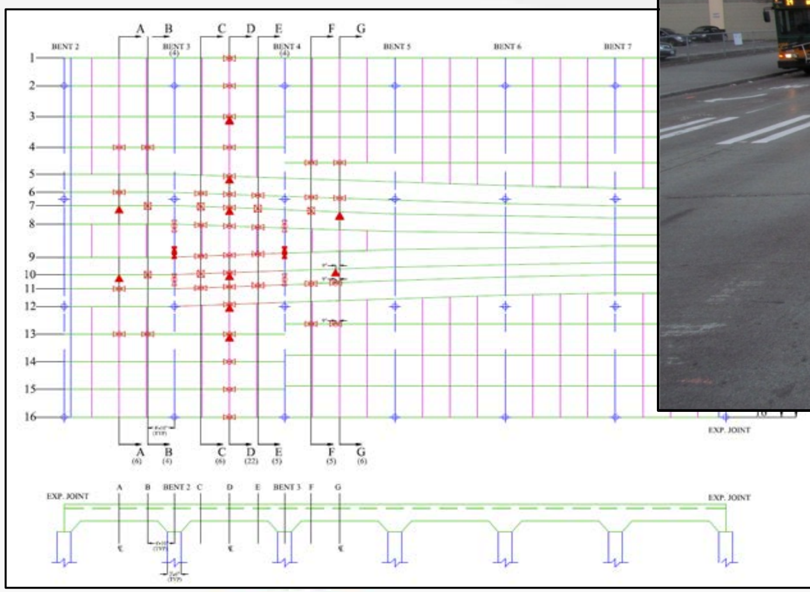
IMPROVING LOAD RATINGS & BRIDGE MANAGEMENT DECISIONS:

Field Testing of the Jackson St. Bridge



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BDI

STRUCTURAL TESTING & MONITORING

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THE EVER-GROWING PROBLEM

Typical reasons for improving or better quantifying load rating of existing structures:

- Missing Construction Details or Design
- Mistakes in Construction
- Changes in Design Codes
- Deterioration or Damage
- Permitting of Heavy Superloads

Many of these issues can often cause Bridge Owners to allocate substantial resources to rehabilitate these structures.

AGE OLD PROBLEM: Bridge Owners have to perform this task with limited resources while dealing with an ever increasing number of deficiently rated bridges.

(LESS MONEY, MORE PROBLEMS)

CONSERVATIVE NATURE OF LOAD RATINGS

Standard AASHTO Load ratings often rely on assumptions related to unknown parameters such as:

- Lateral Load Distribution
- Boundary Conditions
- Construction Details
- Maintenance Work
- Material Properties
- Existing Levels of Deterioration

Structures' live-load carrying capacity is often underestimated.

Bridges end up on Owner's "RED LIST" to be replaced sooner than necessary.

FIELD VERIFIED EVALUATION

The overall goal is to **obtain realistic rating values for bridges in a cost effective manner**.

This is done by:

- Measuring the **response behavior** and determining the structural parameters that produce them.

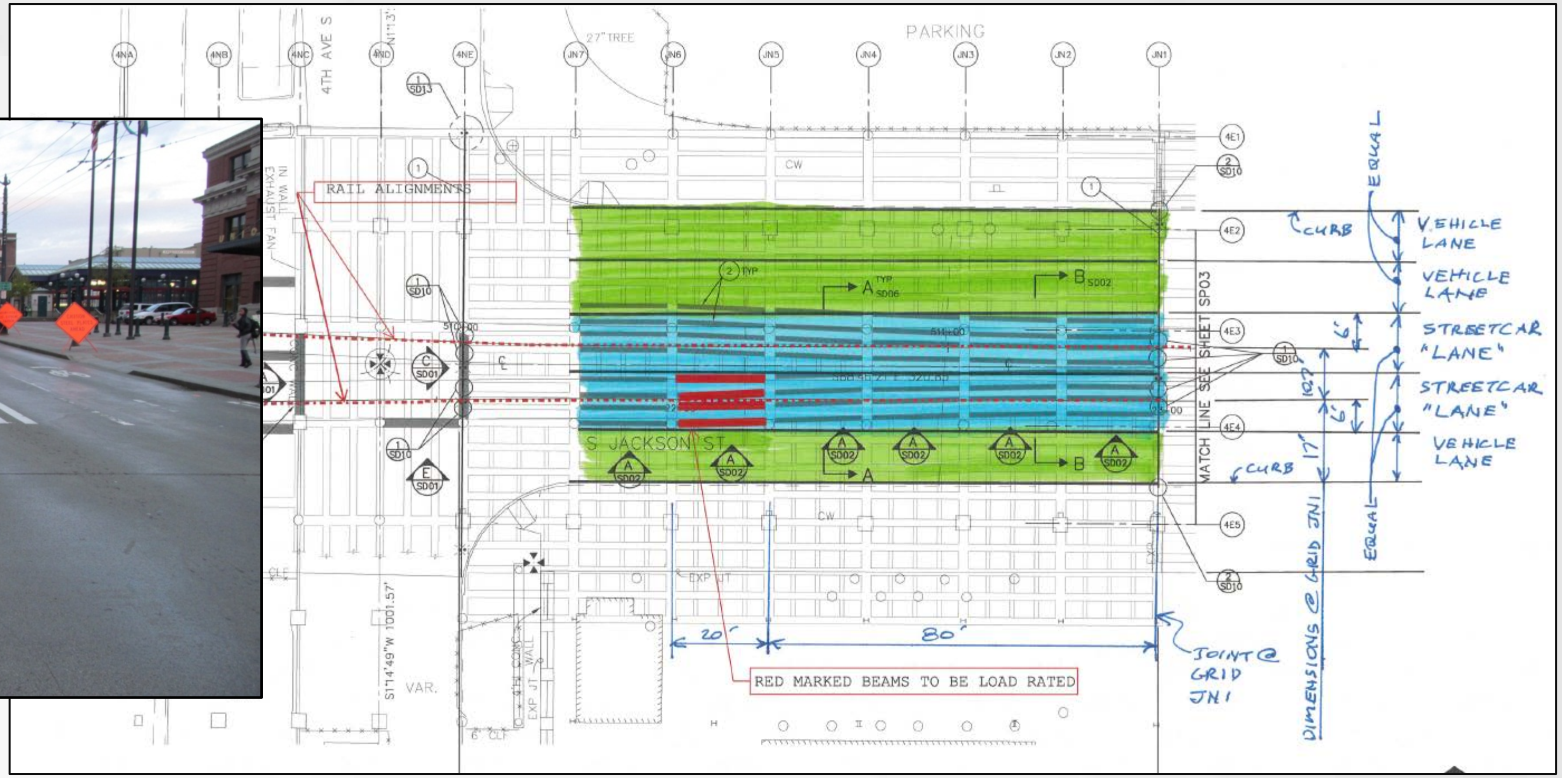
  (Better Quantify the Load Behavior)
- Determine any **material properties** that are unknown or uncertain.

