Summary Report
Condition Reassessment and
Post Tension Strand Evaluation
25 Sigourney Street
Hartford, Connecticut

DCS Project No. BI-2B-034A
Architects Project No. 206063

State of Connecticut
Department of Construction Services
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Investigation Overview

Introduction

In 2005, Hoffmann Architects, Inc. was selected by The State of Connecticut Department of Public Works (CT DPW) to provide design services for the repair, renovation and improvement of the existing parking garage and circular entrance plaza at 25 Sigourney Street in Hartford, Connecticut (Base Contract A/E Services, DPW Project No. BI-2B-034A). On 12 April 2007, Hoffmann Architects issued Contract Documents, and the project was bid in July 2007. Subsequently, the project was put on hold after the bidding phase. Also in 2007, Hoffmann Architects was awarded the Construction Administration (CA) Services for Construction (DPW Project No. BI-2B-034A-CA) for this project.

On 25 March 2010, Hoffmann Architects met with CT DPW to discuss reinstating the Parking Garage repair project at 25 Sigourney Street in Hartford, Connecticut. From this meeting it was agreed that the garage has further deteriorated since 2007 and that a resurvey of the existing conditions would be required in order to quantify the scope of work and solicit more accurate bids from qualified contractors. In accordance with this revised scope of services, Hoffmann Architects submitted to CT DPW a proposal for the Base Contract A/E Services on 13 April 2010.

On 22 July 2010, Mr. Kermit Thompson Director of Project Management with CT DPW, contacted Mr. John Hoffmann, President of Hoffmann Architects, to notify him that a piece of concrete had recently fallen in the garage and that post-tensioning strands had become exposed and had possibly failed. Mr. Thompson asked that Hoffmann Architects review the site on an emergency basis to evaluate the general safety of the garage. Per request of Mr. Thompson Hoffmann Architects issued a proposal 23 July 2010 for an emergency visual evaluation of the garage.

On the 26 July 2010, Robert Marsoli, Project Manager for Hoffmann Architects visited the site to perform a visual inspection of conditions. During this visit Mr. Marsoli noted loose and spalled concrete at horizontal and overhead areas and two recently fractured post tensioning tendons. On 27 July 2010, Lawrence Keenan, Director of Engineering Services for Hoffmann Architects visited the site to confirm Mr. Marsoli’s observations and to further assess conditions. On 27 July 2010 Mr. Keenan issued a summary of his findings, sighting potential hazards due to loose overhead concrete pieces. He also noted that, while he did not believe the fractured post tension strands to be an immediate hazard, they were a serious structural concern and required further evaluation. He also noted that overall condition within the garage appears to have been deteriorating rapidly and recommended that the garage be routinely inspected and that rehabilitation of the garage not be delayed further.

Hoffmann Architects was subsequently notified on three separate occasions that additional fractured post tension tendons were discovered in the garage. On April 7, 2011 one fractured tendon was discovered on Level P3; on 17 July 2011 one fractured tendon was discovered on Level P3 and one on Level P5; and on 6 July 2011 one fractured tendon was discovered on Level P6.

As the nature and scope of deterioration has significantly changed, Hoffmann Architects recommended that an investigation phase be performed to determine the appropriate Scope of Work. This investigation phase would include evaluation of the existing post tension strand system as well as reassessment of the nature and quantity of defects throughout the garage. The goal of this investigation would be to provide an updated scope of recommended repair work with an estimate of probable construction cost.
Mr. Thomas Surprenant, Associate Project Manager with CT DPW (now the DCS), asked that Hoffmann Architects provide a proposal for these investigative services. Mr. Surprenant asked that the proposal encompass only structural issues and that mechanical and electrical

concerns not be assessed at this time. For this project Hoffmann Architects has chosen to team with Whitlock Dalrymple Posten & Associates (WDP), experts in the evaluation and rehabilitation of post tension structures. On 29 July 2010 members of the CT DPW, Servus Management, Hoffmann Architects and WDP met to discuss requirements of this project. Meeting minutes dated the same were issued. On 10 August 2010 Hoffmann Architects, Inc. submitted to CT DPW a proposal for the requested services.

Since this time, the CT DCS has asked that Hoffmann Architects provide a combined proposal re-incorporating mechanical and electrical services and encompassing investigation, contract documents, rebidding, and construction administration services. On 15 February 2011 members of the CT DPW, Servus Management, Hoffmann Architects, Inc., VanZelm Heywood and Shadford, and WDP met to discuss requirements of this project. Meeting minutes dated the same were issued outlining Scope requirements for this project.

The construction of the repair project has an assigned budget of $4,900,000 and is assumed to occur within the year 2012. Hoffmann Architects, Inc. has retained the services of Professional Construction Services, Inc. to provide professional cost estimating services associated with this project.

Purpose

The repair of the garage was previously designed and bid in 2007, although the contract was never awarded. The intent of this project is to resume efforts to rehabilitate the garage consistent with the previous scope of repair work, modified to reflect current garage conditions and current Building Code requirements. The CT DCS has asked that the Scope of Work for this project not be increased beyond that encompassed by the previous Contract Documents; the exceptions to this requirement are that replacement of electrical lighting circuits is to be bid as "Add Alternate" work. In addition, the DCS has directed the design team to review Code requirements to determine if the sprinkler system at the west side (exterior portion) of the garage can be removed.

Site Description

25 Sigourney Street is a public office tower owned by the State of Connecticut. It is comprised of 15 floors of office space and 6 levels of parking. The main entrance to the building exists along Sigourney Street and consists of a circular entrance plaza. This entrance plaza provides access to the parking garage and is the main entrance to the building.

The parking garage is comprised of 272,800 square feet of deck area distributed over all six levels and has a parking capacity for 815 vehicles (including designated accessible spaces). The garage is naturally divided into two discrete sections, herein referred to as the east and west sides, by an expansion joint. The east side of the garage is located within the footprint of the tower, and the west side of the garage is a freestanding structure that extends beyond the tower to the west of the building. The east side extends around a central core area that houses the elevators, stairways, and the building lobby/atrium area.

The project site is bordered on the east side by Sigourney Street, on the north side by Capitol Avenue and I-84, on the west side by Laurel Street, and on the south side by a residential condominium complex.

While the main entrance to the garage is accessed through the circular entrance plaza, a separate entrance for employees exists at Level P2 of the garage and is accessed from Laurel Street. A loading dock exists at the northeast corner of the building and is accessed from Capitol Avenue.

Observations

Garage Utilization

Garage utilization has remained largely unchanged since the previous 2006 investigative work. The garage services commingled employee parking and public parking, with additional parking also provided for State government vehicles (cars) at lower levels.

During this investigation the level of traffic observed traveling through the garage was low although the space utilization was high. Space turnover rates are typically one per day at most spaces throughout the garage, limiting the traffic within the garage. Weekend usage is dramatically reduced with most of the garage empty. Space utilization observed through this investigation is approximated at 90%, with free parking spaces at both the upper and lower levels of the garage.

Accessibility

Circular Entrance Plaza

The entrance plaza consists of a circular drive isle adjacent to an elevated entrance platform. Accessibility features include curb cuts at the far corners of the entrance platform that allow wheelchairs access to the accessible covered entrance door. Consistent with previous findings, these and other features of the plaza deck remain deficient with respect to Americans with Disabilities Act (ADA) requirements and requirements of the 2005 Connecticut Building Code for the following reasons:

- The threshold area in front of the main entrance has an approximate slope of 7%, in excess of the 5% maximum requirement.
- Curb cuts exceed the maximum permissible 1:12 slope
- Accessible routes are not properly marked for identification where they traverse drives.
- No accessible loading zone is provided

Garage

Parking in the garage currently includes 18 designated accessible car spaces and 4 designated accessible van spaces. Accessible car spaces are located at levels P1 through P4 while accessible van spaces are located near the main entrance at Level P4. The quantity of accessible spaces marginally exceeds the minimum number of accessible spaces required under the Americans with Disabilities Act (ADA) and the 2005 Connecticut Building Code, which requires 17 standard [car] spaces and 3 van spaces. However, review of the existing configuration of the spaces revealed many to remain deficient with respect to ADA requirements.

Spaces exist where access isles are obstructed by columns and where the overall access isle size is deficient. Furthermore, in many cases access isles are noncontiguous and do not form an accessible route to facility entrances. Signage at accessible spaces is also deficient with respect to height, with all signs mounted below the minimum required 60” height.

Existing Construction

Circular Entrance Plaza:

No visible changes have been made to the circular entrance plaza since the previous 2006 investigative work. The entrance plaza consists of a circular drive isle, pedestrian walkways and decorative planting areas located above garage and back of house storage and equipment areas. The drive isles and walkways are generally constructed of mortar set brick and granite masonry or concrete pavement above asphaltic waterproofing. Planting areas exist at the perimeter and at the center of the circular drive isle. These planters consist of depressions cast within the concrete deck structure. Waterproofing at these planters is seamless integrated with the waterproofing of the remainder of the plaza deck.

East Side of Garage (Tower Section):

No significant or visible changes have been made to the garage structure or architectural features. This section of garage is located within the footprint of the building tower and consists of cast-in-place flat slab construction with drop panels at columns. The slab system is supported by square cast-in-place concrete columns. The slab is conventionally reinforced with mild, uncoated steel as a conventional two-way slab system. Upturned cast-in-place concrete spandrel panels at the perimeter of the slab provide parapets for the garage and resist accidental car impact.

The garage deck is bare [uncoated] concrete. Corrosion protection of reinforcement is provided by concrete cover. No evidence of previously applied concrete sealers was discovered during this investigation, although such sealers can be difficult to detect after their effectiveness is diminished.

Drainage within the garage is provided by cast-in-place drain basins located away from columns near the center span of the slabs.

Stairwells at this portion of the garage are located within the central core area and are outside of the scope of this investigation.

The ceiling of the garage below conditioned space of the office tower is clad with a metal panel suspended ceiling. The suspended ceiling is supported by galvanized wire attached to the underside of the slab. Insulation is provided by approximately 4” of fiberglass bats laid on top of the panels.

A representative from Building Facilities Management has indicated that the majority of the garage lighting fixtures were replaced in February of 2010. The general use garage lighting fixture is a nominal 1’ x 4’ pendant mounted enclosed and gasketed type with (3) 25watt/4100K/T-5 lamps per fixture. It appears that the fixtures were located directly below former light fixture locations and that new wiring was extended only from the existing underside of the roof deck to each fixture. Therefore it is assumed that the existing branch circuit conduit and wiring was reused from the former light fixture location back to the source power panel.

There has also been a fire alarm system upgrade performed which includes new fire alarm devices at some locations.

West Side of Garage (Garage Wing):

No significant or visible changes have been made to the garage structure or architectural features. This side of the garage is a free-standing structure constructed of conventionally reinforced and post-tensioned cast-in-place concrete. The garage decks are constructed of one way post tension slabs that span between integral conventionally reinforced concrete beams. The beams are asymmetrical, spanning between cast-in-place concrete columns with a cantilever span at the building exterior. Upturned cast-in-place concrete spandrel panels at the perimeter of the slab provide parapets for the garage and resist accidental car impact.

The garage deck is bare [uncoated] concrete. Corrosion protection of mild reinforcement is provided by concrete cover. Corrosion protection of post tensioning strands is provided by integral PVC sheathing. No evidence of previously applied concrete sealers was observed.

Drainage within the garage is provided by cast-in-place drain basins located adjacent to spandrel beams/parapets along the perimeter of the decks.

This portion of the garage is serviced by an integral stairwell located at the southwest corner of the structure. The stairwell is constructed of cast-in-place concrete and clad with brick masonry veneer at the exterior. The roof is ballasted EPDM.

As noted above, a representative from Building Facilities Management has indicated that the majority of the garage lighting fixtures were replaced in February of 2010. The general use garage lighting fixture is a nominal 1' x 4' pendant mounted enclosed and gasketed type with (3) 25watt/4100K/T-5 lamps per fixture. It appears that the fixtures were located directly below former light fixture locations and that new wiring was extended only from the existing underside of the roof deck to each fixture. Therefore it is assumed that the existing branch circuit conduit and wiring was reused from the former light fixture location back to the source power panel.

Also as noted above, there has also been a fire alarm system upgrade performed which includes new fire alarm devices at some locations.

Current Conditions

Circular Entrance Plaza:

The condition of the circular entrance plaza has continued to worsen due to freeze thaw deterioration and due to snow plow impact. Masonry pavers continue to become dislodged and to deteriorate leaving an uneven walking surface. Leaks through the waterproofing membrane have likewise become more severe over time, with larger water stains and increasing spalls observed at the underside of the deck. That notwithstanding, the current scope of repair work includes the complete removal and replacement of all finishes and waterproofing membrane; no changing conditions were observed that would cause modification of this scope of repair work.

Garage Structure (East and West Sides)

The garage structure has deteriorated rapidly. Spalls and incipient spalls were observed at many locations throughout both the east and west portions of the garage. Horizontal spalls are most severe at the post tensioned portion of the garage where many post tension tendons have become exposed due to loss of concrete. Overhead spalls have become severe at various locations throughout both portions of the garage, although the overhead hazard has apparently been diminished by recent efforts to remove loose concrete.

A sounding [lamination] survey was conducted to determine the extent to which laminations in the deck have either grown or multiplied since a sounding survey was last conducted at the garage 5 years ago. This sounding survey consisted of dragging heavy chain over the concrete deck surface and listening for hollow sounds indicative of corrosion induced lamination of the concrete. Based upon this more recent survey, detectable laminations have increased from 4,100 SF in September of 2006 to 17,300 SF in September of 2011. This is an alarming increase of over 320% in measurable deterioration within a 5 year period. Please refer to the Drawings section of this report for drawings showing the extent of laminations detected during the 2006 and current surveys. Both are provided to graphically demonstrate the magnitude of increase in deterioration to the garage.

Perhaps most importantly, the post-tensioning (PT) system within the west side of the garage has severely deteriorated within the last 5 years, with 12 fractured strands having been discovered within this time. A post tension strands investigation was conducted by WDP as part of this investigation (for detailed results please refer to the WDP report entitled "Review of Post-Tensioning Damage", dated 7 October 2011 located in Appendix A). This investigation revealed that the original PT construction was identified to be an un-bonded 7-wire strand with push-through sheathing. While un-bonded post-tensioning systems are still commonly used; the system used at 25 Sigourney St. was found to have the following known inherent deficiencies:

- Push-through sheathing did not form a tight seal around the strand, allowing water to collect at low points in the tendon trajectory;
- The sheathing did not extend to the anchorages, allowing chloride induced corrosion of these components;
- The end anchorages were uncoated and were installed in contact with the back-up reinforcing steel, further allowing corrosion of these components.

The discovered strand failures occurred at the high points in the tendon trajectory. During the investigation, additional failed and corrosion damaged strands were observed at the construction joint on Level 2. The amount of corrosion damage necessitated the closure of this area until repairs could be completed. It is important to note that these failures were generally not visible as they had not erupted through the slab.

The number of strands failures is likely to increase over time, unless extensive repairs are made to restore the corrosion protection system for the strands. The amount and rate of failures cannot be predicted. Furthermore, it has been demonstrated that some of the strand failures will not result in a physical eruption of the strand from the slab surface and will therefore likely go unnoticed.

Failures of the post-tensioning strands are significant as once a strand fails its contribution to the strength of the slab is lost for its full length. In addition, the failure of post-tensioning strands results in a significant release of stored energy which can result in the eruption of the strand from the concrete surface with a potential risk of damage to people or property in the vicinity of the failure.

Based upon these considerations, repairs will be required to replace strands with significant existing corrosion damage, restore the failed strands, and to mitigate future damage. It should be noted that the successful completion of the repairs will not eliminate the possibility of additional strand failures in the future.

Mechanical/Electrical/Plumbing

The following condition assessments were performed by VanZelm Heywood & Shadford. For detailed results please refer to their attached report entitled “Mechanical and Electrical Building Evaluation for the 25 Sigourney Street Garage”, dated 13 October 2011 located in Appendix B).

Mechanicals

The majority of the exhaust ductwork within the parking garage is in fair condition; however, a small section of exhaust ductwork on Parking Level P3 is beginning to corrode. Otherwise the majority of the ventilation system remains largely unchanged and the existing Scope of Work requires little modification.

Electricals

The changes to the electrical infrastructure include the following:

- The garage HID downlight type light fixtures have been replaced with new fluorescent T5 light fixtures;

- Existing exit light fixtures do not appear to have been replaced;
- Most of the surface mounted electrical boxes and some segments of raceway have further deteriorated due to moderate to severe corrosion;
- There has been a fire alarm system upgrade performed which includes some new fire alarm device locations;
- A representative from Building Facilities Management has indicated that have been several recent instances of fire alarm system trouble signals being sent to the fire alarm control panel. As this was outside of this investigation and the Scope of Work it is recommended that the Owner have this issue studied further to determine what corrective action may be require

Fire Protection

All the piping within garage areas for the dry sprinkler systems and the manual dry standpipe systems show major signs of deterioration and corrosion, with the exception of pieces that were reportedly recently replaced due to failure. Additional work will be required in the 'tower' section of the garage to replace deteriorated existing manual dry standpipe system piping with new. All portions of the existing dry sprinkler system and dry standpipe system located in interior conditioned spaces appear to be in good condition.

Plumbing

On several parking levels, the existing garage drain piping shows sign of corrosion and deterioration. Portions of garage drainage piping have already been replaced due to piping failures. Additional work will be required to replace sections of corroded garage drainage piping with new, galvanized steel piping.

Recommended Scope of Work Modifications

General

The following is a list of recommended revisions to the Scope of Work identified in the 12 April 2007 garage repair contract documents necessary to repair existing defects, decrease further deterioration, and correct deficiencies with respect to Code requirements. A brief overview of the previous Scope of Work is included for reference.

Previous Work Scope

On 12 April 2007, Hoffmann Architects issued construction documents for the repair of the garage and plaza at 25 Sigourney Street in Hartford, Connecticut. These documents detailed requirements for the project that would correct defects and deteriorated conditions. Specifically, the Scope of Work included:

<u>Plaza Work</u> Complete removal and replacement of all finishes and furnishing at existing exterior circular entrance plaza including pavement, waterproofing, light fixtures, and furnishings. This work includes repair of existing structural deck and installation of accessibility improvements.

<u>Garage Work</u> Repair of existing deteriorated reinforced concrete elements, application of migrating corrosion inhibitor at discrete locations, replacement of expansion joints, and application of epoxy healer/sealer and traffic bearing membrane, replacement of suspended ceiling, replacement of exposed sprinkler system, re-pipe drainage and install grit separator to meet current code, replace exhaust fans, replaced deterioration electrical devises and conduit, provide lighting and emergency lighting improvements, and replace wash-down system. This work also includes installation of accessibility improvements.

Plaza Work Modifications

The overall condition of the plaza is poor. Now approximately 25 years old, it is beyond its useful life, allows moisture to infiltrate areas below, and is not in compliance with current code and accessibility standards. We therefore maintain our recommendation that a rehabilitation project, consisting of replacing all finishes and water proofing, be performed.

- This investigation has revealed no required or recommended changes to the previously approved Scope of Work.

Garage Work Modifications

The overall condition of the garage is very poor. The garage decks are constructed of severely cracked poor quality concrete which has allowed large amounts of chlorides to be absorbed from deicing chemicals. These chlorides have caused rapid and severe deterioration to occur at embedded mild steel and post tension strand reinforcement. Other defects exist within the garage have been caused by corrosion, age, freeze thaw damage, and impact. This deterioration has spread at an alarming rate and has already caused hazardous conditions to develop. In addition, similar to the plaza area noted above, the garage does not currently comply with current code and accessibility standards.

The following is a list of recommended Scope of Work modifications based upon current conditions identified within this report.

