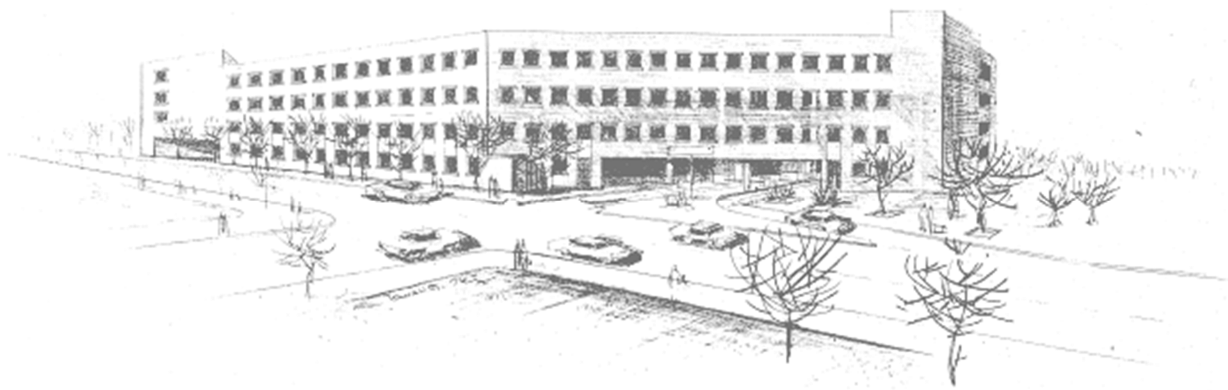
FINAL INSPECTION REPORT

LEO ROY PARKING GARAGE

100 MARKET STREET

LOWELL, MA 01852



GROUP #1

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DEFICIENCY REPORTING GUIDE

BEAM					
DEFECT DESCRIPTION	**SEVERITY**	**PRIORITY**	**PHOTO #**	**FLOOR**	**CONDITION ASSESSMENT**
Efflorescence and leaching	Minor	3	1	1st,2nd, 3rd and 4th	6
Scaling and exposed rebar	Severe	2	7	1st	4
Deterioration of steel beam	Severe	2	17	4th	4
Rust bleeding, leaking joint	Severe	2	13	1st, 2nd and 3rd	4
CEILING					
DEFECT DESCRIPTION	**SEVERITY**	**PRIORITY**	**PHOTO #**	**FLOOR**	**CONDITION ASSESSMENT**
Spalling and exposed rebar	Severe	1	3	1st,2nd, 3rd and 4th	4
Spall with exposed rebar and Electrical cable	Severe	1	4	1st	4
Spall with exposed rebar	Minor	2	12	1st,2nd, 3rd and 4th	4
Spall with exposed rebar	Severe	1	15	3rd	4
COLUMN					
DEFECT DESCRIPTION	**SEVERITY**	**PRIORITY**	**PHOTO #**	**FLOOR**	**CONDITION ASSESSMENT**
Crack and spalling	Critical	1	8	1st	2
Spalling with exposed rebar	Critical	1	9	1st	3
Crack/separation	Severe	1	14	2nd	3
Cracking and spalling	Minor	2	19	4th	4
Deterioration	Minor	2	5	1st	5
Cracking of concrete	Minor	2	6	1st	5
DRAINAGE					
DEFECT DESCRIPTION	**SEVERITY**	**PRIORITY**	**PHOTO #**	**FLOOR**	**CONDITION ASSESSMENT**
Leaking drain pipe	Minor	2	5	1st,2nd and 3rd	5
Leaking drain pipe	Minor	2	19	4th	4
Clogged Drainage	Minor	2	10	1st,2nd, 3rd, 4th and 5th	6
FLOOR					
DEFECT DESCRIPTION	**SEVERITY**	**PRIORITY**	**PHOTO #**	**FLOOR**	**CONDITION ASSESSMENT**
Standing puddle	Minor	3	11	2nd	6
Full width by 1” cracking	Severe	2	16	4th	4
Melting snow	Minor	3	20	5th	
WALL					
DEFECT DESCRIPTION	**SEVERITY**	**PRIORITY**	**PHOTO #**	**FLOOR**	**CONDITION ASSESSMENT**
42 inch by ½” sealed crack	Minor	3	2	4th	5
Incomplete connection	Minor	3	18	4th	6

CATEGORIES OF DEFICIENCIES:

- Minor - Deficiencies which are minor in nature, generally do not impact the structural integrity and could easily be repaired. Examples include but not limited to: Spalling concrete, Minor pot holes, Minor corrosion of steel, Minor scouring, Clogged drainage, etc.

- Severe- Deficiencies which are more extensive in nature and need more planning and effort to repair. Examples include but not limited to: Moderate to major deterioration in concrete, Exposed and corroded rebars, etc.

- Critical - A deficiency in structural element that posses an extreme unsafe condition due to the failure or imminent failure of the element which will affect the structural integrity.

URGENCY OF REPAIR:

- 1=ASAP- Action/Repair should be initiated upon receipt of the inspection report

- 2=Prioritize- Shall be prioritized and repairs made when possible

- 3=Monitor-Pay close attention on the next scheduled visual inspection

CONDITION RATING GUIDE

CONDITION:

- 1 - Imminent Failure: Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability.
- 2 - Critical: Advance deterioration of primary structural elements. Fatigue cracks or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the area until action is taken.
- 3- Serious: Loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failure are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
- 4 - Poor: Advanced section loss, deterioration, spalling or scour.
- 5 - Fair: All primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
- 6 - Satisfactory: Structural elements show some minor deterioration.
- 7 - Good: Some minor problems.
- 8 - Very Good: No problem noted.
- 9 - Excellent: Excellent condition.

REMARKS

INTRODUCTION

The Leo Roy Parking Garage is located at 100 Market street Lowell, MA. It is a 5- story reinforced concrete structure which was constructed approximately 30 years ago. According to its planning, it has an area of 3.862 Acres per floor. The building is constructed of post-tension and reinforced concrete. All inside beams, which extend from east to west, and all roof decks are post-tension concrete. Spandrel beams, columns and all inside beams, which are extended from north to south, are cast-in place reinforced concrete. The conditions observed and noted in the Visual Inspection Report of the parking structure includes moderate to excessive spalled concrete, corroded and exposed post-tension tendons or rebar, and corroded drain pipes on all 5-stories.