  (Better Quantify the structure's capacity)
- With this field data, both refined structural capacities and a field calibrated bridge model can be utilized to **calculate accurate load ratings**.

(Based on Field Test Data, the Structure's Load Ratings can be Accurately Defined)

CASE STUDY: JACKSON ST. BRIDGE REHABILITATION

In 2006, the City of Seattle resurrected their streetcar operations and is currently building a second line along the Jackson Street Corridor.



During the planning phase, it was determined that the structure had a deficient load rating for the proposed streetcar loads (RF=0.42).

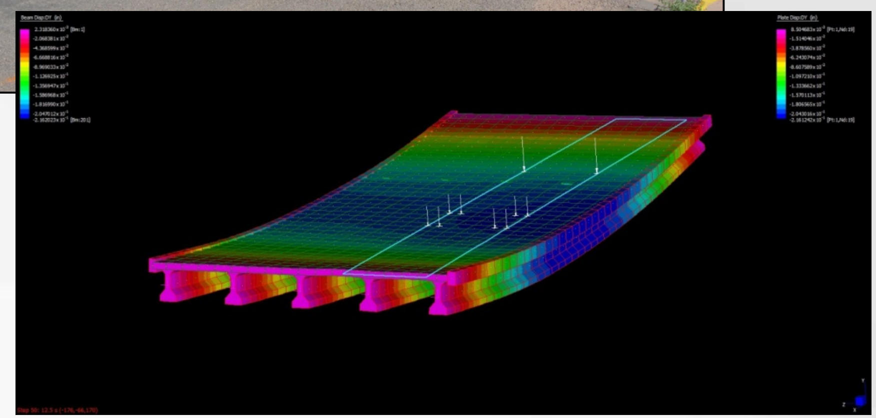
CASE STUDY: JACKSON ST. BRIDGE REHABILITATION

SDOT elected to utilize a field testing program that involved:

1. Concrete Core Tests

2a. Diagnostic Load Tests

2b. Field-Verified Model Calibration



2c. Subsequent Load Rating Procedure.

CONCRETE CORING

First, SDOT performed concrete coring on 3 number of samples.

ASTM C42

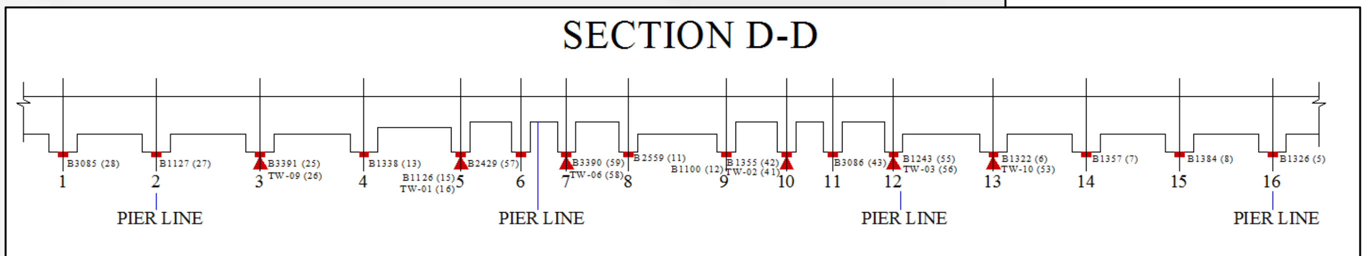
Core Testing

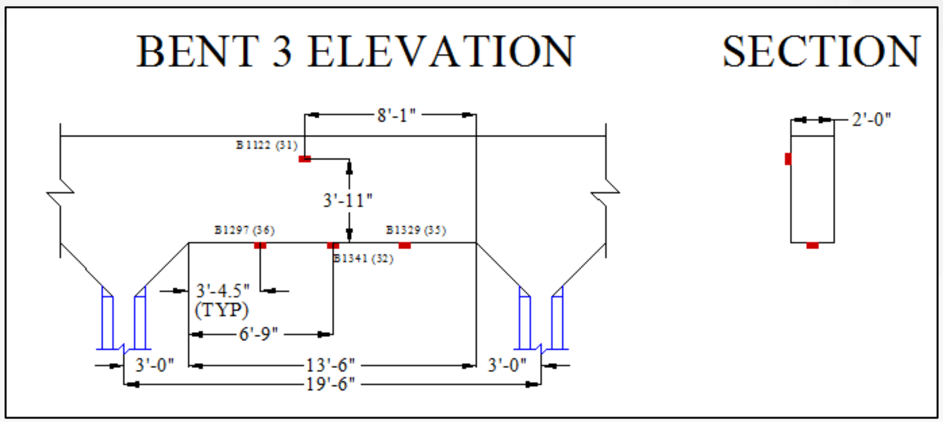
Specimen	Area, in^2	Max Load, Lbs.	Strength, psi
Core 1	5.81	31,150	5,360
Core 2	5.81	30,540	5,260
Core 3	5.81	32,380	5,570

