The Concrete Convention and Exposition

Evaluation of Concrete Prior to Rehabilitation

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October 22, 2019

WHAT IS EVALUATION, AND HOW IS IT DIFFERENT FROM ASSESSMENT?

Per ACI 562:

Structural Assessment: The process of investigating by systematically collecting information regarding the performance of an existing structure; and evaluating the collected information to make informed decisions regarding the need for repair or rehabilitation; and detailing of findings as conclusions and reporting recommendations for the examined structural concrete work area (member, system, or structure).
Examples: GPR, Chain Drag, Petrography, Half-Cell Potential, Infrared Thermography, Drone Surveys, etc.

Structural Evaluation: The process of determining and judging the structural adequacy of a structure, member, or system for its current intended use or performance objective.
Examples: Load Testing, Finite Element Analysis, Core Testing, etc.

EVALUATION FOR CHANGE IN USE

- Structure built in 1960s
- Change in Occupancy
- Increased Risk Category from II to IV (Essential Facilities)
- Evaluation of roof framing required to verify structural capacity and serviceability with increased loading due to increase in Importance Factor

ASCE 7- Table 1.5.2:

Table 1.5-2 Importance Factors by Risk Category of Buildings and Other Structures for Snow, Ice, and Earthquake Loads[a]

Risk Category from Table 1.5-1	Snow Importance Factor, I_s	Ice Importance Factor—Thickness, I_i	Ice Importance Factor—Wind, I_w	Seismic Importance Factor, I_e
I	0.80	0.80	1.00	1.00
II	1.00	1.00	1.00	1.00
III	1.10	1.25	1.00	1.25
IV	1.20	1.25	1.00	1.50

[a]The component importance factor, I_p, applicable to earthquake loads, is not included in this table because it is dependent on the importance of the individual component rather than that of the building as a whole, or its occupancy. Refer to Section 13.1.3.

Denver Building Code:

Section 1608.3 Snow load importance factor is added:

1608.3 Snow load importance factor. The values for the snow load importance factor I, in Table 7-4 of ASCE 7 shall be amended as follows:

Category III.......................................1.2
Category IV.......................................1.4

Roof snow loads increased 40% due to change in Risk Category from II to IV. Therefore, evaluation of structural capacity of the concrete roof tees was required

Evaluation Procedure

Check IEBC "5% Rule":

[BS] 807.4 Existing structural elements carrying gravity loads.

Alterations shall not reduce the capacity of existing gravity load-carrying structural elements unless it is demonstrated that the elements have the capacity to carry the applicable design gravity loads required by the *International Building Code*. Existing structural elements supporting any additional gravity loads as a result of the *alterations*, including the effects of snow drift, shall comply with the *International Building Code*.

Exceptions:

1. Structural elements whose stress is not increased by more than 5 percent.
2. Buildings of Group R occupancy with not more than five dwelling or sleeping units used solely for residential purposes where the *existing building* and its *alteration* comply with the conventional light-frame construction methods of the *International Building Code* or the provisions of the *International Residential Code*.

The 40% increase in snow loads increased the total flexural and shear stress more than 5%, therefore further structural evaluation was required. In addition, it was determined that the roof was originally designed for a built-up roof, and a ballasted roof was installed. The total increase in load was approximately 17%.

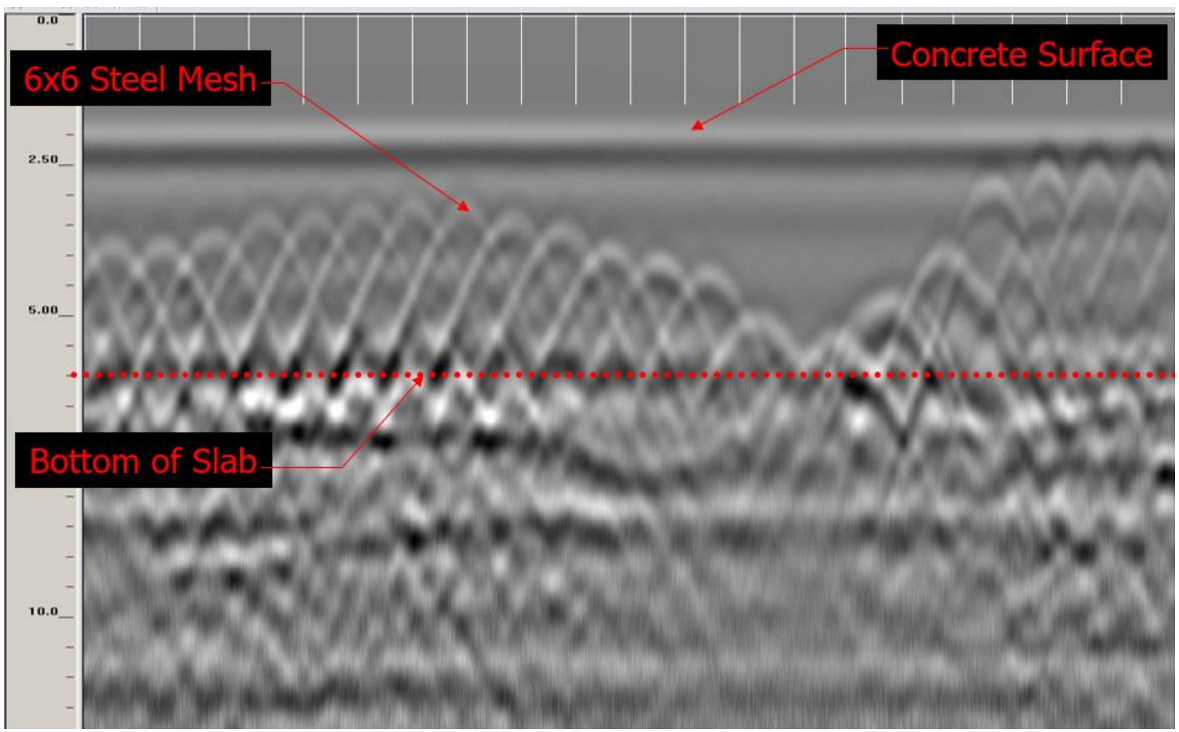
Perform Structural Analysis of Capacity of Concrete Double-Tees at the Roof:

