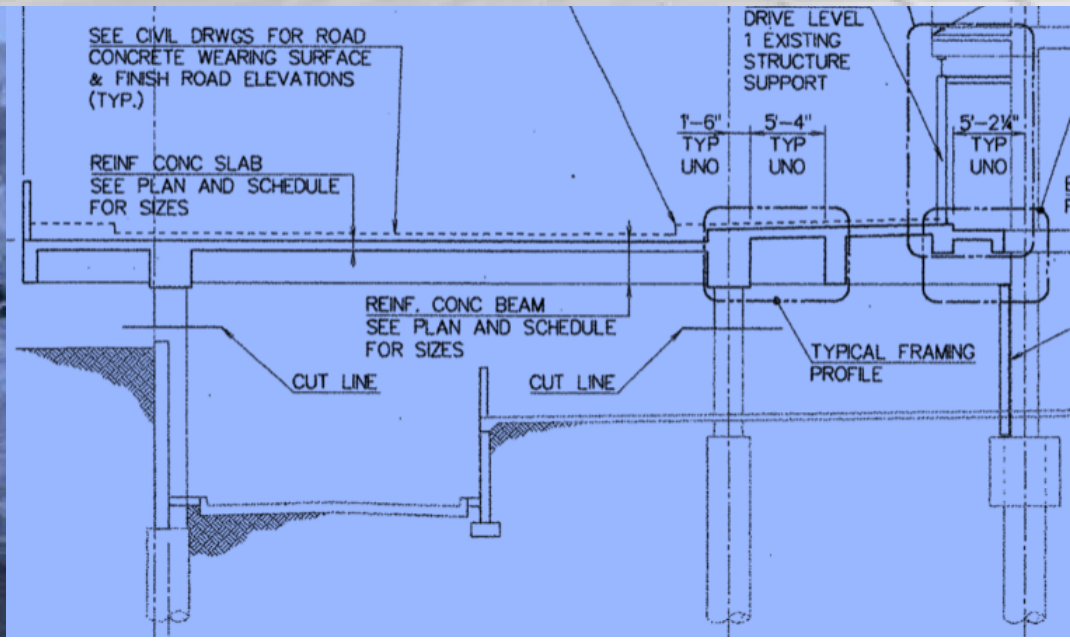
Atwater Street Load Rating

for the

Detroit Grand Prix

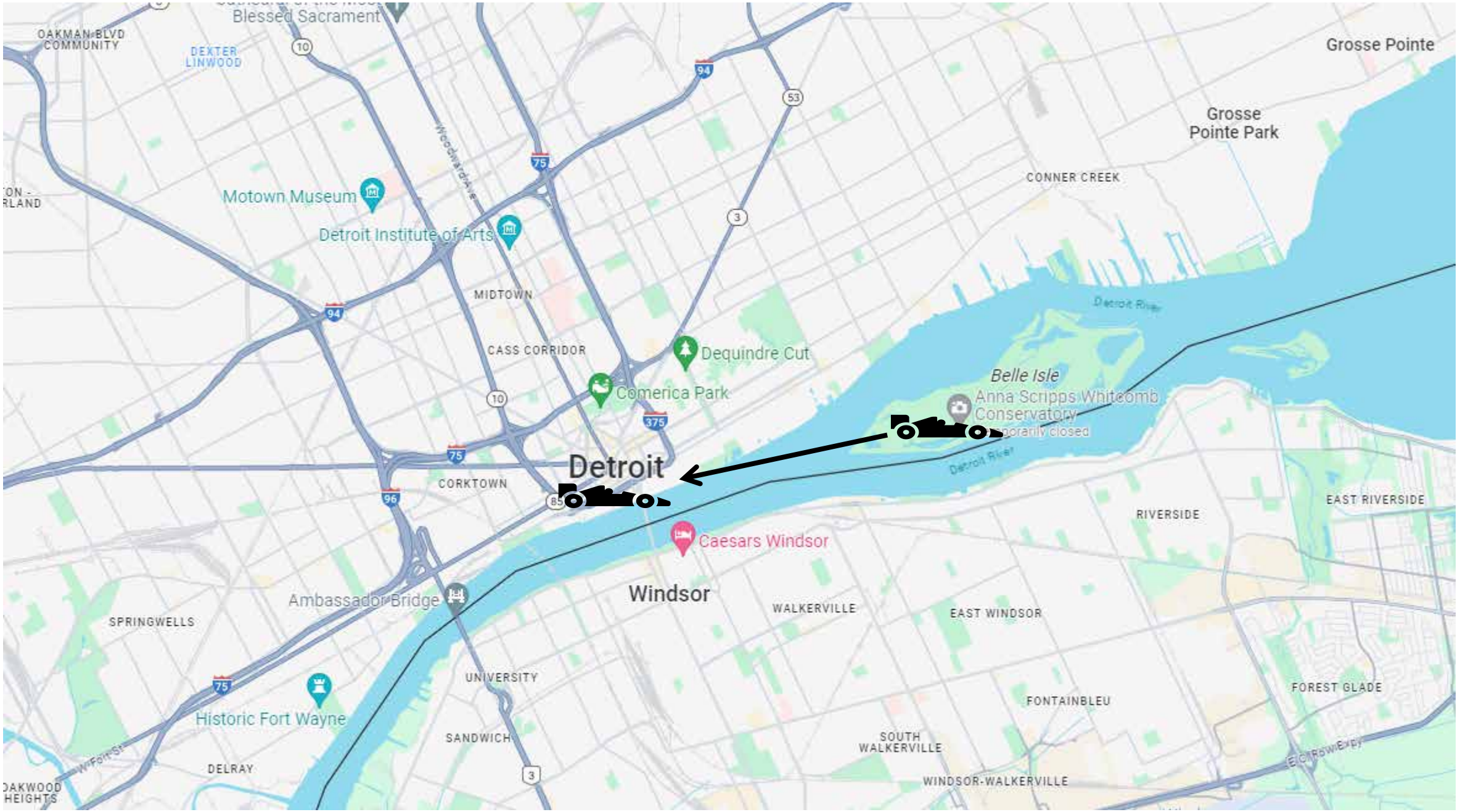


Agenda

- Project Background
- Structure Description
- Load Rating Approach and Analysis
- Findings

Project Background

- The Detroit Grand Prix moved back to downtown Detroit last summer for the first time since 1988.
- IndyCar racecars (think Formula 1) sped along a 1.7-mile track through the City of Detroit reaching speeds of up to 190 mph.

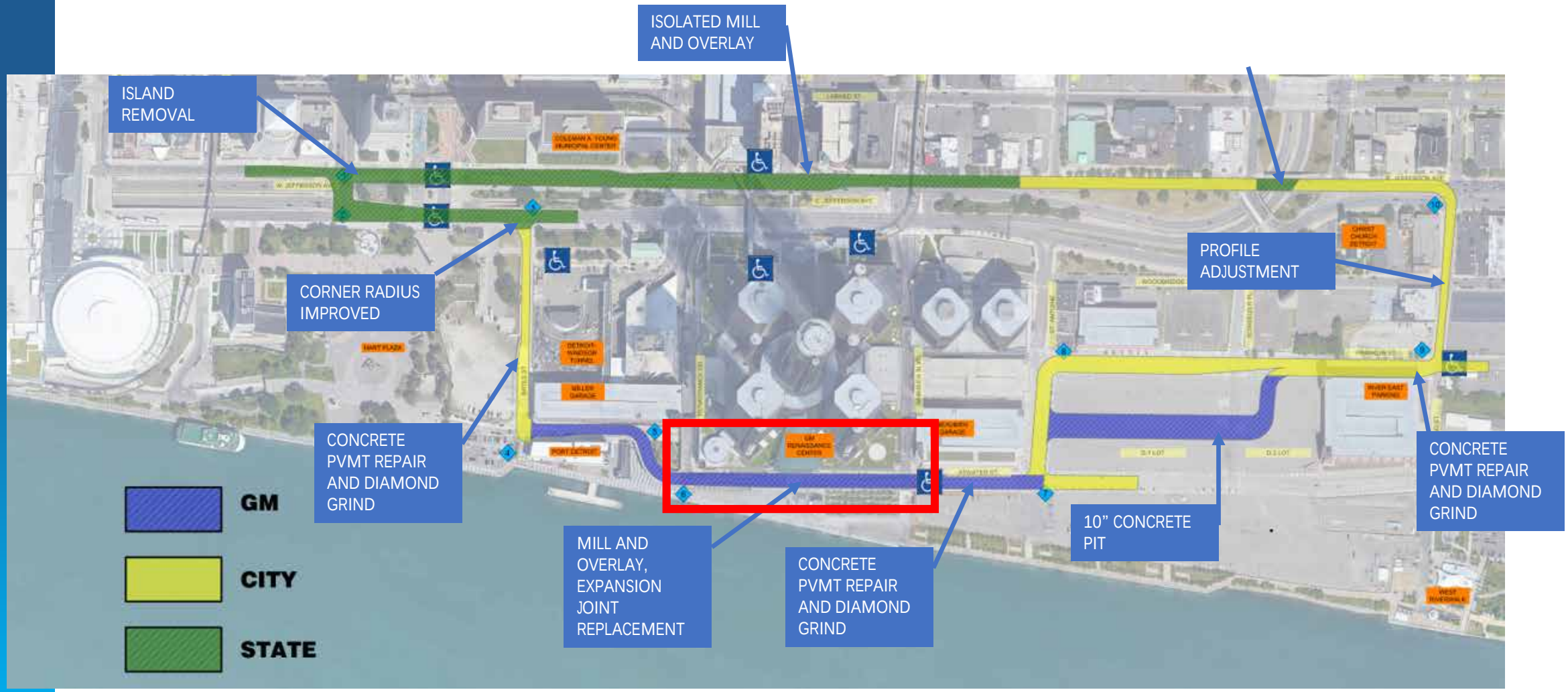

Blessed Sacrament
OAKMAN BLVD COMMUNITY
DEXTER LINWOOD
Grosse Pointe
Grosse Pointe Park
CONNER CREEK
Motown Museum
Detroit Institute of Arts
MIDTOWN
CASS CORRIDOR
Dequindre Cut
Comerica Park
Belle Isle
Anna Scripps Whitcomb Conservatory
Detroit River
Detroit
CORKTOWN
RIVERSIDE
EAST RIVERSIDE
Caesars Windsor
Windsor
Ambassador Bridge
WALKERVILLE
EAST WINDSOR
SPRINGWELLS
UNIVERSITY
FONTAINBLEU
FOREST GLADE
Historic Fort Wayne
SANDWICH
SOUTH WALKERVILLE
DELRAY
WINDSOR-WALKERVILLE

