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The Harbours Condominiums – Garage

Condition Review and Restoration Plan

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Condition Review and Restoration Plan

by
THP Limited, Inc.
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THP #15193.00

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The Harbours Condominiums - Garage
Condition Review & Restoration Plan

Executive Summary

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EXECUTIVE SUMMARY

The Harbours Condominium Garage in Jeffersonville, Indiana, requires structural concrete and waterproofing repairs to update the garage to an overall good condition. The four lower levels of the garage were built in 1991 as a cast-in-place post tensioned concrete structure. The two upper levels were added in 2000 as steel framed with a composite metal deck and concrete slab system. The composite metal deck is a structural component of the slab and acts integral with the concrete to span between the steel beams.

Immediate repairs in 2015 are recommended to address deterioration of the metal deck at Levels 5 and 6 from the July car fire and corrosion. Installation of supplemental steel angles and tubes would shorten the slab span between girders and reinforce the metal deck.

The remaining four years of the restoration plan focus on repairing concrete slab deterioration and installing a traffic bearing waterproofing membrane on the slab to slow future concrete delaminations and spalls. The membrane installed on the upper two levels at the steel framing will prevent chloride-contaminated water infiltration into the slab, which has been causing the corrosion of the metal deck. The corrosion of the metal deck needs to be prevented since it is required structurally for the slab to span between castellated steel beams. The membrane will also limit future freeze-thaw deterioration of the concrete slab, which is advancing at the exposed Level 6.

It is important to waterproof and prevent slab deterioration at the lower garage levels to prevent costly repairs with the embedded steel post tension cables. The original garage is approximately 25 years old and beginning to show signs of more significant concrete deterioration from the corrosion of embedded steel rebar. The restoration plan is recommending that 25 percent of the lower levels be coated with the membrane to waterproof the construction joints at intermediate post tensioned anchorages and at areas of freeze-thaw concrete deterioration.

In addition to the main concrete and waterproofing repairs, the restoration plan recommends painting corroded steel framing, replacing sealant joints at the connector bridges and façade

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panels, installing supplemental drains, and other improvements to maintain the garage structure.

A 5-year restoration plan for the recommended concrete and waterproofing repairs for the Harbours Condominium Garage is included in the last section of this report. The program proposes a total expenditure of $832,000. The Condominium Association may add additional funds to install a traffic bearing water membrane over the entire garage structure as outlined in the report. If the restoration plan is delayed, the plan costs will increase to address more costly repairs associated with the concrete and metal deck of the garage structure.

The Harbours Condominiums - Garage
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Introduction

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INTRODUCTION

Background

THP was retained by The Harbours Condominiums to review the general conditions of the garage located in Jeffersonville, Indiana along the Ohio River. THP conducted the survey of the garage on July 30 and August 6, 2015. The observations, conclusions, and recommendations contained in this report are based exclusively on the following:

- Review of rebar shop drawings for the concrete framed original garage dated August 29, 1991.
- Review of the steel framed garage addition drawings, dated September 19, 2000.
- Visual survey of all slab soffits, floor slabs, beams, columns, and walls.
- Visual survey of waterproofing elements, which includes sealants.
- Visual survey of stair towers.
- Visual survey of façade.
- Representative floor slab chain drag delamination survey.

This report is based on conditions existing as of the date of our survey. THP is confident that these recommendations are appropriate given the scope of our review. THP cannot predict precisely when structural and waterproofing components may fail or otherwise require additional repair. This report contains no express warranty concerning the observations, conclusions, and recommendations. Conditions change with time and use of the facility, thereby meriting further inspection, as well as, potential changes in the recommendations contained herein. It is critical that the Owner timely implement the repairs and maintenance identified in the report and periodically re-evaluate for future repairs and maintenance.

The conclusions and recommendations in this report are provided to the Owner for repair/maintenance planning and budgeting purposes. This report is not intended to be used as a construction document.

THP analyzed the field data and prepared the following report for the garage, along with recommended repairs and an opinion of probable cost as part of the restoration plan.

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A short narrative on the "History of Salt Use" and "Slab Tendons in Post-Tensioned Concrete Structures" are included on the following pages for a description of the garage deterioration mechanisms.

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History of Salt Use

Over fifty years ago, state highway departments in the northern United States adopted policies of "bare-pavement" winter roadway maintenance. These policies led to the use of vast quantities of deicer salts. Toward the end of the 1960's a significant increase in the rate of deterioration of highway structures was noted. In the late 1970's, it became generally recognized that this increased deterioration was due to corrosion of embedded reinforcement accelerated by the presence of chloride, which is the major chemical component in deicer salts. In the late 1970's, it also became generally recognized that parking structures in the northern United Sates were suffering from the same symptoms as highway structures. It is difficult to overstate the severity of salt-induced corrosive deterioration on reinforced concrete structures. On the national level, its destruction of both public and private infrastructure has been estimated as high as $5 billion per year.

Salt-Induced Corrosion in Reinforced Concrete Structures

The process of salt-induced concrete deterioration begins when vehicles track in salt laden slush. The slush melts into saltwater that drips onto the deck and is absorbed into the concrete. When salt dissolves in water, chloride ions are liberated. These ions lower an otherwise high pH concrete matrix, which provides a natural passivity to embedded reinforcing steel. A pH of greater than 11.5 is believed to stabilize the protective film on the embedded steel. Once the pH drops below this value the natural passivity, or protective film, is destroyed and corrosion can be supported and sustained.

Steel reinforcing embedded in concrete will, after a period of time, be completely surrounded with a thin film of oxide compounds. This thin film serves as a protective barrier between the steel and oxygen-bearing moisture, which penetrates the concrete through cracks and pores in the concrete surface. As long as the oxide barrier remains intact, the steel is protected from corroding.

Concrete is normally an alkaline material, which is responsible for the maintenance of the protective oxide film. The stability of the oxide film is upset, however, by the presence of negatively charged chloride ions. Both sodium chloride and calcium chloride deicing agents

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ionize in water, releasing over 60 percent of their weight as chloride ions. These highly reactive ions lower the pH (reduce the alkalinity) of concrete and eventually compromise the iron-oxide film surrounding the embedded steel reinforcing. The compromised oxide film allows the detrimental corrosion process to begin, if the steel is exposed to oxygen and moisture.

Research has shown that a certain "threshold" concentration of chloride ions will support the corrosion process and continue it at approximately the same rate regardless of higher chloride ion concentrations. Once the concentration of chloride ions is over the threshold level, the amount of oxygen-bearing water at the level of the steel reinforcement influences the corrosion rate. Since time is required for the ions and moisture to penetrate the overlaying concrete, the depth of steel reinforcement cover, the permeability of the concrete, and the presence of a water seal on the surface of the concrete are critical factors, among others, in establishing the time before the corrosion process begins, and the rate of the corrosion process once it has commenced.

