Evaluation of the Potential Benefits of Implementing the AASHTO Guide Specifications for the Analysis and Identification of NSTMs, SRMs and IRMs

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Overview of Presentation

- Objective
- What are IRMs?
- Evaluation approach for internal redundancy
- US 41 - White River Bridge and I74 – Wabash River Bridge
- Implementation of IRM guide spec

Objective

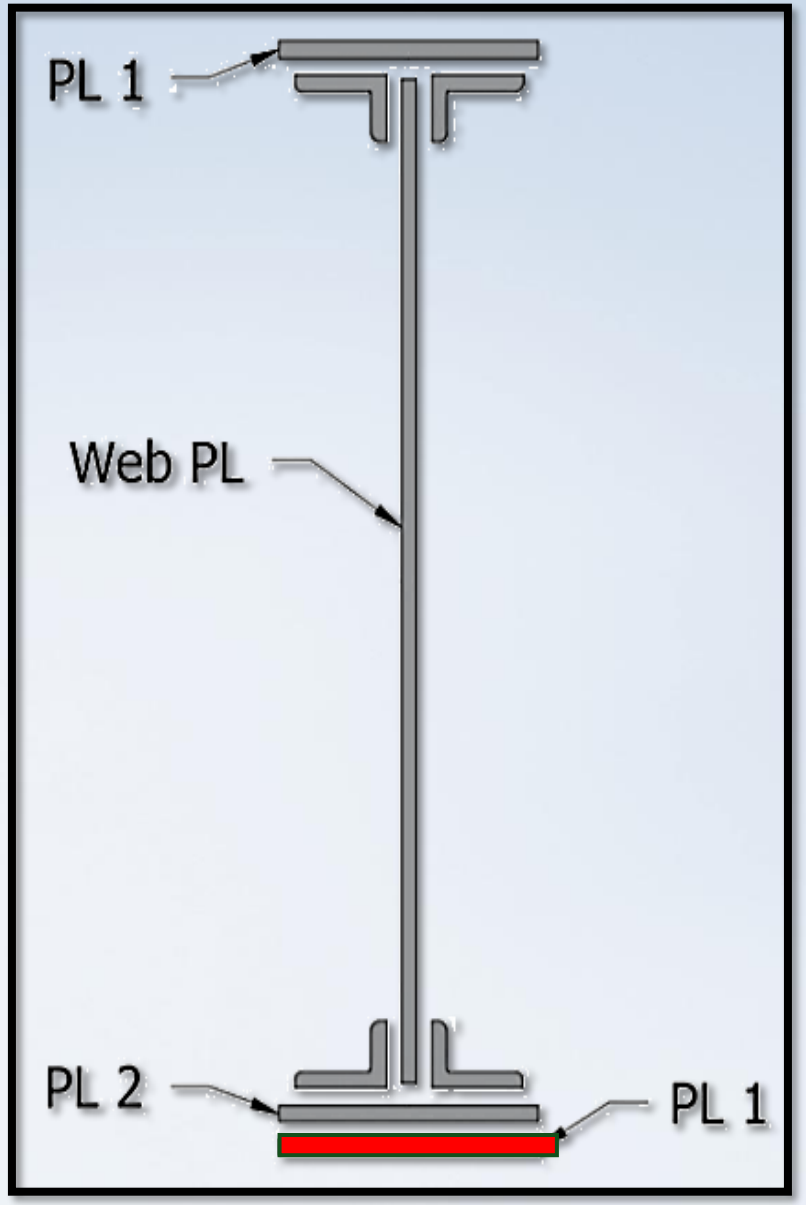
What are IRMs?