On April 15, 2013, an onsite inspection was conducted in areas of Critical and Severe deficiencies with the highest urgency of repair, as listed on the Visual Inspection Report. These areas were the Ceiling (Photo #3), Column E10 (Photo #8), and Beam line G-entrance (Photo #7). The tools used for this inspection were the SilverSchmidt Concrete Test Hammer Type N (Model #34131000) and the Profoscope+ Rebar Detector (Model #39120000), both manufactured by Proceq. The rebound hammer is used for estimating the compressive strength of in-place concrete of the structural components of the parking garage which were determined as deteriorated concrete in the visual inspection. The rebar locator device is used to determine the clear cover of the rebar and to locate the position of rebar in the concrete. Measurements were taken with the rebound hammer in areas that were determined to be clear of rebar by the rebar locator. The rebound hammer and the rebar locator devices were calibrated by taking readings on the same type of structural component which is determined as non-delaminated using visual and sounding inspection methods.

Utilizing the results attained by these instruments and comparing them to results of the control specimen, an analysis was made to these areas of concern to determine the severity of the structures. By doing so, an assessment can be made to address these areas of concern so that they can either be repaired or replaced to meet the safety standards in place.

I) Experimental Result

As set by the ASTM C805 standard, 10 readings from the rebound hammer were taken and the average of them is taken as the control number from the non-delaminated structural component. There was also the average of five readings of the rebar locator taken from the same structural component as the control number. This procedure was done for each inspected structural component See Table 1. These inspections were conducted on three different structural components of the parking garage which were flagged as severe and critical deteriorated structures in the Visual Inspection Report.

The structural components which were inspected are- the ceiling on the third floor between beam seven and beam eight which is flagged severe (see photo # 3), column E10 on first floor which is flagged as critical (see photo #8) and the cross beam on first floor (column line G) between the entrance and up ramp which is flagged as severe (see photo # 7). The control reading for column E10 and for the cross beam is taken from column G10 and for the ceiling is taken from the ceiling between beam six and beam seven which were determined as non-delaminated structural components (see photo # 23). As expected, the control reading was greater than the reading from the delaminated structural components (See Tables 1, 2, and 3). The higher control numbers of the rebound hammer indicate higher compressive strength. The higher control numbers of the rebar locator indicate more clear cover of rebar. These numbers show the concrete strength and the clear rebar cover difference between the delaminated structural component and non-delaminated one.

The average rebound hammer (Q) value is related to the compressive strength of the concrete using a correlation curve prepared by the manufacturer of the rebound hammer (See Figure 1 and Table 4).

II) Data Interpretation/Assessment

Together with visual observations, the measurements confirm that there is some ongoing deterioration in the concrete within the overall structure. At first floor column E10, it was observed that the average reading for the rebound hammer resulted in about a 3000 psi difference from the control. It should be pointed out that most of the concrete in the structure was designed for 4000 psi compressive strength. In some cases the rebound hammer indicates up to 10,000+ psi existing strength. This reading should be used with caution since it is unlikely the actual strength of the concrete is that much higher than the design strength. Some possible sources of this error may include equipment failure or human errors in calibration, operation, reading of measurements, and conversion to psi using the manufacturer's charts. Although the psi reading itself may not be accurate, we can still make an assessment of the structures condition based on the *relative* difference between the experimental measurement and the control. In the case of the column, there is an approximate 30% loss of concrete strength compared to the control. This loss of strength may be due to corrosion of rebar or chemical (such as chloride) attack. Note that the rebar locator was not used at this location as we felt it would not provide significant information due to the layout and condition of the already large areas of exposed rebar.

We observed similar deterioration at Beam line G near the entrance. The rebound hammer showed an even larger difference between control value and experimental reading. This indicates a severe deterioration in the concrete, confirming our visual observation of severe scaling. We also used the rebar locator on this beam in order to evaluate any possible or future corrosion of rebar. Although there was no visible spalling or exposed rebar at this location, the average rebar locator magnetic reading of .9 versus the control reading of 3 indicate a possible lack of cover. This lack of cover could result in ease of infiltration of chlorides which will cause corrosion of the steel. It is also possible that this low magnetic reading indicates that portions of steel may already be corroded or contaminated with chlorides. If the steel is already deteriorated, the magnetic reading may be affected and give such a result. It is possible that this type of deterioration is a result of poor construction practice such as finishing and curing. It is also possible this deterioration could be due to the beams proximity to the open air entrance, resulting in road salt chloride infiltration.

The third and final location we inspected was the ceiling between beams 7 and 8 on the third floor. It is important to note that similar conditions were found at this location on all floors and they may have similar results. We first used the rebound hammer as seen in Photo #21 to determine the condition of the concrete in an area adjacent to a large area of spalling and exposed rebar. The results indicate a significant variation between control readings and experimental readings. This difference was greater than at any of the other two locations and indicates an ongoing problem of concrete deterioration. The proximity of visually spalled concrete suggests the possibility of future spalls in the immediate area. The rebar locator was also used at this location (see photo #22). The experimental reading of 1.2 versus the control of 2 suggests that there is a possible lack of cover or corroded rebar in the area adjacent to the spalls. This indicates that there is a possibility of further spalling of concrete and corrosion of rebar and this area should be monitored for future deterioration. Possible causes of this condition appear to be construction related since a similar condition occurs on all floors in a similar location.

III) CONDITION ASSESSMENT

INSPECTION & REPAIR

During a standard Property Condition Assessment, we first did a visual inspection on the parking structure. During the visual stage, we look for evidence of corrosion, rust, spalling, cracking, and other visible defects. For a more detailed garage inspection, we have used a rebound hammer and a rebar locater to identify the location of the rebar in the test areas. Based on the results of the visual and detailed inspections, we developed a rating for each element inspected using a numerical scale that was derived from the typical bridge structure inspection scale. This scale rates elements from 1 (worst) to 9 (best) conditions. The condition ratings are included in Table 1 at the beginning of this report.

1. OBSERVATIONS

We performed a condition assessment of the garage. A visual examination of the parking facility was performed on the exposed concrete deck and overhead surfaces to assess cracking, rust staining, efflorescence and spalls. Additionally we closely reviewed the condition of the concrete around floor drains or where there was evidence of ponding water.

BEAM

Much of the deterioration to the beams appears to be the result of moisture intrusion, resulting from poor concrete quality, standing water due to poor drainage slopes, improperly detailed or maintained construction joints that existed in the original construction, concrete shrinkage cracking, and/or flexural cracking. As shown furthermore in the appendix, the concrete cover in the regions which present spalling are lower than the concrete that is intact. This is an indicator of more moisture intrusion and consequently more deterioration.

CEILING

Much of the damage to the deck appears to be the result of moisture intrusion, resulting from poor concrete quality, standing water due to poor drainage slopes, improperly detailed or maintained construction joints that existed in the original construction, concrete shrinkage cracking, and/or flexural cracking. As shown furthermore in the appendix the concrete cover in the regions which present spalling are lower than the concrete that is intact, which is an indicator of more moisture intrusion and consequently more deterioration.