- Determine Strand Pattern
- Determine Shear Reinforcing
- Analyze Tees for New Loading

(Some) Ways to Determine Reinforcing in Concrete Structures

Ground-Penetrating Radar (GPR)

Not used because of mesh in tee legs



- Easy to Perform
- Immediate Results
- Limitations include:
  - Moisture in Concrete
  - Steel Fibers in Concrete
  - Excessive Reinforcing Congestion
  - Cannot Determine Exact Bar Size

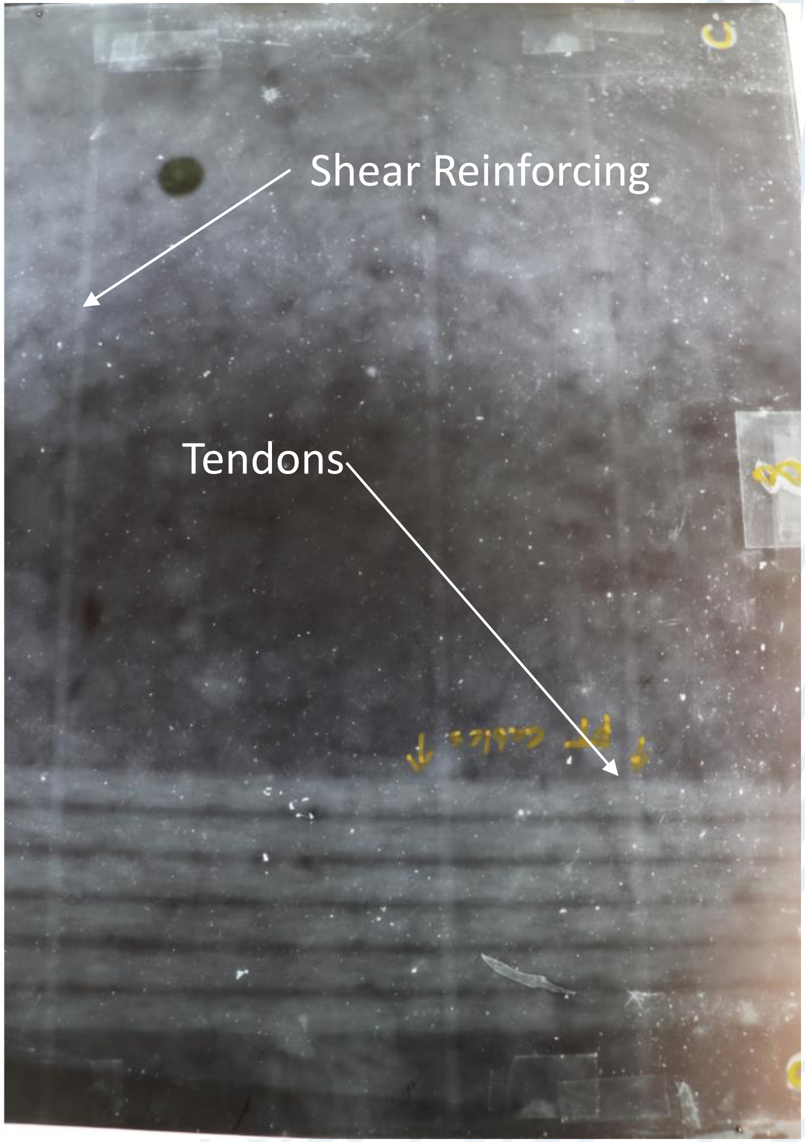
X-Ray

Best for Double-Tee Stems

- Requires Specialized Equipment
- Radiation Limits Public Access
- Results not Immediate (but quick)
- Can accurately Determine Bar Sizes and Locations (But need to consider angle of radiation)
- Cannot determine Stress in Tendons