2023 CHEVROLET DETROIT GRAND PRIX PRESENTED BY LEAR

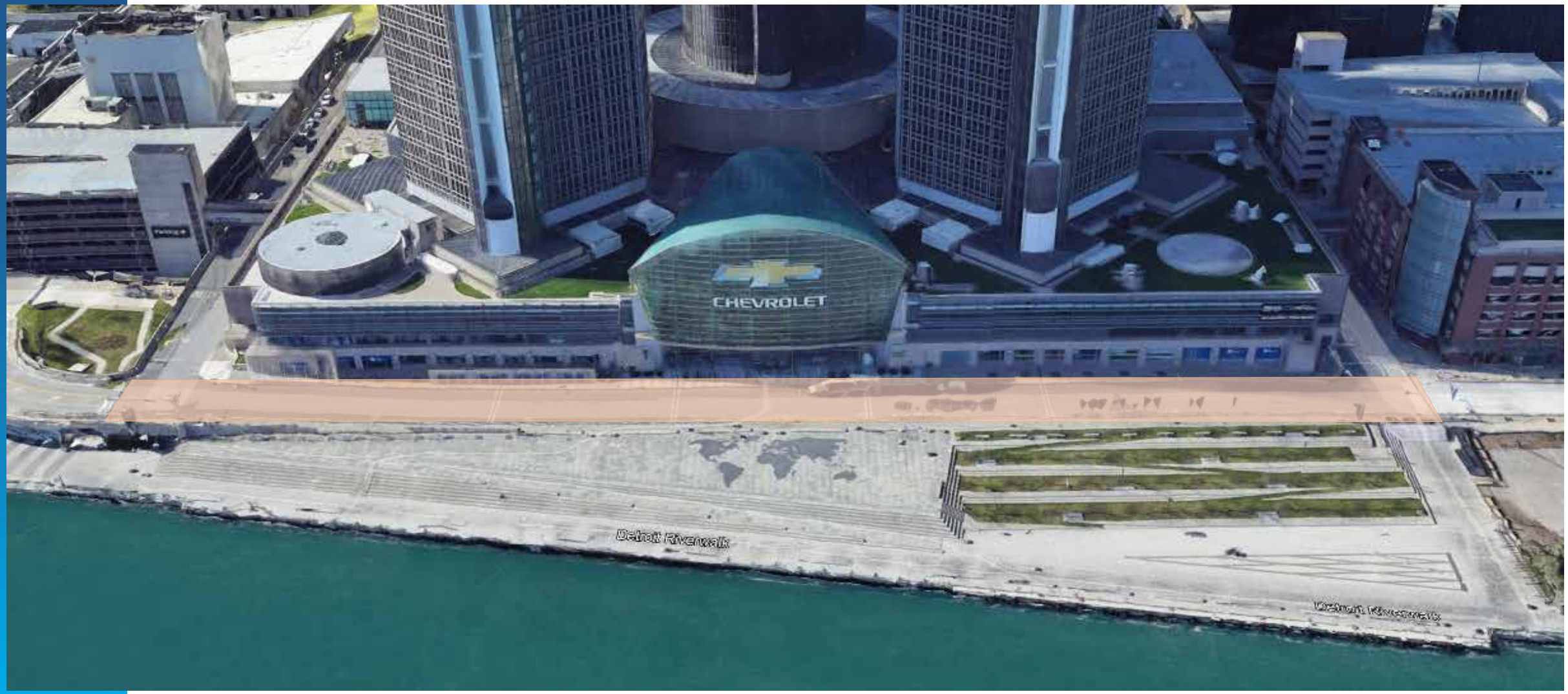
General IndyCar Requirements

- Surface must be smooth without large bumps.
- Surface must be able to endure extreme lateral loads & heavy braking
- All manhole covers must be level with the streets surface and either bolted or welded shut.
- Surfaces must resist tires heating up to 220deg F (104.4deg C)
- Obstructions (e.g. signposts) must be removed.