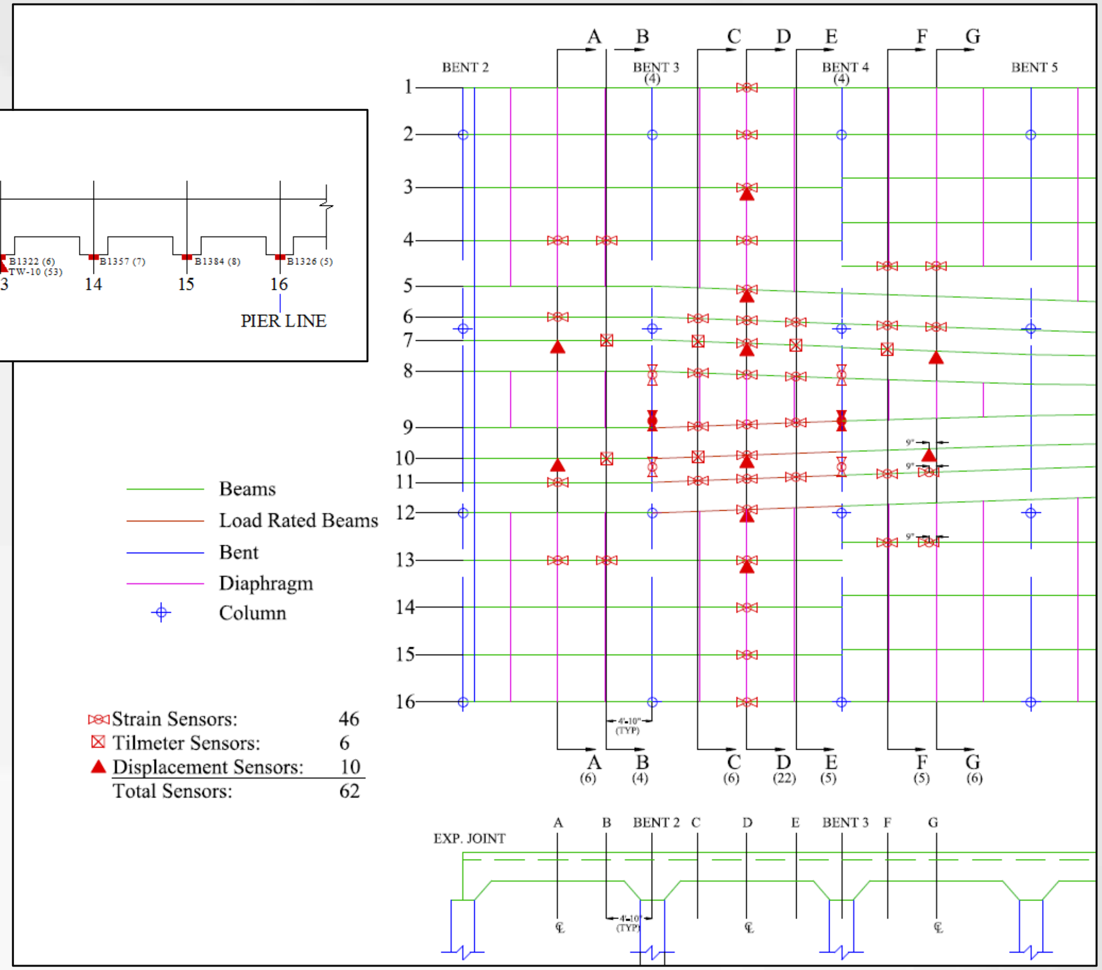
Based on this compressive strength (f_c=~5300psi), the critical shear rating in the beams still could not be increased to above 1.0 for the streetcars.

DIAGNOSTIC LOAD TEST SET UP

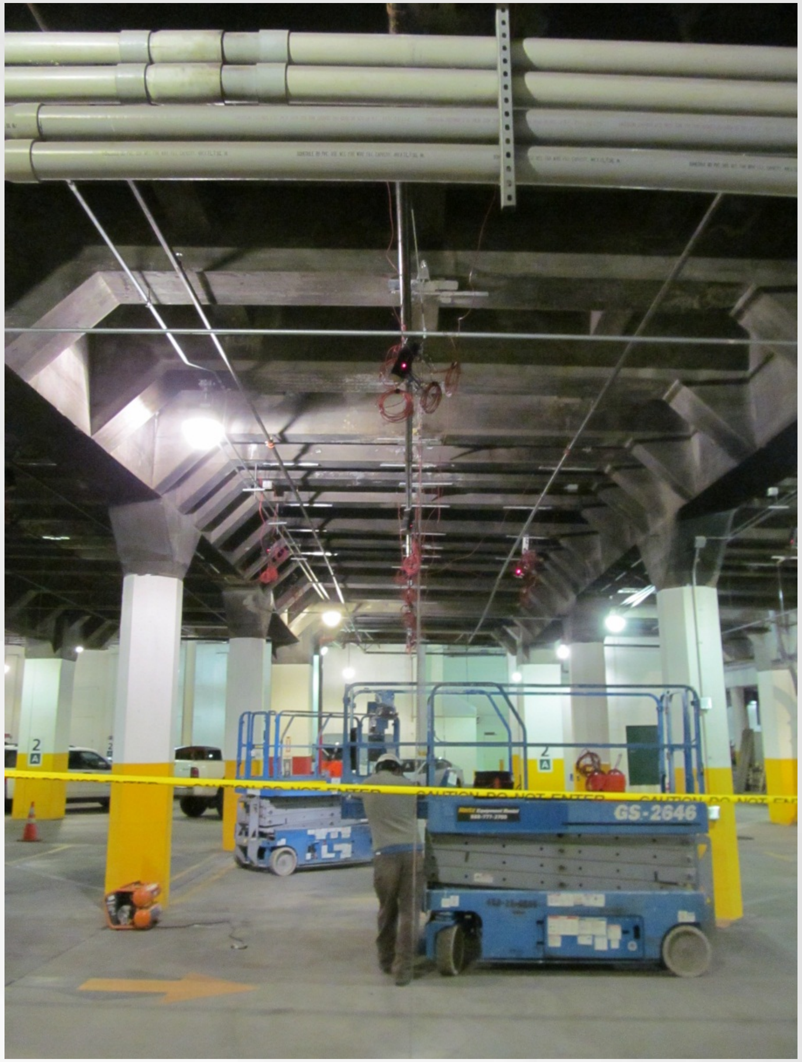
A testing plan including 62 sensors was created to measure strains, rotations, and displacements.







