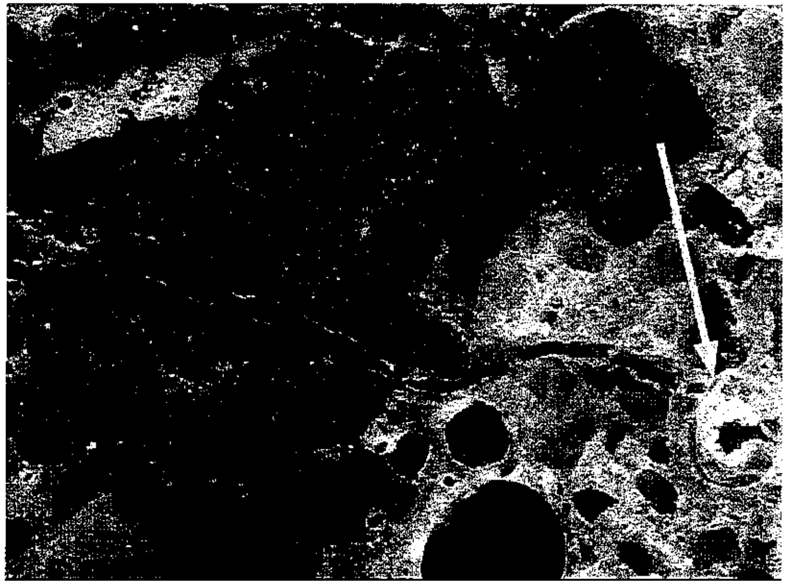


PLATE 5

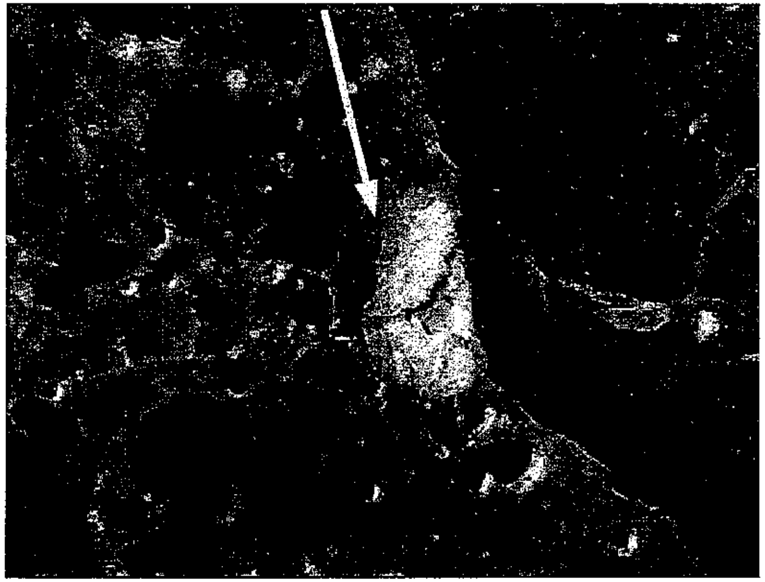


PLATE 6

PLATES 5 AND 6
PREPARED SURFACE SHOWING CRACKING THROUGH AGGREGATE PARTICLES AND ADJACENT PASTE REGIONS
CRACKED, CLEAR-OFF WHITE ALKALIC GEL EXUDATIONS IN VOIDS SHOWN BY YELLOW ARROWS

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 4
UPPER RAKER "339R-P1"

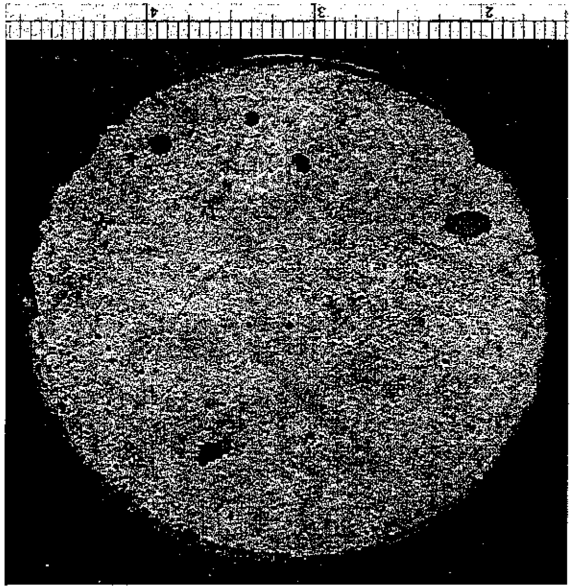


PLATE 7
TOP SURFACE

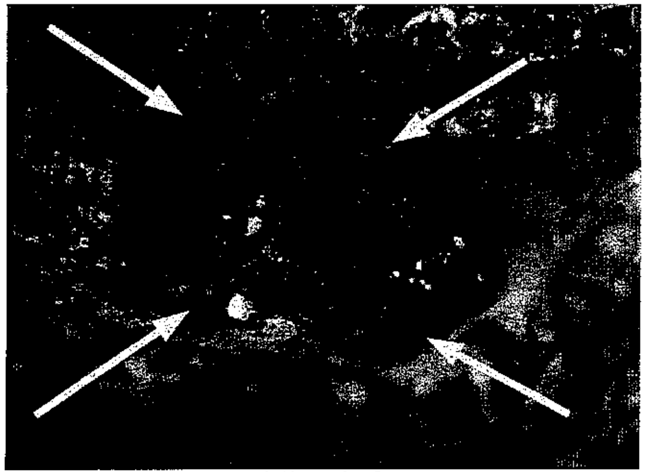


PLATE 8
CUT SURFACE SHOWING CLEAR ALKALIC GEL
EXUDATION IN BOTTOM OF VOID AFTER
WATER IMMERSION

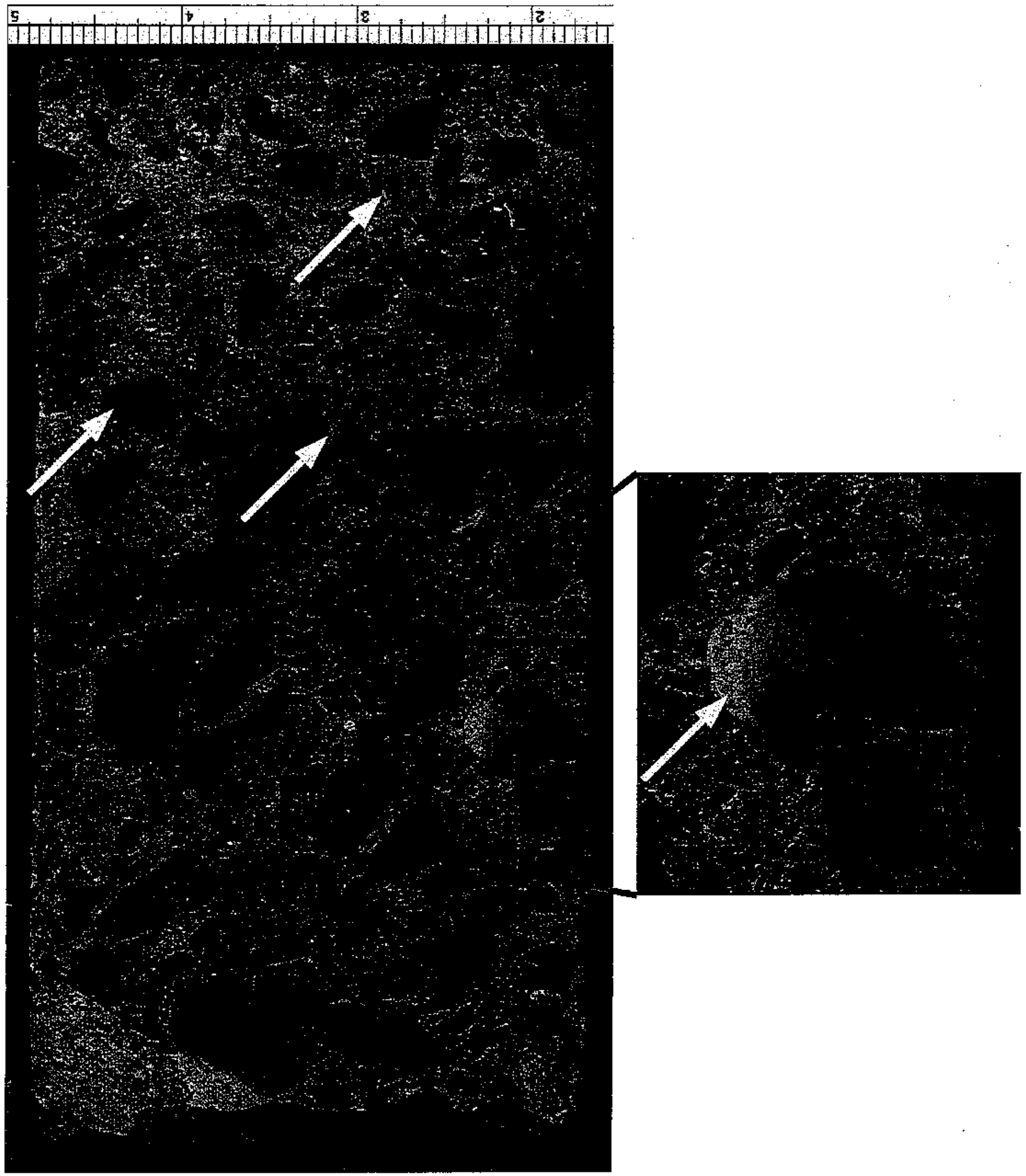


PLATE 9
PREPARED SURFACE WITH YELLOW ARROWS AND RED BOX SHOWING
DEPOSITS IN LARGER IRREGUARLY SHAPED VOIDS

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 4

PEDESTAL SAMPLE "400 P"

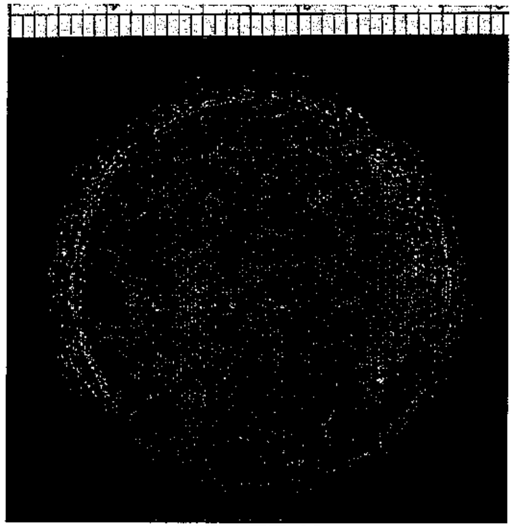


PLATE 10
TOP SURFACE

PLATE 11
TOP SURFACE SHOWING
HEAVILY FRACTURED GRAY
COATING MATERIAL

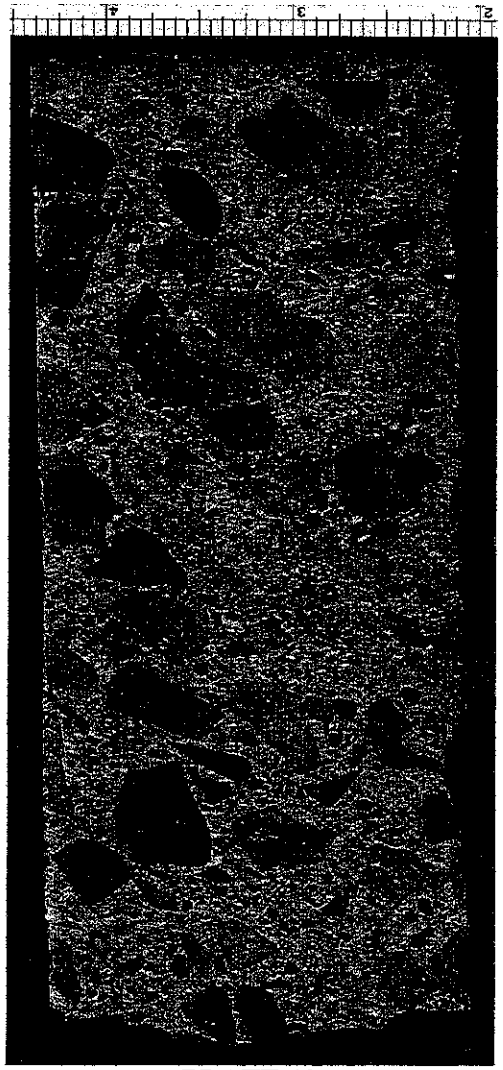


PLATE 12
PREPARED SURFACE

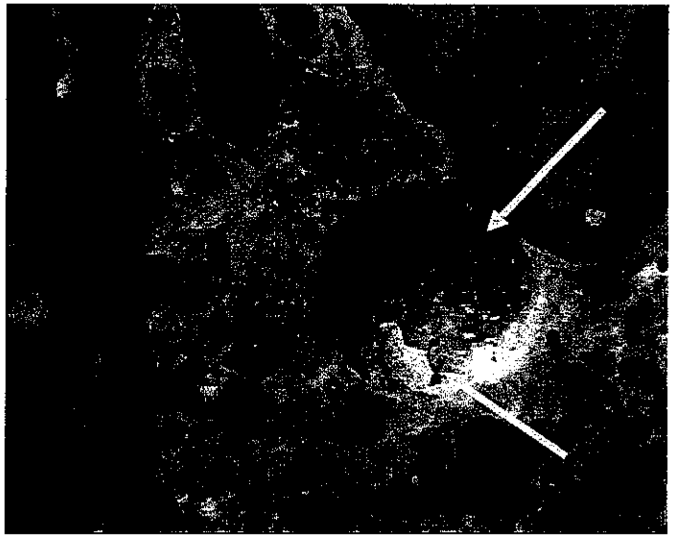


PLATE 13
PREPARED SURFACE SHOWING
PARTIAL INFILLING OF VOID WITH
CLEAR-WHITE
ALKALIC GEL (YELLOW ARROWS)

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 4
PEDESTAL SAMPLE “424 P”

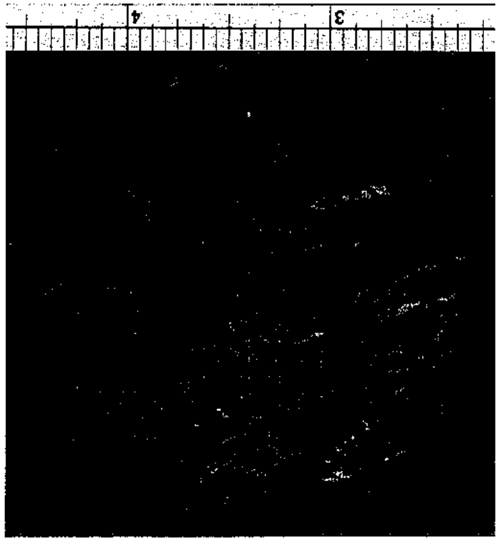


PLATE 14
TOP SURFACE

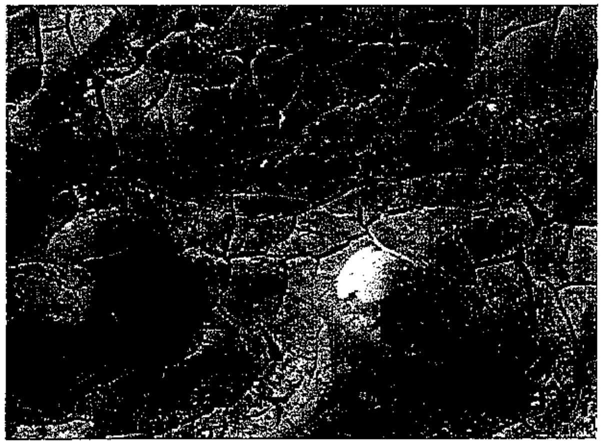


PLATE 15
TOP SURFACE SHOWING HEAVILY FRACTURED GRAY COATING MATERIAL

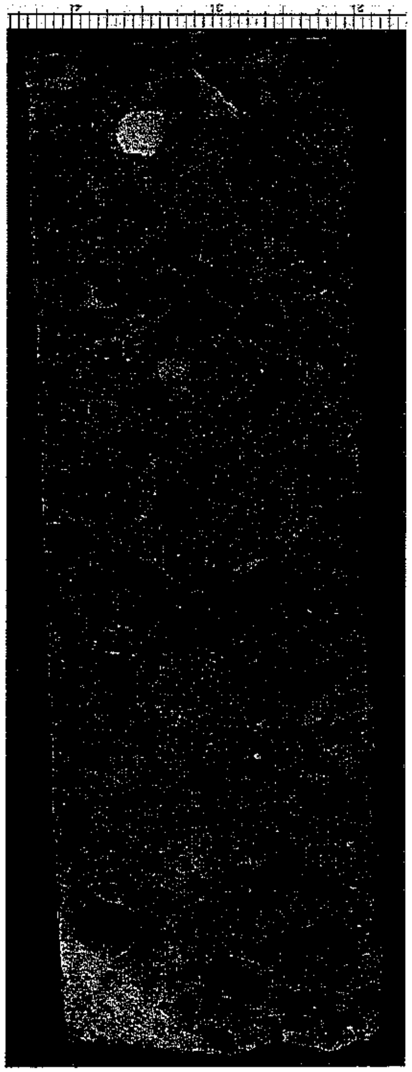


PLATE 16
PREPARED SURFACE


PLATE 17
PREPARED SURFACE SHOWING PARTIAL INFILLING OF CRACKED, WHITE ALKALIC GEL IN VOID (YELLOW ARROW)

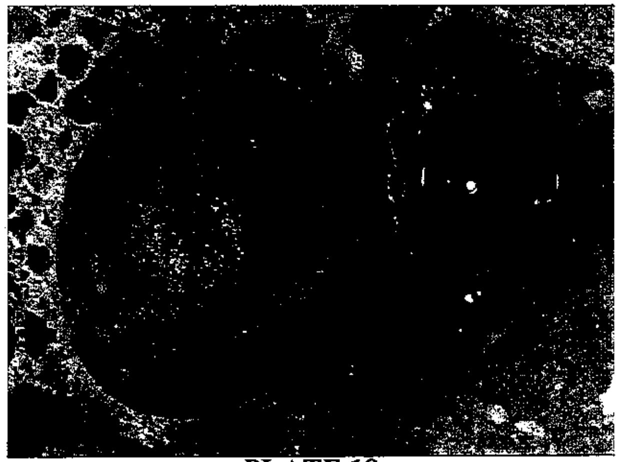


PLATE 18
PREPARED SURFACE SHOWING CLEAR GEL EXUDATIONS IN VOIDS AND SURROUNDING PASTE

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 4

UPPER RAKER SAMPLE “339R-P2”

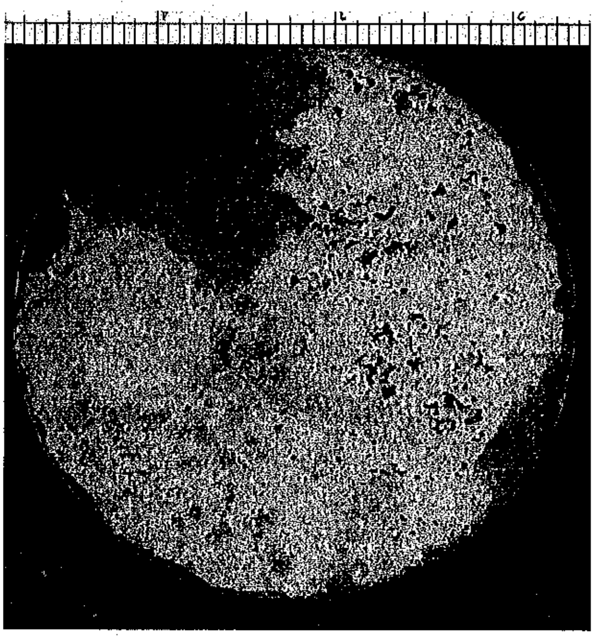


PLATE 19
TOP SURFACE

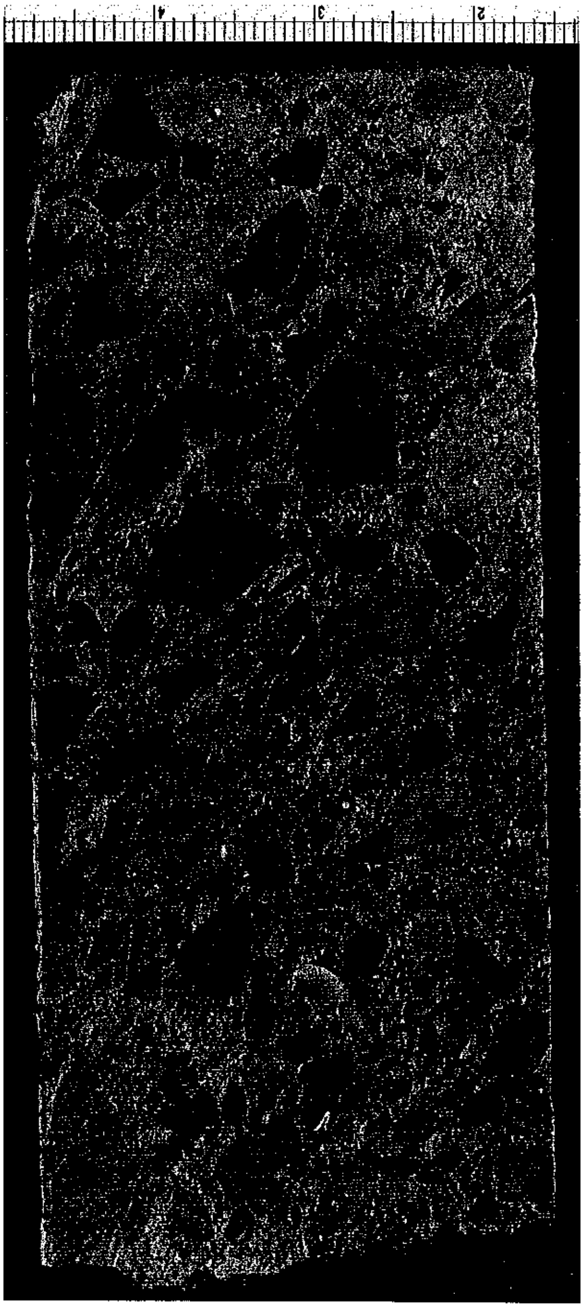


PLATE 20
PREPARED
SURFACE

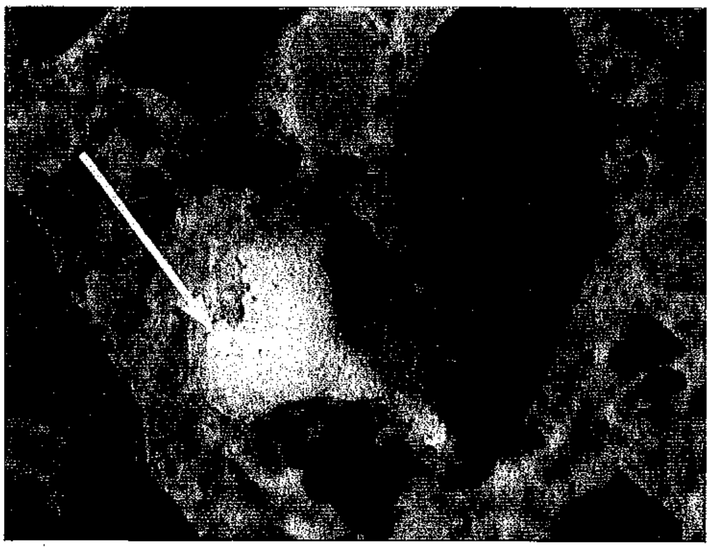


PLATE 21
PREPARED SURFACE SHOWING PARTIAL
INFILLING OF VOID WITH CLEAR-WHITE
ALKALIC GEL (YELLOW ARROW)

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 4
UPPER RAKER SAMPLE "340R-P1"

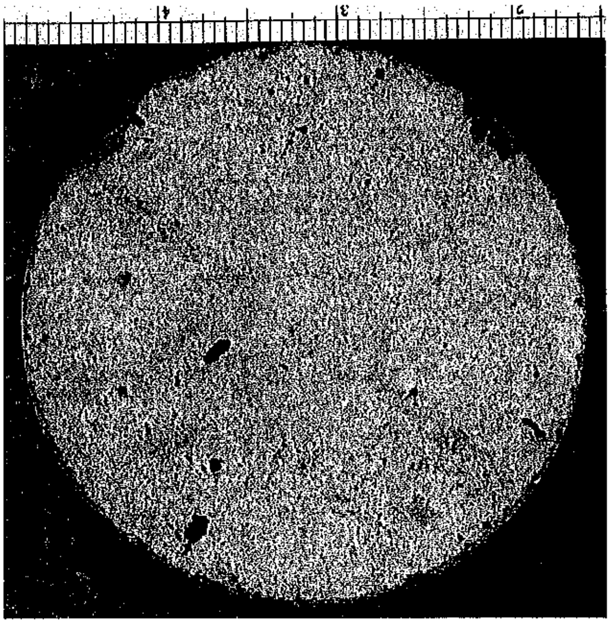


PLATE 22
TOP SURFACE

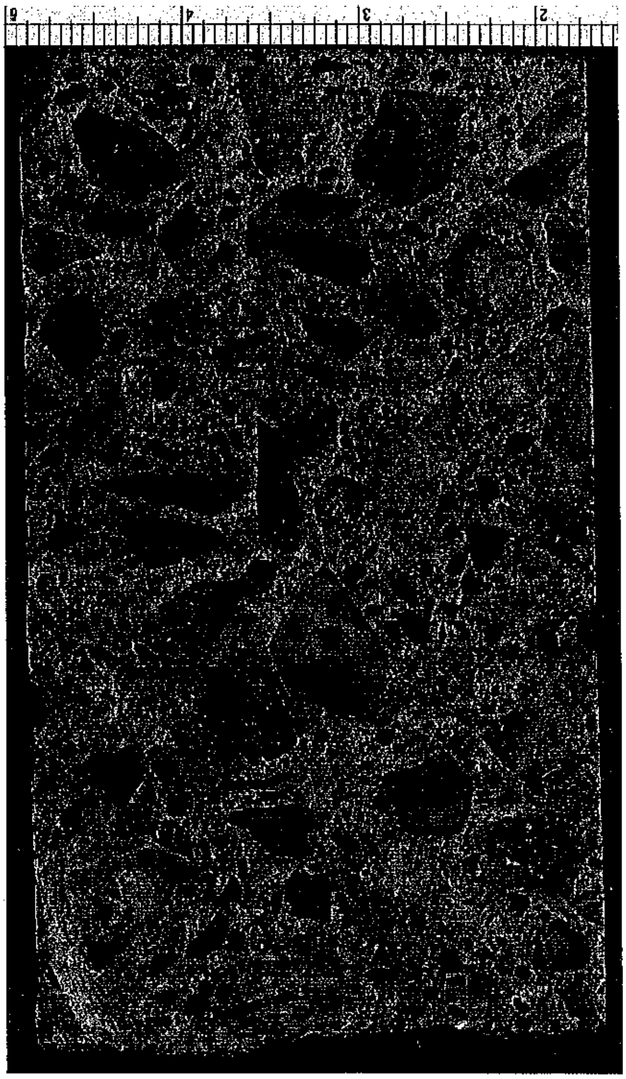


PLATE 23
PREPARED
SURFACE

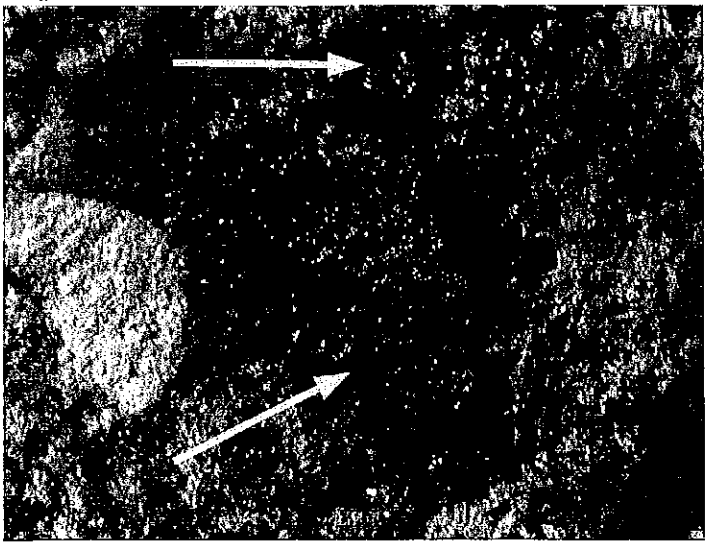


PLATE 24
CUT SURFACE SHOWING CLEAR GEL
EXUDATIONS AT AGGREGATE SURFACE AND
SURROUNDING PASTE (YELLOW ARROWS)

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 4
UPPER RAKER SAMPLE “340R-P2”

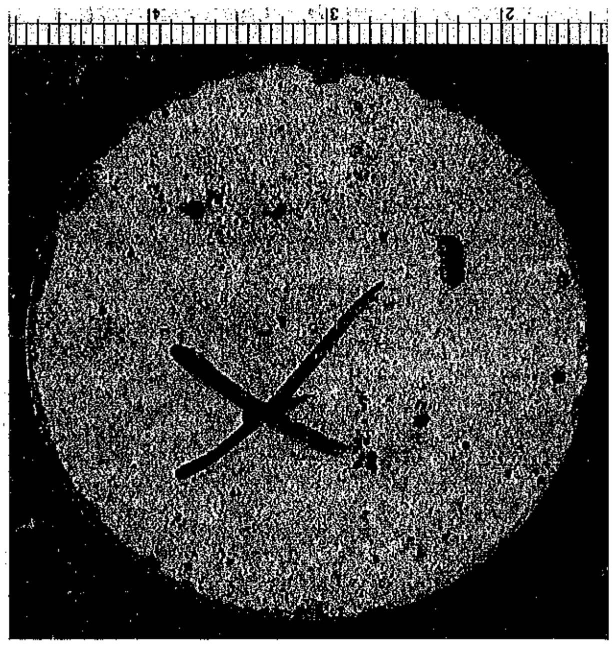


PLATE 25
TOP SURFACE

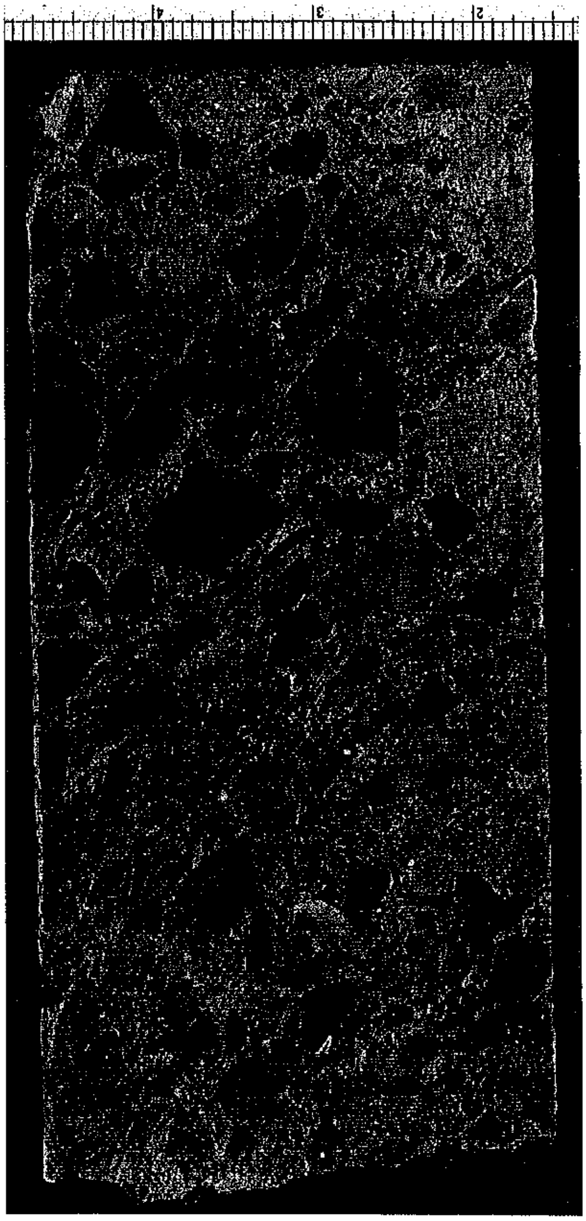


PLATE 26
PREPARED
SURFACE

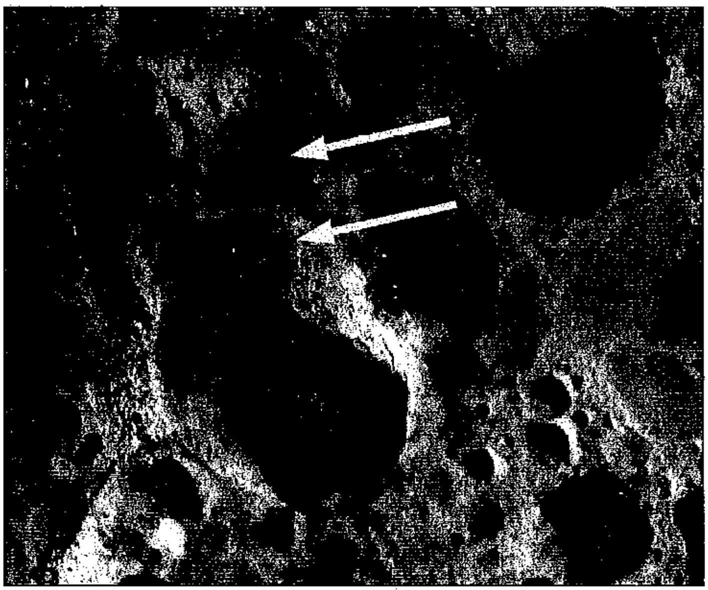


PLATE 27
PREPARED SURFACE SHOWING CLEAR,
CRACKED GEL EXUDATIONS IN VOIDS
(YELLOW ARROWS)

THE ROCK DOCTOR
CONCRETE SOLUTIONS FOR CONCRETE PROBLEMS

PETROGRAPHIC REPORT

DATE: October 10, 2007
WORK ORDER: 07-08-31-01 / Group 5
CLIENT: Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY: Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received six core portions of hardened concrete to determine the general condition of the concrete(s). The core portions were marked **"303UD-P"**, **"323 D-P"**, **"333D-P1"**, **"333UD-P1"**, **"333TD-P1"**, and **"333TUD-P1"**. The core portions measured, in length, approximately 6-1/2, 6, 1-3/4, 1-7/8, 1-3/4, and 2-1/4 inches, respectively. The core portions were approximately 3-1/8 inches in diameter.

It was reported that the submitted samples were taken from the view concourse area. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

SAMPLE PREPARATION AND METHODS

Core samples **"303UD-P"**and **"323 D-P"** were cut in half, approximately perpendicular to the top surfaces. Approx. ¾ of an inch-thick slabs were cut from the remaining samples. The cut surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were determined following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters. Samples **"333D-P1"**and **"333UD-P1"**did not meet minimum traverse length requirements due to inadequate sample size.