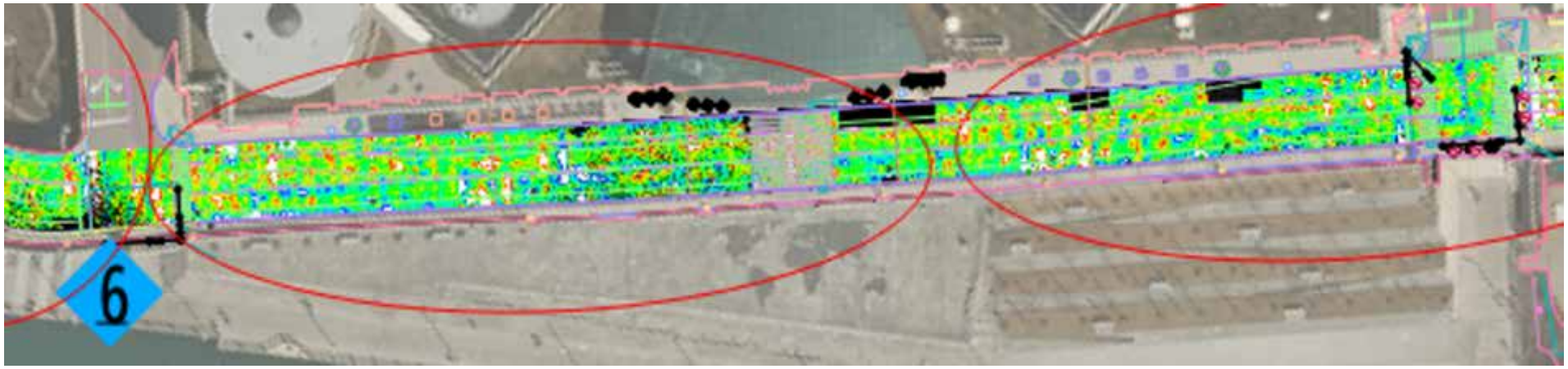
Design Overview

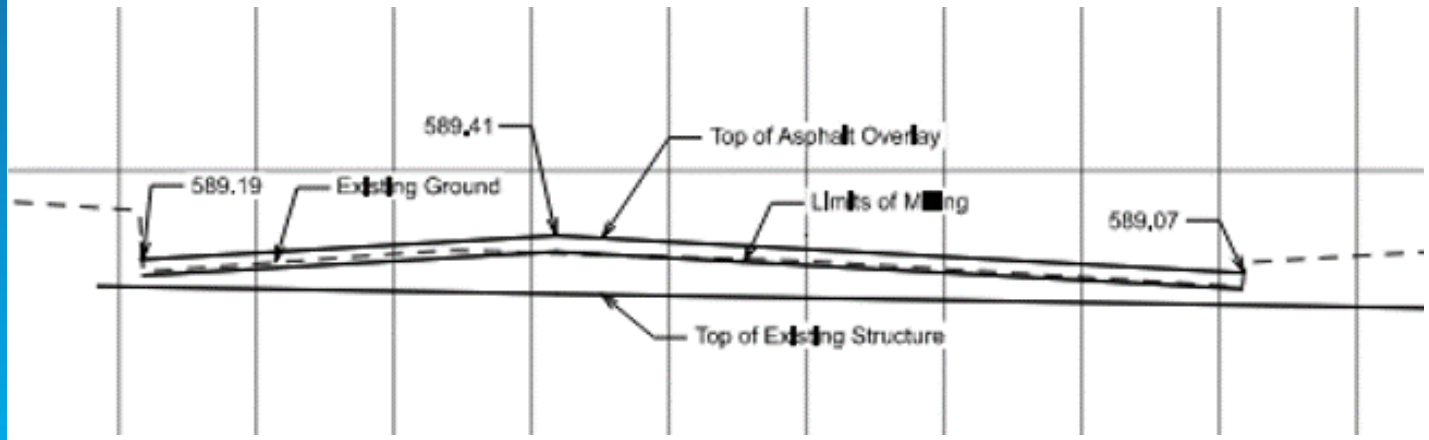


Atwater Street Structure



Atwater St. Work





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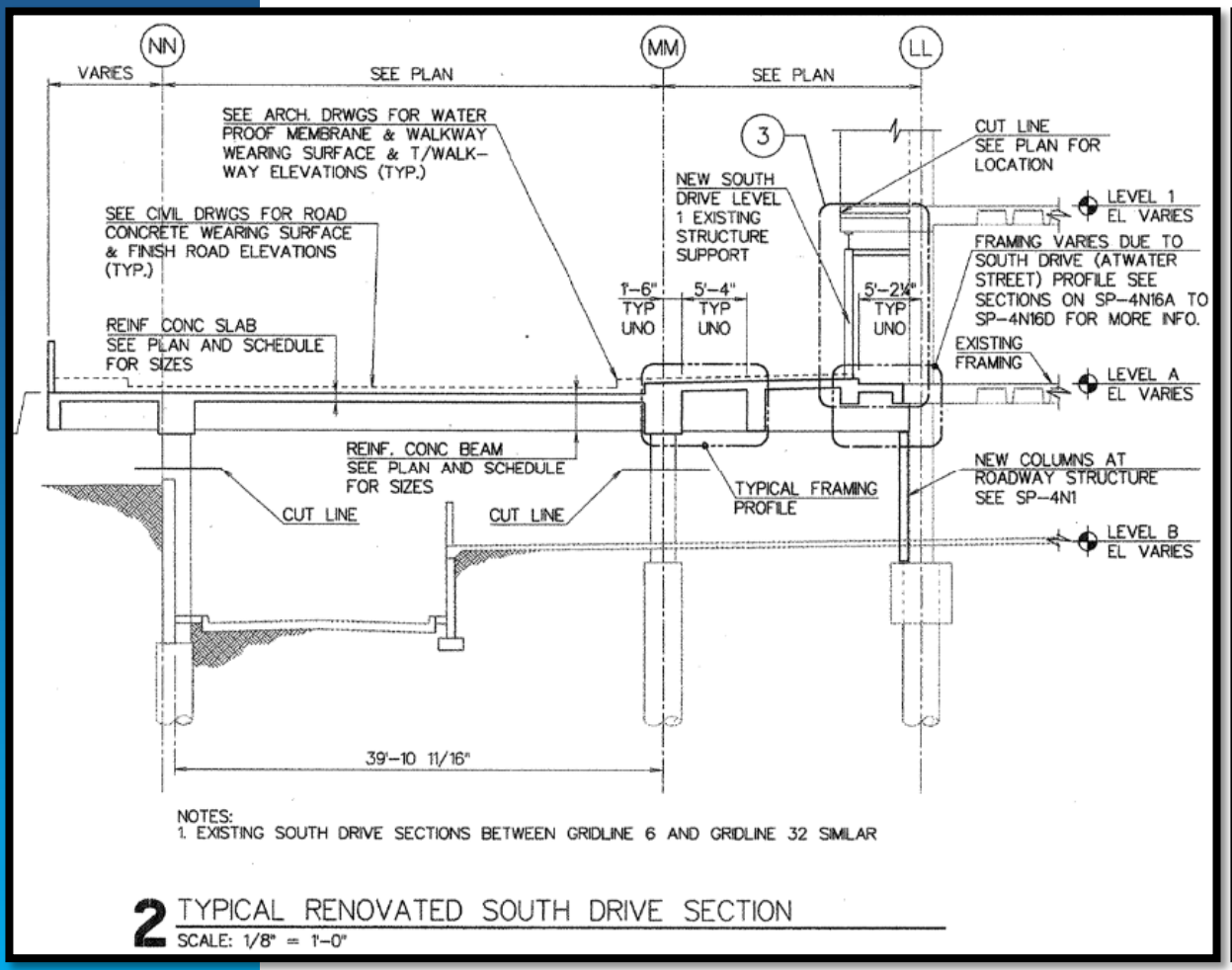
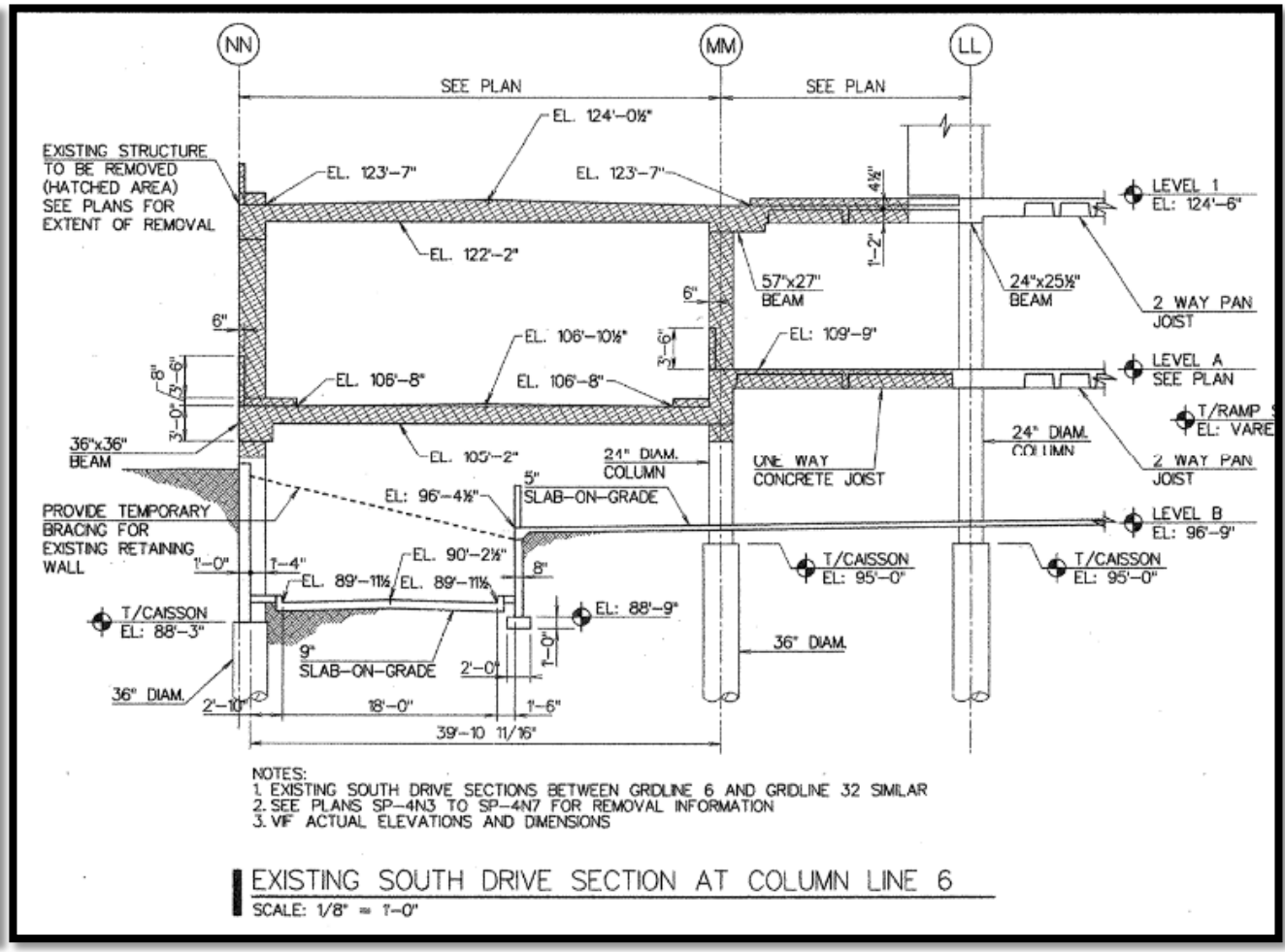