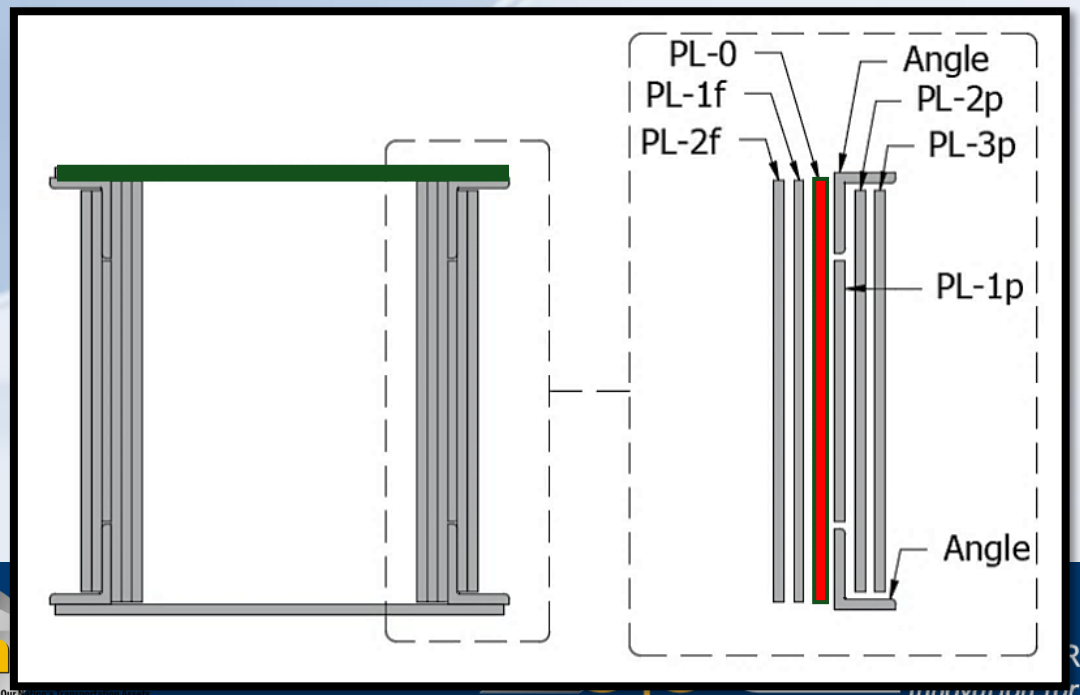
- Steel Bridge Tension Members
  - Non-Redundant Steel Tension Member (NSTMs)
    (Formerly FCMs)
  - Redundant Members
    - Load Path Redundant Members
    - Internally Redundant Members (IRMs)
    - System Redundant Members (SRMs)

What are IRMs?

(Todays focus)

A primary built-up steel member in tension, or with a tension element, that has redundancy within the cross-section, such that fracture of one element will not propagate through the entire member [IRM Guide Spec]