The unprepared samples were partially immersed in water for at least three days to mobilize any alkalic gels present. The cut surfaces of the core portion samples were not immersed in water.

The prepared and unprepared samples were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

"303UD-P"

GENERAL CONDITION: (See PLATES 1-3) The top surface exhibited a generally flat, mostly smooth, soft, mostly elastic, membrane/coating that was gray to dark gray in color. Water readily beaded on this surface and slowly absorbed into the surface. Many, partially exposed fine quartz aggregate particles and numerous, small, air-void septa were present at the exposed surface. Many fine cracks were also present especially at the exposed aggregate peripheries. A 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system ranged from approx. 1/16-3/32 of an inch thick and was composed of three apparent layers. The layer at/adjacent to the exposed surface ranged from approx. 1/5 up to 1/2 of the total coating thickness and appeared to be a top coat-type application that filled irregularities present in the underlying layer of material. This uppermost layer was gray-dark gray in color exhibited a very few, small voids but did not exhibit any aggregate particles. Discontinuous, fine cracks were observed in this material parallel and adjacent to the exposed surface and coincided with the cracking observed at the top surface. At the irregular interface between the two uppermost coating layers, no voids, separations, or cracks were observed. The discontinuous intermediate layer (from zero up to approx. 2/5 of the total coating thickness) was gray in color and exhibited many aggregate particles and several voids. Immediately below the two upper layers, a gray-colored layer was observed approx. ½ of the total coating thickness. This material exhibited several, small voids, with many in line parallel to the top surface in the upper portion of the layer. The bottom surface of this layer exhibited an almost continuous, adhered layer of paste/mortar from the base concrete. An almost continuous separation/crack was present at or within the upper portion of the base concrete. No apparent carbonation was observed in the base concrete. A very small-small amount of microcracking was observed throughout the sample. Approx. 4-5/8 inches below the exposed surface, an 1/8 of an inch diameter steel strand was observed. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light brown-pale gray with a very small-small amount of unhydrated cement particles to light brown-dull white in color, with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 1:

TABLE 1

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α $in.^{-1}$	L in.
"303UD-P"	28.09	2,022	99.60	6.58	4.27	5.5	.0120	332.8	.0128

The inhomogeneously distributed voids were mostly small in size and spherically shaped with larger, spherical to irregularly shaped voids also observed. A small-moderate amount of clusters of voids was observed throughout the sample. In several voids, secondary, internal deposits were observed as coatings/linings of clear material with the optical properties of the alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. A few particles exhibited internal fractures and reaction rims. A few discolored portions of paste were present at a few aggregate peripheries especially associated with particles exhibited internal fractures.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, quartz sandstone, granites, microcrystalline quartz chert, claystone, and siltstone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures.

"323 D-P"

GENERAL CONDITION: (See PLATES 4-6) The top surface exhibited a generally flat, rough, heavily cracked, moderately soft-moderately hard, slightly elastic, membrane/coating that was gray to dark gray in color. The exposed surface was moderately absorptive to water. Many, partially exposed fine quartz aggregate particles and many aggregate sockets were present at the exposed surface. Many fine cracks were also present especially at the exposed aggregate peripheries. A 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system ranged from approx. 5/32-3/16 of an inch thick and was composed of six apparent layers. The uppermost layer at/adjacent to the exposed surface was very thin and appeared to be a top coat-type application that filled irregularities present in the underlying layer of material. This uppermost layer was gray-dark gray in color exhibited a very few, small voids but did not exhibit any aggregate particles. A few, discontinuous, fine cracks were observed in this material parallel and adjacent to the exposed surface and coincided with some of the cracking observed at the top surface. At the irregular interface between the two uppermost coating layers, no voids, separations, or cracks were observed. The second layer below the top surface (from 1/32 of an inch up to approx. 1/16 of an inch thick) was gray in color and exhibited many aggregate particles and many air-void septa. Immediately below the two upper layers, another dark gray-gray colored layer (similar to the exposed layer on this sample and the exposed upper layer in Sample **"303UD-P"**) was observed. This layer ranged in thickness from approx. 1/32 up to approx. 1/16 of an inch and appeared to be a previously applied, top coat-type application that filled irregularities present in the underlying layer of material. Below this layer, a light gray colored material with many fine aggregate particles and many air-void septa was observed. This layer appeared to be similar to the second layer in this sample and ranged in thickness from a veneer up to approx. 1/16 of an inch maximum. The observed fifth and sixth layers were approx. 1/32 of an inch thick and both exhibited several, small voids, with many in line parallel to the top surface in the upper portion of each layer. The bottom layer exhibited a slightly darker gray color as compared to the overlying material. At the bottom surface of these applied coatings, an almost continuous, adhered layer of paste/mortar from the base concrete as present. An almost continuous separation/crack was present at or within the upper portion of the base concrete. No apparent carbonation was observed in the base concrete. A small amount of microcracking was observed throughout the sample. Approx. 3-5/8 inches below the exposed surface, an 1/8 of an inch diameter steel strand was observed. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light brown-pale gray with a very small-small amount of unhydrated cement particles to light brown-dull white in color, with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 2:

TABLE 2

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"323 D-P"	17.60	2,000	98.60	8.60	2.05	7.1	.0121	330.2	.0062

The inhomogeneously distributed voids were mostly small in size and spherically shaped with larger, spherical to irregularly shaped voids also observed. A moderate-abundant amount of clusters of voids was observed throughout the sample. In several voids, secondary, internal deposits were observed as coatings/linings of clear material and partial linings of off-white, crystalline material with the optical properties of the alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 1-1/4 inches. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Several particles exhibited reaction rims. Many particles exhibited internal fractures. Small amounts of light brown-colored paste were observed at a few aggregate peripheries especially the fossiliferous particles.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, quartz sandstone, granites, microcrystalline quartz chert, claystone, and siltstone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Many aggregate particles exhibited internal fractures. A few light brown-colored paste areas were observed at a few aggregate peripheries especially the microcrystalline quartz chert particles.

"333D-P1"

GENERAL CONDITION: (See PLATES 7-10) The top surface exhibited a generally flat, rough, heavily cracked, moderately hard, rigid, membrane/coating that was gray to dark gray in color. The exposed surface was moderately absorptive to water. Many, partially exposed fine quartz aggregate particles and many aggregate sockets were present at the exposed surface. A 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system was approx. 5/32 of an inch thick with one small, localized portion up to 5/16 of an inch thick. The coating system was composed of five apparent layers. The uppermost layer at/adjacent to the exposed surface was cracked, very thin and appeared to be a top coat-type application that filled irregularities present in the underlying layer of material. This uppermost layer was gray-dark gray in color exhibited a very few, small voids but did not exhibit any aggregate particles. At the irregular interface between the two uppermost coating layers, many cracks were observed. The second layer below the top surface (up to approx. 1/16 of an inch thick) was gray in color and exhibited many aggregate particles, many air-void septa, and many cracks. Immediately below the two upper layers, another dark gray-gray colored, discontinuous layer (similar to the exposed layer on this sample and the previously described upper coating layers) was observed. This layer ranged in thickness from zero (not observed) up to approx. 1/16 of an inch and appeared to be a previously applied, top coat-type applications that filled irregularities present in the underlying layer of material. Below this layer, a light gray colored material with many fine aggregate particles and many air-void septa was observed. This layer appeared to be similar to the second layer in this sample and ranged in thickness from a veneer up to approx. 1/16 of an inch maximum. The observed fifth layer was approx. 1/16 of an inch thick and exhibited several, small voids, with a few in line parallel to the top surface in the upper portion. At the bottom surface of these applied coatings, an almost continuous, adhered layer of paste/mortar from the base material was observed. An almost continuous separation/crack was present at or within the upper portion of the base mortar material. No apparent carbonation was observed in the base mortar material. A very small amount of microcracking was observed throughout the sample. Off white-clear material with the properties of alkalic gel were observed on a cut surface after water immersion of sample trimming. The bottom surface was smooth and undulating suggesting placement over plastic/vapor barrier.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and light gray-light brown in color with a small-moderate amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 3:

TABLE 3

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"333D-P1"	25.11	1,374	67.60	4.08	6.15	4.9	.0084	476.2	.0107

The inhomogeneously distributed voids were mostly small and spherically shaped with fewer, larger, spherical-irregularly shaped voids present. A moderate amount of clustering of voids was observed throughout the sample. A higher concentration of voids were observed in the upper half of the sample. Secondary, internal deposits were observed as linings of clear-white material with similar optical properties of alkalic gel were observed in a few voids.

AGGREGATE: The homogeneously distributed aggregate particles were subangular-subrounded in shape with an observed topsize of 3/8 of an inch. The collective aggregate was composed of quartz, microcrystalline quartz chert, feldspar, granites, limestone and one coal particle. Many particles exhibited internal fractures. Several particles exhibited reaction rims. Small, localized, light red-brown staining of the paste was observed adjacent to the observed coal particle.

"333UD-P1"

GENERAL CONDITION: (See PLATES 11-13) The top surface exhibited a generally flat, slightly rough, moderately hard, semi-rigid, membrane/coating that was gray to dark gray in color. The exposed surface was moderately absorptive to water and exhibited many, small cracks especially at the exposed aggregate peripheries. Many, partially exposed fine quartz aggregate particles and many several aggregate sockets were observed at the exposed surface. A 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system ranged in total thickness from approx. 1/16 of an inch up to approx. 1/8 of an inch thick. The coating system was composed of four apparent layers. The uppermost layer at/adjacent to the exposed surface was very thin (veneer up to approx. 1/32 of an inch thick) and appeared to be a top coat-type application that filled irregularities present in the underlying layer of material. This uppermost layer was gray-dark gray in color exhibited a very few, small voids but did not exhibit any aggregate particles. Discontinuous, fine cracks were observed in this material parallel and adjacent to the exposed surface and coincided with the cracking observed at the top surface. The discontinuous second layer of coating material below the top surface (from zero up to approx. 1/32 of an inch thick) was gray in color and exhibited many aggregate particles and many air-void septa. Below this layer, a light gray colored material with many larger air-void septa was observed. This layer ranged in thickness from a 1/32 of an inch up to approx. 1/16 of an inch maximum. The observed fourth, discontinuous layer of coating material ranged from zero up to approx. 1/16 of an inch maximum thickness and exhibited many small voids, with a few in line, parallel to the top surface. At the bottom surface of these applied coatings, an almost continuous, adhered layer of paste/mortar from the base material was observed. An almost continuous separation/crack was present at or within the upper portion of the base mortar material. No apparent carbonation was observed in the base mortar material. A very small amount of microcracking was observed throughout the sample. The bottom surface was smooth and undulating suggesting placement over plastic/vapor barrier.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and light brown-light gray in color with a small-moderate amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 4:

TABLE 4

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			ℓ	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"333UD-P1"	26.7	1,460	71.90	2.2	12.2	3.4	.007	611	.011

The inhomogeneously distributed voids were mostly spherically shaped and small to large in size. A small amount of clustering of voids was observed throughout the sample. A few voids exhibited secondary, internal deposits as coatings/linings of clear material with the optical properties of alkalic gel.

AGGREGATE: The homogeneously distributed aggregate was subangular-subrounded in shape with an observed topsize of 1/2 of an inch. The observed aggregate was composed of microcrystalline quartz chert, quartz, feldspar, granites, sandstone, siltstone, fossiliferous limestone particles and wood fibers. Many particles exhibited small amounts of internal fractures and a few particles exhibited reaction rims.

"333TD-P1"

GENERAL CONDITION: (See PLATES 14-16) The top surface was slightly rough, generally flat and exhibited numerous partially exposed, fine aggregate particles in a slightly recessed, moderately soft-moderately hard matrix. Very small amounts of loosely adhered, very fine, light brown "dust" and dark brown-black debris were also present. Most of the light brown "dust" (presumed to be debris from the coring procedure) was easily washed from the surface. Several, fine cracks were observed at the top surface and several were interconnected and formed "Y"-shaped patterns. An approx. 1-inch diameter semi-circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, no carbonation was observed. A very small amount of microcracking was observed. Off white-clear material with the properties of alkalic gel were observed on a cut surface over a chert aggregate particle after water immersion of a sample trimming. The bottom surface exhibited a thick coating of shiny, black-colored, tar-like material presumed to be a water-stop material.

CEMENTITIOUS MATRIX: The cementitious paste matrix was highly water absorptive, moderately soft-moderately hard, and light brown in color with a small amount of unhydrated cement particles. A small-moderate amount of fly ash was observed with no ground granulated blast furnace slag or other pozzolanic materials being microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 5:

TABLE 5

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"333TD-P1"	27.40	1,529	75.25	6.93	3.95	2.5	.0279	143.4	.0276

The homogeneously distributed voids were mostly large in size and irregular-spherically shaped with fewer, smaller, spherically shaped voids also present. No secondary internal deposits were observed.

AGGREGATE: The homogeneously distributed aggregate was subangular-subrounded in shape with an observed topsize of 3/8 of an inch. The observed aggregate was composed of quartz, feldspar, microcrystalline quartz chert, granites, sandstone, and siltstone particles. Several particles exhibited small amounts of internal fractures and a few particles exhibited reaction rims.

"333TUD-P1"

GENERAL CONDITION: (See PLATES 17-20) The top surface exhibited a generally flat, slightly rough, soft, elastic, membrane/coating that was gray in color with several partially exposed, fine aggregate particles. Water beaded when applied to the exposed surface. A very small amount of fine cracks were observed and seemed to be located at/or near at the exposed aggregate peripheries. A few very small, localized areas exhibited many, interconnected, very fine cracks with a "mud-crack"-type pattern. The coating in this very finely cracked areas was slightly harder than the bulk coating at the exposed surface. A few aggregate sockets were also present at the exposed surface. A 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system ranged from approx. 1/16 up to 1/8 of an inch thick and was composed of three apparent layers. The layer at/adjacent to the exposed surface ranged from a veneer up to approx. 1/16 of an inch thick and was gray in color with many fine aggregate particles and many air-voids present. At the interface between the two uppermost coating layers, no voids, separations, or cracks were observed. The soft, elastic, intermediate layer (from approx. 1/24 up to 1/16 of an inch thick) of material was light gray in color and exhibited several aggregate particles and many voids. The observed aggregate particles were concentrated at/or near the bottom of this layer. A few cracks/separations were also observed at/or near the bottom of this layer. The bottom layer of coating material was light gray-gray in color, hard and rigid, and moderately cracked with a few aggregate particles. The thickness of this layer ranged from a veneer up to approx. 1/32 of an inch thick. The bottom surface of this layer exhibited an almost continuous, adhered layer of paste/mortar from the base mortar material. An almost continuous separation/crack was present at or within the upper portion of the base mortar material. No apparent carbonation was observed in the base concrete. The upper portion of the mortar material exhibited localized, discontinuous, light brown discolorations at the exposed top surface up to approx. 3/8 of an inch depth. A few, vertically oriented cracks were also present and the crack edges coincided with the observed discolorations. A small amount of microcracking was observed throughout the sample. Approx. 1-3/4 and 2 inches inches below the exposed surface, several 1/16 of an inch diameter steel strands were observed. Approx. 2 inches below the top surface, a 1/4 of an inch thick zone of markedly darker gray paste was observed. At/adjacent to the bottom surface, a light brown colored paste zone was present. The bottom surface exhibited a thick coating of shiny, black-colored, tar-like material presumed to be a water-stop material.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately hard, and light brown-dull white in color with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag, or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 6:

TABLE 6

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α $in.^{-1}$	L in.
“333TUD-P1”	37.83	1,800	88.50	4.50	8.41	1.8	.0247	161.7	.0363

The homogeneously distributed voids were mostly large in size and ranged from spherical to irregular in shape. In numerous voids, secondary, internal deposits were observed as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\ H_2O$ as well as infillings and linings of clear-off white material with the optical properties of alkalic gel.

AGGREGATE: The homogeneously distributed aggregate was subangular-subrounded in shape with an observed topsize of 1/4 of an inch. The observed aggregate was composed of quartz, microcrystalline quartz chert, feldspar, granites, siltstone, chalcedonic chert particles and wood fibers. Many particles exhibited internal fractures and several chert particles exhibited reaction rims.

DISCUSSION & CONCLUSION

We received six portions of hardened concrete to determine the general condition of the concrete(s). It was reported that the submitted samples were taken from view concourse areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

The determined air-void system parameters are listed below in TABLE 7:

TABLE 7

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α $in.^{-1}$	L in.
“303UD-P”	28.09	2,022	99.60	6.58	4.27	5.5	.0120	332.8	.0128
“323 D-P”	17.60	2,000	98.60	8.60	2.05	7.1	.0121	330.2	.0062
“333TD-P1”	27.40	1,529	75.25	6.93	3.95	2.5	.0279	143.4	.0276
“333TUD-P1”	37.83	1,800	88.50	4.50	8.41	1.8	.0247	161.7	.0363

The estimated air-void system parameters are listed below in TABLE 8:

TABLE 8

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"333D-P1"	25.1	1,374	67.60	4.1	6.1	4.9	.008	476	.011
"333UD-P1"	26.7	1,460	71.90	2.2	12.1	3.4	.007	611	.011

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi.

- All samples are considered to be air-entrained except **"333UD-P1"**.
- Overall, the observed aggregates in each sample exhibited reaction rims and internal fractures. Alkalic gel deposits were observed in all samples except **"333TD-P1"**. However, gel exudations were observed a cut surface over a chert aggregate particle after water immersion of a sample trimming in Sample **"333TD-P1"**. These features strongly suggest that the collective aggregate should not be considered "durable" due to susceptibility to alkali-silica reactivity.
- The determined spacing factor for Sample **"323 D-P"** was under (acceptable) the recommended, industry standard limit maximum of 0.0080 inches, and is considered to be adequate for exposure in a water-saturated, cyclic, freeze-thaw environment. The determined and estimated spacing factors for the remaining samples are over the recommended, industry standard limit maximum of 0.0080 inches and should not be considered to be adequate for durability in a water-saturated, cyclic, freeze-thaw environments.
- The compressive strength(s) of the concrete represented by this sample/mix design is unknown and comments regarding this will not be made.

No carbonation was observed in the base materials of the examined core samples.

Sample **"333TUD-P1"** exhibited both alkalic gels and ettringite as secondary internal deposits. The presence of ettringite is commonly associated with the occurrence of ASR. The presence of ettringite that has formed due to DEF is associated with precast members that have been exposed to high curing temperatures. It should be noted that ettringite is common in Portland cement based concretes and its presence alone is not indicative of sulfate attack. It must be chemically established that the sulfate content of the concrete is greater than would be supplied by the original sulfate content of the cement.

Based on this examination, the most possible cause of the reported distress, as represented by the submitted samples, is active alkali-aggregate reactivity. Based on this examination and observations including aggregate features and the presence/degree of observed microcracking, the general conditions are deemed:

Poor – Sample **"333TUD-P1"** exhibited both alkalic gels and ettringite as secondary internal deposits, with the highest levels of reactions rims/internal fractures present.

Poor – Sample **"323 D-P"** exhibited alkalic gel exudations, many internal fractures in aggregates, and a small amount of microcracking.

Poor – Sample **"333D-P1"** exhibited alkalic gel exudations, many internal fractures and several reaction rims in aggregates, and a small amount of microcracking.

Fair/Poor – Samples , **"303UD-P"** and **"333UD-P1"** exhibited very small amounts of microcracking and low-moderate amounts of aggregate particles exhibiting reaction characteristics.

Fair – Sample **"333TD-P1"** exhibited very small amounts of microcracking and fewer aggregate particles exhibiting reaction/distress characteristics with no observed secondary deposits. However, gel exudations were observed a cut surface over a chert aggregate particle after water immersion of a sample trimming. **"333TD-P1"** was the only sample that contained fly ash.

Inadequate air-void systems can be likely contributing factors to deficiencies or potential failure and/or further degradation.

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (e.g., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur. Differences in exposure conditions, especially exposure to water, can account for apparent physical changes in condition of the examined samples.

JR Varga

J. R. Varga, Concrete Petrographer

The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  `http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_5.pdf`
- Online version of Plates 1-10 (PDF):
  `http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_5_1_10.pdf`
- Online version of Plates 11-20 (PDF):
  `http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_5_11_20.pdf`

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 5
VIEW CONCOURSE SAMPLE "303 UD-P"

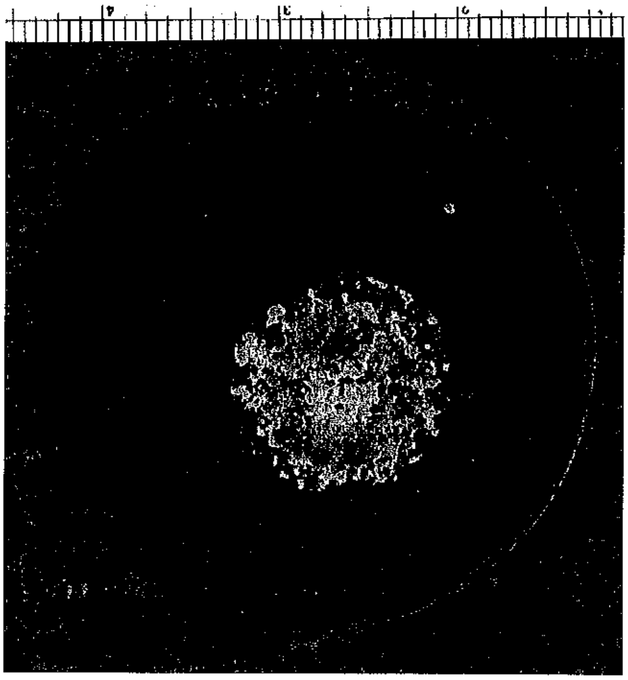


PLATE 1
TOP SURFACE

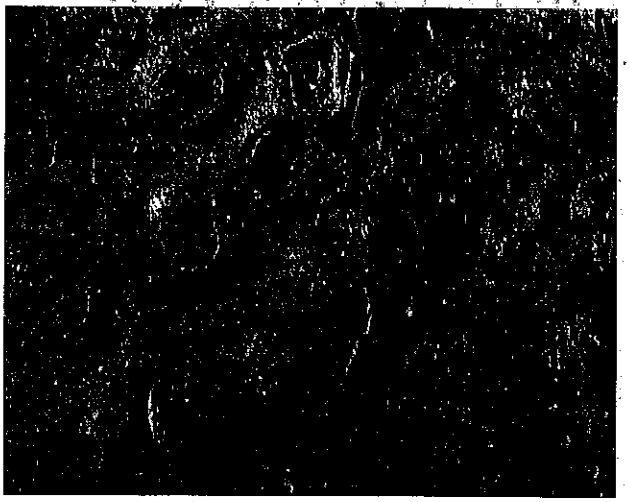


PLATE 2
TOP SURFACE SHOWING
LOCALIZED CRACKING IN
THE GRAY COATING
MATERIAL ESPECIALLY AT
EXPOSED AGGREGATE
PERIPHERIES

PLATE 3
PREPARED
SURFACE

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 5

VIEW CONCOURSE SAMPLE "323D-P"

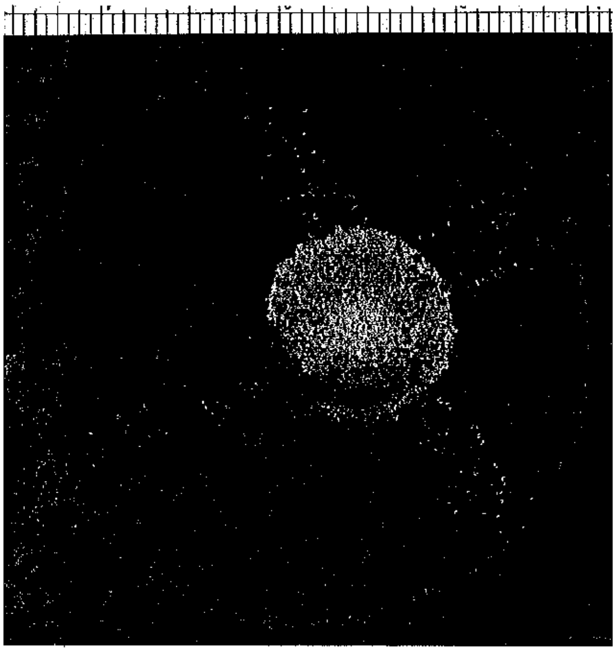


PLATE 4
TOP SURFACE

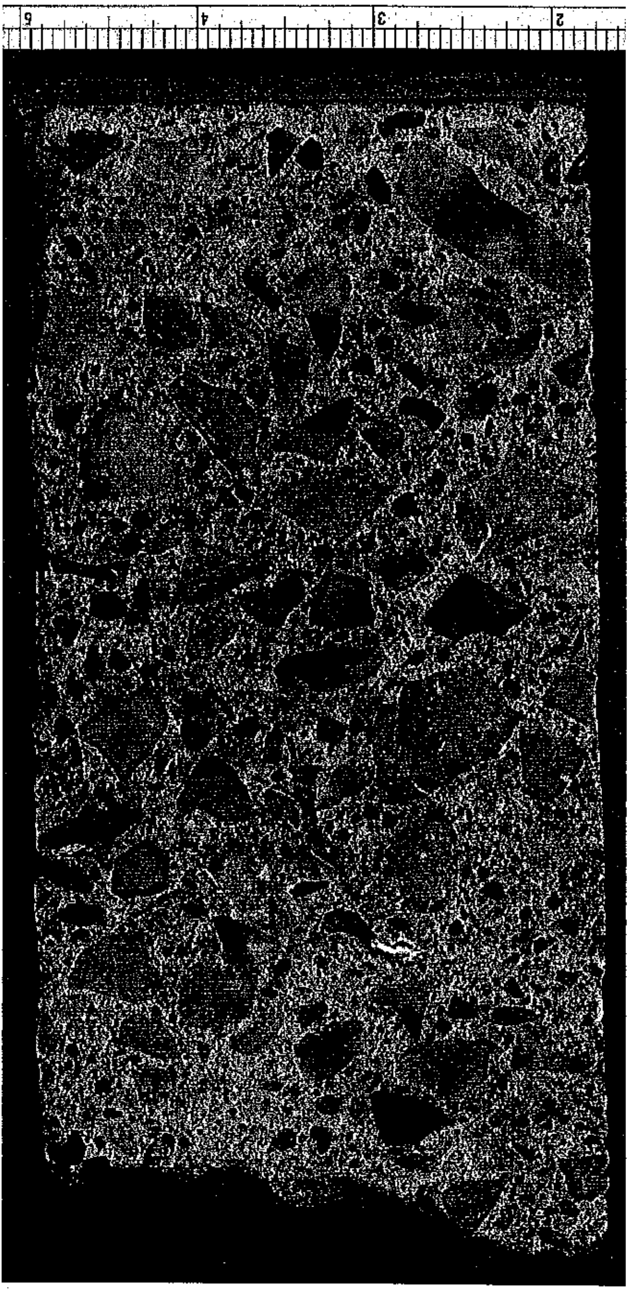


PLATE 6
PREPARED SURFACE

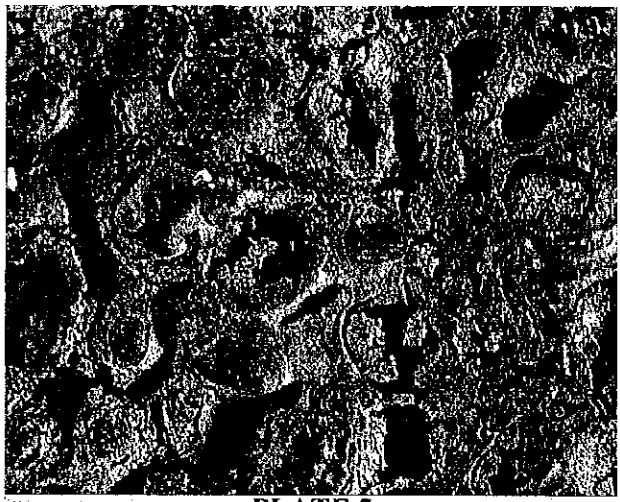


PLATE 5
TOP SURFACE SHOWING HEAVILY CRACKED GRAY COATING MATERIAL AND EXPOSED FINE AGGREGATE PARTICLES

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 5

VIEW CONCOURSE “333 D-P1”

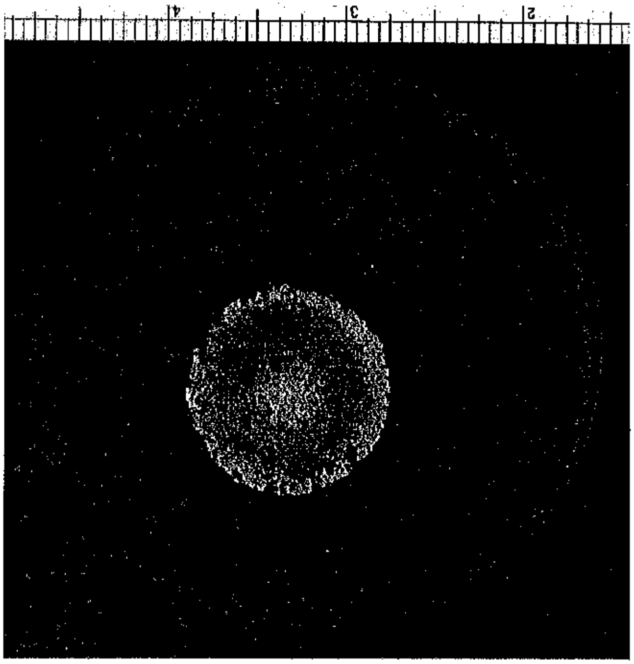


PLATE 7
TOP SURFACE

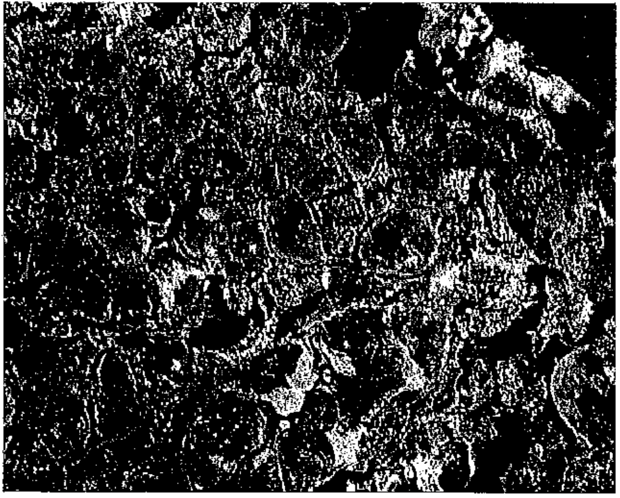


PLATE 8
TOP SURFACE SHOWING HEAVILY CRACKED GRAY COATING MATERIAL AND EXPOSED FINE AGGREGATE PARTICLES

PLATE 9
PREPARED SURFACE

PLATE 10
CUT SURFACE SHOWING GEL EXUDATION AFTER WATER IMMERSION OF SAMPLE TRIMMING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 5
VIEW CONCOURSE SAMPLE "333 UD-P1"

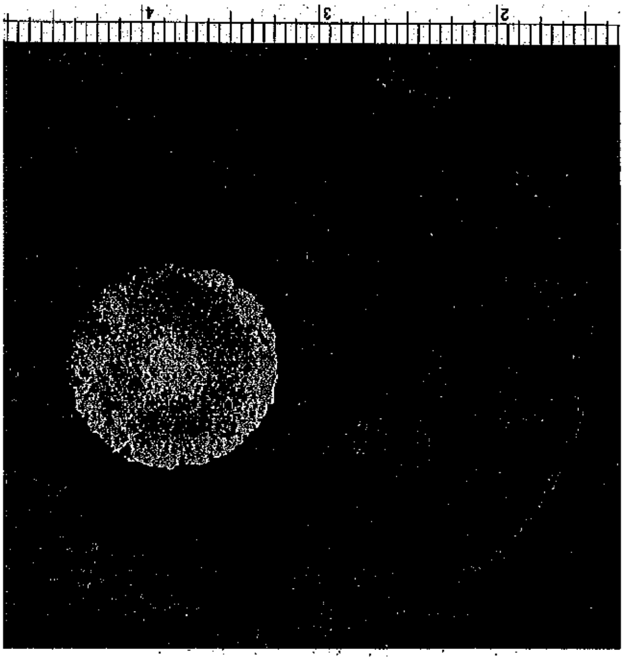


PLATE 11
TOP SURFACE

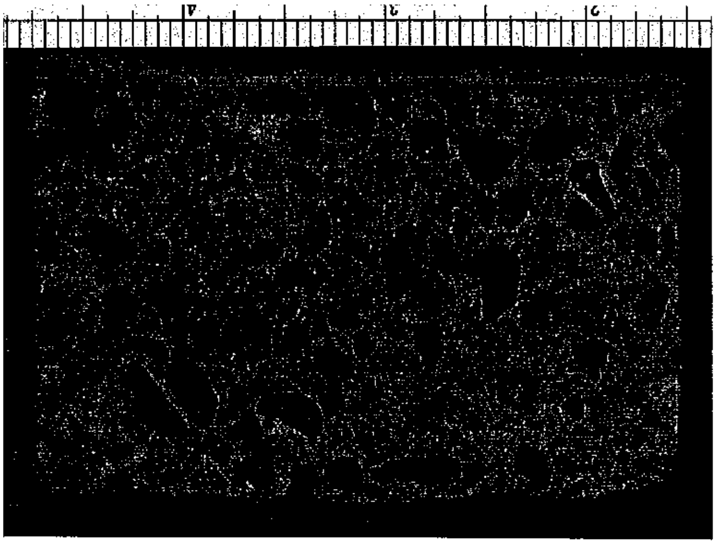


PLATE 13
PREPARED
SURFACE

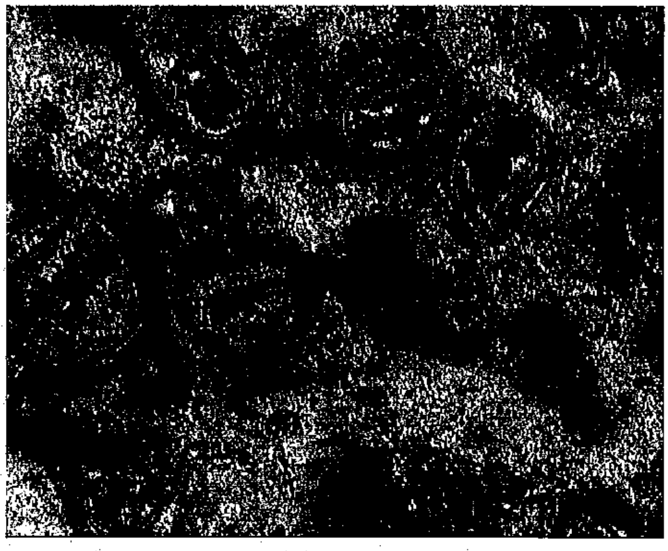


PLATE 12
TOP SURFACE SHOWING PARTIALLY
EXPOSED FINE AGGREGATE PARTICLES
AND AGGREGATE SOCKETS IN CRACKED
GRAY COATING MATERIAL