Atwater St. Current Structure

Atwater St. Prior to circa 2000 construction

Atwater Street Structure

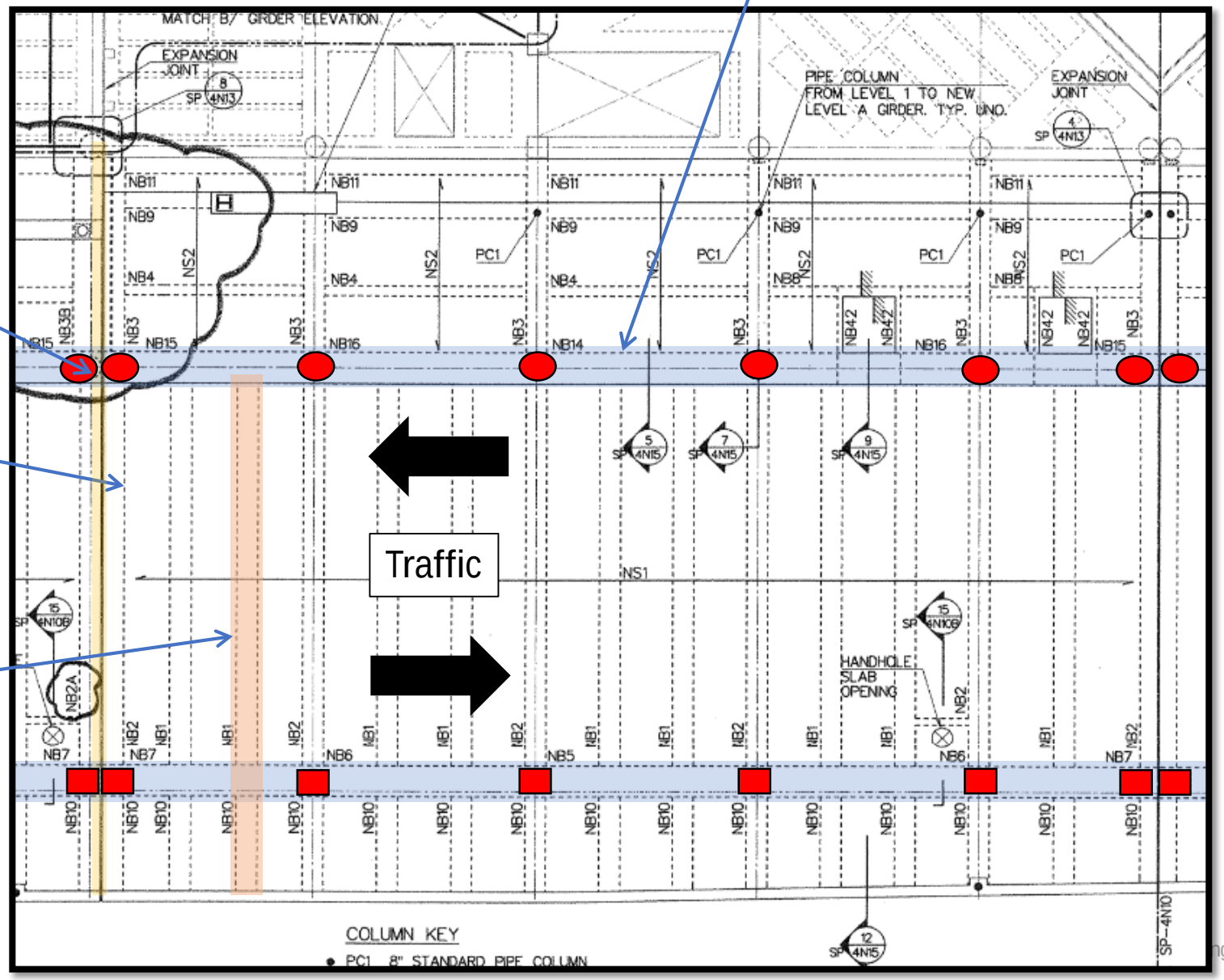
- Typical Framing Plan

Longitudinal Girder

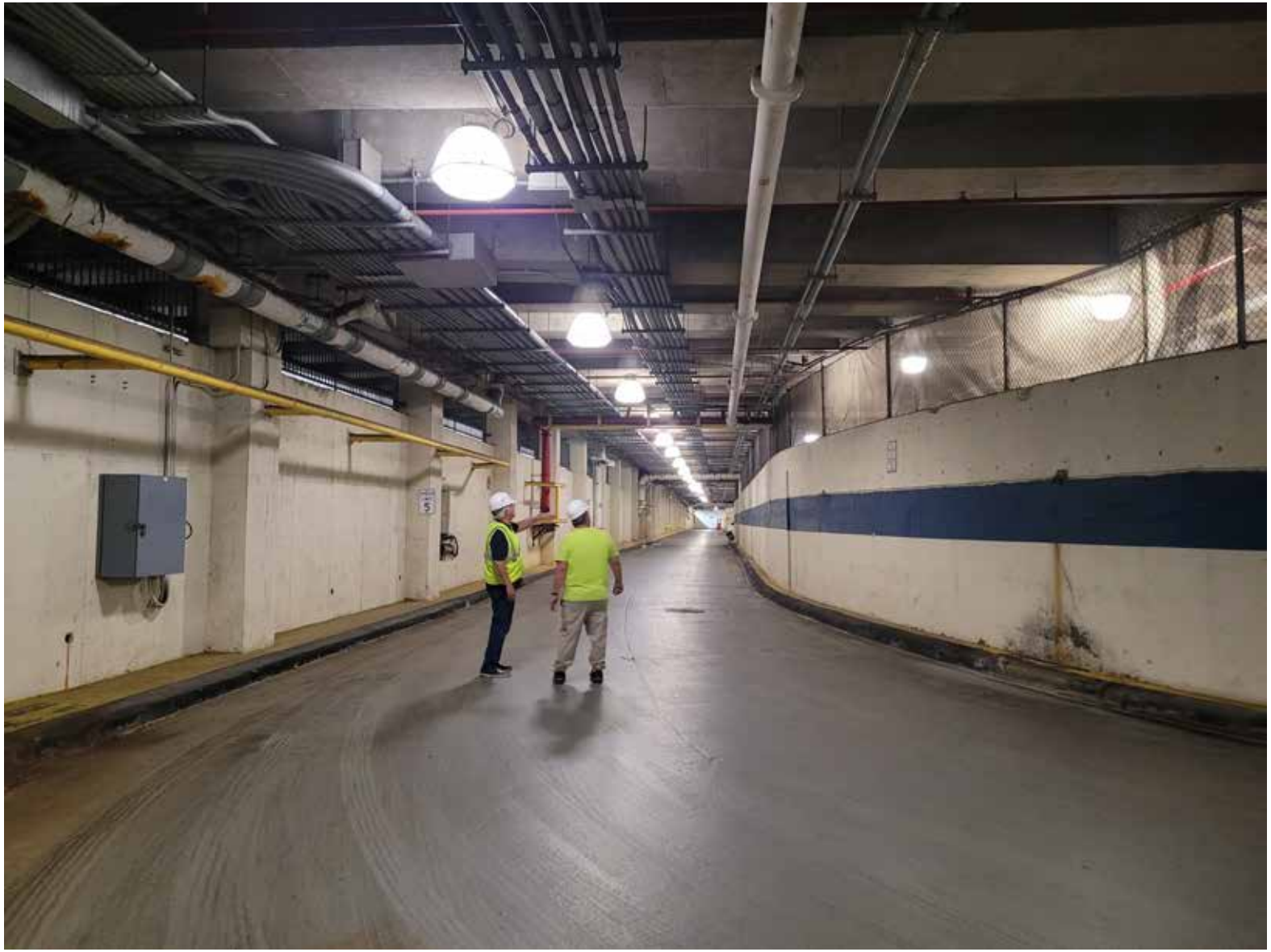
Column

Expansion Joint

Typical Transverse Beam



Field Visit



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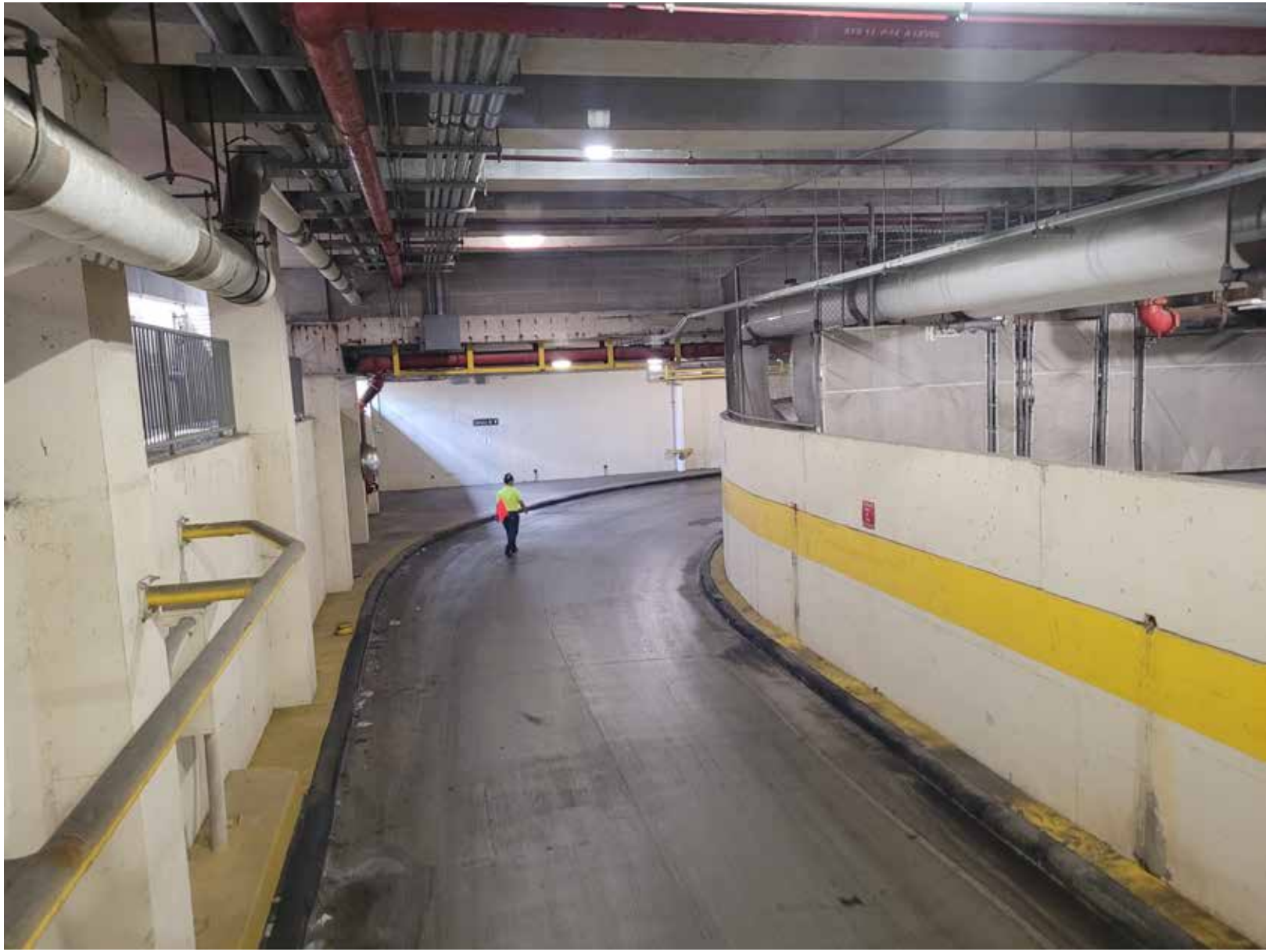