COLUMN

Compressive strength test results of column E10 are found to be considerably lower when compared to the compressive test of the other column (control). This may be the reason why this column presents excessive crack openings. This fact may be a strong argument to contact a structural engineer to conduct a structural analysis to verify whether the column is in the imminence of failure or not.

2. Summary and Recommendations

Concrete is a stone-like material obtained by permitting a carefully proportioned mixture of cement, sand and gravel or other aggregate and water to harden in forms of the shape and dimensions of the desired structure. Concrete as a building material is beneficial for its high fire and weather resistance, local availability at low cost and high compressive strength. However, concrete is brittle by nature and has a low tensile strength unlike its compressive strength. Reinforcing the concrete with steel rebar increases the concrete's tensile strength. With the use of salt to de-ice many surfaces exposed to the elements; bridge decks, parking garages and other reinforced concrete structures directly exposed become susceptible to an expedited deterioration. Programs have been initiated to study the cause and effect of this in order that repair procedures and preventive maintenance could be researched, developed, and implemented.

Research has confirmed that corrosion of the steel rebar was the primary cause of structural deterioration. The presence of chloride in the concrete (from both external and internal sources) greatly accelerates the deterioration process. External sources of chlorides mainly occur from deicing salt applications. Internal sources consisted of calcium chloride admixtures to the concrete used in winter months to speed up the temperature sensitive curing of the concrete mix.

Parking structures are exposed to many seasonal and temperature changes. The use of deicing salts presents itself during the winter months. Deicing salts may be spread directly on the slab floors or from wheel wells of vehicles. Extreme temperature and volume changes can cause cracking of the floors, beams, columns, and walls which can lead to ingress of water and chlorides leading to deterioration.

The ACI (American Concrete Institute) committee 362 State of the Art Report on Parking Structures issued in 1985 states that, "Repairing an existing deteriorated structure involves many unknowns, uncertainties and risks. Especially with regard to repair of deicer caused corrosion damage, the process is considered an extension of the useful life of the deteriorated structure. It is not equivalent to building a new structure with current technology". Hence, for a parking structure's repair program, contingency funds must be anticipated and included in any budget for repairs to account for concealed, unknown, or unanticipated conditions that may be encountered.

Concrete is porous by nature. Hence, it allows moisture and ions to penetrate and contact the reinforcing steel rebars. As part of a comprehensive repair, consideration must be given to stopping water intrusion into other portions of the structure. Several deterioration mechanisms attack and corrode the steel resulting in cracking and spalling of the concrete. This enables access to the reinforcing steel, accelerating the corrosion process and deteriorating the structure. Since the reinforcing steel has less concrete cover, it is more likely to deteriorate. This deterioration can be addressed by halting the moisture and ion ingress through the installation of a barrier.

As part of the deck repairs, underside cracking and spalls that remain should be repaired. Spalls are often the result of uncorrected cracking along reinforcing steel rebars and embedded conduits. If not addressed, deterioration will continue and spalls will develop. This can be repaired by removing the damaged concrete to sound concrete and cleaning the effected reinforcing.

Any reinforcing that has corroded greater than 20% should be closely monitored. A suitable repair mortar must be installed and finished to reduce the likelihood of any future damage. If concrete and reinforcing steel rebars indicate minimal damage, the damage can be removed, the surfaces cleaned and coated to protect from further damage.

Cracking and rust staining of the joists, beams and columns are areas of concern. This evidence indicates that deterioration is taking place. This condition must be halted by preventing the intrusion of moisture in to the affected areas. Wherever spalls are present, they must be removed and repaired in a manner that meets the building specifications of the area.

If efflorescence and rust staining are apparent on some beams of the structure, close inspection of the area should determine if there is any cracking and/or spalling associated with the rust staining. If deterioration is present, the surface should be cleaned and the top and interior surface sealed and/or coated to reduce moisture, especially to the exterior of the structure.

TABLES AND FIGURES

Inspected Ceiling *3rd Floor Ceiling between Beam-7 and Beam-8*		Control Number 3rd Floor Ceiling between beam-6 and Beam-7	
Rebound Hammer (Q)	**Rebar Locator**	**Rebound Hammer (Q)**	**Rebar Locator**
43.5	1.3	73.5	2
43	1.1	76.5	2.1
63	1.3	72	1.9
69.5	1	68.5	1.9
58	1.3	72	2.1
66.5		71	
51		74	
49		72	
56		73	
62		73	
AVG: 56.15	**1.2**	**72.55**	**2**

Table 1. Rebound Hammer and Rebar Locator Reading for Inspection of Ceiling.

Inspected Column *Column E10 1st Floor*	Control Number *Column G10 1st Floor*	
Rebound Hammer (Q)	**Rebound Hammer (Q)**	**Rebar Locator**
69.5	71.8	3.1
69.8	72	3
59	70	2.8
64.5	69	2.9
68	73.5	3.2
69	71.5	
69.5	64	
59	65	
64.5	64.5	
65.5	67.5	
65.83	**68.88**	**3**

Table 2. Rebound Hammer and Rebar Locator Reading for Inspection of column.

TABLES AND FIGURES

Inspected Beam *Beam Line G at the entrance*		Control Number *Column G10 1st Floor*	
Rebound Hammer (Q)	**Bar Locator**	**Rebound Hammer (Q)**	**Rebar Locator**
73.5	1.1	71.8	3.1
67	0.91	72	3
48	0.98	70	2.8
69.5	0.8	69	2.9
59	0.71	73.5	3.2
72		71.5	
48		64	
63		65	
57.5		64.5	
57.5		67.5	
61.5	**0.9**	**68.88**	**3**

Table 3. Rebound Hammer and Rebar Locator Reading for Inspection of Beam.

Ceiling 1st floor between Beam-7 and beam-8				
	Q	**MPa**	**PSI**	**Rebar locator**
Average Inspection Reading	56.15	45	6526.7	1.2
Average Control Number	72.55	82	11893.09	2
Column E10 on 1st Floor				
	Q	**MPa**	**PSI**	**Rebar locator**
Average Inspection Reading	65.83	64	9282.41	----
Average Control Number	68.88	72	10442.71	3
Beam line G-1st Floor				
	Q	**MPa**	**PSI**	**Rebar locator**
Average Inspection Reading	61.5	52	7541.96	0.9
Average Control Number	68.88	72	10442.71	3

Table 4. Relationship between rebound number (Q) and Compressive Strength.

