CONDITION APPRAISAL

# UNIVERSITY OF NORTH DAKOTA PARKING FACILITY

GRAND FORKS, NORTH DAKOTA

Prepared for:
UNIVERSITY OF NORHT DAKOTA

FEBRUARY 4, 2016

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PROJECT # 21-4163.00

FEBRUARY 4, 2016

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## EXECUTIVE SUMMARY

Walker Restoration Consultants (Walker) performed a facility appraisal in November of 2015 to assess the condition of the University of North Dakota Parking Facility in Grand Forks, North Dakota. This report provides a summary of our investigation for the parking facility (parking ramp), but specifically excludes the skyway bridge and east tower facilities pursuant to the Agreement between the University of North Dakota and Walker.

This report includes detailed descriptions of current conditions, repair recommendations, an opinion of probable construction cost for repairs and a 20-Year maintenance budget forecast. Facility components assessed include structural, waterproofing, and façade elements and limited evaluation and documentation of mechanical, electrical and parking access / revenue control systems (PARCS). The facility appraisal consisted of visual observations, but also non-destructive concrete testing and limited concrete materials testing.

In general, the University of North Dakota Parking Facility is in good condition. At the time of the site investigation, we identified loose concrete façade panels at the tops of many columns and one loose concrete cap that we required by secured and/or removed as soon as possible due to safety concerns. No other life safety deficiencies were observed at the time of the site visit.

Recommended current, or short-term, repairs and/or maintenance actions include the following:

| | |
|---|---|
| Structure: | Perform concrete patching, field-topped crossover concrete replacement, and expansion joint installation. |
| Façade: | Repair façade panel attachments, loose concrete caps, correct reverse-sloped flashing at skyway windows, replace broken brick and enlarge brick expansion joints at upper levels. |
| Waterproofing: | Begin replacing sealants and installing penetrating sealers. |
| Mechanical: | Replace broken drain pipes and flush all drains. |

| | |
|---|---|
| Electrical: | Replaced damaged conduit and clean corrosion from corroded conduit. The existing lighting is being evaluated for replacement by others at this time. |
| PARCS: | The existing PARCS is being evaluated for replacement by others at this time. |

An opinion of probable construction costs for current recommended repairs or maintenance actions is $389,200 which includes structural, waterproofing, façade, mechanical and electrical repairs, and a project contingency. Refer to Appendix A for additional information. These actions are recommended to improve serviceability, maintain structural integrity of the facility and provide reliable operation of systems.

Replacement of the parking access / revenue control (PARCS) system has been evaluated by others and is currently scheduled for replacement. Walker is available to peer review this system upon the University's request.

Replacement of the lighting system has been evaluated by others and is currently scheduled for replacement. Walker is available to peer review this system upon the University's request.

In addition, a budget forecast for anticipated repairs, preventative/long-range maintenance costs, and large capital expenditures (e.g. lighting replacement) to assist in planning for these expenses over the next 20 years. Refer to Appendix B for further information.

**Opinion of 2016 Probable Construction Cost**

Structural/Waterproofing/MEP

| | |
|---|---|
| Mobilization | $39,000 |
| Concrete Repairs | $149,000 |
| Waterproofing | $131,000 |
| Facade | $38,000 |
| Mechanical/Electrical/Coatings | $6,600 |
| Contingency | $32,400 |
| **CURRENT REPAIR TOTAL** | **$396,000** |

# INTRODUCTION

## OBJECTIVE

The objective of this engagement is to determine the present physical condition of the existing University of North Dakota Parking Facility in accordance with our proposal dated August 5, 2015.

The objective of this engagement is to:

- Determine the physical condition of the structural, waterproofing, façade, mechanical and electrical systems.
- Identify areas that may require immediate attention.
- Recommend appropriate repairs/alternatives and maintenance actions.
- Present mechanical and electrical system repairs, maintenance and enhancement options.
- Develop an opinion of probable cost for repairs, maintenance actions and enhancement option costs.
- Present a 20-year Budget Forecast to plan for future and recurring maintenance items

The appraisal included the following:

- Structural, Waterproofing, and Facade Condition Survey
- Electrical & Mechanical Condition Survey

## FACILITY DESCRIPTION

Built in 2006, the University of North Dakota Parking Facility is a precast, prestressed concrete parking structure approximately 298 feet long and 186 feet wide. The slabs consist of pre-topped double tees bearing on inverted tee beams, spandrels, columns and wall panels. The parking structure is supported on pile foundations with cast in place grade beams and pile caps. There are four supported parking levels (Levels 2-5) with a total supported floor area of 220,000 square feet and a slab-on-grade (Level 1 and partial Lower Level) with a floor area of 57,000 square feet. The lower level is a concrete slab-on-grade and includes an enclosed storage/shop facility at the center bay that is separated from the parking area.

The parking facility has three (3) combination stair – elevator towers located at the southwest, southeast and northeast corners. The southwest tower extends below grade and connects to a subway to the west. The southeast tower is connected to a skyway bridge across North Columbia Road at Level 3. The landings are field-topped precast concrete plank and the stairs are precast concrete.

Access to and from the facility is provided by on-grade approaches from Second Avenue North. Traffic flow in the parking facility is two-way ninety-degree parking. The north and south end bays and the east and west bays are flat and the center bay is sloped up to the north. The facility provides parking for approximately 760 vehicles.

The façade walls of the structure includes concrete spandrel and wall panels, concrete spandrel panels with cast-in thin brick, brick masonry and precast stone masonry. The façade glazing of the structure includes storefront and curtainwall window systems at the stair-elevator towers and at the skyway at Level 3.

Mechanical systems include gravity drainage of floors and fixtures, one restroom, a small water heater, automated ventilation and fire suppression systems. Sanitary and storm sewer drains with sump baskets and pumps are provided at the lowest level of each stair tower and at the on-grade storage/shop, but there is no pump included at the shop sump pit. Heat for the facility is provided via district hot water piped to the building. Limited areas contain electric heating systems.

Electrical systems include fire alarm system, electrical distribution and primary/emergency lighting systems. Emergency power is provided via on-site backup generator.

Conveying systems include elevators located at the three ramp towers. The southwest tower has two elevators, the southeast tower has two elevators and the northeast tower has one elevator.

## RECOMMENDATIONS

We recommend the following repairs be performed to restore the University of North Dakota Parking Facility to reduce continued deterioration, maintain safe parking, reduce pedestrian hazards and extend the service life of the structure.

### IMMEDIATE REPAIRS

Based on our observations, we recommended that the loose caps and precast façade panels be secured at Level 5 columns to prevent a falling hazard.

### RECOMMENDED BASE REPAIR

We recommend the following repairs to reduce water leakage and subsequent corrosion-induced concrete deterioration, reduce the extent of future repairs, and to extend the service life of the parking facility.

- Repair isolated concrete floor, wall and column spalls and delaminations
- Replace the pour strips at the end bays at all levels.
- Route and seal surface cracks exposed to water.
- Install penetrating water repellant sealer at the Lower Level, Level 1 and Level 2 slabs.
- Replace failed sealant joints at sealed slabs.
- Correct the slope of negatively-sloped flashings.
- Repair the damaged brick piers at columns.
- Provide proper expansion joints at brick/concrete joints.
- Repair damaged precast panels and caps at Level 5 columns.
- Epoxy inject cracks at the double tees.
- Repair one damaged double tee stem.
- Replace damaged drain pipes and electrical conduit.
- Install a proper expansion joint at Level 1 between the supported deck and on-grade paving.

### PREVENTIVE MAINTENANCE

The following items are recommended preventative maintenance actions to ensure safe and reliable performance of the facility systems.

- Bi-annually wash parking floors and flush drains to reduce accumulation of deicers and organic debris.

- Perform quarterly and bi-annual mechanical system testing and maintenance.

## ENHANCEMENT OPTIONS

We recommend evaluating the existing parking layout when the floors are sealed. We observed ADA violations, improper motorcycle striping, and poorly utilized space with the existing layout.

Satisfactory lighting of parking areas and pedestrian pathways is critical to the positive user perception and safe parking. We understand that the existing lights are affected by vibration and often fail. We recommend installing a new LED lighting system that is energy efficient and meets lighting standards.

## OPINION OF PROBABLE CONSTRUCTION COST

Based on our observations and bidding with other projects, our opinion of probable construction cost to perform the current recommended base repair and preventative maintenance noted herein is $389,200. These items are recommended to be performed in 2016. The values presented are intended for budgeting purposes only and do not include soft costs, testing or engineering costs associated with this work. Please refer to Appendix A for further detail.

## BUDGET FORECAST

A 20-year budget forecast has been developed to assist the owner in planning for future preventative and routine maintenance, as well as replacement of essential systems at the end of their useful life. This forecast is provided in tabular form in Appendix B. We have not attempted to show the soft costs of operating the facility or the daily operating costs (housekeeping, cleaning, security, utilities, etc.), nor have we attempted to identify soft costs of managing the maintenance process as these costs will vary with the type and the amount of maintenance required.

## ANNUAL MAINTENANCE PROGRAM

In addition to the current repairs and preventative maintenance recommendations, it is important to establish and follow a consistent maintenance program. It is important to provide annual observation of the structure to monitor the physical state of the building and maximize the service life of the structure. At minimum, an observation by a licensed professional engineer familiar with restoration of parking structures should be performed on a three-year cycle to provide the owner with a professional opinion as to the current condition of the structure.

Programs for annual observation of parking structures have been implemented by many parking structure owners. One such successful program incorporates annual observations of the structure by a qualified and licensed professional engineer, and is augmented by periodic testing to validate observations.

Below is a recommended recurring cycle of observations:

- Year 1: On-site visual observation of the structure including non-destructive testing (delamination survey or equivalent) and concrete materials testing (chloride-ion monitoring). Observations and data are presented to the structure owner in a certified report.
- Years 2 & 3: on-site visual observation of the structure. Observations and data are presented to the structure owner in a certified report.
- Year 4, and onward: repeat from year 1 and continue monitoring program.

This Annual Maintenance Program allows for adjustments to the maintenance plan to be made as time progresses, bringing the plan up to date with the physical condition of the structure.

## OBSERVATIONS

Walker performed a condition survey of this facility in November 2015. The scope of work consisted of a visual observation of the facility combined with a chain drag survey of the supported slabs with the purpose of locating and quantifying the limits of deterioration within the structure. RILEM Tube testing was performed to evaluate the absorption of the concrete and concrete samples were taken to test for chloride ion concentrations in the top of the slabs. Notes and photographs recorded our observations.

General conditions of the underlined item are identified in the paragraph. Indented, ***bolded and italicized*** following the discussion of noted issues are recommended repairs. Refer to Appendices D and E for information on deterioration mechanisms and terminology used. Observations are summarized below:

## STRUCTURAL CONDITION SURVEY

Visual observations were performed at the parking facility to identify the nature and extent of deterioration, leading to an understanding of trends and severity of distress. A visual examination of the concrete floor surface, wall panels and spandrels, columns, walls, expansion and construction joints, drainage, façade, and miscellaneous items was performed. As part of the visual examination, a parking floor slab delamination survey was performed using a chain drag. This technique consists of dragging steel chains across the floor surface. When the chain passes over a delaminated area, a distinct hollow sound is produced. A hammer was used to selectively "sound" other vertical and overhead structural elements. Delaminated areas are then recorded on a plan sheet, along with other deterioration, to quantify distress and deterioration.

<u>Slab-on-Grade Concrete Floor Surfaces</u>
The slab-on-grade floors are generally in good condition and have a few cracks and spalled areas that can become trip hazards. The joints in the slab are sealed. We noticed that the ramp is supporeted on pile foundations, which generally indicates poor soils. The lowest level slabs are also typcailly pile-supported with the parking structure to limit relative movements between the slab and structure. However, these slabs are bearing on grade and may experience greater

**SUMMARY**

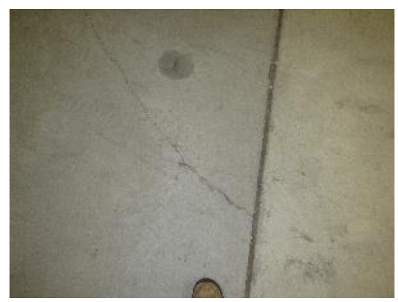


Photo 1


Photo 2


Photo 3

movement, cracking and differential settlement than a typical structure. See Photo 1.

