Restoration and Monitoring of a Thin Lightweight Reinforced Concrete Parking Slab

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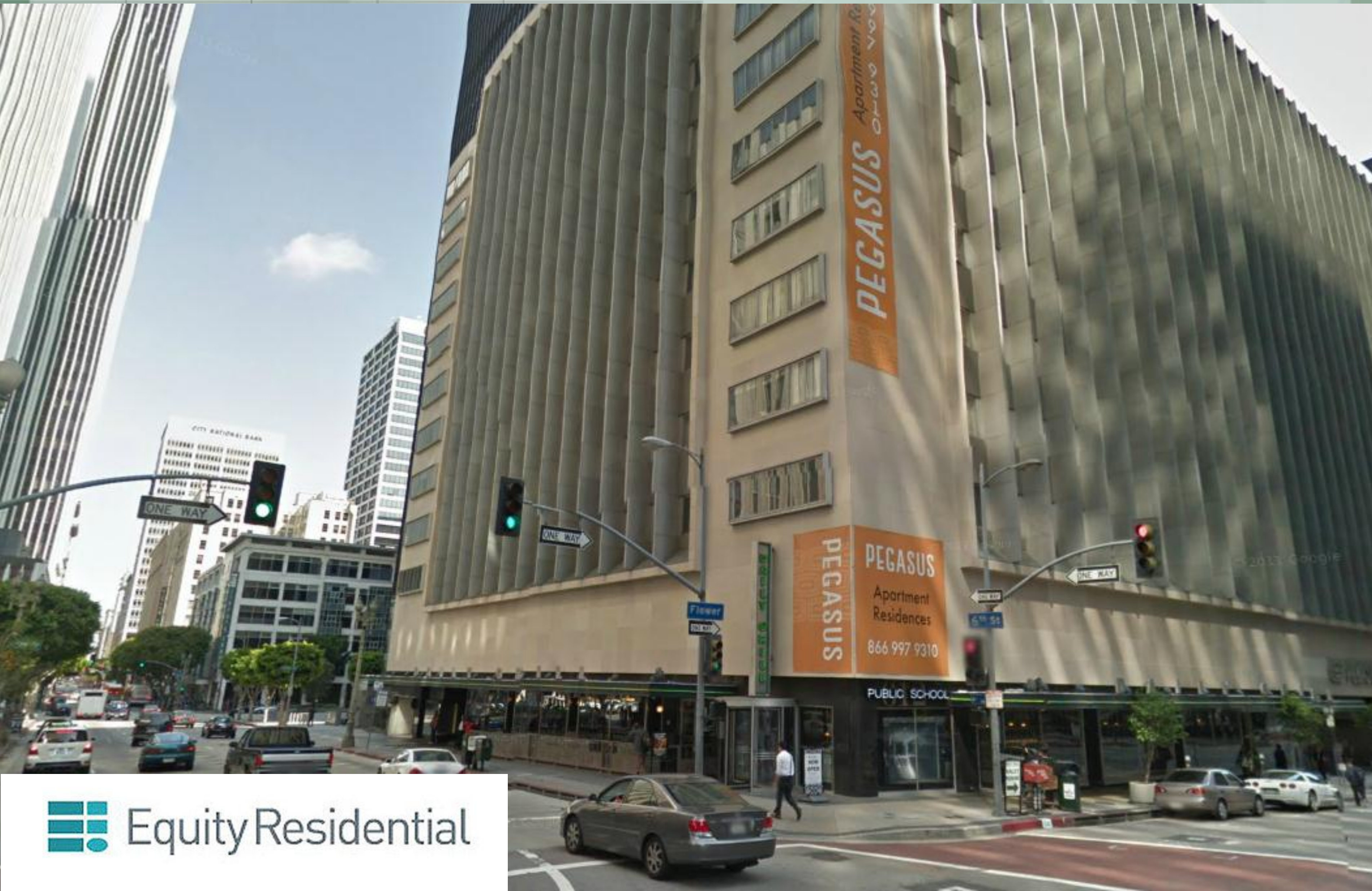
Restoration

WALKER
RESTORATION CONSULTANTS

Project - Pegasus Apartments



Equity Residential

Outline

- History/Challenges on the Project
- Repair Options Considered
- Mockup/Testing (Phase I)
  - Long Term Monitoring Results
- Repair Implementation (Phase II)
- Conclusions

Headquarters for General Petroleum Constructed in 1949

History of the Project

- Originally Constructed in 1949
- Major Renovation/Seismic Upgrade 2002
  - Level 2 and 3 Converted to Parking
  - Levels 3-13 converted to apartments
- Condition Assessment October 2011
  - Full depth concrete floor slab replacement
    - Level 2 – 1,450 sf Cost ≈ $250,000
    - Level 3 – 14,500 sf Cost ≈ $2,500,000

Added to Historical Buildings Register in 2004

Typical Slab Cracking

Full Depth Repair Locations

Full Depth Spall

Punch Thrus

Full Depth Spall

Utility Access Ports

Structural Floor System

- Light weight concrete 95pcf used in floor slab
- 3” thick slab
- Joist/beam spans 20’-2”
- Joist/beam spacing 3’-6”
- Top of joist/beams 2½” below finished floor (beam/joist embedded in concrete by ½”)
- Joists have a clip angle and rebar in the concrete slab
- Rebars: Fy=40 ksi /WWF mesh

Typical 3rd Floor Slab

Concrete Properties

GENERAL NOTES

1- All footings shall rest on firm, undisturbed natural soil at the elevations indicated. Character of soil sand and gravel with some clay.

2- Soil pressure based on the recommendation of the Foundation Engineers report subject to the approval of the Los Angeles City Bldg. Dept.

3- All concrete below First Floor Framing shall be Grade B and have a minimum compressive strength of 3000#/sq. in. at 28 days with a water cement ratio of 6 gals./sack of cement.

4- All other concrete shall be Grade A with light weight aggregate and have a minimum compressive strength of 2500#/sq. in. at 28 days with a water cement ratio of 6¾ gals./sack of cement. Light weight concrete shall weigh not more than 95#/cu. ft.

5- Gunite shall be mixed in proportions of 1 sack of cement to not more than 4½ cu. ft. of light weight aggregate and not more than 3 gals. of water per sack of cement at the discharge of nozzle. Gunite shall have a minimum compressive strength of 3000#/sq. in. at 28 days and weighing not more than 110#/cu. ft.

6- Reinforcing steel shall be new billet, deformed, intermediate grade conforming to A.S.T.M. designation No. A15-39. Reinforcing bars shall lap 40 diameters at splices and dowels, unless otherwise detailed.

7- Cement shall be a standard grade of Portland Cement conforming to A.S.T.M. designation C150-41.