Field Visit

Field Visit

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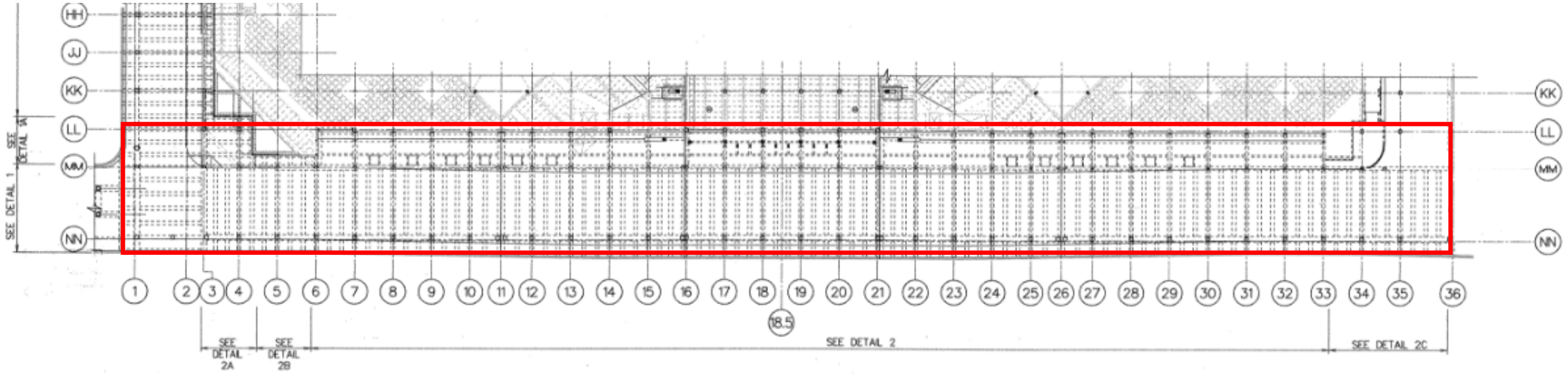
Initial Load Rating Investigation

- Adding load to the structure, no existing rating or calculations on file -> need to evaluate
- Initial investigation was performed.
  - Design check using AASHTO Std. Spec and loads per original plans was performed
    - Structure designed for HS-20
    - Unknown if Alternate Military Loading was considered.
  - Simple beam model for analysis
  - Structure did not pass, especially torsion in longitudinal girders
- Moved to perform a load rating
  - Time was short (had to complete analysis to keep construction on schedule)
  - Just need a rating all parties could live with (pencil sharpening could be done later)

Load Rating Scope

- Atwater Street Between Renaissance Dr W and Beaubien Blvd (i.e., Gridline 1 to 36 and Gridline NN to MM)
- Structural members (transverse beams, longitudinal girders, deck and columns) built from 1998 design plans were rated

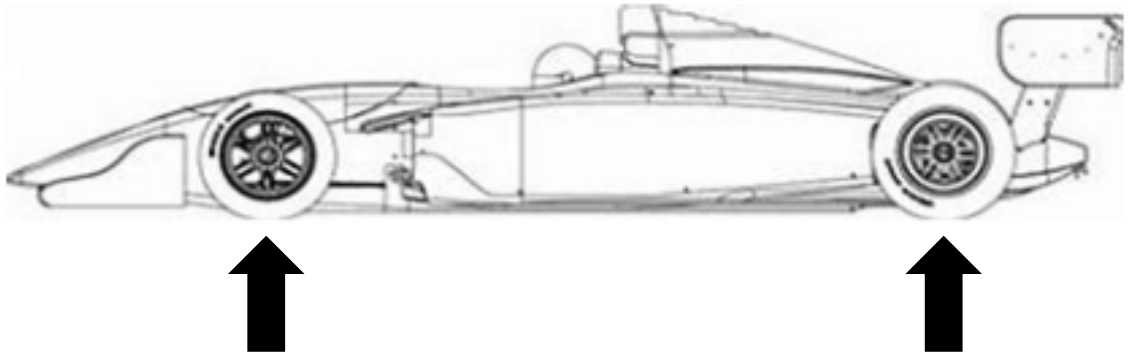


Load Rating Criteria

- LRFR
- MDOT Bridge Analysis Guide
- Dead Loading
  - New 3” uniform additional overlay asphalt wearing surface
  - New Temporary race barrier
  - Existing hanging utility loads
  - Existing wearing surface, partially milled down
  - Existing misc. dead load from planters, light poles, benches, etc. on Atwater St.
- Live Loading
  - All 28 MDOT Legal Vehicles
  - “Normal” Loading was used given that Atwater is not frequented by heavy vehicles
  - Live load factors were taken from the Bridge Analysis Manual using Atwater St. ADTT

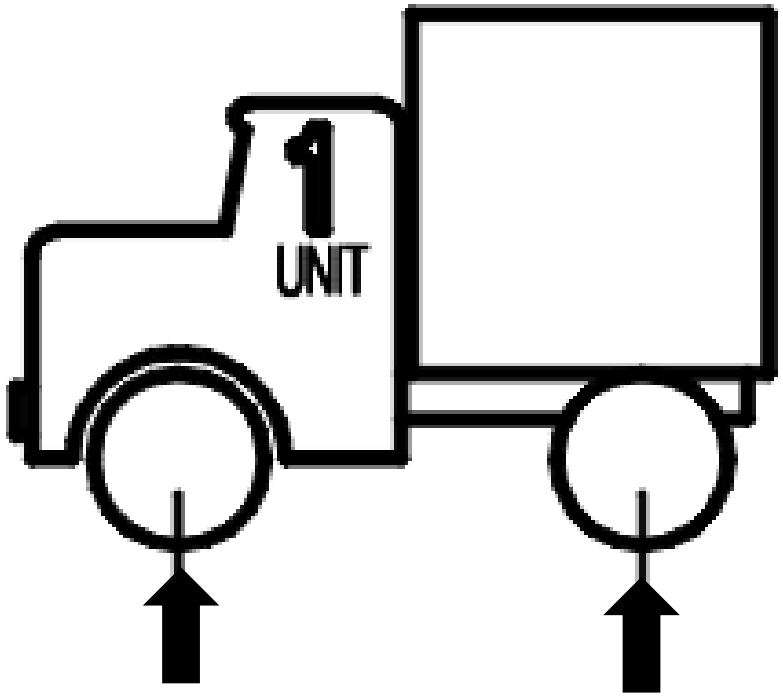
Load Rating Criteria

IndyCar



0.85k 0.85k

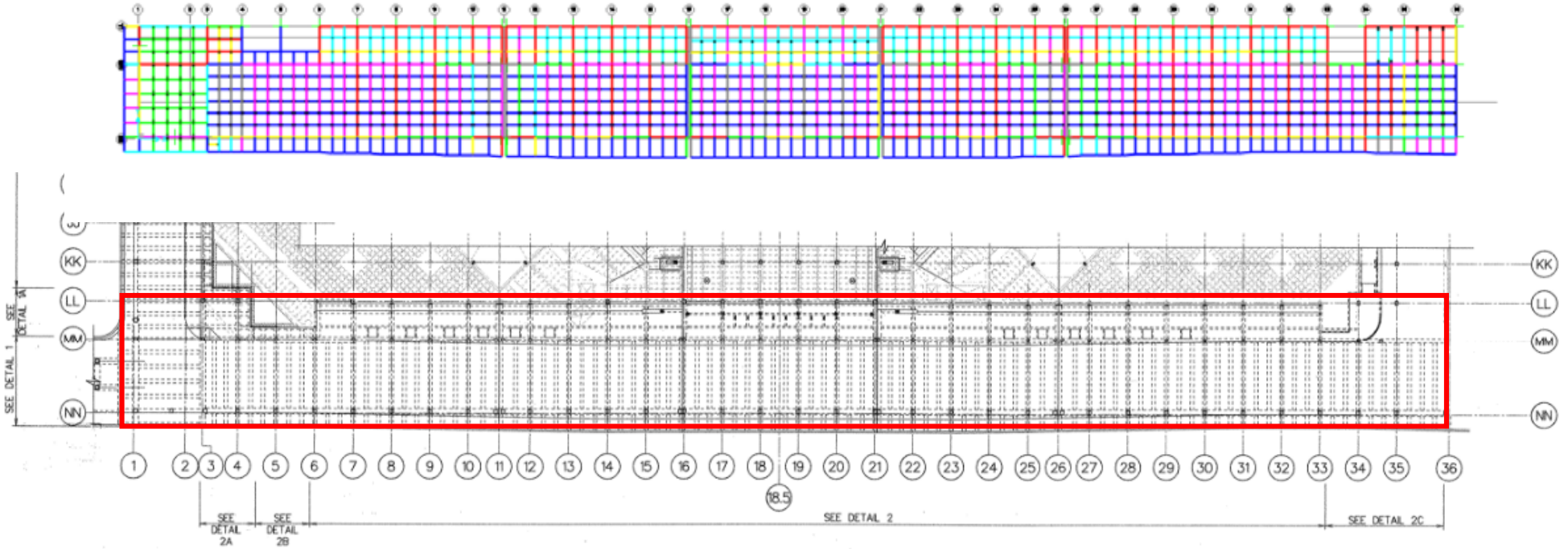
MDOT Truck No. 1 (NL/DL Loading)