In this case, we assumed 5000 psi concrete, 270 ksi tendons and net effective prestress equal to 70% of ultimate tendon strength

Our analysis concluded that the existing Double-Tees did not have adequate strength for the new loads



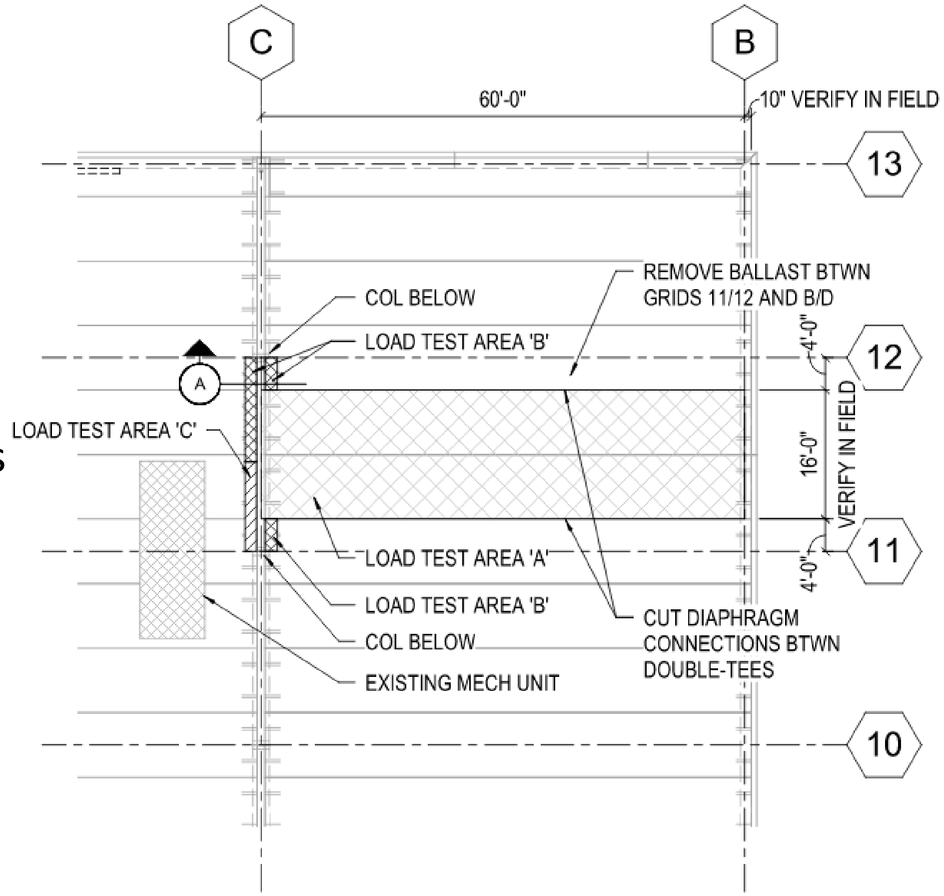
Load Testing

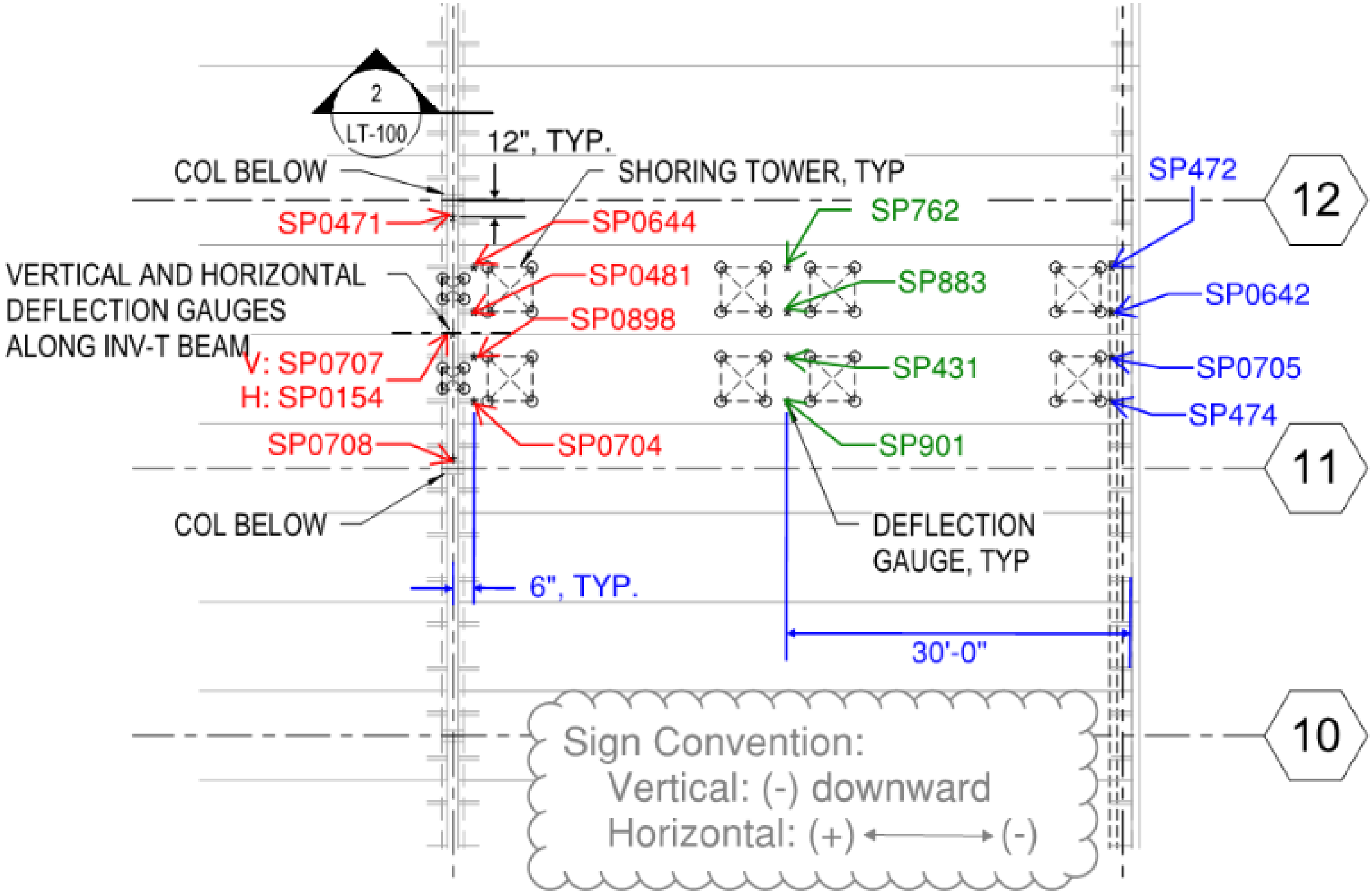
Loads were calculated and applied in accordance with ACI 318 and 437 procedures

ACI 318-14: 1.15 D + 1.5 S
ACI 437.2: $1.0\ D_w + 1.1\ D_s + 1.6\ S$
(Note that ACI 318-19 now aligns with ACI 437 requirements)

Loads were applied using pallets of sandbags with cranes from the adjacent parking lot

Shoring was installed below the test area, and deflections were monitored at each of the load steps