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 5
VIEW CONCOURSE SAMPLE "333TD-P1"

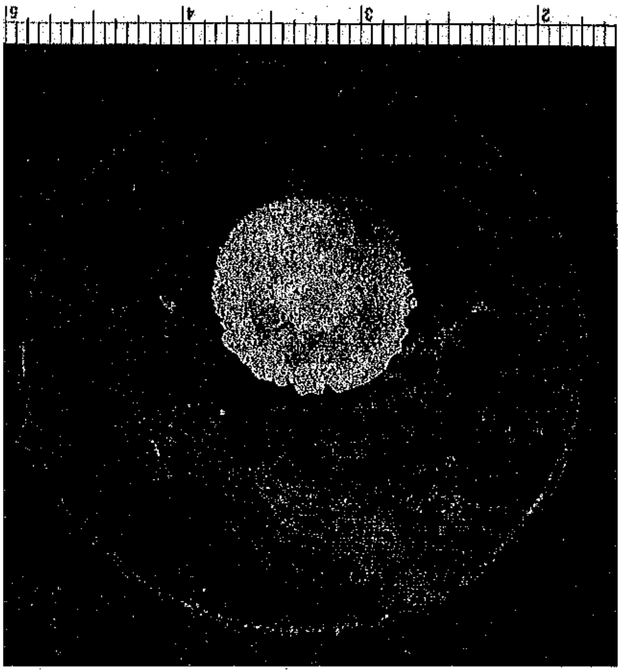


PLATE 14
TOP SURFACE

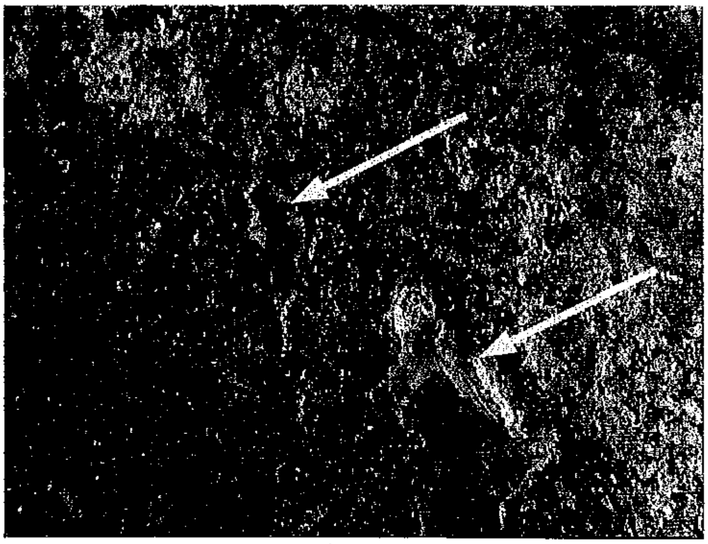


PLATE 16
CUT SURFACE SHOWING CLEAR-OFF WHITE ALKALIC GEL EXUDATIONS ON A CHERT PARTICLE OF THE FINE AGGREGATE (AFTER WATER IMMERSION OF SAMPLE TRIMMING)

PLATE 15
PREPARED SURFACE

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 5
VIEW CONCOURSE "333 TUD-P1"

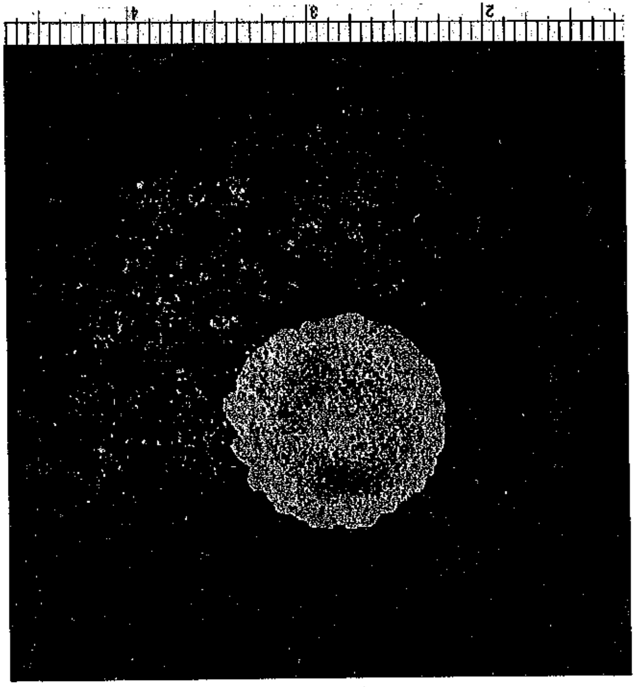


PLATE 17
TOP SURFACE

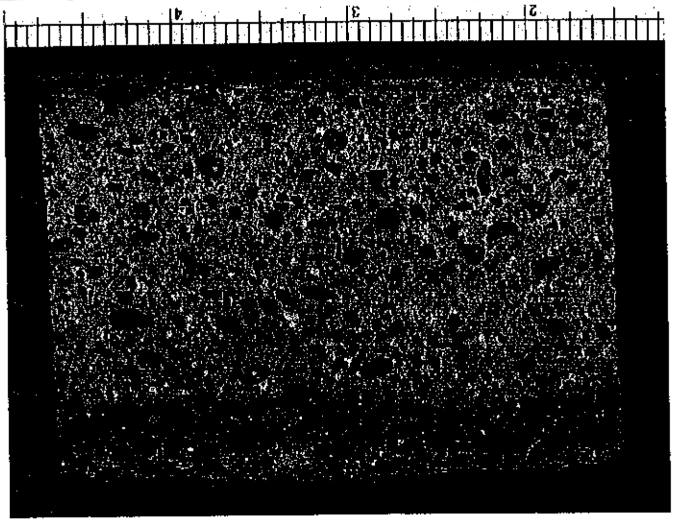


PLATE 19
PREPARED SURFACE

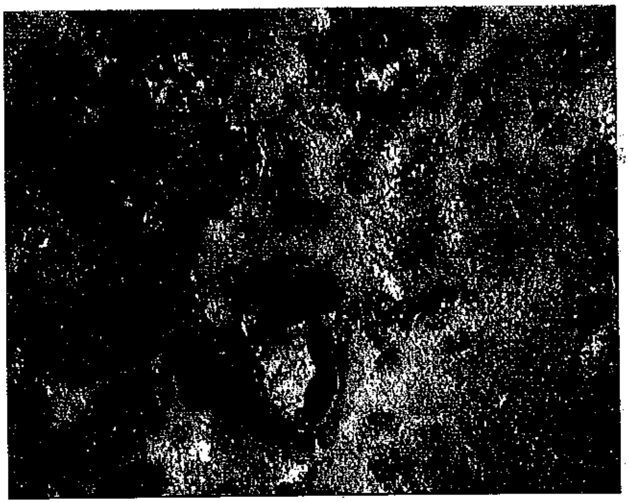


PLATE 18
TOP SURFACE SHOWING
PARTIALLY EXPOSED AGGREGATE
PARTICLES IN DARK GRAY-GRAY
COATING MATERIAL

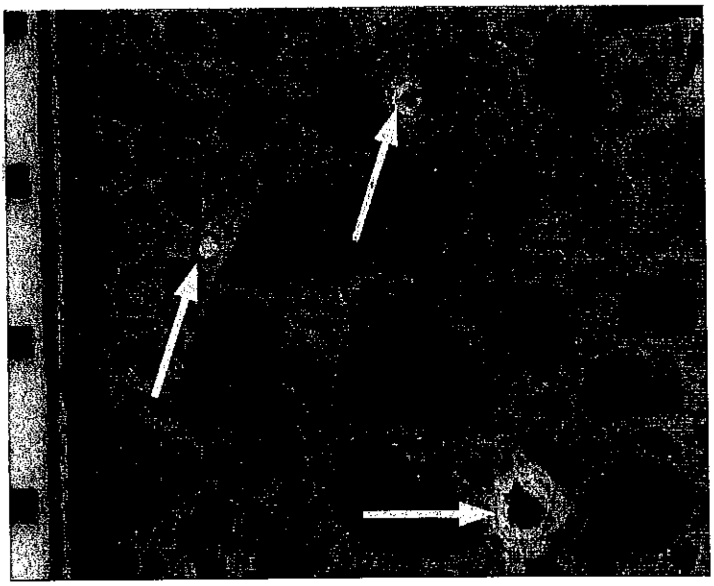


PLATE 20
PREPARED SURFACE SHOWING SECONDARY,
INTERNAL DEPOSITS OF ALKALIC GEL
AND/OR ETTRINGITE IN VOIDS AS COATINGS
AND AN INFILLING (YELLOW ARROWS)

W.O.#: 07-08-31-01 / TCG 0756

GROUP 5 STAINED SAMPLES

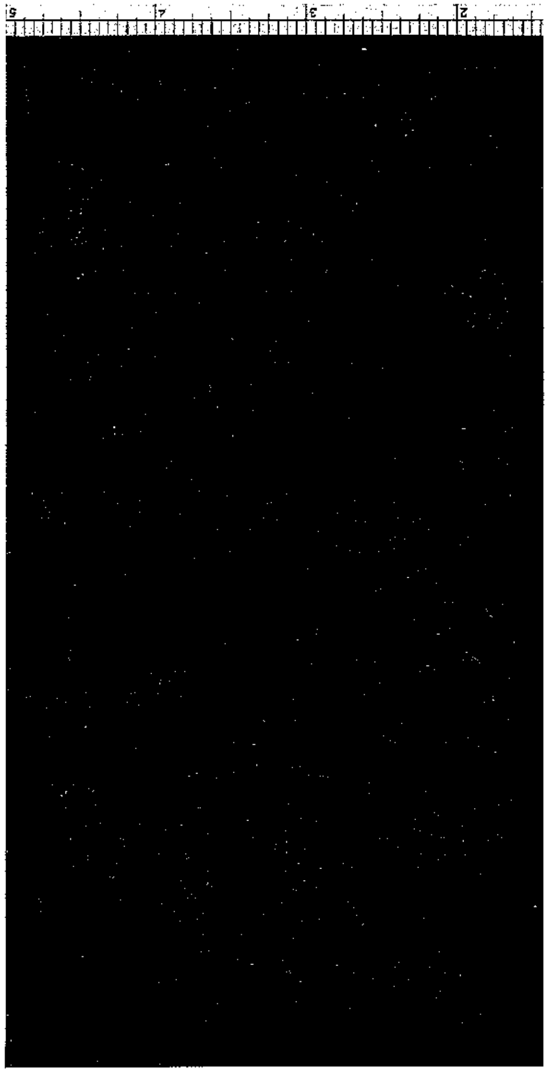


PLATE 1
PREPARED SURFACE OF SAMPLE “303 UD-P”
SHOWING MODERATE AMOUNT YELLOW
STAINING IN PASTE (ESPECIALLY IN LOWER
PORTION) AND WITHIN AGGREGATE PARTICLES
AFTER COBALTINITRITE STAINING

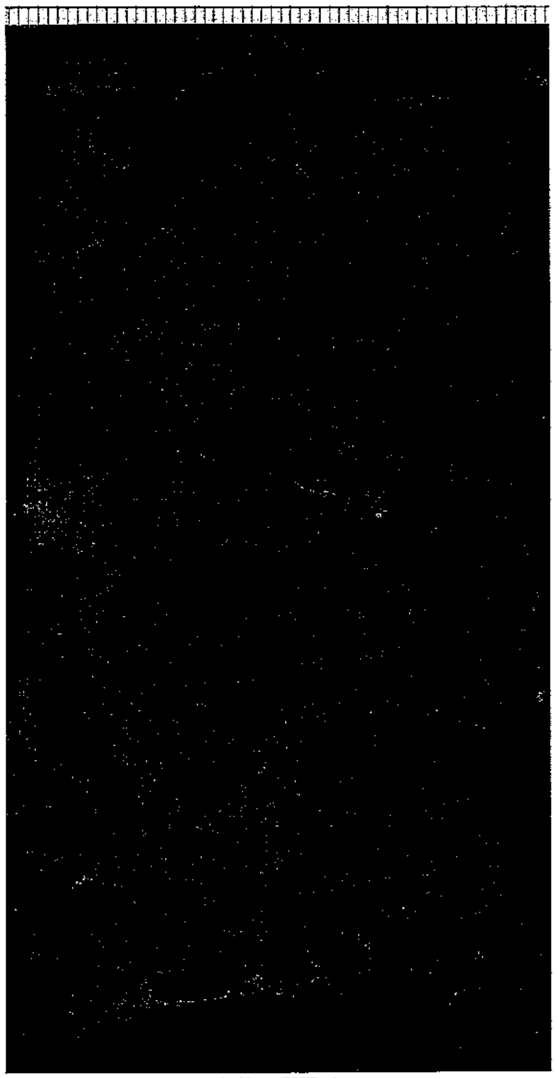


PLATE 2
CUT SURFACE OF SAMPLE “323 D-P”
SHOWING MARKED YELLOW STAINING IN PASTE AND
WITHIN A FEW AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING
NOTE: PURPLE STAINING FROM pH INDICATOR IN UPPER
PASTE PORTION

W.O.#: 07-08-31-01 / TCG 0756
GROUP 5 STAINED SAMPLES

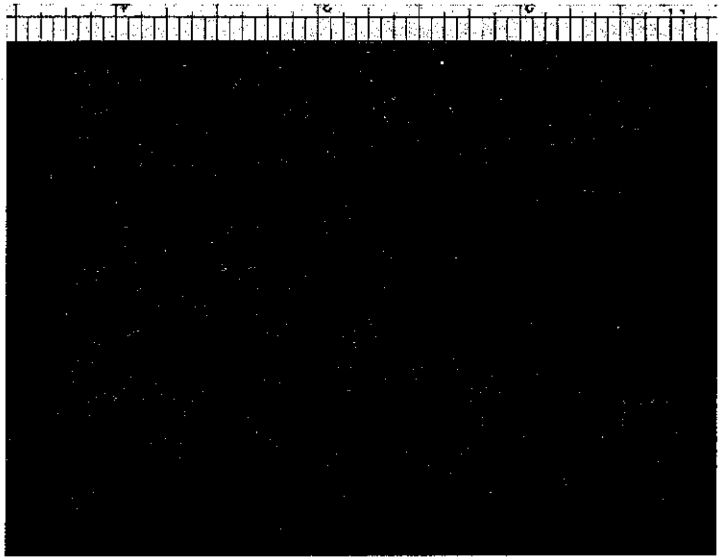


PLATE 3
PREPARED SURFACE OF SAMPLE "333D- P1"
SHOWING MUTED YELLOW STAINING IN PASTE AND WITHIN
AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

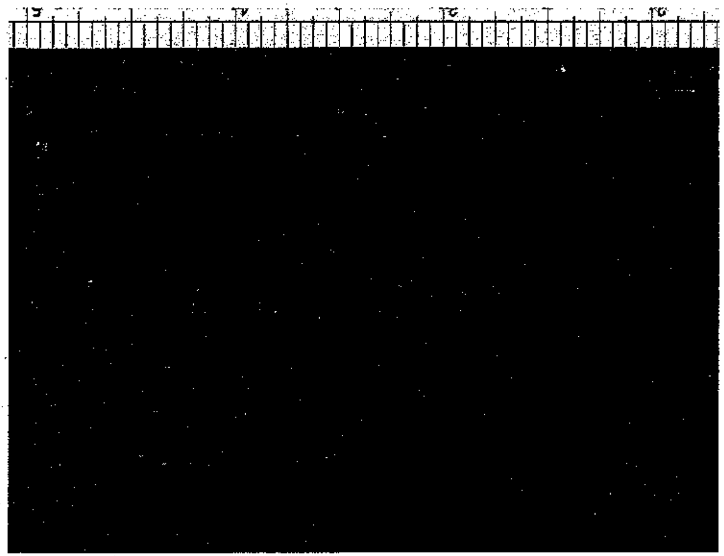


PLATE 4
PREPARED SURFACE OF SAMPLE "333UD-P1"
SHOWING MUTED YELLOW STAINING IN PASTE AND
WITHIN AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756
GROUP 5 STAINED SAMPLES

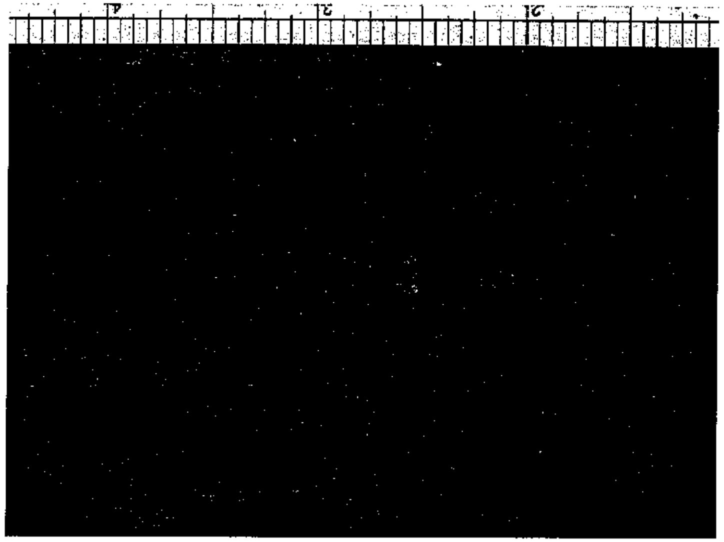


PLATE 5
PREPARED SURFACE OF SAMPLE "333TD-P1"
SHOWING WIDESPREAD YELLOW STAINING IN PASTE AND WITHIN AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

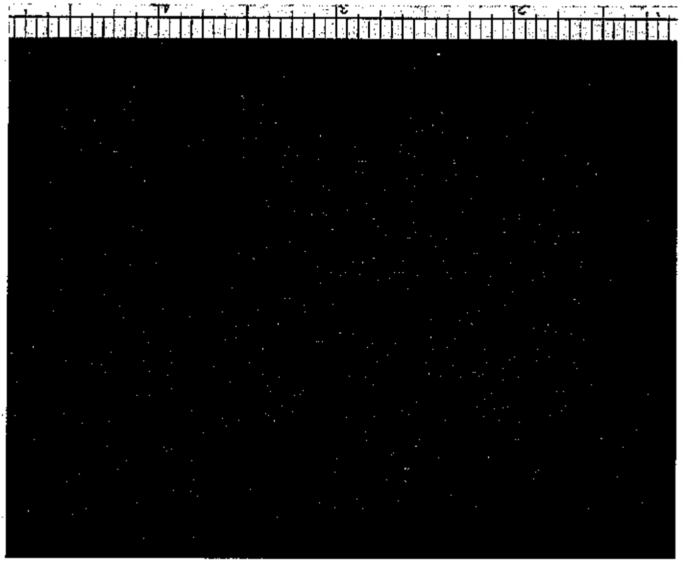


PLATE 6
PREPARED SURFACE OF SAMPLE "333TUD-P1"
SHOWING SMALL LOCALIZED AMOUNTS OF YELLOW STAINING IN PASTE AND WITHIN AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

THE ROCK DOCTOR
CONCRETE SOLUTIONS FOR CONCRETE PROBLEMS

PETROGRAPHIC REPORT

DATE: October 16, 2007
WORK ORDER: 07-08-31-01 / Group 6 View Seating
CLIENT: Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY: Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received six core portions of hardened concrete to determine the general condition of the concrete(s). The core portions were marked **"412 P"**, **"416 P1"**, **"416 P2"**, **"424 P"**, **"436 P"**, and **"343 STEP"**. The core portions measured, in length, approximately 6-3/4, 4, 4-3/4, 3, 5-3/4, and 4 inches, respectively. The core portions were approximately 1-3/4 inches in diameter except for Sample **"343 STEP"** which measured 3-1/8 inches in diameter. Sample **"343 STEP"** was received in a heavily damaged state and friable with numerous cracks and will not be examined.

It was reported that the submitted samples were taken from the view seating area. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

SAMPLE PREPARATION AND METHODS

The examined samples were cut in half, approximately perpendicular to the top surfaces. Core samples **"416 P1"**and **"416 P2"** fell apart during sample preparation and the largest pieces were used for this examination. The cut surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were estimated/determined following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters. Sample **"424 P"**did not meet minimum traverse length requirements due to inadequate sample size.

The unprepared samples were partially immersed in water for at least three days to mobilize any alkalic gels present. The cut surfaces of the core portion samples were not immersed in water.

A portion of the prepared surface of Samples **"412 P"**, the upper portion of the prepared surface of Sample **"416 P2"**, the prepared surface of Sample **"424 P"**, and the unprepared surface of the sample trimming of Sample **"436 P"** were stained using a saturated, aqueous solution of sodium cobaltinitrite (reacts with soluble potassium to produce a yellow precipitate resulting in staining potassium-rich ASR gel) following the guidelines in a July 1998 report titled *"Geochemical Methods for the Identification of ASR Gel"* by Guthrie and Carey, Los Alamos National Laboratory . In addition, a saturated, aqueous solution of Rhodamine B was similarly used to aid this staining procedure by highlighting (providing a high contrast background) the regions of yellow-stained ASR gel and in part, to identify other degradation products.

The prepared, unprepared, and stained sample surfaces were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

"412 P"

GENERAL CONDITION: (See PLATES 1-3) The top surface exhibited numerous, partially exposed fine and coarser aggregate particles in a moderately soft, recessed cement paste matrix. Small amounts of loose, black debris were also present at the exposed surface. An approx. 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, a veneer up to approx. 1/8 of an inch thick zone of carbonated paste was observed. A small amount of microcracking was observed throughout the sample and many were infilled with a very finely crystalline, off white-light brown material that exhibited similar properties as alkalic gel. Approx. 2-3/8 inches below the exposed surface, a 1/4 of an inch diameter steel bar was observed. The bottom surface was a fractured surface.

<u>Sodium Cobaltinitrite/Rhodamine B Staining Method</u>

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in the majority of the paste. Yellow staining was observed in the secondary, internal deposits a few voids, as paste "halos" at aggregate peripheries, within internal fractures in a few aggregate particles, and in microcrystalline quartz chert particles in the fine aggregate portions. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light gray-dull white with a moderate amount of unhydrated cement particles to dull white in color with a small amount of unhydrated cement particles. The darker-colored paste areas were harder as compared to the lighter-colored paste portions. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 1:

TABLE 1

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"412 P"	22.60	1,788	87.00	4.03	5.61	4.4	.0091	438.4	.0111

The inhomogeneously distributed voids were mostly spherical in shape and ranged in size from small to large. Fewer, larger, irregularly shaped voids were also observed. A small-moderate amount of clusters of voids was observed throughout the sample. In a few voids, secondary, internal deposits were observed as coatings/linings of clear-light brown material with the optical properties of the alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-rounded in shape with an observed topsize of 5/8 of an inch. The observed coarse aggregate was composed of lightweight, expanded clay/shale particles. A few particles exhibited small amounts of internal fractures. few discontinuous veneers of darker paste/mortar were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and quartz sandstone particles. A few wood fibers were also observed. A few microcrystalline quartz chert particles exhibited reaction rims. A few aggregate particles exhibited internal fractures.

"416 P1"/"416 P2"

Due to sample degradation, the largest portions of each sample were examined. The collective core features were similar and will be described as one.

GENERAL CONDITION: (See PLATES 4-7) Upon receipt, the samples exhibited many, fine fracture planes that were oriented roughly parallel to the top surfaces. The top surface exhibited numerous, partially exposed fine aggregate particles in a soft, recessed cement paste matrix. Small amounts of loose, black debris were also present at the exposed surface. A fine crack was also present at the top surface. The crack edges were lined with white, finely crystalline material with the optical properties of alkalic gel. A 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, a veneer of carbonated paste was observed. Several fracture planes/cracks were observed roughly parallel to the top surface throughout the sample. A moderate amount of microcracking was observed throughout the sample and many were infilled with a very finely crystalline, off white-light brown material that exhibited similar properties as alkalic gel. A fine, vertically oriented crack was observed from the top surface to an observed depth of 1/8 of an inch. This crack transected paste and a coarse aggregate particle. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in small, localized paste portions. Yellow staining was also observed in microcrystalline quartz chert particles, and in a few reaction rims. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and light brown-pale gray with a very small-small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The surface areas of Samples **"416 P1"** and **"416 P2"** were combined and are reported as one. The air-void system parameters are listed below in TABLE 2:

TABLE 2

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Samples	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"416 P1/2"	20.20	1,505	73.55	1.66	12.2	1.8	.0094	425.6	.0162

The homogeneously distributed voids were mostly small in size and spherical-irregularly shaped. In many voids, secondary, internal deposits were observed as infillings, coatings/linings of clear material and partial linings of off-white, crystalline material with the optical properties of the alkalic gel/carbonated alkalic gel. In many voids, secondary, internal deposits were observed as infillings, coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26 H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 1/2 of an inch. The observed coarse aggregate was mostly composed of cherty limestone particles with lesser amounts of fossiliferous limestone particles. Many particles exhibited reaction rims. Many particles exhibited abundant amounts of internal fractures with many fractures transecting surrounding paste.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, and microcrystalline quartz chert particles. A few microcrystalline quartz chert particles exhibited reaction rims. Many aggregate particles exhibited internal fractures. A few small separations were observed at several paste:aggregate interfaces.

“424 P”

GENERAL CONDITION: (See PLATES 8-10) The top surface exhibited rough, worn surface with numerous partially exposed fine aggregate particles in a recessed paste matrix. Several, large, air-void septa were present at the exposed surface. Moderate amounts of loose, black debris were also present at the exposed surface. A few, fine, “open” cracks were observed at the top surface. A 1-inch diameter, yellow paint “dot”, presumed to be used for marking purposes, was also present at the exposed surface.

In section, a discontinuous veneer of carbonated paste was observed. A very small-small amount of microcracking was observed throughout the sample and many were infilled with a very finely crystalline, off white-light brown material that exhibited similar properties as alkalic gel/carbonated alkalic gel. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in the majority of the paste. Yellow staining was also observed in at a few microcrystalline quartz chert particle peripheries and adjacent to a few reaction rims. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was moderately water absorptive, moderately soft-moderately hard, and light gray in color with a small-moderate amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 3:

TABLE 3

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			ι	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
“424 P”	22.6	925	44.95	4.1	5.51	4.0	.010	392	.012

The homogeneously distributed voids were small-large and spherically shaped with fewer, larger, irregularly shaped voids present. Secondary, internal deposits were observed as partial linings/coatings of clear-white material with similar optical properties of alkalic gel were observed in a few voids.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-rounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of lightweight, expanded clay/shale particles. A few particles exhibited a few internal fractures. A few discontinuous veneers of darker paste/mortar were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and quartz sandstone particles. A few wood fibers were also observed. A very small amount of the observed microcrystalline quartz chert particles exhibited internal fractures.

"436 P"

The sample was received in roughly two half portion separated by a horizontally oriented fracture plane. The portions were taped together.

GENERAL CONDITION: (See PLATES 11-13) The top surface exhibited rough, worn surface with numerous partially exposed fine aggregate particles in a recessed paste matrix. Several, large, air-void septa were present at the exposed surface. Moderate amounts of loose, black debris were also present at the exposed surface. One fine, discontinuous crack was observed at the top surface. A 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, a discontinuous zone of carbonated paste was observed up to approx. 1/16 of an inch thick. A small amount of microcracking was observed throughout the sample and many were infilled with a very finely crystalline, off white-light brown material that exhibited similar properties as alkalic gel/carbonated alkalic gel. Approx. 3-1/2 inches below the exposed surface, a 1/4 of an inch diameter steel bar was observed. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in almost all of the observed paste. Yellow staining was also observed at a few particle peripheries.

CEMENTITIOUS MATRIX: The cement paste matrix was moderately water absorptive, moderately soft-moderately hard, and light brown in color with a small-moderate amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The determined air-void system parameters are listed below in TABLE 4:

TABLE 4

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	ι in.	α in.$^{-1}$	L in.
"436 P"	28.04	1,776	86.40	5.35	5.24	4.1	.0131	306.4	.0154

The inhomogeneously distributed voids were mostly spherically shaped and small to large in size. A few, larger, irregular voids were also present. A small-moderate amount of clustering of voids was observed throughout the sample. A few voids exhibited secondary, internal deposits as coatings/linings of clear-off white material with the optical properties of alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-rounded in shape with an observed topsize of 3/4 of an inch. The observed coarse aggregate was composed of lightweight, expanded clay/shale particles. A few particles exhibited a small amount of internal fractures. A few discontinuous veneers of darker paste/mortar were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and quartz sandstone particles. A few particles exhibited a small amount of internal fractures.

DISCUSSION & CONCLUSION

We received six portions of hardened concrete to determine the general condition of the concrete(s). It was reported that the submitted samples were taken from view seating areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

The determined air-void system parameters are listed below in TABLE 7:

TABLE 7

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"412 P"	22.60	1,788	87.00	4.03	5.61	4.4	.0091	438.4	.0111
"416 P1/2"	20.20	1,505	73.55	1.66	12.2	1.8	.0094	425.6	.0162
"436 P"	28.04	1,776	86.40	5.35	5.24	4.1	.0131	306.4	.0154

The estimated air-void system parameters are listed below in TABLE 8:

TABLE 8

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"424 P"	22.6	925	44.95	4.1	5.51	4.0	.010	392	.012

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi.

- All samples are considered to be air-entrained except **"416 P1/P2"**.
- Overall, the observed lightweight aggregate particles exhibited only small amounts of fracturing and appear to be durable. Samples **"416 P1"**, **"416 P2"** , **"343 STEP"** were received in a heavily damaged/cracked conditions, with numerous cracks. The observed aggregate particles in Samples **"416 P1"** and **"416 P2"** exhibited reaction rims, and abundant amounts of internal fractures, and both alkalic gel deposits and ettringite as secondary deposits in many voids. These features strongly suggest that the collective aggregate should not be considered "durable" due to susceptibility to alkali-silica reactivity.

- The estimated and determined spacing factors were over (unacceptable) the recommended, industry standard limit maximum of 0.0080 inches, and should be considered inadequate for exposure in a water-saturated, cyclic, freeze-thaw environments.
- The compressive strength(s) of the concrete represented by this sample/mix design is unknown and comments regarding this will not be made.

Only small, if any, carbonation was observed in the examined core samples.

Samples "**416 P1**" and "**416 P2**" exhibited both alkalic gels and ettringite as secondary internal deposits. The presence of ettringite is commonly associated with the occurrence of ASR. The presence of ettringite that has formed due to DEF is associated with precast members that have been exposed to high curing temperatures. It should be noted that ettringite is common in Portland cement based concretes and its presence alone is not indicative of sulfate attack. It must be chemically established that the sulfate content of the concrete is greater than would be supplied by the original sulfate content of the cement.

Based on this examination, the most possible cause of the reported distress, as represented by the submitted samples, is active alkali-aggregate reactivity. Based on this examination and observations including aggregate features and the presence/degree of observed microcracking, the general conditions are deemed:

Poor – Samples "**343 STEP**", "**416 P1**" and "**416 P2**" due to heavily fractured received condition and lack of integrity. Samples "**416 P1**" and "**416 P2**"exhibited both alkalic gels and ettringite as secondary internal deposits, with the highest levels of reactions rims/internal fractures present.

Fair/Poor – Samples "**412 P**" and "**424 P**" exhibited small amounts of microcracking and low amounts of aggregate particles exhibiting internal fractures.

Fair/Poor – Sample "**436 P**" exhibited very small-small amounts of microcracking and low amounts of internal fracturing of aggregates.

However, Samples "**412 P**", "**424 P**", and "**436 P**" exhibited marked yellow staining of the pastes after the applications of cobaltinitrite. This suggests that appreciable amounts of mobilized alkalic gel was present within those pastes. The age of these concrete(s) is unknown. Marked disruption of the pastes of these concretes containing lightweight aggregates was not observed, but the potential is existent.

Inadequate air-void systems can be likely contributing factors to deficiencies or potential failure and/or further degradation.

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (e.g., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur. Differences in exposure conditions, especially exposure to water, can account for apparent physical changes in condition of the examined samples.