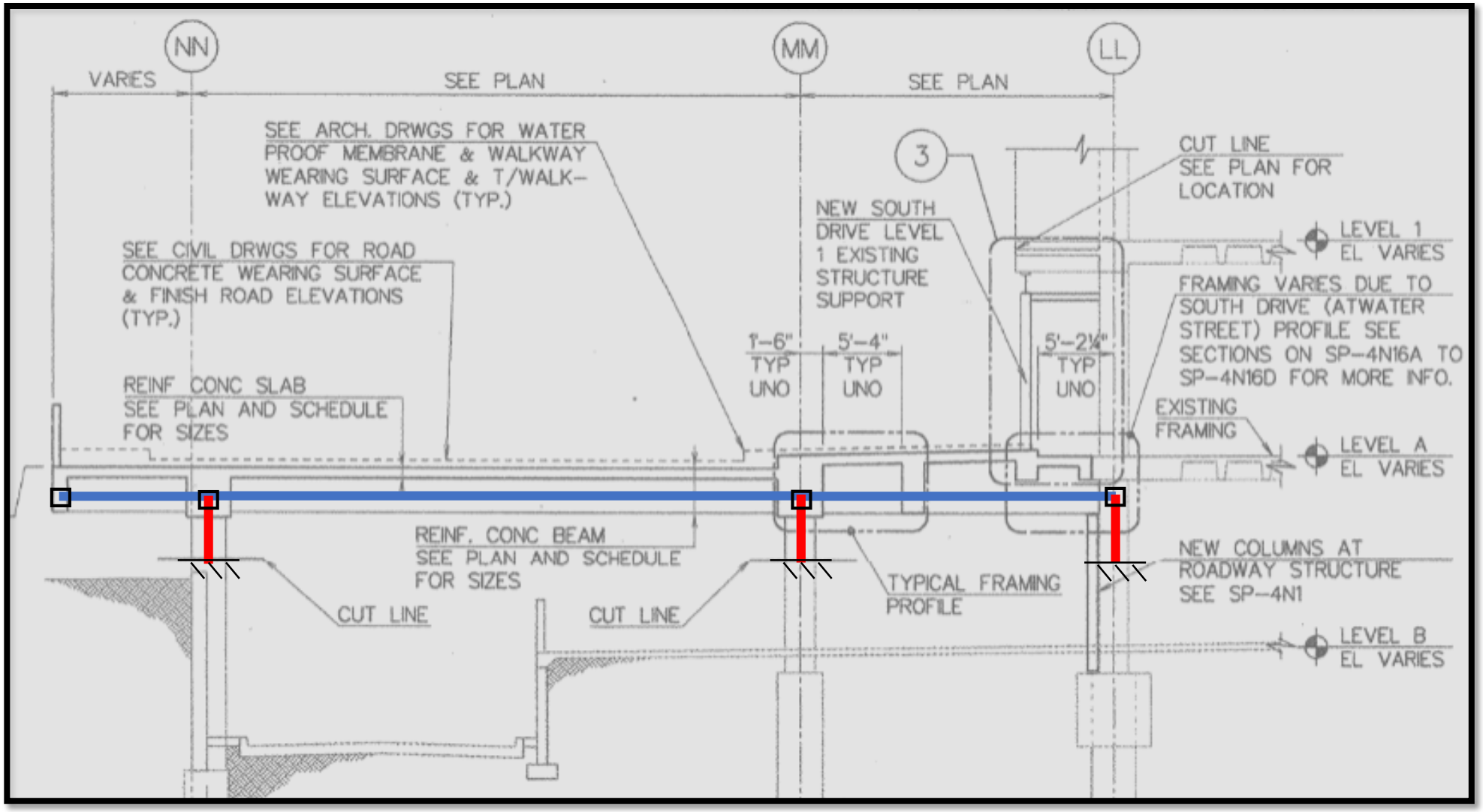
15.4k 15.4k

Analysis Approach: 2D Grid FE Model

- AASHTOWare Bridge Rating could not:
  - Model the transverse CIP beams framing into long. beams.
  - Load rate columns
- Creates 2D grid finite element model in CSiBridge