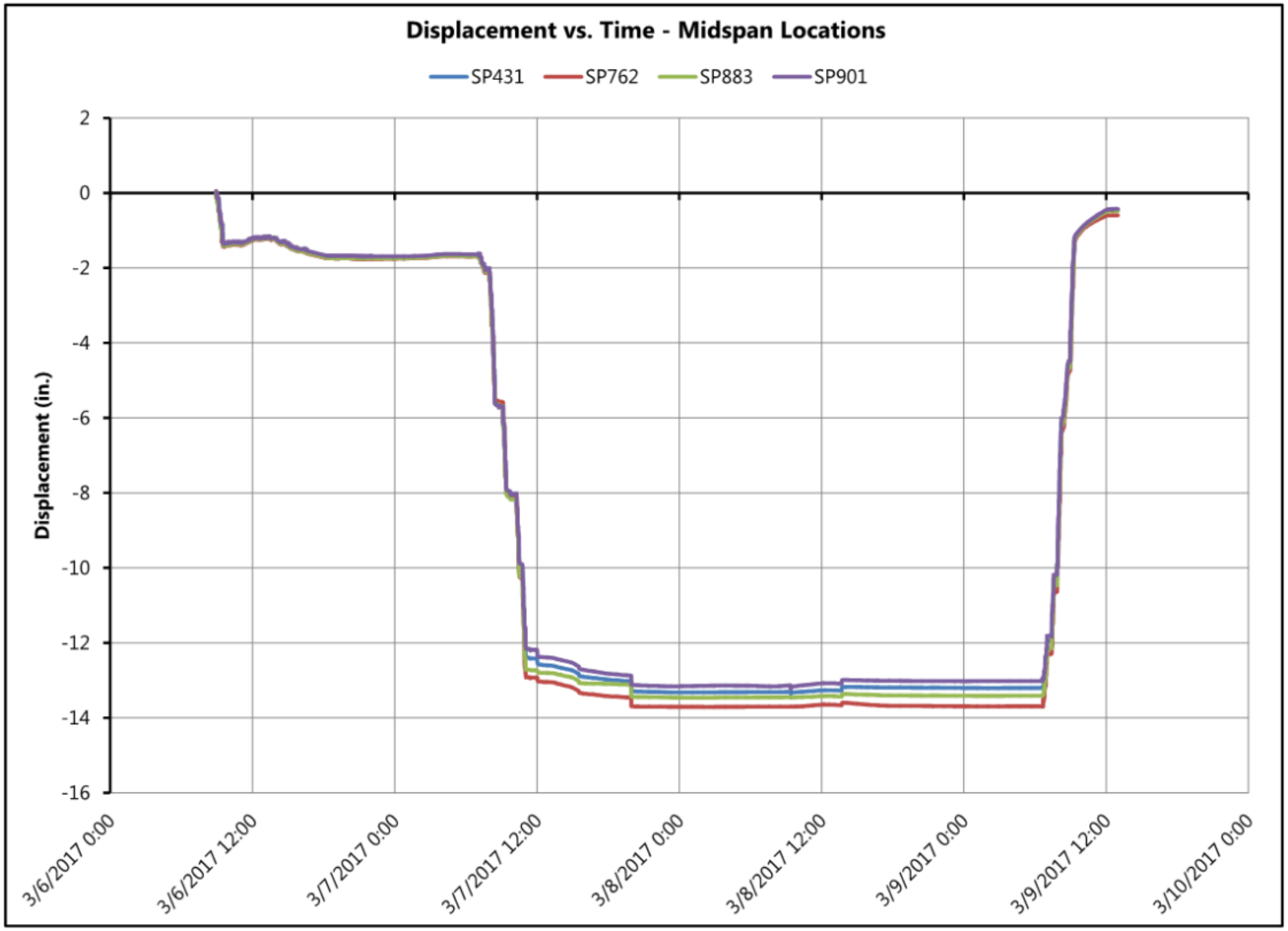


Locations of Deflection Gauges (LVDTs) and Shoring Towers

Instrumentation

Load Testing in Progress

Results



Rebound within ACI Limits, Minor flexural cracking in Tees
No shear cracking in Tees or Inverted Tee Beams

EVALUATION FOR CORROSION DAMAGE

- Parking Structure built in early 1980s
- Corrosion Damage discovered at an interior precast concrete ell beam supporting double-tees on one side
- Evaluation of beam capacity required in order to develop repair plan