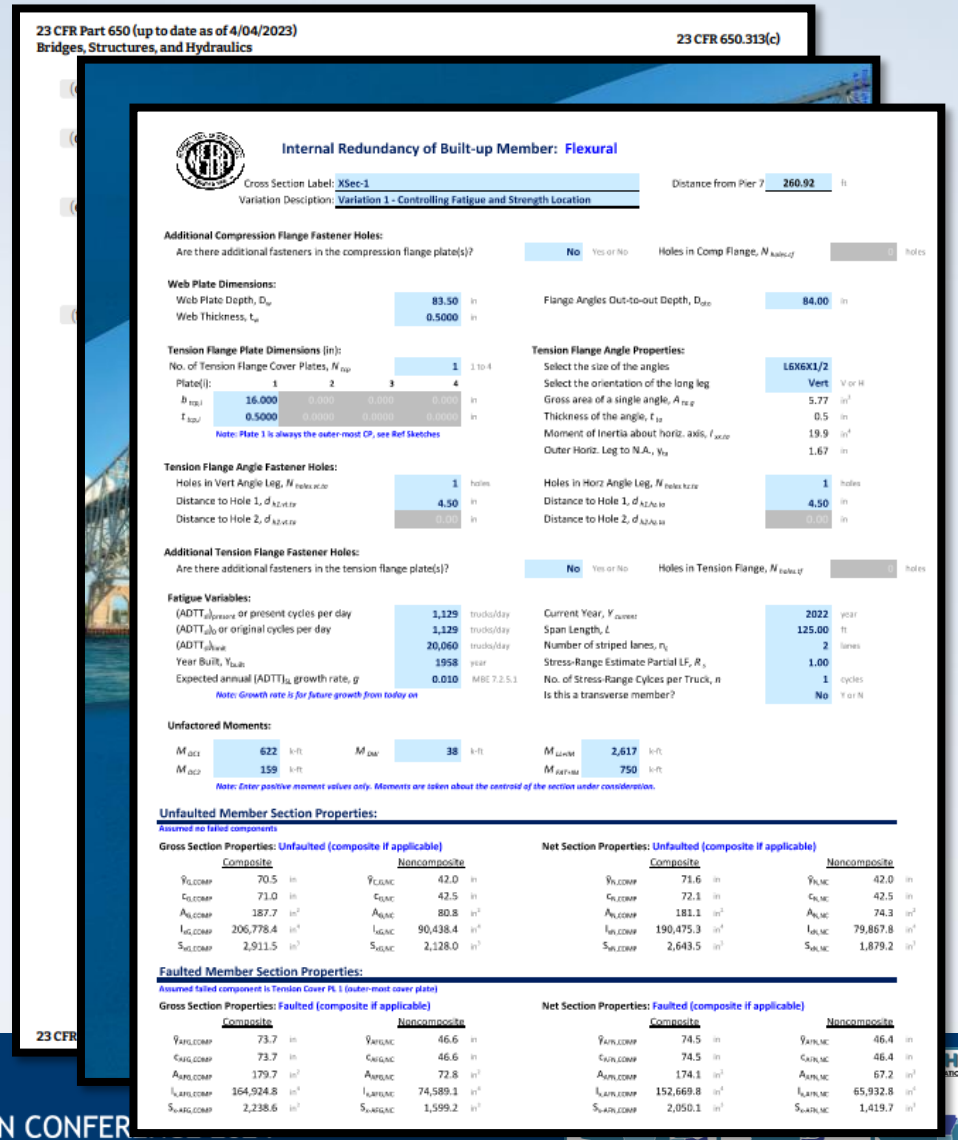


Regulations and Specifications and Tools

- Update to 23 CFR Part 650 [June 6 of 2022]:

- AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members (IRM Guide Spec)

- NSBA/S-BRITE IRM Evaluator Spreadsheet



Evaluation approach for internal redundancy

1. General requirements (screening criteria)
2. Strength capacity in the faulted state check
   a) Fracture on the net section
   b) Yielding on the gross section
3. Fatigue life estimates
   a) Unfaulted State
   b) Faulted State
   c) Total Remaining Fatigue Life
4. Maximum Interval for Special Inspections

Summary of Results

Strength check =	OK	OK or NG
Fatigue case =	II	I(a), I(b), II
Stress range in unfaulted state, Δf_{UFS} =	3.41	ksi
Controlling stress range in faulted state, Δf_{FS} =	5.76	ksi
Controlling faulted state remaining fatigue life, Y_{REM}	**43.5**	Years
Total remaining fatigue life, N_f	**19.4**	Years
Maximum Interval for Special Inspections =	**10.0**	Years

IRM Evaluation – US 41 – White River Bridge

- Gibson County, IN
- 16-span, Steel Two-Girder Twin Bridges
- Built in 1958
- ADT (2021): 11,322, %Trucks = 26%
- Has pin and hanger details
- SPR-3472, Purdue University, July 2011, *Evaluation of the Effects of Super-Heavy Loading on the US-41 Bridge*