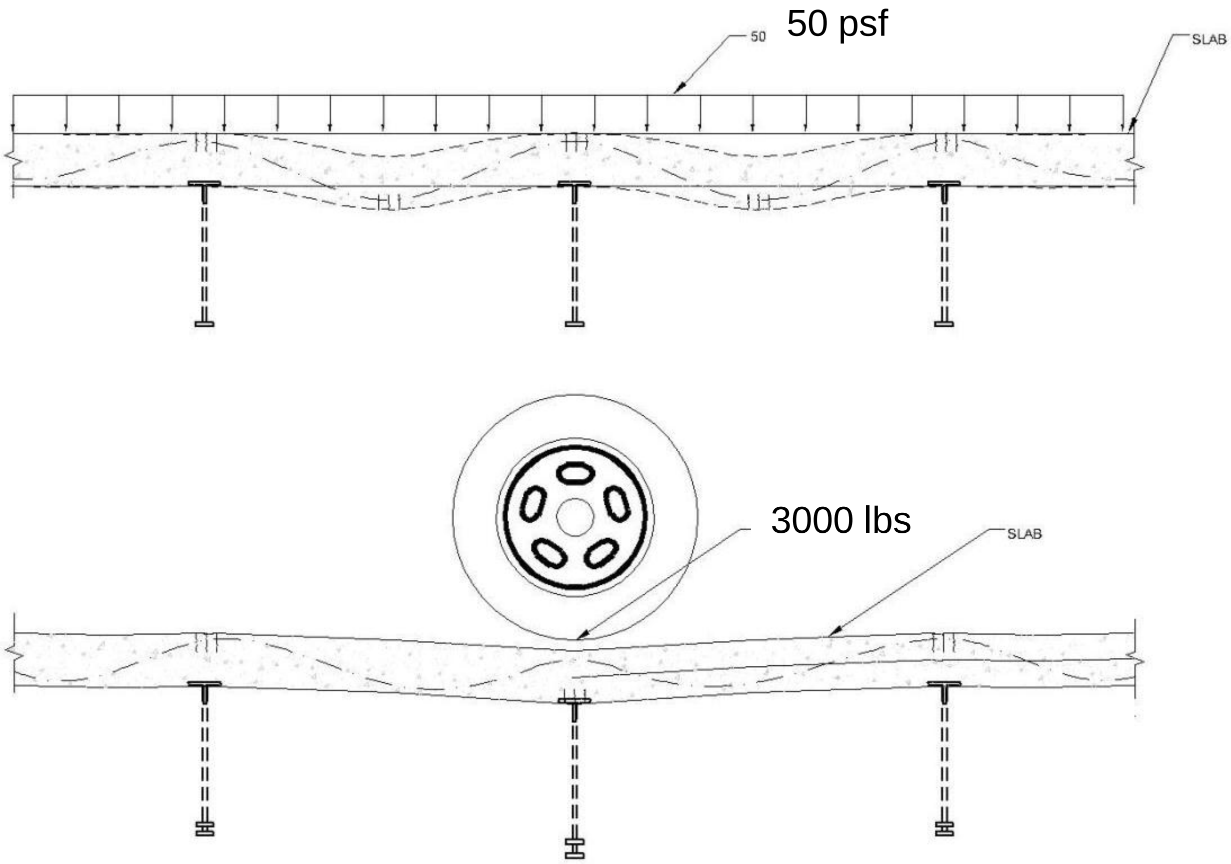
f'_c = 2,500 psi

w/c = 0.6

w = 95 pcf

Very Light Weight Concrete

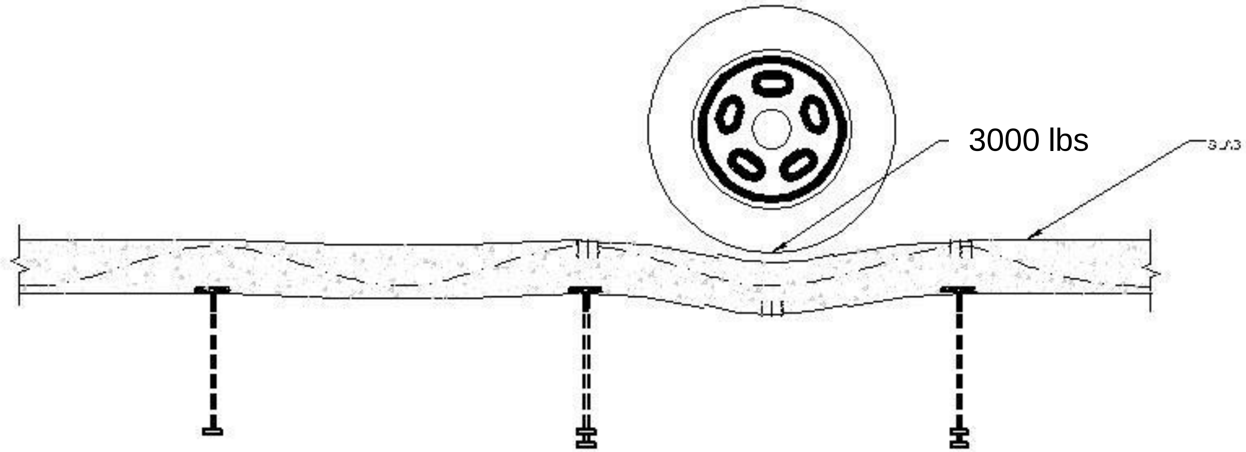
Loading Conditions



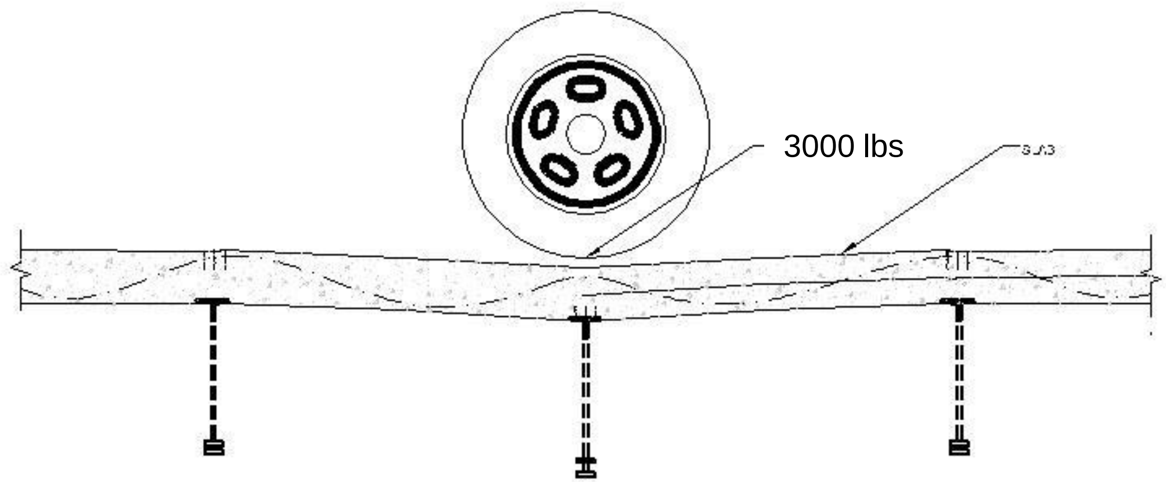
As Designed

As Loaded

As Loaded



Wheel between Joists



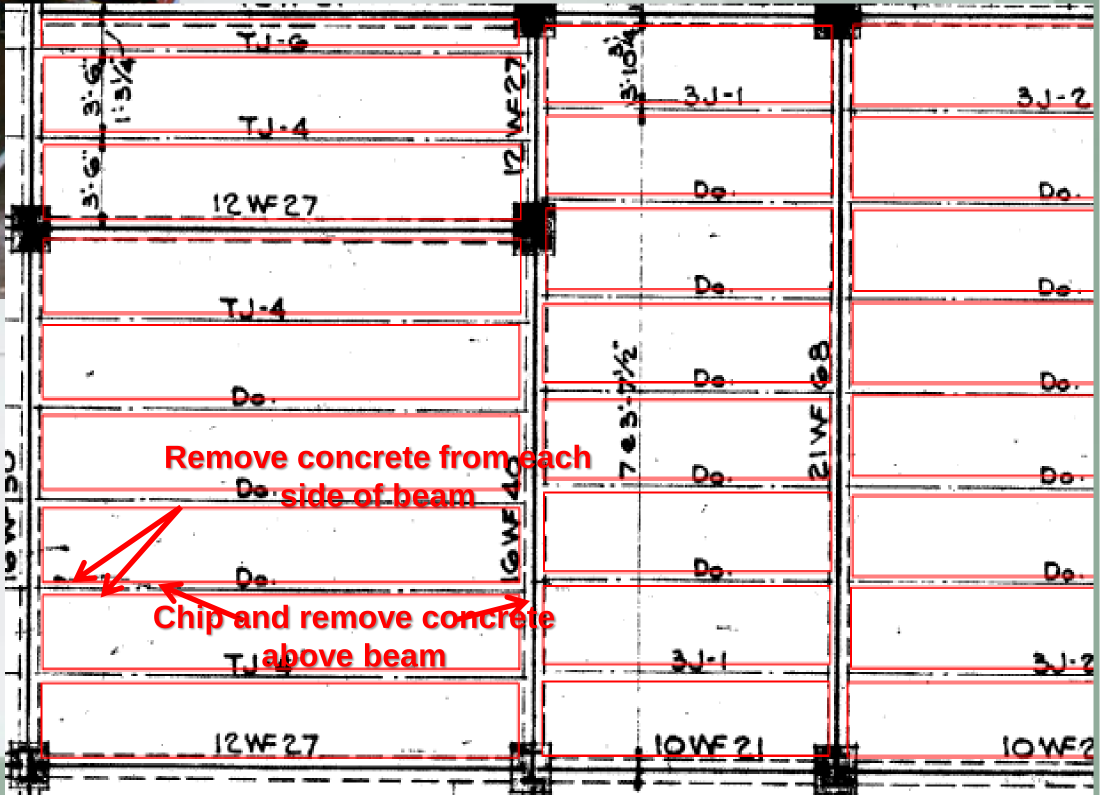
Wheel at Joist

Slab Cracking Caused by Wheel Loads

Repair Options Considered

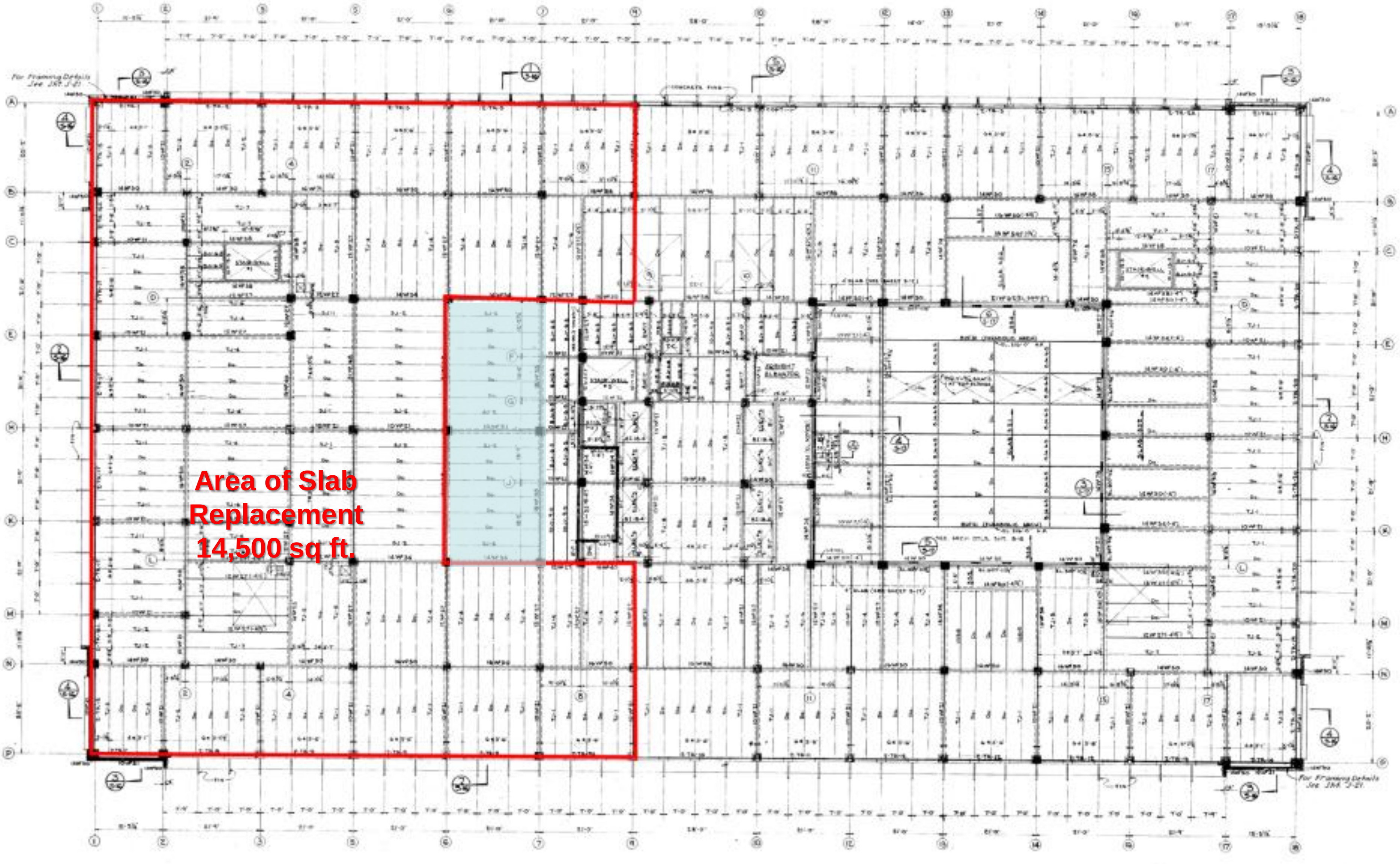
- Demolish/Replace Slab
  - Demolish Slab
    - Saw-cut and Remove Slab
    - Hydro Demolition
  - Replace Slab
    - Form New Concrete Slab
    - Use Stay in Place Metal Forms (Deck)
- Repair/Strengthen Existing Slab