Structural

- Deterioration of post tension strands has occurred requiring that a post tension strand rehabilitation project be performed;
  - Repair of sheathing on exposed strands;
  - Replacement of isolated sections of post-tensioning strands;
  - Replacement of dead / live end anchorages;

- Evaluation / corrosion protection of anchorages at construction joint;
- Repair of anchorages at construction joint;
- Drying and reinjection of grease; Drying is conducted by injecting a dry gas into the sheathing to remove water from the annular space between the strands and sheathing. After the tendons are dried, grease is injected into the sheathing to provide for future corrosion protection.
- After repairs are performed, future failures of the post-tensioning strands may occur. Therefore installation of a monitoring system is recommended. Monitoring systems involve the installation of acoustic sensors that allow for the time and location of future posttensioning strand failures to be recorded. It should be noted that the monitoring system will require a service contract with a professional or with the manufacturing company for monitoring services.

- Chloride induced corrosion of embedded steel reinforcement has rapidly caused severe deterioration of reinforced concrete garage components;
  - Concrete repair quantities have risen by as much as 320%. Contract quantities must be increased accordingly;
  - Further deterioration must be aggressively mitigated, therefore the application of migrating corrosion inhibitor should be increased from just around column strips at the west side of the garage to the entire garage deck surface and overhead crack areas (this will allow epoxy healer sealer application around columns at the east side of the garage and on column strips at the west side of the garage to be deleted from the scope of work); It should be noted that, even with such application, further deterioration will continue, albeit at a reduced rate. Continuing repairs may be necessary.
- In addition to the above it has become clear though this investigation and through Hoffmann Architects tenure on this project that routine and/or preventative maintenance is problematic for operation of the garage. It is our opinion that the level of protection provided by the rehabilitative project should therefore be increased in anticipation of and increased quantity of future recurrent deterioration and minimal amount of maintenance.
  - The previous scope of work included application of a traffic bearing membrane at parking spaces and a heavy duty traffic bearing membrane at travel ways. The use of heavy duty traffic bearing membrane at Level P2 through P5 should be should be expanded from just the travel lanes to the entire deck surface and at Level 6 very heavy duty traffic bearing membrane should be applied to better resist snow plows with little routine maintenance. The price of this improvement is included herein as an “Add Alternate” for consideration.

Mechanical

- Additional sections of exhaust ductwork on Parking Level P3 show signs of corrosion:
  - Replacement of the small corroded section of duct work should be added to the Scope of Work.

Electrical

- The garage HID down-light type light fixtures have been replaced with new fluorescent light fixtures in 2010
  - The Contract Documents must be revised to show the revised garage light

fixtures and present light fixture layout;

- The previous Scope of Work should be modified to delete new light fixtures and cleaning and re-lamping of existing light fixtures.
- Install supplemental lighting at entrance and exits in conformance with Code requirements;
- Due to the current condition of the electrical wiring for the lighting system in the garage and due to the extensive concrete repair work that will affect such wiring, all such wiring must be replaced with a surface mounted system;
- All non-weatherproof fire alarm system devices must be replaced with weatherproof type due to the high moisture environment to which the devices are exposed (It should be noted that, based on the information from Building Facilities Management, numerous fire alarm system trouble signals at the fire alarm control panel have occurred indicating that the entire original fire alarm wiring system (conduit/conductors) may require replacement; however, such work is currently beyond the scope of this project).

Fire Protection

- Fire protection remedial work indicated in the previous Scope of Work still applies; however, the following additional work will be required in the 'tower' section of the parking garage.
  - Replace all existing piping for all dry sprinkler systems and the dry standpipe system, including fittings, couplings, sprinklers, hangers, etc.

Plumbing

- Plumbing remedial work indicated in the previous Scope of Work still applies; however, the following additional work will be required:
  - Replace additional garage drainage piping due to deterioration.

Probable Construction Cost

Based upon the current recommended Scope of Repair work, the estimated probable construction cost of this project is currently **$9,510,000.** It should be noted that this cost includes replacement of the current electrical lighting circuit with a surface mounted system. While it was the original intent of this investigation to explore this modification as "Add Alternate" work it no longer appears possible to save the current system. As Such it has been included within the base price.

Add Alternate Work: Hoffmann Architects recommends that the traffic bearing membrane system be upgraded to minimize maintenance requirements and extend the useful life of the coating. The probable added cost for this upgrade is **$131,000.**

Project Budget Requirements: The construction budget has been set by the DCS at **$4,900,000**. Hoffmann Architects is contractually obligated to modify the Scope of Work to maintain the project cost within budget. However, the nature of the required repair does not allow cost savings to be realized through alternate material selections. As such, meaningful cost reduction will require reduction in the Project Scope and Program Requirements, leaving systems unrepaired and/or unprotected against further deterioration. Should the DCS wish to explore this method of cost reduction Hoffmann Architects would be pleased to assist the DCS in this regard.

Phasing and Project Duration

Due changes to the nature and scope of repair work required to rehabilitate the garage structure, It is our current recommendation that the garage be substantially closed for the duration of the garage repair project to maintain safety during construction and to minimize the project duration.

General Information

Duplication Restrictions

This report is for the sole use of the party for whom the report was prepared. Use of its contents by third parties shall only be with written permission of Hoffmann Architects. Unauthorized use is prohibited and shall release Hoffmann Architects from any and all liability associated with such use. Reproduction of this document, except by the party for whom it was prepared for its own internal use, shall be by written permission of Hoffmann Architects only.

Construction Use Notice

This report is not intended for any purpose other than to report on conditions observed. Its language and recommendations are not sufficiently detailed or specific enough, nor have any drawings been provided, that could serve as a basis for securing proposals for or executing the recommended work. This survey does not represent that unseen problems may not exist. No representation is made or intended that implementation of our recommendations will place the property in a condition wholly free of all defects or hazards.

Construction Costs

Statements of opinion of probable construction costs given in this report do not include professional fees for consultants concerning repair procedures, preparation of construction documents, assistance with bidding, construction contract administration, or on-site observation of construction. Construction costs projected in this report represent an opinion as to what the probable costs, in today's dollars, might be to implement the recommendations. They are based on experience supplemented by published cost estimating sources. They reflect preliminary data and have not been derived from accurate quantities, drawings, details, or specifications. Actual construction costs may therefore vary from the costs in this report.

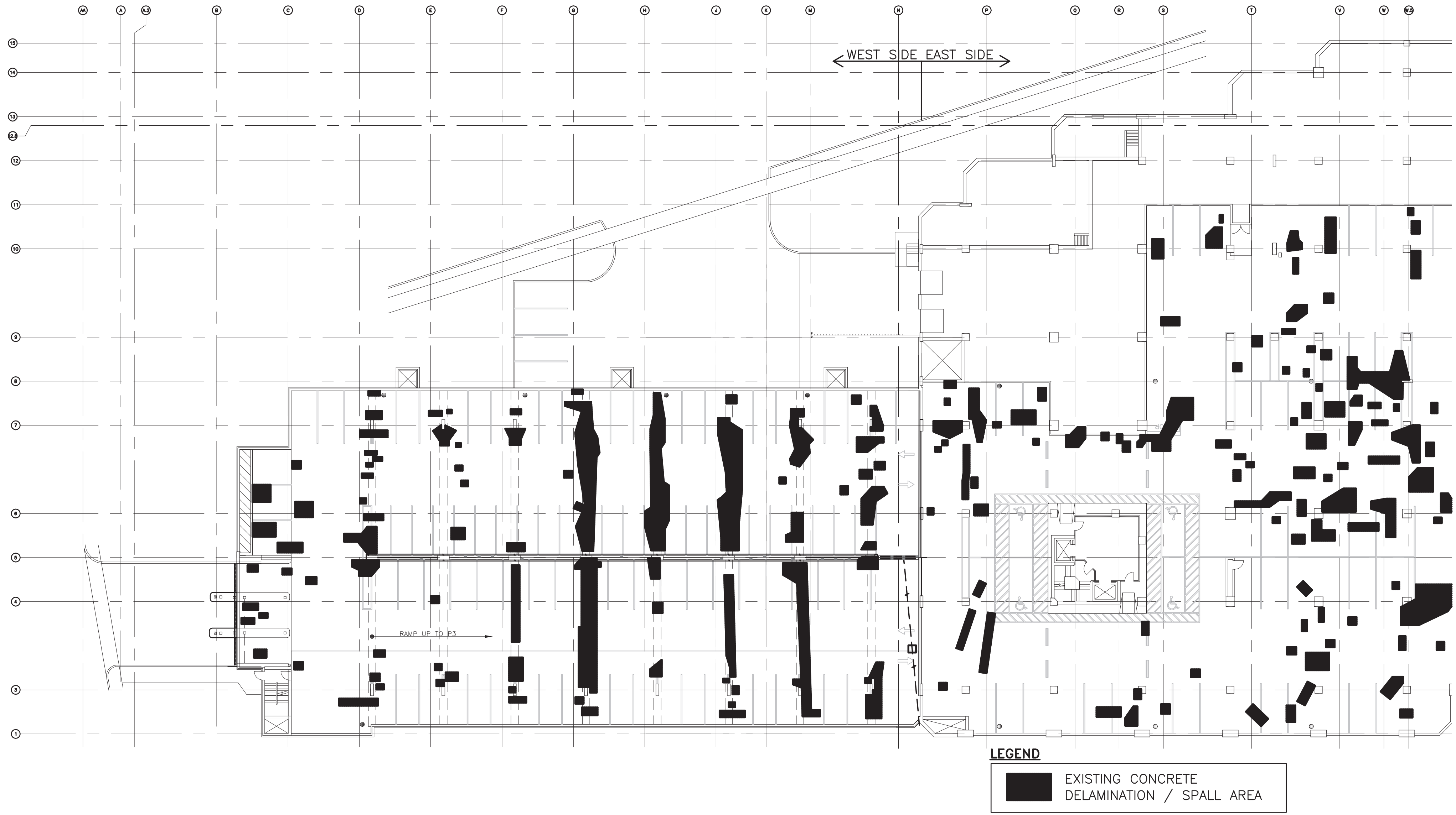
Drawings

- Parking Level P2 (2006 Deck Lamination Survey) *
- Parking Level P2 (2011 Deck Lamination Survey)
- Parking Level P3 (2006 Deck Lamination Survey) *
- Parking Level P3 (2011 Deck Lamination Survey)
- Parking Level P4 (2006 Deck Lamination Survey) *
- Parking Level P4 (2011 Deck Lamination Survey)
- Parking Level P5 (2006 Deck Lamination Survey) *
- Parking Level P5 (2011 Deck Lamination Survey)
- Parking Level P6 (2006 Deck Lamination Survey) *
- Parking Level P6 (2011 Deck Lamination Survey)

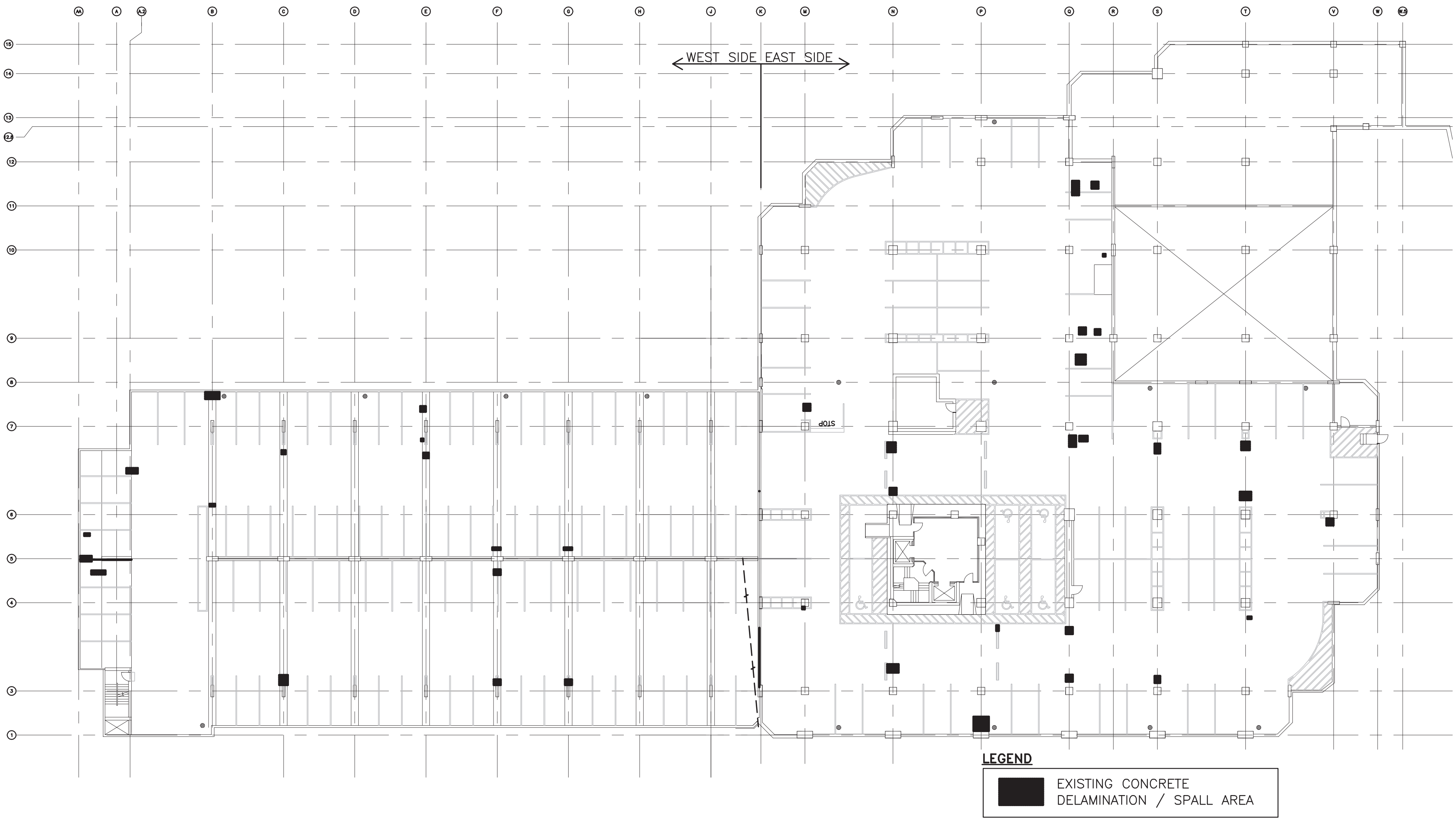
*Note: 2006 Drawings are included for comparative purposes