***Patch damaged concrete, route and seal cracked concrete and replace damaged construction joint sealants.***

<u>Supported Concrete Floor Surfaces</u>
The parking area floors are in good condition with a few, small, isolated concrete delaminations in the cast-in-place cocnrete wash and curb areas, and most of the pour strip area over the inverted tee beams where the precast double tees meet. The pour strips and curbs also have the majority of the cracking. One double tee stem was observed to be damaged at the bearing. Spalling and delaminations were observed at the concrete around the connectors that are located between the spandrel panels and the double tee floor members. Refer to Photos 2 through 4.

***Remove and replace delaminated concrete and repair the double tee stem. A structural review should be performed to verify that the connections between the double tees and spandrels are properly designed for their intended loads and movements. Spalled concrete should be repaired.***

A few random cracks were observed in the supported parking floor slabs and at double tee stems at isolated locations. Leaking floor cracks allow direct infiltration of moisture and chlorides into the floor slab. Refer to Photos 5 and 6.

***Rout and seal floor slab cracks and epoxy inject cracks in double tee stems and flanges.***

<u>Floor Slab Construction Joints</u>
Construction joints in the floor slab are located between the double tee flanges and at the edges of the concrete washes, pour strips and curbs. The joints between the double tees have mostly failed and the joints are sealed at the top and bottom. The double sealant traps moisture between the tees and can cause freeze-thaw deterioration, additional chloride contamination, and premature corrosion of reinforcing steel. The joints at the washes, pour strips and curbs have minimal deterioration, but are missing at some locations. Refer to photo 7 for typical joints.

***Remove and replace deteriorate sealants and add sealants where they are missing. Remove all sealant at the bottom of joints to allow moisture to freely drain.***


Photo 4


Photo 5


Photo 6


Photo 7

Traffic Membrane
This parking facility does not have traffic membrane.

Expansion Joints
This parking facility does not have any expansion joints. Typically, the floor joint between the supported slab and the slab-on-grade is an expansion joint to compensate for the lateral movements and vertical movements. The sealant joint at this location has failed and is currently leaking.

***Install a winged expansion joint with blockouts at the joint between the precast double tees and the slab-on-grade.***

Slab-on-grade Exterior Paving
Paving outside of the ramp is cracking and settling at a few locations. Refer to Photo 8.

***Monitor slab cracking and repair trip hazards.***

Walls and Spandrels
Concrete walls and spandrels are generally in good condition. A few areas of cracked and spalled concrete were observed at connections to the columns and structural deck. Tight, vertical cracks were observed at several locations randomly throughout. Refer to photos 9 and 10.

***A structural review should be performed to verify that the connections are properly designed for their intended loads and movements. Spalled and delaminated concrete should be repaired.***

Columns
One column delamination was observed at Level 1, Grid D-9.

***Repair delaminated column concrete.***

Beams
Inverted tee beams were observed to be in good condition. Pigeons were observed to be nesting at some tee beam ledges.

***Optional: Install bird spikes at inverted tee beams.***

Stair and Stair/Elevator Towers
Stair and stair/elevator towers are generally in good condition. The lobbies were covered with carpeting. Carpeting can hold moisture and cause accelerated deterioration of the underlying concrete. The cast-in-place topping slabs were cracked randomly, but were not failing.

***We recommend removing carpet from lobbies. Smooth concrete should be roughened to prevent slipping. Rugs***


Photo 8

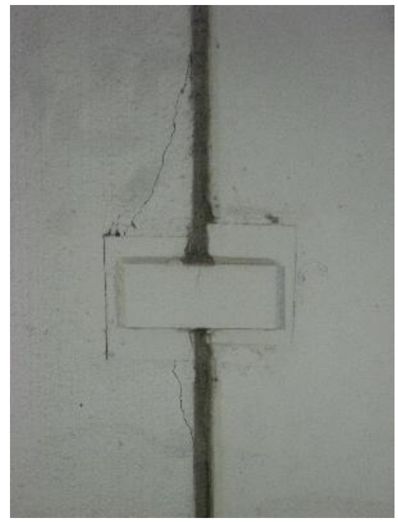


Photo 9


Photo 10


Photo 11

***can be installed in the winter as walk-off areas for snow on shoes.***

Water staining and efflorescence was observed at some of the lobbies at grout pockets over steel connectors and at ceiling tile. It is likely that condensation is causing the water staining.

***Observe windows, grout pockets and mechanical lines during the winter to verify frost or condensation at these areas.***

Facades

The building facades were evaluated visually for performance and deterioration. Some of the observed deficiencies include:

- Failing Sealants
- Cracked brick and mortar joints
- Failed precast column caps and accent bands
- Improperly sloped flashings at window sills
- Storefront/curtainwall mullion caps loosening

The sealants appeared to be at the end of their useful life and are debonding from the substrate material and cohesively failing. The cracked brick appears to be caused by minimal expansion joints between the brick and the building structure. Brick expands as it ages. The vertical stack of brick at the columns does not have relief angles and expansion joints to accommodate the movement. Our thoughts regarding the damage at the column caps and accent bands include the theory that the brick expansion is causing the damage to the caps and accent bands. Improperly sloped flashings below the windows at the south skyway are causing water to leak into the finished space of the skyway interior. Refer to photos 12 through 16.

***Replace failed sealant in the next 3 to 4 years. Cut proper expansion joints into the brick and seal the joints with new, larger sealant joints. Replace cracked brick and mortar joints. Revise the window sill detail to allow the flashing to slope away from the windows. Re-fasten mullion caps that are not completely fastened at glazing systems.***


Photo 12


Photo 13


Photo 14


Photo 15


Photo 16

Roofs

Roofs were not reported to leak, and indications of leaking were not observed at the interior. We understand the roofs are adhered EPDM. Flashings, primary drains and overflow drains appeared adequate. Refer to Photo 17.

***Maintain roof drains and periodically observe roofing seams for damage.***

Photo 17

Drainage

Floor drains and piping were observed to be in good condition and appear to be functioning as designed. Light surface corrosion was noted throughout and a few pipes were observed to be broken and leaking. Refer to Photo 18.

***Replace broken drain lines. Clean pipes on an annual basis. Monitor, clean and paint as needed.***

Photo 18

Electrical and lighting

Electrical systems, powered signage, and lights appeared to be in generally good condition. Some conduit was observed to be corroded where joints above were leaking.

***Replace conduit that is heavily corroded. Clean and paint minimally-corroded conduit.***

Miscellaneous Metals

Miscellaneous metals include bollards, pipe guards, and stair railings. Metals were generally observed to be in very good condition.

***Monitor conditions for deterioration; clean and paint as needed.***

MECHANICAL SURVEY

Mechanical systems were generally observed to be in good condition. There were no reported problems with any of the mechanical systems at the time of the evaluation. Plumbing and ventilation systems were observed to be operating properly. Each of the mechanical rooms adjacent to the elevator shafts has a floor drain. One of these drains was observed to be covered with tape. Refer to photos 19 through 22.

***Monitor systems for performance deficiencies. Flush mechanical room floor drains with water when the ramp drains are flushed.***

Photo 19

Photo 20

Photo 21

## ELECTRICAL SURVEY

Electrical systems were generally observed to be in good condition. Illuminance and lighted emergency exit signage is generally in compliance with requirements. The fire alarm system appears to be in general compliance with requirements. The parking facility has an emergency generator at the northeast corner. Refer to photos 23 and 24.

> ***Maintain lighting as needed and regularly run the generator every month to keep it in working order.***

Existing wiring and circuity was observed visually and facility personnel were interviewed to better determine systems performance. However, hidden deficiencies may be present and concealed from view.

> ***Consider thermal imaging review of electrical systems.***

Existing parking area luminaires contain fluorescent and high-pressure sodium lamps. The addition of motion sensors and modernization of existing systems with current LED technology to enhance illuminance and improve user safety are recommended.

> ***Lighting replacement design by others. Walker is available as an owner's representative upon request.***

Photo 22

Photo 23

Photo 24

## PARCS SURVEY

The PARCS equipment was observed to be functional. It is our understanding that the PARCS system is going to be replaced. Refer to Photo 25.

> ***Walker is available as an owner's representative to evaluate new systems and system options upon request.***

Photo 25

**TESTING**

## CHLORIDE-ION TESTING

Chloride-ion content testing was performed to determine the corrosion potential of the post-tensioning and mild steel reinforcement at various locations in the parking facility. The samples were taken by Walker Restoration and the chloride-ion content testing was performed by American Engineering Testing, Inc. of Saint Paul, MN. Sample location plans are indicated in Appendix C.

Corrosion of mild steel reinforcement may occur when the water-soluble chloride-ions concentrations accumulate to a level greater than 300 parts per million (PPM) along with the presence of moisture and oxygen. This range of chloride concentration is often referred to as the corrosion threshold.

At each site, holes were bored in 1 inch increments for a total depth of 2 inches. The dust samples at each increment are collected and tested providing data indicating the concentration of chloride-ion contamination relative to the depth of concrete. Higher concentrations generally occur on the top surface with diminishing concentrations at lower depths in the concrete. Chloride-ion concentrations at the depth of reinforcement are of particular interest where corrosion potential is of greater concern.

Results of the current chloride-ion testing are shown in Table 1. The critical range for chloride-ion content is between 1" to 2", the depth approaching the reinforcing steel below the floor surface.

**Table 1** – 2015 Chloride-Ion Test Results

| LOCATION | Depth from Top of Slab<br>0" - 1" (PPM) | 1" - 2" (PPM) |
|---|---|---|
| 1 | 2120 | 156 |
| 2 | 800 | 60 |
| 3 | 1640 | 92 |
| 4 | 613 | 61 |
| 5 | 712 | 58 |
| 6 | 333 | 69 |
| 7 | 200 | 72 |
| 8 | 255 | 64 |
| 9 | 122 | |
| 10 | 124 | |

*ASTM C1218 (Water Soluble Chloride Ion Content)*

The current concentrations at the depth of reinforcing steel is not yet significant.

The test results provide an indicator of the chloride-ion contamination relative to the depth of the concrete. The current data at the expected depth of reinforcing steel is below the identified corrosion threshold. The majority of the parking structure slabs are relatively flat parking areas with nominal slope. These areas are not as effective in removing contaminates as compared to the sloped parking areas.

Application of penetrating concrete sealer to the floor surfaces would reduce continued accumulation of new chloride-ions in the structure. Penetrating concrete sealers do not stop the corrosion process, but rather reduces further contamination by chloride-ions and reduces moisture infiltration, thereby reducing the rate of corrosion as it develops.

Other solutions to reduce the rate of corrosion include installation of traffic topping membrane atop concrete surfaces. Generally, this is more effective in reducing the infiltration of chloride-ions, moisture and oxygen into the structure, but is significantly more costly and requires continual maintenance to maintain the protective membrane.

Penetrating concrete sealers are 75% to over 90% effective at reducing moisture and chloride-ions in the floor slab. As noted, sealers will not stop corrosion-induced deterioration of the concrete, but will reduce the infiltration and rate of corrosion. Based on the chloride-ion concentration observed, it appears that significant accumulation has occurred in the top inch of the lower slabs since construction and as such, we presently recommend installing a penetrating sealer at the reinforced slab-on-grade, and at the Level 2 slab in 2015.

Annual cleaning and washing of floor surfaces is recommended to reduce the amount of available chlorides on the top concrete surface. Floor surfaces should be washed bi-annually in the spring to remove salts and other deleterious materials from winter snow and ice control maintenance. Periodic sweeping of the parking facility will also assist in removal of surface-residing chloride residue materials from concrete surfaces and prolong life of sealants and expansion joints systems.

## RILEM TUBE TESTING

Rilem tubes were used to test the absorption of the concrete surface. The concrete absorbed approximately 1 mL (3/4 inch) of water over 20 minutes. It is our opinion that the precast concrete deck is moderately absorptive and should have a penetrating water-repellant sealer installed.

We recommend installing water-repellant sealer at a small area to test the effectiveness of the sealer prior to coating a large area.

Photo 26

## ASSUMPTIONS AND LIMITATIONS

Walker Restoration Consultants developed this report to assist the owner in planning for improvements and maintenance of the facility. We have summarized the evaluation and recommendations in this report for use with additional judgments regarding financial, technical, and operational issues. The recommendations outlined represent current technology for parking structure rehabilitation and maintenance. We have assumed the facility will continue in its present use and will require appropriate repairs and maintenance for this use.