Demolition Alternatives - Saw Cutting



Demolition Alternatives – Hydro-demolition

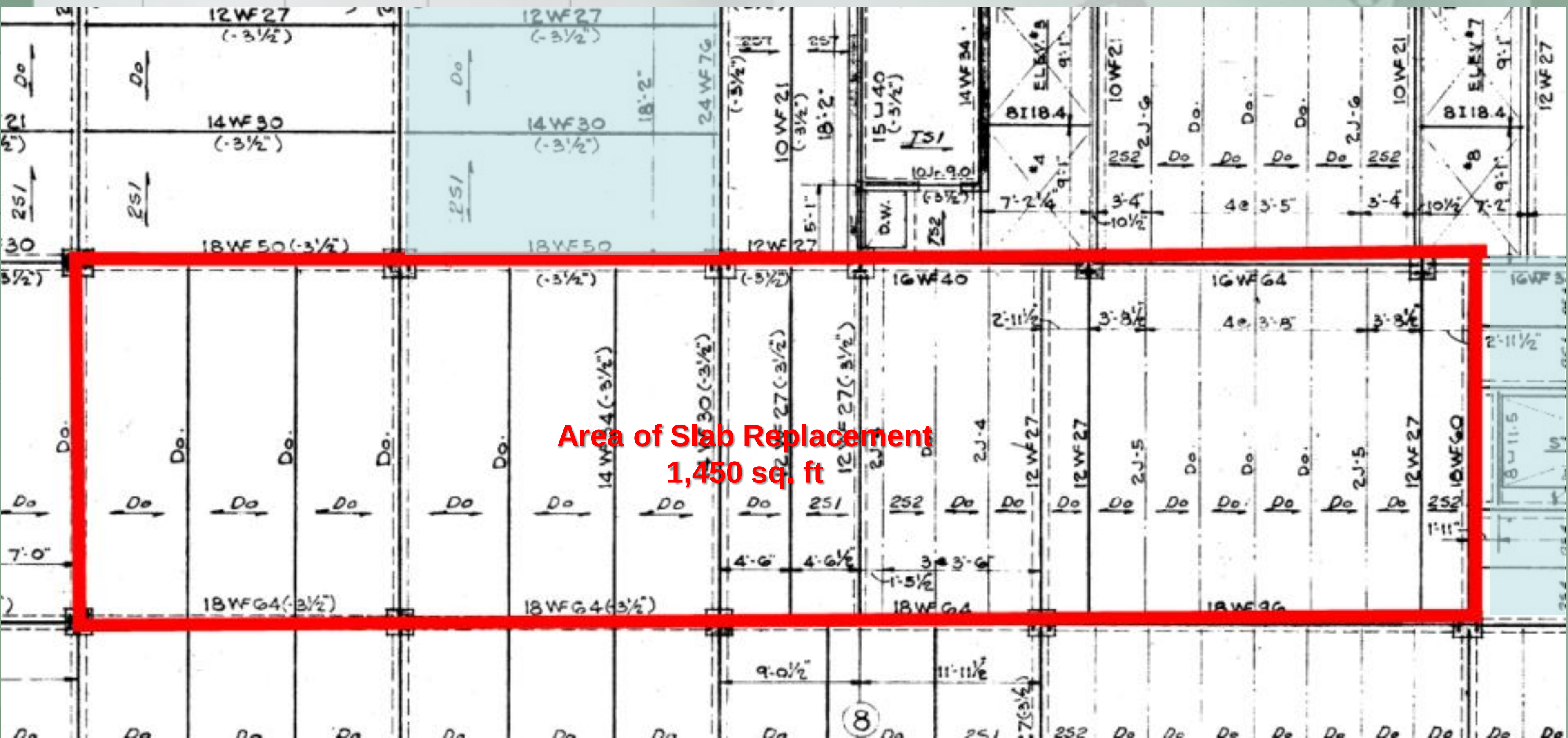
3rd Floor Plan



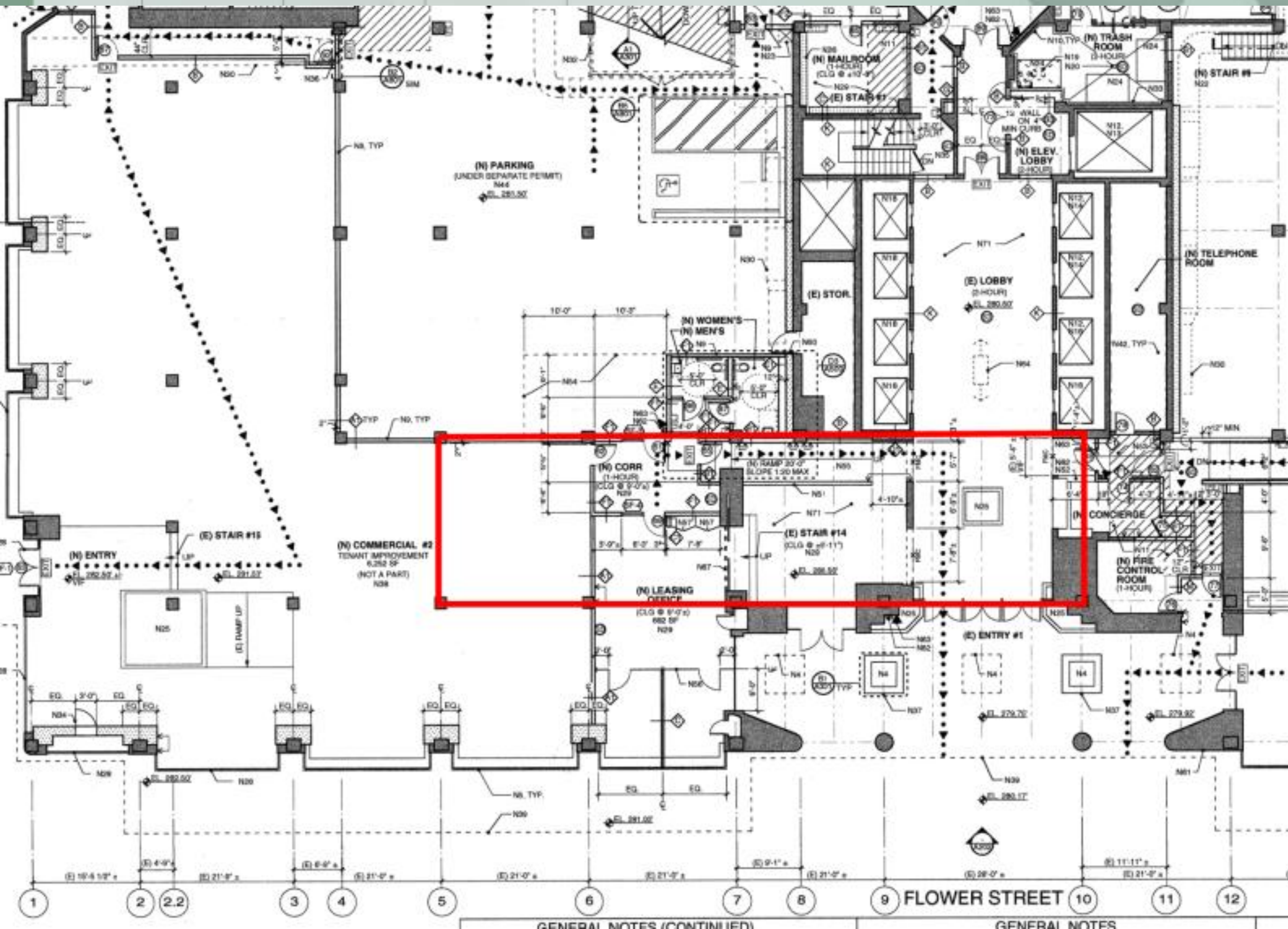
Challenges/Limitations

- Building is occupied
  - Noise/dust abatement
  - Minimum disruption to businesses
  - Preserve finishes in entrance lobby and restaurant
  - Work hours
- Lead Paint
- Small equipment access only
- Debris Removal (Congested Downtown Area!)
- Historic Building