2 PARKING LEVEL P2 – 2006 DECK LAMINATION SURVEY
SCALE: 1/32" = 1'–0"

Date: 9/28/06

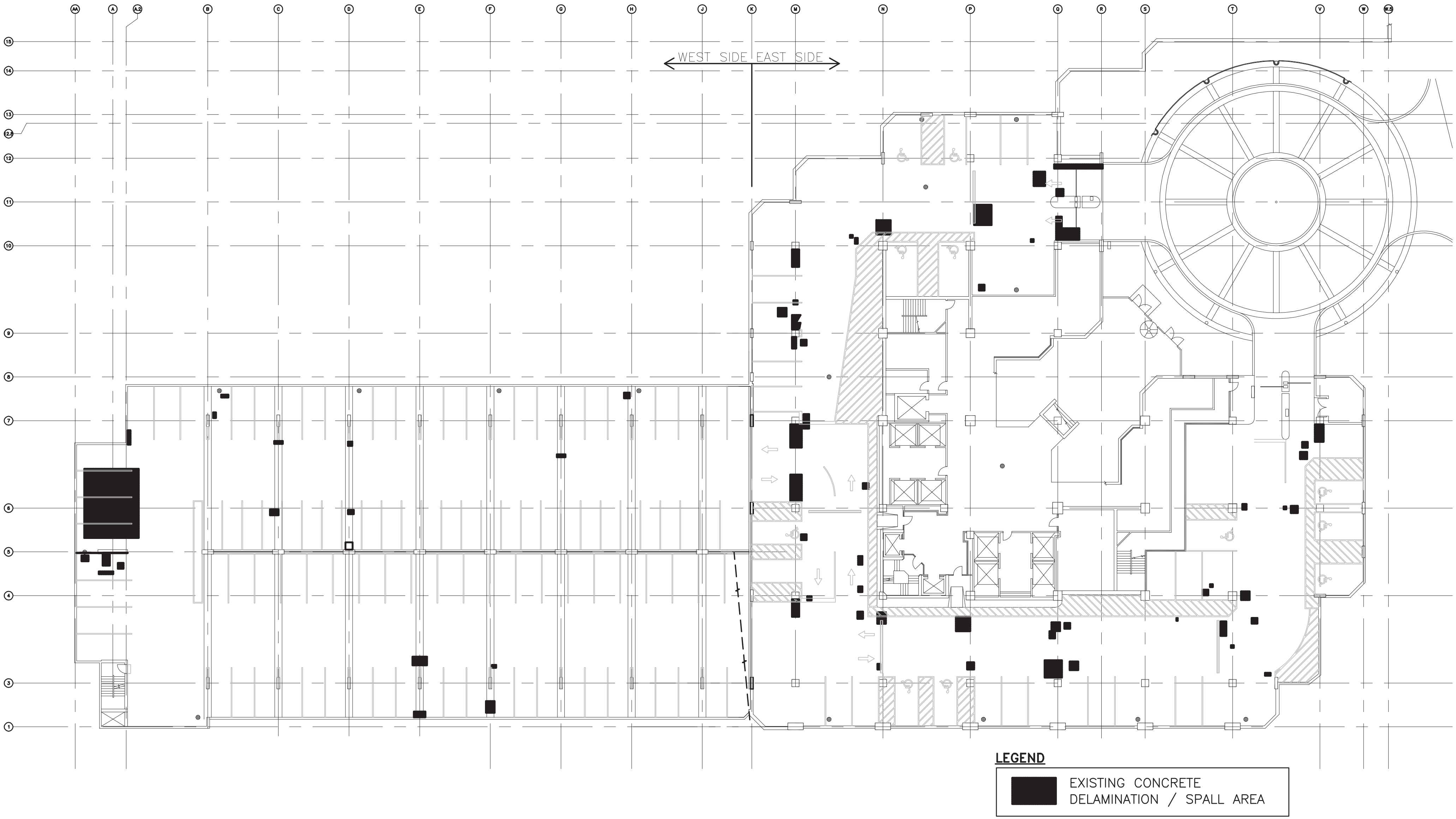


2 PARKING LEVEL P2 – 2011 DECK LAMINATION SURVEY
SCALE: 1/32" = 1'–0"

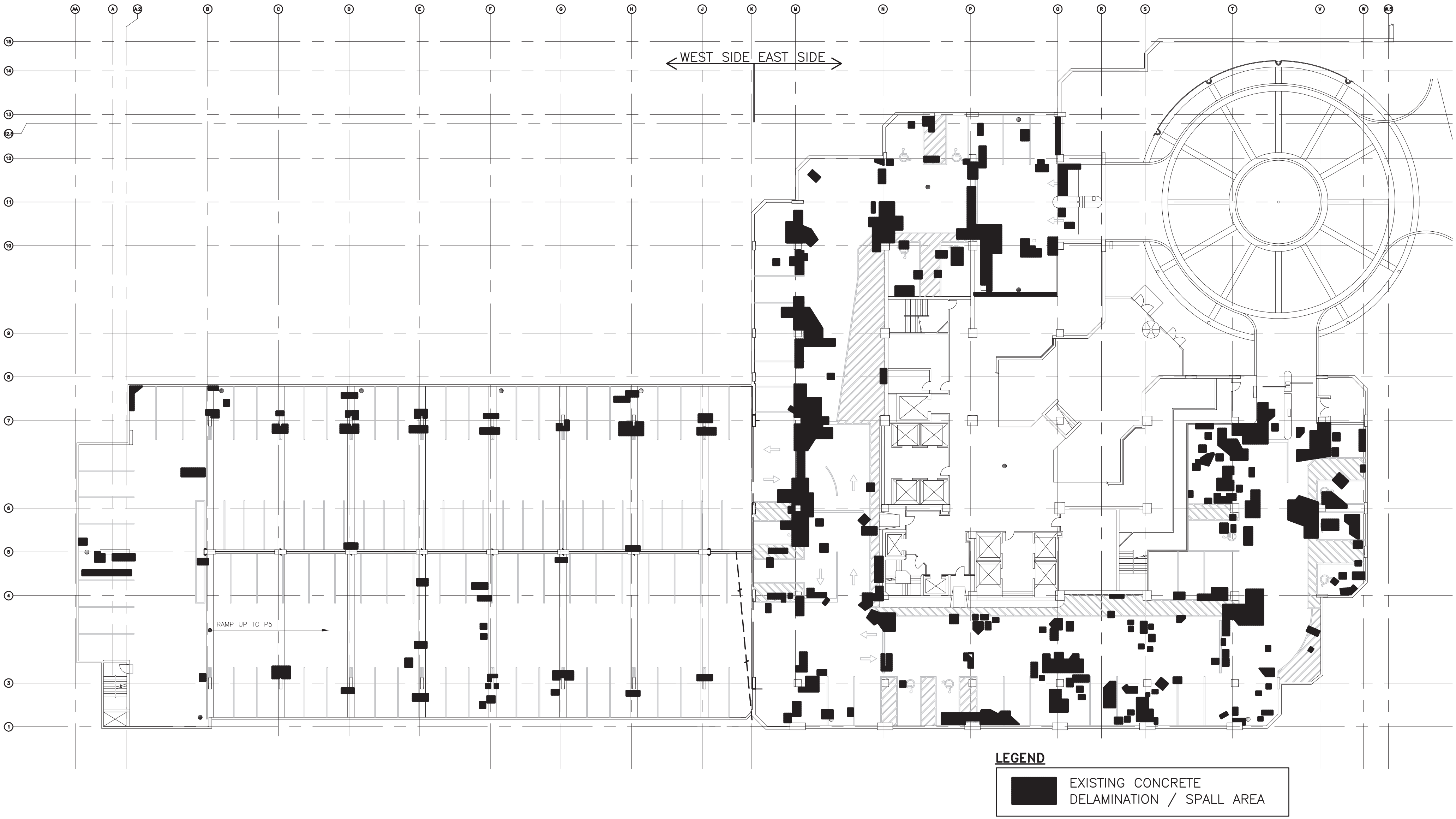


3 PARKING LEVEL P3 – 2006 DECK LAMINATION SURVEY
SCALE: 1/32" = 1'-0"

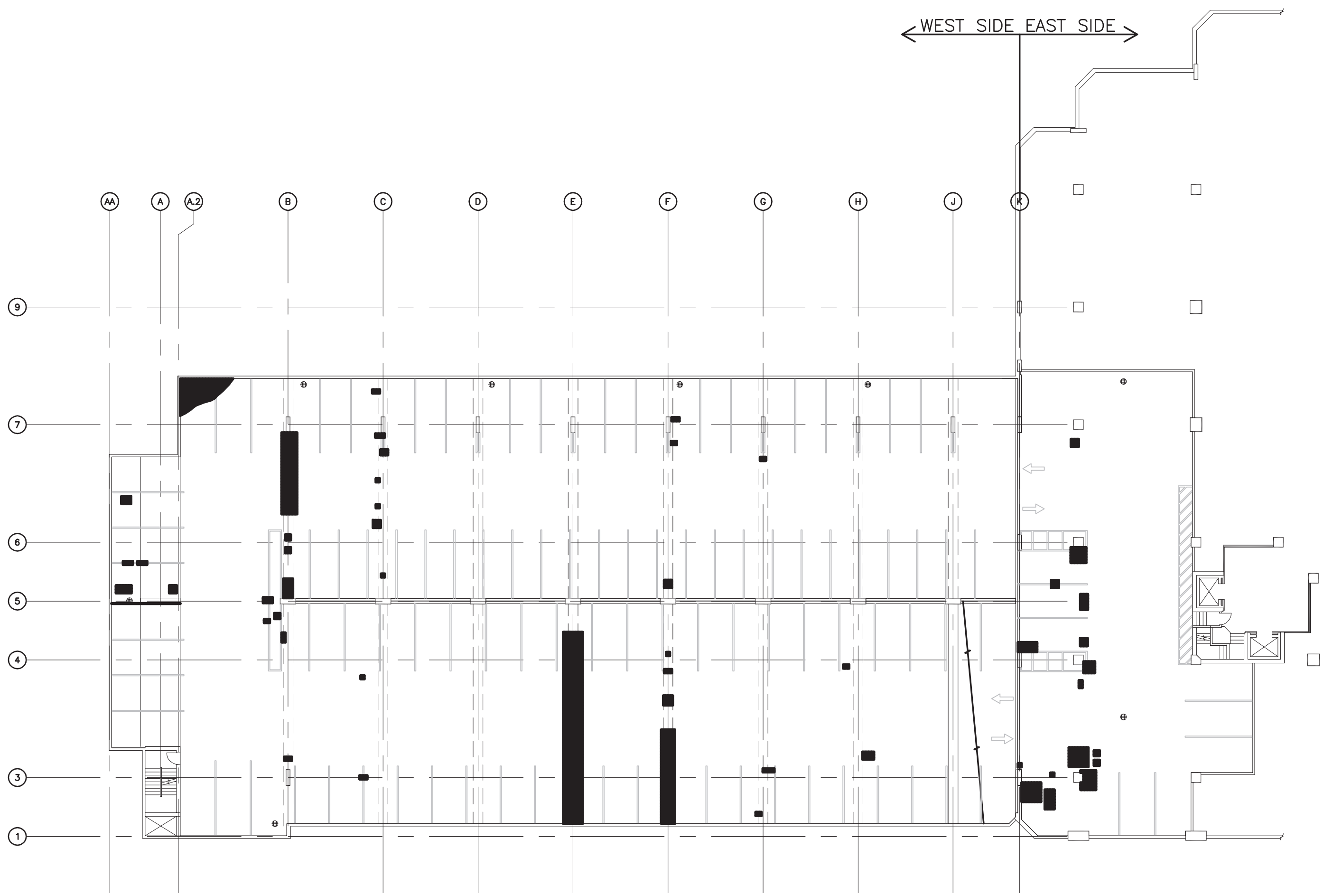
3 PARKING LEVEL P3 – 2011 DECK LAMINATION SURVEY
SCALE: 1/32" = 1'–0"



4 PARKING LEVEL P4 – 2006 DECK LAMINATION SURVEY
SCALE: 1/32" = 1'-0"



4 PARKING LEVEL P4 – 2011 DECK LAMINATION SURVEY
SCALE: 1/32" = 1'-0"

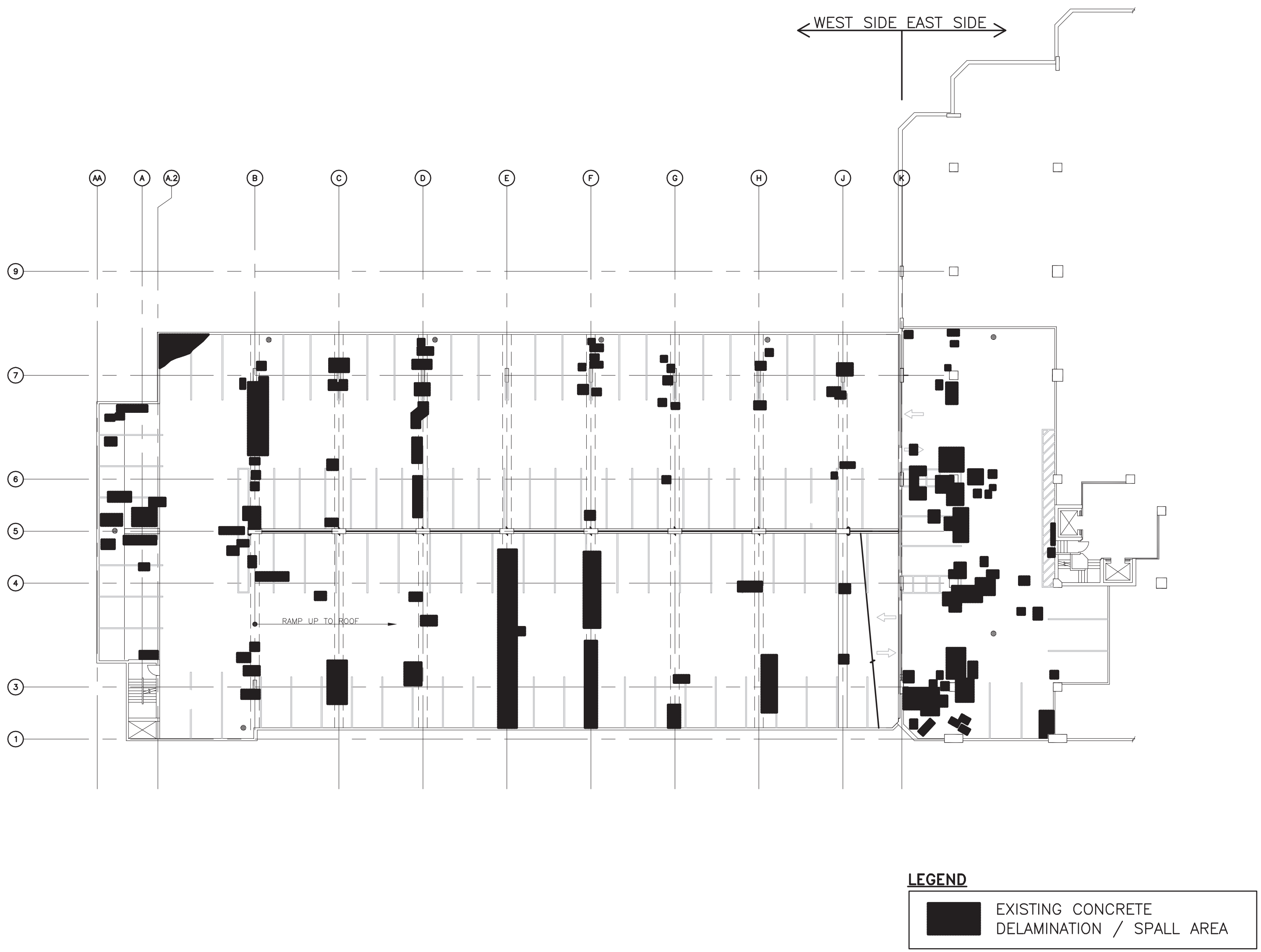


LEGEND

■	EXISTING CONCRETE DELAMINATION / SPALL AREA

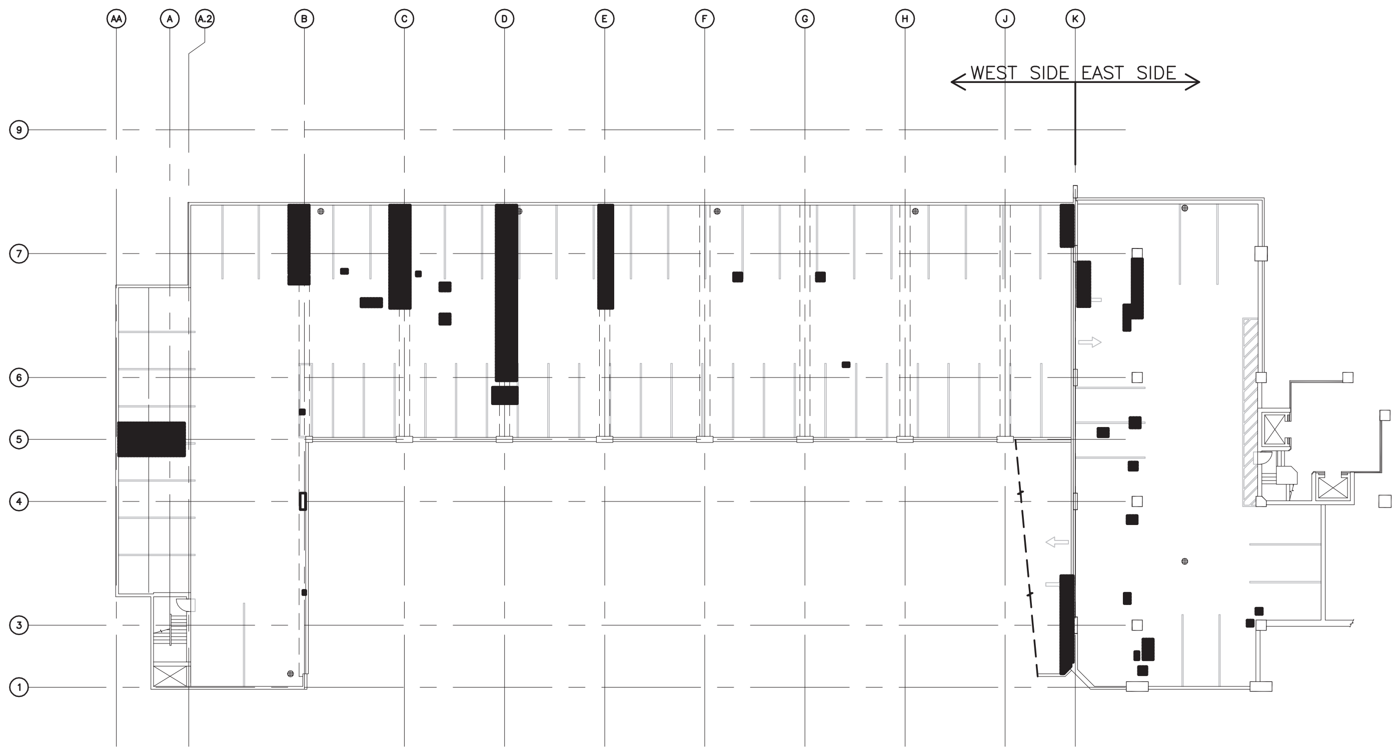
5 EXISTING LEVEL P5 – 2011 DECK LAMINATION SURVEY

SCALE: 1/32" = 1'–0'



5 EXISTING LEVEL P5 – 2011 DECK LAMINATION SURVEY

SCALE: 1/32" = 1'–0'

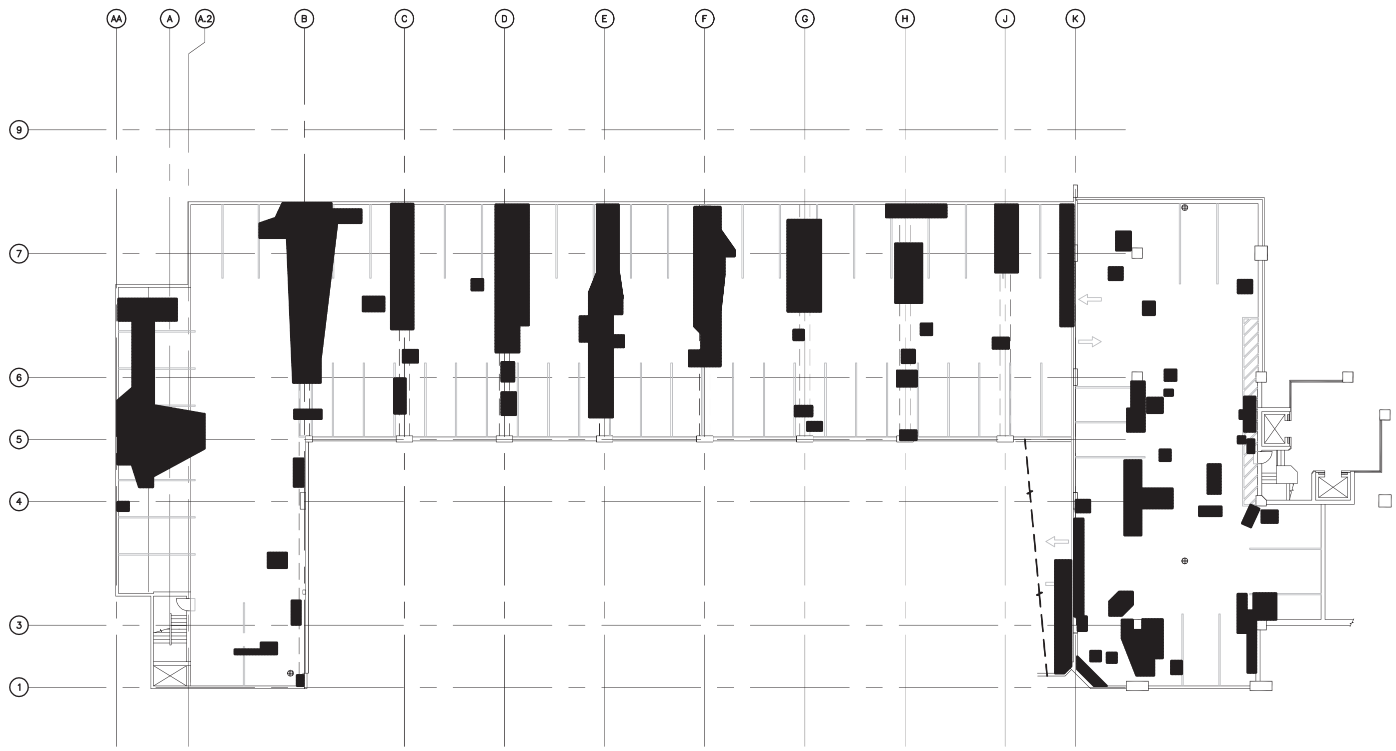


LEGEND

EXISTING CONCRETE DELAMINATION / SPALL AREA

6 EXISTING PARKING LEVEL P6 – 2011 DECK LAMINATION SURVEY

SCALE: 1/32" – 1'–0"



LEGEND

EXISTING CONCRETE DELAMINATION / SPALL AREA

6 EXISTING PARKING LEVEL P6 – 2011 DECK LAMINATION SURVEY

SCALE: 1/32" – 1'-0"

Appendix A

Report entitled "Review of Post-Tensioning Damage"
issued 7 October 2011
by Whitlock Dalrymple Posten & Associates

WHITLOCK DALRYMPLE POSTON & ASSOCIATES, P.C.
C O N S U L T I N G   E N G I N E E R S

MEMORANDUM

TO: Lawrence Keenan, AIA, P.E.
Hoffmann Architects, Inc.

FROM: Keith Kesner, Ph.D., P.E., S.E.
WDP & Associates, P.C.

DATE: October 7, 2011

SUBJECT: 25 Sigourney St. – Review of Post-Tensioning Damage
WDP Project No. 11415

Background Information

WDP & Associates, P.C. (WDP) was retained by Hoffmann Architects (Hoffmann) to perform an investigation into the condition of the post-tensioning system used in a portion of the parking structure located at 25 Sigourney St. in Hartford, CT. The parking structure at 25 Sigourney St. was constructed in two sections; one section located beneath the office tower was constructed using conventional reinforced concrete. The remaining six story section was constructed using post-tensioned slabs and reinforced concrete beams. Based upon the design drawings the original construction of the parking structure was completed in approximately 1986. The original design drawings for the structure were reviewed at the start of the project; however the shop drawings for the post-tensioning system were not available.

The post-tensioning system used in the original construction was identified to be an unbonded 7-wire strand with push-through sheathing. Unbonded post-tensioning systems are still commonly used; however the corrosion protection details have evolved over time. Figure 1 shows the evolution of the corrosion protection for unbounded post-tensioning systems over time. The system used at 25 Sigourney St. has several known deficiencies, these include:

- Push-through sheathing does not form a tight seal around the strand allowing for water to collect at low points in the tendon trajectory
- The sheathing did not extend to the anchorages

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- The anchorages were uncoated and were frequently installed in contact with the back-up reinforcing steel

These known deficiencies were examined as a part of the investigation to determine the extent of possible corrosion damage to the post-tensioning system.