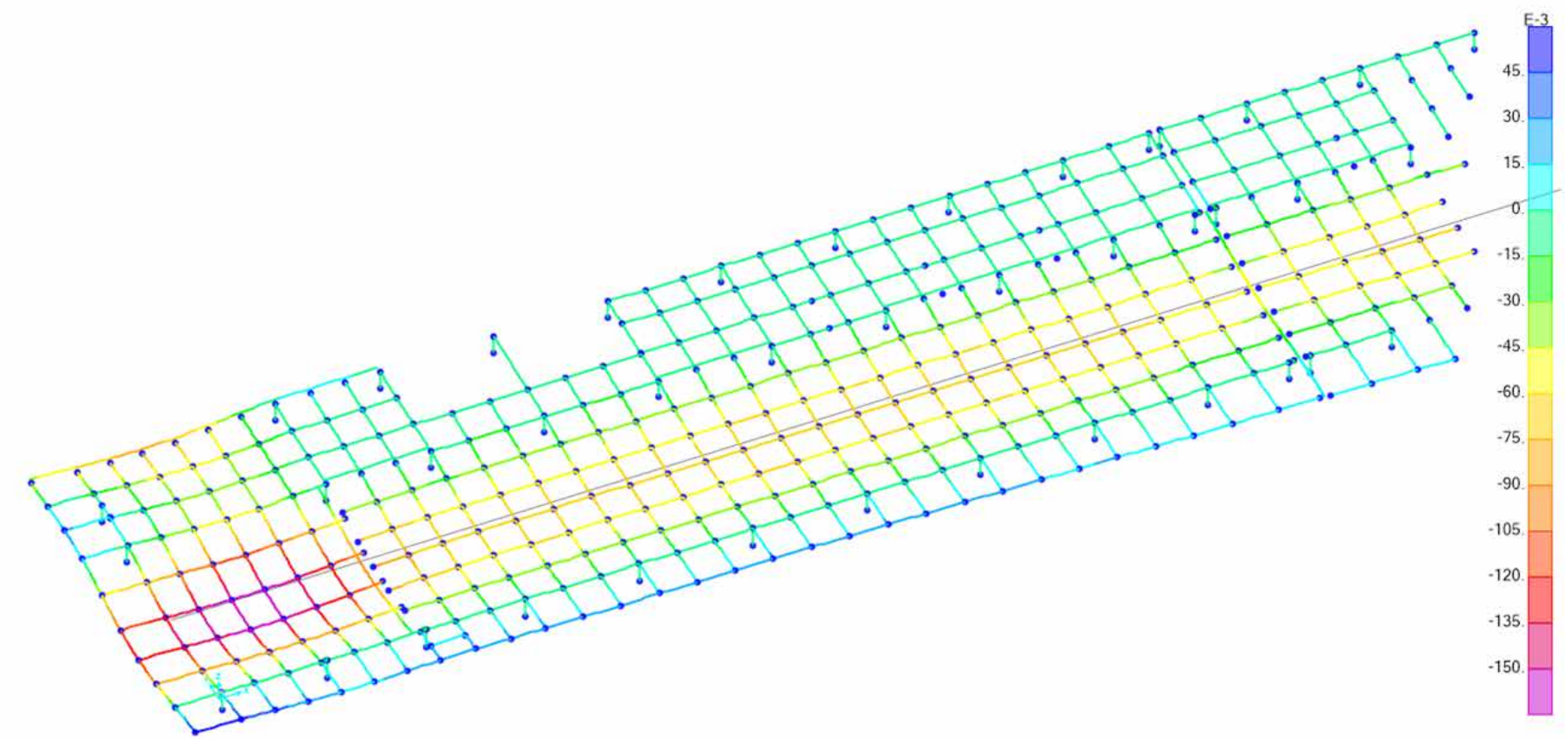


Grid Model for Analysis



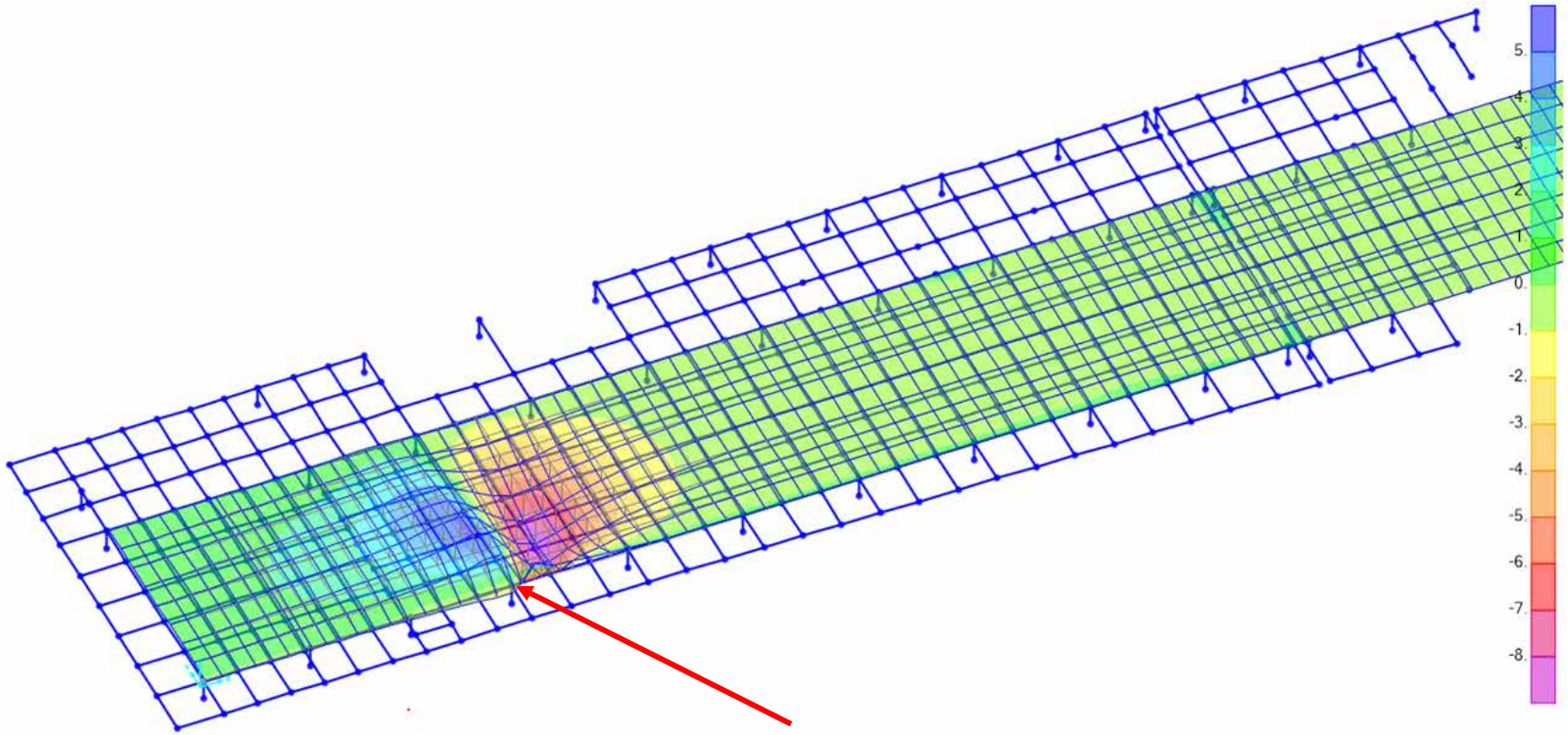
Grid Model for Analysis

- Model deflection under beam self-weight (gridline 1-12)

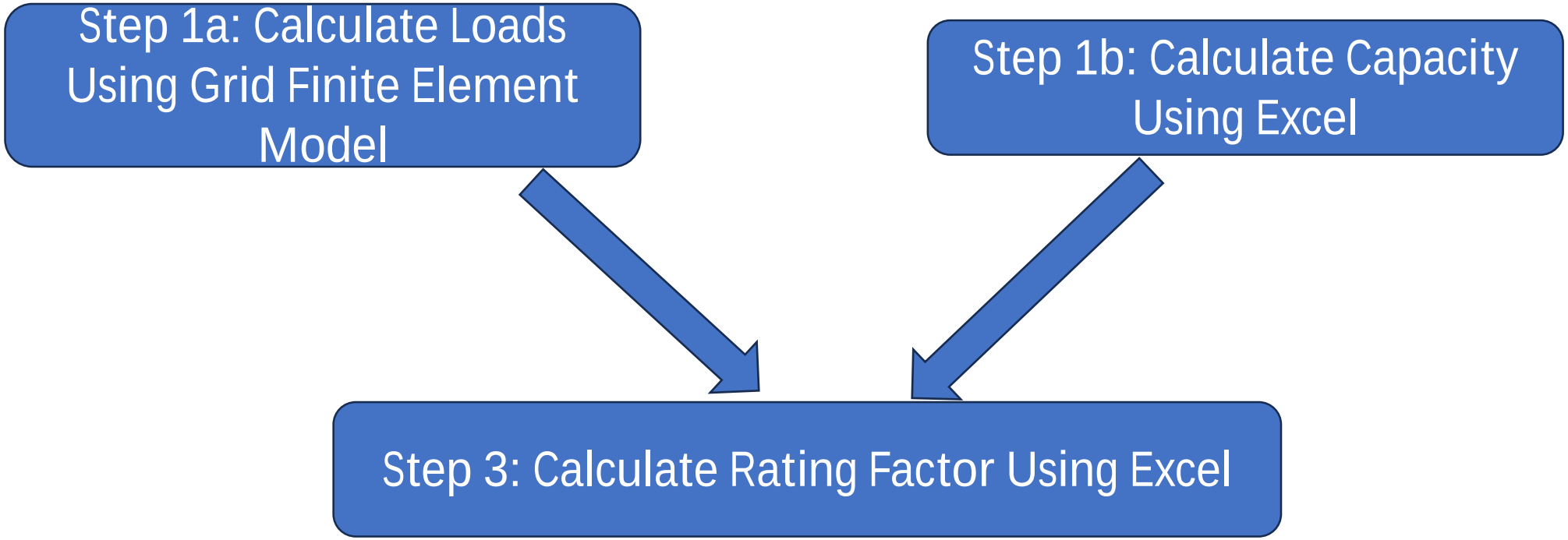


Grid Model for Analysis

§ Influence Surface Diagram for Torsion at the i-end of Frame 250



Load Rating Steps



Beam Capacity Calculation

- Capacities calculated at both ends and middle of the transverse beams and the longitudinal girders

Capacities

Strength	Flexure (M+):	2054.82	kip-ft
	Min. Reinf (M+):	2054.82	kip-ft
	Flexure (M-):	1478.67	kip-ft
	Min. Reinf (M-):	9999.00	kip-ft
	Shear:	231.34	kip
	Combined Shear & Torsion (Shear):	159.73	kip
	Combined Shear & Torsion (Torsion):	115.51	kip-ft
	Long. Reinf for Torsion:	914.40	kip
Service	Flexural Distribution (M+):	1315.70	kip-ft
	Flexural Distribution (M-):	971.53	kip-ft

Rating Factor (RF) Calculation

- Condition factor = 1
- System factor = 1
- Rating factor calculated for Strength I and Service I
- RF calcs were organized similar to BrR output

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)} \qquad (6A.4.2.1\text{-}1)$$

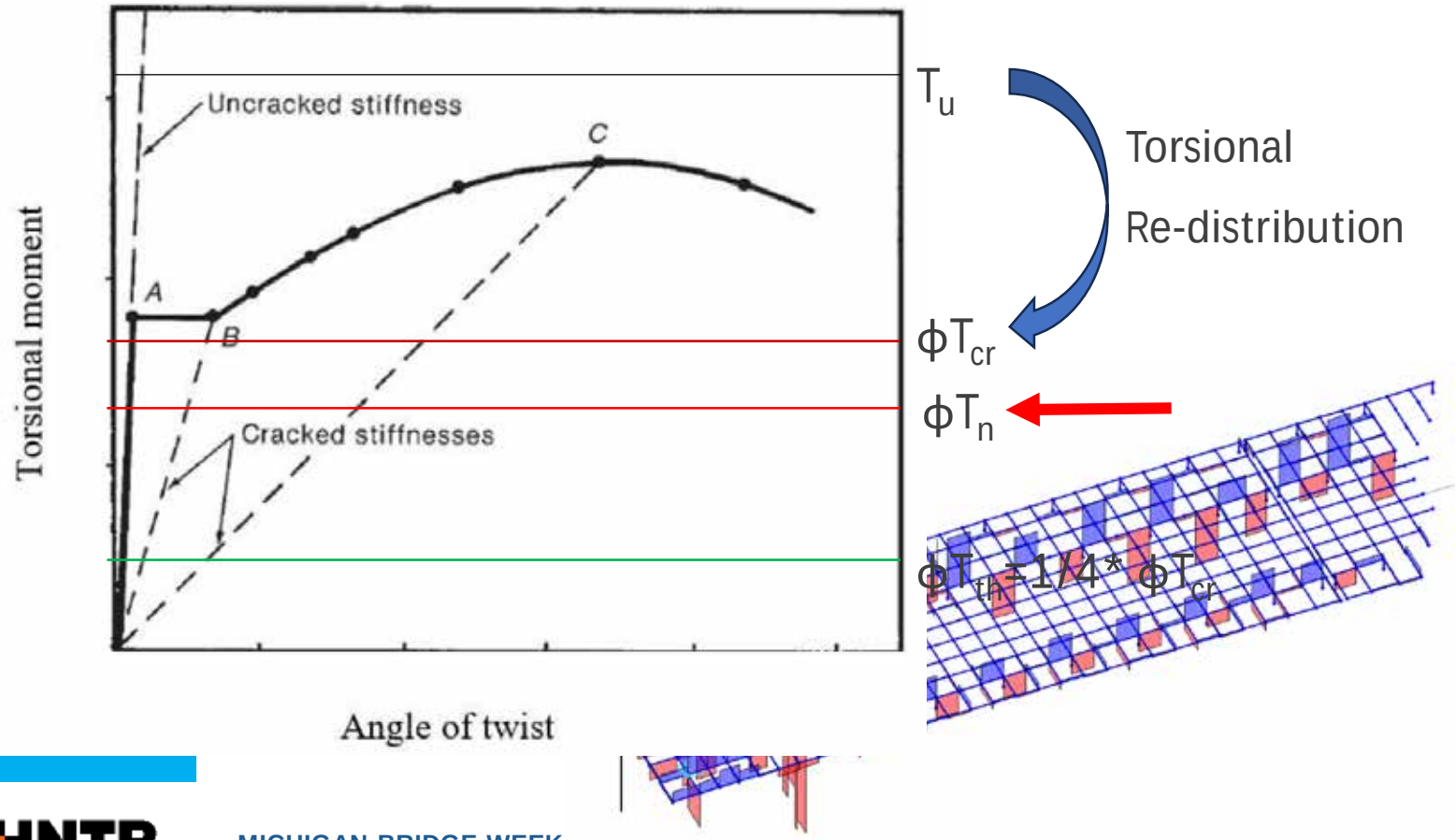
Frame	Location Fraction	AnalSect	Load Combination	Check	Step Type	Attribute	OutputCase	Live Load	Dead Load	DL	LL	Capacity	RF
216	1	NB35	Strength I	Combined Shear & Torsion (Torsion):	Min T	T	MI 2 Unit Truck 16-NL	121.2090985	72.94384182	1.25	1.235722222	226.513828	0.903547363
216	1	NB35	Strength I	Combined Shear & Torsion (Torsion):	Min T	T	MI 2 Unit Truck 17-NL	125.6981271	72.94384182	1.25	1.174577778	226.513828	0.916634954
221	1	NB14	Strength I	Combined Shear & Torsion (Torsion):	Min T	T	MI 2 Unit Truck 16-NL	118.5616545	66.61393767	1.25	1.235722222	219.3860508	0.929078601