Extent of Slab Replacement/Rehab
2nd Floor



First Floor Architectural



Limitations 2nd Floor

- No access to the floor from underside
  - Entrance lobby & leasing office with high end finishes
  - Disruption in leasing operations
  - Disruption to tenants of the building
  - Kitchen of the Daily Grill in the area of slab replacement
  - Extensive slab cracking/shoring issues prevent partial slab replacement options

Fire Proofing

M&E Utilities Attached to 3rd Floor

Lobby/Leasing Area

Fiber Reinforcement

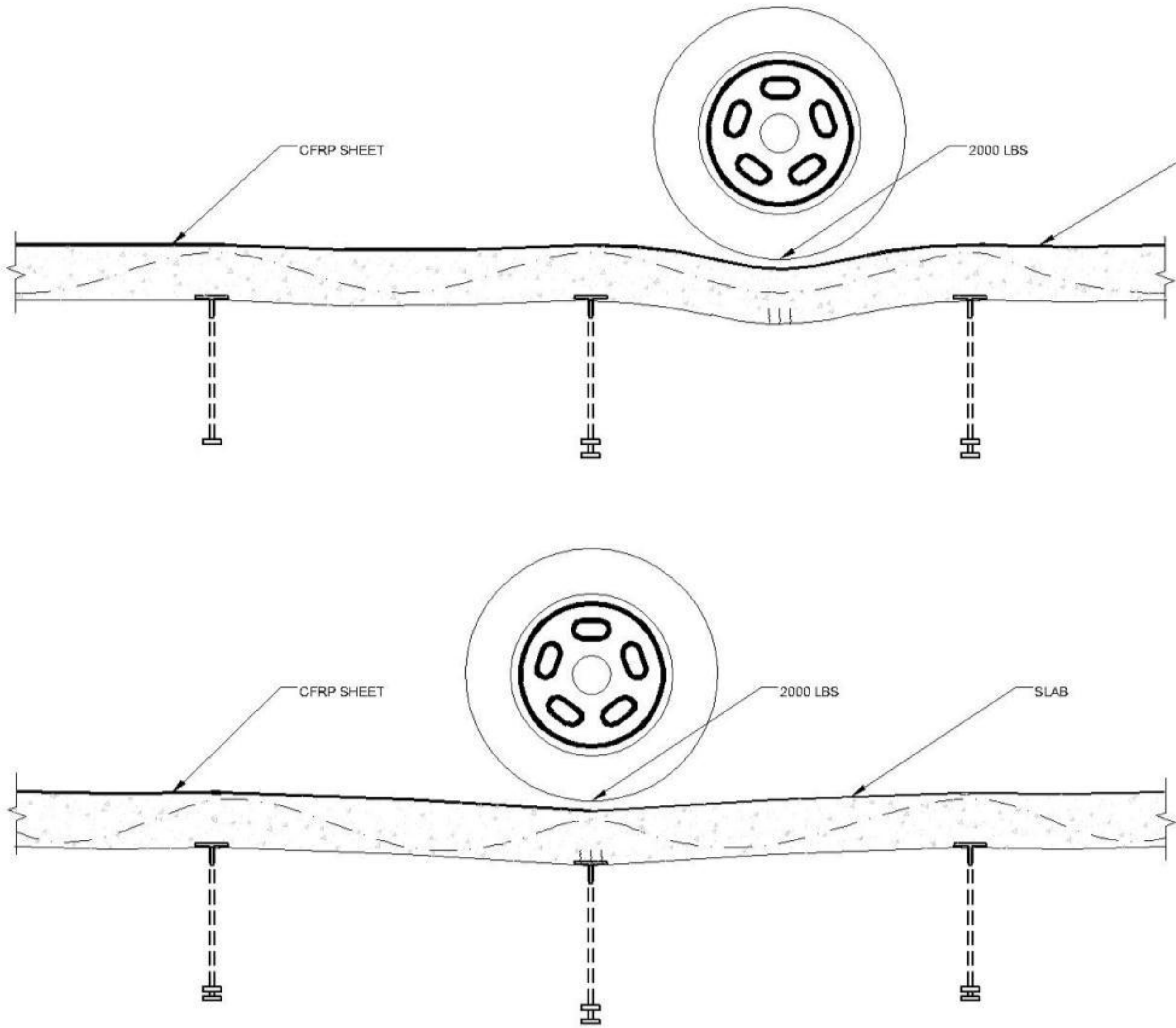
Advantages

- No Shoring required
- Minimal surface prep. required
- Minimizes the possibility of leakage
- Easy/Quick
- Should stiffen the slab considerably
- Reduce the possibility of future surface cracking

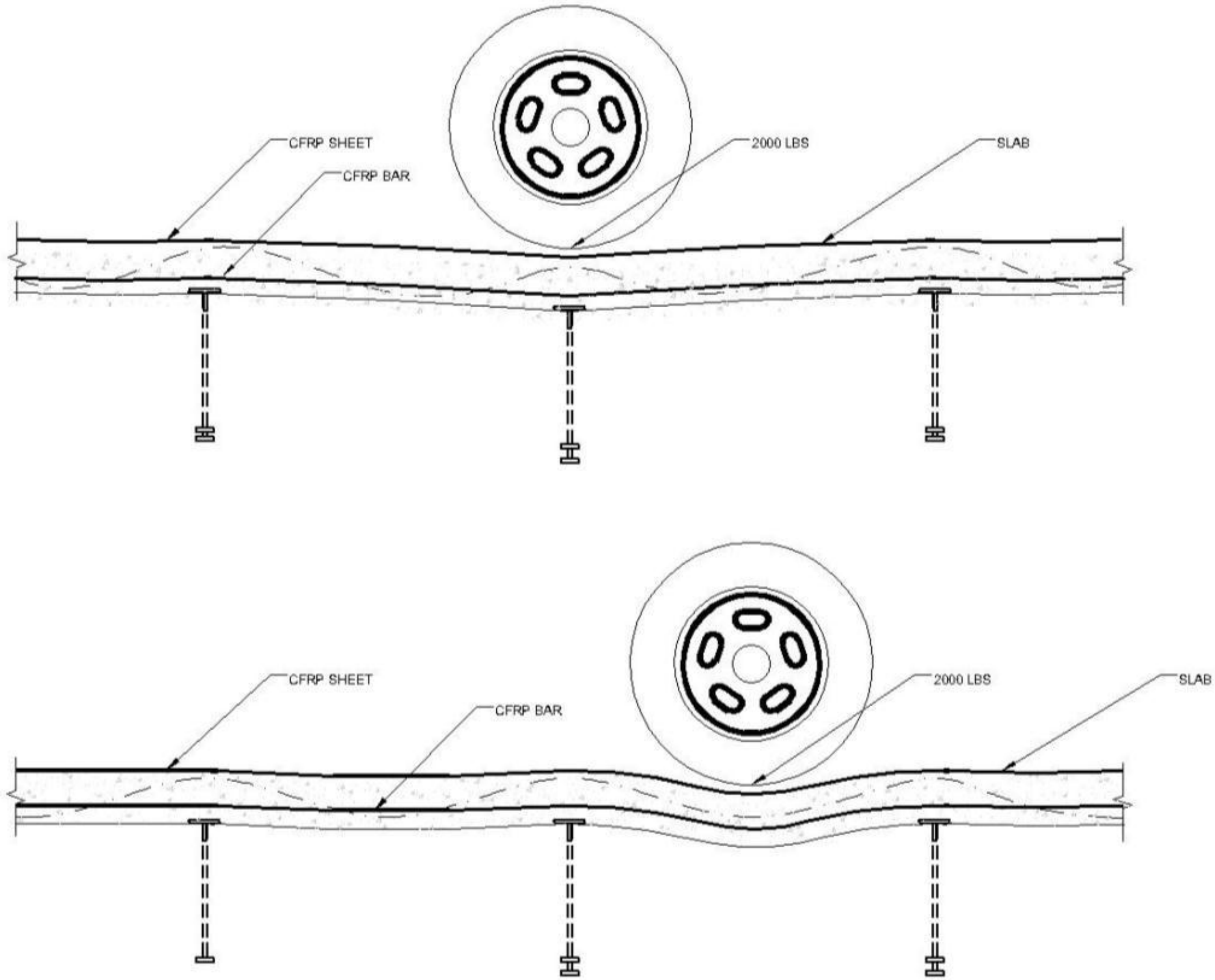
Limitations

- Not as durable as a new slab
- May only provide temporary fix (depending on the condition of exist. concrete)
- Design is not fire rated (would need to replace FRP after fire event)