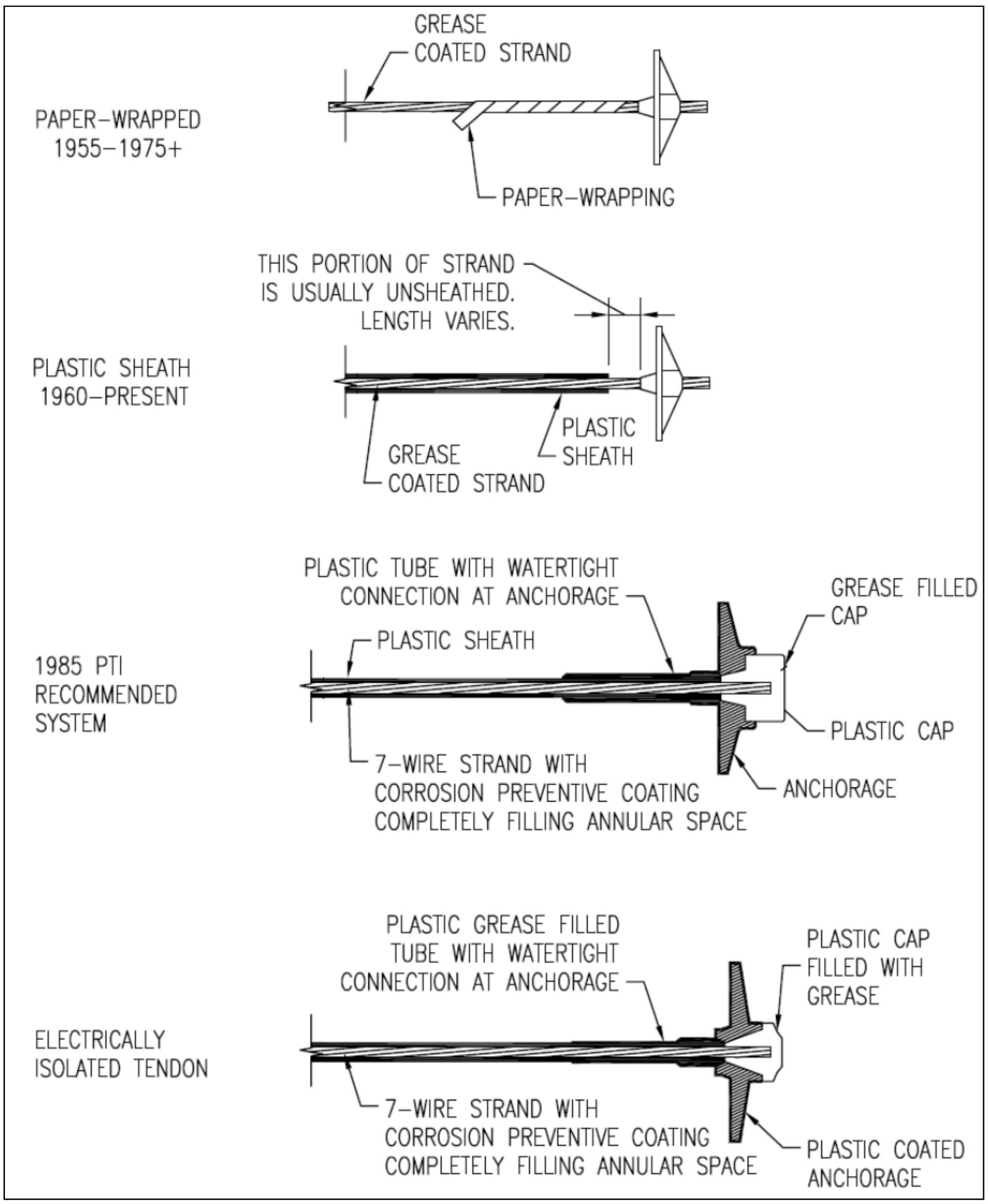

Figure 1. Deficiencies in corrosion protection details. 25 Sigourney St. uses the 2nd system from top. (Figure adopted from ACI 423.4R-98).

Site Investigation

To examine the condition of the post-tensioning system a combination of a visual survey, probes and nondestructive tests were performed. The visual survey was used to identify areas with significant damage, to locate failed post-tensioning strands and to identify probe locations. The probes were performed at locations on both the concrete slab surface and soffits in locations with visible damage and at intact areas. At select locations, samples of the post-tensioning tendons were removed for metallurgical analysis. The probes were performed by a specialty repair contractor working under contract to Hoffmann.

To further examine the condition of the structure, a series of nondestructive tests were performed. The methods used included surface penetrating radar (SPR), measurement of half-cell corrosion potentials and measurement of the chloride content of the concrete. The following sections provide background information on these test methods.

Surface Penetrating Radar

SPR is a nondestructive evaluation technique which utilizes electromagnetic energy to locate objects, subsurface flaws, or interfaces within a material. The technique is also referred to as ground penetrating radar (GPR). The system utilizes a high frequency dipole antenna to transmit a train of discrete amplitude modulation radio wave pulses. A second antenna, housed next to the transmitting antenna, is used to receive the scattered pulses as they return to the surface of the material. The radar unit detects back-scattered radiation that is reflected at the boundary between differing dielectric media. By measuring the time it takes to receive the reflected signal, the depth of an embedded object or interface may be determined. A real-time visual display of the material cross section is recorded as the antennae are moved along the surface. The output is fed to sampling circuitry before being digitally processed by a computer.

The color and intensity of the patterns in the output are related to the amplitude of the reflected signals. Figure 2 illustrates SPR scanning and sample signal output. The bands of alternating light and dark areas which appear in the remainder of the output correspond to the positive and negative reflections of the input wave from subsurface objects. Reflections from a lower dielectric media to a higher one, such as from concrete to steel, will undergo a phase inversion, or reversal, and the boundary will show up as a bright signal (assuming the input wave is dark). Conversely, the boundary from concrete to air (higher dielectric to lower) will show

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up as a dark signal. SPR antennae are specifically tuned to detect cylindrical objects, such as rebar, conduit, pipes, etc. These types of features show up as hyperbolas, or arch shapes, on the data record, as seen in Figure 2.

At 25 Sigourney St., SPR was used to locate both post-tensioning strands and reinforcing steel. Note that both post-tensioning strands and reinforcing steel will have the same appearance in an SPR test results, therefore knowledge of the structure is used to distinguish reinforcing steel from post-tensioning strand.

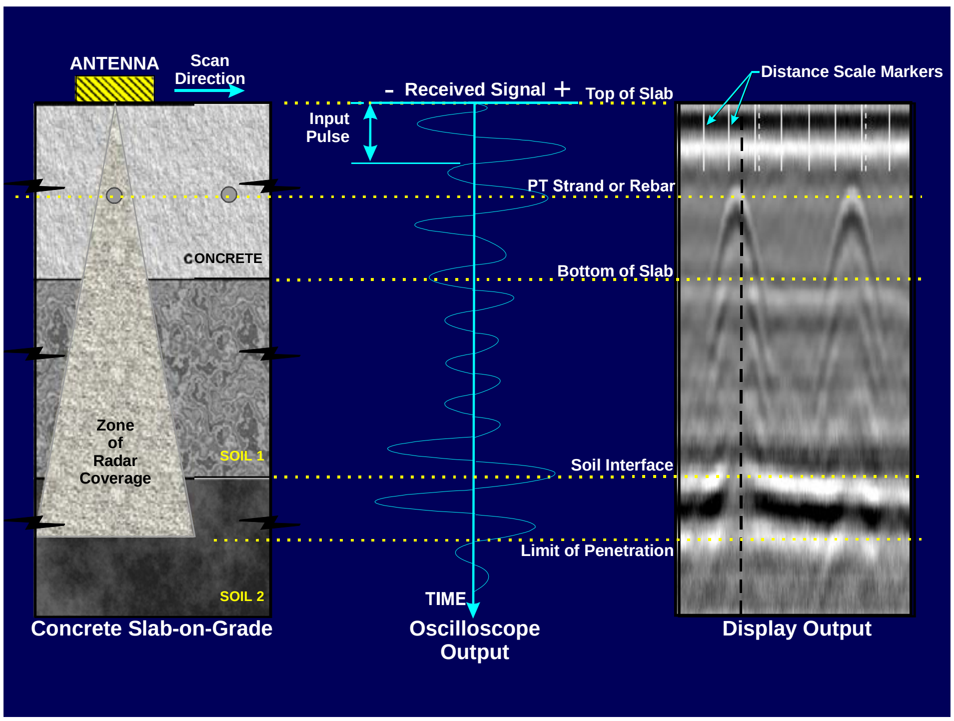

Figure 2. Sample output from a SPR scan.

Half-cell Corrosion Potentials

The half-cell test corrosion potential method is a standard method for indicating whether active corrosion may be occurring in reinforcing steel. The method is described by the ASTM Standard C 876, "Standard Test Method of Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete." The test method uses a standard voltmeter to measure the potential difference between reinforcing steel and a copper-copper sulfate reference electrode. Figure 3 shows the components.

Figure 3. Half-cell corrosion equipment. Clockwise from top: copper- copper sulfate electrode and sponge, lead wires, and voltmeter.

The test uses a voltmeter to measure the potential difference between the reinforcing steel and a copper-copper sulfate reference electrode in contact with the concrete surface. The potential difference indicates the presence or absence of active corrosion of the reinforcing steel. This test method does not provide information regarding the actual rate of corrosion; rather, it indicates where active corrosion may be occurring with or without visual signs of distress. According to the ASTM Standard, a potential difference more positive than –200 mV indicates that there is a 90 percent probability that no active corrosion is occurring. A potential difference more negative than –350 mV indicates a 90 percent probability that active corrosion is occurring. A potential difference between –200 mV and –350 mV indicates that the status of corrosion activity is uncertain; the probability of active corrosion is between 10 and 90 percent.

The corrosion potential measurements only provide useful information regarding bonded steel elements. No reliable information can be obtained regarding the condition of unbonded post-tensioning strands.

At 25 Sigourney St., half-cell corrosion potentials were measured at several locations in the structure. Testing was performed both in parking areas and in drive lanes, with tests typically performed at a spacing of 3 ft. on center. In each test area, continuity of the reinforcing steel was verified prior to performing the tests.

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Chloride Ion Content

Chloride ion (Cl^-) contamination of concrete materials can cause corrosion of the embedded reinforcement. Steel embedded in concrete is protected from corrosion by a passive layer that forms on the steel surfaces in a high pH environment. Chlorides present in the concrete break down the passive layer, leaving the steel susceptible to corrosion when exposed to water and oxygen. Potential sources of chlorides include diffusion of de-icing chemicals throughout the service life of the structure and chloride containing admixtures added at the time of construction normally as a set accelerator for the concrete during periods of cold weather.

The chloride content in the concrete was measured from powder samples removed from the slabs using ASTM C1152. Chloride ion contents above the threshold concentration, generally accepted in the industry as 350 parts chloride per million (ppm), can lead to corrosion of the reinforcing steel when sufficient water and oxygen are present.

Metallurgical Testing

Samples of post-tensioning strand were removed from the structure for metallurgical assessment. The goal of the assessment was to verify the type of corrosion occurring on the post-tensioning strand samples. The metallurgic assessment involved an examination of the corrosion products to determine their composition and testing of the grease to determine is acidity. Failed strand samples were also examined under a microscope to verify the cause of damage. The metallurgical assessment was performed by Lewis Engineering and Consulting, Inc. (Lewis) as a sub consultant to WDP.

Investigation Results

In the following sections the results of the post-tensioning system investigation are presented. Figure 4 shows the overall geometry of a typical parking level, with the direction of the post-tensioning tendons shown. The initial probe openings were completed on the slab surface on Levels 5 and 6 at locations where previous strand failures had occurred. Additional probe openings were made on Levels 4 and 2. At each probe area, openings were made on both the slab surface and soffit to examine the condition of the post-tensioning strands. Openings were also made at the construction joint shown in Figure 4. The probe openings indicated that significant corrosion damage was present at both the high points and low points in the tendon trajectories.

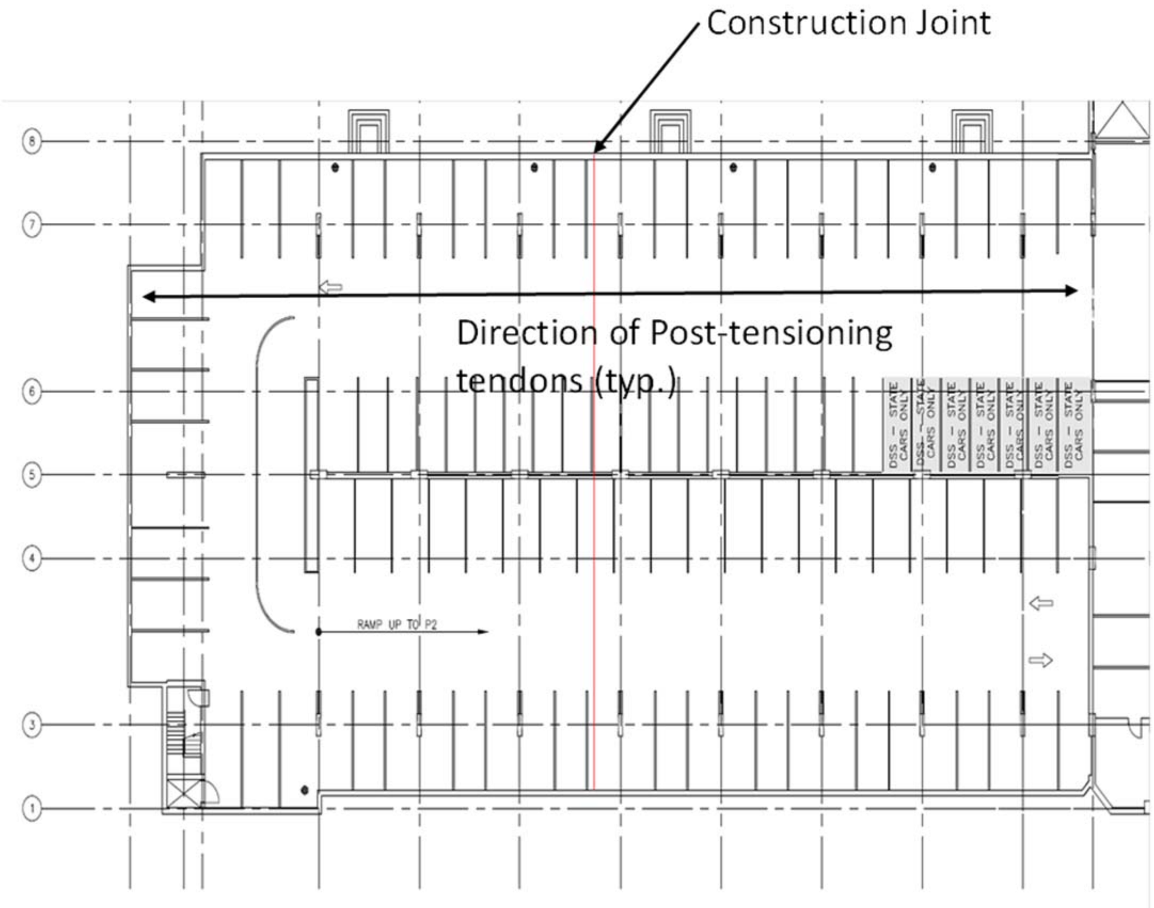

Figure 4. Typical layout of post-tensioning at 25 Sigourney St.

Slab Surface Observations

The probe openings on the top slab surfaces revealed that significant corrosion was present at the high points in the tendon trajectories in locations with low concrete cover. Figures 5 to 7 show typical conditions observed at low cover locations. Approximately twelve failed post-tensioning strands were observed on the top slab surfaces at various locations in the structure. Additional openings were made at the construction joint where known deficiencies are present in the corrosion protection. These are shown in Figure 8.

Figure 5. Failed post-tensioning on Level 6.

Figure 6. Emulsified grease on post-tensioning grease.

Figure 7. Brittle failure of post-tensioning strand on Level 6.

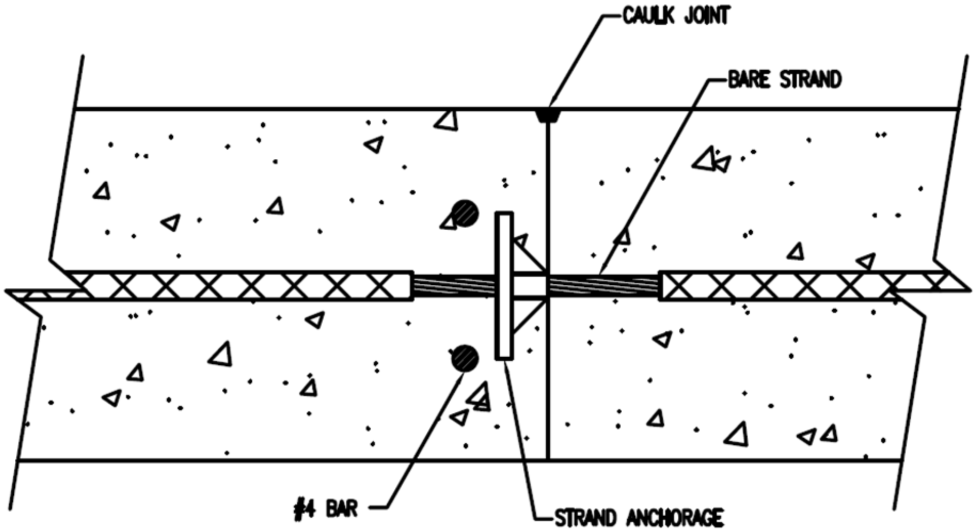

Figure 8. Strand conditions at construction joint. Note lack of positive corrosion protection as strand crosses joint.

During the evaluation, a section on Level 2 was observed with several failed post-tensioning strands at the construction joint. The failed post-tensioning strands were observed at the construction joint located between beam lines D and E. Two failed post-tensioning strands were present in this location, at the start of the investigation and water stains were observed on the slab soffit at the construction joint. Three additional broken strands were observed in this area (total of 5 broken strands). Wire breaks and section loss due to corrosion were observed at other locations. Based upon these observations, the area was closed to parking. Figure 9 to 13 show some of the observed conditions in the area. Based upon the observation of the failed strands, the area on the south half of Level 2 from column lines K to A was closed to parking, as well as the area on Level 1 immediately beneath this area.

Our initial calculations indicated that the isolated failure of up to two strands would not reduce the capacity of the slab to an unsafe level. After the observations of the failed strands on Level 2, additional calculations were performed to examine the capacity of the slab with failed post-tensioning strands. The calculations indicated that with a 50% loss (failure) in post-tensioning strands, the slab had adequate strength to resist dead loads only. Therefore the parking area must remain closed until the strands are repaired.

Figure 9. Openings at construction joint on Level 2.

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Figure 10. Failed strand at construction joint. Note corrosion on anchorage and failed wires.

Figure 11. Corrosion damage on strand, without strand failure.

Figure 12. Failed strand at construction joint (possibly failed during original construction.

Figure 13. Water dripping through construction joint in vicinity of failed strands.

<u>Slab Soffit Observations</u>

Additional openings were made to examine strands at the low points in the tendon trajectories. At these locations, the strands were generally observed to be intact

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however surface corrosion was typically observed. Significant amounts of water and emulsified grease were also observed. Figures 14 and 15 show representative observed conditions on the slab soffits.

Figure 14. Water and emulsified grease on strand.

Figure 15. Corrosion damage to mild reinforcing steel and damage to sheathing on soffit.

Corrosion Testing Results

To assess the condition of the reinforcing steel a series of nondestructive tests were performed. The results of the testing presented in the following sections. Overall, the results indicated that the concrete, particularly on Level 6, was contaminated with chlorides. The half-cell potential testing indicated that active corrosion was present in the tested areas. These results are discussed in the following sections.

Chloride Results

The results of the chloride testing are summarized in Table 1 below. The results indicate that significant chloride contamination has occurred, with more significant contamination on Level 6 which was exposed to weather. The highest chloride content on Level 6 was approximately ten times the corrosion threshold, and between 6 and 9 times greater than the corrosion threshold at the level of the reinforcing steel. Significant differences were not observed between the samples in the drive lane versus the parking stalls.

The results from Level 2 and Level 6 show a significant difference in chloride content with depth, with samples from Level 2 indicating chloride contents near background levels at the level of the reinforcing steel. This is likely the result of the concrete on Level 6 having a higher permeability compared to Level 2.

Table 1 – Summary of Chloride Test Results (ppm)

Sample Id.	Sample Depth (in.)		
	¼ - 1	1 - 2	2 - 3
Level 6 – Drive Lane	3080	2610	980
Level 6 – Parking	2330	1920	1400
Level 2 – Drive Lane	1150	120	90
Level 2 – Parking	1570	190	100

In addition to the chloride tests, carbonation tests were performed on freshly fractured concrete samples using a phenolphthalein solution. Figure 16 shows a tested area on Level 6, in the Figure the carbonation depth is less than ¼" as indicated by the change in indicator color. Similar carbonation results were obtained on tests on the lower levels. The limited carbonation depth was expected based upon the age of the structure and open construction.