IRM Evaluation – US 41 – White River Bridge

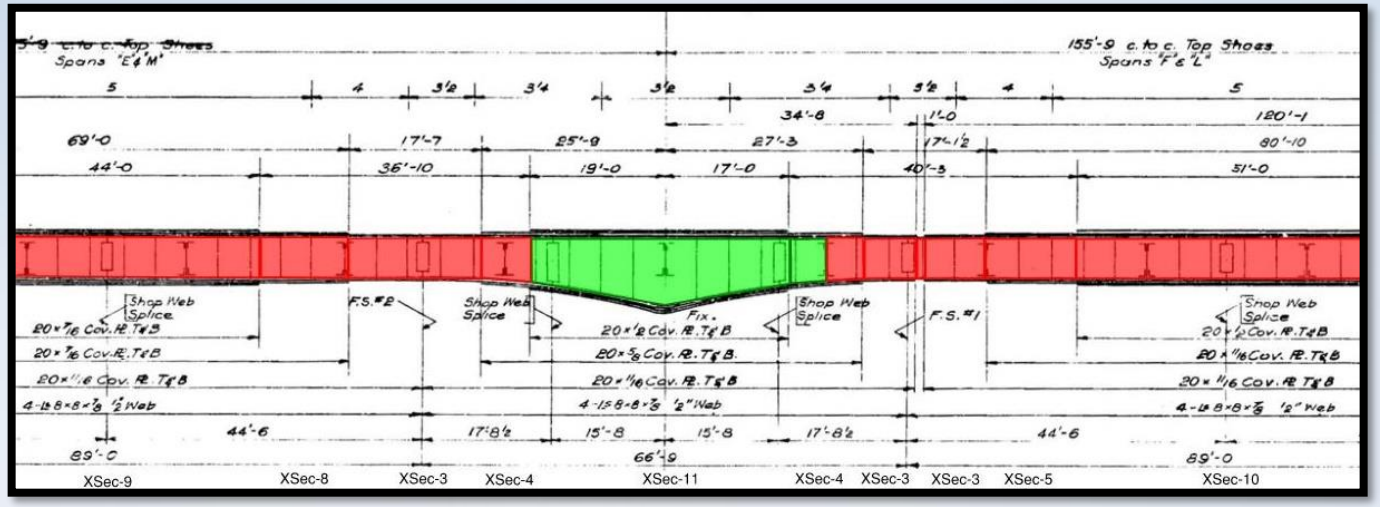
Areas not satisfying the screening criteria for IRM:

Lack of cover plates
20 locations per girder
(~3% of girder length)

Pin and hanger - 4
locations per girder
(~0.5% of girder length)

IRM Evaluations – US 41 – White River Bridge

Using AASHTO fatigue truck design loads:



But Recall…

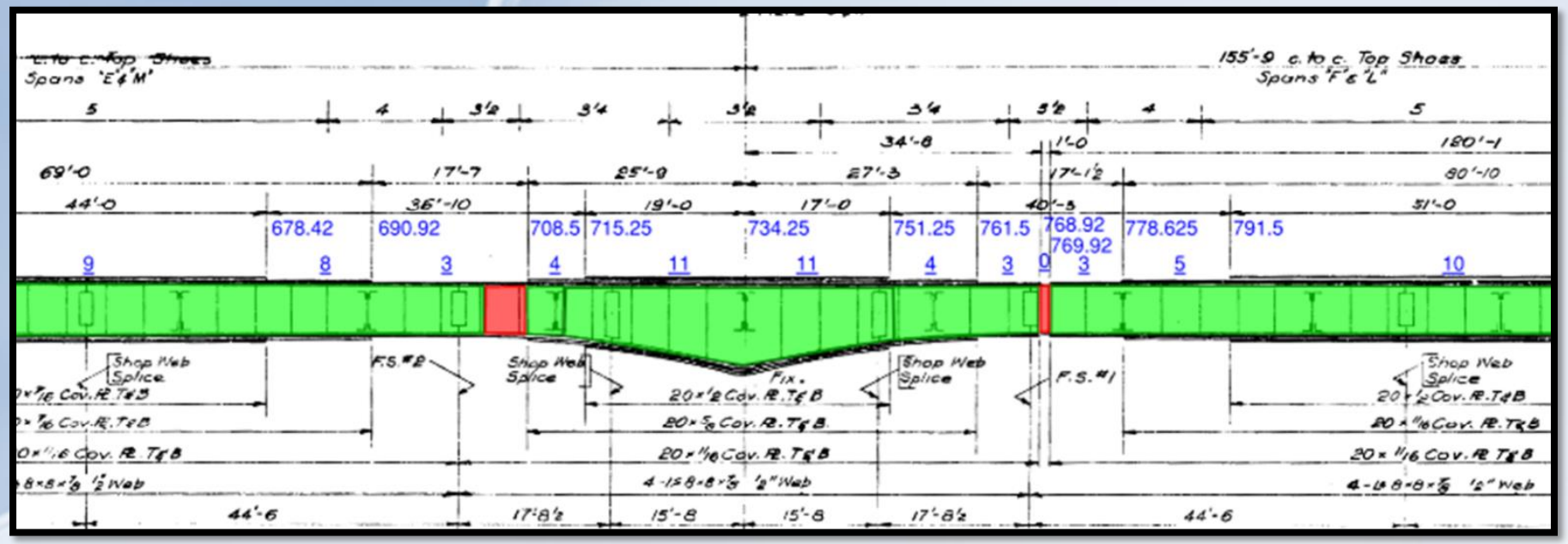
2011 Long Term Monitoring Data:

- Lower effective stresses (~57% Max)
- Lower total cycles per day (~66% Max)
- Composite action

XSec	Strain Gauge	Location (ft)	Eff Stress BrR (ksi)	Eff Stress Field Test (ksi)	Eff Stress Ratio	Location
XSec-10	CH 2	500.625/1902.375	4.6	2.1	0.46	Max Positive Moment Span N
XSec-3	CH 4	452.125/1950.875	7.6	2.8	0.37	Inflection Point Span N
XSec-9	CH 5	422.75/1980.25	4.6	2.5	0.55	Max Negative Moment @ Pier 13
XSec-9	CH 6	422.75/1980.25	3.9	2.1	0.53	Max Negative Moment @ Pier 13
XSec-9	CH 12	422.75/1980.25	3.9	2.2	0.56	Max Negative Moment @ Pier 13
XSec-4	CH 24	344.875/2067.75	3.5	2.0	0.57	Max Positive Moment Span P
XSec-4	CH 26	344.875/2067.75	3.5	2.0	0.57	Max Positive Moment Span P

IRM Evaluations – US 41 – White River Bridge

- Using in-situ effective stress ranges and cycles…



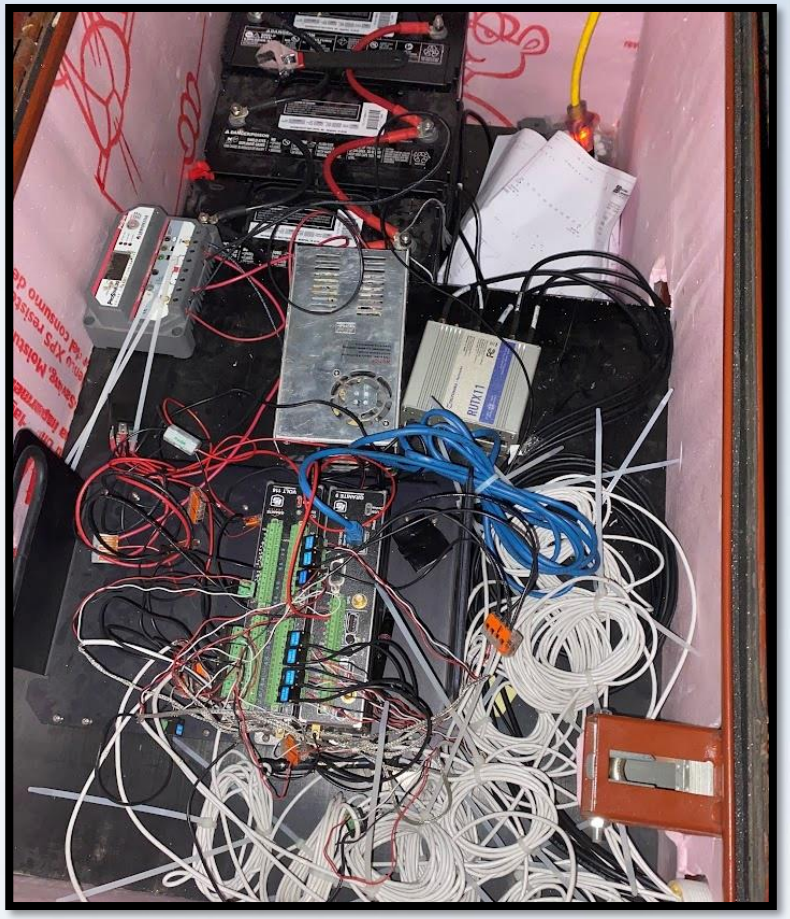
- Nearly 94% of the main girders of the bridge are eligible to be reclassified as IRMs
- Resulted in a *Special Inspection* frequency of 10 years