The extent of our evaluation was limited, and required that certain assumptions be made regarding existing conditions. Some of these assumptions cannot be verified within the physical, financial, and time constraints of our work. The report is our expression of our professional opinion to the best of our information, knowledge and belief, and does not constitute a warranty or guarantee of the items noted, the present or future conditions, or the discovery of possible latent conditions.

### BUDGETING AND OPINION ON COSTS

This condition assessment provides budgeting information based on site observations, limited field survey work, professional judgments, and the experience of Walker Restoration Consultants with similar projects. The opinion of probable costs does not provide a warranty as to the accuracy of such cost opinions as compared to contractor bids or negotiated prices for the work.

### DESIGN, ANALYSIS, AND ADA

Since this facility is currently functioning without evidence of shortcomings in the original design of the building, we did not include review of the design, inspection for concealed conditions, or detailed analysis. A comprehensive review of the facility for ADA compliance was not included in the scope of this project, since ADA compliance is a legal determination and not an architectural or engineering finding.

### REUSE AND MODIFICATIONS

The owner shall not reuse or make modifications to the report without the prior written permission of Walker Restoration Consultants.

## APPENDIX A:

## OPINION OF PROBABLE CONSTRUCTION COST

1. Estimated costs are in contemporary dollars and based on one construction season. For multi-season construction, unit pricing and deterioration are expected increase.
2. Estimates are based on normal daytime workweek and historical data of similar types of work.
3. Construction cost may vary due to time of year and the economy.
4. Probable cost does not include engineering or testing.

## Opinion of Probable Construction Cost - 2015

# Structural/Waterproofing/MEP

| Work Item | Description | Probable Cost | Extension |
|---|---|---|---|
| | **Mobilization** | | **$ 39,000** |
| 1.1 | Project Mobilization | $ 39,000 | |
| | **Concrete Repairs** | | |
| | Floors | | **$ 146,600** |
| 3.1 | Floor, Partial Depth | $ 139,600 | |
| 3.4 | Curb, Partial Depth | $ 400 | |
| 3.5 | Slab on Grade | $ 1,400 | |
| 4.1 | Overhead, Partial Depth | $ 1,200 | |
| 8.1 | Double Tee Stem Repair | $ 4,000 | |
| | Beams, Columns, Walls | | **$ 2,400** |
| 7.1 | Wall, Partial Depth | $ 2,280 | |
| 6.1 | Column, Partial Depth | $ 120 | |
| | **Waterproofing** | | |
| | Sealants | | **$ 56,700** |
| 11.1 | Route and Seal | $ 500 | |
| 11.2 | Construction Joint Sealant Replacement | $ 17,600 | |
| 11.11 | Double Tee Flange Sealant Replacement | $ 28,000 | |
| 11.7 | Cove Sealant | $ 1,600 | |
| 10.3 | Expansion Joint with Blockout | $ 9,000 | |
| | Sealers | | **$ 74,300** |
| 15.1 | Penetrating Water Repellant | $ 69,900 | |
| 11.5 | Double Tee Crack Injection | $ 4,400 | |
| | **Façade** | | |
| | Masonry | | **$ 17,000** |
| 35.1 | Replace Brick | $ 2,500 | |
| 35.2 | Repointing | $ 2,000 | |
| 35.15 | Reset Caps | $ 12,500 | |
| | Flashing | | **$ 21,000** |
| 73.1 | Re-slope Flashing at Skyway | $ 21,000 | |
| | **Mechanical/Electrical/Coatings** | | |
| | Mechanical | | **$ 1,600** |
| 25.3 | Replace Drain Pipe | $ 1,600 | |
| | Electrical | | **$ 1,000** |
| 30.3 | Replace Conduit | $ 1,000 | |
| | Coatings/Paint | | **$ 4,000** |
| 45.1 | Restriping Paving | $ 4,000 | |

| | |
|---|---|
| Repair Costs = | $ 324,600 |
| Mobilization (12%) = | $ 39,000 |
| Contingency (10%) = | $ 32,400 |
| **CURRENT REPAIR TOTAL =** | **$ 396,000** |

Notes:
1. Construction costs are in contemporary dollars and based on a normal daytime workweek, one
2. Costs may vary due to time of year, local economy or other factors.
3. Engineering, testing and other soft costs are not included in above values.

## APPENDIX B:

## 20-YEAR BUDGET FORECAST

## 20-Year Budget Forecast

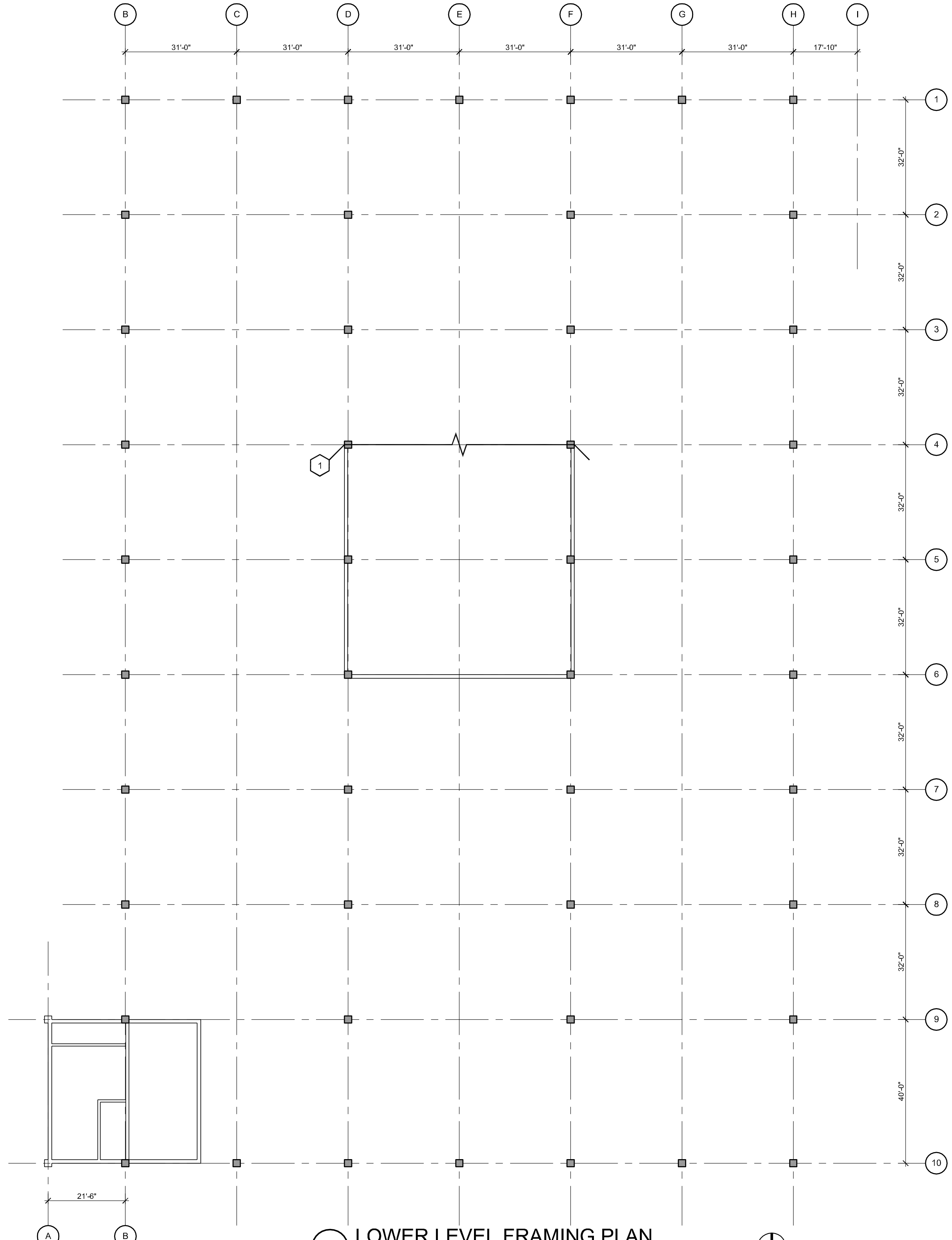
Location: Grand Forks, ND Parking Spaces: 760 Structural Floor Area: 220,000 SF
Construction: Precast Concrete Built: 2006 Total Floor Area: 277,000 SF