The iron-oxide (rust) that is produced as a result of the exposure of the steel to oxygen-bearing moisture has a much larger volume than the parent metal. As a steel reinforcement bar rusts, its volume increases by over a factor of six. This expansion produces large internal splitting stresses in the concrete. In the case of a reinforced concrete slab, where the steel reinforcement is in layers below the surface of the concrete, this pressure from expanding rust first splits the concrete above the rebar away from the concrete below the rebar. This action is termed a "delamination." At the initial stages it may or may not be visible from the surface. At this stage, however, the concrete ceases to be a coherent mass, and the bond between the concrete and steel reinforcement (which is structurally critical) is lost. Continued internal pressure will eventually crack the concrete through to the surface. In the case of top-surface delaminations, the mechanical action of traffic or the uplift caused by entrapped freezing water will eventually completely loosen the delaminated concrete resulting in a "spall." For ceiling delaminations, gravity, vibration from traffic, and pressures from freezing water are responsible for loosening the delamination, resulting in the concrete eventually falling from the ceiling.

Before steel can corrode, positive iron ions must leave the surface of the steel. These iron ions then normally combine with negative oxygen ions in the local environment of the steel

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reinforcement. Since these iron ions are actually positively charged atoms, their ability to leave the parent metal requires the material surrounding the steel bar be a conductor of electrical charge. Salt dissolved in water is a far superior conductor of electric charge than water alone. This electrolytic solution, or electrolyte, does act in surrounding the steel reinforcement in salt-contaminated concrete and greatly enhances the flow of iron ions from the reinforcement after the passive oxide film has been removed.

The Progressive Steps of Chloride-induced Corrosion:

1. Application of salt deicing compounds either by direct application to the structure or by indirect application from melt water and slush carried onto the structure by vehicles.
2. Absorption of the ionized chloride and water into the concrete through cracks and surface pores, and penetration to the level of the reinforcing steel.
3. Lowering of the pH of the concrete in the vicinity of the reinforcing steel, and compromising of the protective oxide layer around the steel.
4. Increase of the electrical conductivity of the concrete in the vicinity of the reinforcing steel.
5. Electrochemical corrosion of the now unprotected steel in the presence of water, oxygen, and a conductive electrolyte creating a complex of iron-oxide corrosion products (rust).
6. Expansion of the reinforcing steel due to the formation of rust and the creation of internal pressures.
7. Internal splitting or “delamination” of the concrete.
8. The separation reaches the surface and a “spall” is created.
9. The spall is removed by the action of traffic and the pressure of entrapped freezing water.
10. Continuation of the process with continued exposure of the structure to moisture.
11. Eventual loss of reinforcing steel bond to the concrete, reduction of usable steel area, and loss of concrete cross-sectional area until the reinforced concrete loses its structural integrity.

Figure 1 depicts the major steps of this process.

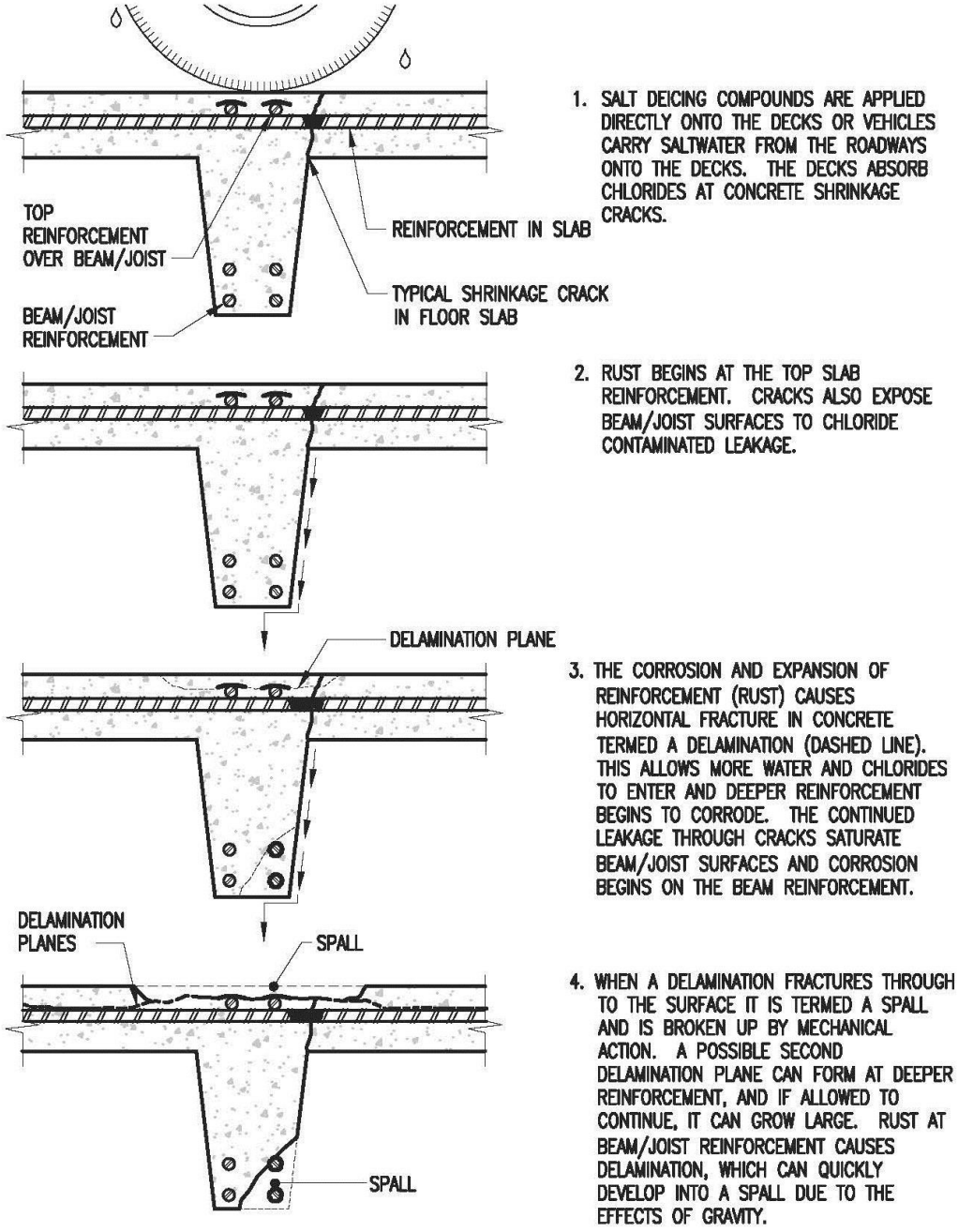

FIGURE 1
PROGRESSIVE STEPS OF CORROSION DETERIORATION.