IRM Evaluations – I74 Wabash River Bridge

- Vermillion County, IN
- Twin, 5 main spans with 12 approach spans
- Steel two built-up girders with added girder
- Built in 1958
- ADT: 17,156, % Trucks = 59%

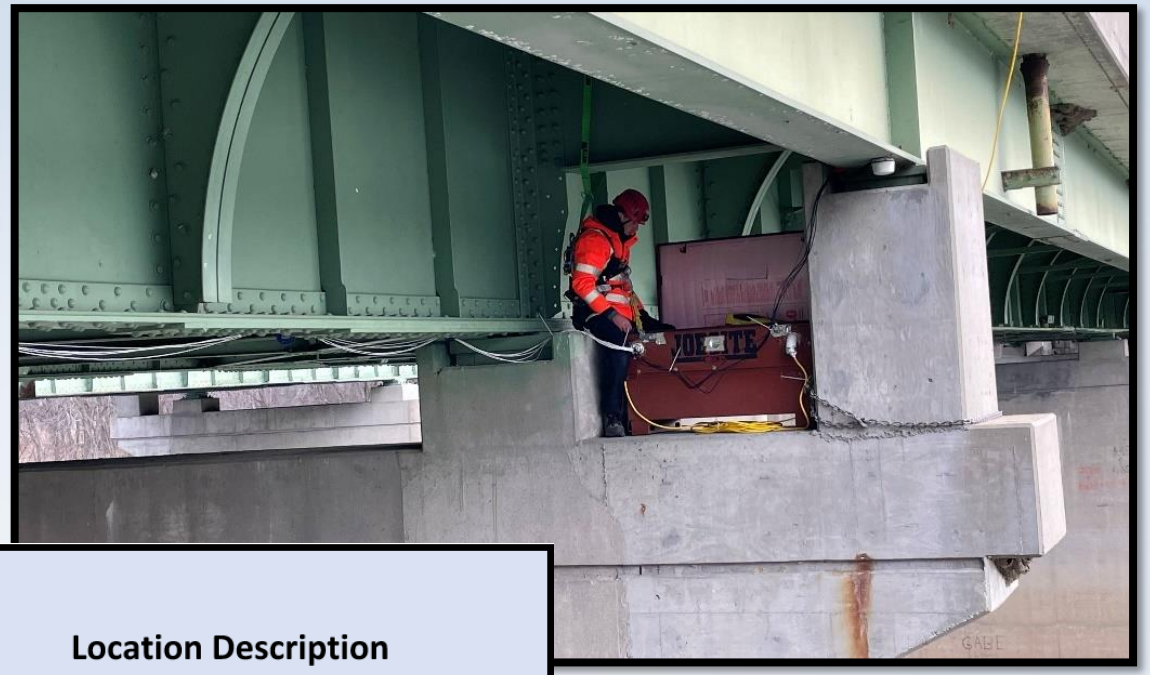
IRM Evaluations – I74 Wabash River Bridge

- Using AASHTO fatigue truck design loads, a high percentage of the structure did not qualify as IRMs due to insufficient remaining fatigue life
- Based on experiences with US 41 Bridge, it was decided to install limited instrumentation and collect data



IRM Evaluations – I74 Wabash River Bridge

- Lower effective stresses (~60% of Stress due to AASHTO Fatigue Truck)
- Lower total cycles per day (~25% of ADTT values)