Figure 16. Concrete surface on Level 6 with phenolphthalein applied.

Half-Cell Corrosion Potentials

Half-cell corrosion potentials were measured at several locations on the slab surfaces in both the parking stalls and drive lanes. The results indicated that active corrosion (half-cells more negative than -350mV) where present on all three levels where tests were performed. These results are summarized in Table 2. Significant differences were not observed between the drive lanes and parking stalls. Significant differences were also not observed between exterior and interior locations on the slabs.

Table 2 – Summary of Half-Cell Corrosion Potential Results

Location	**# Test Points**	**% < -350 mV**	**% > -200 mV**
Level 6	87	86% (75)	0% (0)
Level 5	108	67% (72)	17% (19)
Level 2	201	32% (64)	23% (46)

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Metallurgical Testing Results

To further assess the condition of the post-tensioning tendons, two sections of failed tendon were removed for metallurgical testing. The goal of the metallurgical testing was to insure that the observed corrosion was related to exposure conditions and not the result of embrittlement or other atypical forms of corrosion. The results from the testing are shown in Appendix A.

The testing indicated that the corrosion damage was the result of prolonged exposure to water and chlorides. The pH of the moisture / grease in the sheathing was found to be approximately 3.5, which represents an acidic condition. The decrease in pH was attributed to hydrolysis reactions between the ferric/ferrous ions, chloride and water, which resulted in the formation of iron hydroxides/oxides with associated production of hydrogen ions which acted to reduce the pH. The emulsified grease with a continual water supply and a low pH has limited ability to protect the strand from corrosion.

To further examine the corrosion mechanism, samples of the corrosion product were examined using a scanning electron microscope (SEM) and utilizing the energy dispersive x-ray spectrographic analyzer (EDS) to determine the chemical composition of the reaction products. The results indicated that the corrosion products contained up to 2% chloride.

The metallurgical testing confirmed that the observed corrosion failures were related to “ordinary” chloride induced corrosion, rather than embrittlement related mechanisms. However, the corrosion will continue to occur as long as a supply of water and chloride is present.

Discussion of Investigation Results

The investigation by WDP indicated that significant corrosion had occurred in the post-tensioning system at 25 Sigourney St., and the corrosion is likely to continue as long as a supply of water and chloride is present. Prior to the investigation, corrosion has resulted in the visible failure of post-tensioning strands at approximately 12 locations. Anecdotally, some of these strands failed within the past year.

The previously observed strand failures occurred at the high points in the tendon trajectory. During the investigation, additional failed and corrosion damaged strands were observed at the construction joint on Level 2. The amount of corrosion damage necessitated the closure of this area until repairs can be completed. It is important to note that these failures were generally not visible in the form of a strand eruption through the slab.

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The number of strands failures is likely to increase over time, unless extensive repairs are made to restore the corrosion protection system for the strands. The amount and rate of failures cannot be predicted. Based upon our site observations and previous experience, some of the strand failures will not result in a physical eruption of the strand from the slab surface. Failures of the post-tensioning strands are significant for the following reasons:

- The strands are the primary tension reinforcement in the slabs and due to the unbonded nature of the strands; redevelopment of the strand strength will not occur after a strand failure occurs. This means that once a strand fails, its contribution to the strength of the slab is lost for its full length.
- The failure of post-tensioning strands results in a significant release of stored energy. This can result in the eruption of the strand from the slab surface or soffit, with a potential risk of damage to people or property in the vicinity of the failure.

Based upon these considerations, repairs will be required to replace strands with significant existing corrosion damage, restore the failed strands and to mitigate future damage. It should be noted that the successful completion of the repairs will not eliminate the possibility of additional strand failures in the future.

Repair Recommendations and Estimated Costs

Based upon the results of the investigation, significant repairs will be required to insure the long-term integrity of the post-tensioning system. Specific recommended repairs are presented below. These repairs must be coordinated with concrete spalling repairs and with the installation of a positive waterproof membrane to prevent the ingress of water to the post-tensioning system. The estimated cost for the repairs was developed based upon our previous experience and discussions with repair contractors. The repair quantities are based upon information obtained during our field investigation with an increase in quantities added based upon our previous experience with unknown repair conditions.

Required / Recommended Post-Tensioning System Repairs

The following is a list of recommended repairs to restore the post-tensioning system and to provide for long-term corrosion protection. The first five repair items listed below are traditional post-tensioning repairs that are intended to address existing corrosion damage and to replace failed strand sections. The exact location of these repairs will be delineated during the construction phase of the project. Figures 17 to 19 show some details of these repairs.

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To provide for long-term corrosion protection, a program of tendon drying and grease reinjection is recommended. The tendon drying is a unique process that involves use of dry gas injected into the sheathing to remove water from the annular space between the strands and sheathing. After the tendons are dried, grease is injected into the sheathing to provide for future corrosion protection.

Even if the repairs are completed, future failures of the post-tensioning strands may occur. Therefore, the installation of a monitoring system is also recommended to allow for strand failures to be documented. Monitoring systems involve the installation of acoustic sensors that allow for the time and location of future post-tensioning strand failures to be recorded. An investigation can then be made to verify the cause of the strand failure. Results from monitoring systems are typically used in the planning of future maintenance repairs. The following is a list of required / recommended repairs:

- Repair of sheathing on exposed strands
- Replacement of isolated sections of post-tensioning strands
- Replacement of dead / live end anchorages
- Evaluation / corrosion protection of anchorages at construction joint
- Repair of anchorages at construction joint
- Drying and reinjection of grease
- Installation of a monitoring system

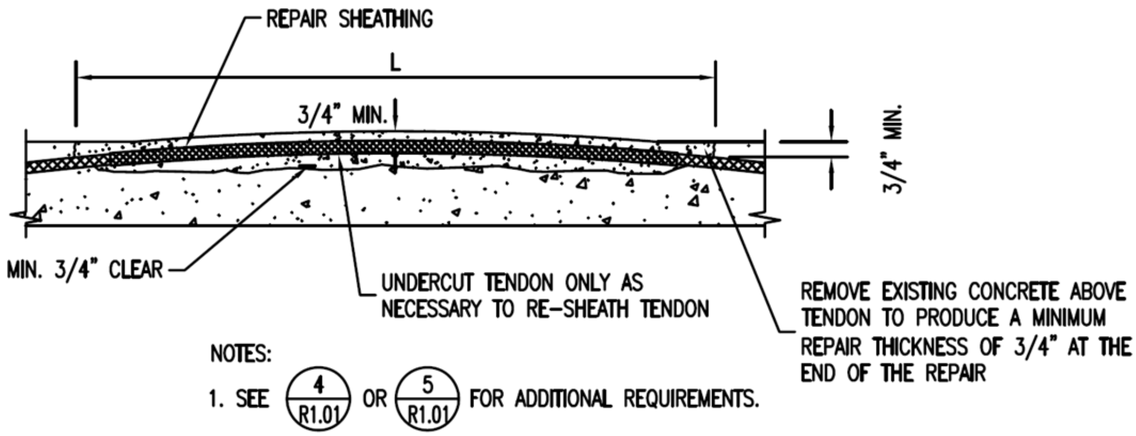

Figure 17. Strand corrosion protection repair.

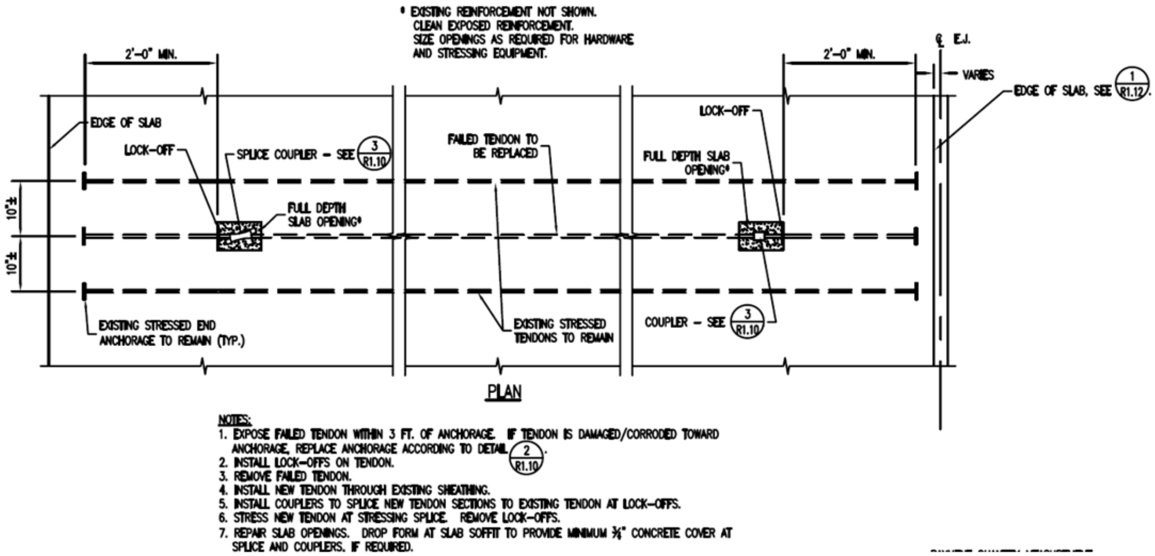

Figure 18. Strand replacement detail.

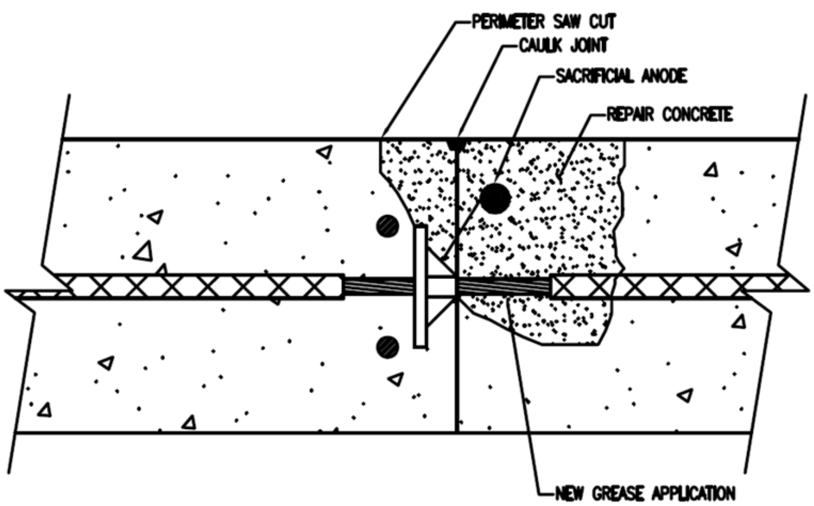

Figure 19. Corrosion protection repair at construction joint without strand / anchorage replacement.

Estimated Repair Costs

The estimated costs for the repairs to the post-tensioning system are shown in Table 3 below. These costs were developed based upon our experience with repairs to post-tensioning systems and discussions with repair contractors. WDP is not a construction cost estimator, and therefore cannot guarantee the accuracy of the cost estimates. The estimated costs are also limited to repairs associated with the post-tensioning system and associated concrete repair. These estimated costs do not include costs for concrete repairs due to reinforcing steel corrosion, installation of a waterproof coating or other repairs.

Table 3 – Summary of Estimated Post-Tensioning Repair Costs

Repair Item	Estimated Quantity	Unit Price ($/Unit)	Estimated Cost ($)
Sheathing Repair	6,000 Lf	4.50 $/LF	$ 27,000
Isolated strand replacement	100 locations	2,500 $/location[1]	$ 250,000
Anchorage replacement	50 locations	1,500 $/anchorage	$ 75,000
Construction joint corrosion protection	400 locations	600 $/location	$ 240,000
Construction joint anchorage repair	80	4,000 $/location	$ 320,000
Drying and regreasing of strands	-	-	$ 350,000[2]
Monitoring system installation	122,000 SF	2.75 $/SF[3]	$ 355,000
		Total Estimated Cost	**$ 1,617,000**

1. Unit price includes replacement of approximately 20 lf. of strand
2. Estimated cost provided by specialty contractor
3. Estimated cost based upon previous installations. Cost shown does not include annual monitoring fees.

Summary

An evaluation of the post-tensioning system at the 25 Sigourney St. parking structure has been completed. The results indicated that significant corrosion damage has occurred to the post-tensioning system in the 25^+ year old structure, and the damage is likely to continue to occur as long as water and chlorides are applied to the structure. The damage to the post-tensioning system was in the form of isolated strand failures, corrosion to exposed post-tensioning strand sections and failures at an intermediate construction joint. The grease, which serves as the primary corrosion protection mechanism for the strand, was generally found to be wet, emulsified and likely ineffective.

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To assess the significance of the corrosion failures, calculations were performed that indicate the slabs have sufficient strength to accommodate a localized failure of up to two post-tensioning strands. During the investigation, a section on Level 2 with approximately five strand failures at the construction joint was observed. This section was closed to parking.

Repairs will be required to insure the long-term integrity of the structure. The repairs will need to address both the existing damage to the post-tensioning system and to improve the corrosion protection. The most significant repairs will be required at the intermediate construction joint, where only limited corrosion protection was provided by the original construction details. To insure the long-term integrity of the strands, the drying of the strand sheathing and reinjection of grease is recommended. This will restore the corrosion protection on the strands. Installation of a monitoring system is also recommended. The monitoring system will allow for any future post-tensioning strand failures to be documented and will aid in maintenance repair planning.

The estimated cost for the post-tensioning system repairs was determined to be $1.617M, which was developed based upon our previous experience and discussions with specialty repair contractors. This does not include costs associated with general concrete repairs, waterproofing repairs and other necessary repairs.

Appendix A – Metallurgical Testing Report

WDP

Lewis Engineering and Consulting, Inc.

2106 NW 67th Place, Suite #2 | Richard O. Lewis, P. E. | (352) 375-7687
Gainesville, FL 32653 | Facsimile: (352) 375-7689

October 4, 2011 **VIA EMAIL and USPS**

Keith Kesner, PhD, P.E., S.E.
Associate
WDP & Associates, P.C.
50 Washington Street, Suite 751
South Norwalk, CT 06854

RE: Laboratory Evaluation of Failed Unbonded Tendons
Connecticut Parking Garage Deck
WDP Ref: 11415
LEC Job No.: L3607

Dear Dr. Kesner:

An evaluation and analysis of two failed A416 sheathed tendons submitted to us by your office has been completed. Both tendon samples exhibited corrosion failures at one end and were in severely distressed condition. The following information was transcribed from identification markings on tape attached to each sample:

Strand No.1 - L6 South E Centerline
Strand No.2 - 2S Sigourney St. 11415

The PE sheathing on Strand No.1 was generally intact but contained multiple locations of physical damage that had punctured the sheathing and visible iron oxide corrosion products mixed with emulsified grease. An example of one such location is shown in **Figures 1 and 2**. A second location of typical sheathing damage and exposed grease and corrosion product is shown in **Figure 3**.

The sheathing on Strand No.2 was far more severely damaged compared to Strand No.1. There was no visible grease which provided a less obstructed view of the severely corroded strand wire within the sheath. An example of the typical appearance of Strand No.2 is shown in **Figures 4 and 5**. A second location of typical damage and appearance of the corroded strand wires is shown in **Figure 6**.

LABORATORY ANALYSIS

A sample of the relatively dry strand corrosion products was removed from Strand No.2 and was finely ground with a mortar and pestle. The powdered corrosion product was placed in a cone-shaped filter paper and rinsed with distilled water. The pH of the filtrate water was measured using pHydrion® indicator strips. **Figure 7** shows the wetted strip placed adjacent to the color scale. The color indicated by the strip corresponds to an acidic pH of nominally 3.5. A closer view of the color comparison between the strip and the color scale is shown in **Figure 8**.

A portion of the PE sheathing was stripped from Strand No.1 exposing the heavily iron oxide stained emulsified grease as shown in **Figure 9**. An attempt was made to measure directly with an indicator strip the pH of the grease. There was enough free water available, however, to develop a color on the strip. Distilled water was dripped onto the grease and allowed to stand briefly to absorb soluble constituents from the grease emulsion. An indicator strip immediately produced the same yellow-green color as shown in **Figure 7** when placed in contact with the water droplets as shown in **Figure 10**. The color developed corresponds to the same low acidic pH of 3.5 developed on the wetted sample from Strand No.2.

SCANNING ELECTRON MICROSCOPY/EDS XRAY ANALYSIS

Samples of relatively dry iron oxide corrosion products were removed from near the fractured ends of both strand samples. These samples were affixed to mounting studs for examination in the scanning electron microscope (SEM) and utilizing the energy dispersive x-ray spectrographic analyzer (EDS) attached the SEM. Two sets of combined graphical/tabular results of the SEM/EDS analyses are attached in **Appendix A**.

Spectrum **Strand 1, EDS 1** in the appendix was recorded with the displayed image encompassing a large number of the iron oxide particles on the stud. The elemental composition indicated is a mix of iron oxide and cementitious particles, plus approximately 2 weight percent chloride. Further examination of individual oxide particles identified some particles that were predominately iron oxide with a comparable concentration of chloride. Many others were primarily iron oxide also, but with significantly higher amounts of chloride, approaching 8 weight percent as shown in spectrum **Strand 1, EDS 3**.

A similar pattern of findings were recorded for corrosion product samples from Strand No.2. Numerous particles that were identified as being primarily iron oxide contained chloride at concentrations varying generally between 1.5 to 2 weight percent. Numerous other iron oxide particles analyzed contained high concentrations of chloride in the 8 weight percent range, similar to the high chloride results recorded for Strand No.1.

DISCUSSION AND CONCLUSIONS

A laboratory examination and chemical analysis of corrosion products present on the two samples of severely corroded and failed sheathed strand confirms that, (1) moisture containing significant amounts of chloride has migrated through the deck concrete to the PE sheathed tendons and gained entry at locations of physical damage or poorly sealed anchorage locations, (2) as moisture wicked along inside the sheath emulsifying the grease and wetting the strand wires, corrosion initiated and (3) hydrolysis reactions between ferrous/ferric ions, chloride and water resulted in precipitation of iron hydroxides/oxides and production of hydrogen ion and chloride, or hydrochloric acid. This aggressive acid condition would have been sustained as long as there was a periodic continuing supply of moisture and chloride to the strand. The end result of this process is ultimately strand failure as observed on the two samples submitted.

Prepared and submitted by,

Richard O Lewis

Richard O. Lewis, P.E.