Slab Tendons in Post-Tensioned Concrete Structures

The potential for corrosion of the high-stressed, high-strength cables in post-tensioned concrete presents additional concerns relative to long term deterioration. In this type of structural system, the primary reinforcement is composed of high strength steel wires in sheathing that is installed in the slab prior to the concrete being placed around them. After the concrete hardens, these cables are pulled and stretched with hydraulic jacks to nearly 30,000 lbs. After jacking, the wires are locked-off at anchorages, typically called end anchorages or intermediate anchorages depending on their locations in the slab. Jacking or tensioning of the wires after the concrete is cast yields the term "post-tensioning." It produces a beneficial compression in the concrete and provides reinforcement in that manner. Two types of post-tensioning systems are commonly used, bonded and un-bonded. In un-bonded systems, the wires are pre-coated with grease, are never grouted and are permanently free to slide within the sheathing.

Post-tensioning tendon corrosion differs from that of mild steel corrosion in several significant ways:

- In un-bonded systems, tendon corrosion is usually not forewarned by concrete spalling because the expanding oxide product fills voids in the sheathing and does not exert expansive splitting forces on the concrete.
- Tendon corrosion normally occurs at localized points along the tendon length as opposed to along substantial lengths of mild steel reinforcement. These points occur where tendons are exposed due to sheathing terminations, ruptures or tears, alone or in combination with, leaking cracks or joints and inadequate grease protection.
- Very little corrosion and pitting are required before tendons break due to their stressed state. Also due to their high tension stress from initial jacking, great energy is released when un-bonded tendons break, analogous to a broken rubber band.
- When broken, an un-bonded tendon's structural value could be lost throughout its entire stressed length between anchorages.

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Garage Report

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Garage Report

STRUCTURAL DESCRIPTION

The Harbours Condominium Garage was built as two phases and two different structure types. The lower levels consist of a slab-on-grade level (Level 1) and three structured levels of concrete framing (Level 2 to Level 4). The two upper levels (Level 5 and Level 6) is steel framed with a composite concrete slab. Vehicle access to the garage is located at the north elevation via a secure gate. The traffic pattern in the garage is two-way circulation. The footprint of the garage is approximately 122 ft. by 172 ft., totaling 92,500 sq. ft. of supported slab, plus the Level 1 on grade parking (Photo 01).

The original concrete framed section of the garage was built in 1991. The construction type is a cast-in-place post tensioned garage. This construction type consists of high strength post tensioned (PT) steel cables embedded in the concrete slab and beams as the main reinforcement. The slab is 7 in. thick and spans approximately 23 ft. 6 in. between PT concrete beams. The structural PT cables run perpendicular to the concrete beams and a second layer of PT cables run parallel to the main beams to help limit cracking and distribute load to the structural cables. The PT reinforced concrete beams are 16 in. wide by 30 in. deep and span approximately 60 ft. to the reinforced concrete columns (Photo 02).

The steel framed garage expansion was built in 2000. The footprint is offset approximately 15 ft. to the east of the original garage. Openings are cut in the original slab for the installation of concrete columns that support the steel columns that frame Level 5 and Level 6. The slab is a 6 in. thick system consisting of a 3 in. deep 20 gauge composite metal deck plus 3 in. of concrete above the flutes of the metal deck. The composite slab system typically spans 9 ft. to castellated steel beams. A castellated beam is produced by cutting a beam length-wise following a hexagonal pattern. The top and bottom halves of the beam are then staggered and welded together to create a deeper beam. The steel beams are 27 in. deep and span 60 ft. to steel columns (Photo 03 and 04).

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Each level of the garage is connected to the condominium building for patron access. Steel stairs at the north and south elevation provide patron access between Level 4 and Level 6. A hot dipped steel stair is located between Level 1 and Level 2.

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OBSERVATIONS

Slab of the Steel Framed Garage Expansion

The Level 6 (roof) concrete slab is deteriorating at the surface from water infiltration and freeze-thaw. The freeze-thaw action is breaking apart the cementitious paste at the slab surface, exposing the concrete aggregate, and opening the pores of the slab to additional water infiltration.

Water ponds along the east slab edge of the Level 6 flat bay (Photo 05). The water does not pitch to the two floor drains along the slab edge. The worst slab freeze-thaw deterioration is along this slab edge. The ponding water is corroding the base of the steel garage columns and vehicular barrier posts (Photo 06). Waterproofing was previously installed at the base of the columns and posts at the south end of the flat bay (Photo 07). However, water is still migrating around the columns and posts and corroding the garage steel framing below. The water that does not pond along the flat bay runs down the Level 6 sloped bay (Photo 08). A metal stud wall with an EDPM roof membrane was installed in order to limit water drainage and windblown rain from entering the garage (Photo 09).

A chain drag survey was performed on Level 6 and representative areas of the lower garage levels. A heavy steel chain is pulled across the garage slab listening for solid versus hollow audible noises. The audible difference in the sound locates debonded/deteriorated concrete from corrosion of steel rebar versus intact solid concrete. The survey of steel framed garage slab located approximately 600 sq. ft. of deteriorated concrete slab either from freeze-thaw or corrosion of embedded steel rebar (Photo 10 and 11). The slab deterioration will continue to accelerate from the porous nature of the slab due to freeze-thaw damage (Photo 12).

Deterioration of the concrete slab is also accelerating from failed sealant, open slab cracks, and missing sealant at slab construction joints. Chloride-contaminated water is migrating down to the structural composite metal deck and steel beams causing corrosion. Below is a summary of these typical conditions:

- The sealant located in a Level 6 construction joint between two slab pours is deteriorating from UV exposure and debonding from the concrete (Photo 13).

- A composite metal deck concrete slab is conducive to cracking as a parking garage. Cracks appear from concrete shrinkage, restraint from the large slab pours without joints, and top slab tensile stress over beams due to negative moments (Photo 15). The thickness of the cracks is more than a "hairline," which is allowing water to migrate into the slab down to the metal deck (Photo 15).
- Waterproofing sealant is missing at slab construction joints (Photo 16).