Slab with CFRP Strengthening Only



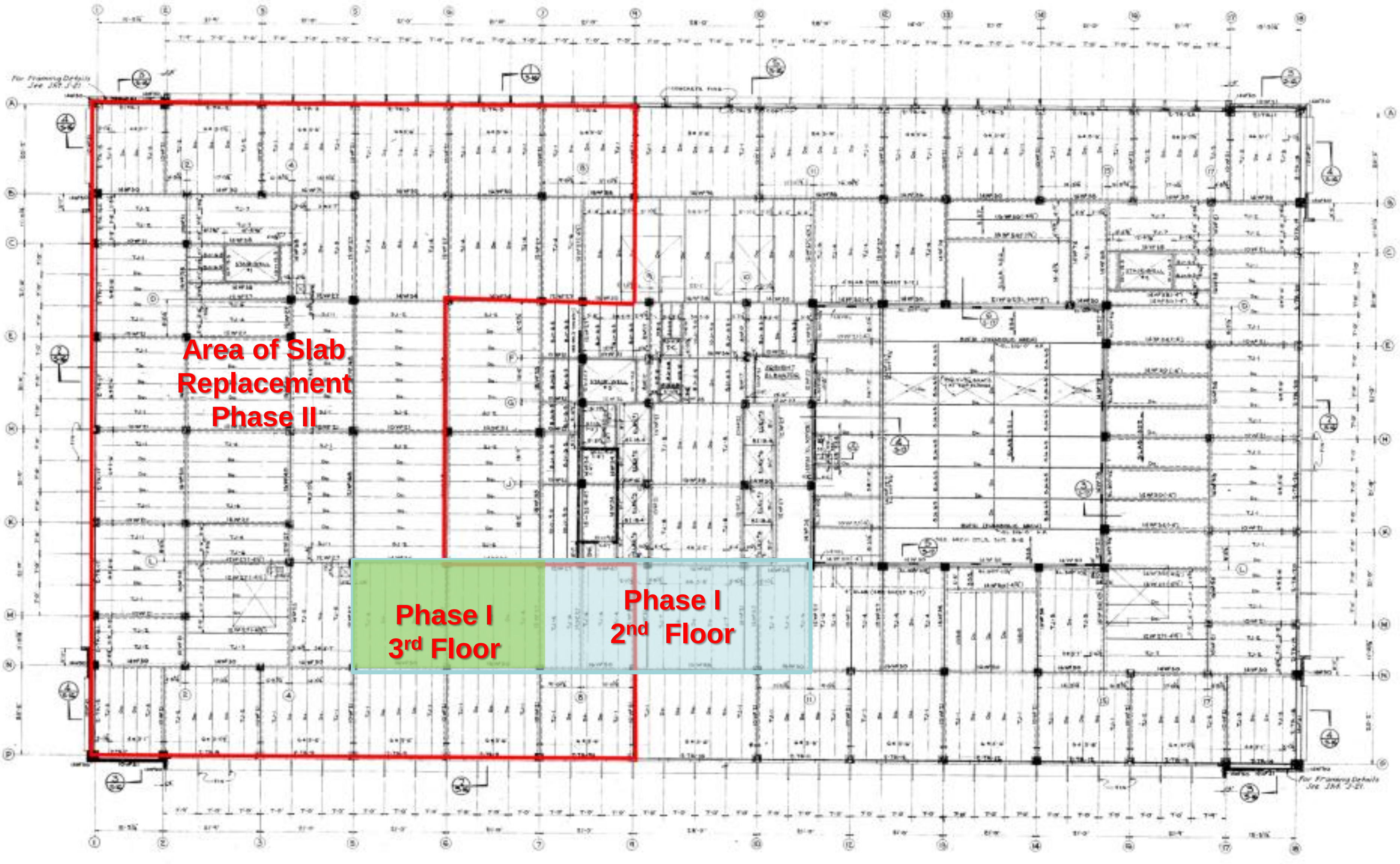
Strengthening with CFRP Fabric+ CFRP Bars



Rehabilitation Approach

- Repair the cracks and spalls on the floor slab
- Reinforce a small portion of the slab with CFRP
  - Option 1: CFRP Sheets at the top
  - Option 2: CFRP Sheets at the top + CFRP rods embedded in the slab
- Monitor the slab for a few months to evaluate the performance of the two repair methods
- Select repair method for the whole slab

Repair Areas



Crack Repair

- Rout & fill cracks

    > 1/32”

Gravity Fill Cracks with Epoxy

- Sikadur 22
- Sikadur 52

Routed and Repaired Cracks on the Floor

Flood Coat of Cracks

- Sikadur 52

  Fill Cracks < 1/32”

Full Depth Repairs

Carbon Fiber Rod Installation

Carbon Fiber Reinforced Polymer (CFRP) Installation

Broadcast Topping for Traction

Structural Monitoring

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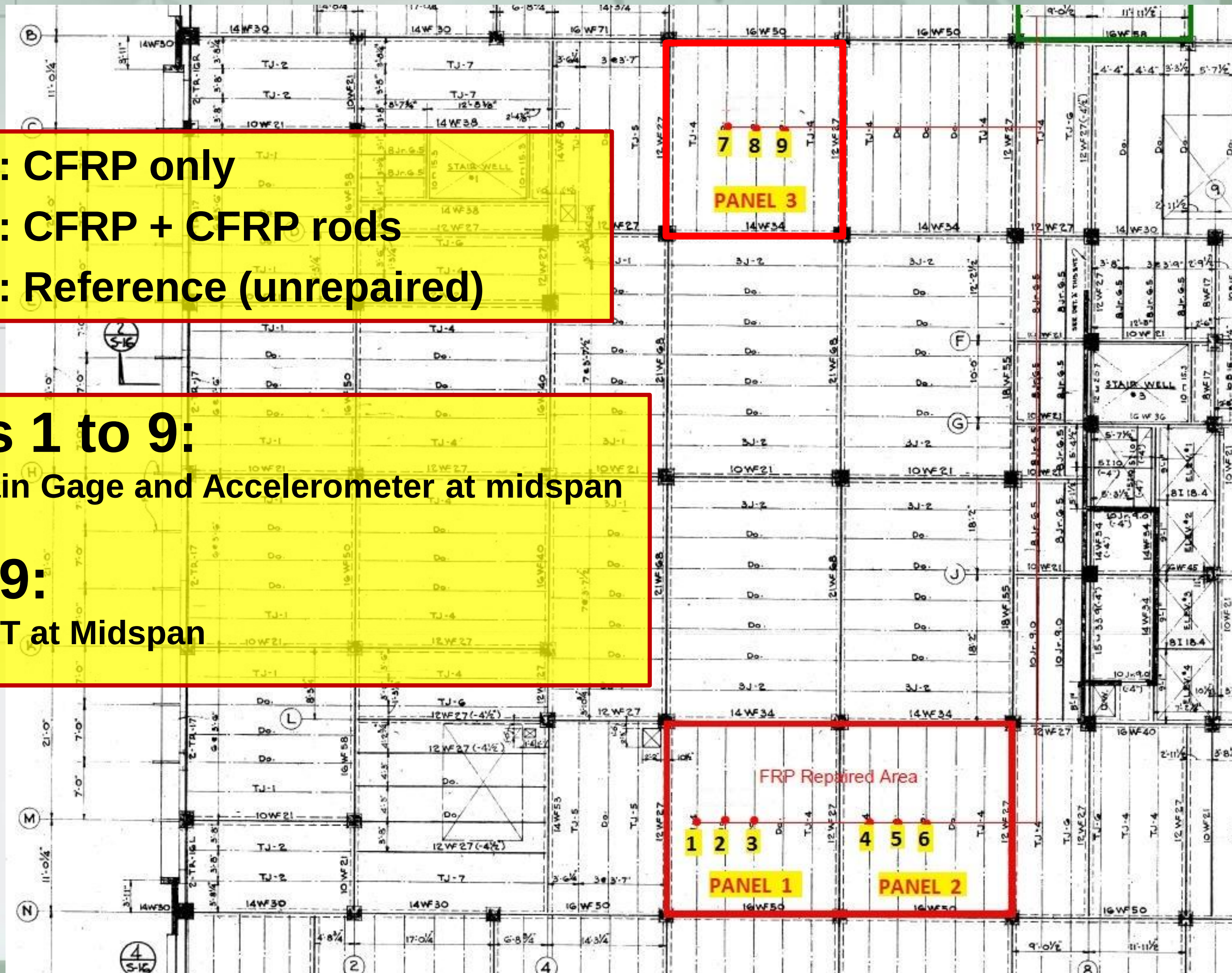
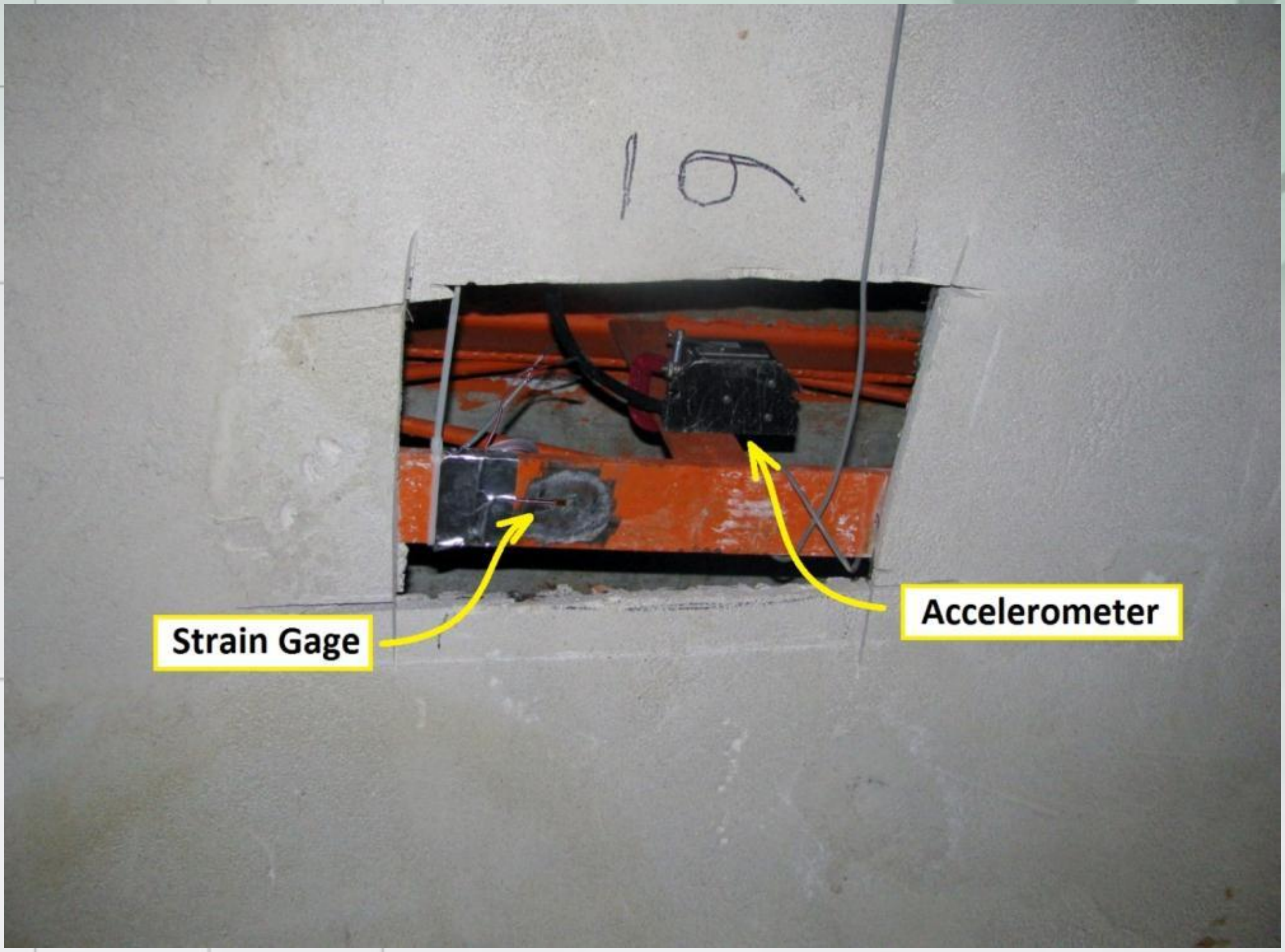
Instrumentation Layout