OCTOBER 4, 2011

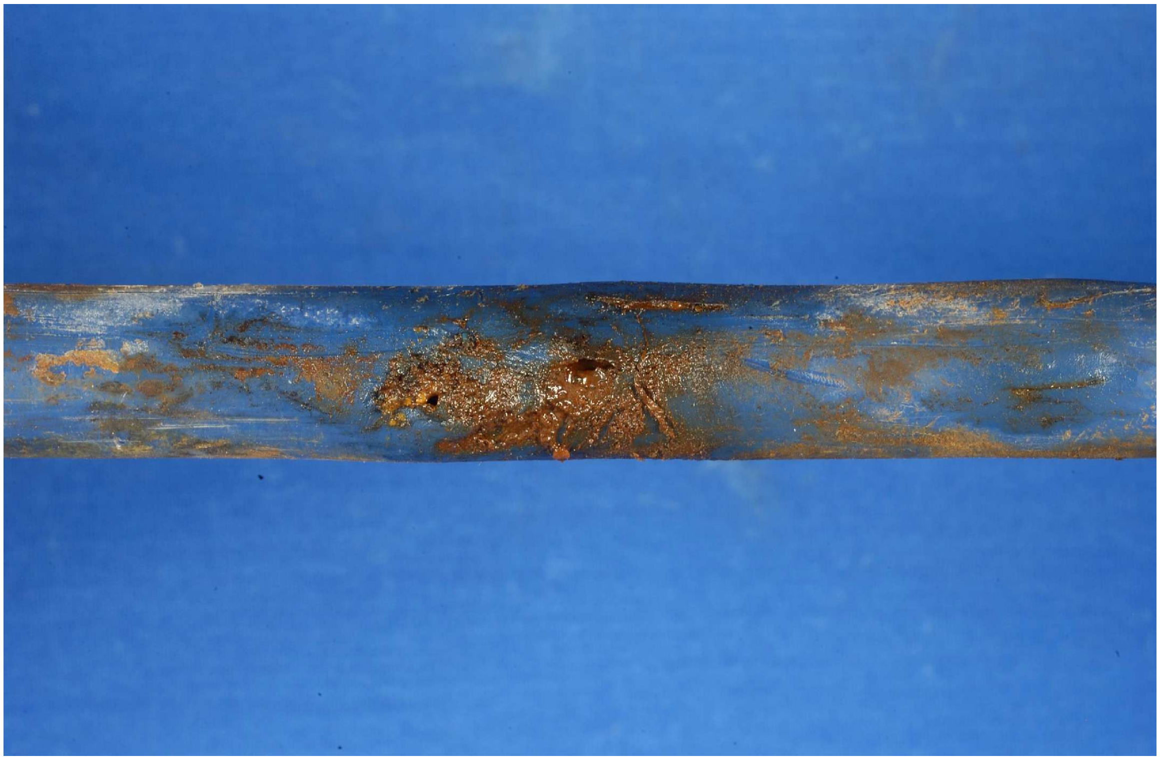


Figure 1. View of a portion of strand #1 identified as “L6 South E Centerline at a location of damage to the polyethylene (PE) sheath where iron corrosion product stained grease is visible. L3607 093011 01

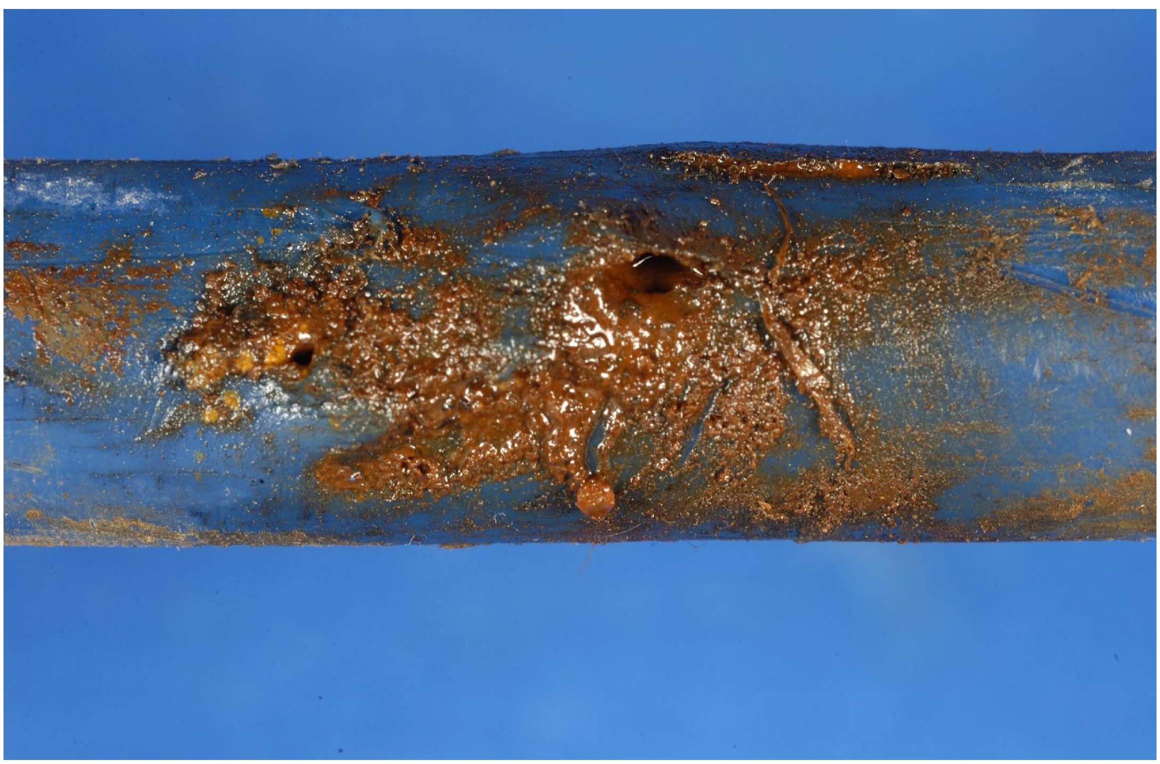


Figure 2. Close view of location shown in Figure 1. L3607 093011 02

Figure 3. Second location of many on strand #1 showing evidence of sheath damage. L3607 093011 03

Figure 4. Severely damaged PE sheathing and visibly corroded strand wire on strand #2. L3607 093011 04

Figure 5. Close view of location shown in Figure 4. L3607 093011 05

Figure 6. Second location of sheath damage and strand wire corrosion on strand #2. L3607 093011 06

Figure 7. pH indication of 3.5 obtained on water sample prepared by mixing distilled water with finely ground corrosion products on strand #2. L3607 093011 07

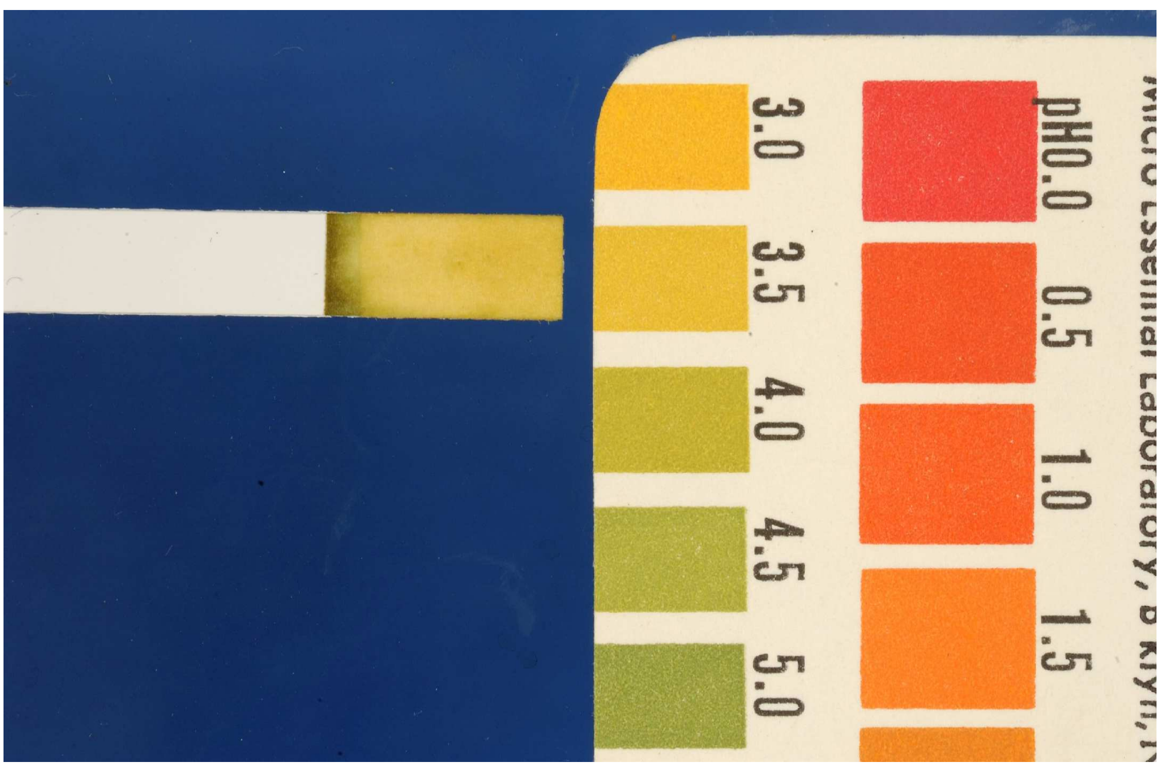


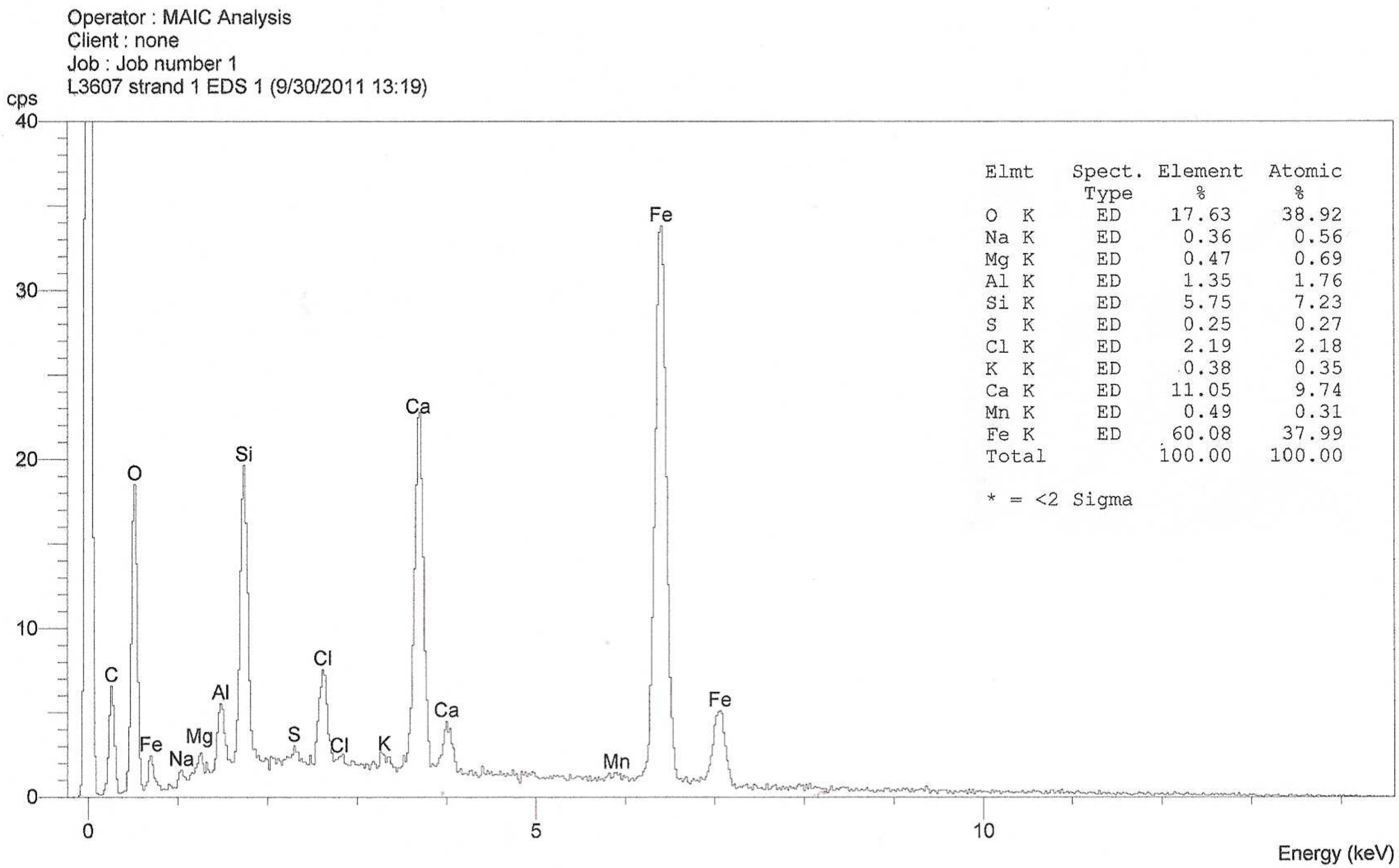
Figure 8. Close image of pH indicating paper and color scale shown in Figure 7. L3607 093011 08

Figure 9. Section of sheathing removed on strand #1 where distilled water has been dripped onto the orange stained grease. L3607 093011 09

Figure 10. pH indicator strip placed in contact with wetted grease; color reaction indicates a pH of 3.5 when compared to color scale in Figure 7. L3607 093011 10

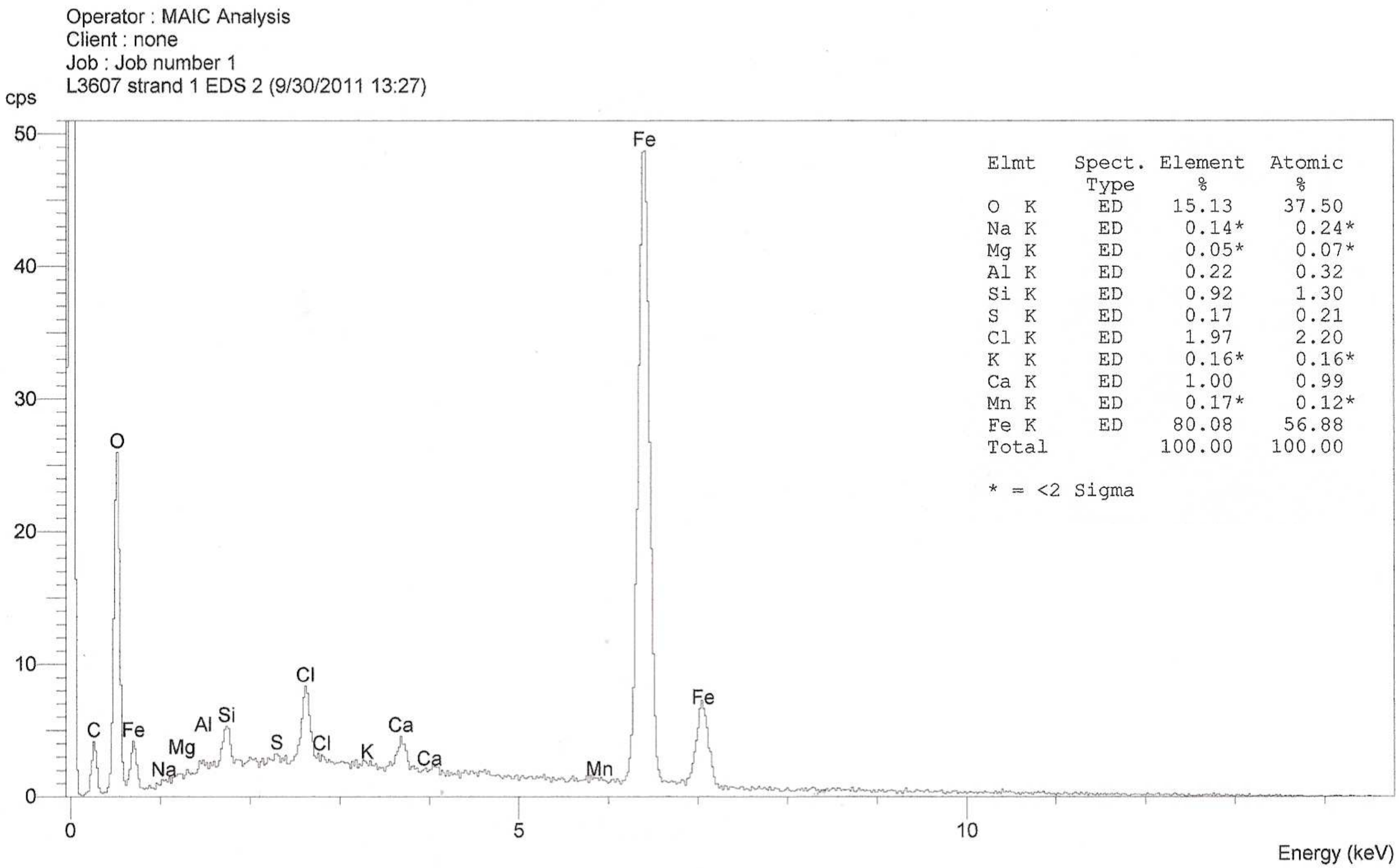
APPENDIX A

SEM/EDS ANALYSES



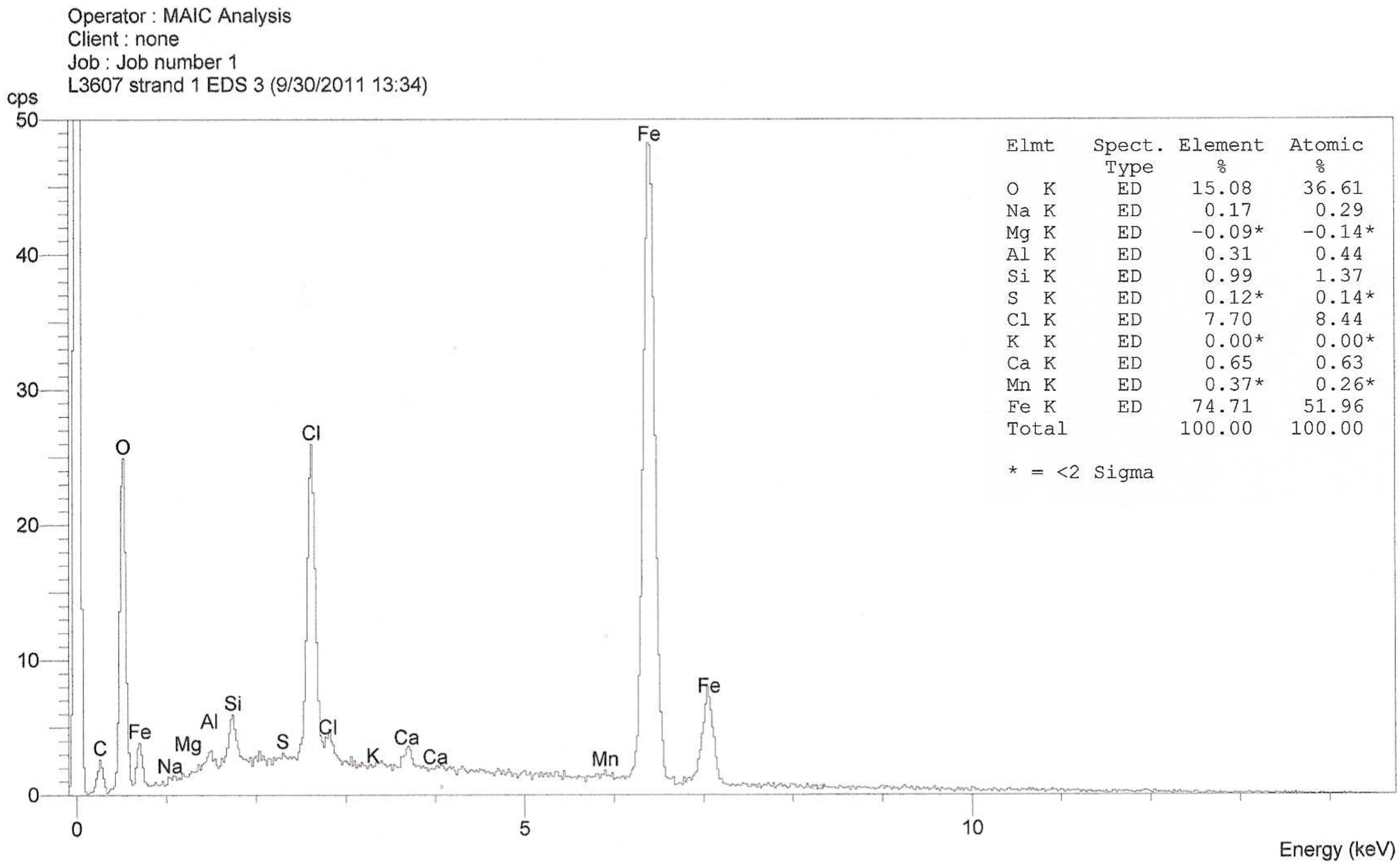
Elmt	Spect. Type	Element %	Atomic %
O K	ED	17.63	38.92
Na K	ED	0.36	0.56
Mg K	ED	0.47	0.69
Al K	ED	1.35	1.76
Si K	ED	5.75	7.23
S K	ED	0.25	0.27
Cl K	ED	2.19	2.18
K K	ED	0.38	0.35
Ca K	ED	11.05	9.74
Mn K	ED	0.49	0.31
Fe K	ED	60.08	37.99
Total		100.00	100.00

Strand 1, EDS 1.