JR Varga

J. R. Varga, Concrete Petrographer

The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_6.pdf
- Online version of Plates 1-10 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_6_1_13.pdf

W.O.#: 07-08-31-01 GROUP 6 / TCG 0756

SAMPLE “412 P”

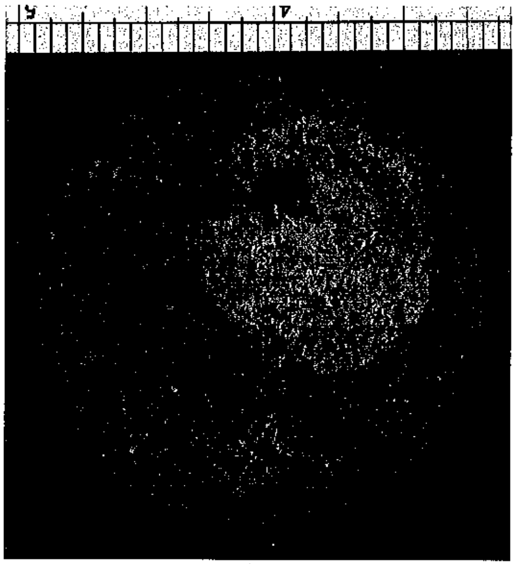


PLATE 1
TOP SURFACE

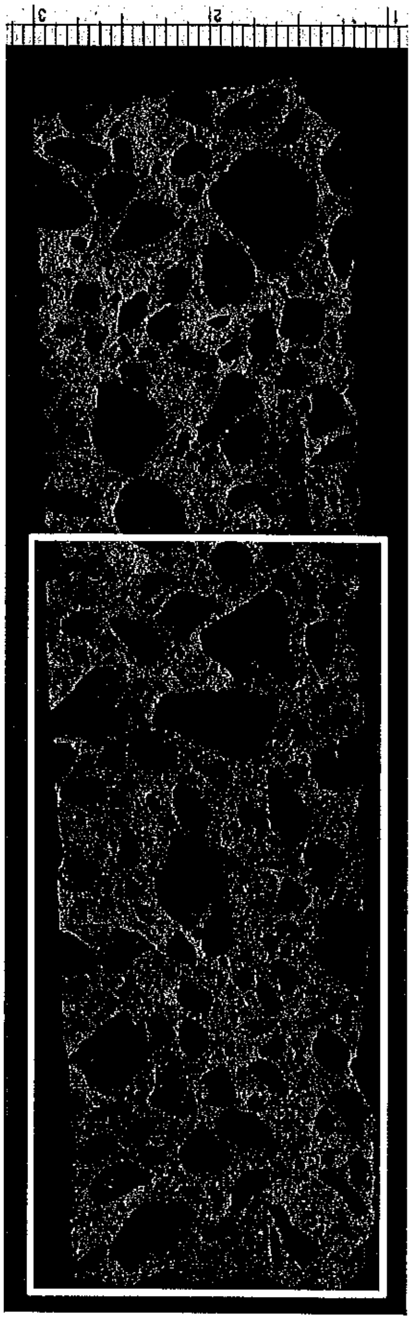


PLATE 2
PREPARED SURFACE
WHITE BOX SHOWN IN
PLATE 3

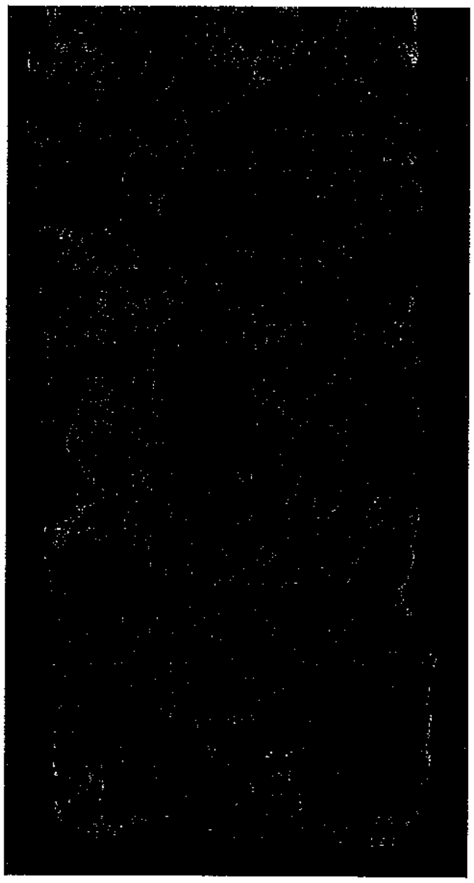


PLATE 3
PREPARED SURFACE AFTER STAINING WITH COBALTINITRITE
NOTE: MARKED YELLOW STAINING OF THE PASTE

W.O.#: 07-08-31-01 GROUP 6 / TCG 0756

SAMPLE "416 P2"

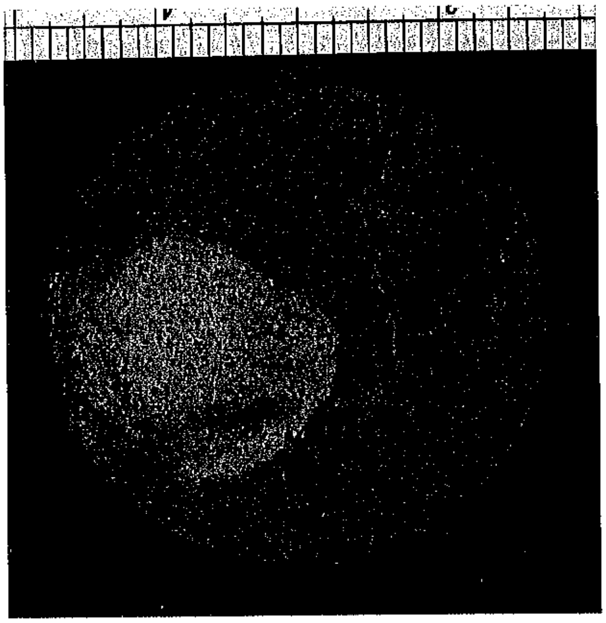


PLATE 4
TOP SURFACE

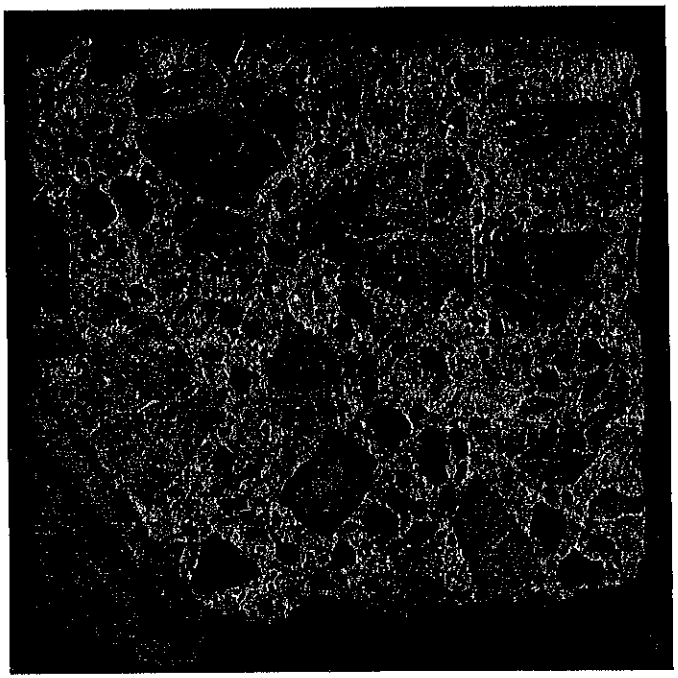


PLATE 6
PREPARED SURFACE /UPPER PORTION
SHOWING HEAVY FRACTURING IN
PASTE AND AGGREGATES

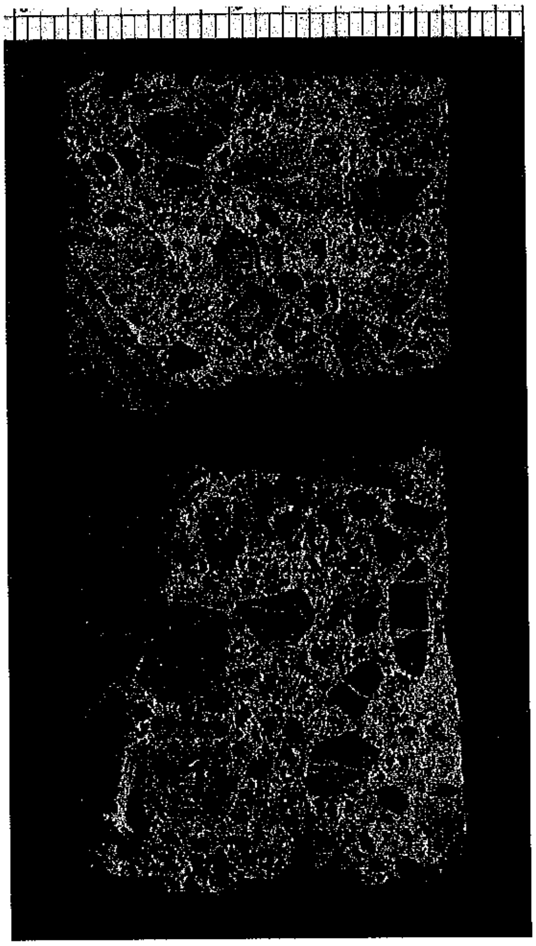


PLATE 5
PREPARED SURFACES
UPPER PORTION SHOWN IN
PLATE 6

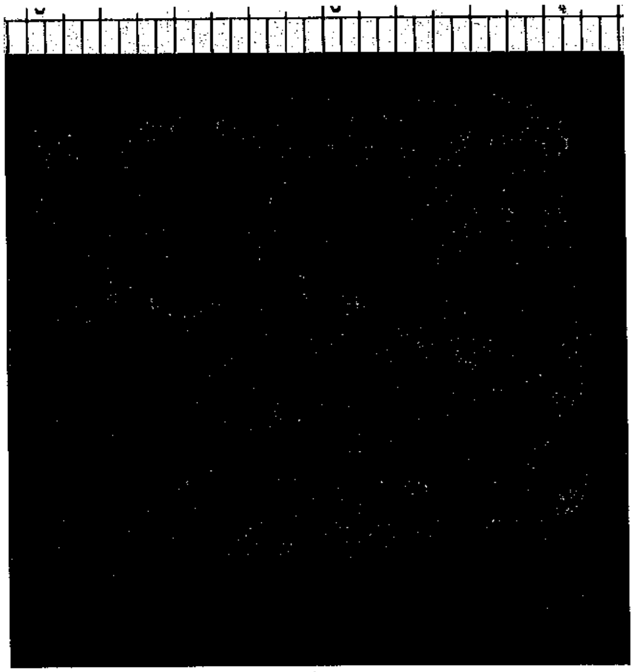


PLATE 7
PREPARED SURFACE/UPPER PORTION AFTER
STAINING WITH COBALTINITRITE
NOTE: LOCALIZED YELLOW STAINING OF
SMALL PASTE AREAS AND WITHIN AGGREGATE
PARTICLES ESPECIALLY WITH REACTION RIMS

W.O.#: 07-08-31-01 GROUP 6 / TCG 0756

SAMPLE “424 P”

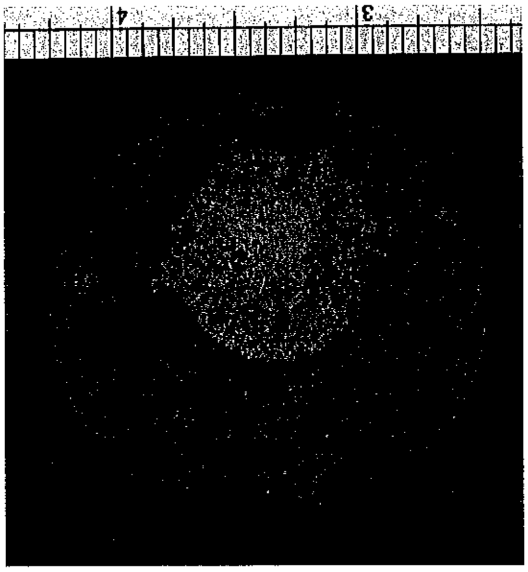


PLATE 8
TOP SURFACE

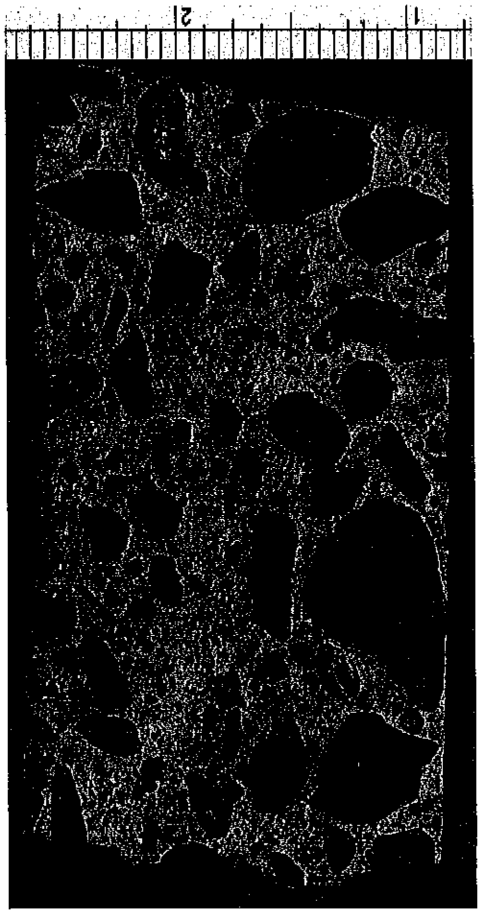


PLATE 9
PREPARED SURFACE

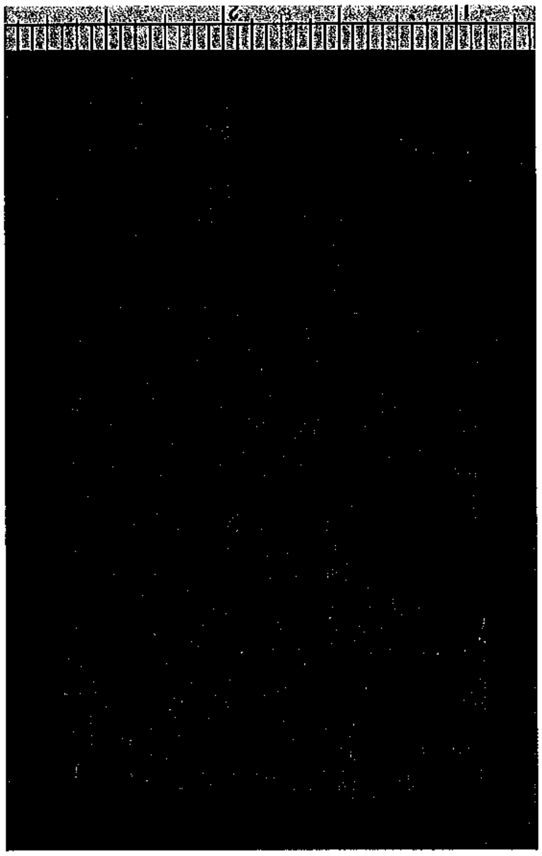


PLATE 10
PREPARED SURFACE AFTER STAINING
WITH COBALTINITRITE
NOTE: YELLOW STAINING OF CENTRAL
PASTE PORTION

W.O.#: 07-08-31-01 GROUP 6 / TCG 0756

SAMPLE "436 P"

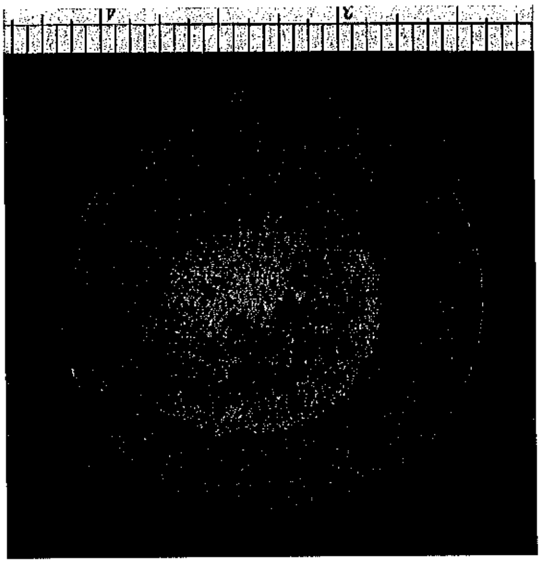


PLATE 11
TOP SURFACE

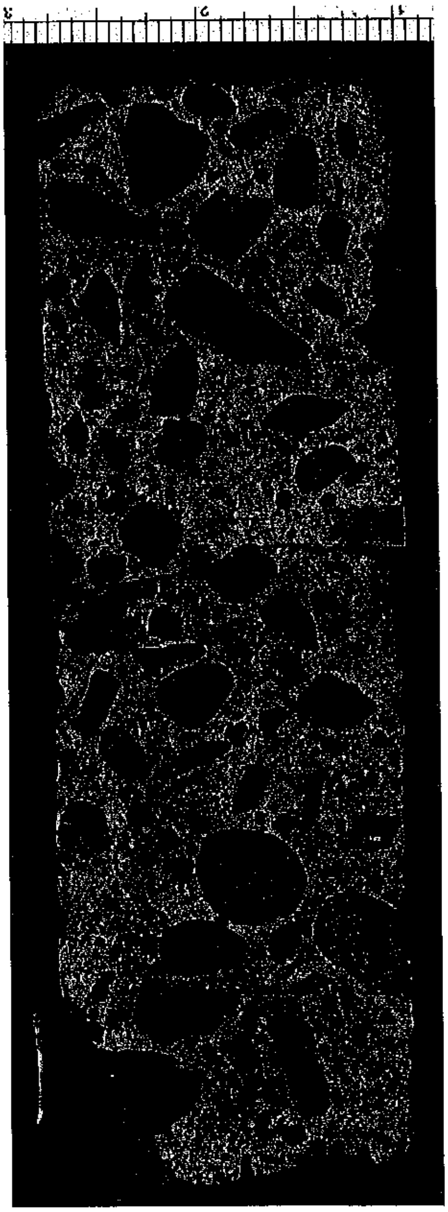


PLATE 12
PREPARED SURFACE

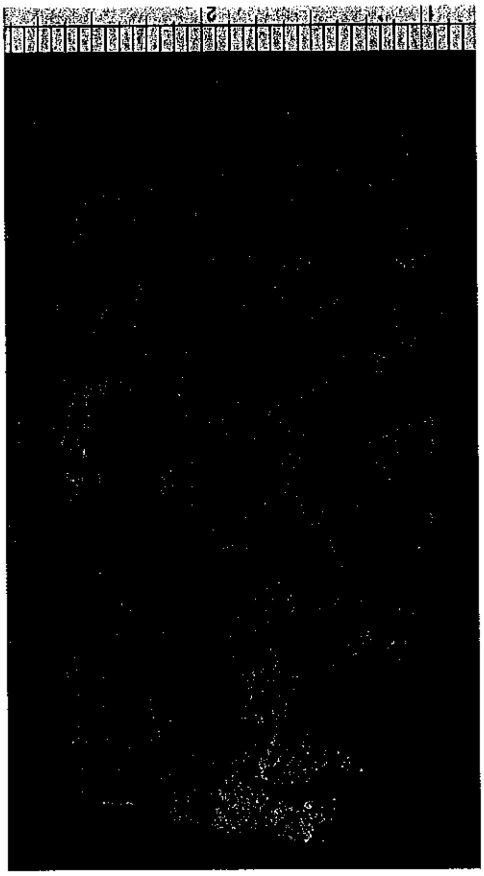


PLATE 13
CUT SURFACE (LOWER SAMPLE HALF) AFTER
STAINING WITH COBALTINITRITE
NOTE: MARKED YELLOW STAINING OF THE PASTE

THE ROCK DOCTOR
CONCRETE SOLUTIONS FOR CONCRETE PROBLEMS

PETROGRAPHIC REPORT

DATE:	October 20, 2007
WORK ORDER:	07-08-31-01 / Group 7 Club Level
CLIENT:	Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY:	Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received nine core portions of hardened concrete to determine the general condition of the concrete(s). The core portions were marked **"CLUB1 P1"**, **"CLUB1 P2"**, **"CLUB2 P1"**,**"CLUB2 P2"**, **"208 P1"**, **"208 P2"**, **"209 P1"**, **"209 P2"**,and **"238 P RF STEP"**. The core portions measured, in length, approximately 5, 3-3/4, 5-1/4, 5, 5-1/2, 3-1/2, 5-1/4, 5-1/2, and 4-3/4 inches, respectively. The core portions were approximately 1-3/4 inches in diameter except for Sample **"238 P RF STEP"** which measured 3-1/8 inches in diameter. Another core sample received in a plastic bag labeled **"343 P STEP"** was also received. This sample was very heavily cracked and friable and no sample could be cut for it due to its fractured condition.

It was reported that the submitted samples were taken from the club level area. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

SAMPLE PREPARATION AND METHODS

The examined samples were cut in half, approximately perpendicular to the top surfaces. The cut surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were estimated/determined following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters. Sample **"424 P"**did not meet minimum traverse length requirements due to inadequate sample size.

The unprepared samples were partially immersed in water for at least three days to mobilize any alkalic gels present. The cut surfaces of the core portion samples were not immersed in water.

The prepared surfaces of Samples **"CLUB1 P2"**, **"CLUB2 P2"**, and **"208 P2"** and the upper portion of the prepared surface of Sample **"209 P1"** were stained using a saturated, aqueous solution of sodium cobaltinitrite (reacts with soluble potassium to produce a yellow precipitate resulting in staining potassium-rich ASR gel) following the guidelines in a July 1998 report titled *"Geochemical Methods for the Identification of ASR Gel"* by Guthrie and Carey, Los Alamos National Laboratory . In addition, a saturated, aqueous solution of Rhodamine B was similarly used to aid this staining procedure by highlighting (providing a high contrast background) the regions of yellow-stained ASR gel and in part, to identify other degradation products.

The prepared, unprepared, and stained sample surfaces were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

"CLUB1 P1" and "CLUB1 P2"

The samples exhibited similar features and will be described as one.

GENERAL CONDITION: (See PLATES 1-5) The top surface exhibited a generally smooth, soft, elastic membrane/coating that was gray to light gray in color. Water initially beaded when applied to this surface and was slowly absorptive. Many, partially exposed fine quartz aggregate particles, a few aggregate sockets, and several fine, cracks were present at the exposed surface. The cracks were mostly located at exposed aggregate peripheries. Small areas exhibited harder, finely cracked gray coating material. A 1-inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system was approx. 3/32 of an inch thick and appeared to be composed of four layers of material. The uppermost layer at/adjacent to the exposed surface was dark gray in color, ranged in thickness from a veneer up to approx. 1/32 of an inch, and appeared to be a top coat-type application that filled irregularities present in the underlying layer of material. This uppermost layer exhibited a very few, small voids but did not exhibit any aggregate particles. At the irregular interface between the two uppermost coating layers, no cracks or separations were observed. The second layer below the top surface (up to approx. 1/32 of an inch thick) was soft, elastic, and light gray in color with many fine aggregate particles. Immediately below the two upper layers, a dark gray-gray colored, soft, elastic material was observed with many air-void septa present. This layer ranged was observed up to approx. 1/40 of an inch thick. Below this layer, the fourth layer was gray colored material with many air-void septa and ranged in thickness from approx. 1/40 up to 1/32 of an inch thick. At the bottom surface of these applied coatings, an almost continuous, adhered layer of paste/mortar from the base material was observed. An almost continuous separation/crack was present at or within the upper portion of the base concrete. No apparent carbonation was observed in the base concrete. A small amount of microcracking was observed throughout the sample and most were infilled with off-white, fine crystalline material with similar optical properties as alkalic gel/carbonated alkalic gel. Several, small separations were observed at several paste:aggregate interfaces. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in small localized paste areas and within many aggregate particles especially those exhibiting reaction rims. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light gray-dull white with a moderate amount of unhydrated cement particles to dull white in color with a small amount of unhydrated cement particles. The darker-colored paste areas were harder as compared to the lighter-colored paste portions. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The point counts of Samples **"CLUB1 P1"** and **"CLUB1 P2"** were combined and are reported as one. The estimated air-void system parameters are listed below in TABLE 1:

TABLE 1

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"CLUB1 P1/2"	20.9	1,566	76.30	4.7	4.5	4.4	.011	373	.012

The inhomogeneously distributed voids were mostly small and spherically shaped with larger, spherically shaped voids also present. Fewer, larger, irregularly shaped voids were also observed. A small amount of clusters of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as coatings/linings of clear-off-white material with the optical properties of the alkalic gel/carbonated alkalic gel. In a few voids, secondary, internal deposits were observed as tufts and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26 H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. Many particles exhibited reaction rims and several particles exhibited small amounts of internal fractures. Small, localized areas of paste exhibited a darker color or stained appearance adjacent to several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, quartz sandstone and siltstone and claystone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures.

"CLUB2 P1" and **"CLUB2 P2"**

The samples exhibited similar features and will be described as one, unless otherwise noted.

GENERAL CONDITION: (See PLATES 6-10) The top surface was mostly composed of a generally smooth surface exhibiting soft, elastic membrane/coating that was gray to light gray in color. Water initially beaded when applied to this surface and was slowly absorptive. Many, partially exposed fine quartz aggregate particles, and a few aggregate sockets, and many fine cracks (mostly located at exposed aggregate peripheries) were present at the exposed surface. A small-moderate amount of localized areas at the exposed surfaces exhibited harder, finely cracked, gray coating material. A ¾ of an inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system ranged from approx. 3/32-1/8 of an inch thick and was composed of five apparent layers. The discontinuous, uppermost layer at/adjacent to the exposed surface ranged in thickness from zero (non-existent) up to approx. 1/32 of an inch and appeared to be a top coat-type application that filled irregularities present in the underlying layer of material. This uppermost layer was gray-dark gray in color exhibited a very few, small voids but did not exhibit any aggregate particles. At the irregular interface between the two uppermost coating layers, no voids, separations, or cracks were observed. The second layer below the top surface (from 1/32 of an inch up to approx. 1/16 of an inch thick) was gray in color and exhibited many aggregate particles and many air-void septa. Immediately below the two upper layers, another layer of material, similar to the second layer as described above, was observed in Sample **"CLUB2 P1"**. observed. This layer ranged in thickness from very thin up to approx. 1/32 of an inch maximum thickness. In Sample **"CLUB2 P2"**, the third layer appeared to be a thinner application (up to approx. 1/40 of an inch thick) that was composed of similar, gray-colored material without any aggregate particles present. Below these layers, the fourth layer was composed of a light gray colored material with many air-void septa. This layer was approx. 1/40 of an inch thick. The observed fifth layer was gray in color, approx. 1/32 of an inch thick and exhibited many air-void septa. At the bottom surface of these applied coatings, an intermittent adhered layer of paste/mortar from the base concrete was present. An almost continuous separation/crack was present at or within the upper portion of the base concrete or at the coating system:base concrete interface. A veneer up to approx. 1/8 of an inch thick zone of carbonated cement paste was observed in the base concrete. A small amount of microcracking was observed throughout the sample and most were infilled with off-white, fine crystalline material with similar optical properties as alkalic gel/carbonated alkalic gel. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in small, localized paste portions. Yellow staining was also observed in the interiors of several aggregate particles. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light gray-dull white with a moderate amount of unhydrated cement particles to dull white in color with a small amount of unhydrated cement particles. The darker-colored paste areas were harder as compared to the lighter-colored paste portions. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The point counts of Samples **"CLUB2 P1"** and **"CLUB2 P2"** were combined and are reported as one. The air-void system parameters are listed below in TABLE 2:

TABLE 2

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Samples	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"CLUB2 P1/2"	25.82	1,863	90.60	5.31	4.86	4.7	.0114	351.4	.0130

The inhomogeneously distributed voids were mostly small in size and spherically shaped. With fewer, larger, spherical voids present. A small amount of clusters of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as partial coatings/linings of clear-off white material with the optical properties of the alkalic gel/carbonated alkalic gel. In many voids, secondary, internal deposits were observed as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\ H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. Several particles exhibited reaction rims and several particles exhibited small amounts of internal fractures. Small, localized areas of paste exhibited a darker color or stained appearance adjacent to several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, quartz sandstone and siltstone and claystone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures.

"208 P1" and **"208 P2"**

The samples exhibited similar features and will be described as one.

GENERAL CONDITION: (See PLATES 11-15) The top surface exhibited a hard, dark gray, heavily cracked, coating material with a few, partially exposed fine aggregate particles. The observed fine cracks exhibited a "mud-crack"-type pattern. Water initially beaded when applied to this surface and was moderately absorptive. An approx. ¾ of an inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system was approx. 1/16 of an inch thick and appeared to be composed of three layers of material. The uppermost layer at/adjacent to the exposed surface was soft, elastic, and light gray in color with many fine aggregate particles. The observed thickness ranged from approx. 1/32 – 1/50 of an inch. Immediately below this layer, a gray colored, soft, elastic material was observed with a few air-void septa present. This layer was observed to be approx. 1/64 of an inch thick and exhibited a discontinuous fine separation that bisected portions of the material. Below this layer, the third layer was soft, elastic, light red-pink in color and very thin. At the bottom surface of this layer, an almost continuous, separation/crack was present at the interface with the underlying base concrete or within the upper portion of the base concrete. Small amounts of adhered paste/mortar from the base concrete were also observed at/adjacent to the bottom surface of the light red-pink layer. No apparent carbonation was observed in the base concrete. A small-moderate amount of microcracking was observed throughout the sample and most were infilled with off-white, fine crystalline material with similar optical properties as alkalic gel/carbonated alkalic gel. A few, small separations were observed at several paste:aggregate interfaces. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in many, localized paste areas. Yellow staining was also observed in many aggregate particles, at aggregate peripheries and adjacent to reaction rims. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light gray-dull white with a moderate amount of unhydrated cement particles to dull white in color with a small amount of unhydrated cement particles. The darker-colored paste areas were harder as compared to the lighter-colored paste portions. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 3:

TABLE 3

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"208 P1/2"	22.50	1,760	85.35	4.72	4.77	4.6	.0102	393.5	.0115

The inhomogeneously distributed voids were mostly small and spherically shaped with larger, spherically shaped voids also present. Fewer, larger, irregularly shaped voids were also observed. A small amount of clusters of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as coatings/linings of clear-off-white material with the optical properties of the alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. Many particles exhibited reaction rims and several particles exhibited small amounts of internal fractures.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and quartz sandstone particles. A few of the observed microcrystalline quartz chert particles exhibited reaction rims. Several particles exhibited internal fractures.

"209 P1" and **"209 P2"**

The samples exhibited similar features and will be described as one.

GENERAL CONDITION: (See PLATES 16-20) The top surface exhibited a hard, dark gray, heavily cracked, coating material with a few, partially exposed fine aggregate particles. The observed fine cracks exhibited a "mud-crack"-type pattern. Water initially beaded when applied to this surface and was moderately absorptive. An approx. 1 inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system was approx. 1/16 of an inch thick and appeared to be composed of three layers of material. The uppermost layer at/adjacent to the exposed surface was soft, elastic, and light gray in color with many fine aggregate particles. The observed thickness ranged from approx. 1/64 of an inch. Immediately below this layer, a gray colored, soft, elastic material was observed with a few air-void septa present. This layer was observed to be approx. 0.01 of an inch thick and exhibited an almost continuous fine separation that bisected the layer. Below this layer, the third layer was soft, elastic, light red-pink in color and very thin. At the bottom surface of this layer, a continuous, separation/crack was present with small amounts of adhered paste/mortar from the base concrete. A 1/16 of an inch thick zone of carbonated paste was present in the upper portion of the base concrete. A small amount of microcracking was observed throughout the sample and most were infilled with off-white, fine crystalline material with similar optical properties as alkalic gel/carbonated alkalic gel. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in many, small portions of the observed paste. Yellow staining was also observed in several coarse aggregate particles, many fine aggregate particles, and at many aggregate peripheries.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from pale brown-light gray in color with a small amount of unhydrated cement particles to pale brown-dull white with a very small-small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The determined air-void system parameters are listed below in TABLE 4:

TABLE 4

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"209 P1/2"	24.74	2,057	100.05	4.42	5.60	5.9	.0075	532.3	.0092

The inhomogeneously distributed voids were mostly small and spherically shaped with fewer, larger spherical-irregularly shaped voids also observed. A small-moderate amount of clustering of voids was observed throughout the sample. Many voids exhibited secondary, internal deposits as coatings/linings of clear-off white material with the optical properties of alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-rounded in shape with an observed topsize of 1-1/8 inches. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. Several particles exhibited reaction rims and several particles exhibited small amounts of internal fractures. A few, discontinuous, lighter colored paste areas were observed at a few aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and quartz sandstone particles. A few particles exhibited reaction rims. Several particles exhibited a small amount of internal fractures.

"238 P"

GENERAL CONDITION: (See PLATES 20-24) The top surface was slightly rough and generally flat with numerous, partially exposed fine aggregate particles in a recessed paste matrix. Numerous air-void septa were also present at the exposed surface. The color was mottled from light brown to light brown gray with one fine crack bisecting the top surface. This crack exhibited darker paste at its edges and was infilled with off-white, very fine, crystalline material with some optical properties of alkalic/carbonated alkalic gel.

In section, a carbonation zone up to approx. 3/16 of an inch was observed. One vertically oriented crack (coinciding with the previously described surface crack at the top surface) was observed to a maximum depth of approx. 1-3/8 inches. This crack transected paste and aggregate particles. Portions of this crack were infilled with off-white-white deposits of material with similar optical properties of alkalic/carbonated alkalic gel. An abundant amount of microcracking and cracking was observed throughout the sample. Many cracks were infilled with a very finely crystalline, off white-light brown material that exhibited similar properties as alkalic gel/carbonated alkalic gel. The bottom surface was a fractured surface that also exhibited alkalic gel/carbonated alkalic gel deposits.

CEMENTITIOUS MATRIX: The highly water absorptive, cement paste matrix was, moderately soft-moderately hard, and variegated in color from light brown-pale gray in color with a small amount of unhydrated cement particles to light brown-dull white with a very small amount of unhydrated cement particles. Lighter colored paste areas were softer as compared to darker paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 5:

TABLE 5

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α $in.^{-1}$	L in.
"238 P"	25.23	2,033	100.15	6.54	3.86	6.4	.0102	391.9	.0098

The inhomogeneously distributed voids were small and spherically shaped with larger, spherical to irregularly shaped voids also present. A small-moderate amount of clustering of voids was observed throughout the sample. An abundant amount of secondary, internal deposits were observed as linings/coatings and infillings of clear-white material with similar optical properties of alkalic gel and as coatings/linings, partial linings, tufts, and blooms of internally radiating fine, needle-like crystals with the optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\ H_2O$. Several voids exhibited linings of alkalic gel infilled with ettringite deposits.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-rounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. Most of the aggregate particles exhibited reaction rims and most particles exhibited internal fractures. A few, discontinuous, lighter colored paste areas were observed at a few aggregate peripheries. A few particles exhibited internal fractures infilled with alkalic gel.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, quartz sandstone and siltstone and claystone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures.

DISCUSSION & CONCLUSION

We received nine core portions of hardened concrete to determine the general condition of the concrete(s). It was reported that the submitted samples were taken from club level areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

The determined air-void system parameters are listed below in TABLE 6:

TABLE 6

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α $in.^{-1}$	L in.
"CLUB2 P1/2"	25.82	1,863	90.60	5.31	4.86	4.7	.0114	351.4	.0130
"209 P1/2"	24.74	2,057	100.05	4.42	5.60	5.9	.0075	532.3	.0092
"238 P"	25.23	2,033	100.15	6.54	3.86	6.4	.0102	391.9	.0098

The estimated air-void system parameters are listed below in TABLE 7:

TABLE 7

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"CLUB1 P1/2"	20.9	1,566	76.30	4.7	4.5	4.4	.011	373	.012
"208 P1/2"	22.5	1,760	85.35	4.7	4.8	4.6	.010	393	.012

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi.

- All samples are considered to be air-entrained.
- Overall, the observed aggregates in each sample exhibited reaction rims and internal fractures. Alkalic gel deposits were observed in all samples. The results of staining using cobaltinitrite showed active gels in paste and aggregates. These features strongly suggest that the collective aggregate should not be considered "durable" due to susceptibility to alkali-silica reactivity.
- The estimated and determined spacing factors were over (unacceptable) the recommended, industry standard limit maximum of 0.0080 inches, and should be considered inadequate for exposure in a water-saturated, cyclic, freeze-thaw environments.
- The compressive strength(s) of the concrete represented by this sample/mix design is unknown and comments regarding this will not be made.

Only small amounts, if any, of carbonation were observed in the examined core samples.

The **"CLUB1"**, **"CLUB 2"** and **"238 P"** samples exhibited both alkalic gels and ettringite as secondary internal deposits. The presence of ettringite is commonly associated with the occurrence of ASR. The presence of ettringite that has formed due to DEF is associated with precast members that have been exposed to high curing temperatures. It should be noted that ettringite is common in Portland cement based concretes and its presence alone is not indicative of sulfate attack. It must be chemically established that the sulfate content of the concrete is greater than would be supplied by the original sulfate content of the cement.

Based on this examination, the most possible cause of the reported distress, as represented by the submitted samples, is active alkali-aggregate reactivity. Based on this examination and observations including aggregate features and the presence/degree of observed microcracking, the general conditions are deemed:

Very Poor – Sample **"238 P"** exhibited abundant cracking and microcracking, abundant amounts of alkalic gels and ettringite as secondary internal deposits, with the highest levels of reactions rims/internal fractures present.