- **Panel 1: CFRP only**
- **Panel 2: CFRP + CFRP rods**
- **Panel 3: Reference (unrepaired)**

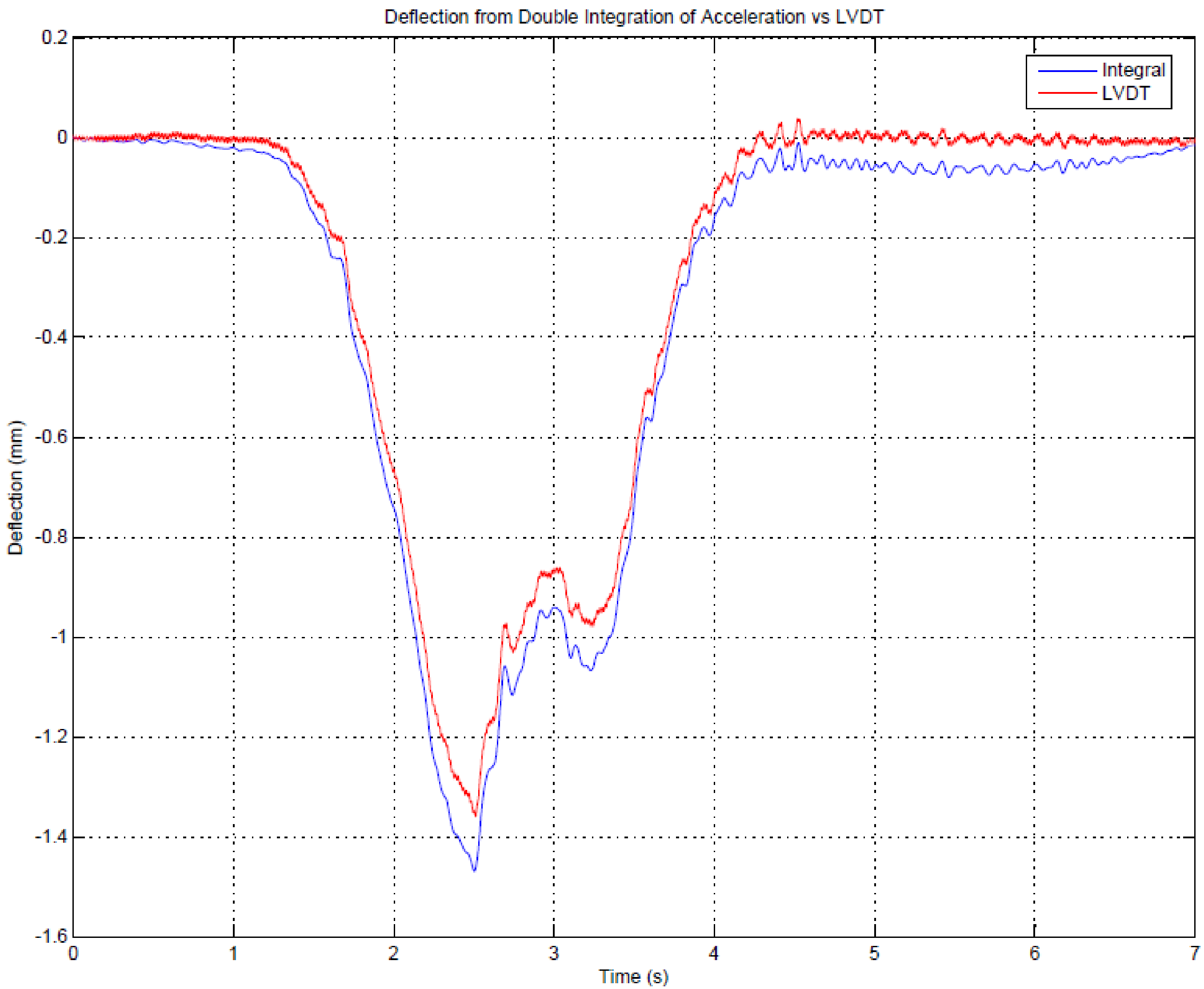
- **Joists 1 to 9:**
  Strain Gage and Accelerometer at midspan
- **Joist 9:**
  LVDT at Midspan