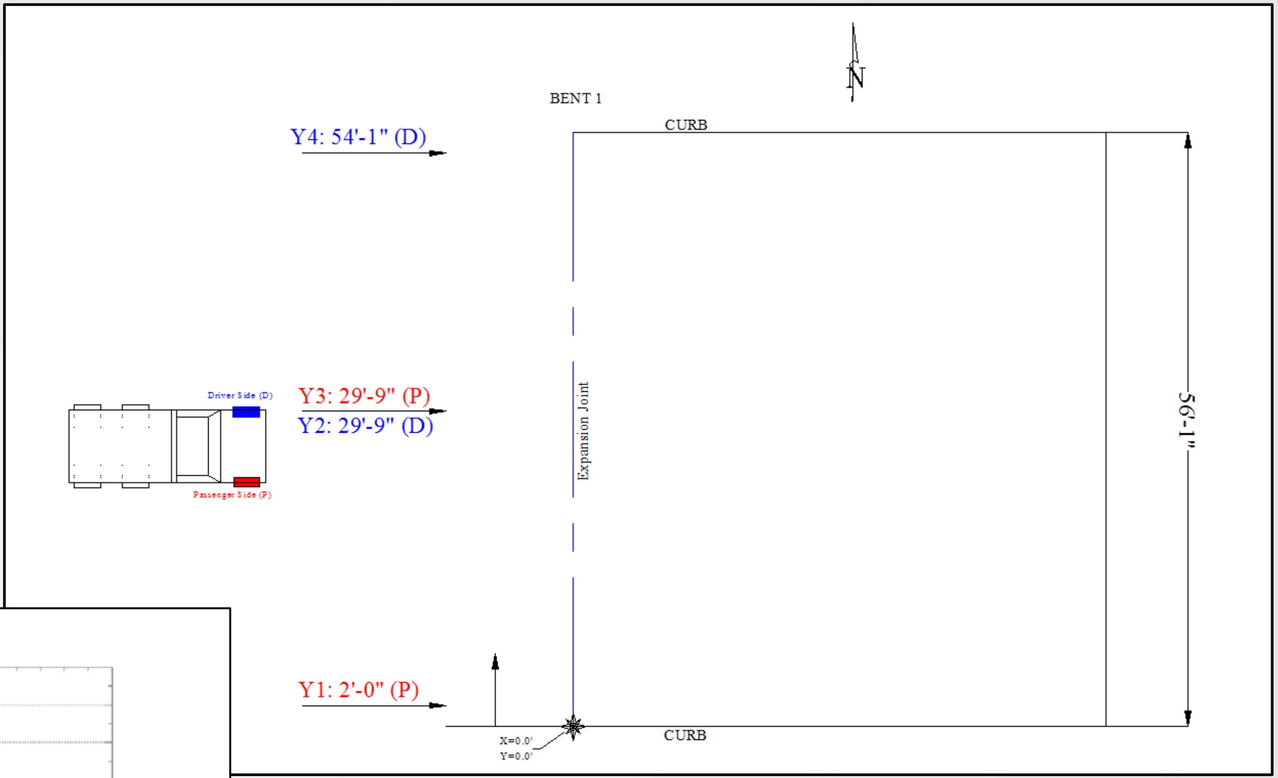
INSTRUMENTATION INSTALLATION

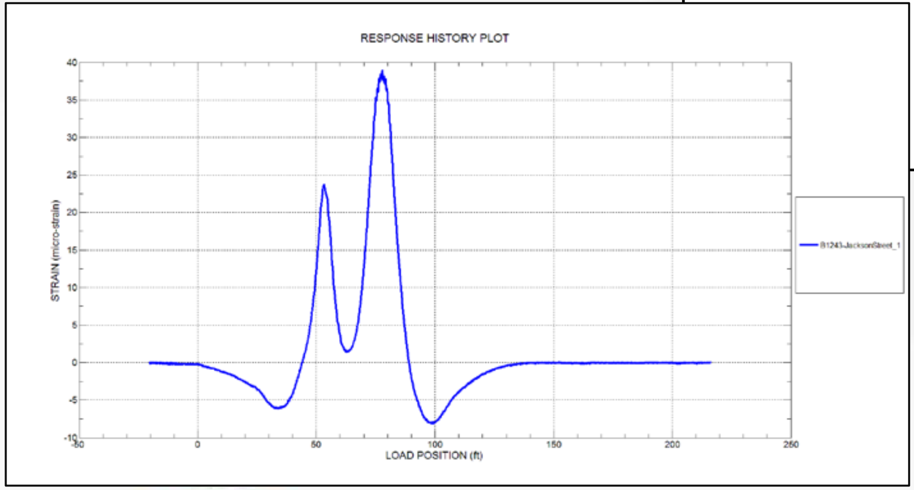


RUNNING LOAD TEST

Data was recorded at 40 Hz from all sensors as the test vehicle crossed the structure along four different lateral positions.