Poor – Samples **"208 P"** exhibited small-moderate amounts of microcracking and moderate amounts of reactions rims in the coarse aggregates and low amounts of internal fracturing of aggregates.

Poor – Sample **"CLUB1"** exhibited small amounts of microcracking, ettringite, and a moderate amount of reactions rims in the coarse aggregate with low amounts of aggregate particles exhibiting internal fractures.

Poor – Samples **"CLUB2"** and **"209 P"**exhibited small amounts of microcracking, ettringite, and low amounts of reactions rims in the coarse aggregate with low amounts of aggregate particles exhibiting internal fractures.

Inadequate air-void systems can be likely contributing factors to deficiencies or potential failure and/or further degradation.

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (e.g., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur. Differences in exposure conditions, especially exposure to water, can account for apparent physical changes in condition of the examined samples.

JR Varga

J. R. Varga, Concrete Petrographer

The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_7.pdf
- Online version of Plates 1-15 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_7_1_15.pdf
- Online version of Plates 16-24 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_7_16_24.pdf

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 7

CLUB LEVEL "CLUB1 P1" AND "CLUB1 P2"

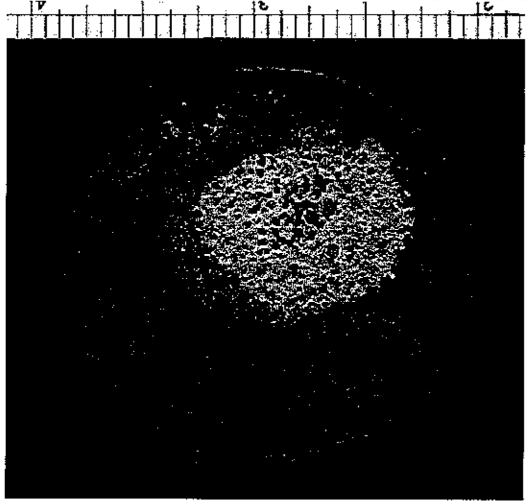


PLATE 1
TOP SURFACE

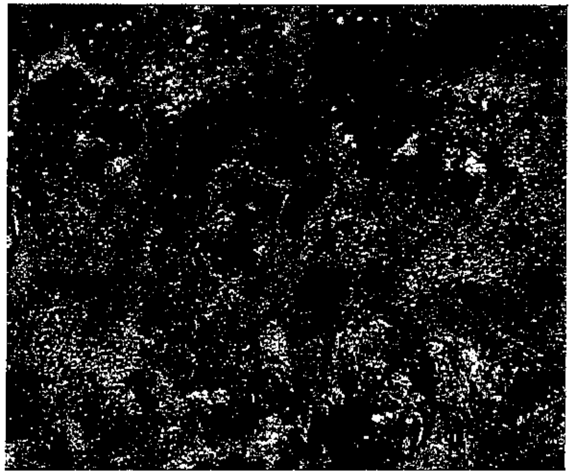


PLATE 2
TOP SURFACE SHOWING LOCALIZED CRACKING IN THE GRAY COATING MATERIAL ESPECIALLY AT EXPOSED AGGREGATE PERIPHERIES

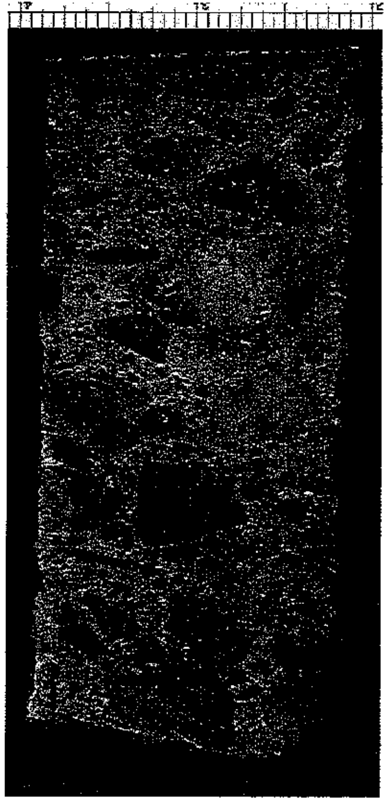


PLATE 3
PREPARED SURFACE
"CLUB1 P1"

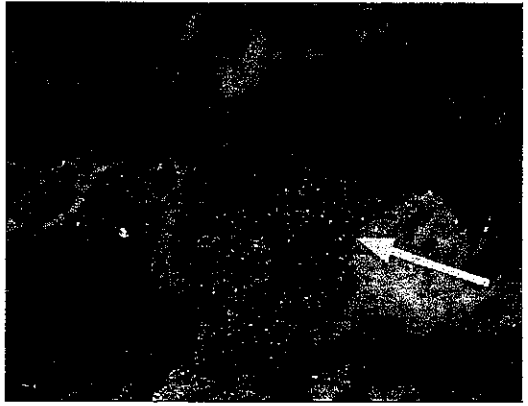


PLATE 4
PREPARED SURFACE "CLUB1 P2"CORE EDGE SHOWING CLEAR, CRACKED GEL EXUDATION

PLATE 5
PREPARED SURFACE
"CLUB1 P2"
SHOWING YELLOW STAINING IN PASTE AND WITHIN AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 7

CLUB LEVEL “CLUB2 P1” AND “CLUB2 P2”

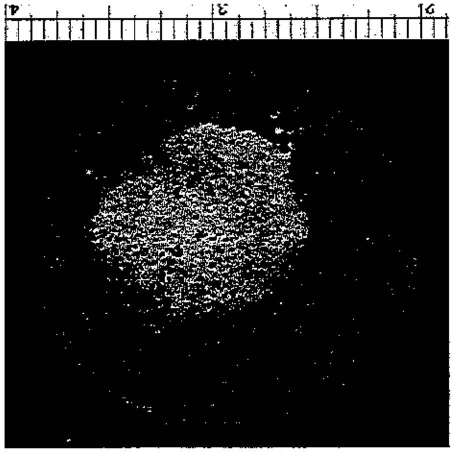


PLATE 6
TOP SURFACE

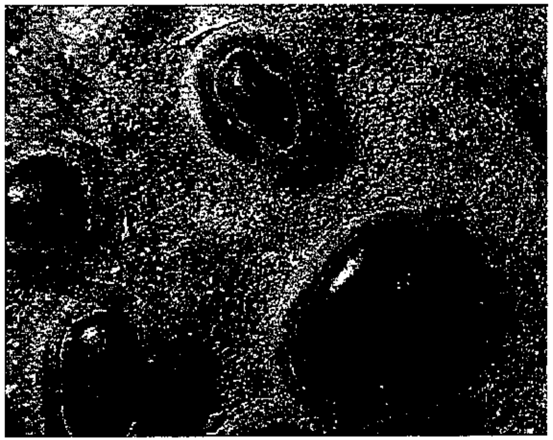


PLATE 7
TOP SURFACE SHOWING BOTH “SMOOTH” AND FINELY CRACKED PORTIONS OF GRAY COATING MATERIAL WITH EXPOSED FINE AGGREGATE PARTICLES

PLATE 8
PREPARED SURFACE
“CLUB2 P1”

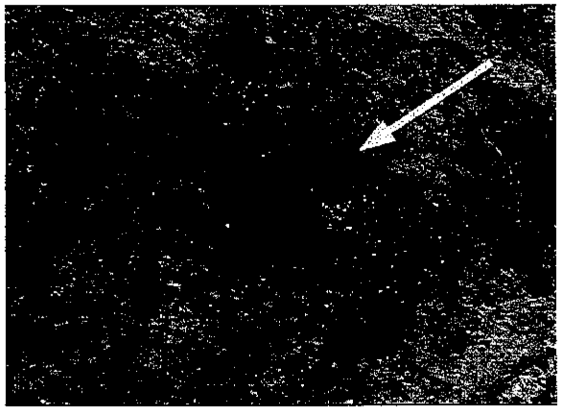


PLATE 9
CUT SURFACE SHOWING CLEAR GEL EXUDATION AFTER WATER IMMERSION OF SAMPLE TRIMMING

PLATE 10
PREPARED SURFACE “CLUB2 P2” SHOWING YELLOW STAINING IN PASTE AND WITHIN AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 7
CLUB LEVEL “208 P1” AND “208 P2”

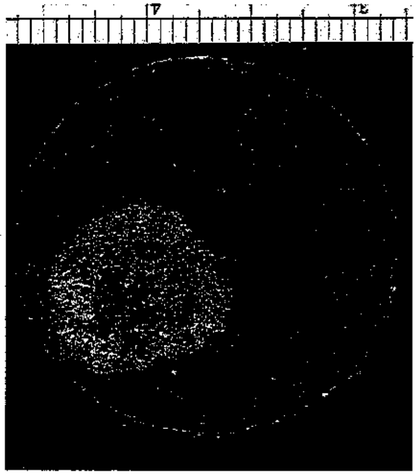


PLATE 11
TOP SURFACE

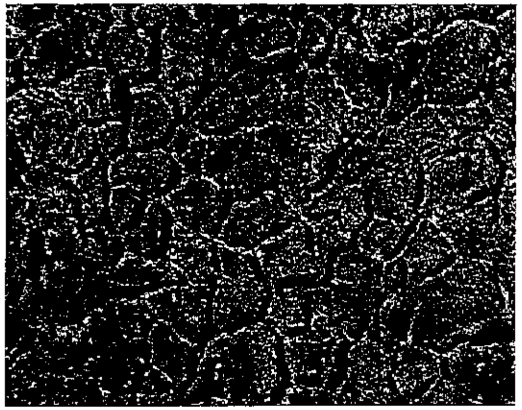


PLATE 12
TOP SURFACE SHOWING
HEAVILY CRACKED GRAY
COATING MATERIAL AND A
FEW EXPOSED FINE
AGGREGATE PARTICLES

PLATE 13
PREPARED SURFACE
“208 P1”

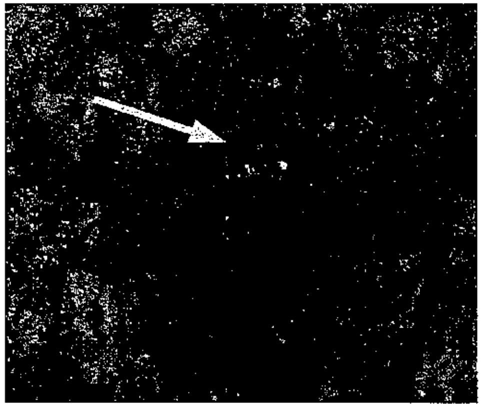


PLATE 14
CUT SURFACE SHOWING
GEL EXUDATION AFTER
WATER IMMERSION OF
SAMPLE TRIMMING

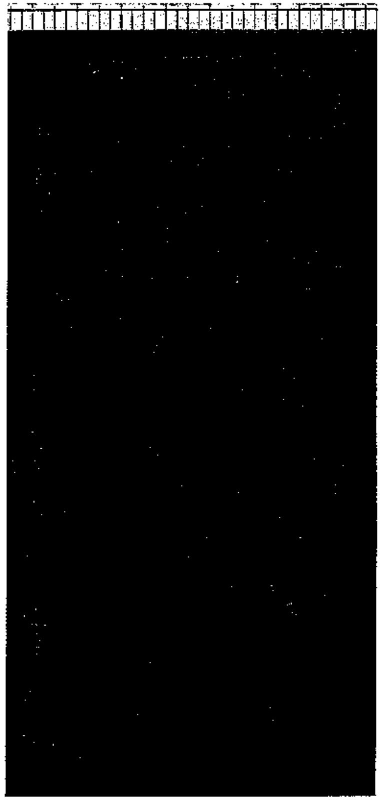


PLATE 15
PREPARED SURFACE “208 P2”
SHOWING YELLOW STAINING
IN PASTE AND WITHIN
AGGREGATE PARTICLES
AFTER COBALTINITRITE
STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 7

CLUB LEVEL "209 P1" AND "209 P2"

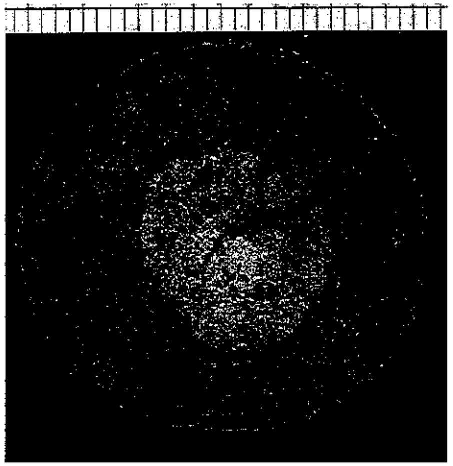


PLATE 16
TOP SURFACE

PLATE 17
TOP SURFACE SHOWING LOCALIZED FINE, "MUD-CRACK"-TYPE CRACKING IN THE GRAY COATING MATERIAL

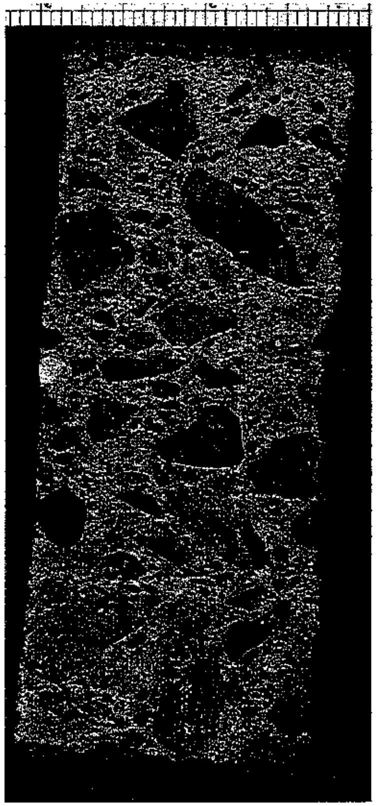


PLATE 18
PREPARED SURFACE
"209 P2"

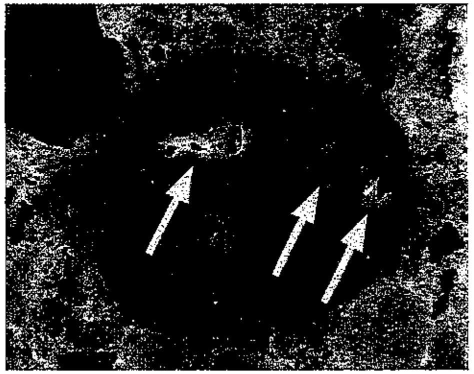


PLATE 19
PREPARED SURFACE "209 P2" SHOWING ALKALIC GEL EXUDATIONS ON A CHERT PARTICLE

PLATE 20
PREPARED SURFACE UPPER PORTION OF SAMPLE "209 P1" SHOWING YELLOW STAINING IN PASTE AND WITHIN AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 7
CLUB LEVEL "238 P"

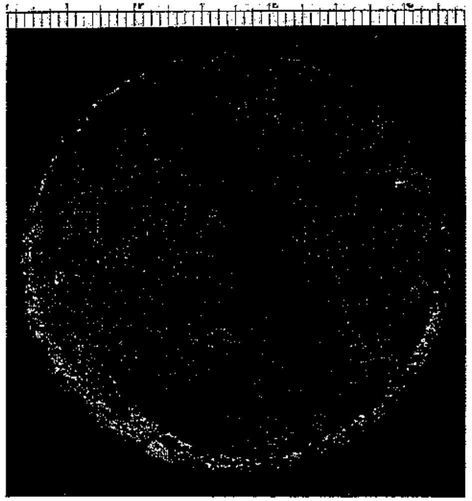


PLATE 21
TOP SURFACE

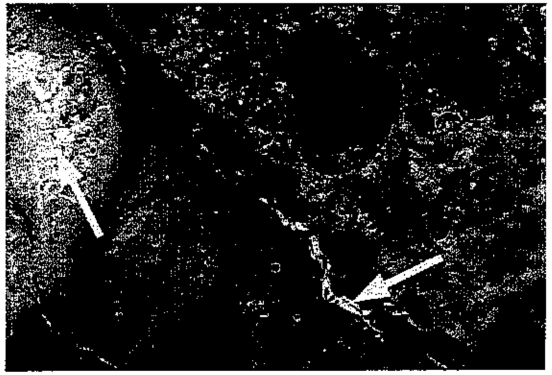


PLATE 22
PREPARED SURFACE SHOWING
ALKALIC GEL EXUDATIONS WITHIN
AGGREGATE PARTICLE AND IN
SURROUNDING PASTE

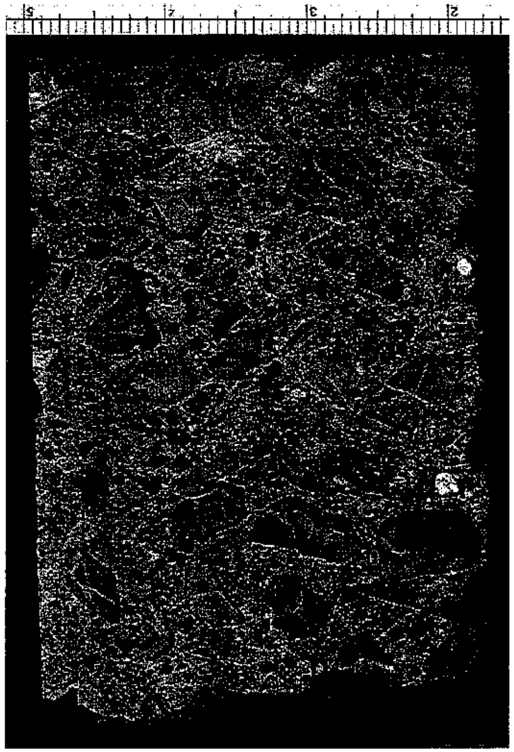


PLATE 23
PREPARED SURFACE

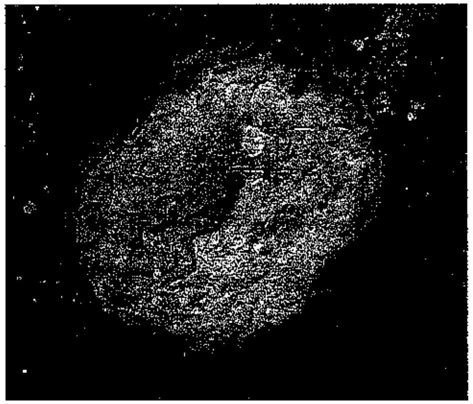


PLATE 24
PREPARED SURFACE
SHOWING OFF-WHITE,
CRACKED ALAKLIC
GEL INFILLING VOID

THE ROCK DOCTOR
CONCRETE SOLUTIONS FOR CONCRETE PROBLEMS

PETROGRAPHIC REPORT

DATE:	October 24, 2007
WORK ORDER:	07-08-31-01 / Group 8 Upper Back Panels and Scoreboard
CLIENT:	Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY:	Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received five core portions of hardened concrete to determine the general condition of the concrete(s). The core portions were marked **"343BP-P"**, **"344BP-P"**, **"435BP-P"**,**"436BP-P"**, and **"SCOREBOARD SB-P"**. The core portions measured, in length, approximately 5-1/4, 5-1/2, 4-1/4, 5-3/4, and 6-1/4 inches, respectively. The core portions were approximately 1-3/4 inches in diameter except for Sample **"SCOREBOARD SB-P"** which measured approx. 3-1/4 inches in diameter. Sample **"343BP-P"**was received in two portions that were taped together.

It was reported that the submitted samples were taken from upper back panel and scoreboard areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

SAMPLE PREPARATION AND METHODS

The examined samples were cut in half, approximately perpendicular to the top surfaces. The cut surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were estimated/determined following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters. Samples **"343BP-P"**, **"344BP-P"**, **"435BP-P"**, and **"436BP-P"** did not meet minimum traverse length requirements due to inadequate surface area/minimum traverse lengths.

The unprepared samples were partially immersed in water for at least three days to mobilize any alkalic gels present. The cut surfaces of the core portion samples were not immersed in water.

After petrographic examinations, the prepared surfaces were stained using a saturated, aqueous solution of sodium cobaltinitrite (reacts with soluble potassium to produce a yellow precipitate resulting in staining potassium-rich ASR gel) following the guidelines in a July 1998 report titled *"Geochemical Methods for the Identification of ASR Gel"* by Guthrie and Carey, Los Alamos National Laboratory . In addition, a saturated, aqueous solution of Rhodamine B was similarly used to aid this staining procedure by highlighting (providing a high contrast background) the regions of yellow-stained ASR gel and in part, to identify other degradation products.

The prepared, unprepared, and stained sample surfaces were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

"343BP-P"

GENERAL CONDITION: (See PLATES 1-4) The top surface was generally flat and smooth with several, partially exposed, fine aggregate particles in a moderately soft paste matrix. Several air-void septa were also present at the exposed surface. The exposed surface appeared to be a formed surface. The color was mottled from light brown to light brown-light gray. Small, remnants of clear material were present at the top surface. This material softened when acetone was applied and is presumed to be from a membrane curing compound or sealer. Water initially beaded at the top surface and slowly was absorbed. An approx 1 inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also present at the exposed surface.

In section, the upper ¾ of an inch was less water absorptive as compared to the bulk paste and did not readily "wet-out" resulting in a lighter color after water was applied to the surface. A small amount of microcracking was observed throughout the sample. Many cracks were infilled with a very finely crystalline, off white-light brown material that exhibited similar properties as alkalic gel/carbonated alkalic gel. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct, yellow staining from the application of the sodium cobaltinitrite solution in small, localized paste areas and within many aggregate particles. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft, and subtly variegated from light gray-light brown with a small amount of unhydrated cement particles to light brown-dull white in color with a very small amount of unhydrated cement particles. The darker-colored paste areas were harder as compared to the lighter-colored paste portions. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 1:

TABLE 1

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	ι in.	α in.$^{-1}$	L in.
"343BP-P"	22.5	1,560	76.75	1.9	11.8	3.5	.005	736	.009

The inhomogeneously distributed voids were mostly spherically shaped and ranged in size from small to large. A very small-small amount of clusters of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as coatings/linings of clear-off-white material with the optical properties of the alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. Several particles exhibited reaction rims and a few particles exhibited small amounts of internal fractures. Small, localized areas of paste exhibited a darker color or stained appearance adjacent to several aggregate peripheries. Also, small amounts of small, irregular separations were observed at several aggregate peripheries. Lighter-colored, soft, white paste was present in the paste adjacent to these separations.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, quartz sandstone and siltstone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures. Also, small amounts of small, irregular separations were observed at several aggregate peripheries. Lighter-colored, soft, white paste was present in the paste adjacent to these separations.

"344BP-P"

GENERAL CONDITION: (See PLATES 5-7) The top surface was generally flat and smooth with several, partially exposed, fine aggregate particles in a moderately soft paste matrix. Several air-void septa and small amounts of loose, fine black debris/material were also present at the exposed surface. The exposed surface appeared to be a formed surface. The color was mottled from light brown to light brown-light gray. Water initially beaded at the top surface and slowly was absorbed. An approx. 1 inch diameter, yellow paint "dot", presumed to be used for marking purposes, and in black ink "6" DEE... 2 O" were also observed on the exposed surface.

In section, the upper 1/8-1/4 of an inch was less water absorptive as compared to the bulk paste and did not readily "wet-out" resulting in a lighter color after water was applied to the surface. A small-moderate amount of microcracking was observed throughout the sample. Many cracks were infilled with a very finely crystalline, off white-light brown material that exhibited similar properties as alkalic gel/carbonated alkalic gel. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct, yellow staining from the application of the sodium cobaltinitrite solution in small, localized paste areas and within many aggregate particles. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately hard-moderately soft, and pale brown-dull white in color with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 2:

TABLE 2

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"344BP-P"	19.1	1,720	83.65	1.1	17.4	3.1	.004	1,138	.007

The inhomogeneously distributed voids were mostly spherically shaped and ranged in size from small to large. A very small-small amount of clusters of voids was observed throughout the sample. In several voids, secondary, internal deposits were observed as coatings/linings of clear-off-white material with the optical properties of the alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. Several particles exhibited reaction rims and several particles exhibited small amounts of internal fractures. Small, localized areas of paste exhibited a darker color or stained appearance adjacent to several aggregate peripheries. Also, small amounts of small, irregular separations were observed at several aggregate peripheries. Lighter-colored, soft, white paste was present in the paste adjacent to these separations.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, quartz sandstone and siltstone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Many aggregate particles exhibited internal fractures. Also, small amounts of small, irregular separations were observed at several aggregate peripheries. Lighter-colored, soft, white paste was present in the paste adjacent to these separations.

"435BP-P"

GENERAL CONDITION: (See PLATES 8-11) The top surface was generally flat and smooth with numerous, partially exposed fine aggregate particles in a soft paste matrix. Many, random, fine cracks were also present at the exposed surface. The color was mottled from light brown to light brown-light gray. An approx. 1 inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also observed on the exposed surface.

In section, a carbonation zone from a veneer up to approx. 1/8 of an inch was observed. A small-moderate amount of microcracking was observed throughout the sample. Many cracks were infilled with a very finely crystalline, off white-light brown material that exhibited similar properties as alkalic gel/carbonated alkalic gel. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed localized yellow staining from the application of the sodium cobaltinitrite solution in small localized paste areas and within several many aggregate particles. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately hard-moderately soft, and pale brown-dull white in color with a very small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 3:

TABLE 3

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"435BP-P"	19.1	1,201	58.45	5.1	3.75	2.8	.018	222	.017

The homogeneously distributed voids were mostly small and spherically shaped with larger, spherically shaped voids also present. In many voids, secondary, internal deposits were observed as coatings/linings of clear to off-white material with the optical properties of the alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-subrounded in shape with an observed topsize of 1-1/8 inches. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. A few particles exhibited reaction rims and several particles exhibited small amounts of internal fractures. Small, localized areas of paste exhibited a darker color or stained appearance adjacent to several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, quartz sandstone and siltstone particles. A few microcrystalline quartz chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures.

"436BP-P"

GENERAL CONDITION: (See PLATES 12-15) The top surface was generally flat and smooth with numerous, partially exposed fine aggregate particles in a soft paste matrix. One, approx ¼ of an inch diameter "pit" was also observed at the top surface. A few, random, fine cracks were also present at the exposed surface. The color was mottled from light brown to light brown-light gray. Yellow lines of waxy material were observed at he exposed surface in an "X" pattern.

In section, a carbonation zone from a veneer up to approx. 3/16 of an inch was observed. A small-moderate amount of microcracking was observed throughout the sample. Many cracks were infilled with a very finely crystalline, off white-light brown material that exhibited similar properties as alkalic gel/carbonated alkalic gel. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in many, small portions of the observed paste. Yellow staining was also observed in several coarse aggregate particles, many fine aggregate particles, and at many aggregate peripheries.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft, and subtly variegated from light gray-light brown with a small amount of unhydrated cement particles to light brown-dull white in color with a very small amount of unhydrated cement particles. The darker-colored paste areas were harder as compared to the lighter-colored paste portions. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The estimated air-void system parameters are listed below in TABLE 4:

TABLE 4

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"436BP-P"	20.4	1,694	82.55	6.8	3.0	7.9	.009	466	.007

The inhomogeneously distributed voids were mostly spherically shaped and ranged in size from small to large. A small-moderate amount of clusters of voids was observed throughout the sample. In many voids, secondary, internal deposits were observed as coatings/linings of clear-off-white material with the optical properties of the alkalic gel/carbonated alkalic gel.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-rounded in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. Many particles exhibited reaction rims and several particles exhibited small amounts of internal fractures. A few, discontinuous, lighter colored paste areas were observed at a few aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, hematitic quartz sandstone, and siltstone particles. Several particles exhibited reaction rims. Several particles exhibited a small amount of internal fractures. Also, small amounts of small, irregular separations were observed at several aggregate peripheries. Lighter-colored, soft, white paste was present in the paste adjacent to these separations.

"SB-P"

GENERAL CONDITION: (See PLATES 16-19) The top surface was rough with numerous, partially exposed fine aggregate particles and one partially exposed coarse aggregate particle in a slightly recessed paste matrix. A few, random, fine cracks were also present at the exposed surface. The color was mottled from brown to light brown-light gray and loose fine dust was also present. An approx. 1 inch diameter, yellow paint "dot", presumed to be used for marking purposes, was also observed on the exposed surface.

In section, a carbonation zone up to approx. 1/8 of an inch was observed. A small-moderate amount of microcracking and cracking was observed throughout the sample. Many cracks were infilled with a very finely crystalline, off white-light brown material that exhibited similar properties as alkalic gel/carbonated alkalic gel. The bottom surface was a fractured surface.

CEMENTITIOUS MATRIX: The highly water absorptive, cement paste matrix was, moderately soft, and light brown in color with a very small-small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 5:

TABLE 5

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"SB-P"	18.93	2,065	101.75	1.94	9.76	1.3	.0150	265.9	.0236

The homogeneously distributed voids were large in size and spherical-irregularly shaped with small and spherically shaped voids also present. Secondary, internal deposits were observed as linings/coatings and infillings of clear-white material with similar optical properties of alkalic gel and as coatings/linings in many voids.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-rounded in shape with an observed topsize of 1-1/8 inches. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. Many aggregate particles exhibited reaction rims and many particles exhibited internal fractures. A few, discontinuous, lighter colored paste areas were observed at a few aggregate peripheries. Also, small amounts of small, irregular separations were observed at several aggregate peripheries. Lighter-colored, soft, white paste was present in the paste adjacent to these separations.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, quartz sandstone and siltstone and claystone particles. Many microcrystalline quartz chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures. Also, small amounts of small, irregular separations were observed at several aggregate peripheries. Lighter-colored, soft, white paste was present in the paste adjacent to these separations.

DISCUSSION & CONCLUSION

We received five core portions of hardened concrete to determine the general condition of the concrete(s). It was reported that the submitted samples were taken from upper back panels and scoreboard areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

The determined air-void system parameters are listed below in TABLE 6:

TABLE 6

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"SB-P"	18.93	2,065	101.75	1.94	9.76	1.3	.0150	265.9	.0236

The estimated air-void system parameters are listed below in TABLE 7:

TABLE 7

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"343BP-P"	22.5	1,560	76.75	1.9	11.8	3.5	.005	736	.009
"344BP-P"	19.1	1,720	83.65	1.1	17.4	3.1	.004	1,138	.007
"435BP-P"	19.1	1,201	58.45	5.1	3.75	2.8	.018	222	.017
"436BP-P"	20.4	1,694	82.55	6.8	3.0	7.9	.009	466	.007

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi.

- Only Samples **"435BP-P"** and **"436BP-P"**are considered to be air-entrained.
- Overall, the observed aggregates in each sample exhibited reaction rims and internal fractures. Alkalic gel deposits were observed in all samples. The results of staining using cobaltinitrite showed active gels in paste and aggregates. These features strongly suggest that the collective aggregate should not be considered "durable" due to susceptibility to alkali-silica reactivity.
- The estimated spacing factors for Samples **"344BP-P"** and **"436BP-P"** were **under** (acceptable) the recommended, industry standard limit maximum of 0.0080 inches, and should be considered adequate for exposure in a water-saturated, cyclic, freeze-thaw environments.
- The compressive strength(s) of the concrete represented by this sample/mix design is unknown and comments regarding this will not be made.

Only small amounts, if any, of carbonation were observed in the examined core samples.

Based on this examination, the most possible cause of the reported distress, as represented by the submitted samples, is active alkali-aggregate reactivity. Based on this examination and observations including aggregate features and the presence/degree of observed microcracking, the general conditions are deemed:

Poor – Sample **"SB-P"** exhibited small-moderate microcracking, alkalic gel, with the highest levels of reactions rims/internal fractures present. Also, paste separations observed at aggregate peripheries can be indicative of paste expansion.

Poor – Samples **"344BP-P"** exhibited small-moderate amounts of microcracking, alkalic gels, and moderate amounts of reactions rims in the coarse aggregates and higher amounts of internal fracturing of aggregates. Also, paste separations observed at aggregate peripheries can be indicative of paste expansion.

Poor – Sample **"343BP-P"** exhibited small amounts of microcracking, alkalic gels, and moderate amounts of reactions rims in the aggregates with low amounts of aggregate particles exhibiting internal fractures. Also, paste separations observed at aggregate peripheries can be indicative of paste expansion.

Poor – Sample **"436BP-P"** exhibited small-moderate amounts of microcracking, alkalic gels, and higher amounts of reactions rims in the aggregates with low amounts of aggregate particles exhibiting internal fractures. Also, paste separations observed at fine aggregate peripheries can be indicative of paste expansion.

Poor – Samples **"435BP-P"** exhibited small-moderate amounts of microcracking, alkalic gels, and low amounts of reactions rims in the coarse aggregate with low amounts of aggregate particles exhibiting internal fractures.

Inadequate air-void systems can be likely contributing factors to deficiencies or potential failure and/or further degradation.

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (e.g., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur. Differences in exposure conditions, especially exposure to water, can account for apparent physical changes in condition of the examined samples.