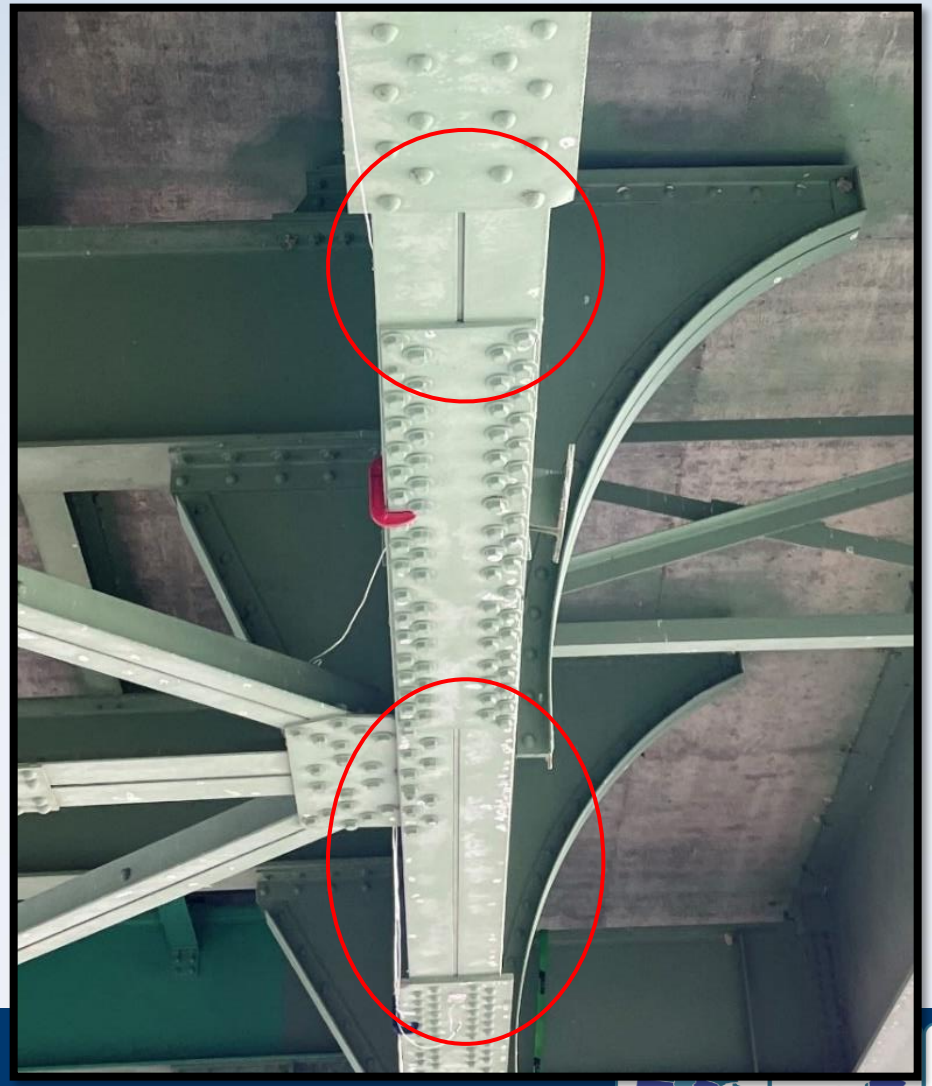


XSec	Strain Gauge	Distance from Pier 7 (ft)	Eff Stress Fatigue Truck (ksi)	Eff Stress Field Test (ksi)	Eff Stress Ratio	Cycles/day	Location Description
XSec-1	SG1	56.95	4.92	2.75	0.559	182.8	Specific Cross Section Check
XSec-1	SG2	56.95	4.92	2.33	0.474	1128.9	Specific Cross Section Check
Xsec-2	SG6	163.67	4.23	2.56	0.604	161.6	Near Max Positive Moment Region
Xsec-2	SG7	163.67	4.23	2.34	0.553	58.7	Near Max Positive Moment Region
XSec-00	SG8	194.92	5.43	2.63	0.484	162.8	Near Inflection Area
XSec-00	SG10	194.92	5.43	2.30	0.424	940.0	Near Inflection Area

IRM Evaluations – I74 Wabash River Bridge

- 10-year inspection frequency for around 79% of bridge length

- Again, some areas do not meet screening criteria due to lack of any cover plates
  - Very small proportion of the bridge however