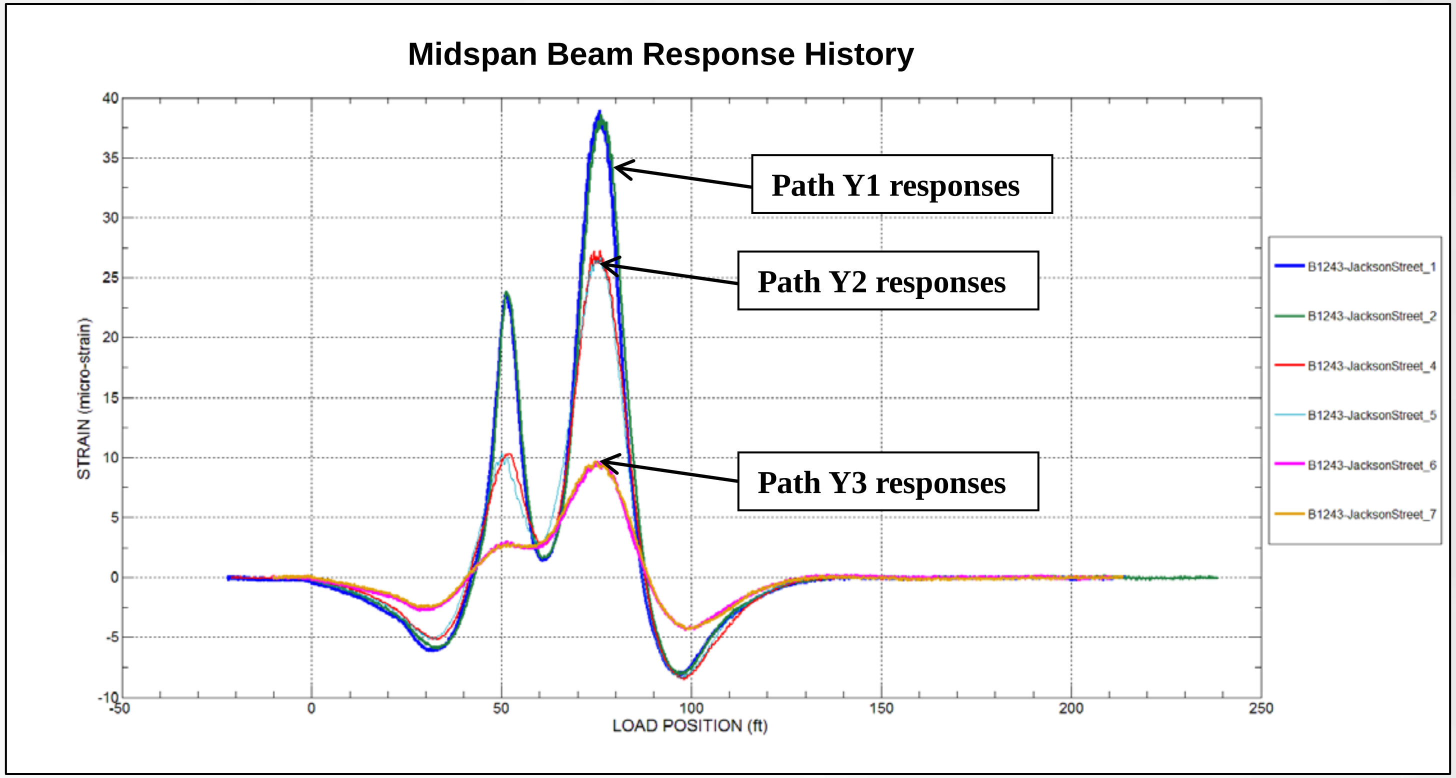
(Shown as Paths Y1 –Y4)





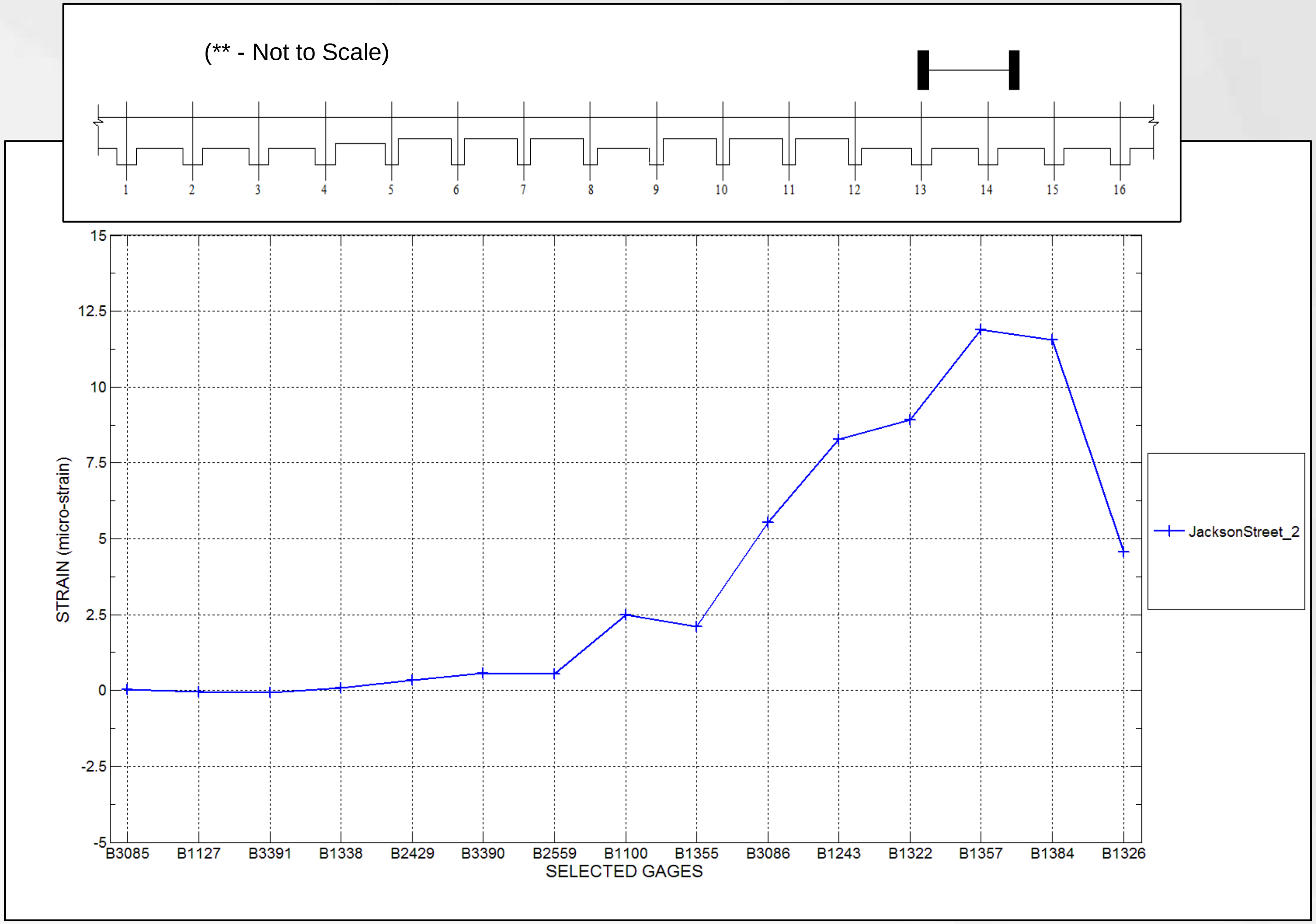
DATA REVIEW

All of the field data was examined graphically to provide a *qualitative* assessment of the structure's live-load response.