JR Varga

J. R. Varga, Concrete Petrographer

The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_8.pdf
- Online version of Plates 1-15 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_8_1_11.pdf
- Online version of Plates 16-24 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_8_12_19.pdf

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 8

UPPER BACK PANELS "343BP- P"

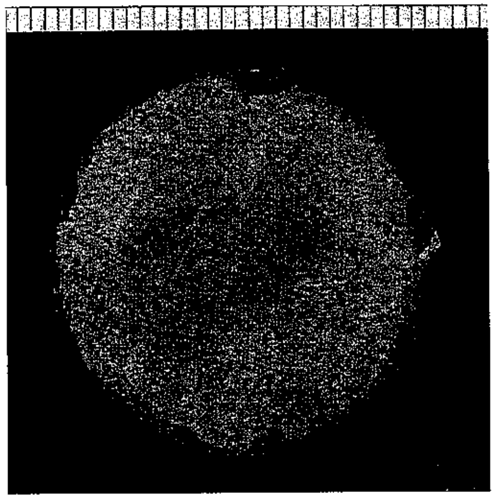


PLATE 1
TOP SURFACE

PLATE 2
CUT SURFACE "343BP-P" SHOWING
CLEAR TO OFF-WHITE, CRACKED GEL
LINING IN VOID

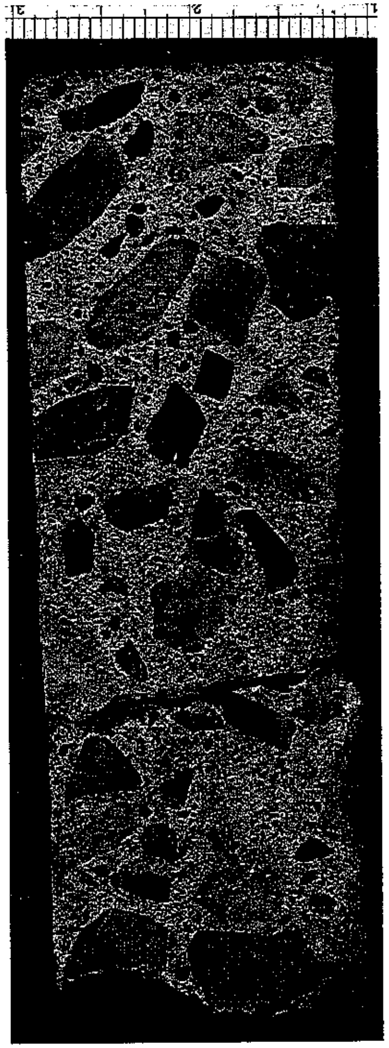


PLATE 3
PREPARED SURFACE
"343BP-P"

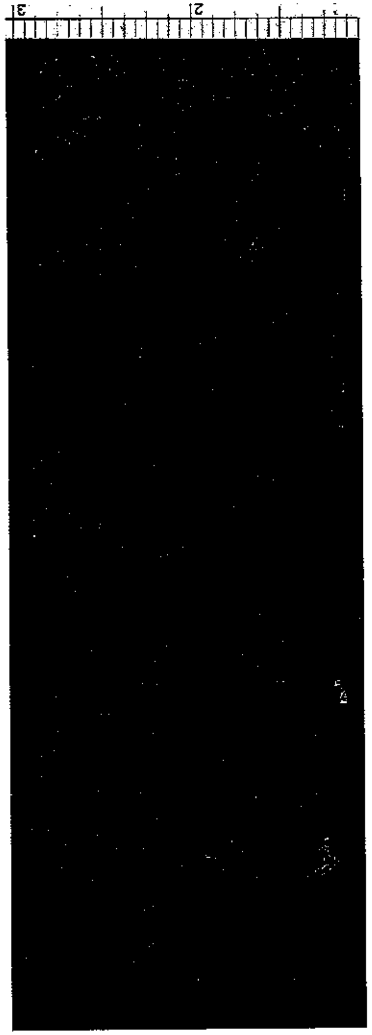


PLATE 4
PREPARED SURFACE "343BP- P"
SHOWING LOCALIZED YELLOW
STAINING IN PASTE AND WITHIN
MANY AGGREGATE PARTICLES
AFTER COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 8

UPPER BACK PANELS "344BP- P"

PLATE 5
TOP SURFACE

PLATE 6
PREPARED SURFACE
"344BP-P"

PLATE 7
PREPARED SURFACE "344BP-P"
SHOWING LOCALIZED, YELLOW
STAINING IN PASTE AND WITHIN
MANY AGGREGATE PARTICLES
AFTER COBALTINITRITE
STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 8
UPPER BACK PANELS "435BP- P"

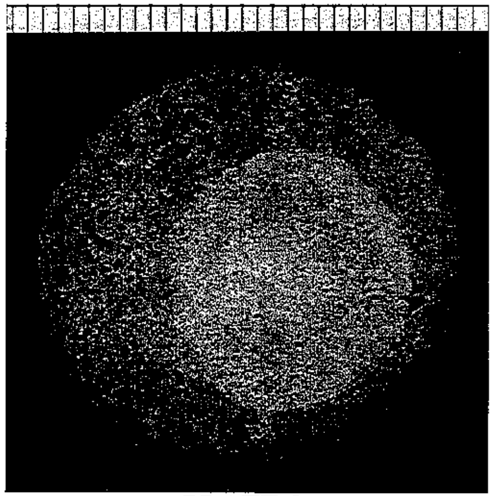


PLATE 8
TOP SURFACE

PLATE 9
CUT SURFACE SHOWING
CLEAR TO OFF-WHITE
GEL EXUDATIONS IN
VOID

PLATE 10
PREPARED SURFACE
"435BP-P"

PLATE 11
PREPARED SURFACE "435BP-P"
SHOWING YELLOW STAINING
MOSTLY WITHIN AGGREGATE
PARTICLES AFTER
COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 8

UPPER BACK PANELS "436BP- P"

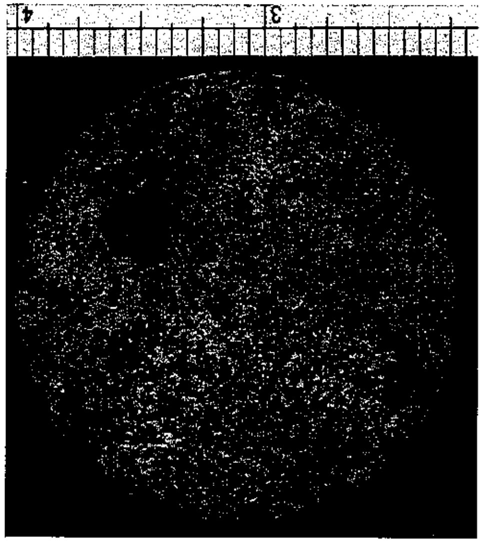


PLATE 12
TOP SURFACE

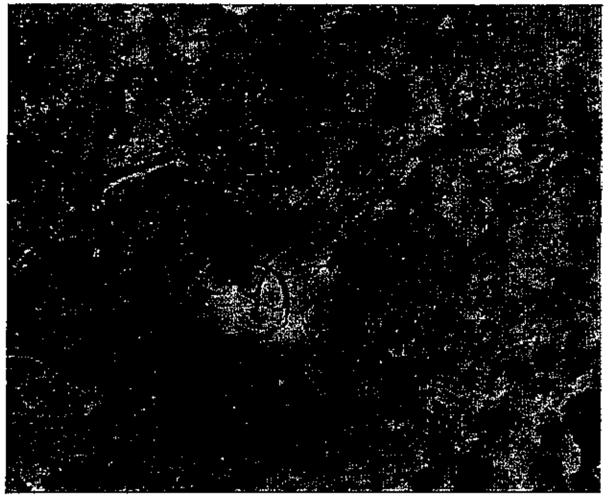


PLATE 13
CUT SURFACE "436BP-P" SHOWING
OFF-WHITE, CRACKED GEL
EXUDATION ON CHERT PARTICLE

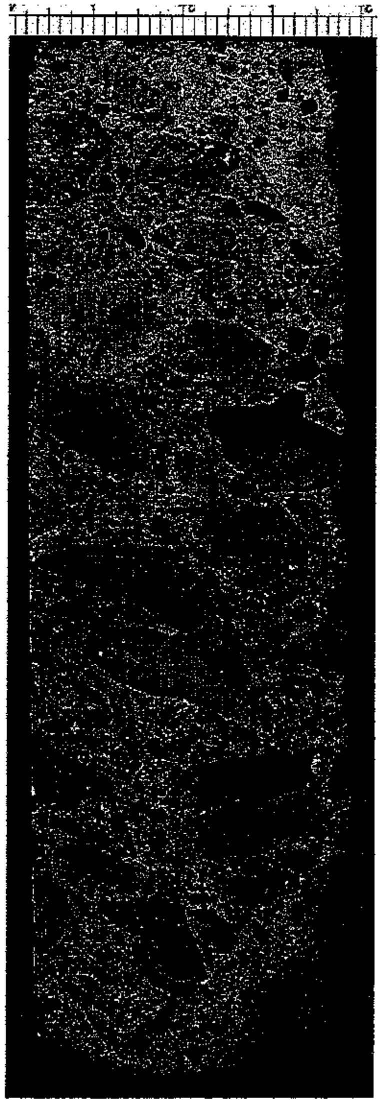


PLATE 14
PREPARED SURFACE
"436 BP-P"

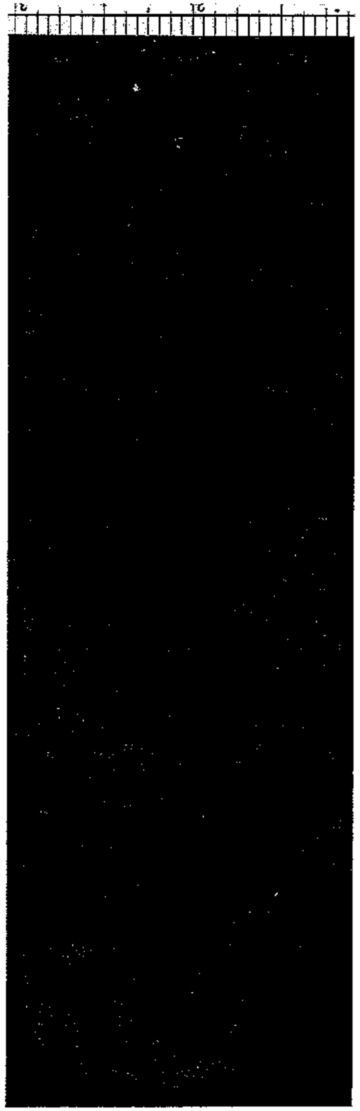


PLATE 15
PREPARED SURFACE "436BP-P"
SHOWING YELLOW STAINING IN
LOCALIZED PASTE AREAS AND
WITHIN AGGREGATE PARTICLES
AFTER COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 8
SCOREBOARD “SB-P”

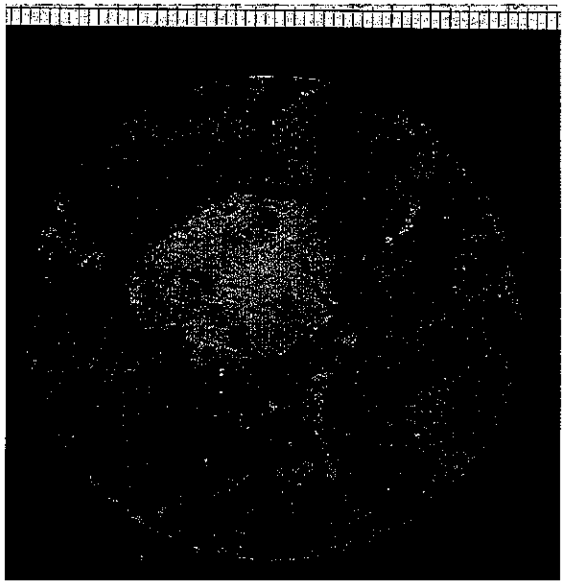


PLATE 16
TOP SURFACE

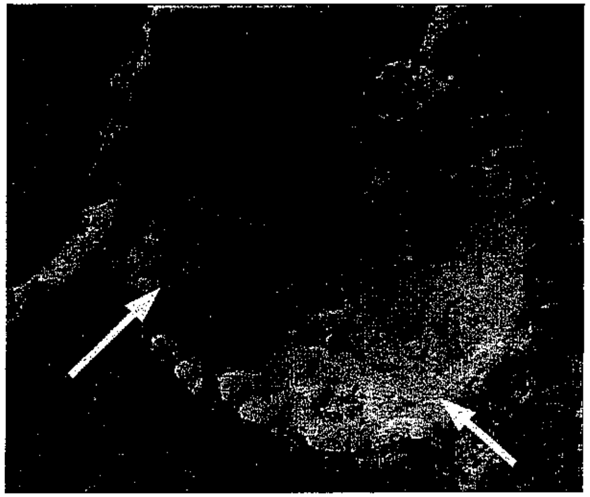


PLATE 17
PREPARED SURFACE SHOWING OFF-WHITE
TO LIGHT BROWN GEL EXUDATION ON
PORTION OF VOID INTERIOR

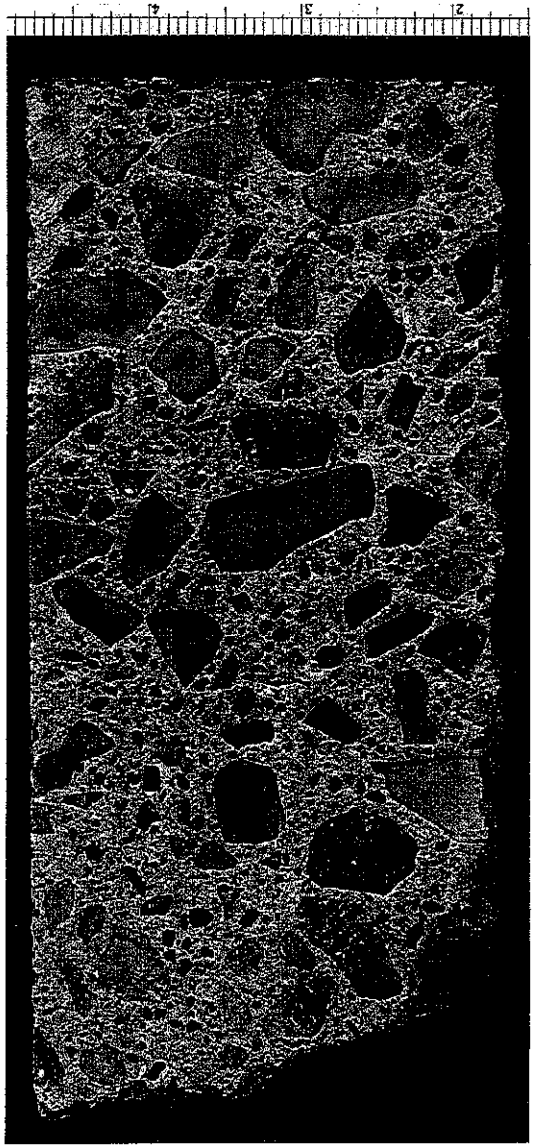


PLATE 18
PREPARED SURFACE
“SB-P”

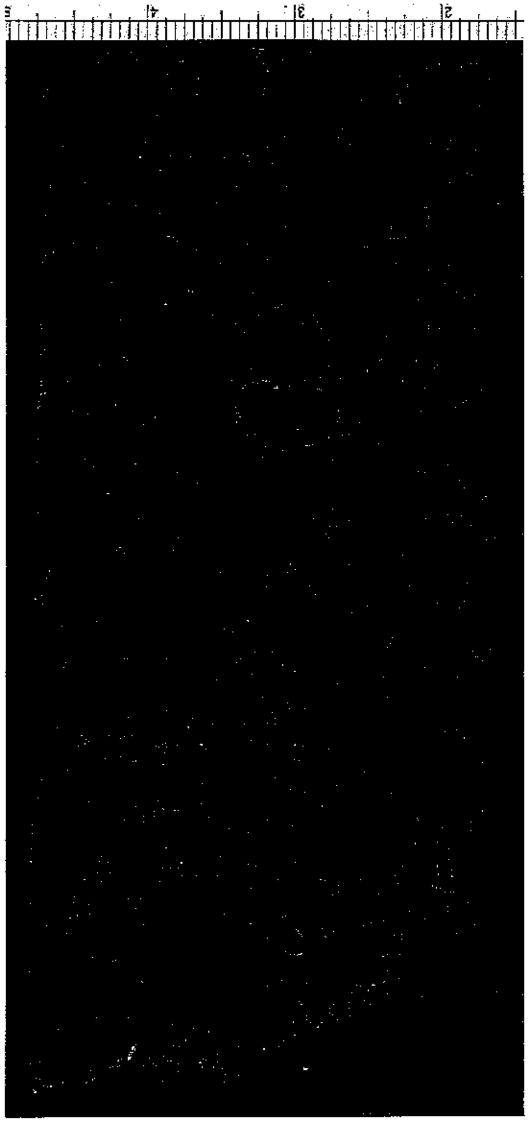


PLATE 19
PREPARED SURFACE “SB-P”
SHOWING YELLOW STAINING IN
LOCALIZED PASTE AREAS AND WITHIN
AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING

PETROGRAPHIC REPORT

DATE:	December 14, 2007
WORK ORDER:	07-08-31-01 / Group 8b Scoreboard
CLIENT:	Tourney Consulting Group / TCG 0756 Kauffmann Stadium
PREPARED BY:	Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received one core portions of hardened concrete to determine the general condition of the concrete(s). The core portion was marked **"07104 12-03-07 Wall Very Bottom Foundation"**. The core sample measured approximately 5-5/8 inches in diameter X 9 inches in length.

It was reported that the submitted sample was taken from the base of the scoreboard. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

SAMPLE PREPARATION AND METHODS

The submitted sample was cut in half, approximately perpendicular to the top surfaces as well as horizontal to the top surface resulting in two samples for preparation and examination. Two of the cut samples' surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were estimated/determined following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters.

The unprepared sample sections were partially immersed in water for at least three days to mobilize any alkalic gels present. The perpendicular cut surfaces of the core portion samples were not immersed in water.

After petrographic examination, the prepared surfaces were stained using a saturated, aqueous solution of sodium cobaltinitrite (reacts with soluble potassium to produce a yellow precipitate resulting in staining potassium-rich ASR gel) following the guidelines in a July 1998 report titled *"Geochemical Methods for the Identification of ASR Gel"* by Guthrie and Carey, Los Alamos National Laboratory . In addition, a saturated, aqueous solution of Rhodamine B was similarly used to aid this staining procedure by highlighting (providing a high contrast background) the regions of yellow-stained ASR gel and in part, to identify other degradation products.

The prepared, unprepared, and stained sample surfaces were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

GENERAL CONDITION: (See PLATES 1-4) The top surface exhibited numerous, circular scratches/gouges that are presumed to be from the coring procedure. The edges at the top surface were "beveled" outward from the top surface toward the core edge, that is at an obtuse angle.

In section, no carbonation was observed. A small amount of microcracking and cracking was observed throughout the sample. Most of the cracks appeared to be "fresh" and jagged and were free of any secondary deposits. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in many, small localized paste areas and within many aggregate particles especially those exhibiting reaction rims. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The highly water absorptive, cement paste matrix was soft-moderately soft, and variegated from dull brown-dull white in color with a very small-small amount of unhydrated cement particles to dull white in color with a very small, if any, amounts of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 1:

TABLE 1

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	I in.	α in.$^{-1}$	L in.
	19.31	2,056	102.00	2.14	9.02	1.1	.0202	197.9	.0306

The homogeneously distributed voids were large in size and spherical-irregularly shaped with small and spherically shaped voids also present. Secondary, internal deposits were observed as linings/coatings and infillings of clear-off white material with similar optical properties of alkalic gel and as coatings/linings in many voids. Also, many voids exhibited secondary, internal deposits as tufts, blooms, and partial linings of internally radiating fine, needle-like crystals with the optical properties of the mineral ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26 H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subangular in shape with an observed topsize of 7/8 inches. The observed coarse aggregate was composed of cherty limestone and fossiliferous limestone particles. Many aggregate particles exhibited reaction rims and several exhibited internal fractures. A few, discontinuous, lighter colored paste areas were observed at a few aggregate peripheries especially at fossiliferous limestone particles.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-subrounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, claystone, wood fibers, and chalcedonic chert particles. Many chert particles exhibited reaction rims. Several aggregate particles exhibited internal fractures.

DISCUSSION & CONCLUSION

We received one core sample of hardened concrete to determine the general condition of the concrete(s). It was reported that the submitted sample was taken from the base of the scoreboard. Petrographic examination was requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. A mix design was not available at the time of this writing.

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi.

- The submitted sample is considered to be non-air-entrained.
- Overall, many of the observed aggregates exhibited reaction rims and internal fractures. Alkalic gel deposits were observed. The results of staining using cobaltinitrite showed active gels in paste and aggregates. These features strongly suggest that the collective aggregate should not be considered "durable" due to susceptibility to alkali-silica reactivity. Also, many voids exhibited secondary, internal deposits as tufts, blooms, and partial linings of internally radiating fine, needle-like crystals with the optical properties of the mineral ettringite.
- The determined spacing factor was **over** (unacceptable) the recommended, industry standard limit maximum of 0.0080 inches, and should be considered inadequate for exposure in a water-saturated, cyclic, freeze-thaw environments.
- The compressive strength(s) of the concrete represented by this sample/mix design is unknown and comments regarding this will not be made.

No carbonation was observed in the examined core sample.

A small amount of microcracking and cracking was observed throughout the sample. Most of the cracks appeared to be "fresh" and jagged and were free of any secondary deposits. This suggests that some post-coring damage had occurred.

Based on this examination, the most possible cause of the reported distress, as represented by the submitted sample, is active alkali-aggregate reactivity. Based on this examination and observations including aggregate features and the presence/degree of observed microcracking, the general condition is deemed:

> Poor – Sample **"SB-P"** exhibited a small microcracking, secondary deposits of alkalic gels and ettringite, with many aggregate particles exhibiting reactions rims and/or internal fractures.

An inadequate air-void system can be a likely contributing factor to deficiencies or potential failure and/or further degradation.

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (erg., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur.

JR Varga

J. R. Varga, Concrete Petrographer

The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_8b.pdf
- Online version of Plates 1-4 (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_8b_1_4.pdf

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 8b
SCOREBOARD FOUNDATION

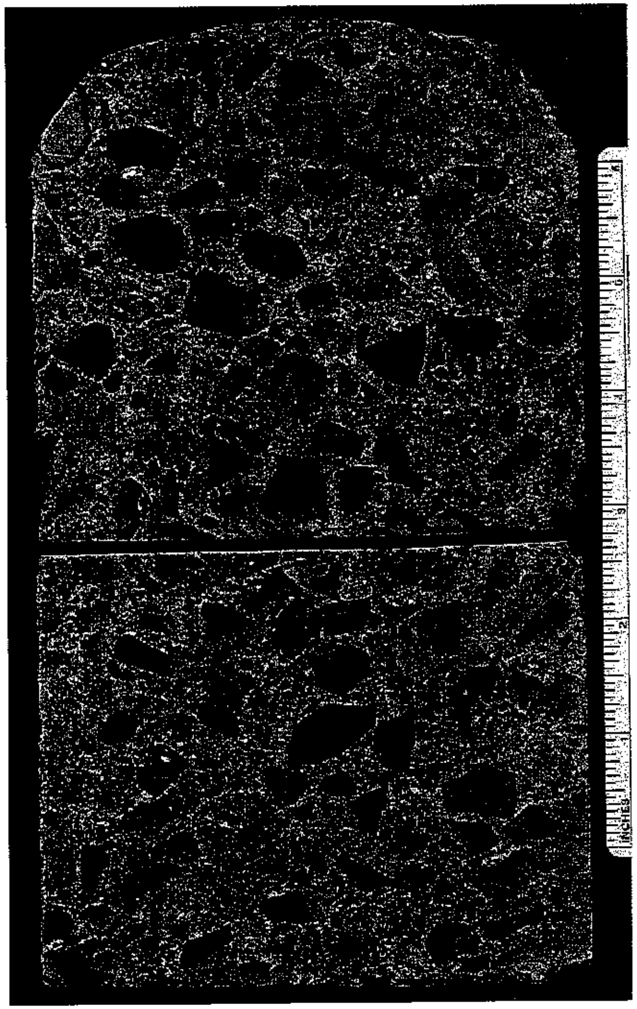


PLATE 1
PREPARED SURFACE SECTIONS

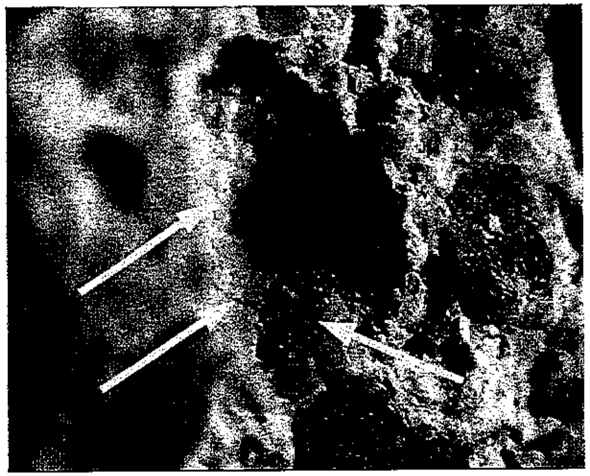


PLATE 2
FRACTURED SURFACE SHOWING
CLEAR TO OFF-WHITE, CRACKED GEL
LINING IN VOID

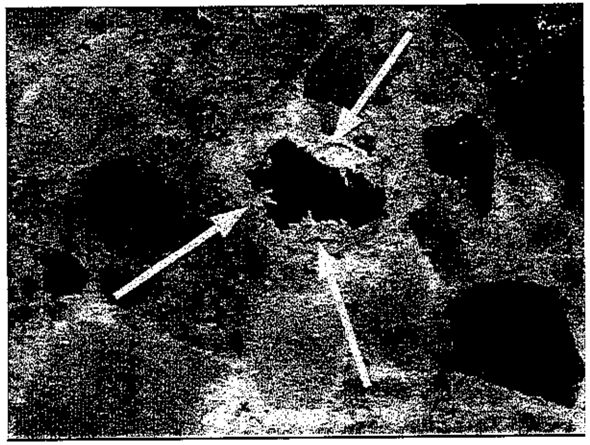


PLATE 3
PREPARED SURFACE SHOWING
TUFTS/PARTIAL LININGS OF ETTRINGITE
CRYSTALS

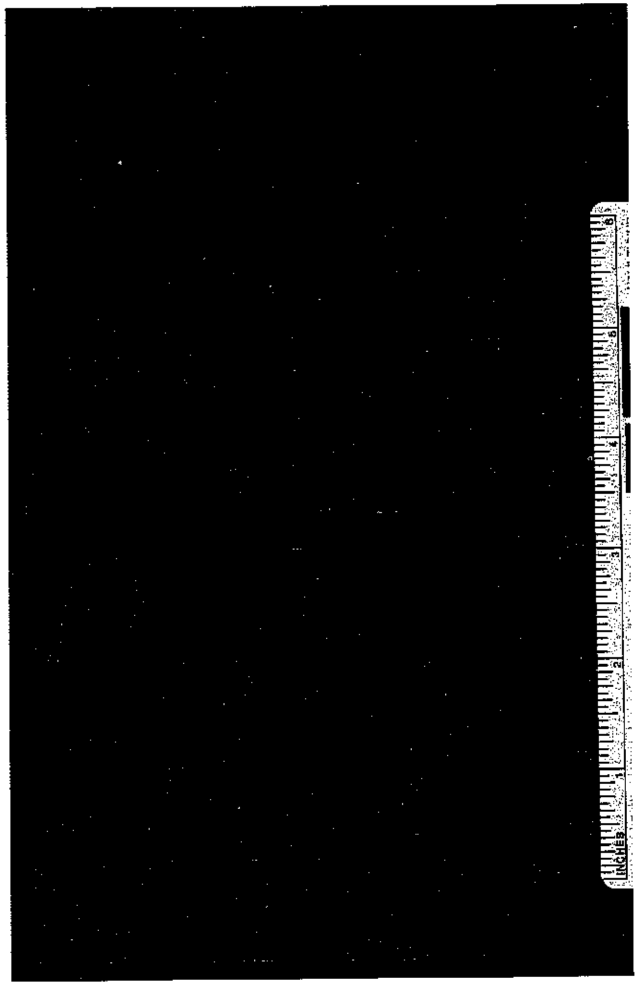


PLATE 4
PREPARED SURFACES
SHOWING LOCALIZED YELLOW
STAINING IN PASTE AND WITHIN
MANY AGGREGATE PARTICLES
AFTER COBALTINITRITE STAINING

THE ROCK DOCTOR
CONCRETE SOLUTIONS FOR CONCRETE PROBLEMS

PETROGRAPHIC REPORT

DATE: December 20, 2007

WORK ORDER: 07-08-31-01 / Group 9 Service

CLIENT: Tourney Consulting Group / TCG 0756 Kauffmann Stadium

PREPARED BY: Jeffrey R. Varga, Concrete Petrographer, The Rock Doctor, Inc.

INTRODUCTION

We received four core portions of hardened concrete to determine the general condition of the concrete(s). The core portions were marked **"103 TD-P"**, **"103 TUD-P"**, **"SLA16-P"**, and **"SLB25-P"**. The core portions measured, in length, approximately 4-3/4, 3-1/2, 7, and 3-1/4 inches, respectively. The core portions were approximately 3-1/4 inches in diameter.

It was reported that the submitted samples were taken from tunnel and service areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Several digital photographs were also submitted. Mix designs were not available at the time of this writing.

SAMPLE PREPARATION AND METHODS

The core samples were cut in half, approximately perpendicular to the top surfaces. The cut surfaces were ground using water and abrasive materials following our standard procedure. The air-void system parameters were determined and estimated following the guidelines of ASTM C 457-06 *"Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete"*. The modified point count method was utilized with a magnification of 100 diameters.

The unprepared samples were partially immersed in water for at least three days to mobilize any alkalic gels present. The cut surfaces of the core portion samples were not immersed in water.

After petrographic examinations, the prepared surfaces were stained using a saturated, aqueous solution of sodium cobaltinitrite (reacts with soluble potassium to produce a yellow precipitate resulting in staining potassium-rich ASR gel) following the guidelines in a July 1998 report titled *"Geochemical Methods for the Identification of ASR Gel"* by Guthrie and Carey, Los Alamos National Laboratory . In addition, a saturated, aqueous solution of Rhodamine B was similarly used to aid this staining procedure by highlighting (providing a high contrast background) the regions of yellow-stained ASR gel and in part, to identify other degradation products.

The prepared and unprepared samples were examined following the guidelines of ASTM C 856-04 *"Standard Practice for Petrographic Examination of Hardened Concrete"*.

RESULTS OF PETROGRAPHIC EXAMINATION

"103 TD-P"

GENERAL CONDITION: (See PLATES 1-4) The top surface exhibited a partially adhered membrane/coating that was mottled in color from light gray to dark gray. The light gray portions were soft and flexible while the dark gray portions were hard and exhibited cracking with a few partially exposed fine aggregate particles. The surface was slowly absorptive to water. An approx. 1-inch diameter, discontinuous, circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system was approx. 1/8 of an inch thick and was composed of five apparent layers. The layer at/adjacent to the exposed surface was thin and almost continuous and exhibited a small amount of small voids and several fine aggregate particles. At the interface with the underlying material, no voids, separations, or cracks were observed. The underlying layer (approx. 1/4 of the total topping thickness) was light gray in color, soft and flexible with a few, small air-voids. At the bottom surface of this layer, a continuous separation/crack was present. The third layer was light gray in color, soft and flexible with several fine aggregate particles. At the interface with the underlying material, no voids, separations, or cracks were observed. The fourth layer was light gray in color, soft and flexible with a few, small air-voids. At the interface with the underlying material, no voids, separations, or cracks were observed. The fifth layer was light gray in color, soft and flexible with several, small air-voids. At the bottom surface of this layer, at the interface with the base concrete, a continuous separation/crack was present. Small portions of the base concrete were adhered to the bottom surface of the coating system.

No carbonation was observed at the top surface of the base concrete. A small-moderate amount of microcracking was observed throughout the sample. Most of the observed microcracks were infilled with off white material with similar optical properties of alkalic gel and carbonated alkalic gel. After immersion in water, the sample trimming exhibited off white to clear exudations of material with the optical properties of alkalic gel on cut surfaces. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in several, small localized paste areas (especially in the lower portion of the sample) and within several aggregate particles especially those exhibiting reaction rims. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cementitious paste matrix was highly water absorptive, moderately soft-moderately hard, and variegated from pale gray-light brown with a small amount of unhydrated cement particles to light brown-dull white in color, with a very small amount of unhydrated cement particles. The lighter colored paste areas were softer than the darker colored paste areas. A very small amount of fly ash was observed with no ground granulated blast furnace slag or other pozzolanic materials being microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 1:

TABLE 1

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	$\bar{l}$ in.	α in.$^{-1}$	L in.
"103TD-P"	22.73	2,028	100.00	8.04	2.83	7.6	.0106	376.7	.0075

The inhomogeneously distributed voids were mostly small and spherically shaped with fewer larger, spherical voids observed. Fewer, larger, irregularly shaped voids also observed. A small-moderate amount of clusters of voids was observed throughout the sample. Many voids exhibited partial linings and coatings of clear to off white material with similar optical properties of alkalic gel and carbonated alkalic gel. Partial linings and coatings of fine needle-like, internally radiating crystals were observed in several voids. These crystals exhibited similar optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\ H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including fossiliferous limestone and cherty particles. A few particles exhibited internal fractures. A few particles exhibited reaction rims. Small amounts of continuous and discontinuous zones of lighter-colored paste were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, claystone, siltstones, and microcrystalline quartz chert particles. Several chert particles exhibited internal fractures and reaction rims.

"103TUD-P"

GENERAL CONDITION: (See PLATES 5-8) The top surface exhibited a generally flat, soft, mostly hard, dark gray material with numerous, fine cracks with smaller amounts of light gray, elastic, material. The exposed surface exhibited many aggregate sockets and a few partially exposed, fine aggregate particles. The surface was slowly absorptive to water. An approx. 1-inch diameter, discontinuous, circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface.

In section, the observed membrane/coating system was approx. 1/32 to 1/16 of an inch thick and was composed of two apparent layers. The layer at/adjacent to the exposed surface was approx. 1/2 of the total coating thickness, was light gray in color, flexible, and exhibited a small amount of small voids and several fine aggregate particles. At the interface between the two apparent coating layers, no voids, separations, or cracks were observed. The underlying layer (approx. 1/2 of the total coating thickness) exhibited a small-moderate amount of small air-voids. At the bottom surface of this layer, an almost continuous, separation/crack was present at or near the interface of the coating system and the base concrete. An adhered layer of paste/mortar from the base concrete was observed at the bottom coating surface.

No carbonation was observed at the top surface of the base concrete. A small-moderate amount of microcracking was observed throughout the sample. Most of the observed microcracks were infilled with off-white material with similar optical properties of alkalic gel and carbonated alkalic gel. After immersion in water, the sample trimming exhibited off white to clear exudations of material with the optical properties of alkalic gel on cut surfaces. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in small localized paste areas and within many aggregate particles especially those exhibiting reaction rims. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cementitious paste matrix was highly water absorptive, moderately soft-moderately hard, and variegated from pale gray-light brown with a small amount of unhydrated cement particles to light brown-dull white in color, with a very small amount of unhydrated cement particles. The lighter colored paste areas were softer than the darker colored paste areas. A very small-small amount of fly ash was observed with no ground granulated blast furnace slag or other pozzolanic materials being microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 2:

TABLE 2

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α in.$^{-1}$	L in.
"103TUD-P"	15.60	1,744	86.00	6.65	2.35	4.8	.014	286	.0082

The inhomogeneously distributed voids were mostly spherically shaped and small in size with larger, spherical-irregularly shaped voids also observed. Fewer, larger, irregularly shaped voids also observed. A small amount of clusters of voids was observed throughout the sample. Partial linings/infillings of clear to off-white material with similar optical properties of alkalic gel and carbonated alkalic gel were observed in many voids. Partial linings and coatings, tufts, blooms of fine needle-like, internally radiating crystals were observed in several voids. These crystals exhibited similar optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\, H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of limestone particles including fossiliferous and cherty limestone particles. A small amount of internal fractures were observed. A few particles exhibited reaction rims. Discontinuous veneers of softer, light brown-colored "halos" or rims of paste were observed at several aggregate peripheries.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, claystone, siltstones, microcrystalline quartz chert, and shale particles. A few particles exhibited internal fractures. A few microcrystalline quartz chert particles exhibited reaction rims.

"SLA16-P"

GENERAL CONDITION: (See PLATES 9-12) The top surface was generally flat, worn, slightly rough with numerous partially exposed fine aggregate particles in a flat paste matrix. Very small amounts of clear-light brown, wax-like material was observed on the exposed surface. Many fine scratches were also present.