SENSOR PLACEMENT ON JOISTS
Strain Gages and Accelerometers



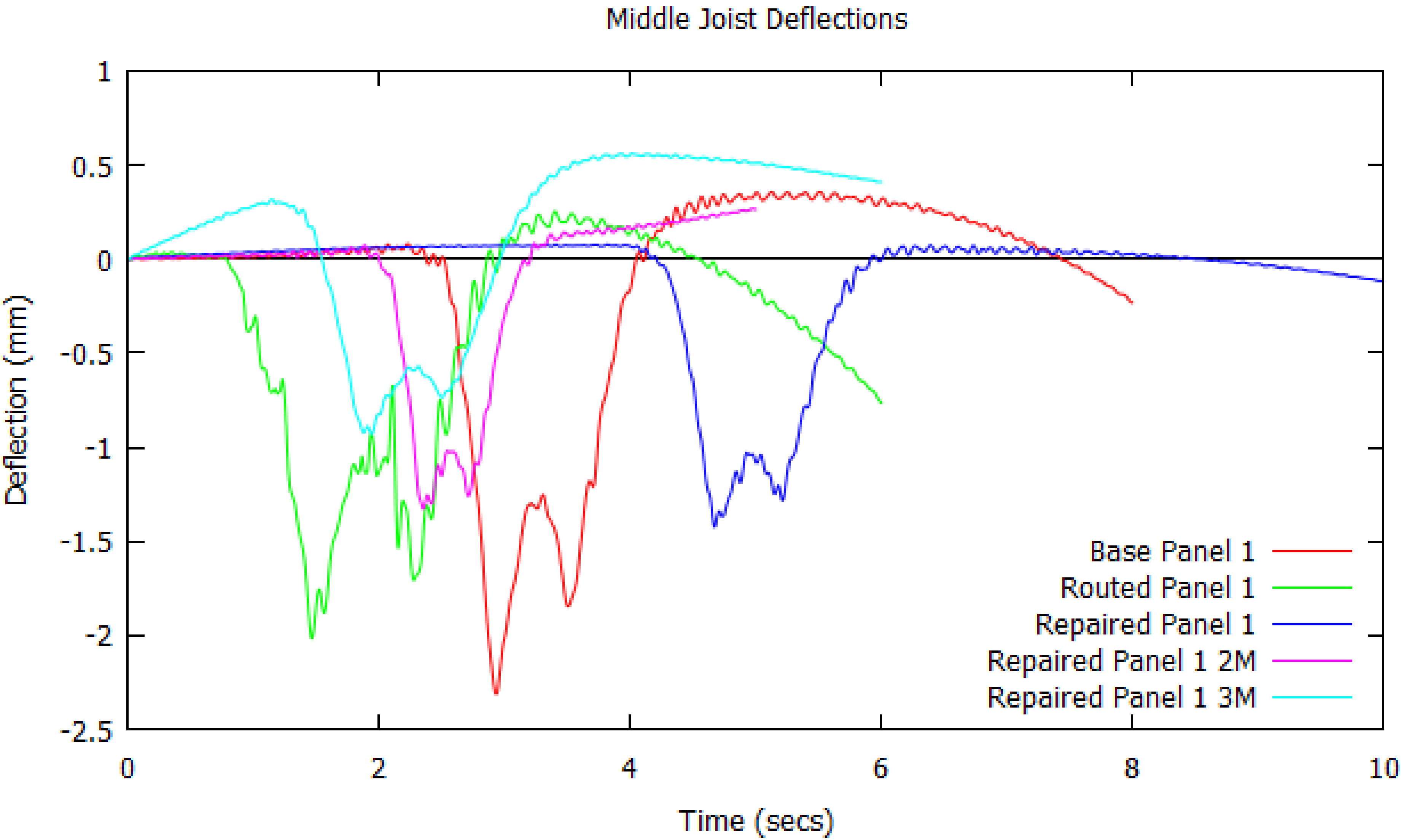
Comparison of Accelerometer with LVDT



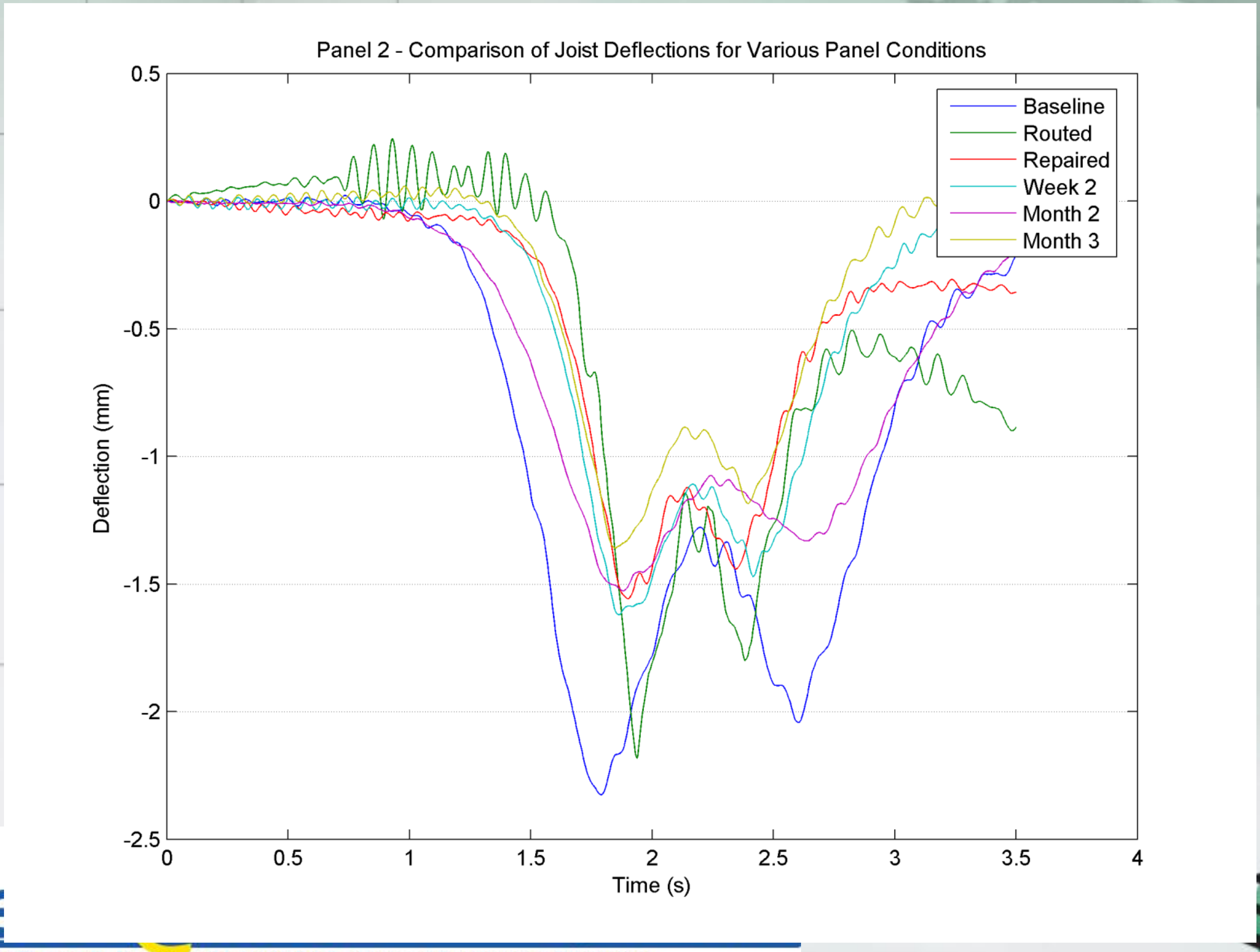
Loading Vehicle

- 2007 Saturn Vue Greenline FWD Hybrid SUV
- Weight: 3500lbs
- Weight distribution (% front / rear): 59/41
- Wheel base: 106.6in / 2707mm

Deflections over Time - Panel 1



Deflections over Time - Panel 2



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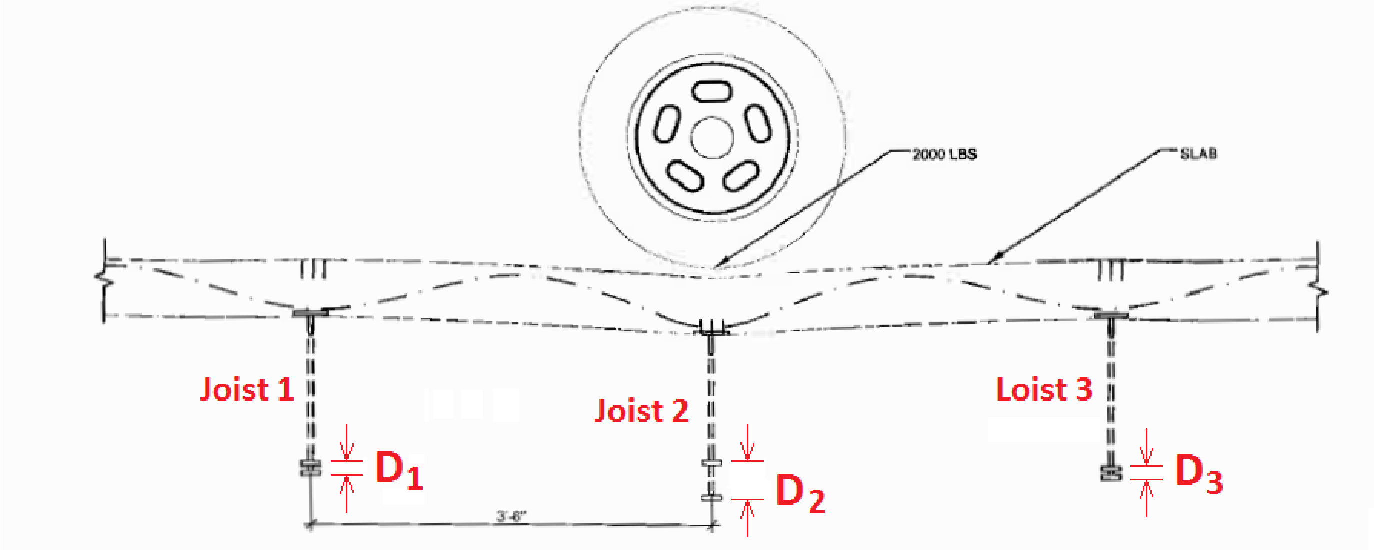
How is Load Sharing Calculated



$$Load\ sharing\ Joist\ 1 = \frac{D_1}{D_2}\ \%$$

$$Load\ sharing\ Joist\ 3 = \frac{D_3}{D_2}\ \%$$

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Base Condition Results - Panel 1 (Unrepaired)