Slab of the Original Concrete Framed Garage Section

The cast-in-place post tensioned concrete lower levels are experiencing slab deterioration from being more heavily parked, resulting in more cyclic loading and track-in chloride-contaminated ice melt. In addition to the tracked in water, wind-blown rain is creating ponding water on the south side of Level 4 (Photo 17). Sections of the concrete framed slab experience freeze-thaw damage, but less severe than Level 6 (Photo 18 and 19). The representative chain drag slab survey of the lower levels located approximately 1,550 sq. ft. of deterioration. The deterioration is concentrated at slab post tensioned intermediate anchorages (construction Joints) due to the extra steel rebar at these joints from the hydraulic jacking forces. Sealant was not installed at the slab construction joints, which has allowed chloride-contaminated water to migrate to the steel rebar (Photo 20).

Garage Ramp over the Bicycle Storage Room

The exterior garage vehicle ramp at the north elevation is built as a structured slab with steel rebar (Photo 21). The condominium bicycle storage room is located below the ramp. Approximately, 100 sq. ft. of slab deterioration was surveyed on the ramp from the chain drag survey. The steel rebar appears to have been placed near the slab surface which is corroding more quickly due be its location in the higher concentration of chloride ions in the concrete (Photo 22).

Slab Chloride Ion Content Testing

To aid in the evaluation of the garage and to determine the extent of chloride contamination in the floor slabs, chloride ion content testing of concrete powder samples was performed. Concrete powder samples were removed from six locations. Laboratory testing of the powder

samples taken in one inch increments down to a depth of 2 in. or 3 in. depending on the location in the garage to determine the chloride contamination of the floor slabs from exposure to deicing salts, either tracked in or by direct application.

Research has established that chloride concentrations in the range of 1.3 to 1.9 lbs/yd^3 will promote and accelerate corrosion of grey steel rebar in concrete with the presence of moisture and oxygen.

A summary of the floor slab chloride laboratory test results are below. The test results from CTL Group are in Appendix A. The CTL results are provided as a weight percentage and the result below have been converted into pounds per cubic yard (lbs/yd^3).

1: Level 5 Drive, West Flat Bay		2: Level 5 Park, East Sloped Bay	
0 to 1 inch depth	7.87 lbs/yd^3	0 to 1 inch depth	11.8 lbs/yd^3
1 to 2 inch depth	2.35 lbs/yd^3	1 to 2 inch depth	1.68 lbs/yd^3
2 to 3 inch depth	1.33 lbs/yd^3	2 to 3 inch depth	0.78 lbs/yd^3
3: Level 6 Park, West Flat Bay		**4: Level 3 Park, West Flat Bay**	
0 to 1 inch depth	7.95 lbs/yd^3	0 to 1 inch depth	10.3 lbs/yd^3
1 to 2 inch depth	2.98 lbs/yd^3	1 to 2 inch depth	1.41 lbs/yd^3
2 to 3 inch depth	1.02 lbs/yd^3		
5: Level 3 Drive, West Flat Bay		**6: Level 3 Drive, East Sloped Bay**	
0 to 1 inch depth	18.3 lbs/yd^3	0 to 1 inch depth	18.6 lbs/yd^3
1 to 2 inch depth	1.84 lbs/yd^3		

Samples 1 through 3 are from the steel framed section of the garage. Per the original garage drawings, slab temperature/crack control steel rebar is located above the metal deck typically with a clear distance to the top of approximately 1 in. to 1-1/2 in. The chloride tests indicate the embedded steel rebar is at the threshold for corrosion with moisture and oxygen. More rapid concrete slab deterioration is anticipated at the slab if the current conditions are maintained.

Samples 4 through 6 are from the original post-tensioned concrete slab at the lower levels. Original garage drawings were not available for review. Similarly built garages typically have slab rebar located near the top slab over the girders and near the bottom slab at mid-span between girders. The higher chloride concentration at the top 1" of the slab, as compared to the steel framed garage, is likely due to age and being more heavily parked, resulting in more track-in chloride-contaminated ice melt. The chloride tests indicate the embedded steel rebar, near the top of the slab over the girders, is in an environment that promotes rebar corrosion. The testing corresponds to the high quantity of slab deterioration surveyed from the chain drag survey.

Soffit/Underside of the Concrete Metal Deck Slab and Steel Framing

The original garage drawings indicate that the metal deck was designed compositely and required structurally for the concrete slab. The embossing of the metal deck transfers shear forces between the concrete and metal deck creating the composite slab system. The metal deck is the "tension" reinforcement for the slab. The original drawings do not show steel rebar in the bottom flutes of the metal deck which would indicate that the deck was design only as a form. Therefore, corrosion of the metal deck is a structural capacity concern that weakens the garage slab. The following issues are occurring at the metal deck:

- Corrosion of the metal deck is occurring above girders and beams due to water leakage at slab cracks and construction joints (Photo 23). The corrosion is causing sections of the deck to completely deteriorate since the material is only 20 gauge thick (0.0355 in.) (Photo 24).
- Corrosion of the metal deck is occurring near the slab edge below Level 6 due to the water drainage and ponding water (Photo 25).
- Corrosion of the deck is occurring adjacent to the beam interrupting the continuity of the deck (Photo 26 and 27).

The upper levels' steel framing is experiencing minor surface corrosion from water leakage through the slab and metal deck and at slab edges. The following issues are occurring at the steel framing:

- The worst surface corrosion is occurring at the middle of the garage between the east and west bays (Photo 28). The slab pitches to the middle of the garage to floor drains. Water bypasses the drains at cracks and failed waterproofing.
- The metal studs supporting the wall EDPM roof membrane are heavily corroded between flat and sloped bay of Level 6. One stud is completely failed due corrosion (Photo 29).
- Water is running down the face of the steel framed columns at the middle of the garage. The worst steel corrosion is located at the column (Photo 30).
- Section loss of the steel framing is not visible and supplemental steel reinforcement does not appear necessary at this time.

Garage Car Fire Damage

A two vehicle car fire occurred in the garage on the east bay of Level 5 in July 2015. The garage structure immediately adjacent and above the car fire was reviewed:

- Concrete slab delaminations and spalls did not occur due to the car fire heat at Level 5 or Level 6 based on a chain drag survey.
- The steel beams at Level 6 above the car fire have damage to the paint system (Photo 31).
- The composite metal deck above the car fire is warped and damaged. The metal deck does not appear to be acting composite with the concrete slab (Photo 32).

Soffit/Underside of PT Concrete Slab and Concrete Framing

No visual signs of concrete deterioration at the slab soffit, beams, and columns exist in the original concrete garage. Slab waterproofing is not installed at slab construction joints and at the openings cut in the slab for the concrete columns supporting the steel framed addition. Water is leaking around the slab openings at the new concrete columns which will eventually cause deterioration (Photo 33).