In section, a zone of lower pH paste (approx. 9) was observed with a thickness of approx. 3/8 of an inch. A moderate amount of microcracking was observed throughout the sample. Most of these microcracks were infilled with light brown-off white material with similar optical properties of alkalic gel and carbonated alkalic gel. After immersion in water, the sample trimming exhibited a small amounts of localized, clear-off-white exudations of material with the optical properties of alkalic gel on cut surface. The bottom surface was a fractured surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in many, localized paste areas and within many aggregate particles especially those exhibiting reaction rims. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, soft-moderately hard, and variegated from pale gray-light brown with a small amount of unhydrated cement particles to dull white-light gray with a very small amount of unhydrated cement particles. The lighter colored paste areas were markedly softer than the darker colored paste areas. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 3:

TABLE 3

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	l in.	α $in.^{-1}$	L in.
"SLA16- P"	23.91	2,020	99.55	8.51	2.81	8.2	.0104	384.6	.0073

The inhomogeneously distributed voids were spherically shaped and ranged in size from small to large with fewer, larger, irregularly shaped voids also present. A moderate amount of clustering of voids was observed throughout the sample. In several voids, secondary, internal deposits of clear to off-white material with similar optical properties of alkalic gel and carbonated alkalic gel were observed as partial linings and coatings. In a few voids, tufts and blooms of fine needle-like, internally radiating crystals were observed. These crystals exhibited similar optical properties of the mineral, ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26\,H_2O$.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was subangular-subrounded in shape with an observed topsize of 1 inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Many particles exhibited internal fractures and several particles exhibited reaction rims.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, and claystone particles. A few reactions rims were observed especially associated with microcrystalline quartz chert particles. Several particles exhibited internal fractures.

"SLB25-P"

GENERAL CONDITION: (See PLATES 13-16) The top surface was generally flat, slightly rough with a "worn" appearance and exhibited numerous partially exposed, coarse and fine aggregate particles in a flat, dark gray paste matrix. An approx. 1-inch diameter circular spot of yellow-colored material, presumed to be used for marking purposes, was also present at the exposed surface. Several, small irregularly shaped voids were present at a few aggregate peripheries.

In section, a zone of carbonated paste was observed up to approx. 3/8 of an inch thick. A small-moderate amount of microcracking was observed. Most of these microcracks were infilled with off-white material with similar optical properties of alkalic gel and carbonated alkalic gel. After immersion in water, the sample trimming exhibited a localized, clear exudations of material with the optical properties of alkalic gel on cut surface. The bottom surface was a smooth, flat formed surface.

Sodium Cobaltinitrite/Rhodamine B Staining Method

Visual assessments, including using a petrographic microscope, showed distinct yellow staining from the application of the sodium cobaltinitrite solution in small, localized paste areas (especially adjacent to end surfaces) and within many aggregate particles especially those exhibiting reaction rims. Rhodamine B staining resulted in pink colorations especially in fractures/cracks.

CEMENTITIOUS MATRIX: The cement paste matrix was highly water absorptive, moderately soft-moderately hard, and subtly variegated from light gray-light brown in color with a small amount of unhydrated cement particles to light brown-dull white in color with a very small-small amount of unhydrated cement particles. No fly ash, ground granulated blast furnace slag or other pozzolanic materials were microscopically observed.

AIR-VOID CONTENT: The air-void system parameters are listed below in TABLE 4:

TABLE 4

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	ι in.	α in.$^{-1}$	L in.
"SLB25-P"	19.24	1,440	71.20	4.44	4.33	5.2	.0085	470.2	.0092

The inhomogeneously distributed voids were mostly small in size and spherically shaped with fewer, larger, spherical to irregularly shaped voids also present. In several voids, secondary, internal deposits of clear to off-white material with similar optical properties of alkalic gel and carbonated alkalic gel were observed as partial linings and coatings.

COARSE AGGREGATE: The homogeneously distributed coarse aggregate was angular-subrounded in shape with an observed topsize of 7/8 of an inch. The observed coarse aggregate was composed of limestone particles including cherty and fossiliferous limestone particles. Several particles exhibited small internal fractures and exhibited reaction rims. A few paste portions adjacent to several aggregate particles exhibited lighter-colored paste regions.

FINE AGGREGATE: The homogeneously distributed fine aggregate was angular-rounded in shape and was composed of quartz, feldspar, granites, microcrystalline quartz chert, claystone, and siltstone particles. Many chert particles exhibited internal fractures and reaction rims.

DISCUSSION & CONCLUSION

We received four core portions of hardened concrete to determine the general condition of the concrete(s). It was reported that the submitted samples were taken from taken from tunnel and service areas. Petrographic examinations were requested to determine if any deficiencies or potential failure/degradation mechanisms could be identified prior to any concrete repairs or replacements. Mix designs were not available at the time of this writing.

The air-void system parameters for all samples are listed below in TABLE 5:

TABLE 5

AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
Sample	Paste % by vol.	Points	Length, in.	Air, % by vol.	P/A	n	ι in.	α in.$^{-1}$	L in.
"103TD-P"	22.73	2,028	100.00	8.04	2.83	7.6	.0106	376.7	.0075
"SLA16- P"	23.91	2,020	99.55	8.51	2.81	8.2	.0104	384.6	.0073

The estimated air-void system parameters for all samples are listed below in TABLE 5:

TABLE 5

ESTIMATED AIR-VOID SYSTEM PARAMETERS

		TRAVERSE		PARAMETERS OF THE AIR-VOID SYSTEM					
	Paste %		Length,	Air, %			l	α	L
Sample	by vol.	Points	in.	by vol.	P/A	n	in.	in.$^{-1}$	in.
"103TUD-P"	15.60	1,744	86.00	6.65	2.35	4.8	.0140	286.0	.0082
"SLB25-P"	19.24	1,440	71.20	4.44	4.33	5.2	.0085	470.2	.0092

According to ACI and PCA, durable concrete in a water saturated, cyclic freeze-thaw environment usually is air-entrained (air content of 3-7% by volume), manufactured with durable aggregates, exhibits a spacing factor, L, of 0.0080 inches or less, and attains an ultimate compressive strength of at least 4,000 psi. The examined samples are considered to be air-entrained. Overall, the observed aggregates exhibited signs or evidence of reactivity including internal fractures and reaction rims. After water immersion, alkalic gel exudations were present in all samples strongly suggesting active/ongoing alkali-silica reactivity. The determined spacing factors for Samples **"103TUD-P"** and **"SLB25-P"** were over the recommended, industry standard limit maximum of 0.0080 inches and are considered unacceptable for freeze-thaw durability in water saturated environments. The compressive strength(s) of the concrete represented by this sample/mix design is unknown and comments regarding this will not be made.

All Portland cement based concretes will carbonate over time. When carbonation occurs early in the life of the concrete, the strength development of the affected area can be compromised. Samples **"SLA16-P"** and **"SLB25-P"** exhibited various depths of carbonated/lower pH paste. However, the carbonated zones and the respective bulk pastes exhibited similar hardnesses. This suggests that the carbonation had occurred over the service lives of the concretes.

Based on this examination, the the general condition of the concrete(s), including aggregate features and the presence/degree of observed microcracking, were deemed:

"103 TD-P" - Poor - exhibited small-moderate amounts of microcracking and small-moderate aggregate distress

"103TUD-P" - Poor - exhibited small-moderate amounts of microcracking and aggregate distress

"SLA16-P" - Poor - exhibited moderate amounts of microcracking and moderate-high level of aggregate distress

"SLB25-P" - Poor - exhibited small amounts of microcracking and relative highest level aggregate distress

The most possible cause for observed distress, as represented by the submitted samples, is active alkali-aggregate reactivity. Differences in exposure conditions, especially exposure to water, can account for these relative, different physical conditions. Inadequate air-void systems can be likely contributing factors to deficiencies, potential failure, and/or further degradation under similar exposure conditions. However, no marked evidence of freeze-thaw distress was observed.

Fly ash observed in Samples **"103TD-P"** and **"103TUD-P"**.

Small, irregular voids were observed Sample **"SLB25-P"** at aggregate peripheries. This can be indicative of paste expansion.

It must be noted that Alkali-Silica Reaction (ASR) takes place between certain reactive, poorly crystalline or metastable silica minerals, volcanic or artificial glasses, and other siliceous-bearing aggregates (e.g., opal, chalcedony, cherts, rhyolites, dacites, etc.) and the alkalis from Portland cement paste or external sources. A reaction product gel forms that, in the presence of water, expands and may cause cracking and/or expansion of mortar and concrete. Three conditions, **sufficient moisture, alkalis, and reactive forms of silica or aggregate(s)**, must be present for ASR to occur. If one of these components is not present, the reaction will not occur. Differences in exposure conditions, especially exposure to water, can account for apparent physical changes in condition of the examined samples. If the ASR is left unchecked, expansion will continue until moisture is removed, the source of alkalis is depleted, or the reactive silica components are consumed.

JR Varga

J. R. Varga, Concrete Petrographer
The Rock Doctor, Inc.

EXTERNAL RESOURCES

Please consult your documentation for portal access information (password-protected).

- Online version of this report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/report_07083101_Group_9.pdf

- Online version of this Plates 1-16 report (PDF):
  http://www.rock-doctor.com/clients/tourney/07083101/plates_07083101_Group_9_1_16.pdf

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 9
SERVICE "103 TD-P"

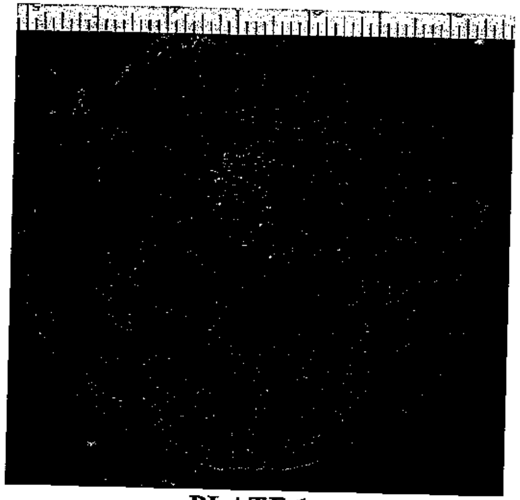


PLATE 1
TOP SURFACE

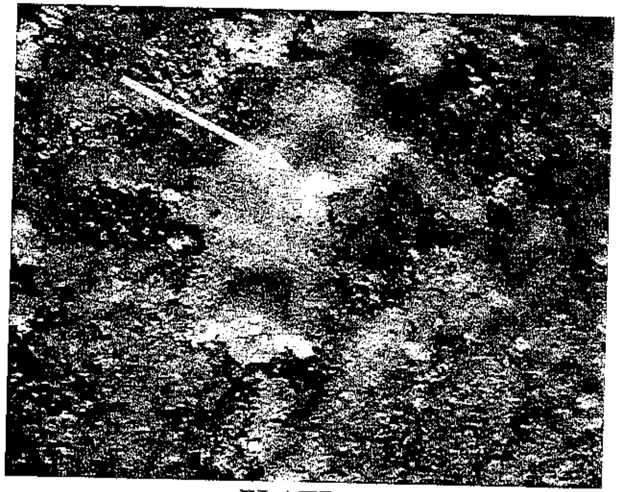


PLATE 2
CUT SURFACE "103TD-P" SHOWING
OFF-WHITE, GEL EXUDATION

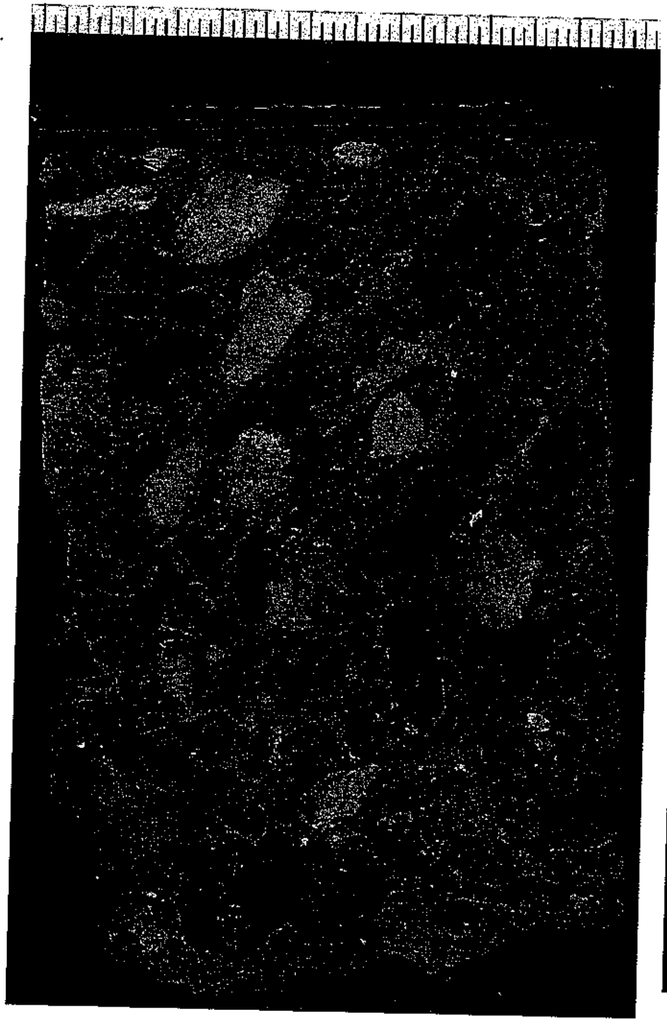


PLATE 3
PREPARED SURFACE
"103 TD-P"

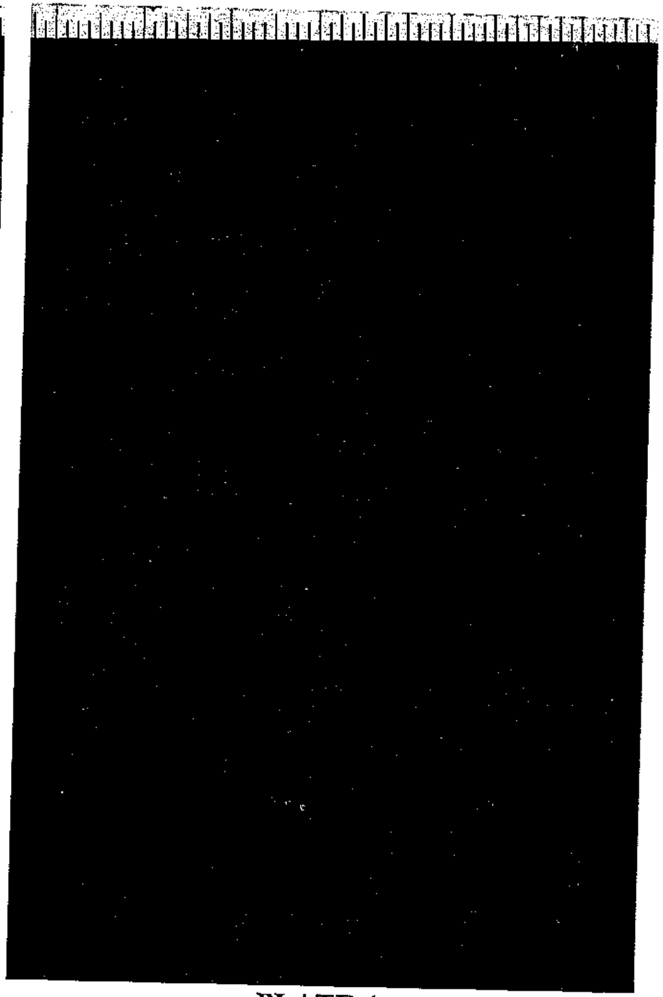


PLATE 4
PREPARED SURFACE "103TD-P"
SHOWING LOCALIZED YELLOW
STAINING IN PASTE AND WITHIN
SEVERAL AGGREGATE PARTICLES
AFTER COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 9

SERVICE "103TUD-P"

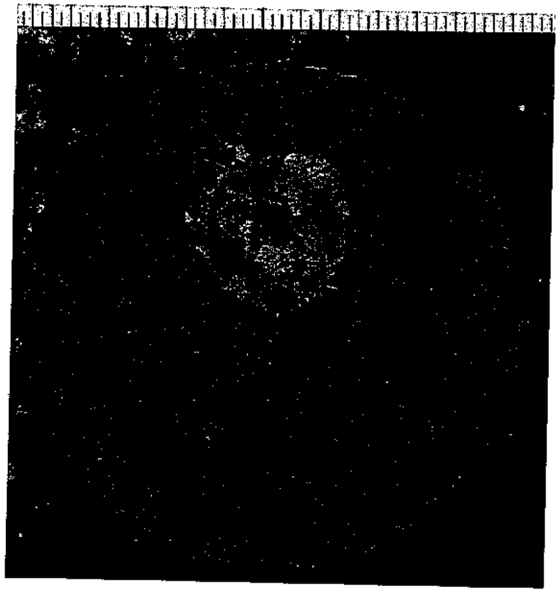


PLATE 5
TOP SURFACE

PLATE 6
CUT SURFACE "103TUD-P" SHOWING
CRACKED GEL "BUBBLE" EXUDATION

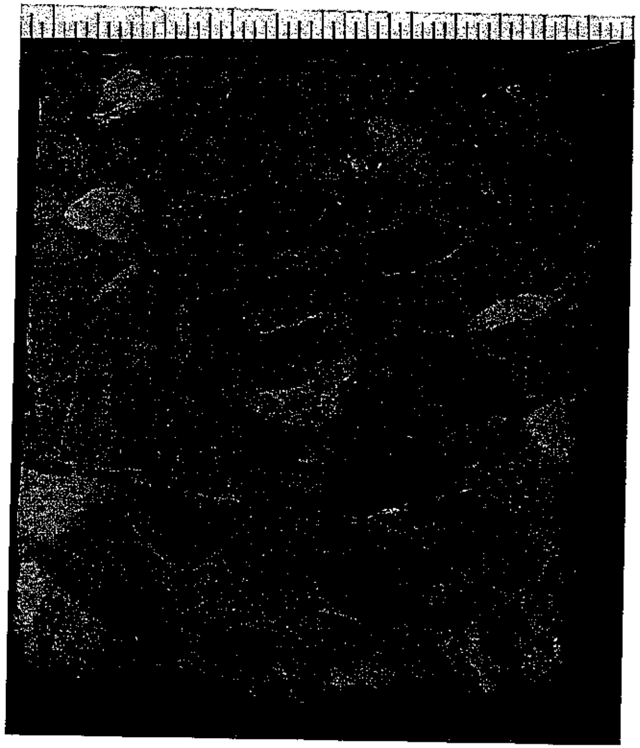


PLATE 7
PREPARED SURFACE
"103TUD-P"

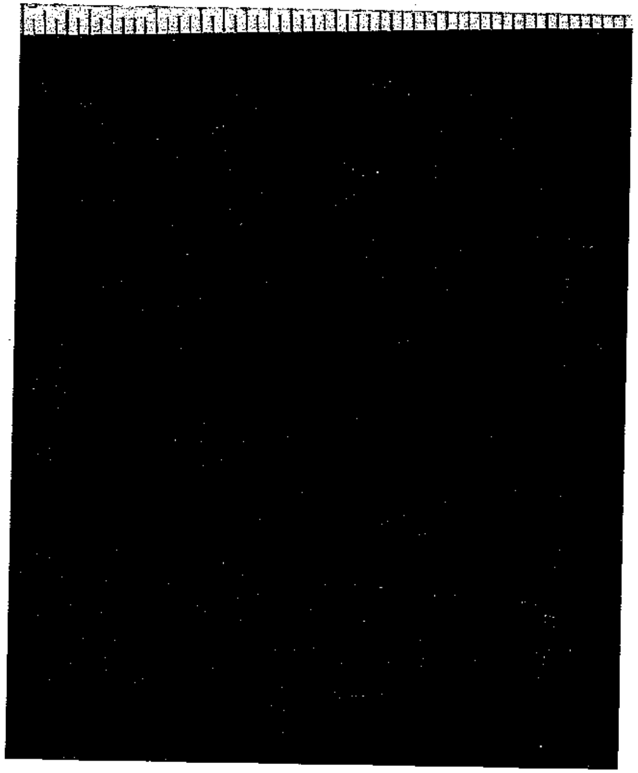


PLATE 8
PREPARED SURFACE "103TUD-P"
SHOWING LOCALIZED, YELLOW
STAINING IN PASTE AND
ASSOCIATED WITH MANY
AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 9
SERVICE "SLA16-P"

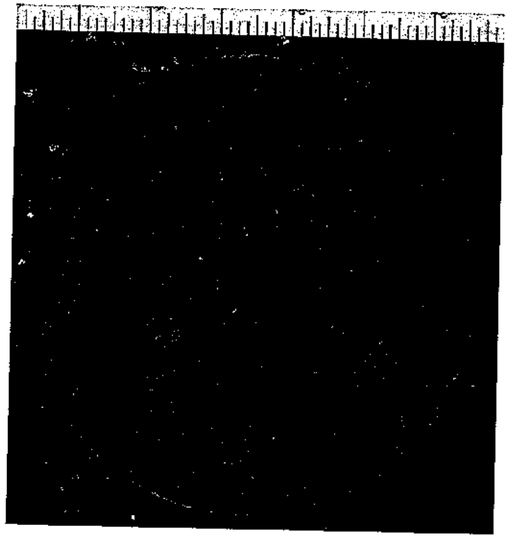


PLATE 9
TOP SURFACE

PLATE 10
CUT SURFACE "SLA16-P" SHOWING
OFF-WHITE INETRNALLY
RADIATING CRYSTALS OF
ETTRINGITE IN VOID

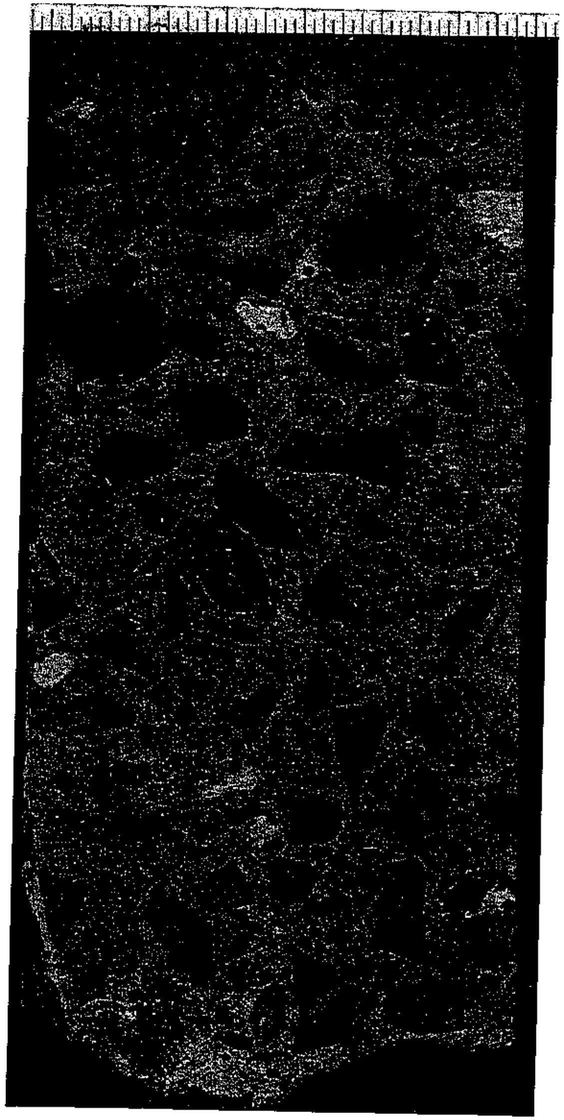


PLATE 11
PREPARED SURFACE
"SLA16-P"

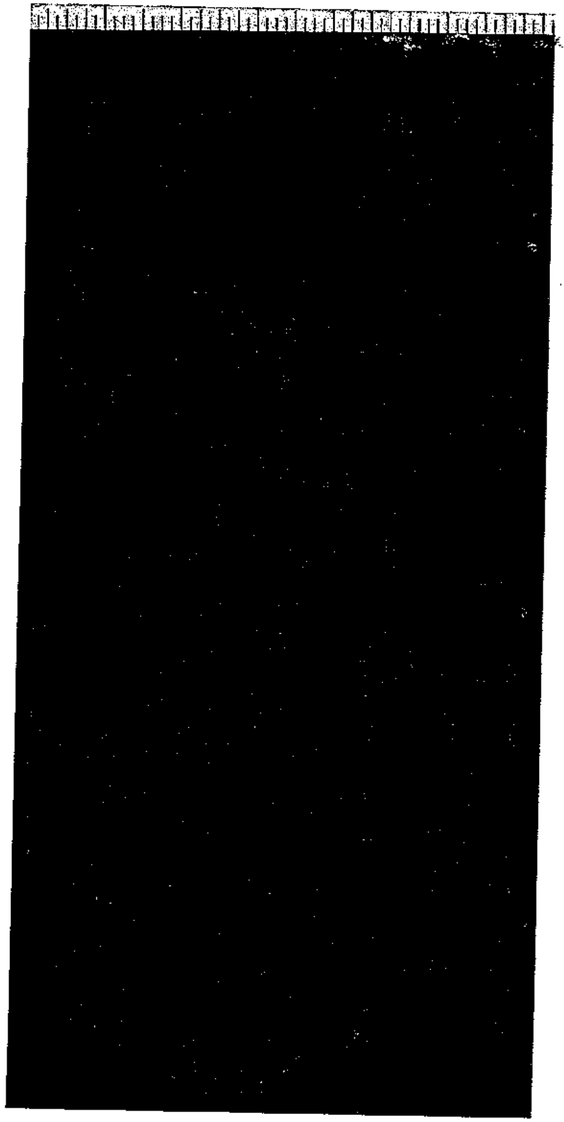


PLATE 12
PREPARED SURFACE "SLA16-P"
SHOWING YELLOW STAINING OF
PASTE AND ASSOC. WITH MANY
AGGREGATE PARTICLES AFTER
COBALTINITRITE STAINING

W.O.#: 07-08-31-01 / TCG 0756 / GROUP 9
SERVICE "SLB25-P"

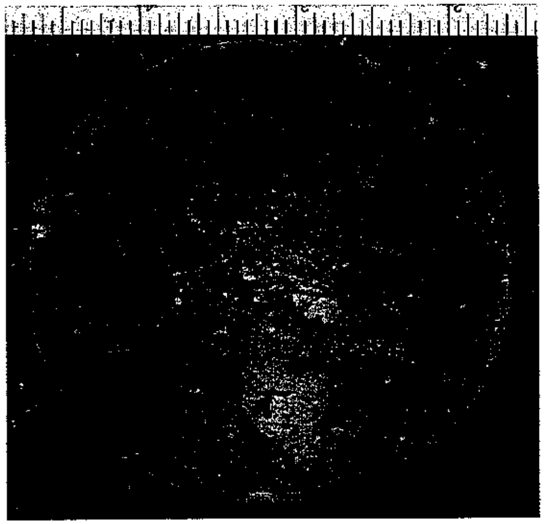


PLATE 13
TOP SURFACE

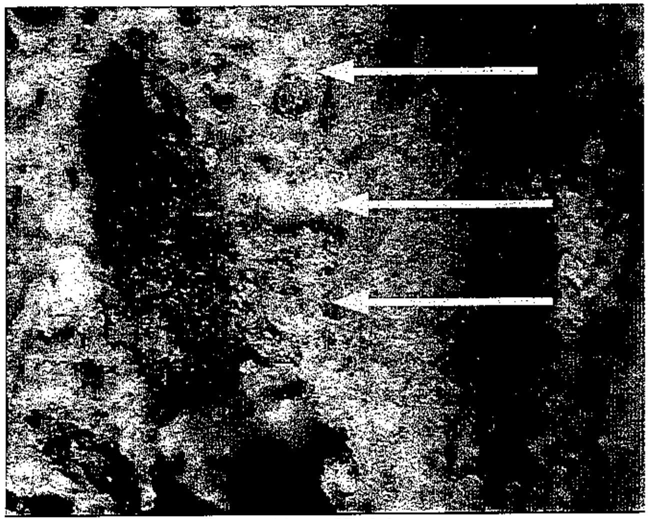


PLATE 14
CUT SURFACE SHOWING CLEAR TO OFF-WHITE GEL EXUDATIONS ON PASTE

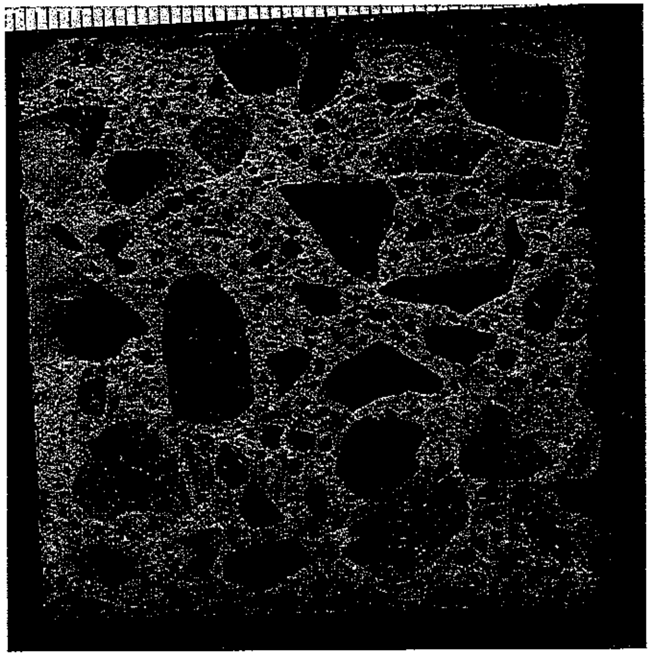


PLATE 15
PREPARED SURFACE
"SLB25-P"

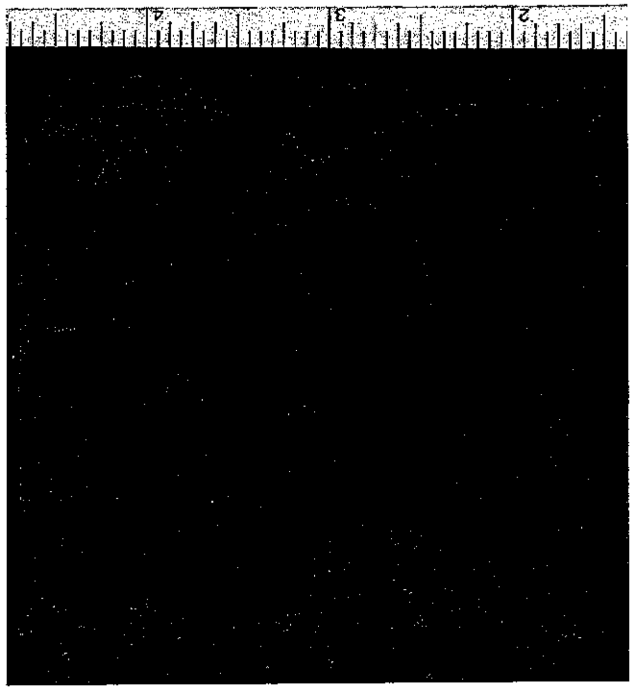


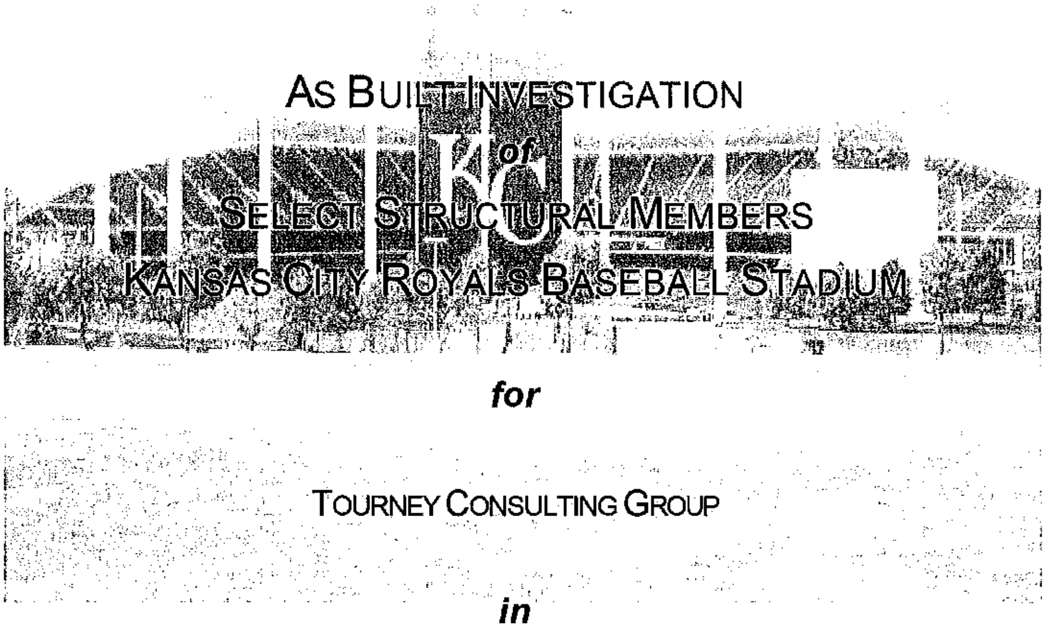
PLATE 16
PREPARED SURFACE "SLB25-P" SHOWING YELLOW STAINING IN PASTE PORTIONS AND WITHIN OR ASSOCIATED WITH MANY AGGREGATE PARTICLES AFTER COBALTINITRITE STAINING

APPENDIX C

GROUND PENETRATING RADAR REPORT

RADARVIEW

TECHNICAL REPORT



AS BUILT INVESTIGATION
of
SELECT STRUCTURAL MEMBERS
KANSAS CITY ROYALS BASEBALL STADIUM

for

TOURNEY CONSULTING GROUP

in

KANSAS CITY, MO

AUGUST 20-21, 2007

PROJECT NO. RV0779

RADARVIEW LLC
www.radarviewllc.com
1209-B First Street, Humble, TX 77338 Phone 281.446.7363 Fax 281.812.6590

RADARVIEW

CIVIL/STRUCTURAL AND GEOTECHNICAL SURVEYS

Client:	Tourney Consulting Group	*Project No:*	RV0779
Location:	KC Royals Stadium, Kansas City, MO	*Total Pages:*	14 including cover and this page
Client P.O. No:		*Date:*	August 20-21, 2007

Report Title: As-built investigation of Select Structural Members

Summary:

Radarview was contracted to perform a non destructive volumetric as built survey for Tourney Consulting Group at the Kansas City Royals Stadium in Kansas City, MO. There were three areas investigated including Plaza Level Section 102, Field Level Section 139, and the Club Level Section 107 (See sections 2-4). The need for the project stems from a condition survey and planned alterations of the stadium. Radarview utilized a high peak frequency electromagnetic system (GPR/Ground Penetrating Radar) for performing the data acquisition onsite.