| Description | Maintenance Frequency | Current Cost | 20-Year Total Cost | 2017 | 2018 | 2019 to 2021 | 2022 to 2026 | 2027 to 2031 | 2032 to 2036 |
|---|---|---|---|---|---|---|---|---|---|
| **Concrete/Interior Repairs** | | $ 149,000 | $ 661,000 | $ 1,500 | $ 1,500 | $ 18,000 | $ 140,000 | $ 250,000 | $ 250,000 |
| Floors (Top & Bottom Surfaces) | 5 years | $ 146,600 | $ 562,000 | $ 1,000 | $ 1,000 | $ 10,000 | $ 110,000 | $ 220,000 | $ 220,000 |
| Beams, Columns, Walls | 5 years | $ 2,400 | $ 19,000 | $ 500 | $ 500 | $ 3,000 | $ 5,000 | $ 5,000 | $ 5,000 |
| Barrier Cables | 10-20 years | $ - | $ 80,000 | $ - | | $ 5,000 | $ 25,000 | $ 25,000 | $ 25,000 |
| **Waterproofing** | | $ 131,000 | $ 777,700 | $ 227,900 | $ - | $ 4,000 | $ 50,000 | $ 448,800 | $ 47,000 |
| Traffic Bearing Crack and Joint Sealant | 5-10 years | $ 46,100 | $ 190,800 | $ 71,600 | $ - | $ 2,000 | $ 10,000 | $ 105,200 | $ 2,000 |
| Non-Traffic Crack and Joint Sealant | 10-20 years | $ 1,600 | $ 210,800 | $ 61,200 | $ - | $ 2,000 | $ 10,000 | $ 127,600 | $ 10,000 |
| Crack Injection | 5 years | $ 4,400 | $ 13,000 | $ - | $ - | $ - | $ 3,000 | $ 5,000 | $ 5,000 |
| Expansion Joint - Repair | 5-10 years | $ - | $ 5,000 | $ - | $ - | $ - | $ 3,000 | $ 2,000 | $ - |
| Expansion Joint - Replace | 10-15 years | $ 9,000 | $ 9,000 | $ - | $ - | $ - | $ - | $ 9,000 | $ - |
| Apply Penetrating Sealer | 5-10 years | $ 69,900 | $ 260,100 | $ 95,100 | $ - | $ - | $ - | $ 165,000 | $ - |
| Apply/Maintain Traffic Membrane | 7-12 years | $ - | $ 89,000 | $ - | $ - | $ - | $ 24,000 | $ 35,000 | $ 30,000 |
| **Façade/Roof** | | $ 38,000 | $ 1,521,500 | $ - | $ 155,300 | $ 20,000 | $ 195,500 | $ 1,070,200 | $ 80,500 |
| Precast Maintenance | 10-20 years | $ - | $ 193,200 | $ - | $ 50,000 | $ 10,000 | $ 20,000 | $ 103,200 | $ 10,000 |
| Brick Maintenance | 10-20 years | $ 2,500 | $ 90,000 | $ - | $ 25,000 | $ 5,000 | $ 40,000 | $ 10,000 | $ 10,000 |
| Mortar Maintenance | 5 years | $ - | $ 42,000 | $ - | $ 10,000 | $ 2,000 | $ 10,000 | $ 10,000 | $ 10,000 |
| Mortar Repointing | 25 years | $ 2,000 | $ 679,500 | $ - | $ 500 | $ - | $ 1,000 | $ 677,000 | $ 1,000 |
| Wall/Cap Sealants | 10-20 years | $ - | $ 53,200 | $ - | $ 34,800 | $ - | $ 500 | $ 17,400 | $ 500 |
| Glazing Maintenance | 10-20 years | $ 21,000 | $ 35,000 | $ - | $ - | $ - | $ 30,000 | $ - | $ 5,000 |
| Glazing Restoration | 20-30 years | $ - | $ 245,600 | $ - | $ - | $ - | $ - | $ 245,600 | $ - |
| Roof Sealants Maintenance | 5 years | $ - | $ 14,000 | $ - | $ 5,000 | $ 3,000 | $ - | $ 2,000 | $ 4,000 |
| Roof Replacement | 20 years | $ - | $ 84,000 | $ - | $ - | $ - | $ 84,000 | $ - | $ - |
| Parapet/Wall Cap Maintenance | 10-20 years | $ 12,500 | $ 85,000 | $ - | $ 30,000 | $ - | $ 10,000 | $ 5,000 | $ 40,000 |
| **Mechanical-Electrical-Plumbing, Conveying** | | $ 2,600 | $ 1,712,000 | $ 6,000 | $ 6,000 | $ 32,000 | $ 109,000 | $ 146,000 | $ 1,413,000 |
| Annual MEP Maintenance | Annual | $ - | $ 74,000 | $ 2,000 | $ 2,000 | $ 15,000 | $ 20,000 | $ 20,000 | $ 15,000 |
| Flush Drains | Annual | $ - | $ 24,000 | $ 1,000 | $ 1,000 | $ 3,000 | $ 6,000 | $ 6,000 | $ 7,000 |
| Drain Repair/Replacement | 10-30 years | $ 1,600 | $ 33,000 | $ 500 | $ 500 | $ 2,000 | $ 10,000 | $ 12,000 | $ 8,000 |
| Plumbing Fixture Replacement | 10-20 years | $ - | $ 40,000 | $ - | $ - | $ 5,000 | $ 10,000 | $ 20,000 | $ 5,000 |
| HVAC Replacement | 10-20 years | $ - | $ 175,000 | $ - | $ - | $ - | $ 25,000 | $ 75,000 | $ 75,000 |
| Electrical Conduit Repair | 5 years | $ 1,000 | $ 11,000 | $ 500 | $ 500 | $ 1,000 | $ 3,000 | $ 3,000 | $ 3,000 |
| Lighting Replacement (LED) | 20-30 years | $ - | $ 100,000 | $ - | $ - | $ - | $ - | $ - | $ 100,000 |
| Fire Alarm System Replacement | 10-15 years | $ - | $ 25,000 | $ - | $ - | $ - | $ 25,000 | $ - | $ - |
| Elevator Maintenance | 5 years | $ - | $ 30,000 | $ 2,000 | $ 2,000 | $ 6,000 | $ 10,000 | $ 10,000 | $ - |
| Elevator Replacement | 25-30 years | $ - | $ 800,000 | $ - | $ - | $ - | $ - | $ - | $ 800,000 |
| Generator Replacement | 25-30 years | | $ 400,000 | $ - | $ - | $ - | $ - | $ - | $ 400,000 |
| **Architectural Finishes/Miscellaneous** | | $ 4,000 | $ 494,000 | $ 20,000 | $ 36,000 | $ 78,000 | $ 114,000 | $ 132,000 | $ 114,000 |
| Wash/Degrease/Sweep Parking Deck | Annual | $ - | $ 277,000 | $ 14,000 | $ 14,000 | $ 42,000 | $ 69,000 | $ 69,000 | $ 69,000 |
| Parking Revenue System Maintenance | Annual | $ - | $ 40,000 | $ 2,000 | $ 2,000 | $ 6,000 | $ 10,000 | $ 10,000 | $ 10,000 |
| Parking Revenue System Replacement | 10-15 years | $ - | $ 20,000 | $ - | $ - | $ - | $ - | $ 20,000 | $ - |
| Repaint Traffic Markings | 10-15 years | $ 4,000 | $ 12,000 | $ 4,000 | $ - | $ - | $ - | $ 8,000 | $ - |
| Repaint Handrails/Frequent Wear Areas | 7-12 years | $ - | $ 35,000 | $ - | $ 10,000 | $ - | $ 5,000 | $ 15,000 | $ 5,000 |
| Repaint Concrete/Masonry Surfaces | 15-20 years | | $ 110,000 | $ - | $ 10,000 | $ 30,000 | $ 30,000 | $ 10,000 | $ 30,000 |
| Subtotal | | $324,600 | $5,166,200 | $255,400 | $198,800 | $152,000 | $608,500 | $2,047,000 | $1,904,500 |
| Contingency, 10% | | $32,400 | $516,620 | $25,540 | $19,880 | $15,200 | $60,850 | $204,700 | $190,450 |
| General Conditions, 12% | | $39,000 | $619,944 | $30,648 | $23,856 | $18,240 | $73,020 | $245,640 | $228,540 |
| Consulting, Testing, & Engineering Fees, 12% | | $39,000 | $619,944 | $30,648 | $23,856 | $18,240 | $73,020 | $245,640 | $228,540 |
| **Opinion of Maintenance Budget** | | $396,000 | $6,302,764 | $311,588 | $242,536 | $185,440 | $742,370 | $2,497,340 | $2,323,490 |
| | Cost Per SF = | $1.43 | $22.75 | | | | | | |
| | Cost Per Space = | $521.05 | $8,293.11 | | | | | | |
| | | Cost Per SF/Year = | $1.14 | | | | | | |

1. Construction costs are in contemporary dollars and based on a normal daytime workweek, one construction season and historical data of similar types of work.
2. Costs may vary due to time of year, local economy or other factors.
3. Engineering, testing and other soft costs are not included in above values.

# APPENDIX C:

## TYPICAL FLOOR PLAN & TEST LOCATIONS




1 LOWER LEVEL FRAMING PLAN

NORTH


WALKER
RESTORATION CONSULTANTS
1660 South Highway 100
Suite 424
Minneapolis, MN 55416
952.595.9116 Ph
952.595.9518 Fax
www.walkerrestoration.com


OWNER'S AND/OR SUB'S LOGO

# UND
## LOT #10 PARKING STRUCTURE RESTORATION
GRAND FORKS NORTH DAKOTA

MARK | DATE | DESCRIPTION | ISSUE:

PROJECT NO: 21-4163.00
DRAWN BY: RJL
CHECKED BY: MR

SHEET TITLE:
LOWER LEVEL STRUCTURAL PLAN

R100

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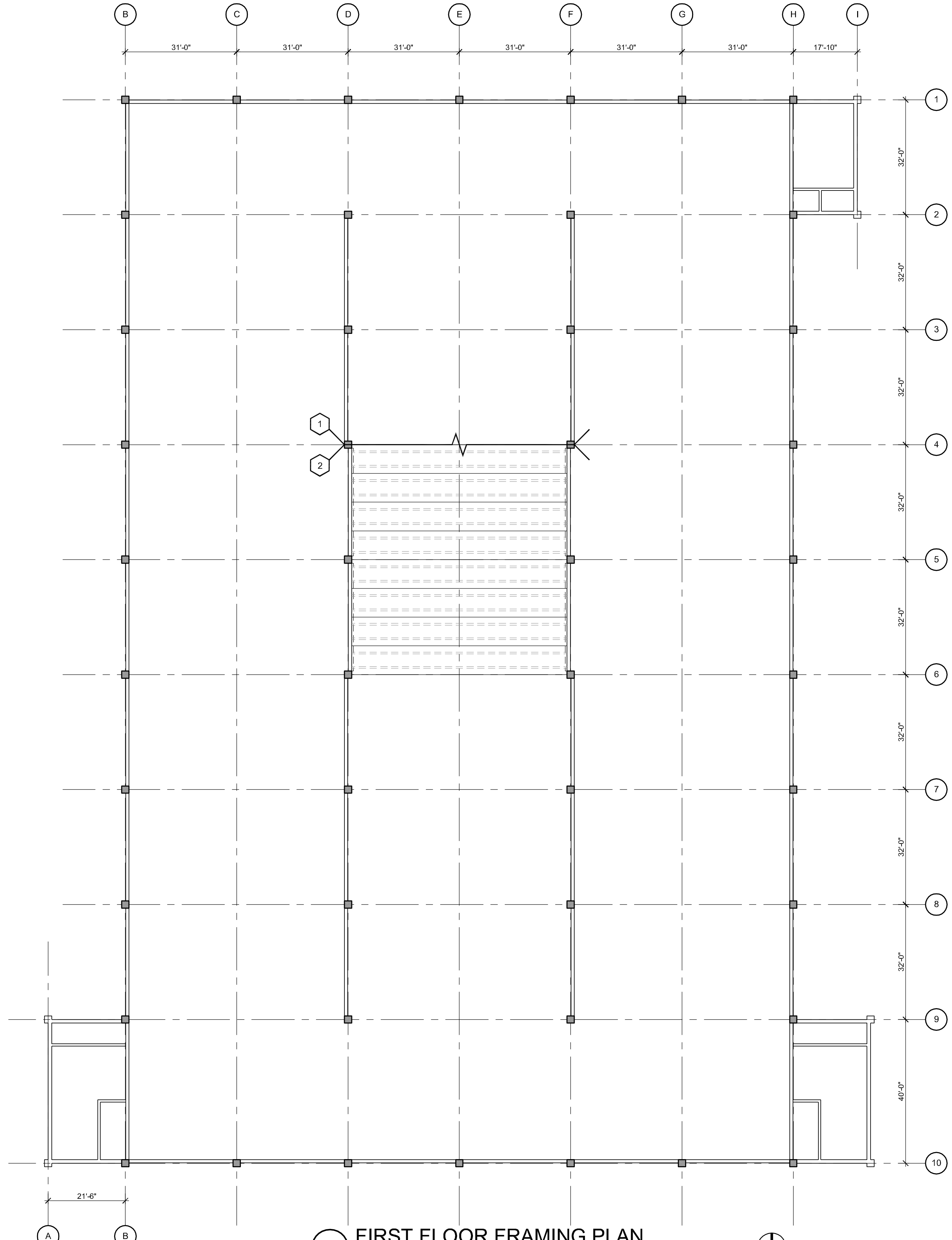


1 FIRST FLOOR FRAMING PLAN

NORTH

**WALKER**
RESTORATION CONSULTANTS
1660 South Highway 100
Suite 424
Minneapolis, MN 55416
952.595.9116 Ph
952.595.9518 Fax
www.walkerrestoration.com

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# UND
## LOT #10 PARKING STRUCTURE RESTORATION
GRAND FORKS NORTH DAKOTA

| MARK | DATE | DESCRIPTION |
|---|---|---|
| | | ISSUE: |

PROJECT NO: 21-4163.00
DRAWN BY: RJL
CHECKED BY: MR
SHEET TITLE:

FIRST FLOOR STRUCTURAL PLAN

R101

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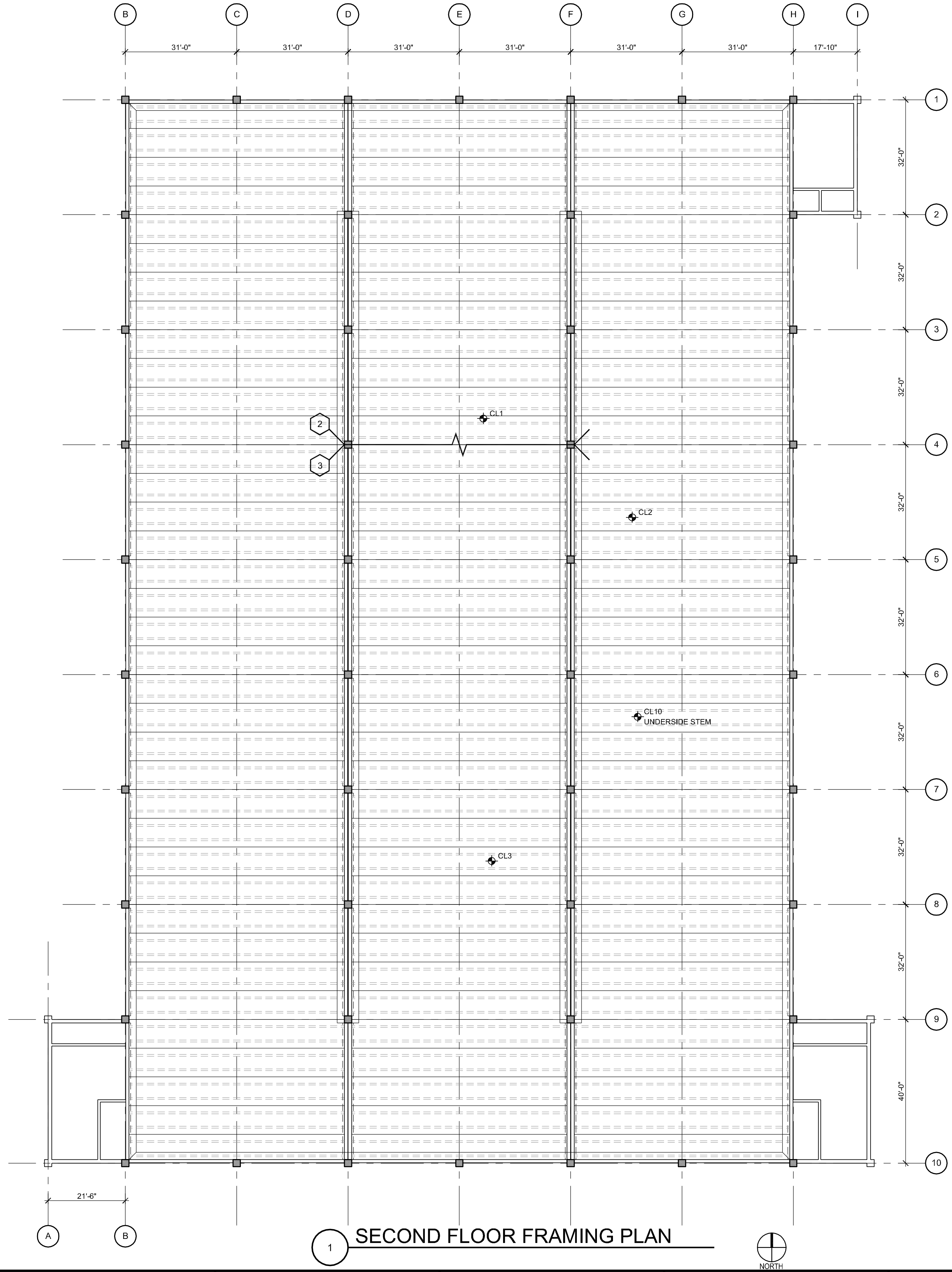