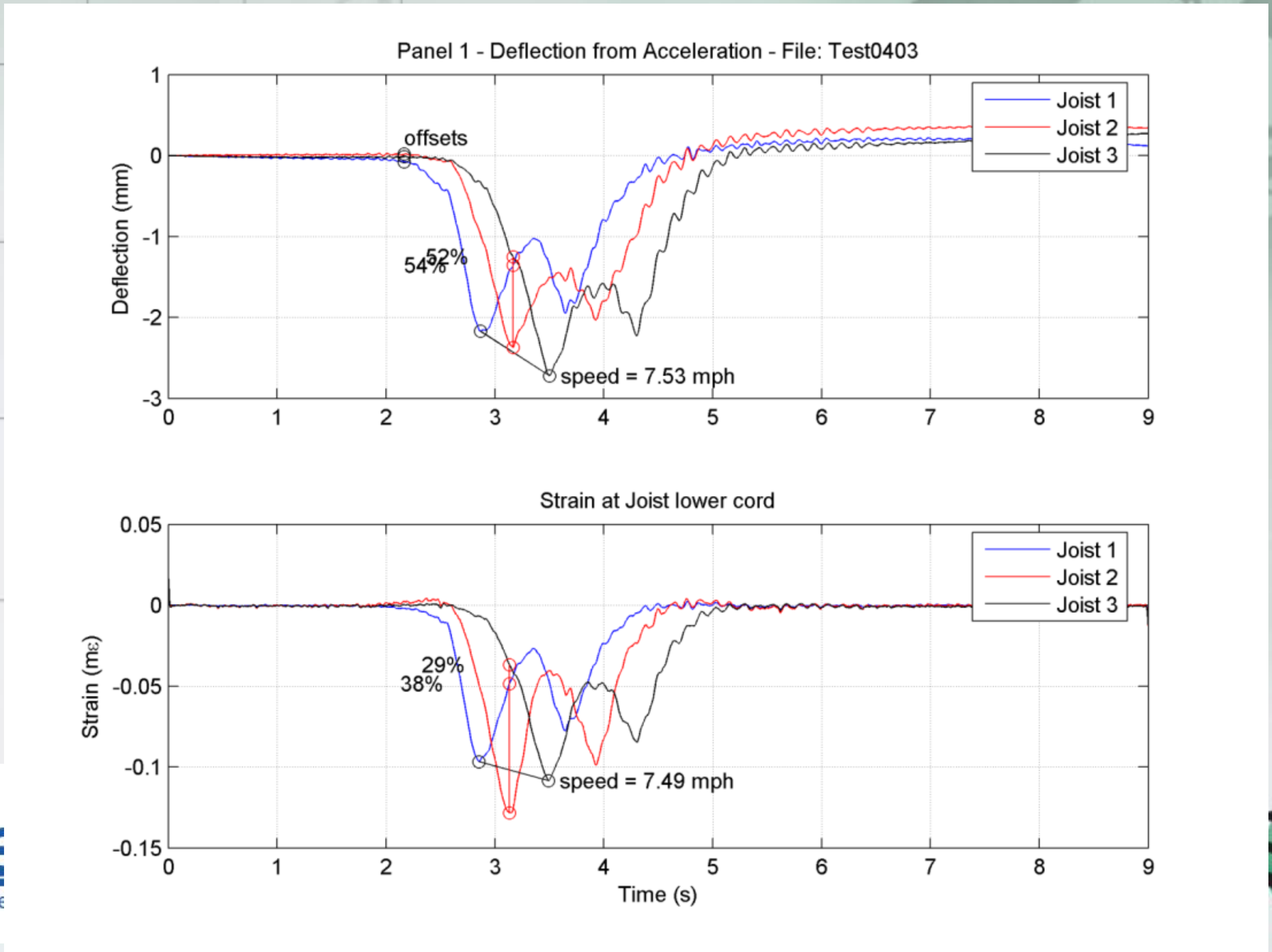
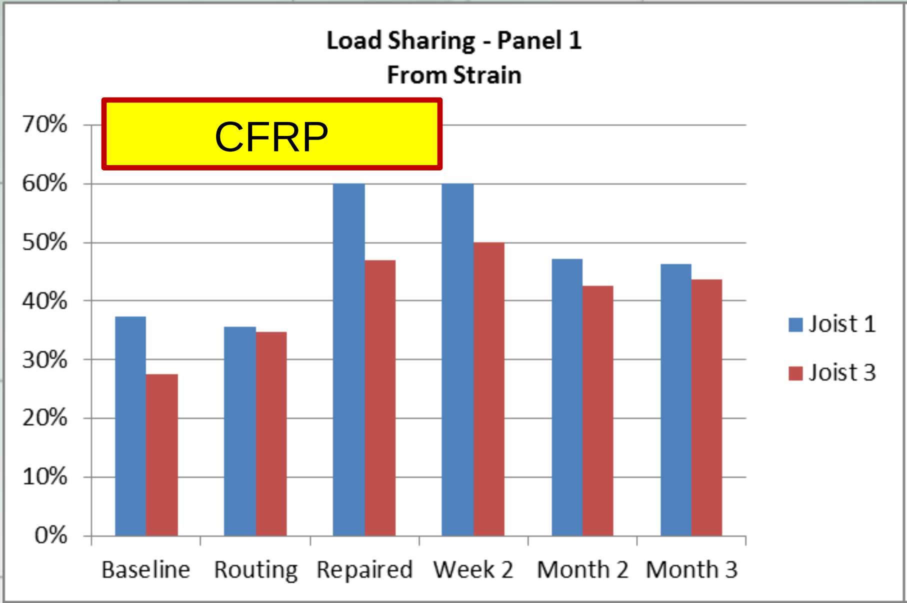
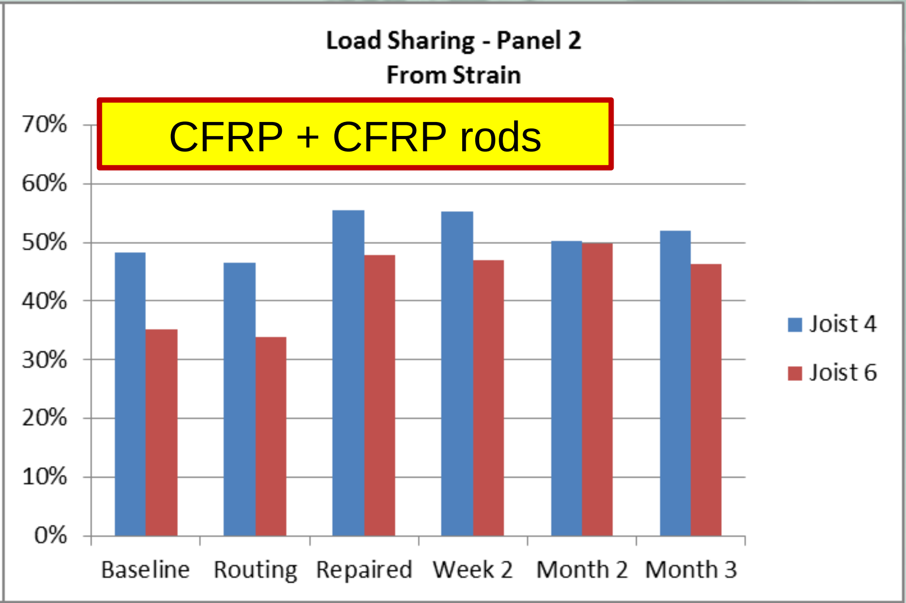


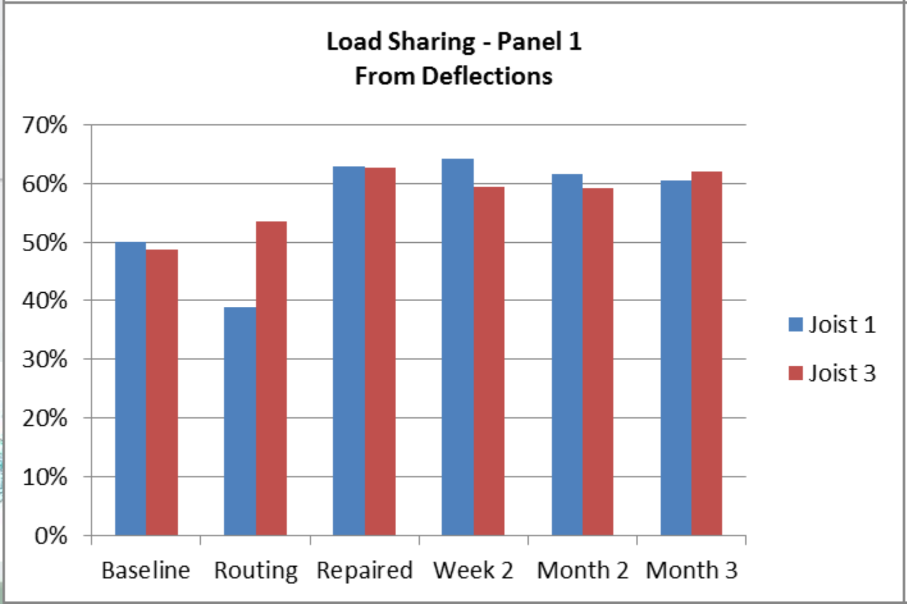
Table of Load Sharing Results

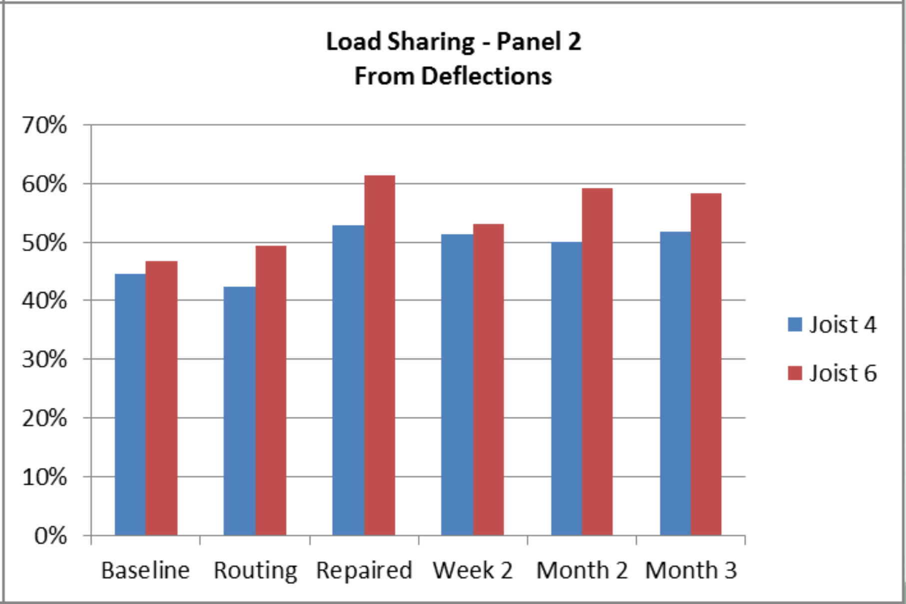
	Tests used		From Deflection Panel 1		From Strain Panel 1		From Deflection Panel 2		From Strain Panel 2	
			Joist 1	Joist 3	Joist 1	Joist 3	Joist 4	Joist 6	Joist 4	Joist 6
Test 04	3-7	Baseline	50%	49%	37%	28%	45%	47%	48%	35%
Test 06	4-7	Routing	39%	54%	36%	35%	42%	49%	46%	34%
Test 11	4 6-8	Repaired	63%	63%	60%	47%	53%	61%	55%	48%
Test 15	2 4 6 8	Week 2	64%	59%	60%	50%	51%	53%	55%	47%
Test 17	3 5 7 9	Month 2	62%	59%	47%	43%	50%	59%	50%	50%
Test 19	1 2 4-8	Month 3	61%	62%	46%	44%	52%	58%	52%	46%

Comparison of Results









Interpretation of Results

- Deflections Reduced by almost 40% (2.5 mm – 1.4 mm)
- Improved Load Sharing between Joists
- The behavior appears to have stabilized after the first month

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Results/Recommendations

- Evaluated Two options
  - CFRP Sheets
  - CFRP Sheets +CFRP Rods
- Both options have similar behavior
- Recommended using CFRP Sheets only for the rest of the floor

Phase II Repairs

FRP Application

Adhesion/Bond Testing

Finished Repairs

Questions!