TABLES AND FIGURES

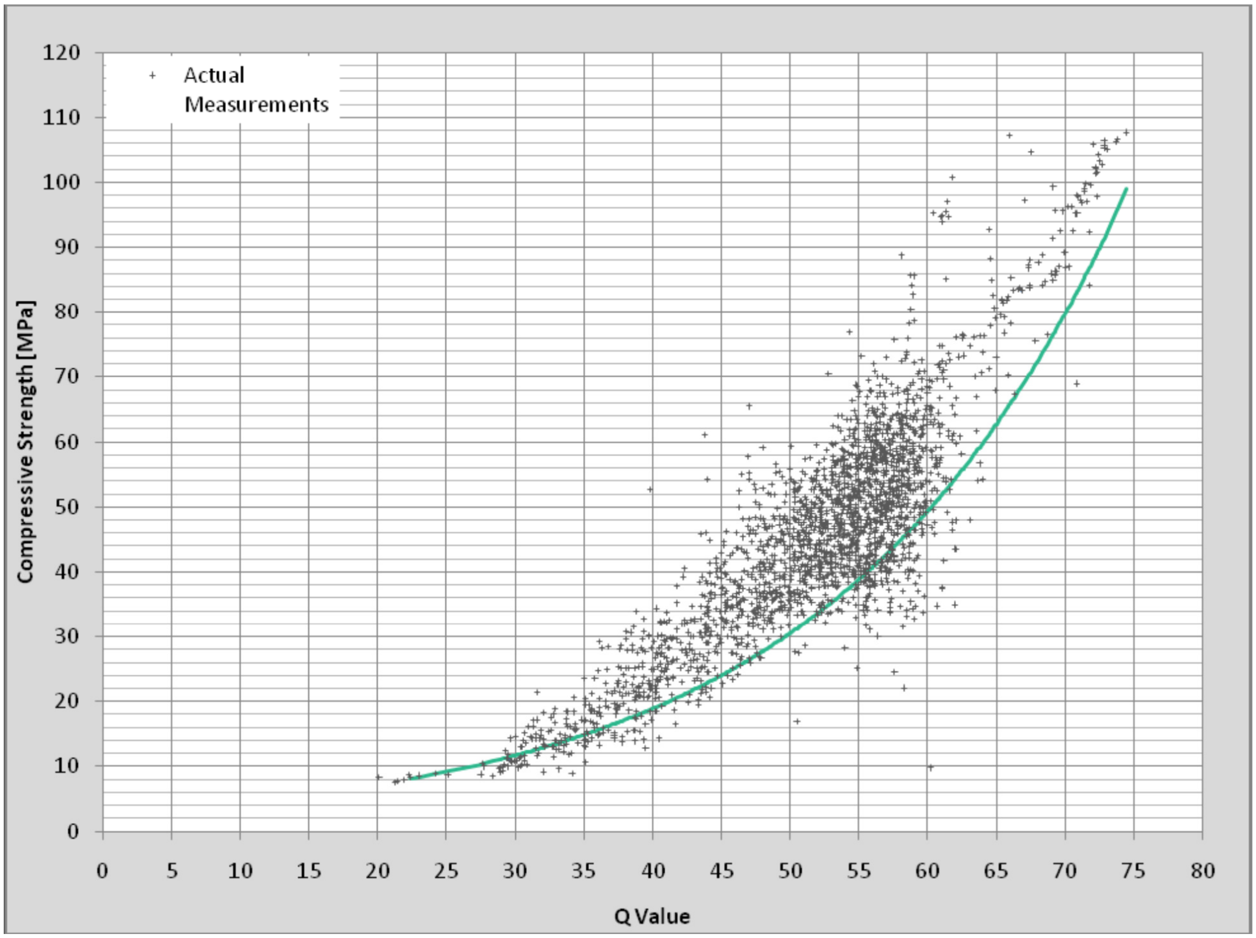


Figure 1. Correlating Rebound Hammer (Q) and Compressive Strength.