Condominium Building Connector Bridges

Connector bridges to the condominium building are located at the upper levels of the garage since the steel structure is offset from the concrete structure (Photo 34). The waterproofing

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sealant installed in the joint between the garage and bridge is typically failed and water infiltration is causing corrosion of the steel bent edge plates below (Photo 35). Connector bridges are also located at the southwest corner of the garage at Level 3 and 4 (Photo 36). The waterproofing sealant installed in the joint between the garage and bridge is deteriorating from exterior exposure and debonding from the edge of the concrete (Phot 37). The powder coated paint system on the rails at the connector bridges is wearing from UV and daily contact resulting in corrosion of the steel (Photo 38).

Garage Stairs

A steel framed stair tower with concrete landings is located between Levels 4 and 6 at the north and south elevations of the garage. The following issues are occurring at the stairs:

- The construction joint between the garage slab and concrete landings is open allowing water to infiltrate to the steel framing (Photo 39).
- The stairs, especially the north elevation stringers, are beginning to show minor signs of corrosion (Photo 40).
- The steel framing and metal deck below the landings are experiencing wear and corrosion (Photo 41).

A hot-dipped galvanized stair is located in the west bay of the garage between Level 1 and Level 2 (Photo 42). No visual issues were observed at the stair tower.

Garage Facade

The perimeter wall panels at the steel framed upper levels consist of a perforated metal panel welded to steel channels and angles. The bottom panel support consists of two angles welded together to create a "U" shape. This profile is collecting debris and water corroding the steel (Photo 43). The perforated metal panels' paint coating is wearing from atmospheric exposure and has minor signs of corrosion (Photo 44). Paint repairs or replacement of the metal panels is not part of the restoration plan and would be anticipated in more than five years.

The perimeter wall panels at the concrete framed lower levels consist of precast concrete panels attached to the garage structure via welded embed plates and angles (Photo 45). The

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sealant between adjacent panels is breaking down from UV exposure (Photo 46). Minor surface corrosion is occurring at the welds connecting the panels to the garage structure due to insufficient painting.

A CMU wall is located at the west elevation of the garage between Level 5 and Level 6. A tan paint coating is installed on the wall and wearing from UV exposure, allowing water to migrate into the wall system (Photo 49). The flashing at the Level 6 slab and wall top appears to be functioning to limit water infiltration.

A property wall is located at the north elevation of the garage, which supports the garage ramp. The precast panels and cap stones at the top of the wall are stained from biological growth and exposure since it is north facing and near vegetation (Photo 50).

DISCUSSION

The Harbours Condominium Garage review and restoration plan is well timed with the lifecycle of the parking garage. More costly structural repairs exist in the garage to address corroded composite metal floor deck. However, a majority of the recommend repairs address waterproofing issues that will prevent additional structural repairs. If the recommended restoration plan is not implemented in a timely manner, costly structural repairs will be necessary at widespread composite metal deck corrosion, section loss of structural steel, and concrete repairs at the lower levels including post tensioned cable repairs.

A summary of the restoration plan and the corresponding reason to implement the repairs are detailed below under either the steel framed levels or original concrete framed levels.

Steel Framed Garage Repairs – Upper Levels

The steel framed garage expansion drawings provided by the Condominium Association indicate a composite metal deck and concrete slab. Therefore, the metal deck is a permanent structural part of the slab system and not a temporary form used to pour the concrete over the steel beams. The metal deck acts as the tension reinforcement of the concrete slab similar to steel rebar embedded into a concrete slab. It is critical to prevent the corrosion of the metal deck.

The restoration plan recommends the following repairs to the steel framed garage levels:

- Repair the floor slab deterioration from corrosion of embedded steel and freeze-thaw damage.
- Install a 4 foot wide concrete drainage wash along the slab edge of Level 6 at the middle of the garage. The wash would be designed to prevent water from ponding along the slab edge and direct it to floor drains. The installation of additional floor drains is recommended along the wash, which could be connected into the existing piping.
- Install a traffic bearing slab membrane on both Level 5 and Level 6 of the garage. The traffic bearing membrane prevents water from penetrating into the concrete slab.

Additional membrane material will be required on Level 6 to fill the voids in the concrete slab from the freeze-thaw deterioration.

- Install supplemental steel angles and tubes to support the slab below corroded metal deck and at the car fire. The slab currently spans 9'-0" between castellated steel beams. The supplemental steel would support the slab at a shorter span, which would not require the metal deck. The steel would also reinforce the bearing immediately adjacent to the castellated beams where corrosion is occurring at slab cracks and construction joints.
- Replace the metal stud wall at Level 6 that prevents wind-blown rain from entering the garage. The replacement system would be similar construction, but the details would coordinate with the slab membrane to prevent water infiltration at the slab edge.
- Perform epoxy paint repairs to steel framing experiencing more significant corrosion. The painting will typically occur at the middle of the garage between the flat and sloped bays.
- The supplemental steel repairs at the metal deck, steel paint repairs, and membrane installation is also planned for the north and south elevation stair towers.

Concrete Framed Original Garage Repairs – Lower Levels

The concrete framed lower levels of the garage are reinforced with high strength post tensioned steel cables embedded in the slab and beams. Corrosion of the cables typically occurs at the intermediate anchorages (construction joints). At this point, the restoration plan is not recommending the entire slab of the concrete framed levels be coated with a traffic bearing waterproofing membrane. A combination of installing a membrane system and water repellent is recommended on the lower levels. The installation of a complete membrane system may be necessary in 5 to 10 years depending on how deterioration continues. The Condominium Association may select the option to install the membrane on the entire concrete framed slab now. The cost associated with this option will be discussed in the restoration plan.

The restoration plan recommends the following repairs to the concrete framed garage levels:

- Repair the floor slab deterioration from corrosion of embedded steel repair and freeze-thaw damage.
- Install a traffic bearing slab membrane system on areas of the slab experiencing significant freeze-thaw damage and install a 4'-0" wide strip over the construction joints at intermediate post tensioned anchorages.
- Install a water repellent on sections of the slab not planned to receive the membrane. The water repellent will help shed chloride-contaminated water from penetrating the slab. Therefore, it will slow chloride ions from building up in the slab resulting in steel rebar corrosion.
- The installation of the water repellent is also recommended on the garage ramp above the bicycle storage room after completing concrete repairs.
- Install supplemental drains at ponding water.