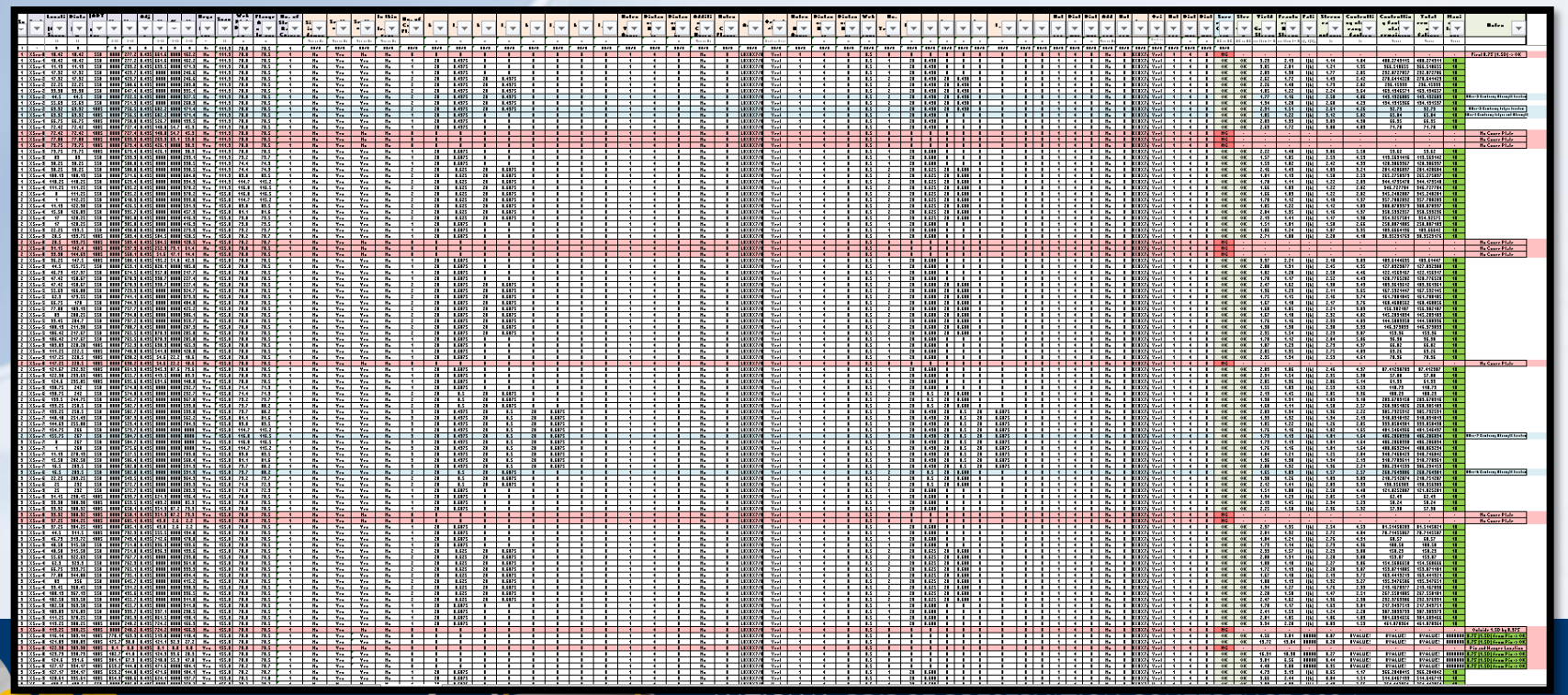


Summary of Results

	US 41 - White River Bridge	I74 - Wabash River Bridge
Locations Evaluated	330	112
Percent Passing IRM Evaluation	~94%	~79%
Total IRMs Length	9012 ft	1786 ft
Special Inspection Interval	10 years	10 years

Implementation Method and Lessons Learned

- Data and organizational overload
  - Macros developed to evaluate every point along
- Long term bridge monitoring adds valuable data for to evaluations



Implementation Method and Lessons Learned

- NSBA/S-BRITE Spreadsheet are very useful
- Should implement into existing bridge software (AASHTOWare BrR)
  - Purdue & INDOT working collaboratively on implementation within Indiana
- Procedures for integration of special inspections for IRMs needs FHWA approval.
  - Must develop detailed procedures

		Frequency	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Inspection Type	Routine	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	NSTM	24 months	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	Special (IRM)	10 years	N/A	No	No	No	No	No	No	No	No	No	Yes	No	No	No	No
	Underwater	60 months	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes

		Frequency	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
Inspection Type	Routine	24 months	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	NSTM	24 months	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
	Special (IRM)	10 years	No	No	No	No	No	Yes	No	No	No	No	No	No	No	Yes	No	Yes
	Underwater	60 months	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No

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Thank You!