Location of damage

Initial concrete removal revealed damage to bearing and torsion reinforcement

Initial concrete removal on the Ell beam revealed severely corroded prestressing steel, and potentially significant concrete deterioration in the beam bearing area.

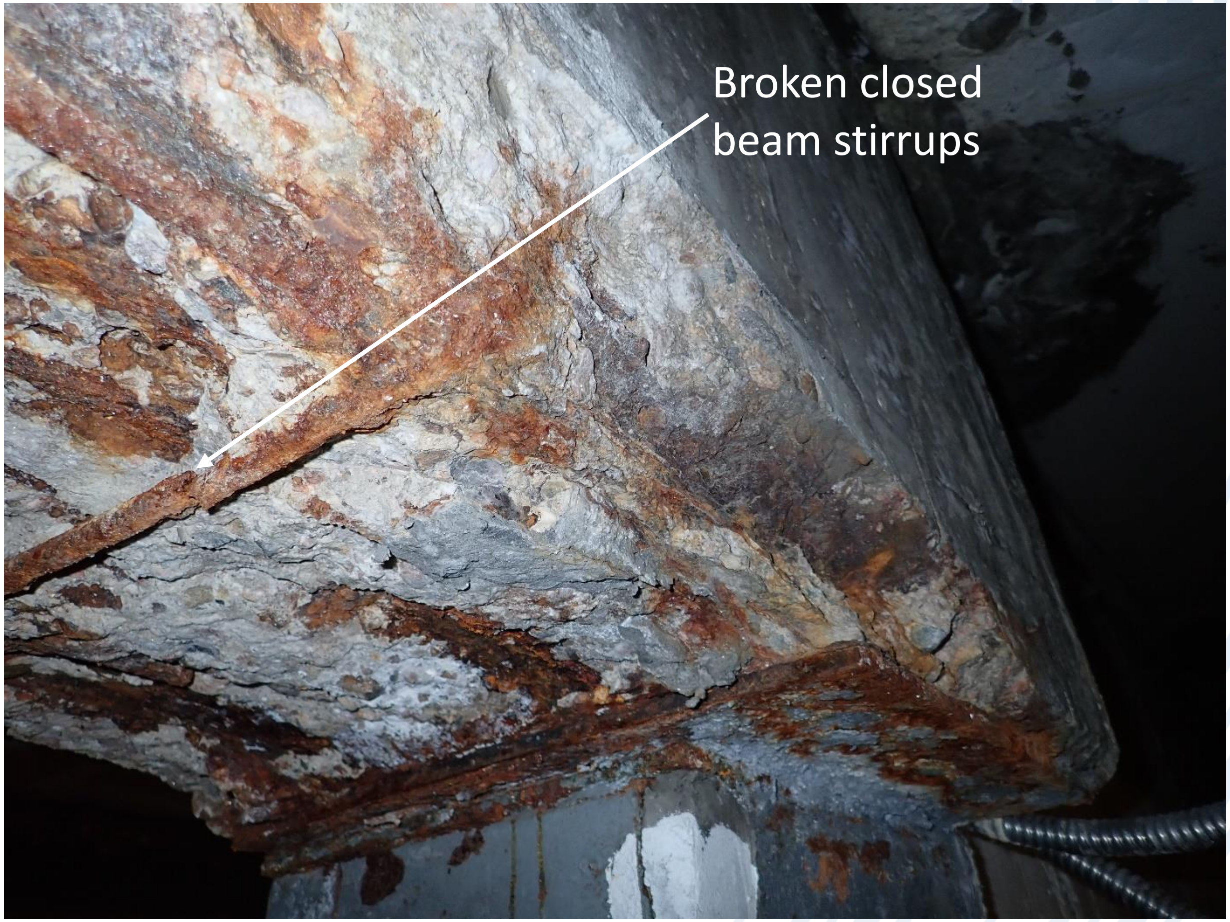
At this time, we did not yet know extent of damage but installed shoring prior to any additional concrete removal. This work was part of a larger concrete repair project at the garage.