TABLES AND FIGURES

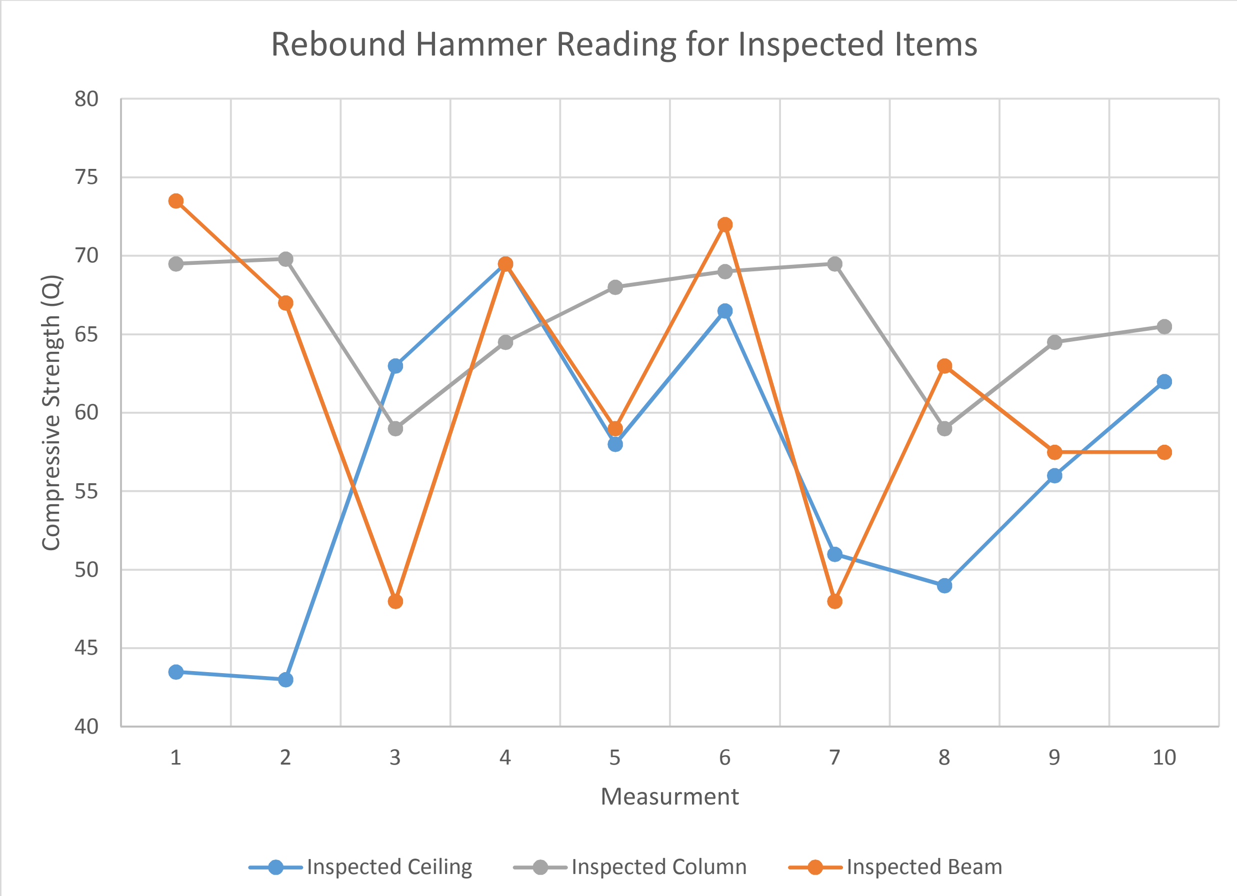


Figure 2. Rebound Hammer Reading for Inspected Items

TABLES AND FIGURES

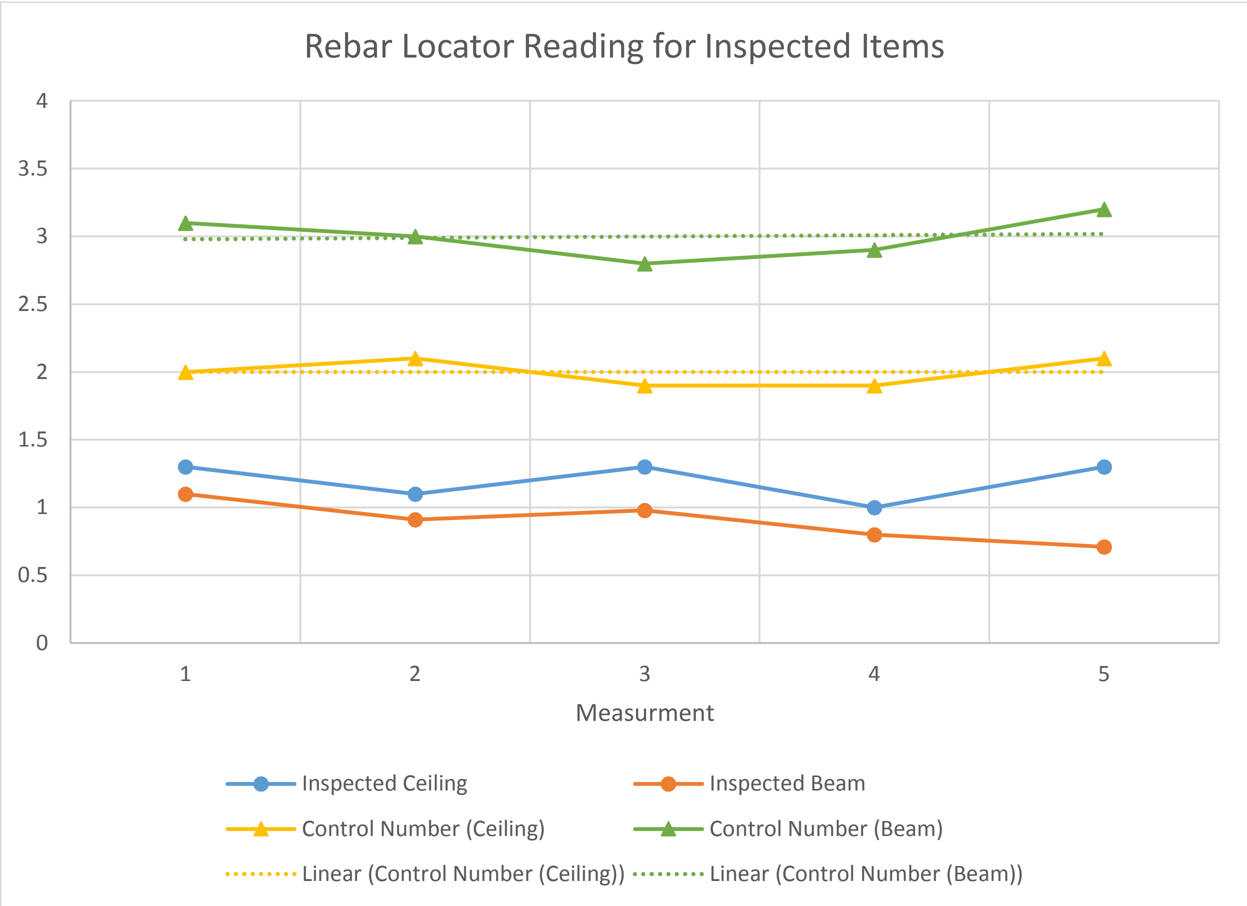
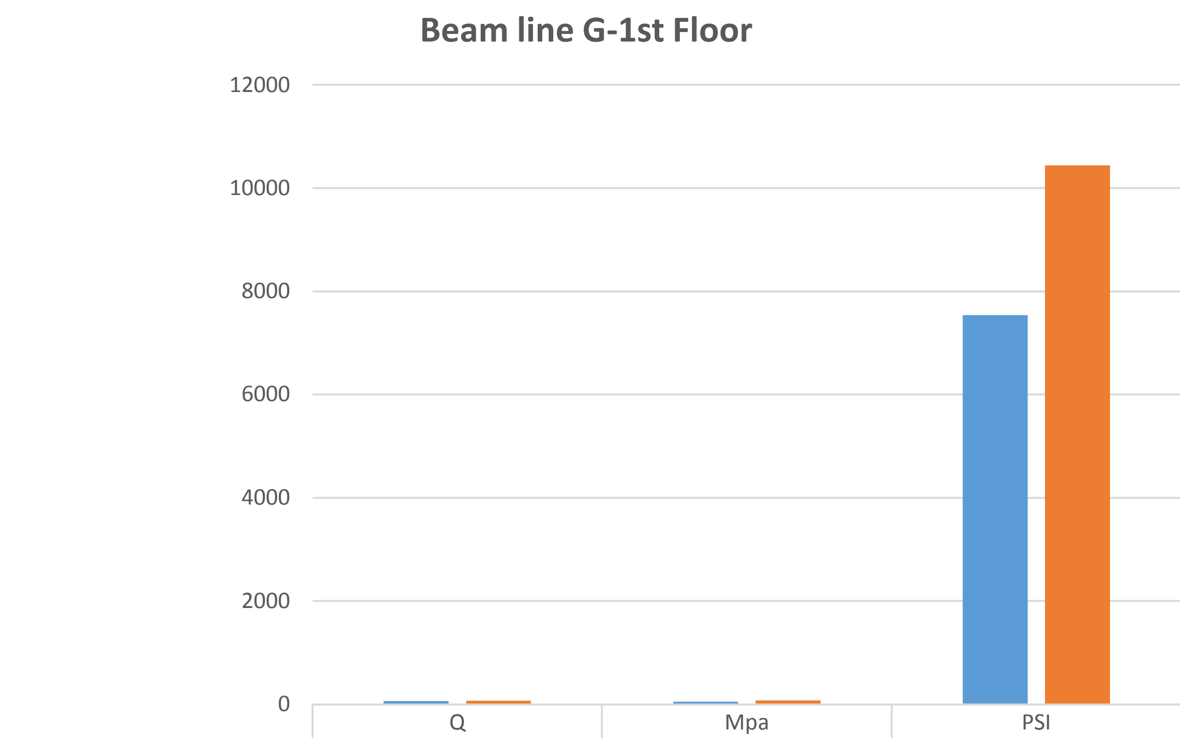