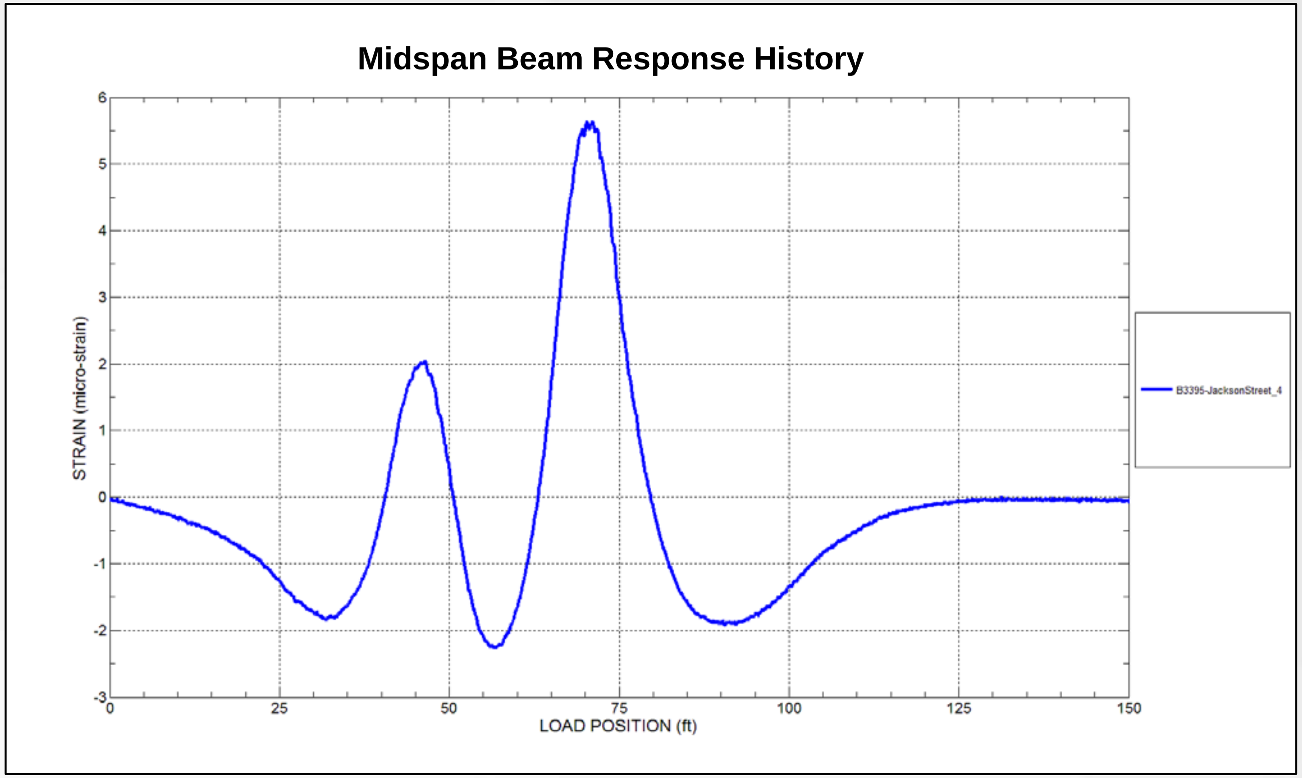
REPRODUCIBILITY & LINEARITY

DATA REVIEW



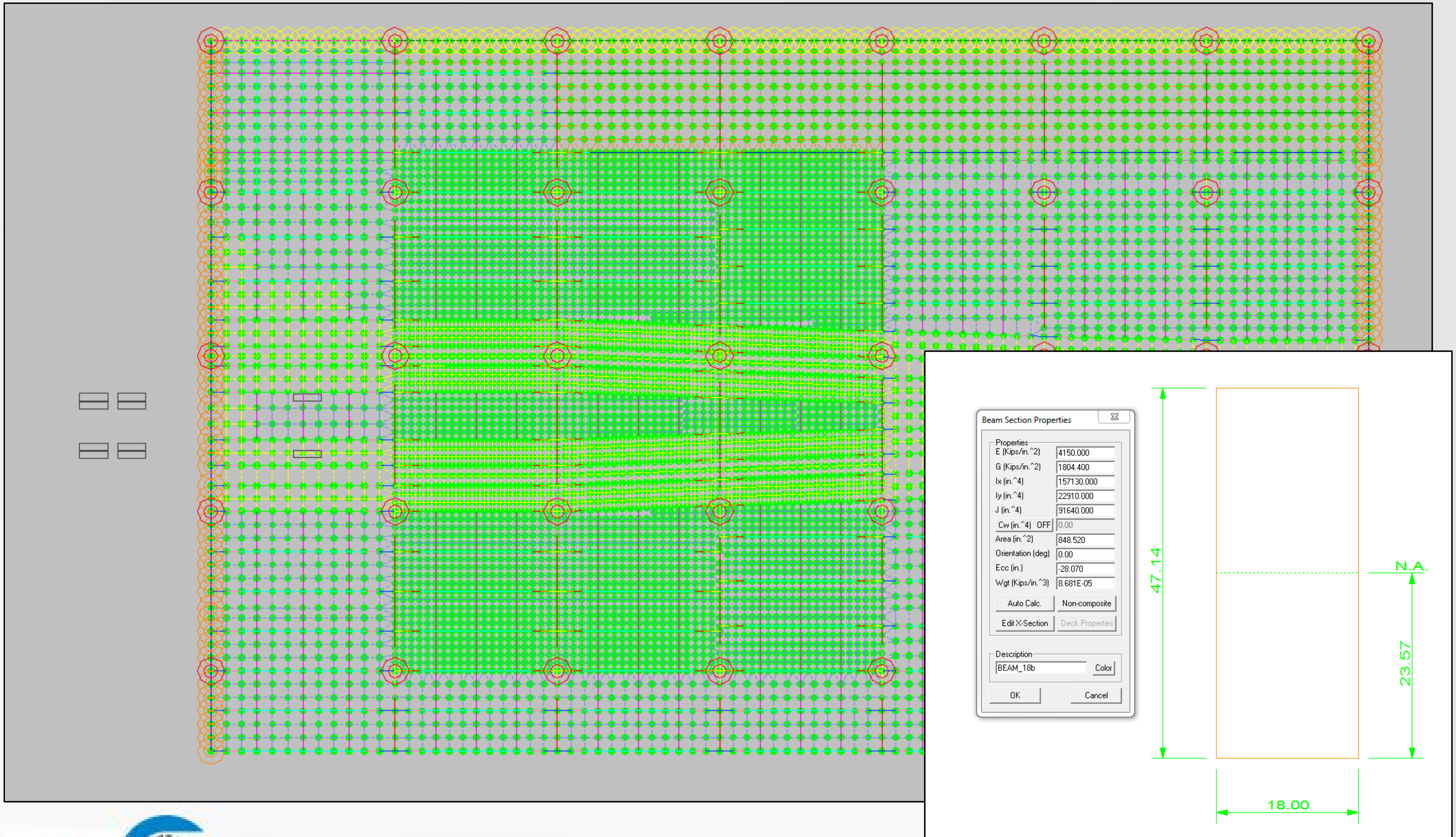
Lateral Load Distribution

DATA REVIEW



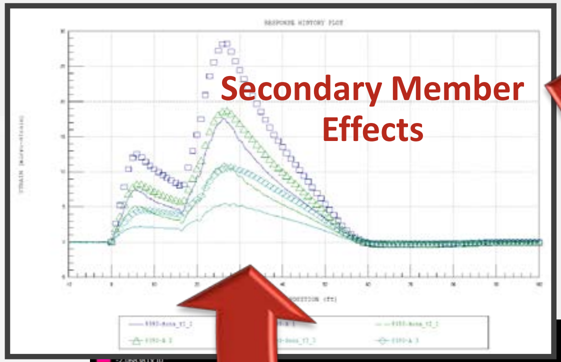
Continuity & End-Restraint

FINITE ELEMENT MODEL DEVELOPMENT

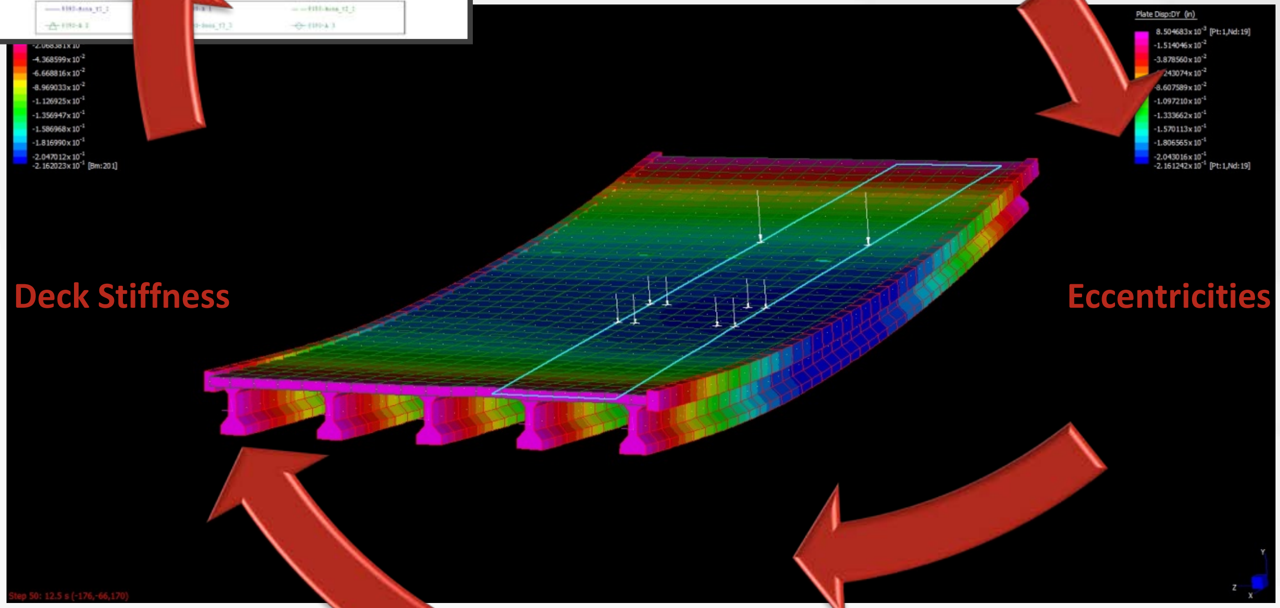


THE INTEGRATED APPROACH
USING FIELD DATA TO CALIBRATE MODEL