Shoring for Double-Tees and Ell Beam to Slab-on-Grade

The cause of the corrosion was determined to be salt-laden water leaking from the level above, due to poor drainage and a failed sealant joint (Deferred Maintenance)

As additional concrete was removed, we discovered:

- Closed stirrups at the beam were corroded and broken in places.
- Extensive corrosion of prestressing tendons
- Large amount of concrete loss within development zone for the prestressing tendons

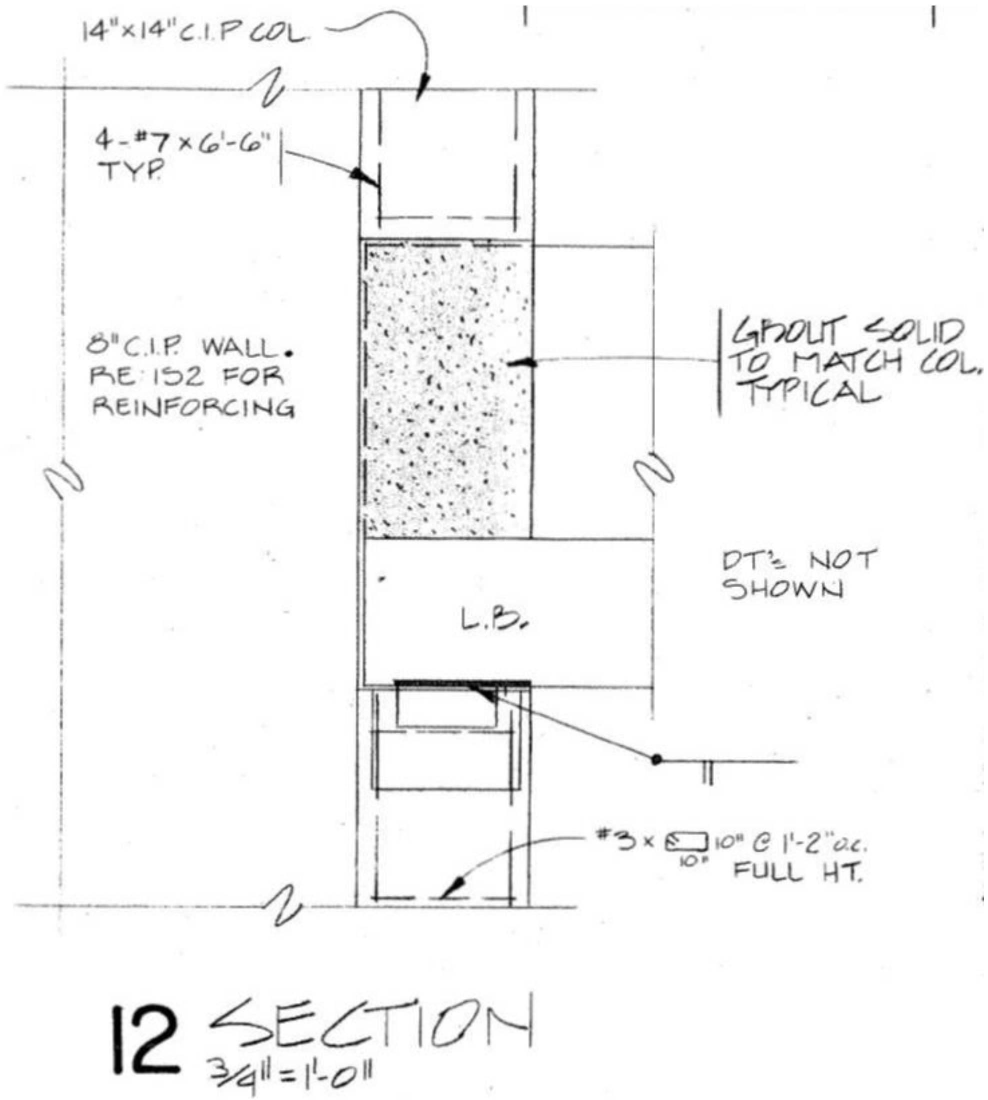


Therefore, structural strengthening was determined to be required.