Façade Garage Repairs

The restoration plan recommends the following façade repairs:

- Replace the sealant between adjacent precast wall panels at the lower levels.
- Perform paint repairs at the steel embed plates at the precast wall panels.
- Clean out, install weeps, and perform paint repairs to the bottom "U" shaped steel support for the upper levels' façade panels.
- Install an elastomeric paint coating on the CMU wall between Level 5 and Level 6 at the west elevation of the garage to limit water infiltration.
- Clean and install a water repellent on the north elevation property wall to limit additional dirt buildup.

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The Harbours Condominiums - Garage
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Restoration Plan

RESTORATION PLAN

Overview

A five-year restoration plan totaling $832,000 for repairs and maintenance issues is outlined in the following pages for the Harbours Condominium Garage in Jeffersonville, Indiana.

Cost Summary by Year:

- 2015 $44,250
- 2016 $363,750
- 2017 $245,750
- 2018 $149,250
- 2019 $29,000

A significant investment is recommended in waterproofing (traffic bearing membrane) the entire slab in the steel framed levels of the garage to protect the composite metal deck and waterproofing approximately 25 percent of the concrete framed levels to protect PT cables and slow freeze-thaw deterioration. These waterproofing repairs would be in conjunction with concrete slab repairs, slab drainage repairs, and supplemental drains. The Condominium Association may decide to install the traffic bearing waterproofing membrane on the entire lower levels' slab in lieu of installing a water repellent. A water repellent helps shed chloride-contaminated water to the drains where a traffic bearing waterproofing membrane prevents chloride-contaminated water infiltration since it is a coating. The price difference between the water repellent and traffic bearing waterproofing membrane is $1.00 verse $5.00 per sq. ft. respectively installed on the slab. The installation of the traffic bearing waterproofing membrane over the entire lower levels would add approximately $145,000 to the restoration plan.

The other work associated with the restoration plan address the following repairs:

- Install supplemental steel framing to decrease the composite metal deck span at the car fire and corroded sections. This work is planned in 2015 and 2016 due to the structural concerns with the metal deck span.
- Install an epoxy paint system on steel framing experiencing corrosion.
- Sealant repairs at the connector bridges to the condominium building.
- Façade painting and sealant repairs.

The following notes supplement the Proposed Garage Restoration Plan and are referenced as a superscript where applicable.

(1) Probable costs are based on 2015 dollars and adjusted with a 2% year inflation.

(2) An allowance for A/E fees has not been included in the repair costs.

(3) Budget and review do not include allowance for plumbing, electrical, lighting, and mechanical systems of the garage.

(4) Funds allocated for maintenance repairs are intended to account for unforeseen conditions and anticipated routine repair items that subsequently occur.

(5) Costs are based on performing all yearly work as one repair package and not separated between multiple contractors or repair packages.

The Harbours Condominiums - Garage
Proposed Garage Restoration Plan [1] [2] [3] [4] [5]

2015 Recommend Repairs			
Year	Repair Type	Total Price	
2015	Level 6 (Roof): Reinforce Damaged Composite Metal Deck of the Concrete Slab from Car Fire	$	15,000.00
2015	Level 5 & 6 (Roof): Reinforce Corroded Composite Metal Deck of the Concrete Slab	$	12,500.00
2015	Repair Concrete Slab Deterioration - Emergency Type Work	$	9,000.00
2015	General Conditions, Barricades, Mobilization, Profit	$	5,250.00
2015	Contingency	$	2,500.00
Total 2015 Opinion of Probable Repair Cost		**$**	**44,250.00**

2016 Recommend Repairs			
Year	Repair Type	Total Price	
2016	Level 6 (Roof): Install Concrete Wash Along Flat Bay	$	13,500.00
2016	Level 6 (Roof): Install Concrete Wash Along Sloped Bay	$	10,500.00
2016	Level 6 (Roof): Install Concrete Wash at Crossover / Parking Stops	$	7,750.00
2016	Level 6 (Roof): Install Supplemental Drains Along Wash	$	9,000.00
2016	Level 6 (Roof): Repair Concrete Slab Deterioration above Steel Framing	$	9,500.00
2016	Level 6 (Roof): Install Slab Waterproofing Membrane above Steel Framing	$	121,500.00
2016	Level 6 (Roof): Repair Metal Stud Wall and Waterproofing	$	8,500.00
2016	Level 5 & 6 (Roof): Reinforce Corroded Composite Metal Deck of the Concrete Slab	$	37,500.00
2016	Level 2-4: Repair Concrete Deterioration above Concrete Framing	$	66,250.00
2016	Level 2-4: Install Slab Waterproofing Membrane Strips at PT Construction Joints	$	13,000.00
2016	General Conditions, Barricades, Mobilization, Profit	$	44,500.00
2016	Contingency	$	22,250.00
Total 2016 Opinion of Probable Repair Cost		**$**	**363,750.00**

The Harbours Condominiums - Garage
Proposed Garage Restoration Plan [(1) (2) (3) (4) (5)]

2017 Recommend Repairs		
Year	Repair Type	Total Price
2017	Level 6 (Roof): Miscellaneous Painting of Steel Framing	$ 27,500.00
2017	Level 5: Miscellaneous Painting of Steel Framing	$ 27,500.00
2017	All Levels Bridges: Install an Expansion Joint Between Garage and Condo	$ 4,500.00
2017	All Levels Bridges: Miscellaneous Painting and Sealant Repairs Between Garage and Condo	$ 5,000.00
2017	Level 5: Repair Concrete Slab Deterioration above Steel Framing	$ 14,500.00
2017	Level 5: Install Slab Waterproofing Membrane above Steel Framing	$ 107,500.00
2017	Garage Vehicle Ramp: Repair Concrete Deterioration	$ 4,500.00
2017	Garage Vehicle Ramp: Install a Water Repellent on the Slab	$ 2,250.00
2017	Garage Vehicle Ramp: Install an Expansion Joint at the Garage.	$ 4,000.00
2017	Garage Vehicle Ramp: Clean Biological Growth from the Exterior Panels at North Elevation	$ 3,500.00
2017	General Conditions, Barricades, Mobilization, Profit	$ 30,000.00
2017	Contingency	$ 15,000.00
Total 2017 Opinion of Probable Repair Cost		**$ 245,750.00**