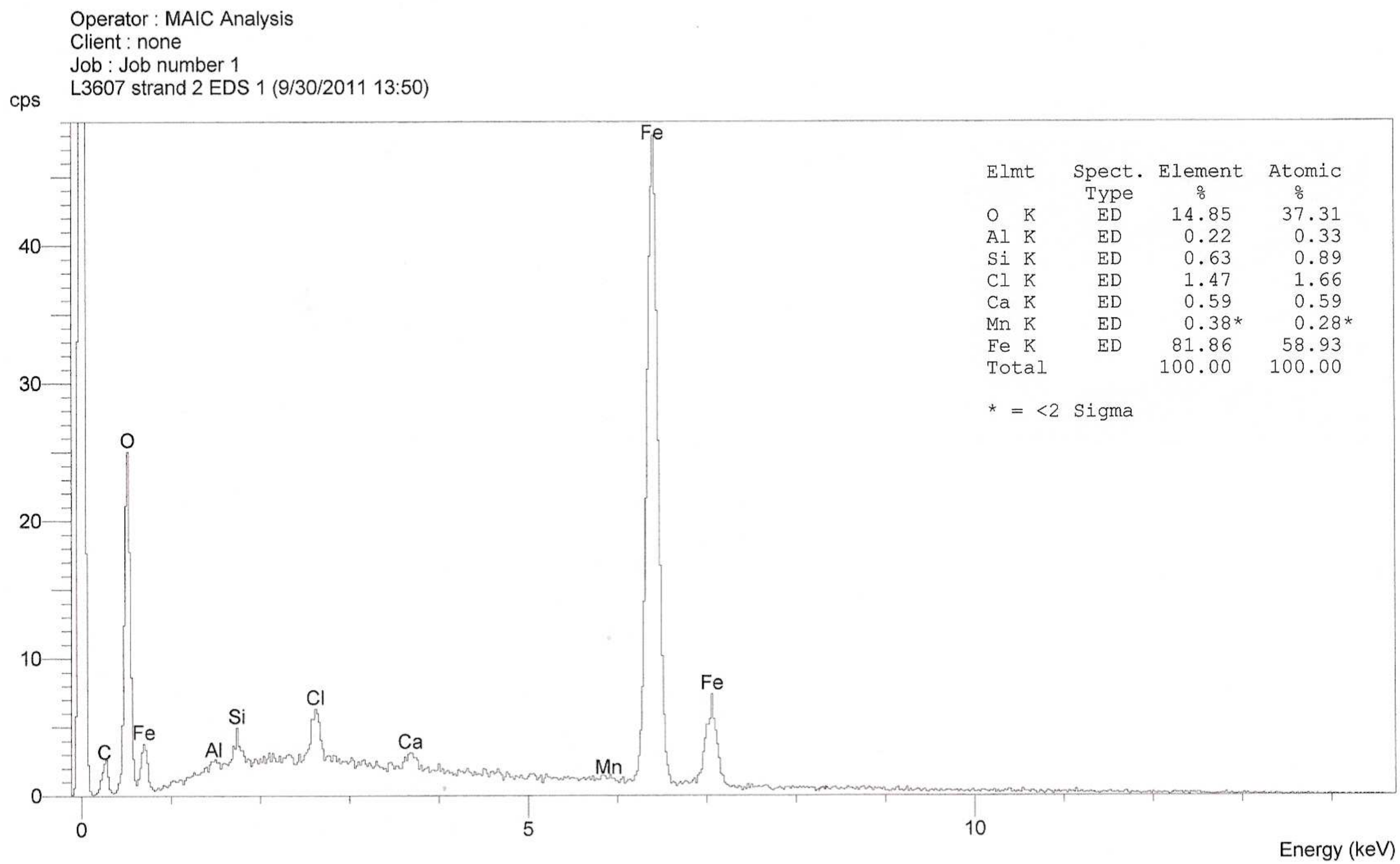


Elmt	Spect. Type	Element %	Atomic %
O K	ED	15.13	37.50
Na K	ED	0.14*	0.24*
Mg K	ED	0.05*	0.07*
Al K	ED	0.22	0.32
Si K	ED	0.92	1.30
S K	ED	0.17	0.21
Cl K	ED	1.97	2.20
K K	ED	0.16*	0.16*
Ca K	ED	1.00	0.99
Mn K	ED	0.17*	0.12*
Fe K	ED	80.08	56.88
Total		100.00	100.00

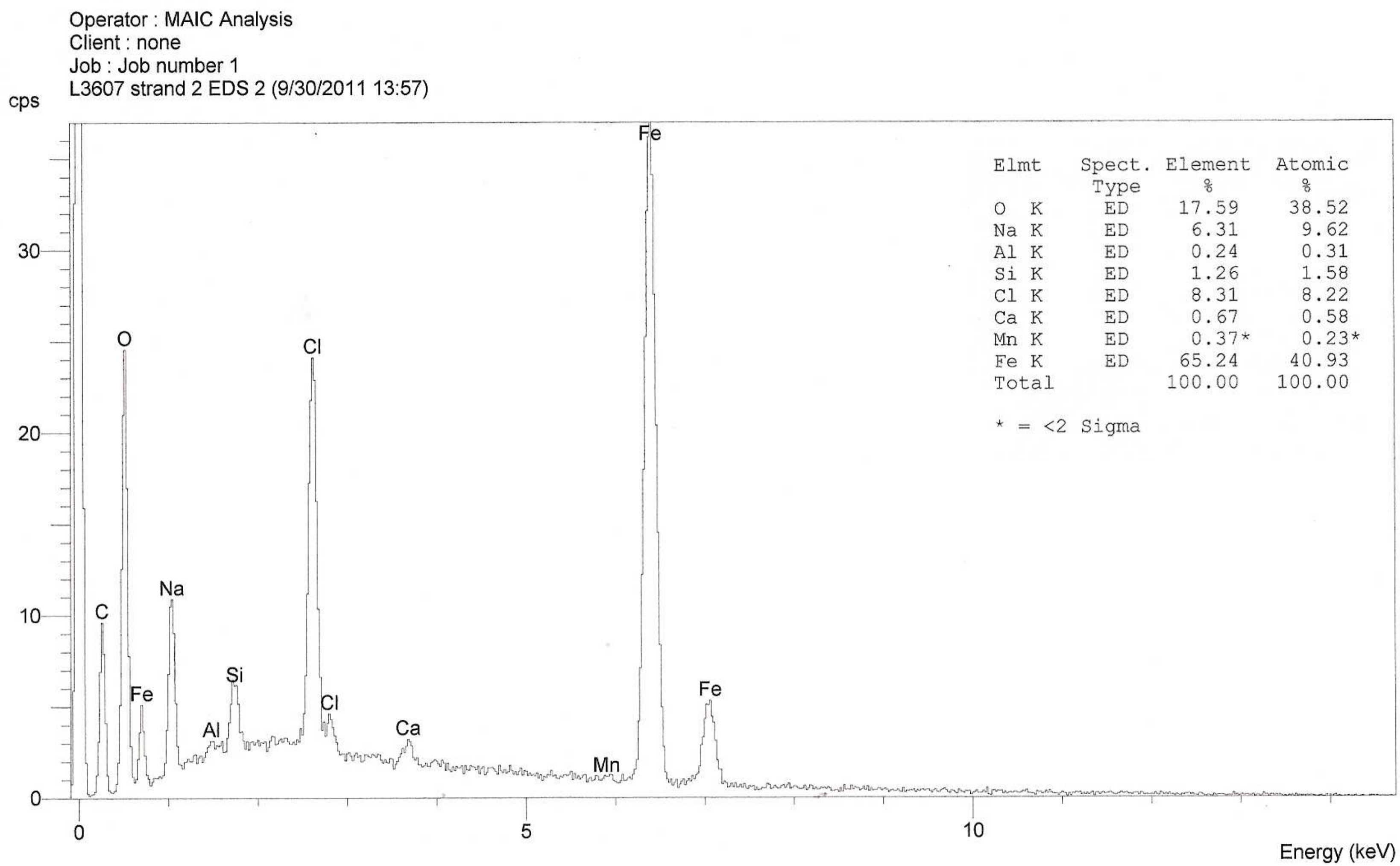
Strand 1, EDS 2.



Strand 1, EDS 3.



Strand 2, EDS 1.



Elmt	Spect. Type	Element %	Atomic %
O K	ED	17.59	38.52
Na K	ED	6.31	9.62
Al K	ED	0.24	0.31
Si K	ED	1.26	1.58
Cl K	ED	8.31	8.22
Ca K	ED	0.67	0.58
Mn K	ED	0.37*	0.23*
Fe K	ED	65.24	40.93
Total		100.00	100.00

* = <2 Sigma

Strand 2, EDS 2.

Appendix B

Report entitled "Mechanical and Electrical Building Evaluation
for the 25 Sigourney Street Garage"
issued 13 October 2011 by
VanZelm Heywood and Shadford

MECHANICAL AND ELECTRICAL BUILDING EVALUATION

FOR THE

25 SIGOURNEY STREET GARAGE

HARTFORD, CONNECTICUT
DPW PROJECT NO. BI-2B-034-A

Prepared on

October 13, 2011

By

van Zelm Heywood & Shadford, Inc.
Mechanical and Electrical Engineers
10 Talcott Notch Road
Farmington, CT 06032
van Zelm #2005096.02

A. INTRODUCTION

van Zelm, Heywood and Shadford, Inc. has been commissioned by Hoffmann Architects to review the mechanical and electrical systems for the 25 Sigourney Street Garage in Hartford, Connecticut. This report should be read in conjunction with Design Documents as issued on 4/12/2007. The purpose of this document is to provide an update on any changes that have occurred since the Design Documents were issued.

The review consists of visual inspection of installation and conditions of sprinkler systems, rainwater drainage systems, ventilation systems, lighting, electrical raceways, and fire alarm systems within the garage spaces and associated garage stairways. A review was also made of the 4/12/2007 Design Documents to determine any scope of work changes required to accommodate current conditions.

Items in the 4/12/2007 Design Documents not specifically revised by this report shall continue to apply.

B. MECHANICAL SUMMARY

The changes to the mechanical infrastructure from the 4/12/2007 Design Documents include:

1. The majority of the ventilation system remains unchanged. It appears that the plans are accurate and require little modification, except as noted herein.

C. MECHANICAL OBSERVATIONS

Mechanical Observations include the following:

1. The exhaust ductwork within the fan room appears to be in good condition.
2. A section of ductwork on Parking Level P2 has been replaced with new, galvanized type ductwork.
3. The majority of the exhaust ductwork within the parking garage is in fair condition; however, a small section of exhaust ductwork on Parking Level P3 is beginning to corrode. See attached photographs labeled "Photo 1 Parking Level P3" and "Photo 2 Parking Level P3".

D. MECHANICAL RECOMMENDATIONS

After reviewing the 4/12/2007 Design Documents, the mechanical remedial work indicated still applies; however, additional work will be required as noted below.

1. Additional sections of exhaust ductwork on Parking Level P3 show signs of corrosion and should be replaced.

2. Refer to Appendix for information on mechanical modifications to the project.

E. ELECTRICAL SUMMARY

The changes to the electrical infrastructure from the 4/12/2007 Design Documents include:

1. The garage HID downlight type light fixtures have been replaced with new fluorescent light fixtures.

2. Existing exit light fixtures do not appear to have been replaced.

3. Most of the surface mounted electrical boxes and some segments of raceway have further deteriorated due to moderate to severe corrosion.

4. There has been a fire alarm system upgrade performed which includes some new fire alarm device locations.

5. A representative from Building Facilities Management has indicated that have been several recent instances of fire alarm system trouble signals being sent to the fire alarm control panel. It is recommended that the Owner have this issue studied further to determine what corrective action may be required.

F. ELECTRICAL OBSERVATIONS

The electrical system review included the following:

- Observe physical conditions of light fixtures and associated raceways.
- Observe physical conditions of fire alarm system components and associated raceways.

A representative from Building Facilities Management has indicated that the majority of the garage lighting fixtures were replaced in February of 2010. The general use garage lighting fixture is a nominal 1’ x 4’ pendant mounted enclosed and gasketed type with (3) 25watt/4100K/T-5 lamps per fixture. It appears that the fixtures were located directly below former light fixture locations and that new wiring was extended only from the existing underside of the roof deck to each fixture. Therefore it is assumed that the existing branch circuit conduit and wiring was reused from the former light fixture location back to the source power panel. In general the garage light fixtures appeared in good condition and most were observed operating correctly. There are selected fixtures with burned-out lamps and/or bad ballasts. There are selected light fixtures on level “P4” and level “P5” that have evidence of rust on the fixture enclosure and/or lens that would indicate that water has penetrated the branch circuit conduits and travelled to the light fixtures.

It does appear that garage light fixtures were replaced one-for-one and that there are no visible branch circuit wiring changes made to revise any normal power light fixtures to emergency power light fixtures. Based on this observation there may not be sufficient emergency lighting in all areas. Also the need for additional light fixtures at garage entrances/exits to meet Illuminating Engineers Society North America (IESNA) guidelines for transitional lighting was identified in the original report, because the existing light fixtures were replaced one-for-one it is reasonable to assume that additional light fixtures will still be required.

The exit sign light fixtures do not appear to have been changed as part of the recent lighting upgrade and are generally in poor condition. Throughout the garage, exit signs have poorly illuminated letters or are not operating. The stencil plates in most of the exit signs have fallen into the exit sign housing. Some exit sign enclosures show signs of deterioration. The 4/12/2007 Design Documents require replacement of the existing exit signs.

On sixth level parking, the pole mounted light fixtures on the top deck of the garage appear in good physical condition with some minor corrosion visible.

In general the fire alarm system appeared to be in good condition. It appears that a fire alarm system upgrade has been performed recently and that several fire alarm devices with surface mounted wiring have been added. Several devices are partially visually obscured by mechanical piping systems. Some original fire alarm devices have signs of minor corrosion. The original fire alarm system wiring is concealed in the concrete slabs. In a meeting with Building Facilities personnel on 9-26-11 it was noted that there have been many instances of fire alarm system trouble signals being received at the fire alarm system control panel that appear to come from wiring grounding issues most likely related to water entering the original conduit system. Upgrades to the fire alarm system are not included in the 4/12/2007 Design Documents.

In general the electrical wiring in the garage is installed in thin wall steel raceway utilizing set-screw connections and NEMA 1 fittings that are not sealed against moisture. The back boxes and junction boxes observed are stamped steel with knockouts and non-gasket cover plates. Larger pull boxes are steel boxes with non-gasketed screw-on cover plates. Disconnect switches and wireways used are also NEMA-1 rated with no gaskets. The boxes, devices and equipment, and portions of the raceways have minor to significant corrosion relating to moisture. Most of the junction boxes have significant corrosion. Due to the materials and methods used in the construction of the electrical systems, and the amount of moisture that is allowed to enter into the electrical raceway systems and equipment and the external corrosion that has been observed, the condition and integrity of the wiring distribution of the garage systems has to be questioned and presumed to have been adversely affected by moisture.

G. ELECTRICAL RECOMMENDATIONS

After reviewing the 4/12/2007 Design Documents, the electrical remedial work indicated still applies; however, additional work will be required including the following:

The existing general use garage light fixtures were installed in 2010. These fixtures appear to provide sufficient light levels, however some supplemental fixtures may be required at garage entrances and exits. The 4/12/2007 Design Documents do not show the revised garage light fixtures and would have to be updated to reflect the present light fixture type layout. The Owner will have to determine if the current fluorescent light fixtures are acceptable since HID type light fixtures shown on the Design Documents.

Based on discussion with the Owner, the existing light fixtures will be reused and in areas that are presently under illuminated additional fixtures will be provided, specifically at the entry and exit to the garage.

Replace all non-weatherproof fire alarm system devices with weatherproof type due to the high moisture environment that the devices are exposed to. Based on the information from Building Facilities Management of numerous fire alarm system trouble signals at the fire alarm control panel, the entire original fire alarm wiring system (conduit/conductors) should be replaced.

The garage light fixtures are served by a conduit system that is installed within the concrete floor/ceiling slabs. Based on the anticipated extent of concrete slab remediation work it is reasonable to assume that some lighting branch circuit conduits will be adversely affected by new construction.

Due to the materials and methods used for the electrical wiring throughout the garage, with wiring being installed in thin wall steel raceway, utilizing set screw connections and NEMA-1 fittings that utilize stamped steel boxes with knockouts, and non-gasketed covers, and the degree of corrosion that has been observed, all wiring should be replaced. In addition new wiring utilizing surface mounted RGS conduit with threaded fittings, with cast metal boxes with manufactured hubs, using larger NEMA-4X boxes and water-tight fittings should be provided. NEMA-4X rated devices should also be used for equipment such as disconnect switches. All conduit penetrations into the building structure should be appropriately sealed.

Refer to Appendix for information on electrical modifications to the project.

H. PLUMBING/FIRE PROTECTION SUMMARY

FIRE PROTECTION: The piping for the dry sprinkler systems and manual dry standpipe system is fabricated from black steel and is corroded significantly, especially internally, where microbial elements have eaten away at the piping over time. In addition, black steel piping typically contains rust particles within the piping system that can foul sprinkler heads and prevent proper sprinkler head operation that will interfere with fire suppression. Current NFPA 13 and 14 standards require dry sprinkler and dry standpipe systems exposed to the atmosphere to be constructed of galvanized steel.

PLUMBING: The existing garage drains connect to a single grit separator on the lowest level which discharges to the city storm sewer system. Per current Code requirements, the open decks of the garage must drain to the city storm sewer system through a grit separator and the covered portions of the garage must drain to the city sanitary sewer system through an oil/grit separator.

I. PLUMBING/FIRE PROTECTION OBSERVATIONS

FIRE PROTECTION: All the piping within garage areas for the dry sprinkler systems and the manual dry standpipe systems show major signs of deterioration and corrosion. All portions of the existing dry sprinkler system and dry standpipe system piping, fittings, control valves, sprinklers and hangers located in interior conditioned spaces appear to be in good condition.

A representative from Building Facilities Management has indicated the following items:

- Many sections of the existing black steel dry sprinkler and dry standpipe system pipe mains and branch mains have been replaced with new galvanized pipe due to pipe failures.

- Additional work will be required in the 'tower' section of the garage to replace existing manual dry standpipe system piping with new.

PLUMBING: All parking decks currently have deck drains that are connected to a grit separator located on the lowest level. The grit separator discharge is currently connected to the city storm sewer system. This condition violates current Plumbing Code and MDC standards and will require modifications. The Plumbing Code requires all parking deck drains located in areas open to atmosphere such as the top level to be connected to the storm sewer system. All other parking level deck drains located in covered areas, (all levels below the top level), must be connected to the city sanitary sewer system after passing through an oil/grit separator. On several parking levels, the existing garage drain piping shows sign of corrosion and deterioration. Portions of garage drainage piping have already been replaced due to piping failures.

The following items are additional items observed:

- Additional work will be required to replace sections of corroded garage drainage piping with new, galvanized steel piping.

J. PLUMBING/FIRE PROTECTION RECOMMENDATIONS

FIRE PROTECTION: After reviewing the 4/12/2007 Design Documents, the fire protection remedial work indicated still applies; however, additional work will be required in the 'tower' section of the parking garage. The recommendation is to replace all existing piping for all dry sprinkler systems and the dry standpipe system, throughout the entire garage, including fittings, couplings, sprinklers, hangers, etc.

Refer to Appendix for information on fire protection modifications to the project.

PLUMBING: After reviewing the 4/12/2007 Design Documents, the plumbing remedial work indicated still applies; however, additional work will be required. The recommendation is to re-pipe the drains in the open portions (top level) of the garage, so that those garage drains flow through a new grit separator. The drains for the covered parking levels would remain connected to the existing grit separator which must modified to include the oil separation function per MDC standards and then be connected to the city sanitary sewer system. Some portions of existing garage drain piping should also be replaced due to deterioration, corrosion and cracking.