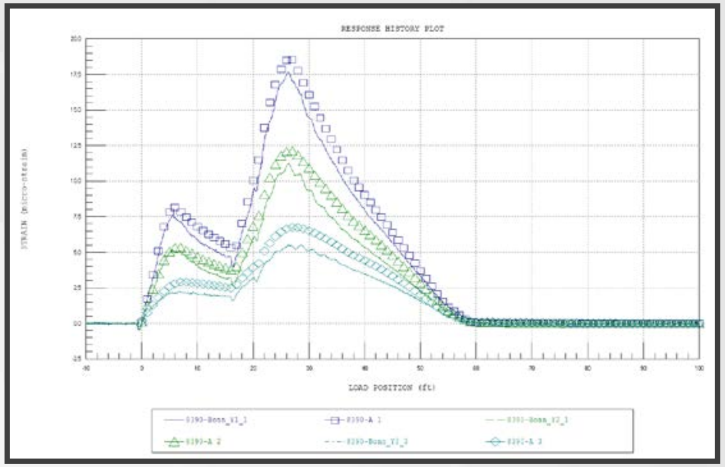
1. Compare field data to initial FE model
2. Adjust parameters to “calibrate” FE model
3. Use calibrated model to perform load ratings



Beam Stiffness



End Restraint



MODEL CALIBRATION RESULTS

The model was calibrated until an acceptable match between measured and computed response was achieved (correlation coefficient of ~0.95).