2018 Recommend Repairs		
Year	Repair Type	Total Price
2018	Level 5-6: North & South Elevation Steel Stair Repairs: Painting, Deck Repairs, Waterproofing	$ 10,000.00
2018	Level 2-4: Waterproofing Slab Penetrations at Concrete Column Supporting the Steel Framing	$ 7,500.00
2018	Level 2-4: Install Slab Waterproofing Membrane at Areas with Freeze Thaw Deterioration	$ 63,000.00
2018	Level 2-4: Install Slab Water Repellent at Areas with No Freeze Thaw Deterioration	$ 35,000.00
2018	Level 2-4: Concrete Panel Exterior Façade Sealant Repairs and Paint Support Angles	$ 6,500.00
2018	General Conditions, Barricades, Mobilization, Profit	$ 18,250.00
2018	Contingency	$ 9,000.00
Total 2018 Opinion of Probable Repair Cost		**$ 149,250.00**

The Harbours Condominiums - Garage
Proposed Garage Restoration Plan [(1) (2) (3) (4) (5)]

2019 Recommend Repairs			
Year	Repair Type	Total Price	
2019	Level 5-6: Install Paint Coating on West Elevation CMU Wall	$	8,750.00
2019	Level 5-6: Steel Panel Exterior Façade Debris Removal, Install Weeps, and Minor Touch-up Painting	$	10,000.00
2019	Level 2-4: Supplemental Drains	$	5,000.00
2019	General Conditions, Barricades, Mobilization, Profit	$	3,500.00
2019	Contingency	$	1,750.00
Total 2019 Opinion of Probable Repair Cost		**$**	**29,000.00**

Total Proposed Garage Restoration Plan Opinion of Probable Repair Cost	**$**	**832,000.00**

The Harbours Condominiums - Garage
Condition Review & Restoration Plan

Photos

The Harbours Condominiums Garage - Photo 01

North elevation of garage at the vehicle ramp.

The Harbours Condominiums Garage - Photo 02

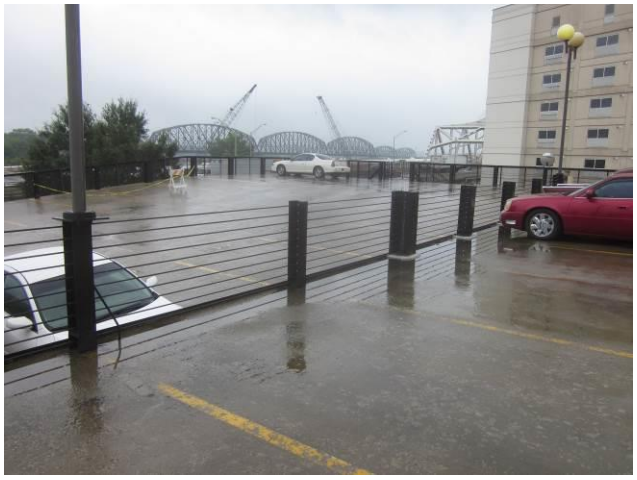
Lower levels garage post tensioned concrete framing. Newer concrete column penetrating the lower level slab supporting the upper levels steel framing.

The Harbours Condominiums Garage - Photo 03

Upper levels garage steel framing with a composite concrete floor slab.

The Harbours Condominiums Garage - Photo 04

Concrete columns at the east elevation supporting the upper levels steel framing.

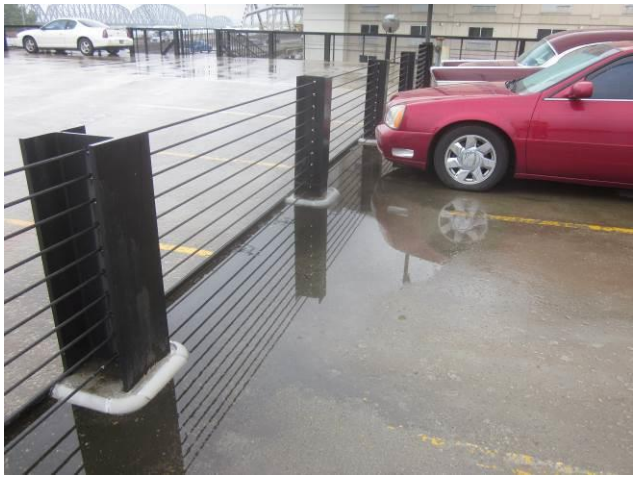


The Harbours Condominiums Garage - Photo 05

Level 6 (roof) ponding water along the flat bay of the garage.

The Harbours Condominiums Garage - Photo 06

Level 6 (roof) ponding water along the flat bay of the garage. Corrosion at the base of the steel garage columns.



The Harbours Condominiums Garage - Photo 07

Level 6 (roof) ponding water along the flat bay of the garage. Freeze-thaw deterioration of the concrete slab along the slab edge.

The Harbours Condominiums Garage - Photo 08

Metal stud wall with an EDPM membrane at Level 6 (roof) between the flat and slope bay of the garage.

The Harbours Condominiums Garage - Photo 09

Metal stud wall with an EDPM membrane at Level 6 (roof) between the flat and slope bay of the garage. Area drain at the bottom of the ramp.

The Harbours Condominiums Garage - Photo 10

Level 6 (roof) slab freeze-thaw deterioration of the concrete slab.

The Harbours Condominiums Garage - Photo 11

Level 6 (roof) slab freeze-thaw deterioration of the concrete slab with an open spall.

The Harbours Condominiums Garage - Photo 12

Level 6 (roof) slab freeze-thaw deterioration of the concrete slab with an open spall developing.

The Harbours Condominiums Garage - Photo 13

Water leakage at deteriorated sealant in a slab construction joint on Level 6 (roof). Water leakage to steel framing below. Concrete slab deterioration adjacent to the joint.

The Harbours Condominiums Garage - Photo 14

Composite concrete floor slab cracking at the steel framed levels of the garage. Cracks run perpendicular to the steel beams.

The Harbours Condominiums Garage - Photo 15

Composite concrete floor slab cracking at the steel framed levels of the garage.

The Harbours Condominiums Garage - Photo 16

Lower level slab construction joint. No sealant installation in the joint.

The Harbours Condominiums Garage - Photo 17

Level 4 ponding water at the post tensioned concrete framing located at the south elevation.

The Harbours Condominiums Garage - Photo 18

Minor slab freeze thaw deterioration at the lower levels post tensioned concrete framing.

The Harbours Condominiums Garage - Photo 19

Slab freeze thaw deterioration at the lower levels post tensioned concrete framing.

The Harbours Condominiums Garage - Photo 20

Concrete spalls at a lower level intermediate slab post tensioned anchor construction joint.

The Harbours Condominiums Garage - Photo 21

Garage concrete vehicle ramp above the bike storage room.

The Harbours Condominiums Garage - Photo 22

Concrete deterioration at the garage vehicle ramp. Shallow rebar with minimum concrete cover.