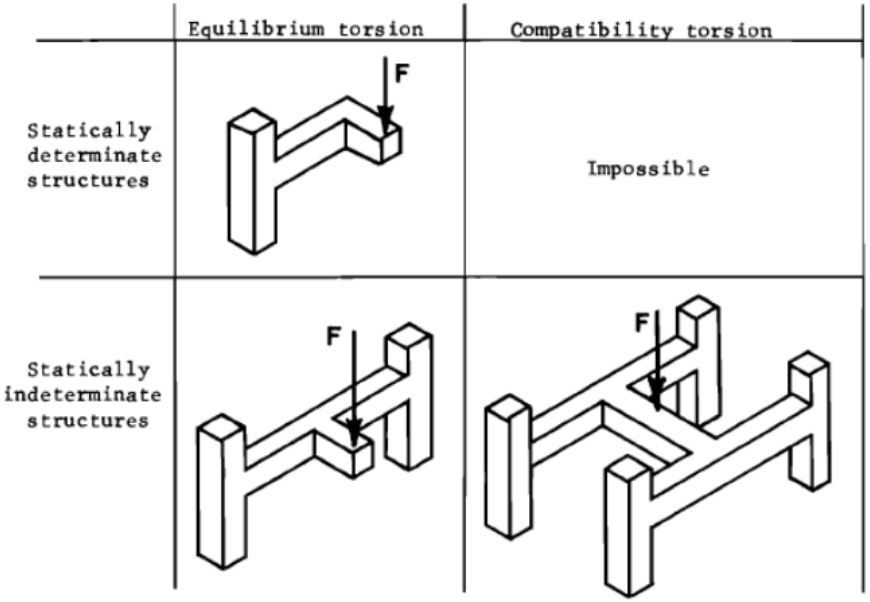
Findings

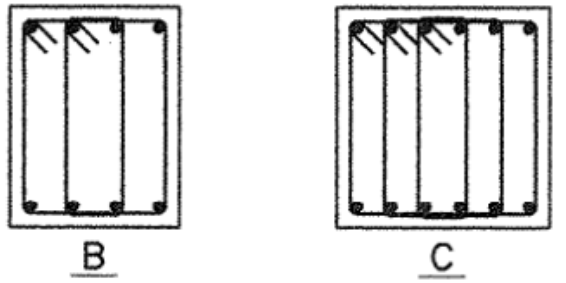
- Structure is inadequate to carry the full weight of Michigan-specific legal loads
- Side-by-side loading and axle weight were critical, unlike a bridge where total load is generally related to RF
- Columns did not control
- Deck did not control

Findings

- Combined shear and torsion produced the minimum rating factor
  - Higher torsion observed in longitudinal girders

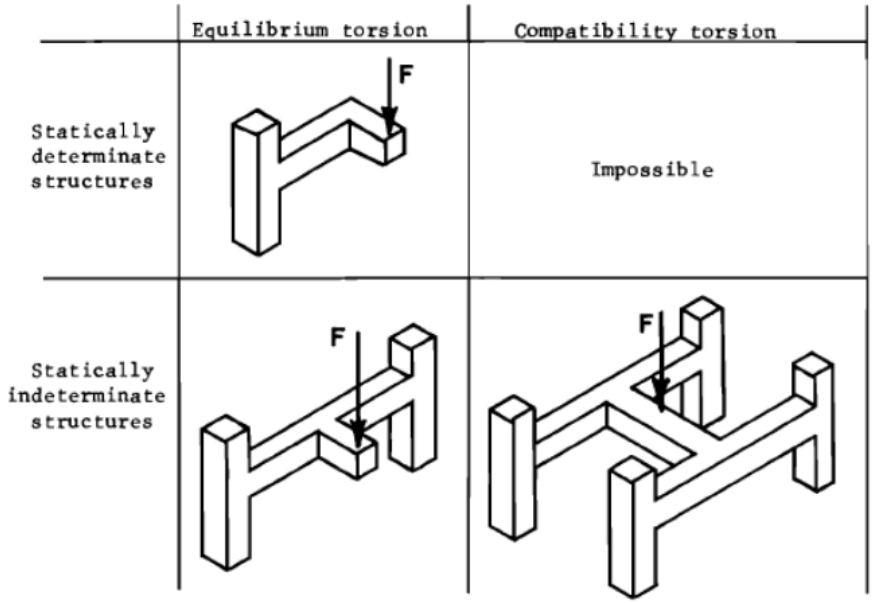


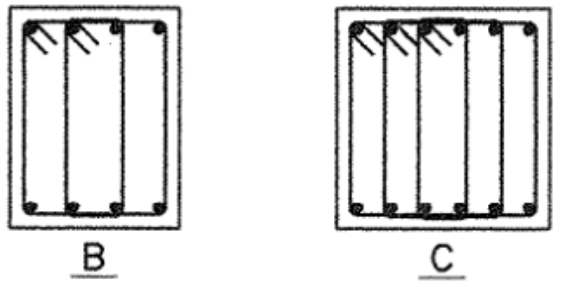




Findings

- Combined shear and torsion produced the minimum rating factor
  - Higher torsion observed in longitudinal girders
  - Torsional resistance is less than torsional cracking moment -> cannot redistribute torsion
  - Checked ACI codes revisions related to torsion design back to 1988 edition
  - Use general procedure in LRFD to calculate angle of inclination to increase torsional resistance

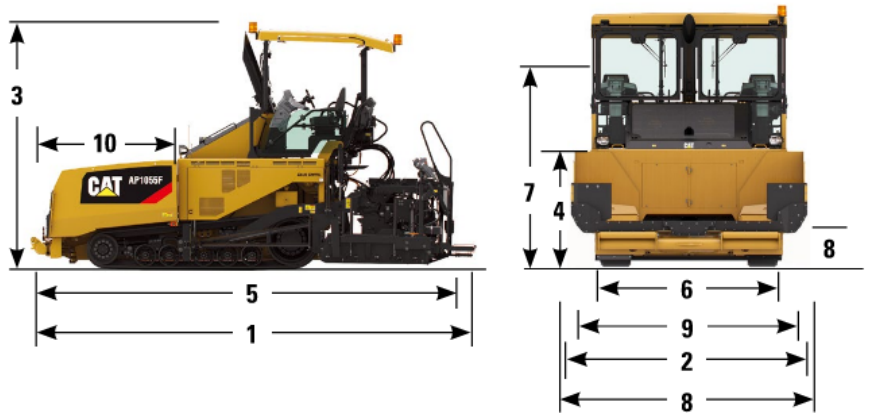




Final Load Rating Recommendations

- Recommend installing posting sign at all points of entry to the elevated Atwater stretch
- Recommend performing load rating on portions of Renaissance Drive West and Beaubien Boulevard which are also supported on structure

Construction Check



- With a low rating, how would the contractor mill and overlay the street?
  - Golf carts with dumps on the back?
- A construction check was performed.
- The delivery method was **CMGC** so we could talk directly with the contractor and get exactly what equipment they were going to use.
- We analyzed configurations of milling and paving machines, and dump trucks.
- Plan notes were developed to control equipment spacing.
- In-line is ok, side-to-side is problematic.

If we had more time….

- Explore the consequences of allowing torsional re-distribution in beams which weren't designed for torsion at all.
- Strategically consider cracked section properties to further re-distribute forces.
- Evaluate torsion capacity using other methods like strut & tie.
- Evaluate using striped lane locations.
- Look at decreasing impact due to low speed along Atwater.

Race Results

§ The race started a little rough….

Race Results

- But Alex Palou, who also won pole position, was the victor