The following conclusions were made from this analysis:

- The structure behaved like a **two-way RC structure**
  - A high level of continuity / end-restraint was observed that altered the shear and moment profiles from previously assumed
- The Structure had **much better load distribution** than provided by AASHTO distribution factors.
- The structural elements were found to have **a larger average stiffness** than is typically assumed for an RC structure (results agreed with core sample results)

FIELD VERIFIED LOAD RATING RESULTS

Load ratings were computed for numerous load conditions:

- Up to five lanes loaded
- Combinations of streetcars, design vehicles, and permit vehicles

Critical beam LFR load rating factors for rating loads.

Rating Load	Location/Limiting Capacity	Inventory Rating Factor	Operating Rating Factor
Street Cars	Interior Beam at Face of Bent / Shear	3.51	5.86
HS-20	Interior Beam at Face of Bent / Shear	1.91	3.20
HS-20 + Street Car	Exterior Beam at Face of Bent / Shear	1.97	3.29
HS-20 + Overload	Exterior Beam at Face of Bent / Shear	1.93	3.23
HS-20 + Overload + Street Car	Exterior Beam at Face of Bent / Shear	**1.85**	**3.09**

Conclusions:

- Shear in the beams no longer controlled the load ratings.
- Shear strengthening was no longer required.
- Due to the observed continuity, the critical rating was now the bents (cross-beams) in negative flexure (LFR Inventory Rating of 0.97).
  - However, these members were found to have significant structural redundancy for bending (Reserve positive moment capacity)

CONCLUSIONS

The following conclusions were made as a result of the testing program:

- The structure's concrete was found to be much stronger than typically assumed.
- The structure was found to have much better load distribution (Longitudinally & Laterally) than AASHTO typically allows engineers to assume.
- As result of both these conclusions, the largest component of the proposed rehabilitation was eliminated in this region of the Jackson St Corridor.
- Based on cost estimates before and after the completion of the testing program, rehabilitation costs were reduced by approximately 30%.

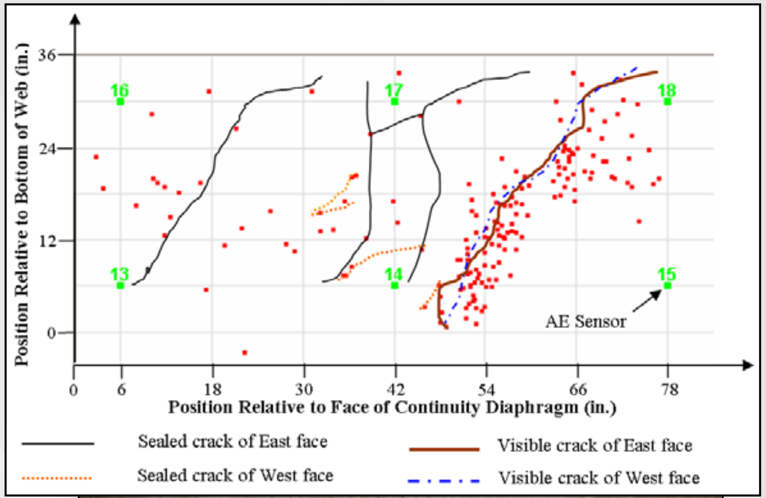
ESTIMATES OF LOAD RATING IMPROVEMENT

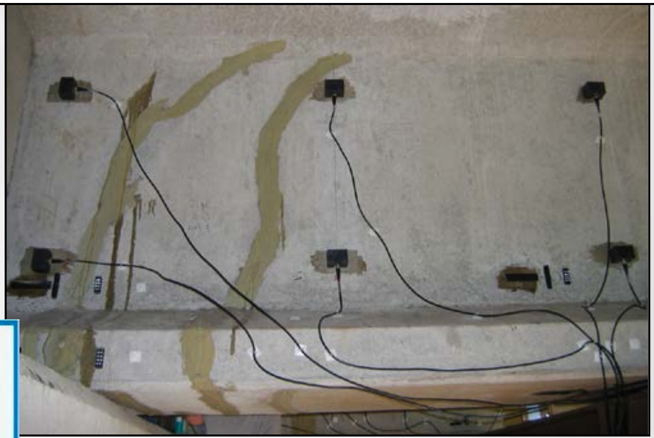
Bridge Type	Influencing Factors	Percent Improvement**
RC Slabs	Greatest benefit, end conditions, edge stiffening, no longitudinal joints	30 to 60%
Beam Slab Bridges	Ratings controlled by moment, Beam lines > wheel lines, End conditions and edge stiffening	20 to 40%
Culverts and arches	Function of fill depth, end-conditions, span length	20 to 30%
Truss Bridges	Members inline with floor system	0 to 30%
Beam Slab Bridges	Ratings controlled by shear, # of beam lines equal to , edge stiffening.	0 to 15%
2 Girder bridges	No improvement in distribution. End conditions may influence ratings.	0 to 15%

**** - Based on BDI's experiences over the last 24 years (Load Testing ONLY)**

Other NDE techniques to define capacity

Ground Penetrating Radar (GPR)





Acoustic Emissions (AE)

LOAD RATINGS DON'T ALWAYS IMPROVE!

- Distribution improved
- Midspan Rating Factor increased from 0.65 to 1.16
- Shift in inflection point
- L/3 (60% of A_s terminated)
- RF = 0.34 (LRFR)

Lincoln, RI

- Load test detected isolated deficiency
- Localized repairs performed with CFRP
- Bridge is in service with no load restrictions

THANK YOU! QUESTIONS?

BDI

SDOT
Seattle Department of Transportation

kpff

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