Figure 3. Rebar Locator Reading for Inspected Items

TABLES AND FIGURES



	Q	Mpa	PSI
Average Inspection Reading	61.5	52	7541.96
Average Control Number	68.88	72	10442.71

Average Inspection Reading   Average Control Number

Figure 4. Beam line G-1st Floor Comparison

TABLES AND FIGURES

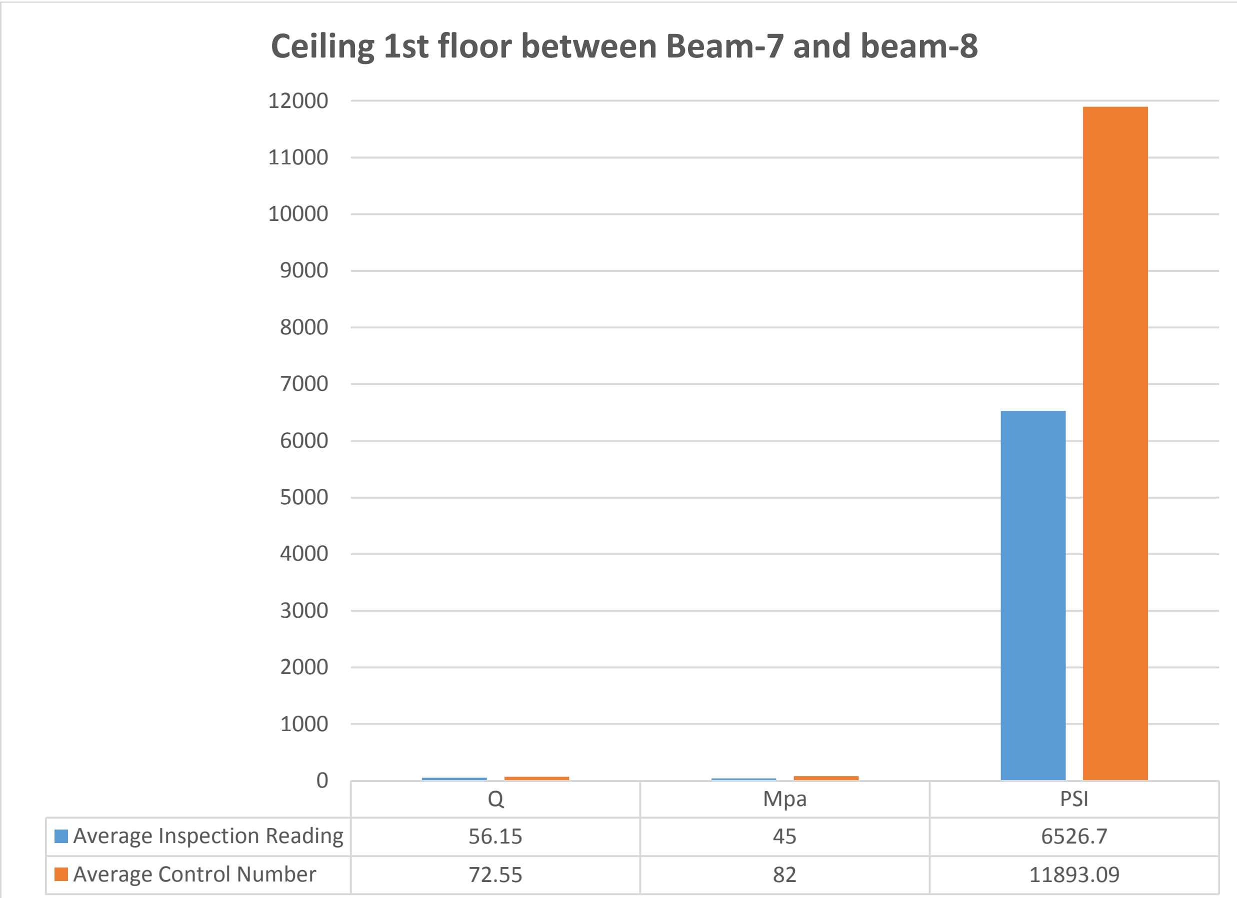


Figure 5. Ceiling 1st floor between Beam-7 and beam-8

TABLES AND FIGURES

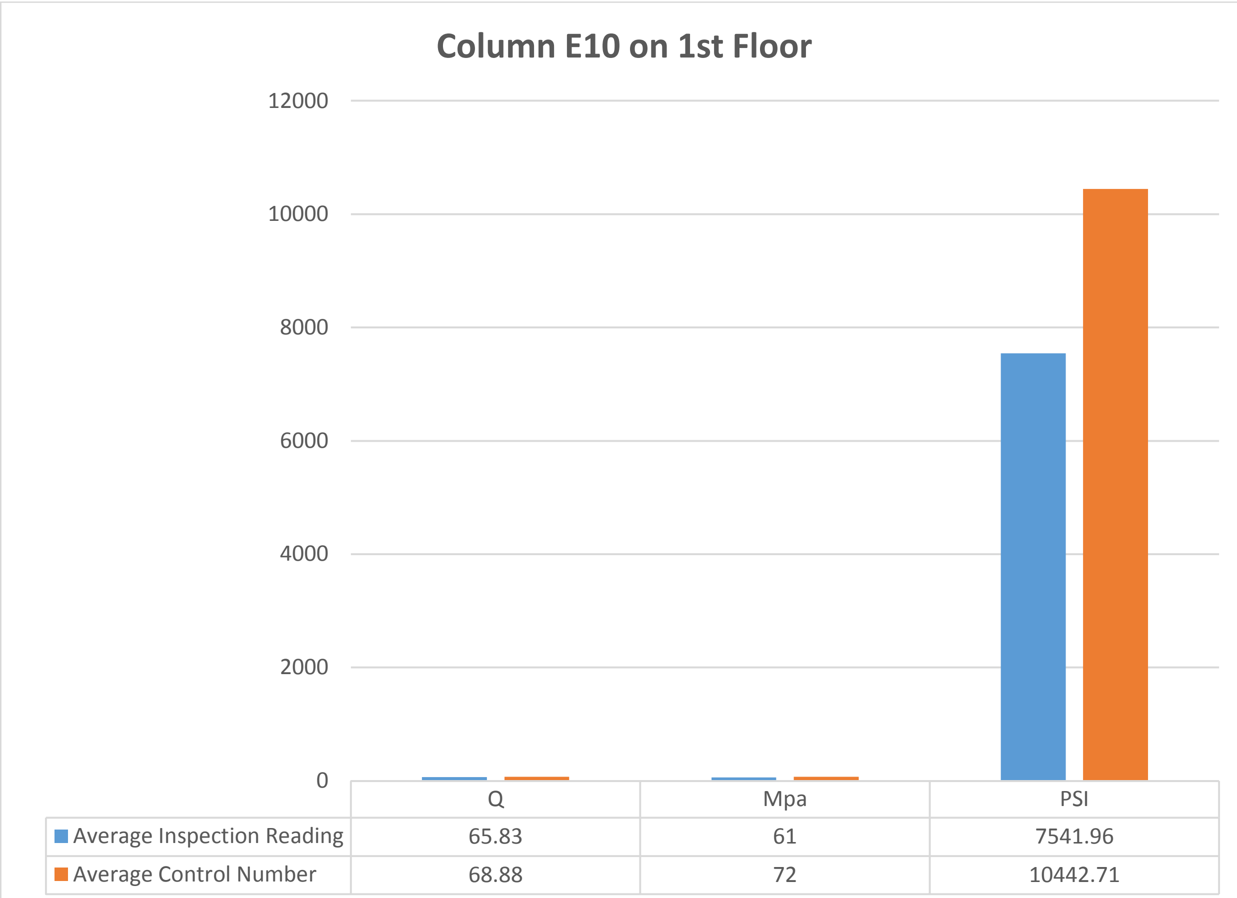


Figure 6. Column E10 on 1st Floor Comparison

TABLES AND FIGURES

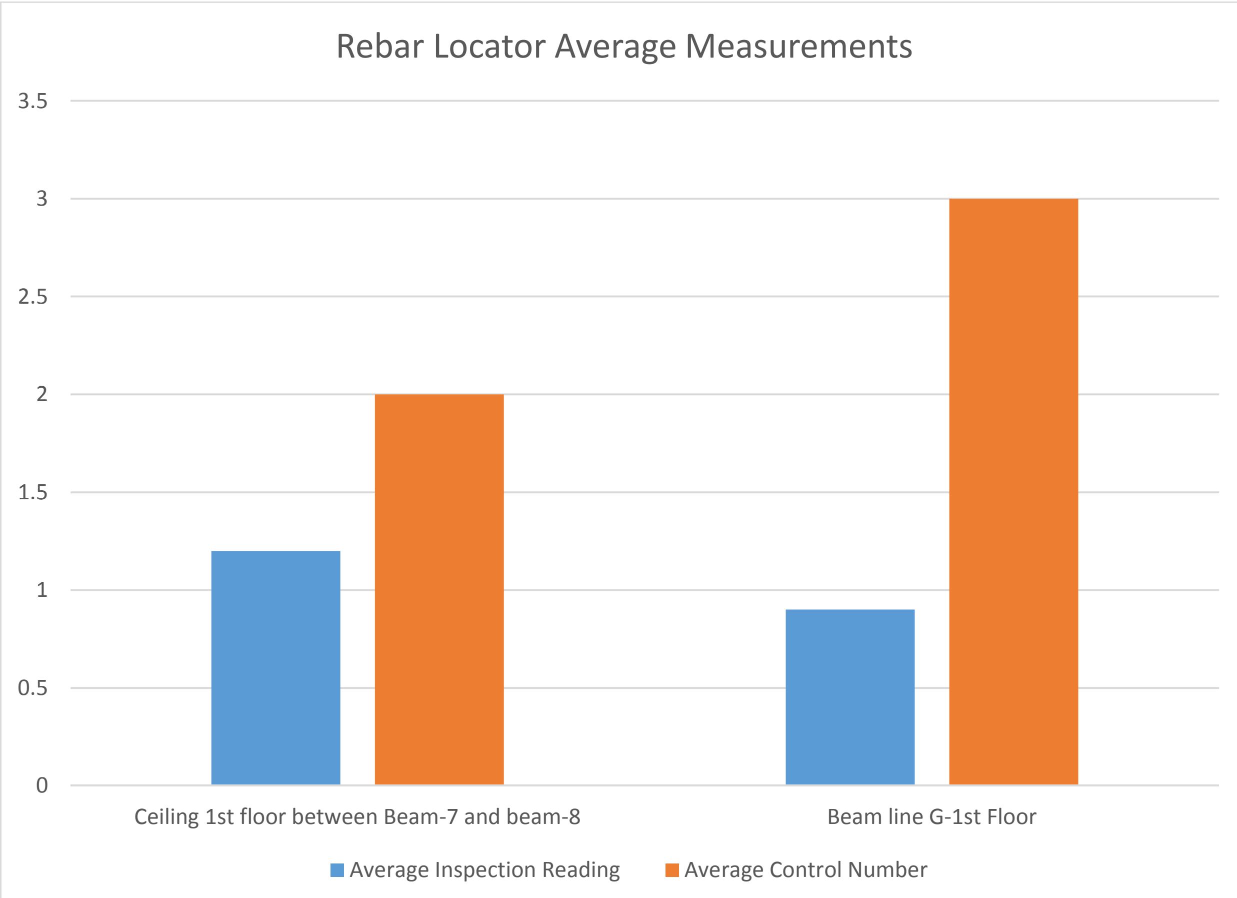


Figure 7. Rebar Locator Average Measurements

PHOTO LOG

Photo 1: Efflorescence and leaching at cross beam K on 1st floor, typical
Photo 2: 42 inch by ½" sealed crack in concrete masonry block adjacent to 1st floor entrance
Photo 3: Failed patch with spalling and exposed rebar, full width of structure between beams 7 and 8on first floor, typical all floors.
Photo 4: 10" x 10" spall with exposed rebar and electrical cable in ceiling on 1st floor between columnsR-8 and R-9.
Photo 5: Deterioration of column R-7 adjacent to leaking drain pipe on 1st floor.
Photo 6: Cracking of concrete adjacent to leaking drain pipe at column G-3 on 1st floor
Photo 7: Severe scaling with exposed reinforcement in cross beam (column line G) between entrance and up ramp on 1st floor.
Photo 8: ½" by full beam height crack with spalling of beam support at column E-10, 1st floor.
Photo 9: Spalling with exposed rebar at beam support at column E-10, 1st floor.
Photo 10: Clogged drain at bottom of 1st floor up ramp. Typical all drains on all floors.