1 SECOND FLOOR FRAMING PLAN


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RESTORATION CONSULTANTS
1660 South Highway 100
Suite 424
Minneapolis, MN 55416
952.595.9116 Ph
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## LOT #10 PARKING STRUCTURE RESTORATION
GRAND FORKS NORTH DAKOTA

| MARK | DATE | DESCRIPTION |
|---|---|---|
| | | ISSUE: |

PROJECT NO: 21-4163.00
DRAWN BY: RJL
CHECKED BY: MR

SHEET TITLE:
SECOND FLOOR STRUCTURAL PLAN

R102

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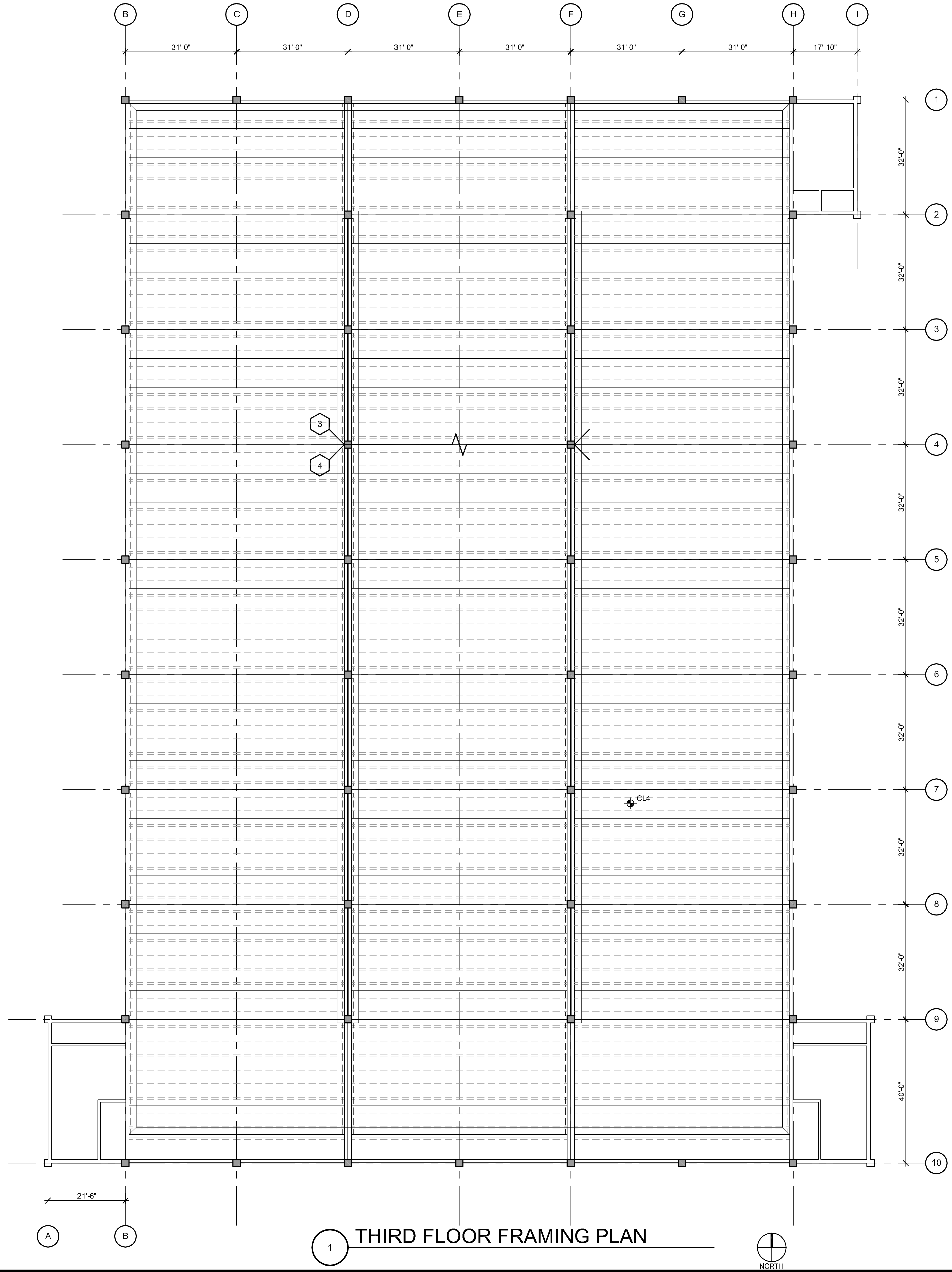


1 THIRD FLOOR FRAMING PLAN


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952.595.9518 Fax
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## LOT #10 PARKING STRUCTURE RESTORATION
GRAND FORKS NORTH DAKOTA

| MARK | DATE | DESCRIPTION |
|---|---|---|

ISSUE:

PROJECT NO: 21-4163.00
DRAWN BY: RJL
CHECKED BY: MR

SHEET TITLE:
THIRD FLOOR STRUCTURAL PLAN

R103

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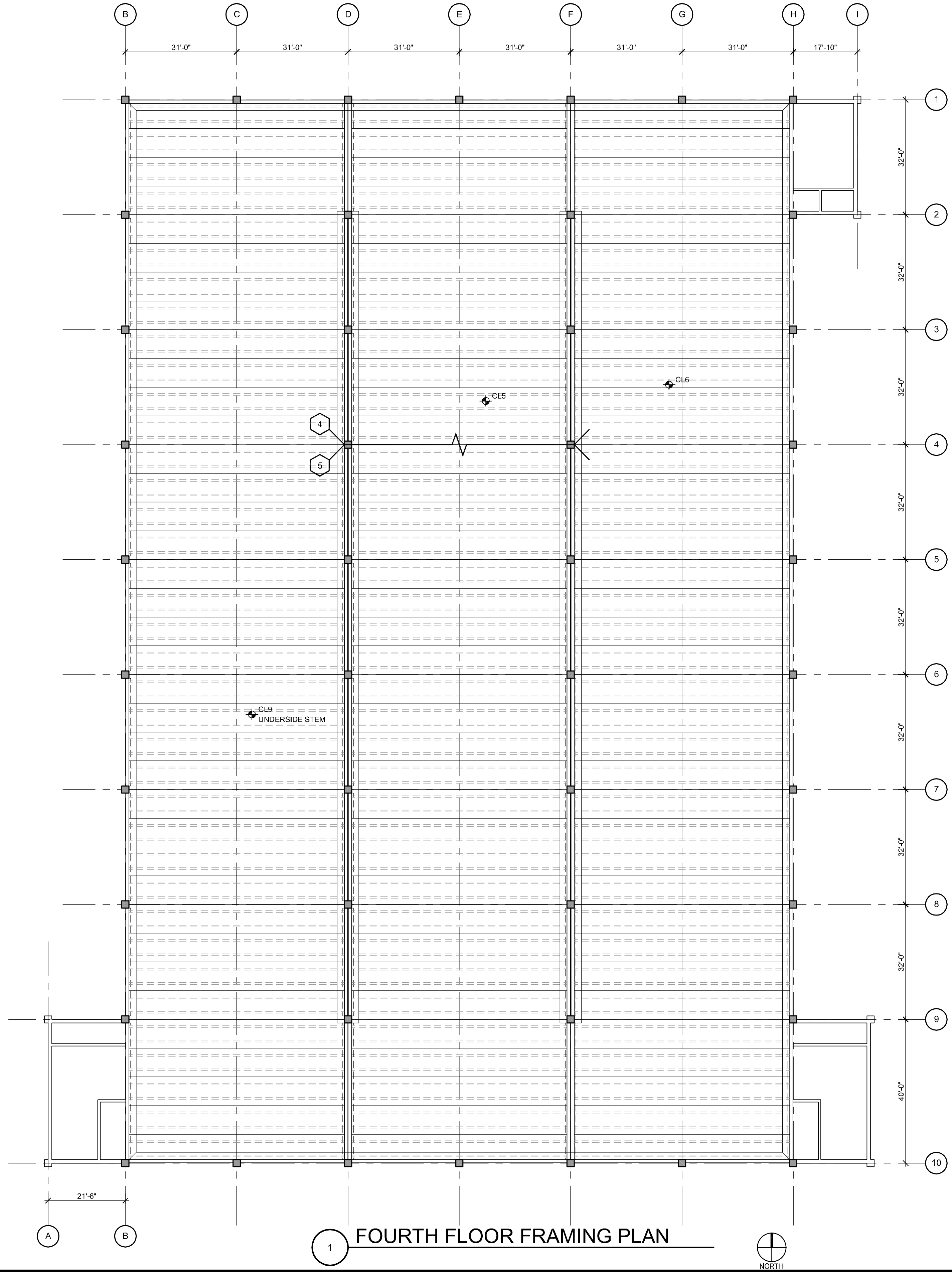


# FOURTH FLOOR FRAMING PLAN

WALKER RESTORATION CONSULTANTS
1660 South Highway 100
Suite 424
Minneapolis, MN 55416
952.595.9116 Ph
952.595.9518 Fax
www.walkerrestoration.com

OWNER'S AND/OR SUB'S LOGO

UND
LOT #10 PARKING STRUCTURE RESTORATION
GRAND FORKS NORTH DAKOTA

| MARK | DATE | DESCRIPTION |
|---|---|---|

ISSUE:

PROJECT NO: 21-4163.00
DRAWN BY: RJL
CHECKED BY: MR

SHEET TITLE:
FOURTH FLOOR STRUCTURAL PLAN

R104

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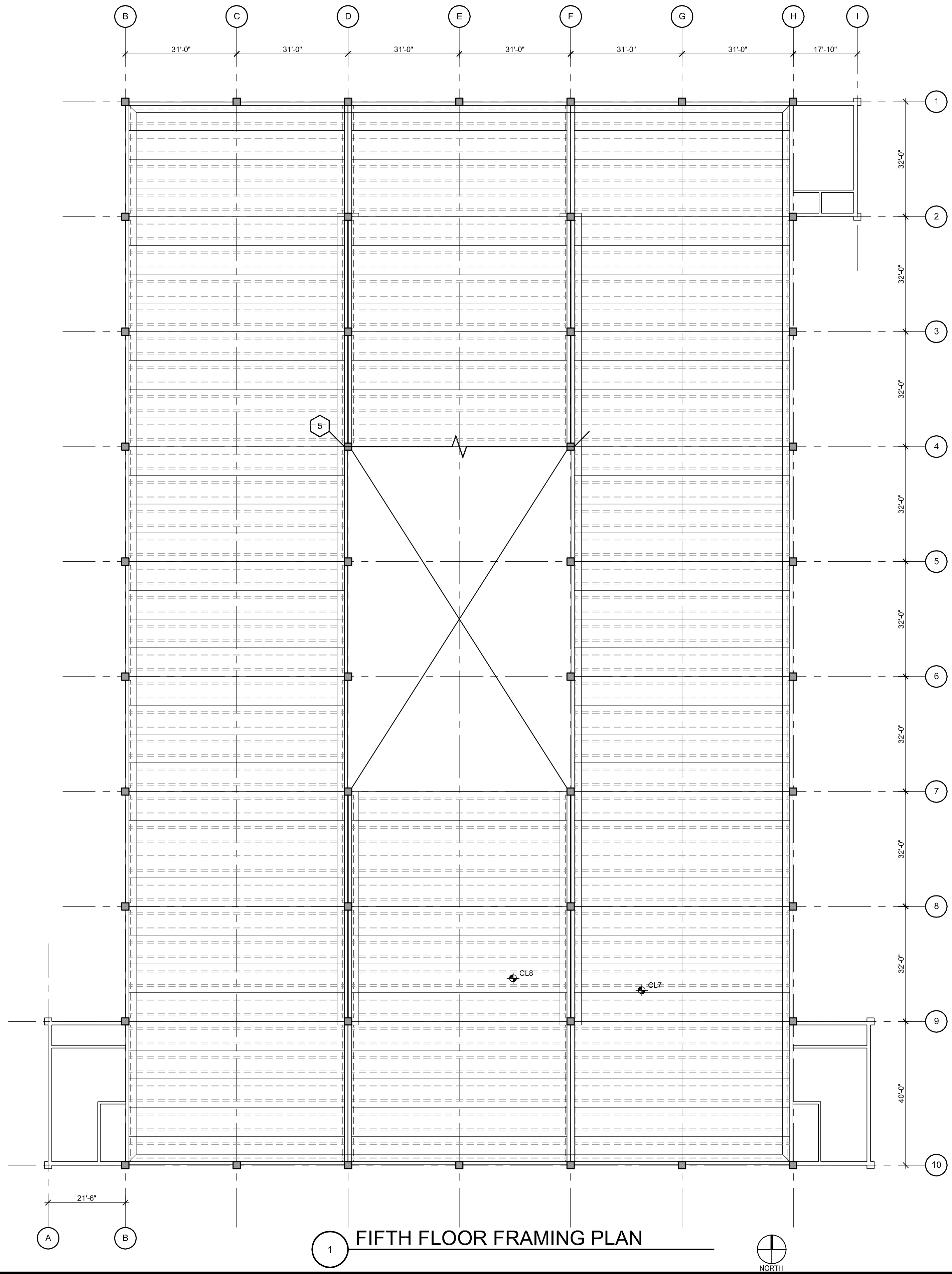


1 FIFTH FLOOR FRAMING PLAN


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RESTORATION CONSULTANTS
1660 South Highway 100
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Minneapolis, MN 55416
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952.595.9518 Fax
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# UND
## LOT #10 PARKING STRUCTURE RESTORATION

GRAND FORKS NORTH DAKOTA

| MARK | DATE | DESCRIPTION |
|---|---|---|
| | | ISSUE: |

| | |
|---|---|
| PROJECT NO: | 21-4163.00 |
| DRAWN BY: | RJL |
| CHECKED BY: | MR |

SHEET TITLE:

FIFTH FLOOR STRUCTURAL PLAN

R105

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## APPENDIX D:

## DETERIORATION MECHANISMS

The following discussion provides information describing typical types of reinforced concrete deterioration. Concrete deterioration generally falls into one of several major categories: corrosion induced spalling, scaling, cracking, and leaching. Concrete deterioration caused by corrosion of reinforcement steel is prevalent throughout the country. The information regarding scaling deterioration due to freeze-thaw cycling is most applicable to the northern tier states, whereas weathering deterioration due to moisture and temperature cycling is applicable in the southern or mild climate states. Joint deterioration is also included in this discussion because it generally contributes to concrete distress. These deterioration mechanisms are, to varying degrees, the cause of the durability problems experienced by many of today's parking structures.

Spalls in reinforced concrete surfaces are usually dish shaped cavities with varying depths and surface areas. Spalls can occur individually or in-groups covering several hundred square feet.

Spalling is preceded by fractures called delaminations. Delaminations are horizontal splitting, cracking or separation of the concrete slab in a plane roughly parallel to, and generally near the upper surface of the concrete. Delaminations are found frequently in bridge deck and parking facilities. The delamination is generally caused by the corrosion of reinforcing steel or by freezing and thawing. Fractures originate at corrosion damaged reinforcement or other embedded metal and migrate to the nearest surface. Freeze-thaw, traffic action and additional corrosion influence the rate of fracture migration and spall development.

| ELEMENT | ATOMIC NO. | ATOMIC RADIUS | IONIC RADIUS |
|---|---|---|---|
| $Cl^-$ | 17 | 0.99Å | 1.81Å |
| $Ca^+$ | 20 | 1.97Å | 0.99Å |
| $Na^+$ | 11 | 1.86Å | 0.95Å |

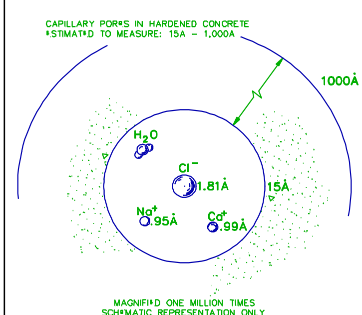



FIGURE A1 – CHLORIDE IONS AND CAPILLARIES

## CONTAMINATION

Concrete is a naturally porous material. Excess water, not required for hydration, eventually dries leaving behind an interconnected network of pores. Concrete pores have diameters ranging from 15 to 1,000 Angstroms. See Figure A1.

The chloride ion diameter is less than 2 Angstroms. Penetration of chloride ions into concrete, and subsequent accumulation, occurs readily on surfaces exposed to deicing salts, wetting and drying and freeze-thaw cycles.

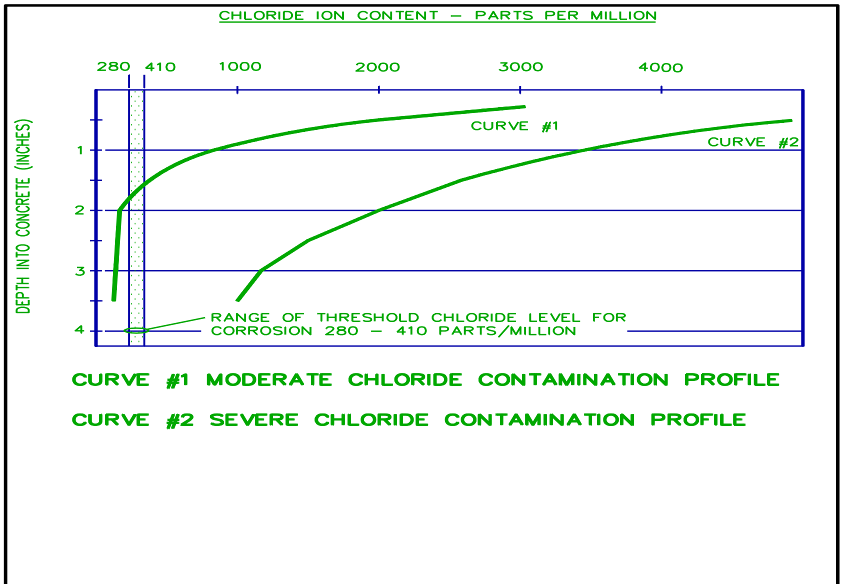



FIGURE A2 – CHLORIDE CONTENT VS. DEPTH INTO CONCRETE

Essentially all concrete is susceptible to chloride ion contamination by virtue of its natural porosity.

A thin oxide film remaining after manufacturing and the passive effect of highly alkaline concrete usually protects reinforcement embedded in concrete. Chloride ions can penetrate all types of concrete and accumulate in sufficient quantities to initiate corrosion of embedded reinforcement. Research indicates that corrosion begins when water soluble chloride ion accumulation exceeds 280 to 410 parts per million in the concrete (or 375 to 550 parts per million of acid soluble). See Figure A2.

## CORROSION

Metallic corrosion is a dynamic electro-chemical process and induces progressive deterioration. Corrosion by-products (rust) occupy a volume at least 2.5 times that of the parent metal. The expansion causes high tensile stress, which cracks ("delaminates") the surrounding concrete. Initial cracking can occur when section loss of the parent metal is five percent or less. Cracks first appear vertically over the reinforcement nearest the exposed surface. These cracks allow direct access of moisture and additional chloride to the reinforcement, causing accelerated corrosion and subsequent delamination.

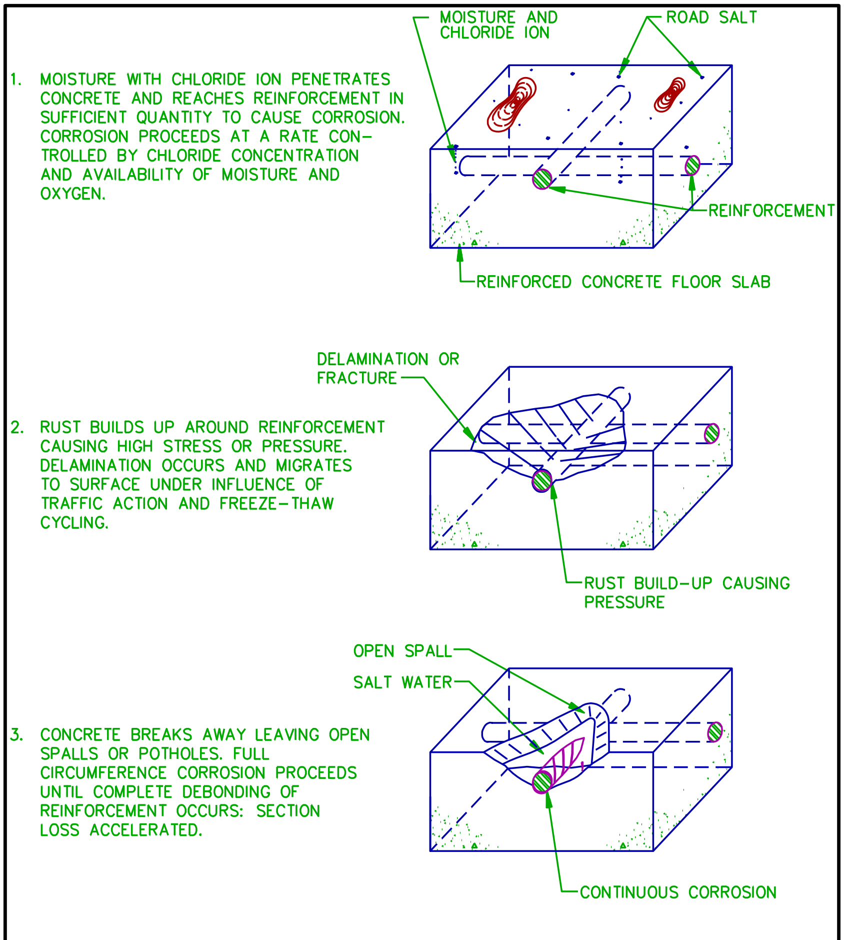



**FIGURE A3 – CORROSION-INDUCED SPALLING PROCESS: FLOORS**

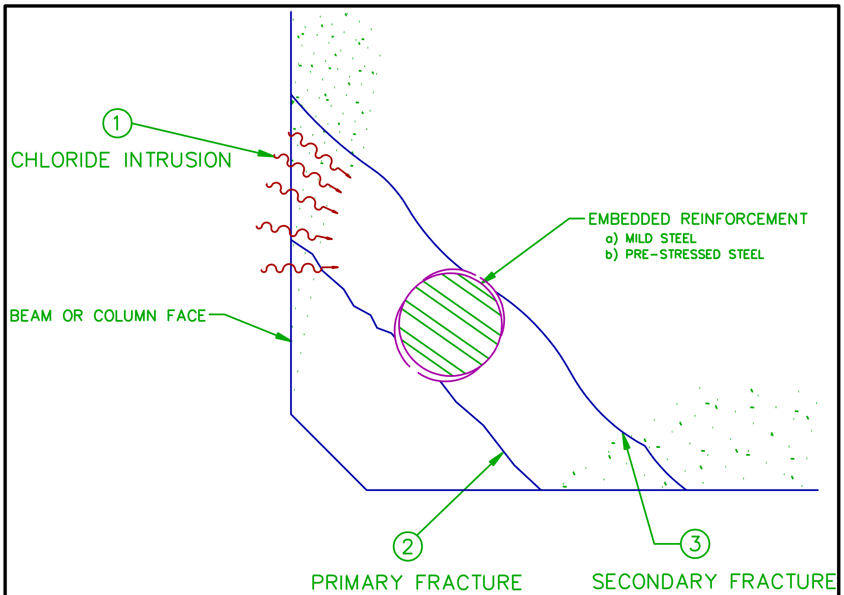
CORROSION INDUCED SPALLING IN FLOOR SLAB

EXTENSIVE FLOOR SLAB SPALLING

## CORROSION INDUCED DISTRESS

The impact that corrosion has on a structural member is variable. Three things happen, all of which are detrimental to the structural integrity:

a. Surface spalling causes maintenance and serviceability problems. See Figure A3.
b. Corrosion results in loss of cross-sectional area of the reinforcing steel. When significant area is lost due to corrosion, the load carrying capacity of the structural member (floor, beam, column) is reduced.
c. Corrosion of reinforcement results in debonding from the concrete causing loss of monolithic interaction. The progressive movement of reinforcement as a result of corrosion induced jacking, especially on columns, can reduce load carrying capacity. See Figure A4.