See section 2-4 for results

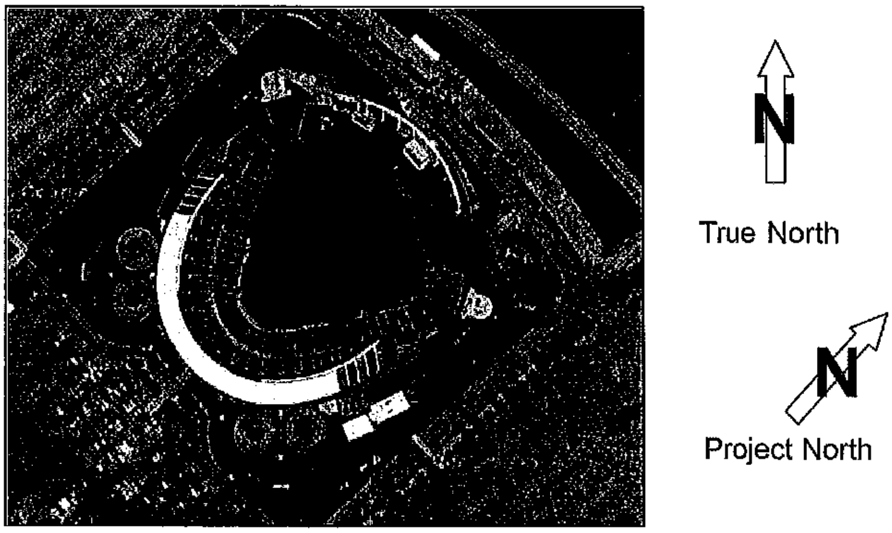
Prepared By: Todd Allen
Reviewed by: Todd Allen

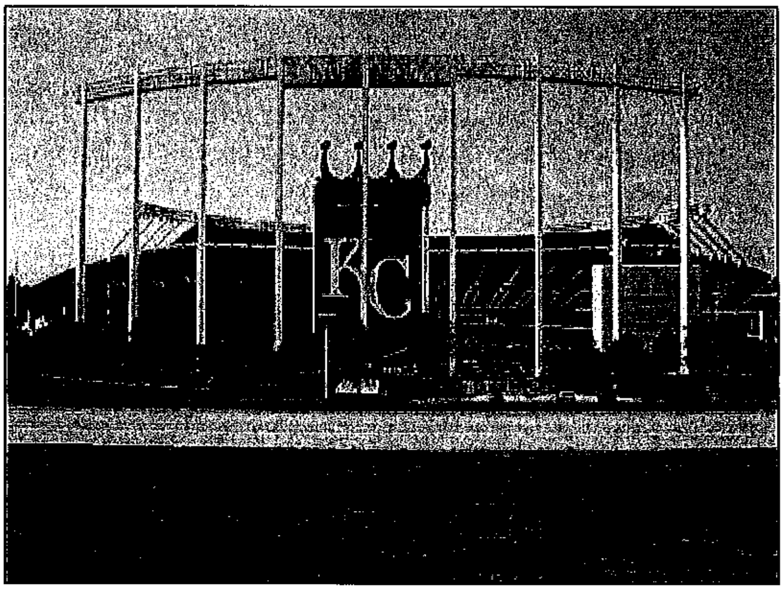
CONTENTS

1 INTRODUCTION

Radarview was contracted to perform a non destructive volumetric as built survey for Tourney Consulting Group at the Kansas City Royals Stadium in Kansas City, MO. There were three areas investigated including Plaza Level Section 102, Field Level Section 139, and the Club Level Section 107 (See sections 2-4). The need for the project stems from a condition survey and planned alterations of the stadium. Radarview utilized a high peak frequency electromagnetic system (GPR/Ground Penetrating Radar) for performing the data acquisition onsite.

A grid layout was used on the survey areas using 4" and 12" survey line increments. The data was post-processed into a 3D model created by interpolation. This model was used to determine reinforcement placement.

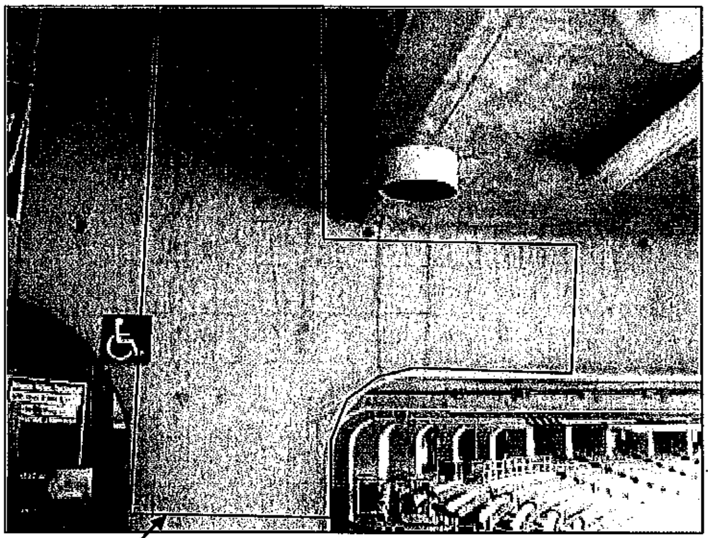




2 PLAZA LEVEL_SECTION 102-103

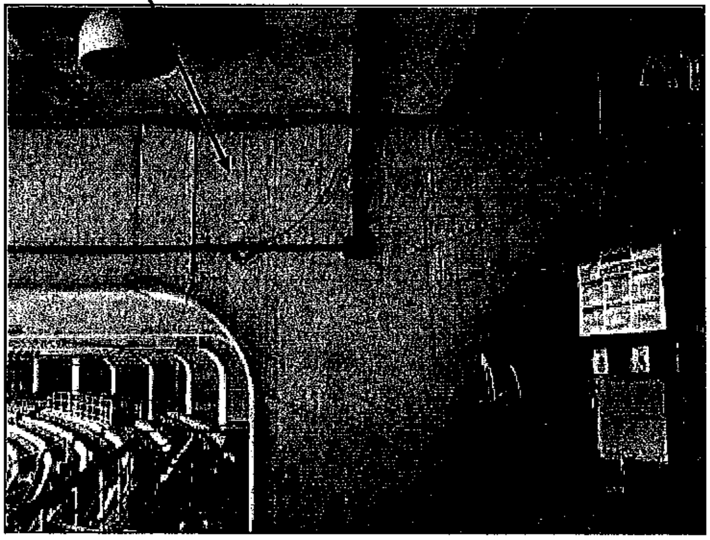
2.1 Overall view of the scan areas

The column and beam below were scanned from both sides and the reinforcement positions were marked on the surface to facilitate planned modifications. The west face was imaged for report purposes.



West Face of column and beam

Reinforcement is marked on the surface

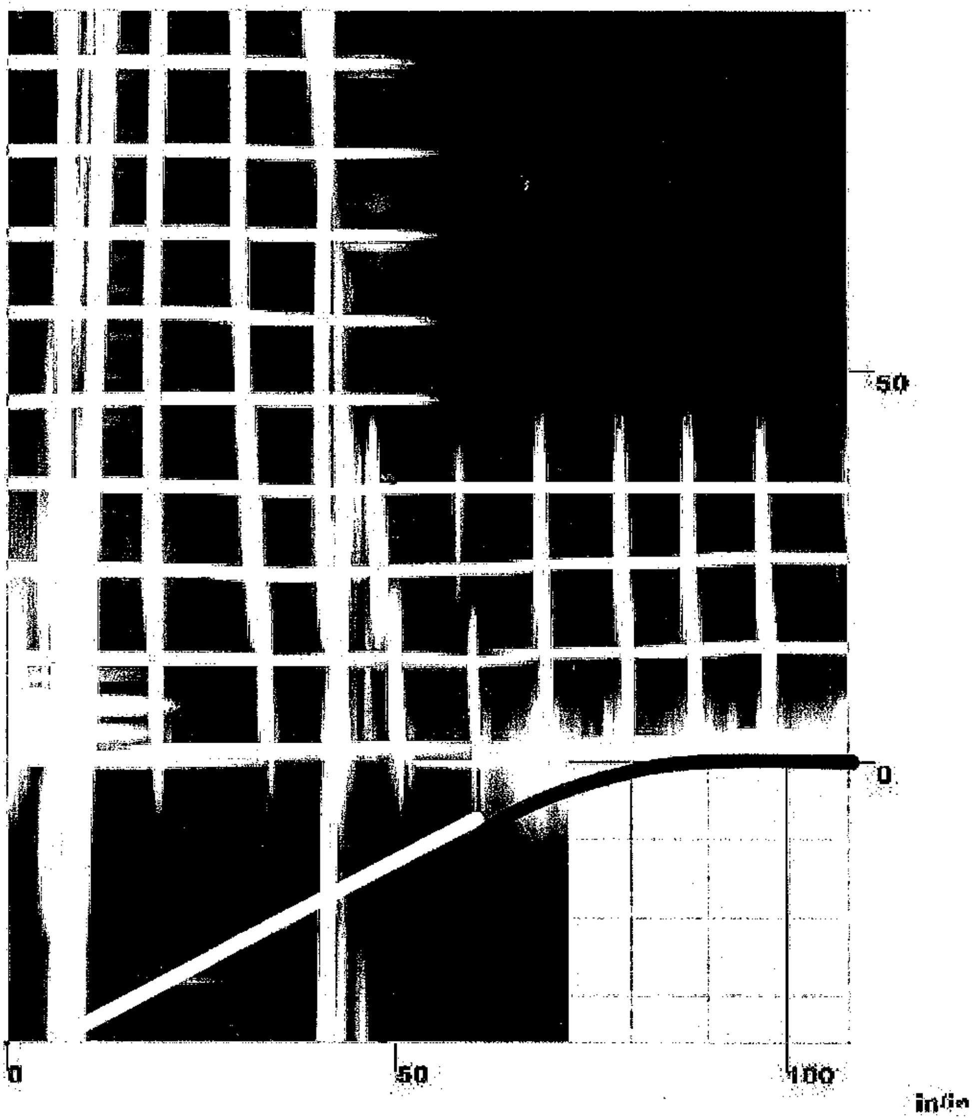


East Face of column and beam

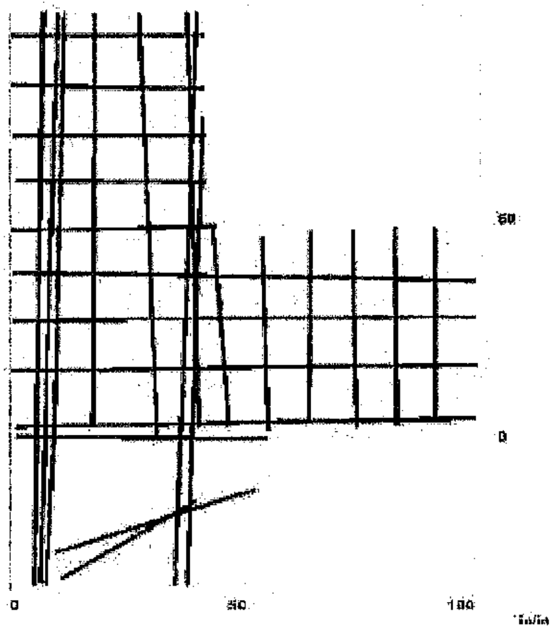
Reinforcement is marked on the surface

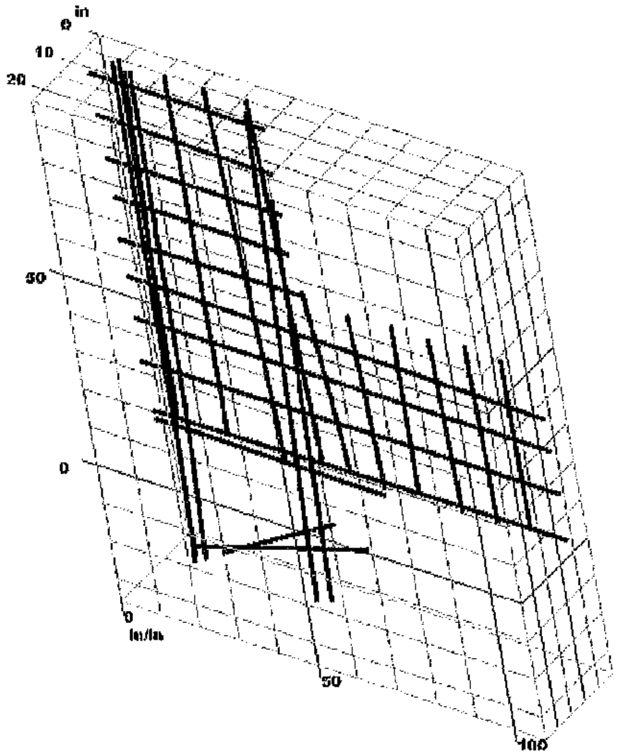
2.1.1 Scan Results

The image below reveals the reinforcement positions for the west face of the column and beam in Section 102-103. The results were marked on the surface of the east and west sides.



Additional views of the reinforcement model.

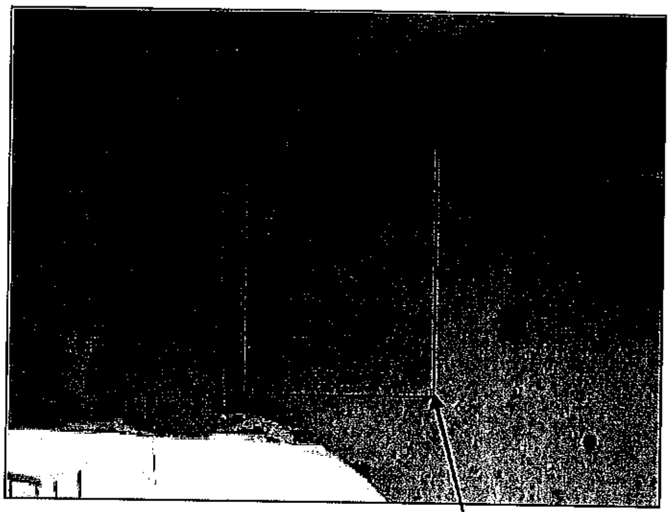




3 FIELD LEVEL_SECTION 139

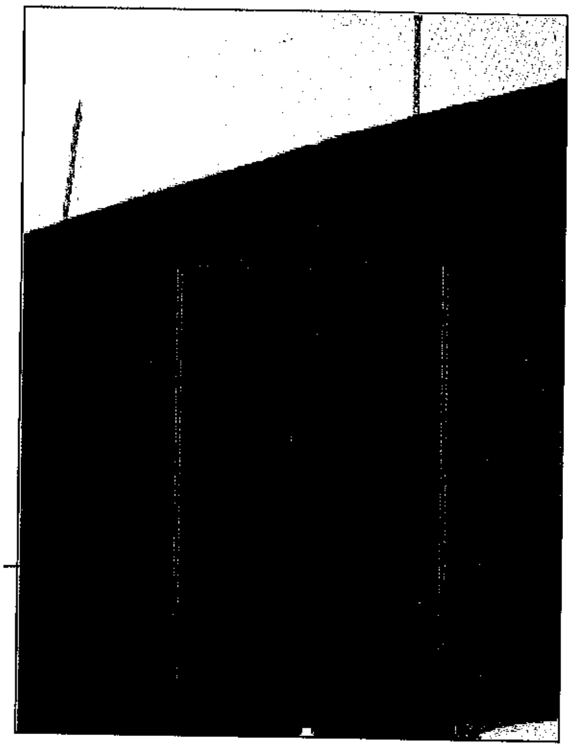
3.1 Overall view of the scan areas

Deterioration was present on the bottom edge of the spandrel panel near Section 139. Reinforcement details were requested to facilitate the repair. An attempt was made to provide clues as to how the connection is made between the column and the spandrel panel.



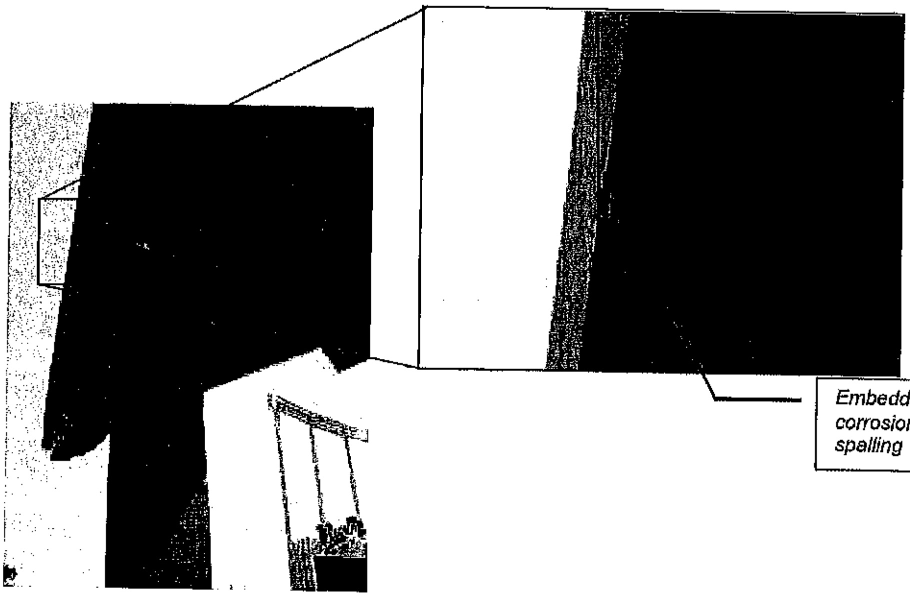
South Face of column

Scan area 1



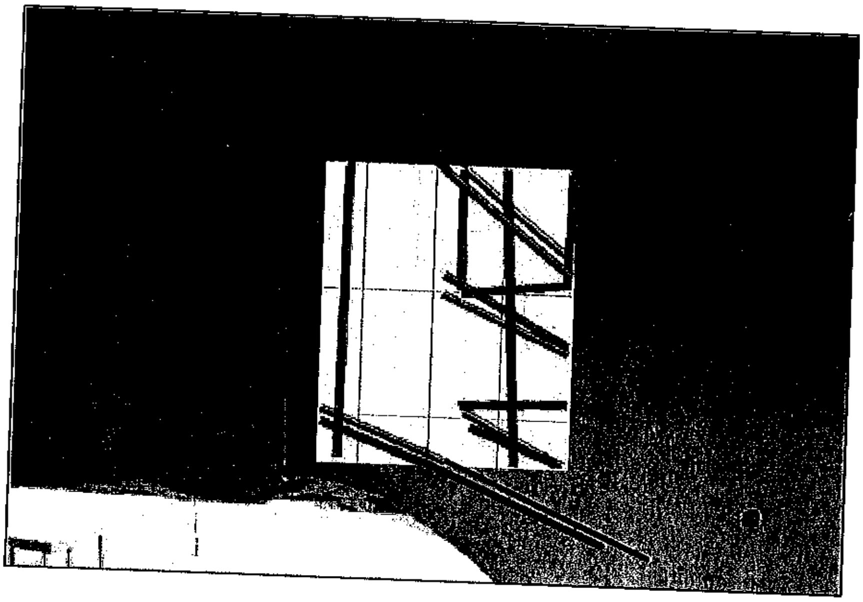
Scan area 2

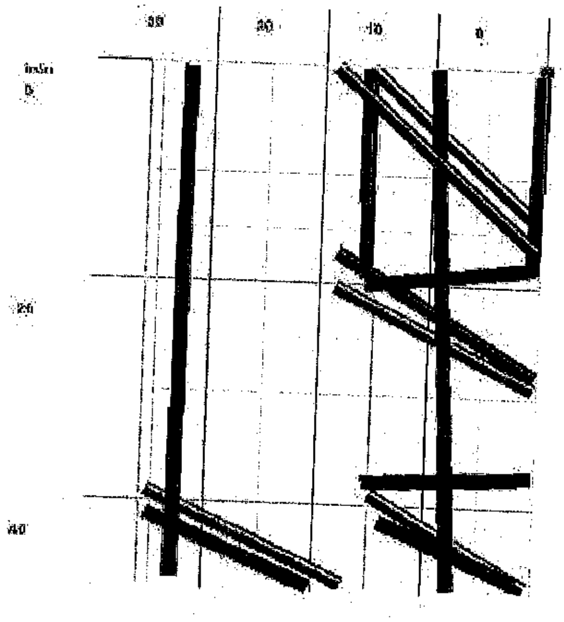
East Face of spandrel panel

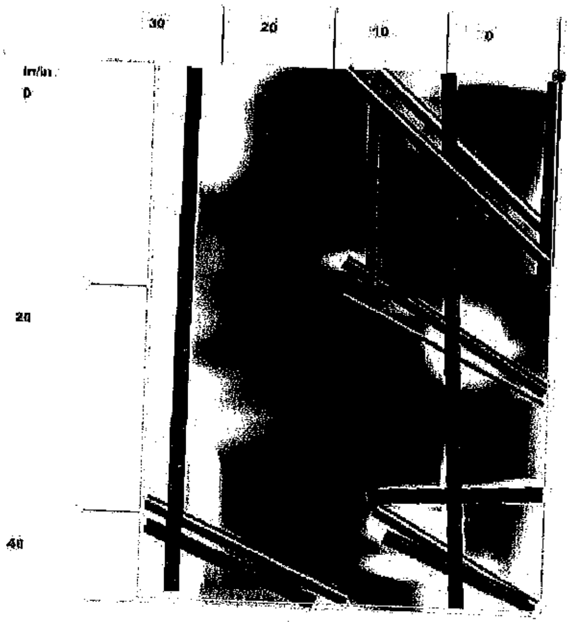


Embedded metal corrosion and spalling

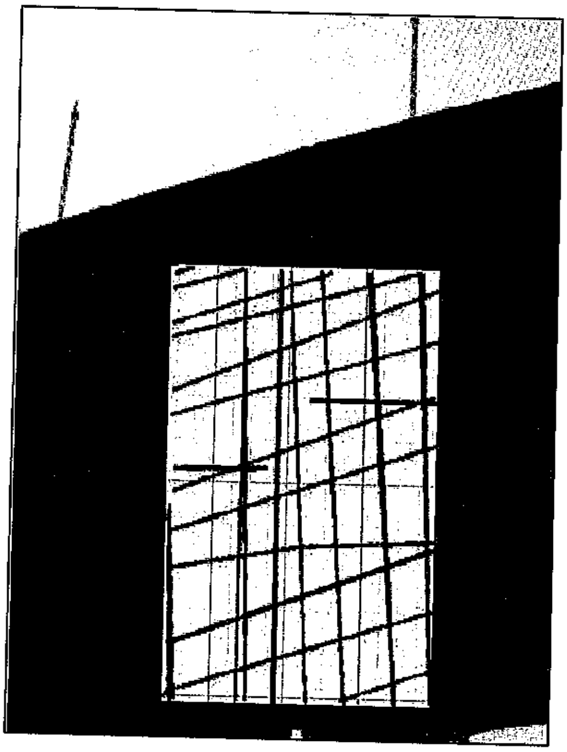
3.1.1 Scan Results_Area 1

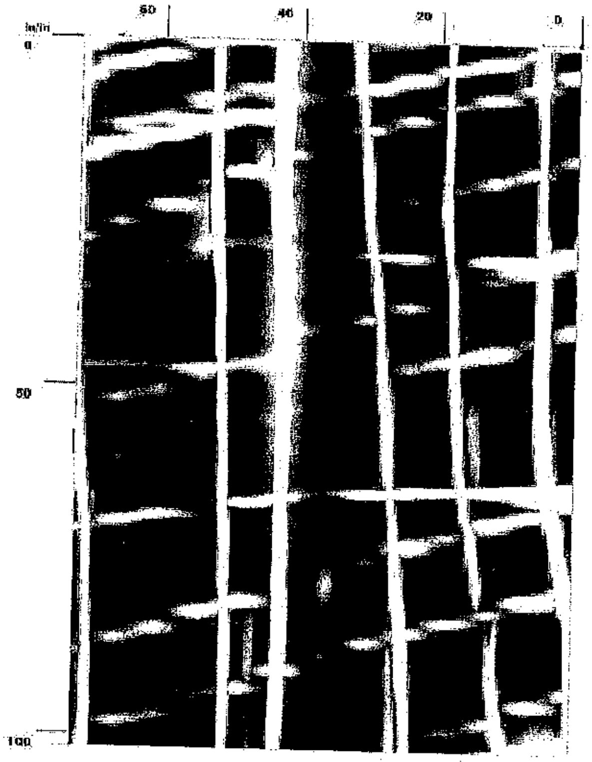




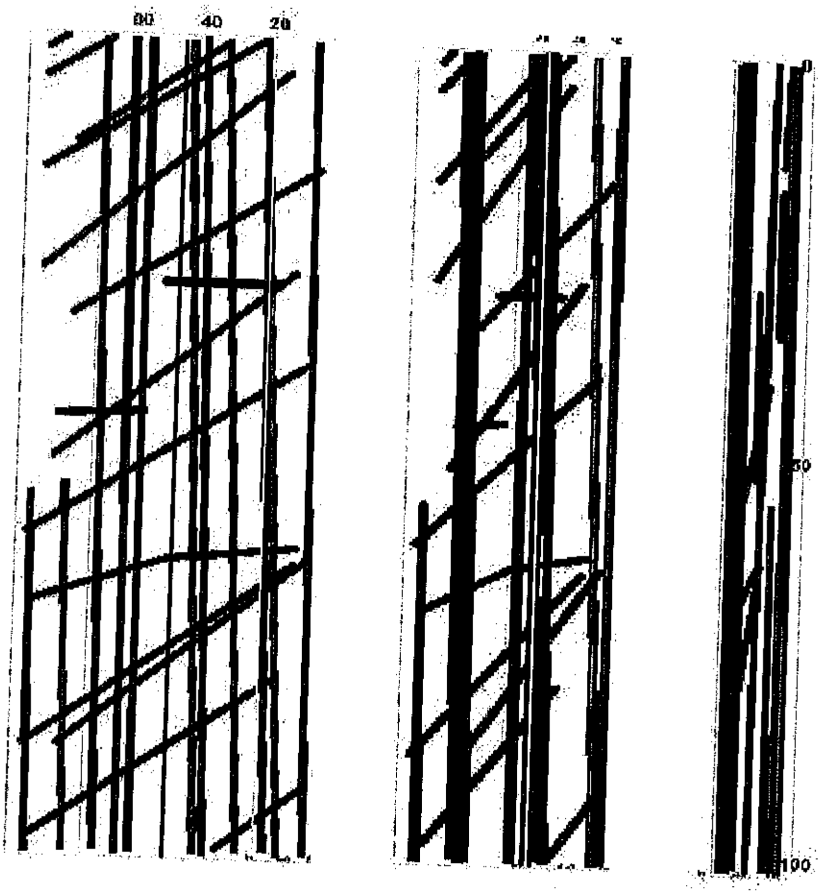


3.1.2 Scan Results_Area 2





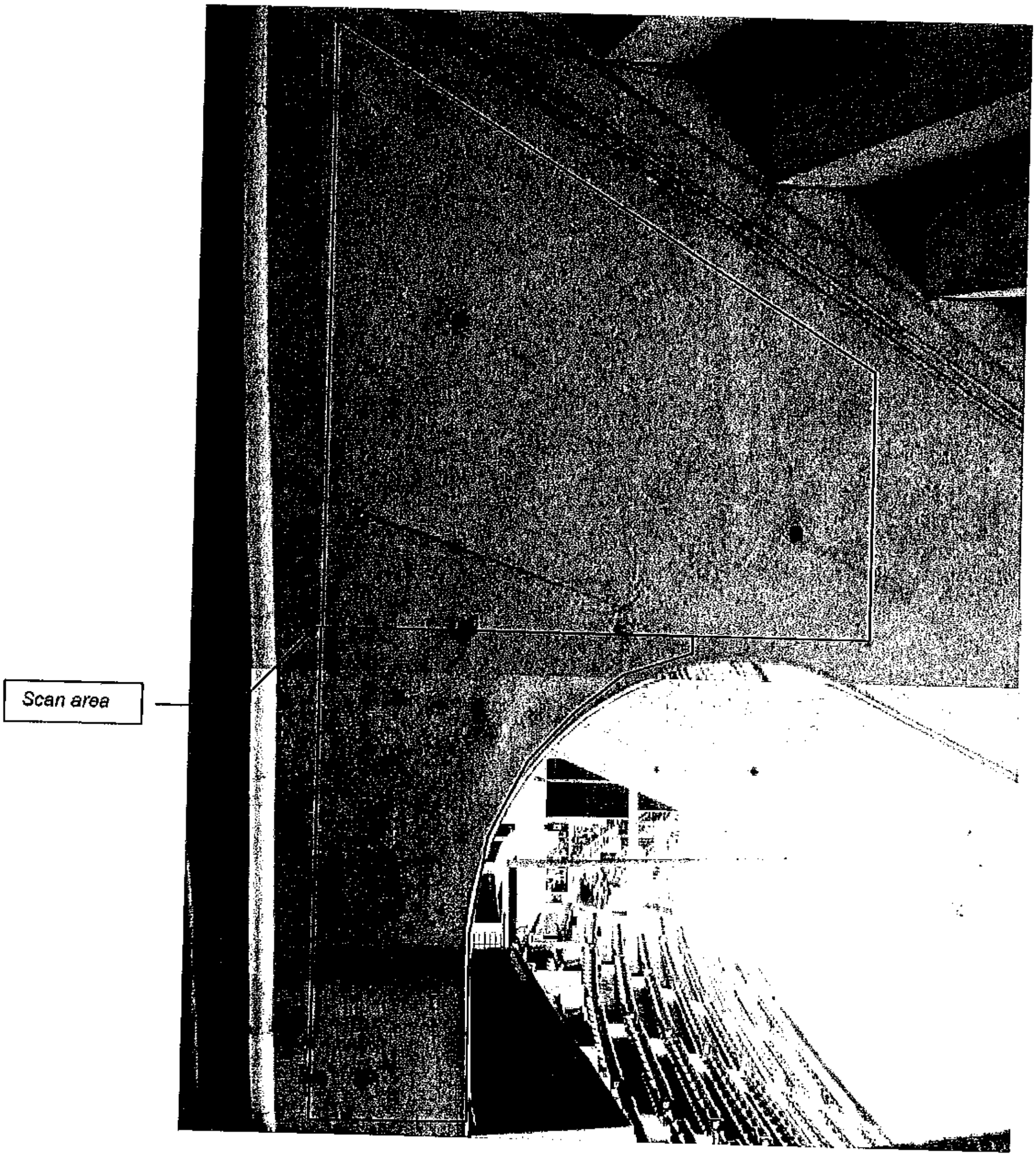
Additional views of the reinforcement model.



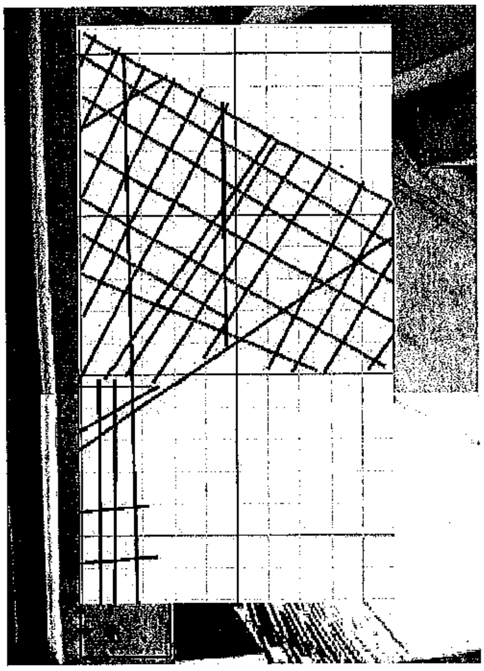
4 CLUB LEVEL_SECTION 107

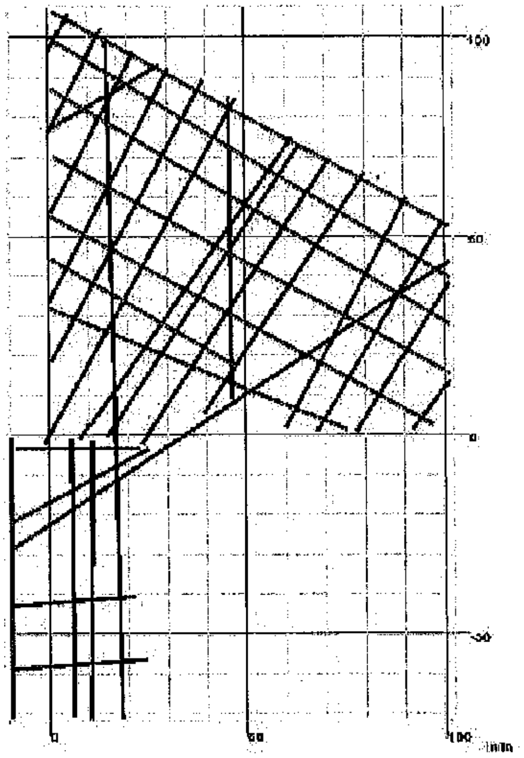
4.1 Overall view of the scan areas

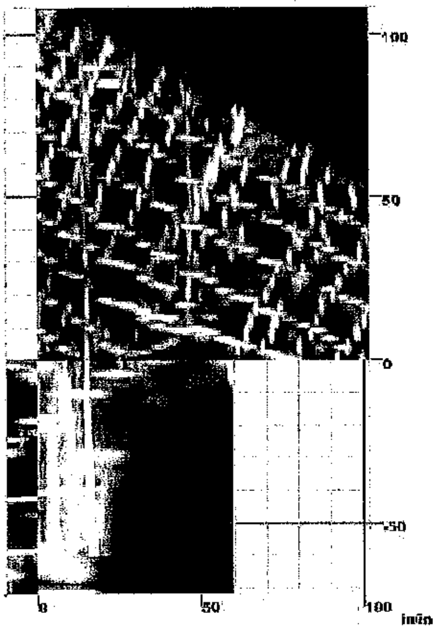
The column and raker beam below were scanned on the east face and a 3D model of the reinforcement placement was created to aid planned modifications to an adjacent raker beam that could not be scanned due to access limitations.

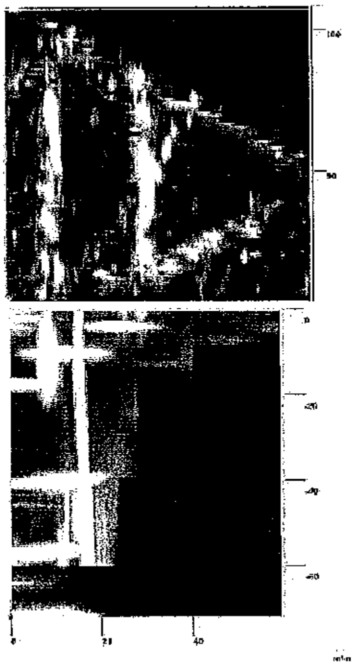


4.1.1 Scan Results









Additional view of the reinforcement model.