Photo 11: Standing puddle at bottom of down ramp on 2nd floor
Photo 12: 12"x15" spall with exposed rebar on 2nd floor adjacent to column K-10, typical on floors 1-4
Photo 13: Failure of expansion joint and leaking at beam 10 on 2nd floor, typical all floors.
Photo 14: Half beam height x 1" W crack at beam support at column E-10, 2nd floor.
Photo 15: 18" W x ~10' L spall with exposed rebar in ceiling between columns K-5 and K-6, 3rdfloor.
Photo 16: Full width by 1" cracking in 4th floor pedestrian foot bridge
Photo 17: Deterioration of steel beam support connection on 4th floor pedestrian bridge
Photo 18: Incomplete connection of brick facing to concrete masonry blocks at 4th floor pedestrian bridge.
Photo 19: Cracking and spalling at beam support adjacent to leaking drain at column G-10, 4thfloor.
Photo 20: Melting snow stockpile on roof deck
Photo 21: Rebound Hammer on a ceiling
Photo 22: Rebar Locator on a ceiling
Photo 23: Non-delaminated structural component-used for control

PHOTOS

Photo 1: Efflorescence and leaching at cross beam K on 1st floor, typical

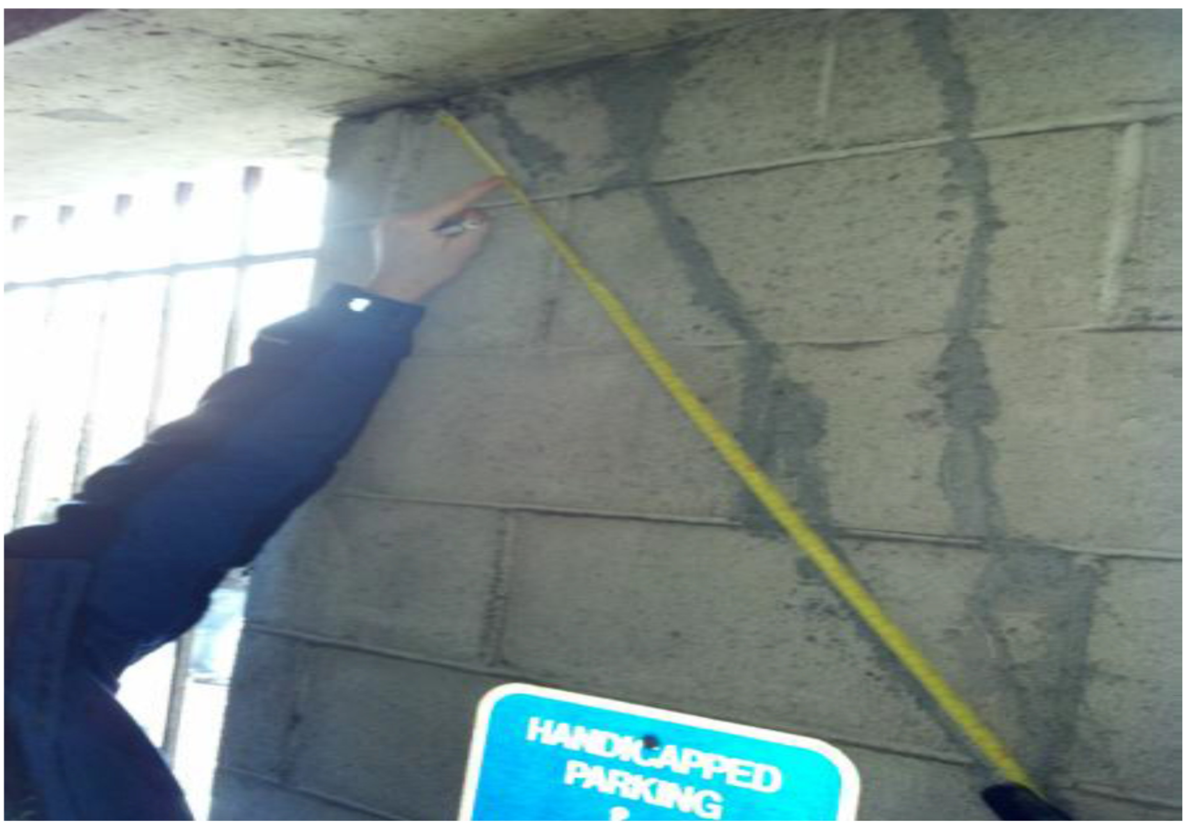


Photo 2: 42 inch by ½" sealed crack in concrete masonry block adjacent to 1st floor entrance

PHOTOS

Photo 3: Failed patch with spalling and exposed rebar, full width of structure Between beams 7 and 8 on first floor, typical all floors.

Photo 4: 10" x 10" spall with exposed rebar and electrical cable in ceiling on 1st floor between columns R-8 and R-9.

PHOTOS

Photo 5: Deterioration of column R-7 adjacent to leaking drain pipe on 1st floor.