**PROCESS DESCRIPTION**

1. CHLORIDE ION INTRUSION CONTAMINATES CONCRETE – LOWERS PH AND INDUCES CORROSION OF EMBEDDED REINFORCEMENT.
2. CORROSION BY-PRODUCTS "RUST" DEVELOP AT BAR SURFACE AND REQUIRE EXPANSION ROOM.
3. RUST EXPANSION CAUSES HIGH TENSILE STRESS WHICH CRACKS SURROUNDING CONCRETE.
4. ADDITIONAL SALT WATER GETS INTO CRACKS.

**FIGURE A4 – SPALL DEVELOPMENT-BEAMS/COLUMNS**

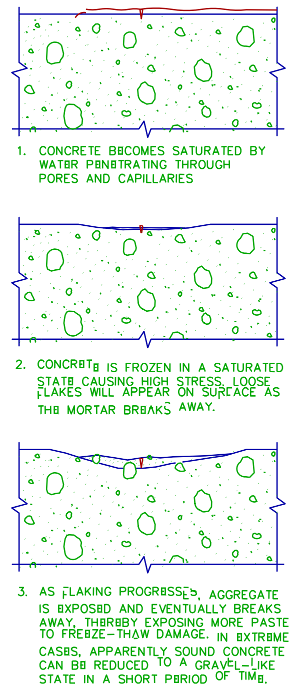



**FIGURE A5 – CONCRETE SURFACE SCALING**

The bottom reinforcement corrodes similar to the top. Surface spalling near mid-span reduces the concrete section as a function of spall depth. Concrete section reduction at mid-span can significantly reduce the structural capacity of the concrete member. At the same time, severe corrosion of bottom reinforcement can result in over stressing and possible reinforcement yielding or failure.

CORROSION OF REINFORCING STEEL IN/THROUGH CONCRETE BEAM

## SCALING

Scaling is characterized by progressive deterioration of the concrete surface through paste (sand/cement) failure. It results from the disruptive forces generated in the paste when the concrete freezes. Scaling is common in those areas of the continent subject to freeze/thaw cycling. See Figure A5.

Scaling begins with a slight surface flaking, which becomes deeper with continuing exposure. Initially, only the surface texture and small amounts of paste are eroded. Eventually, however, coarse aggregate is exposed, and larger surface areas are affected.

Scaling can continuous network of pores and capillaries. This network gives concrete its porosity. Porosity or "permeability" is generally high for concrete mixes with a high water/cement ratio and low for mixes with a low water/ cement ratio.


SURFACE SCALING

High porosity allows the concrete to absorb significant free water during exposure to rain or snow. If concrete becomes saturated during a freeze cycle, ice accumulates in the pore structure.

The destructive mechanism is not ice accumulation itself, but rather pressure generated during ice development. Water migration through the pore network exerts significant pressures during freezing. It has been substantiated that water pressures cause the paste to significantly impair the serviceability of concrete intended as driving or walking surfaces.


HEAVY SURFACE SCALING

Concrete is naturally porous. Excess water not required for hydration (hardening), but needed for workability during mixing, placement, consolidation and finishing eventually dries, leaving behind a continuous network of pores and capillaries. This network gives concrete its porosity. Porosity, or “permeability” is generally high for concrete mixes with a high water/cement ratio and low for mixes with a low water/cement ratio.

## INFLUENCING FACTORS

There are a number of factors that influence the nature and extent of scaling on concrete surfaces. The following discussion is not intended to convey any particular order of importance for the factors reviewed. There are two categories of influencing factors.

The first category defines and describes those factors related to the service environment. Factors associated with the environment are number and intensity of freeze-thaw cycles, presence of deicer chemicals and degree of saturation.

### *NUMBER AND INTENSITY OF FREEZE-THAW CYCLES*

As previously discussed, freezing is the principal cause of scaling. If there were no freeze-thaw cycles, scaling could not occur. It has been established that the number of freeze-thaw cycles directly influences the deterioration rate. For similar concretes subjected to equivalent degrees of saturation, concrete exposed to the higher number of freeze-thaw cycles will disintegrate earlier and more severely than concrete subjected to fewer freeze-thaw cycles.

In addition to the number of cycles, the rate or cycle intensity is also significant. Rapid freeze-thaw cycling is far more destructive to concrete than slow freeze-thaw cycling owing to redistribution of pressures in the concrete matrix. Concrete surfaces exposed to direct sunlight during winter periods are subject to more frequent and rapid cycling than concrete that is exposed to ambient temperatures, but shaded from direct sunlight.

### *PRESENCE OF DEICER CHEMICALS*

The impact which deicer chemicals (salt) have on scaling is both mechanical and chemical. High concentrations of salt depress the pore water freezing point and increase the osmotic pressures that cause paste failure. In addition, high salt concentrations can set up a counter system of pressures caused by the alkaline/acid relationships between the concrete and pore water, respectively. It has also been speculated that desiccation of the salt water occurs. In a typical freezing cycle, the fresher (less salty) water tends to rise toward the surface of the concrete and freezes first, trapping the more heavily salted water below the surface, where it freezes later. Because it is trapped, the salt water exerts increased pressure when it does freeze.

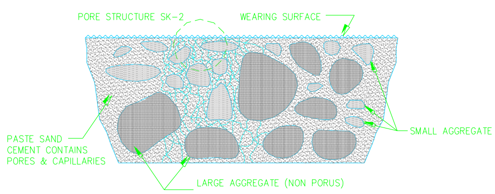
### *DEGREE OF SATURATION*

As previously discussed, excess water is required within the pore network during freezing to induce disruptive pressures. Concrete that is relatively dry and subject to freeze-thaw cycling experiences minimal disruption. Continually moist concrete will disintegrate rapidly during freeze-thaw cycling because the water cannot escape without generating disruptive pressures.

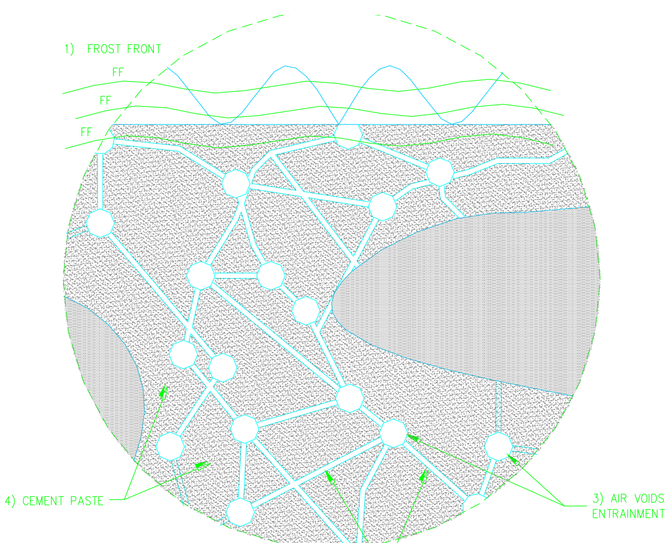
The second category of influencing factors is that associated with the particular concrete and its design features. Material properties that greatly influence the susceptibility of concrete to scaling are air entrainment, strength, water/cement ratio and the mix design.

## *AIR ENTRAINMENT*

Air entrainment has been used successfully for the past 40 years to protect concrete against scaling. Air entrainment consists of a uniform dispersion of small bubbles in the paste matrix. These bubbles compete with the pore network for water during freezing and thus relieve the destructive pressures. Research has shown that the bubbles must have a particular size and spacing to be effective at protecting concrete.




CONCRETE SECTION @ WEARING SURFACE




1) FROST FRONT ADVANCES
2) WATER CHANGES VOLUME PRIOR TO ICE FORMATION AND APPLIES PRESSURE TO CAPILLARIES IN CONCRETE
3) AIR BUBBLE IN PORE OF SATURATED CONCRETE ABSORBS HYDRAULIC SHOCK DURING WATER MOVEMENT
4) CEMENT PASTE STRUCTURE THAT PROVIDES STRENGTH TO CONCRETE REMAINS INTACT AND DURABLE

PORES
(AIR VOIDS & CAPILLARIES SHOWN ENLARGED FOR CLARITY)

*STRENGTH*

In addition to air entrainment, the development of minimum strength prior to the first frost exposure is needed to insure adequate resistance against freeze-thaw damage. Concrete strength must be at least 3500 psi prior to exposure to the freezing cycle if it is to remain durable in service. Properly air entrained concrete that has not gained sufficient strength before freezing will be subject to premature freeze-thaw deterioration.

*WATER-CEMENT RATIO*

As previously discussed the water-cement ratio directly influences concrete porosity (permeability). Highly permeable concretes are more susceptible to rapid saturation than are those of lower permeability. Concrete has a certain tolerance for moisture. Moisture diffusion within a relatively dry matrix can influence the concentrations of water and can minimize saturation, thus preventing premature deterioration.

*MIX DESIGN*

Design of the concrete mix, especially the cement factor, water-cement ratio and use of maximum size coarse aggregate fraction can enhance long term durability. The mix design should be tested prior to concrete placement in order to insure that the air system specified is achieved during construction. It is common to find differences between the specified and measured air entrainment in the plastic concrete and in the air content of the finished hardened slab.

Concrete design details and concepts also influence susceptibility to scaling. Concrete floor surfaces or pavements subjected to frequent freezing and deicer chemical application can be designed to drain rapidly, minimizing critical saturation potential. Parking facility floor slabs designed with a minimum one-and-one-half percent grade will rapidly drain and will be inherently less susceptible to scaling due to the limited potential for saturation. Well-designed gradients for drainage and an adequate number of surface drains will eliminate excess water and keep the pavement fairly dry. Floor slabs that are unusually flat or have few drains will experience rapid destruction due to their high potential for saturation.

The above discussion is intended to provide an overview of the scaling process and familiarize the reader with those conditions that impact upon this distress mechanism and its influence on structural members. A more detailed discussion is provided in the American Concrete Institute (ACI) Committee Report entitled "Guide to Durable Concrete", ACI 201.2R-77. Please refer to that document for additional information.

## CRACKING

Concrete cracking is caused by stress. This stress is either construction or service related. Cracking commonly attributed to construction is caused by improper concrete placement, consolidation, and/or curing; premature removal of forms; or by plastic shrinkage of the concrete. Service related cracking is usually due to the temperature changes, load, settlement, or internal stresses. Corrosion of reinforcement and aggregate chemical reaction are common causes of internal stress.


CRACKS RADIATING FROM COLUMN

Not all cracking is detrimental to the concrete member. In many cases, cracks are anticipated and reinforcement is provided to transfer stress across the cracks. Properly positioned reinforcement arrests crack development by keeping cracks short and tightly closed. Cracking can be detrimental when it occurs to an extent and with a frequency not expected. If this happens, steps are necessary to minimize the effect cracking has on long-term structure durability.