When removing deteriorated concrete from the level above, a void below the cast-in-place concrete column was identified.

Note that the column is cast integral with the adjacent CIP concrete wall

Void below Column



The original construction documents specified grout above the top of the ell beam and above the ledge of the ell beam in order to provide a continuous vertical load path for the column.

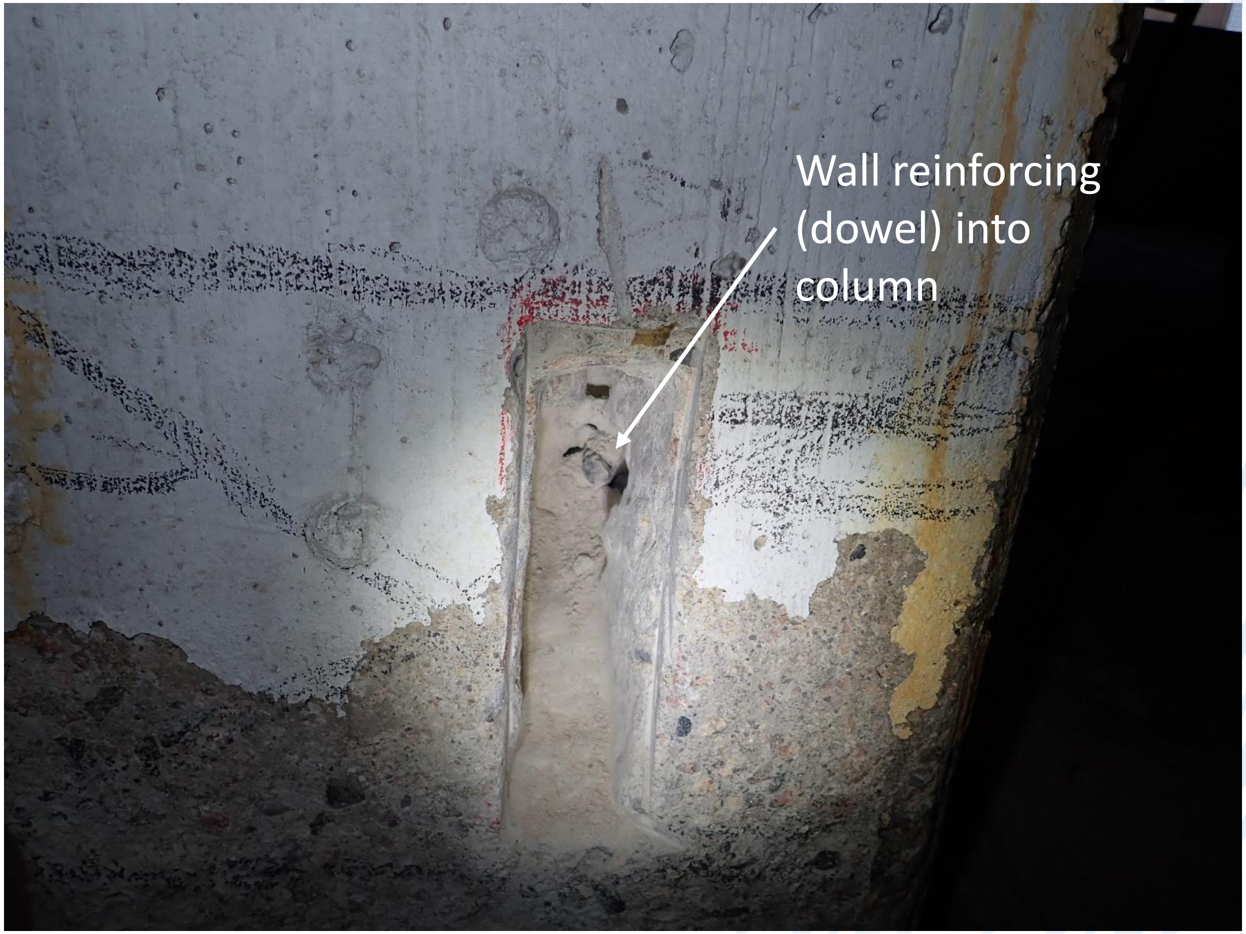
This grout was not installed

The only load path for the column load was through the interface with the 8" CIP wall