The Harbours Condominiums Garage - Photo 23

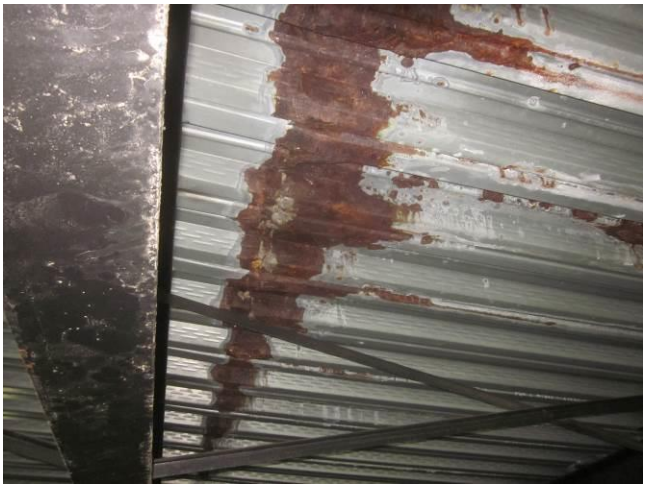
Steel girder top and bottom flange and metal deck corrosion either at a slab crack or open construction joint.

The Harbours Condominiums Garage - Photo 24

Composite metal deck corrosion and minor beam corrosion.

The Harbours Condominiums Garage - Photo 25

Composite metal deck corrosion and steel beam and column corrosion.



The Harbours Condominiums Garage - Photo 26

Composite metal deck corrosion and cracking below Level 6 of the garage.

The Harbours Condominiums Garage - Photo 27

Composite metal deck corrosion and minor beam corrosion.

The Harbours Condominiums Garage - Photo 28

Steel beams, girders, and column corrosion at the separation between the flat and sloped bays of the garage (middle of garage).

The Harbours Condominiums Garage - Photo 29

Steel girders corrosion below the metal stud wall with an EDPM membrane at Level 6. Metal studs are significantly corroded. Right metal stud is failed.

The Harbours Condominiums Garage - Photo 30

Steel column corrosion at the base where it transitions to a concrete column.

The Harbours Condominiums Garage - Photo 31

Level 6 composite concrete metal deck located directly above the July 2015 car fire.

The Harbours Condominiums Garage - Photo 32

Deformed Level 6 composite concrete metal deck located directly above the July 2015 car fire.

The Harbours Condominiums Garage - Photo 33

Water leakage around a concrete column penetrating the lower level framing which support the steel framed portion of the garage.

The Harbours Condominiums Garage - Photo 34

Upper level garage to condominium bridge.

The Harbours Condominiums Garage - Photo 35

Failed sealant joint at an upper level garage to condominium bridge. Corroded steel edge angle below the failed sealant.

The Harbours Condominiums Garage - Photo 36

Lower level garage to condominium bridge.

The Harbours Condominiums Garage - Photo 37

Failed sealant joint at a lower level garage to condominium bridge. No steel edge angle at the lower lever joints.

The Harbours Condominiums Garage - Photo 38

Paint deterioration and minor corrosion at a garage to condominium bridge.

The Harbours Condominiums Garage - Photo 39

Open construction joint allowing water leakage between the garage and exterior steel framed stair, north and south garage elevation.

The Harbours Condominiums Garage - Photo 40

Minor corrosion of the exterior framed stair stringer, north and south garage elevation.

The Harbours Condominiums Garage - Photo 41

Minor corrosion of the exterior framed stair steel and metal deck, north and south garage elevation.

The Harbours Condominiums Garage - Photo 42

Galvanized metal steel between Level 1 (slab-on-grade) and level 2 of the garage.

The Harbours Condominiums Garage - Photo 43

Upper levels perimeter metal panel façade. Debris and water is trapped in the "u" shaped base of the metal panels causing corrosion.

The Harbours Condominiums Garage - Photo 44

Corrosion of the upper levels perimeter metal panel façade and "u" shaped base.

The Harbours Condominiums Garage - Photo 45

Lower levels perimeter concrete panel façade. Failed sealant between two adjacent panels.

The Harbours Condominiums Garage - Photo 46

Lower levels perimeter concrete panel façade. Failed sealant between two adjacent panels.

The Harbours Condominiums Garage - Photo 47

Minor corrosion of the steel angle embed plates/angles supporting the concrete panel façade.

The Harbours Condominiums Garage - Photo 48

CMU wall at the upper levels west elevation of the garage.

The Harbours Condominiums Garage - Photo 49

CMU wall at the upper levels west elevation of the garage. Worn paint coating allowing water to migrate into the wall system.

The Harbours Condominiums Garage - Photo 50

Biological growth and staining at the exterior wall panels of the garage entrance ramp, north elevation.

The Harbours Condominiums - Garage
Condition Review & Restoration Plan

Appendix A – Concrete Chloride Testing

DRAFT

Client:	**THP Limited, Inc.**	CTL Project No:	**430014**
Project:	**The Harbours Garage Assessment**	CTL Project Mgr.:	**Ross Kelly**
		Analyst:	**MS**
Contact:	**Greg Schmitz**	Approved:	*Cyler Hayes*
Submitter:	**Greg Schmitz**	Date Analyzed:	**13-Aug-15**
Date Received:	**10-Aug-15**	Date Reported:	**14-Aug-15**

REPORT of ACID-SOLUBLE CHLORIDE

Sample Identification			Determined Chloride	
CTL ID	Client ID	Description	(wt% sample)	(ppm Cl)
4029801	1-A	Concrete Powder	0.201	2010
4029802	1-B	Concrete Powder	0.060	600
4029803	1-C	Concrete Powder	0.034	340
4029804	2-A	Concrete Powder	0.302	3020
4029805	2-B	Concrete Powder	0.043	430
4029806	2-C	Concrete Powder	0.020	200
4029807	3-A	Concrete Powder	0.203	2030
4029808	3-B	Concrete Powder	0.076	760
4029809	3-C	Concrete Powder	0.026	260
4029810	4-A	Concrete Powder	0.263	2630
4029811	4-B	Concrete Powder	0.036	360
4029812	5-A	Concrete Powder	0.468	4680
4029813	5-B	Concrete Powder	0.047	470
4029814	6-A	Concrete Powder	0.476	4760

Notes:
1. This analysis represents specifically the samples submitted as received.
2. Analysis by potentiometric titration with silver nitrate. (ASTM C1152-04(2012)^{e1})
3. This report may not be reproduced except in its entirety.

DRAFT

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