Leaching is caused by frequent water migration through cracks. As water migrates through, it carries along part of the cementing constituents, depositing them as a white film, stain, or in extreme cases, stalactites on the ceiling below. This process will weaken the concrete over a period of years and is accelerated by porous or perpetually moist concrete. Leaching frequently occurs from cracks at gutter lines.

## JOINT DETERIORATION

The two most common provisions made for crack control (relief of restraint) in concrete slabs are control joints and expansion joints. Such joints have long been a cause of maintenance problems. Joints on supported floor slabs must be sealed against water leakage and against intrusion of sand and dirt. Both situations are damaging to the joint system.

Construction joints deteriorate for several reasons, which are usually associated with failure of the sealant or the adjacent concrete. Joint sealants may not have the required degree of flexibility, bond, strength, or durability for a particular application. If concrete adjacent to the joint is not sufficient durable, then local scaling will cause joint sealant adhesion failure.

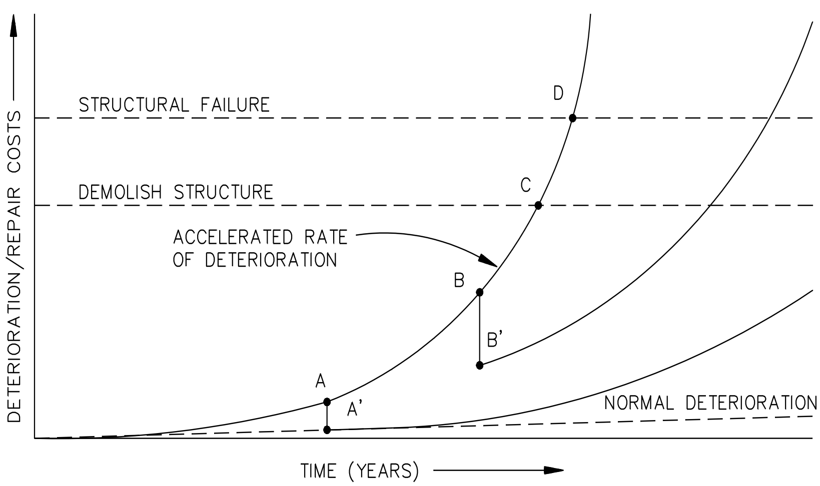
FAILED JOINT SEALANT

Expansion joints are also susceptible to premature deterioration. The most common causes of early deterioration are joint design or sealant material selection, incorrect installation of the expansion device, and/or in-service damage from traffic, snowplows or vandalism.

FAILED EXPANSION JOINT

## PARKING STRUCTURES

Parking structures are somewhat similar to the human body in that if they are properly constructed and cared for from the beginning, they will with few exceptions, provide a long and useful service life. Figure A6 below illustrates this point.




NOTE:

1. Points A – D represent stages of accelerated deterioration in parking structures.
2. Structures repaired at point A cost less overall and last longer than structures repaired at point B. [Compare curve A' to B']

**FIGURE A6 – PARKING STRUCTURE DETERIORATION CURVE**

The first curve illustrates the difference between a parking structure's normal life span if no maintenance/repair is done versus a parking structure that receives proper and appropriate maintenance/repair over the course of its life span (normal deterioration). Points A and B represent the affect that an effective program of maintenance and repair has on a parking structure's useful service life. Points C and D represent the extreme results of the absence of an appropriate maintenance/repair program.

## APPENDIX E:

## GLOSSARY OF GENERAL TERMS

**ABRASION RESISTANCE**: Ability to resist being worn away by rubbing and friction.

**AIR ENTRAINMENT**: The inclusion of air in the form of minute bubbles, (generally smaller than 1 mm), during the mixing of concrete to help prevent scaling.

**CONCRETE**: Mixture of portland cement, fine aggregate, coarse aggregate, and water, with or without admixtures.

**CORROSION**: Disintegration or deterioration of concrete or reinforcement by electrolysis or by chemical attack.

**CRAZE CRACKS**: Fine, random cracks, or fissures caused by shrinkage, which may appear in a surface of plaster, cement paste, mortar, or concrete.


CRAZE CRACKING

**DEFLECTION**: A variation in position or shape of a structure or element due to effects of loads or volume change, usually measured as a linear deviation from an established plane.

**DELAMINATION**: In the case of a concrete slab, a delamination is the horizontal splitting, cracking, or separation of a slab in a plane roughly parallel to, and generally near, the upper surface. Delaminations are typically caused by corrosion of reinforcing steel or separation between concrete topping and underlying elements.

**DETERIORATION**: Disintegration or chemical decomposition of a material during service exposure.

**DIAGONAL CRACK**: An inclined crack caused by shear stress, usually at about 45 degrees to the neutral axis of a concrete member; or a crack in a slab, not parallel to the lateral or longitudinal dimensions.

**DURABILITY**: The ability of concrete to resist weathering action, chemical attack, abrasion, and other conditions of service.

**EFFLORESCENCE**: A deposit of mineral salts, usually white in color, formed on a concrete or masonry surface.

**ENTRAINED AIR**: Microscopic air bubbles intentionally incorporated in concrete during mixing by the use of chemical agents or specialty cement.

**ENTRAPPED AIR**: Air voids in concrete which are not purposely entrained and which are significantly larger and less useful than those of entrained air.

**EPOXY CONCRETE**: A mixture of epoxy resin, catalyst, fine aggregate, and coarse aggregate.

**HAIRLINE CRACKING**: Small cracks of random pattern in an exposed concrete surface.

**JOINT SEALANT**: Compressible material used to exclude water and solid foreign material from joints.

**MAINTENANCE**: Taking periodic actions that will either prevent or delay damage or deterioration or both.

**MICROCRACKS**: Microscopic cracks within concrete.

**OVERLAY**: A layer of concrete or mortar, seldom thinner than 1 inch, placed on and usually bonded to the worn or cracked surface of a concrete slab to either restore or improve the function of the previous surface.

**PACHOMETER**: Instrument for nondestructively locating and estimating concrete cover and/or diameter of embedded reinforcement.

**PATTERN CRACKING**: Fine openings on concrete surfaces in the form of a pattern; resulting from a decrease in volume of the material near the surface, or increase in volume of the material below the surface, or both.

**PEELING**: A process in which thin flakes of mortar are broken away from a concrete surface, such as by deterioration or by adherence of surface mortar to forms as they are removed.

**PITTING**: Development of relatively small cavities in a surface, due to phenomena such as corrosion or cavitation, or, in concrete, localized disintegration. (See also POPOUT)

**PLASTIC CRACKING**: Cracking that occurs in the surface of fresh concrete soon after it is placed and while it is still plastic.

**POPOUT**: The breaking away of small portions of concrete surface due to internal pressure which leaves a shallow, typically conical, depression.


FLOOR SLAB POPOUTS

**PRECAST CONCRETE**: Concrete cast elsewhere than in its final position.

**PRESTRESSED CONCRETE**: Concrete in which stresses of such magnitude and distribution are introduced that the tensile stresses resulting from the service loads are counteracted to the desired degree.

> _Pretensioned_ concrete is prestressed concrete in which stressing tendons are tensioned _before_ the concrete hardens.
>
> _Post-Tensioned_ concrete is prestressed concrete in which stressing tendons are tensioned _after_ the concrete hardens.

**REINFORCEMENT**: Bars, (smooth or deformed), wires, strands, tendons and other elements that are embedded in concrete in such a manner that reinforcement and concrete act together to resist applied forces.

> _Conventional_ reinforcement is non-prestressed smooth or deformed bar or wire reinforcement with yield strengths in the 40,000-75,000 psi range.
>
> _Prestressed_ reinforcement is steel bars, wires or strands with ultimate strengths in the 250,000-270,000 psi range, strong enough to permit effective pre- or post-tensioning.


FLOOR SCALING

**SANDBLASTING**: A system of cutting or abrading a surface, such as concrete, by a stream of sand ejected from a nozzle at high speed by compressed air; often used for cleanup or for exposure of aggregate in architectural concrete.


HEAVY FLOOR SCALING

**SCALING**: Local flaking or peeling away of the near-surface portion of hardened concrete or mortar; also of a layer from metal. (Note: Light scaling of concrete does not expose coarse aggregate; medium scaling involves loss of surface mortar of 5-10 mm in depth and exposure of coarse aggregate; severe scaling involves loss of surface mortar of 5-10 mm in depth with some loss of mortar surrounding aggregate particles 10-20 mm in depth; very severe scaling involves loss of coarse aggregate particles as well as mortar generally to a depth greater than 20 mm.)

**SHORT SPAN**: A structural system that doesn't span the full parking module, resulting in columns between parked vehicles.

**SHOTCRETE**: Process in which all ingredients, including mixing water, are mixed before introduction into the delivery hose; it may be pneumatically conveyed or moved by displacement.

**SHRINKAGE CRACKING**: Cracking of a structure or member due to failure in tension caused by external or internal restraints as reduction in moisture content develops, or as carbonation occurs, or both.

**SPALL**: A dish-shaped cavity or void formed by the broken surface, edge, or corner of a larger mass such as a floor slab, beam, column, wall, etc. Spalls are usually the result of weathering, pressure, or volume change of the larger mass.

**TENDON**: A steel element such as a wire, cable, bar, rod, strand, or group of such elements used to impart prestress to concrete when the element is tensioned.

**TRANSVERSE CRACKS**: Cracks that develop at right angles to the long direction of a member.


CORROSION INDUCED SPALLING AT UNDERSIDE OF WAFFLE SLAB


CORROSION OF REINFORCING STEEL IN FLOOR SLAB


CORROSION INDUCED SPALLING IN FLOOR SLAB

**CONDITION TERMS:** We define condition terms used in the report below. Please note that when terms are applied to an overall system, certain portions of the system may be in a different condition.

**Excellent**: Item is in "as new" condition requiring no rehabilitation and should perform in full accordance with its useful expected life.

**Good**: Item is sound and performing its function, although it may show signs of normal wear and tear. Some incidental rehabilitation work may be recommended.

**Fair**: Item is performing adequately at this time but exhibits deferred maintenance, substandard workmanship, and evidence of previous repairs, are obsolete, or are approaching the end of its typical useful expected life. Repair, replacement, or maintenance is necessary to prevent further deterioration, or to prolong its useful life.

**Poor**: Item has either failed or cannot be relied upon to continue performing its original function. Present condition could contribute or cause the deterioration of other adjoining elements or systems. Repair or replacement may be required.

## APPENDIX F:

## CHLORIDE ION TEST DATA

WALKER
RESTORATION CONSULTANTS

# CHLORIDE ION CONTENT DETERMINATION
# LABORATORY ANALYSIS RESULTS FORM

| Sample No. | Sample Identification | CHLORIDE ION CONTENT -PPM- Depth Increment Tested 0" – 1" | 1" – 2" | | Comments |
|---|---|---|---|---|---|
| CL1 & CL1A | Drive Lane | 2120 | 156 | | Level 2, E.3-3.2 |
| CL2 & CL2A | Drive Lane | 800 | 60 | | Level 2, F.7-4.6 |
| CL3 & CL3A | Drive Lane | 1640 | 92 | | Level 2, E.3-7.5 |
| CL4 & CL4A | Drive Lane | 613 | 61 | | Level 3, F.7-7.2 |
| CL5 & CL5A | Drive Lane | 712 | 58 | | Level 4, E.3-3.4 |
| CL6 & CL6A | Drive Lane | 333 | 69 | | Level 4, F.7-3.4 |
| CL7 & CL7A | Drive Lane | 200 | 72 | | Level 5, F.7-8.8 |
| CL8 & CL8A | Drive Lane | 255 | 64 | | Level 5, E.3-8.6 |
| CL9 | Tee Stem | — | — | 122 | Level 2 Underside, B.2-6.4 |
| CL10 | Tee Stem | — | — | 124 | Level 4 Underside, F.7-6.3 |
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## American Information

Date Received: 11/19/15 mHuberty
Test Required: Water-Soluble Chloride-Ion Content
Samples Tested By: J Beaty BR

AMERICAN ENGINEERING TESTING, INC.
St. Paul, MN

## Walker Information

Project Name: UND Grand Forks
Project Number: 21-4163.00
Samples Taken By: Mike Retterath
Date Sampled: 11-11-15
Number Submitted: 18
Date Submitted: 11-18-15