Refer to Appendix for information on plumbing modifications to the project.

K. PHOTOS

PHOTO 1 Parking Level P3

PHOTO 2 Parking Level P3

APPENDIX

The following are items that vary from the information shown on Construction Documents dated 4/12/2007:

MECHANICAL

- **ADD** (25) linear feet of new 36” x 20” galvanized ductwork
- **ADD** (30) linear feet of new 24” x 12” galvanized ductwork

ELECTRICAL

- **DELETE** the following quantities of new light fixtures to be provided:
  (55) Type “A”
  (123) Type “A1”
  (32) Type “B”
  (32) Type “B1”
  (9) Type “B2”

- **ADD** work to clean and re-lamp (194) type “EA” (existing) light fixtures.

- **ADD** new surface mounted conduit/conductors for the current garage light fixtures, assume 35’-0” of ¾” RGS threaded conduit with 2#12, 1#12 Ground wire per light fixture for (250) light fixtures.

- **ADD** new surface mounted conduit/conductors for selected existing fire alarm system devices, assume 4,500 L.F. of ¾” RGS threaded conduit with 4#16AWG wire.

FIRE PROTECTION

- **ADD** (300) linear feet of new 6” galvanized steel piping w/ couplings, fittings, hangers, etc. for replacement of the tower dry standpipe system.
- **ADD** (150) linear feet of new 4” galvanized steel piping w/ couplings, fittings, hangers, etc. for replacement of the tower dry standpipe system

PLUMBING

- **ADD** (300) linear feet of new 6" galvanized steel drainage piping w/ couplings, fittings, hangers, etc. for replacement of corroded sections of the existing garage drain, drainage system.
- **ADD** (400) linear feet of new 4" galvanized steel drainage piping w/ couplings, fittings, hangers, etc. for replacement of corroded sections of the existing garage drain, drainage system.

Appendix C

Project Cost Estimate
issued 13 October 2011 by
Professional Construction Services, Inc.

PROFESSIONAL CONSTRUCTION SERVICES, INC.
P.O. BOX 4697
STAMFORD, CT 06907-0697
203-322-2730
FAX 203-547-6057
E-MAIL lfinkel@proconstserv.com
www.proconstserv.com

DATE: 10/13/2011

PROJECT:
GARAGE REPAIRS
25 SIGOURNEY STREET
HARTFORD, CT
DPW PROJECT NO. BI-2B-034A

ARCHITECT:
HOFFMANN ARCHITECTS
2321 WHITNET AVENUE
HAMDEN, CT 06518
203-239-6660
FAX 203-239-6340

DATE: ########

ITEM	SPEC. SECTION	DESCRIPTION	GARAGE/PLAZA	COMMENTS	234,823 $/SF	ALTERNATE COATING SYSTEM
1		DIVISION 2				
2		DEMOLITION	51,237		0.22	
3	02220	EARTHWORK	17,540		0.07	
4	02250	SITE PREPARATION	10,000		0.04	
5	02513	CONCRETE PAVING	90,022		0.38	
6	02760	PAVEMENT MARKING AND SIGNSGE	37,627		0.16	
7		MISC SITE	54,687		0.23	
8		DIVISION 3			-	
9		CONCRETE			-	
10	03900	CONCRETE RESTORATION	4,188,458		17.84	
11		DIVISION 4			-	
12		DIVISION 5			-	
13	05500	MISC METALS	59,800		0.25	
14		DIVISION 6			-	
15		DIVISION 7			-	
16	07140	FLUID APPLIED WATERPROOOFING	80,475		0.34	
17	07190	WATER REPELLANT COATINGS	6,438		0.03	
18	07570	FLUID APPLIED TRAFFIC TOPPINGS	1,408,484		0.45	106,416
19	07900	MEMBRANE TYPE EXPANSION JOINT	-		-	
20		DIVISION 8			-	
21		DIVISION 9			-	
22	09260	METAL PAN CEILINGS	526,546		2.24	
23		DIVISION 15			-	
24	15400	PLUMBING	198,000		0.84	
25		FIRE PROTECIION	509,610		2.17	
26	15500	HEATING	126,143		0.54	
27		DIVISION 16			-	
28	16100	ELECTRICAL	334,150		1.42	
29					-	
30					-	
31		SUB TOTAL	7,699,216		32.79	106,416
32		GENERAL CONDITIONS	384,961	5.00%	1.64	5,321
33		SUB TOTAL	8,084,177		34.43	111,737
34		OVERHEAD AND PROFIT	615,937	8.00%	2.62	8,513
35		SUB TOTAL	8,700,114		37.05	120,250
36		BUILDING PERMIT	156,602	1.80%	0.67	2,165
37		SUB TOTAL	8,856,716		37.72	122,415
38		BOND	177,134	2.00%	0.75	2,448
39		TOTAL	9,033,851		38.47	124,863
		ESCALATION	475,205	5.26%	2.02	6,568
1		TOTAL	9,509,056		40.49	131,431

DIVISION 2

DEMOLITION				
PLAZA				-
REMOVE ALL PAVEMENT FINISHES	8,047	SF	3	24,142
REMOVE PLANTER MATERIALS	1	ALLOW	1,000	1,000
REMOVE WATERPROOFING	8,047	SF	2	16,095
REMOVE GRANITE CURBING - SAVE FOR REUSE	1	ALLOW	10,000	10,000
TOTAL				51,237

02220 EARTHWORK			UP	TOTAL
EXCAVATE FOR SUBSURFACE DRAINAGE	151	CY	10	1,508
TRENCHING AND BACKFILL	500	LF	20	10,000
NEW SOIL	151	CY	40	6,032
TOTAL				17,540

02250 SITE PREPARATION	QUANTITY	UNIT	UP	TOTAL
				-
TEMPORARY PROTECTION AND DUST CONTROL	1	ALLOW	10,000	10,000
				-
				-
				-
TOTAL				10,000

02520 CONCRETE PAVING				
PLAZA - NEW CAST IN PLACE PAVEMENT				-
NEW CAST IN PLACE WALKS				-
NEW CONCRETE SIDEWALK	2,396	SF	8	19,168
COLORED PRESSED CONCRETE	684	SF	18	12,312
INTEGRAL COLORED CONCRETE PANELS	3,760	SF	13	48,886
NEW CAST IN PLACE CONCRETE RAMPS	1,057	SF	8	8,456
CONCRETE RAMP	150	SF	8	1,200
TOTAL				90,022

02760 PAVEMENT MARKINGS AND SIGNAGE		PM11	PM12	PM13	PM14	PM15	PM16
	-						
STRIPING/HC SYMBOLS, ETC.	-						

ARROWS	112	EACH	75.00	8,400	20	22	24	28	12	6
HC STALLS	27	EACH	100.00	2,700	2	6	7	12		
ADD'L STRIPED AREAS	47	EACH	100.00	4,700	8	6	8	20	2	3
STALL MARKINGS	595	EACH	15.00	8,925	120	110	124	81	96	64
CENTER LINES	4,502	LF	1.00	4,502	1000	1027	1,050	500	600	325
HC SIGNS	27	EACH	200.00	5,400	2	6	7	12		
BUMPS	22	EACH	100.00	2,200	5	6	6	5		
	-			-						
FLEXIBLE BOLLARDS	4	EACH	100.00	400					2	2
				-						
ACCESSIBLE RAMP SIGNS	2	EACH	200.00	400						
TOTAL				37,627						

MISC SITEWORK

PRECAST CONCRETE LIGHT BOLLARDS	11	EACH	500	5,500
FLUSH GRANITE BAND AND CURBING	338	LF	50	16,912
NEW PC CONCRETE PLANTERS - 5' DIA	2	EACH	2000	4,000
PLANTER WALL	113	LF	250	28,274
				-
TOTAL				54,687

DIVISION 3

03900 CONCRETE RESTORATION
WEST SIDE - FULLY EXPOSE POST TENSION CABLES - REPAIR PVC CONDUIT COVERING THEM
CABLES WHERE DAMAGED - REMOVE EXISTING CABLES
EXPOSE END ANCHORAGES
DESTRESS CABLES
REMOVE CABLES
INSTALL NEW CABLES
STRESS CABLES
REPAIR SPALLS AND LAMINATIONS AT COLUMNS, BEAMS, WALLS AND CEILINGS USING PARTIAL DEPTH PATCHING TECHNIQUES
REPAIR OR REPLACE DETERIORATED OR POORLY CONFIGURED CIP CONC WASHES

REMOVE CONCRETE CURBING AT RAILING
NEW CONCRETE CURBING AT RAILING

HORIZONTAL PARTIAL DEPTH PATCH	20,000	SF	90	1,800,000								
OVERHEAD CONCRETE REPAIRS	2,000	SF	125	250,000								
VERTICAL CONCRETE REPAIRS	300	SF	150	45,000								
POST TENSION REPAIR	1	FROM REPORT	1,617,000	1,617,000	BY WPD							
TRENCH SLAB	1,500	SF	10	15,000								
CONCRETE WASH	3,600	SF	25	90,000								
				-								
						RG11	RG12	RG13	RG14	RG15	RG16	
APPLY MIGRATING CORROSION INHIBITOR TO BASE OF COLUMNS - SOG	70	EACH	50	3,500.00								
				-								
APPPLY EPOXY HEALER/SEALER		SF	1	-			18232	19192	16888	12024	6524	
MIGRATING INHIBITOR	213,000	SF	1.73	367,958								
FERROGARD 903				-								
TOTAL				4,188,458								
MASTER BUILDERS EMACO S88-CI		55# BAG	0.66	PER #	0.45	CF/BAG	36	PER BAG	80.66667	PER CF		
INSTALLATION									84	PER CF		
TOTAL LABOR AND MATERIAL									164.6667	PER CF		
CONVERT TO $/SF			3 INCHES THICK	4.00	SF/CF	41.17	PER SF					
SIKA FERROGARD 903	5	GAL	122.75	100.00	SF/GAL	1.23						
INSTALL						0.5						
MATERIAL AND LABOR						1.73						
COATING												
SHOTBLAST	1	PER SF										
COATING	3	PER SF										
PATCHES HORIZ	100-120/SF	60/SF QUANTITY										
VERT OH PATCHES	175											

DIVISION 5

05500 METAL FABRICATIONS				
SECURITY BOLLARDS - PLAZA FRONT ENTRANCE				-
				-
REMOVE RAILING SYSTEM	1,500	LF	8	12,000
INSTALL NEW BARRIER CABLE SYSTEM	1,500	LF	18	27,000
9 WIRES				-
				-
NEW HANDRAIL	150	LF	100	15,000
RAIL	58	LF	100	5,800
				-
TOTAL				59,800
MATL	0.80	PER LF/CABLE		
L & M	1.75	PER LF/CABLE		

DIVISION 7	QUANTITY	UNIT	UP	TOTAL					
07140 FLUID APPLIED WATERPROOFING	8,047	SF	10.00	80,475					
PLAZA				-					
				-					
TOTAL				80,475					
07190 WATER REPELLANT COATINGS									
PLAZA	8,047	SF	0.80	6,438					
				-					
TOTAL				6,438					
07570 FLUID APPLIED TRAFFIC TOPPING					RG22	RG23	RG24	RG25	RG26
PREPARE DECK SURFACES AND APPLY TRAFFIC BEARING MEMBRANE									
CONIPUR	234823	SF	6.00	1,408,484	59366	64416	54441	33524	23076
				-					
TOTAL				1,408,484					
ALTERNATE									
07570 FLUID APPLIED TRAFFIC TOPPING					RG22	RG23	RG24	RG25	RG26
VERY HIGH TRAFFIC AREA (3 BROADCAST EPOXY WEAR COURSE				-					
SYSTEM AT EXPOSED TOP DECKS)	25650	SF	8	205,200					
				-					
HIGH TRAFFIC AREA (2 BROADCAST EPOXY WEAR COURSE SYSTEM				-					
AT ALL OTHER ELEVATED GARAGE DECKS)	187100	SF	7	1,309,700					
TOTAL				1,514,900					
DIFFERENTIAL				106,416					
07900 MEMBRANE TYPE EXPANSION JOINTS									
REMOVE EXPANSION JOINTS				-					
NEW EXPANSION JOINTS				-					
				-					
REPLACE EXPANSION JOINTS	582	LF	90	52,380	118	118	118	118	110
				-					
TOTAL				52,380					
WABOCRETE MEMBRANE SYSTEM		PER LF							

JOINT SEALANTS

TOTAL		-

								material/ sf
SONNIBORN CONIPUR II DECK COATING SYSTEM	http://www.bestmaterials.com							
PRIMER	3.4	GALLON	169.95	PER KIT	300.00	SF/KIT		0.57
BASE	4.66	GALLON	208.95	PER KIT	300.00	SF/KIT		0.70
TOP	4.78	GALLON	269.95	PER KIT	765.00	SF/KIT	AT 10 MIL	0.35
			269.95		510		AT 15 MILS	0.53
			269.95		383		AT 20 MILS	0.71
MATERIAL COST FOR SYSTEM	AT 20 MILS TOP COAT/15 MILS AT SPACES							2.50
INSTALL								3.50
TOTAL MATERIAL AND INSTALLATION								6.00

DIVISION 9

09514 METAL PAN CEILINGS	QUANTITY	UNIT	UP	TOTAL	RG31	RG32	RG33
GRID	36313	SF	2.00	72,626	10851	19079	6383
PAN	36313	SF	10.00	363,130			
COMPRESSION STRUTS - 2' OC	9079	EACH	10.00	90,790			
TOTAL				526,546			

DIVISION 15

	QUANTITY	UNITS	UP	TOTAL
PLUMBING				
PLAZA REMOVE PLUMBING SYSTEMS				
REMOVE IRRIGATION				-
NEW PLUMBING				-
NEW IRRIGATION				-
				-
				-
GARAGE				-
REPIPE COVERED PARKING GARAGE DRAINAGE SYSTEM TO CITY SEWER	250	LF	50	12,500
NEW GRIT/OIL WATER SEPARATOR (CAST-IN -PLACE)	1	EACH	40,000	40,000
REPLACE DETERIORATED PIPING	500	LF	100	50,000
DISCONNECT ROOF DRAINS FROM RWL SYSTEM	33	EACH	1,000	33,000
NEW WASH DOWN SYSTEM	1	ALLOW	25,000	25,000
6" GALVANIZED DRAINAGE PIPING FOR REPLACEMENT OF CORRODED				-
SECTIONS OF EXISTING GARAGE DRAIN, DRAINAGE SYSTEM	300	LF	65	19,500
				-
4" GALVANIZED DRAINAGE PIPING FOR REPLACEMENT OF CORRODED				-
SECTIONS OF EXISTING GARAGE DRAIN, DRAINAGE SYSTEM	400	LF	45	18,000
TOTAL				198,000

	QUANTITY	UNITS	UP	TOTAL
FIRE PROTECTION				
REMOVE EXISTING DRY PIPE SPRINKLER SYSTEM	23,965	LF	4	95,860
REMOVE AND REPLACE STANDPIPES	2	EACH	5,000	10,000
NEW DRY PIPE SPRINKLER SYSTEM	1510	HEADS	250	377,500
6" GALVANIZED STEEL PIPE FOR REPLACEMENT OF THE TOWER DRY				-
STANDPIPE SYSTEM	300	LF	65	19,500
				-
4" GALVANIZED STEEL PIPE FOR REPLACEMENT OF THE TOWER DRY				-
STANDPIPE SYSTEM	150	LF	45	6,750
TOTAL				509,610

GARAGE REPAIRS
25 SIGOURNEY STREET, HARTFORD, CT

HVAC	QUANTITY	UNITS	UP	TOTAL
REMOVE ALL GARAGE FANS	7	EACH	500	3,500
NEW GARAGE FANS				-
IEF-1 - 18000 CFM	1	EACH	5,000	5,000
IEF-2 - 18,000 CFM	1	EACH	5,000	5,000
IEF-3 - 18,000 CFM	1	EACH	5,000	5,000
WEF-1 - 18500 CFM	1	EACH	7,000	7,000
WEF-2 - 18500 CFM	1	EACH	7,000	7,000
WEF-3 - 18500 CFM	1	EACH	7,000	7,000
WEF-4 - 32000 CFM	1	EACH	10,000	10,000
DUCTWORK				
48X12	134	LF	80	10,720
48X20	49	LF	91	4,443
36X16	95	LF	69	6,587
30X20	153	LF	67	10,200
40X40	388	LF	107	41,387
			-	-
36X20 GALVANIZED	25	LF	75	1,867
24X12 GLAVANIZED	30	LF	48	1,440
TOTAL				126,143

DIVISION 16
ELECTRICAL

	QUANTITY	UNITS	UP	TOTAL
PLAZA				-
REMOVE ELECTRICAL SYSTEMS				-
NEW OUTLETS				-
NEW LIGHTING				-
A	55	EACH	250	13,750
A1	123	EACH	250	30,750
B	32	EACH	250	8,000
B1	32	EACH	250	8,000
B2	9	EACH	300	2,700
C	12	EACH	250	3,000
C1	6	EACH	250	1,500
X	33	EACH	350	11,550
SA	3	EACH	1,000	3,000
D PLAZA	11	EACH	1,000	11,000
CLEAN AND RELAMP EXISITNG FIXTURE NOTE 5	220	EACH	50	11,000
REVISE WIRING FOR EXIST POLEMTD PKG DK FIXT NOTE 19	3	EACH	500	1,500
NEW INVERTER	3	EACH	500	1,500
REPLACE EXIST LT POLE BOLT COVERS NOTE 20	3	EACH	100	300
REPLACE JB NOTE 21,22	8	EACH	150	1,200
REPLACE PULL BOX NOTE 23	0	EACH		-
NEW WEATHER PROOF JB NOTE 25	0	EACH		-
NEW JB FOR GATE SYSTEM NOTE 27	7	EACH	500	3,500
NEW DISCONNECT SW NOTE 28	0	EACH		-
NEW CONDUIT SUPPORTS NOTE 29	0	EACH		-
SEAL WALL PENETRATIONS NOTE 30	0	EACH		-
RE?	4	EACH	100	400
STROBE		EACH	250	-
REMOVE STROBE		EACH	50	-
PULL STATION		EACH	150	-
REMOVE PULL		EACH	50	-
				-
				-
GARAGE				-

REMOVE ALL CORRODED ELECTRICAL EQUIPMENT, BOXES, RACEWAYS AND WIRING				-
				-
NEW PANEL	1	EACH	5,000	5,000
REMOVE CONDUIT FOR LIGHT FIXTURES AND FIRE ALARM SYSTEM	13250	LF	2	26,500
NEW SURFACE MOUNTED CONDUIT/CONDUCTORS FOR CURRENT GARAGE LIGHT FIXTURES				-
3/4 RGS W/2#12, 1#12 GROUND WIRE	8750	LF	14	122,500
				-
NEW SURFACE MOUNTED CONDUIT/CONDUCTORS FOR FIRE ALARM SYSTEM DEVICES				-
3/4 RGS W/4#16 AWG WIRE	4500	LF	15	67,500
TOTAL				334,150

Table 3 – Summary of Estimated Post-Tensioning Repair Costs

Repair Iten	Estimated Quantity	UNIT		Unit Price ($/Unit)	UNIT		Estimated Cost ($)	
Sheathing	6,000	LF	$	4.50	$/LF	$	27,000	
Isolated str	100	LOCATIONS	$	2,500	$/LOCATION	$	250,000	1
Anchorage	50	LOCATIONS	$	1,500	$/ANCHORAGE	$	75,000	
Constructic	400	LOCATIONS	$	600	$/LOCATION	$	240,000	
Constructic	80	LOCATIONS	$	4,000	$/LOCATION	$	320,000	
Drying and -						$	350,000	2
Monitoring	122,000	SF	$	2.75	$/SF	$	355,000	3
Total Estimated Cost						$	1,617,000	

1. Unit price includes replacement of approximately 20 lf. of strand
2. Estimated cost provided by specialty contractor
3. Estimated cost based upon previous installations. Cost shown does not include annual monitoring fees.