Photo 6: Cracking of concrete adjacent to leaking drain pipe at column G-3 on 1st floor

PHOTOS

Photo 7: Severe scaling with exposed reinforcement in cross beam (column line G) between entrance and up ramp on 1st floor.

Photo 8: ½" by full beam height crack with spalling of beam support at column E-10, 1st floor.

PHOTOS

Photo 9: Spalling with exposed rebar at beam support at column E-10, 1st floor.

Photo 10: Clogged drain at bottom of 1st floor up ramp. Typical all drains on all floors

PHOTOS

Photo 11: Standing puddle at bottom of down ramp on 2nd floor

Photo 12: 12"x15" spall with exposed rebar on 2nd floor adjacent to column K-10, typical on floors 1-4

PHOTOS

Photo 13: Failure of expansion joint and leaking at beam 10 on 2nd floor, typical all floors.

Photo 14: Half beam height x 1" W crack at beam support at column E-10, 2nd floor.

PHOTOS

Photo 15: 18" W x ~10' L spall with exposed rebar in ceiling between columns K-5 and K-6, 3rdfloor.

Photo 16: Full width by 1" cracking in 4th floor pedestrian foot bridge

PHOTOS

Photo 17: Deterioration of steel beam support connection on 4th floor pedestrian bridge

Photo 18: Incomplete connection of brick facing to concrete masonry blocks at 4th floor pedestrian bridge

PHOTOS

Photo 19: Cracking and spalling at beam support adjacent to leaking drain at column G-10, 4thfloor.

Photo 20: Melting snow stockpile on roof deck

PHOTOS

Photo 21: Rebound Hammer on third floor Ceiling

Photo 22: Rebar Locator on third floor ceiling

Photo 23: Typical non-delaminated structural component-used for control