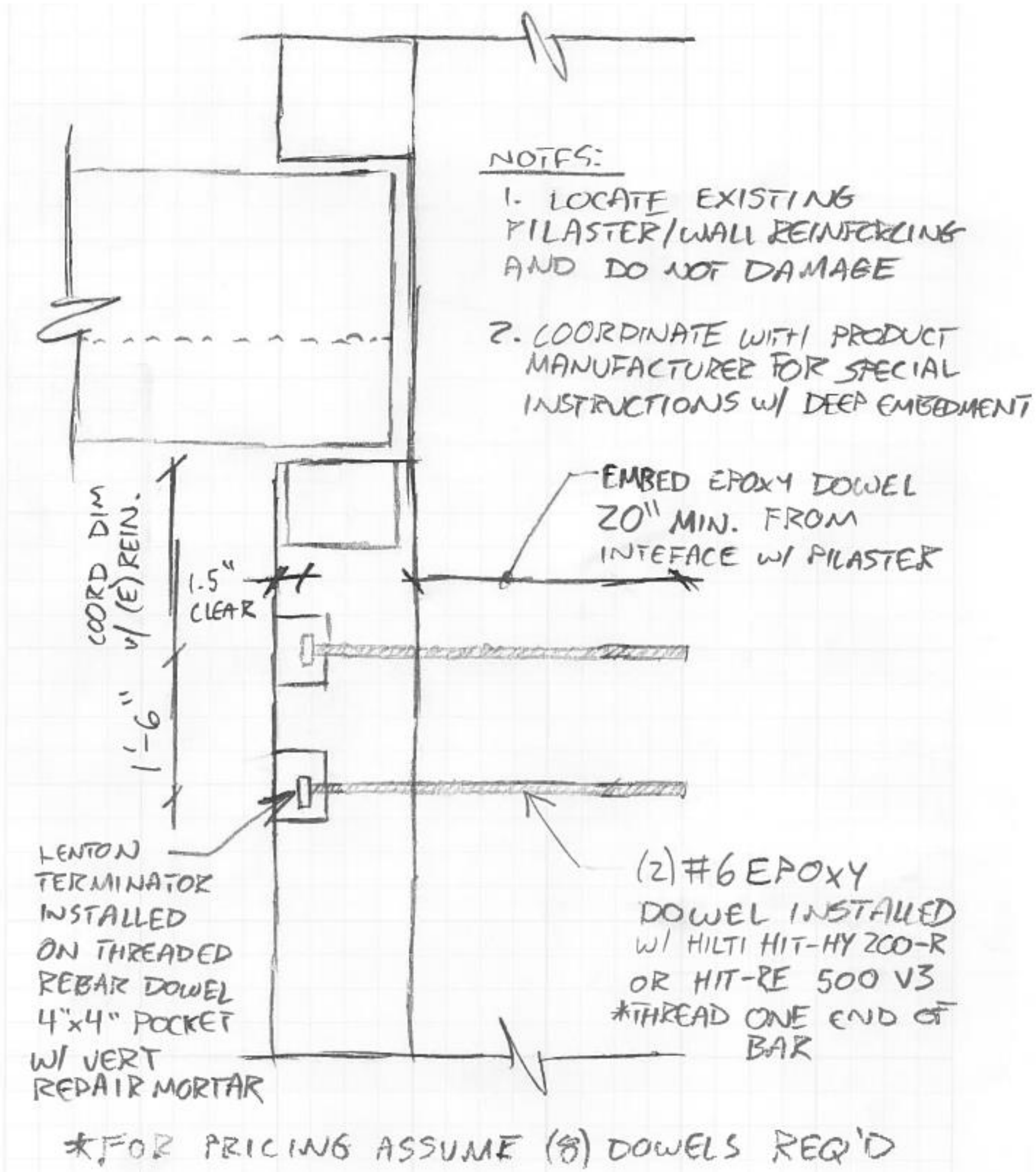
No dowels between the column and wall were shown on the original construction documents.

Something was transferring load from the column to the wall.

In order to determine the presence of dowels, we performed GPR testing of the column, followed by selective demolition



Wall reinforcing, acting as dowels, only extended approximately 6 inches from the wall into the column



We performed an analysis of the wall to determine if it can take the column load, then designed a repair capable of transferring all the column load into the wall at each floor level

Dowels were installed with the structure shored

After dowels were installed, concrete removal continued to sound concrete and undamaged reinforcing

Note markings on Ell Beam from GPR Reinforcing Location

Reinforcing before and after repair
Supplemental reinforcing added

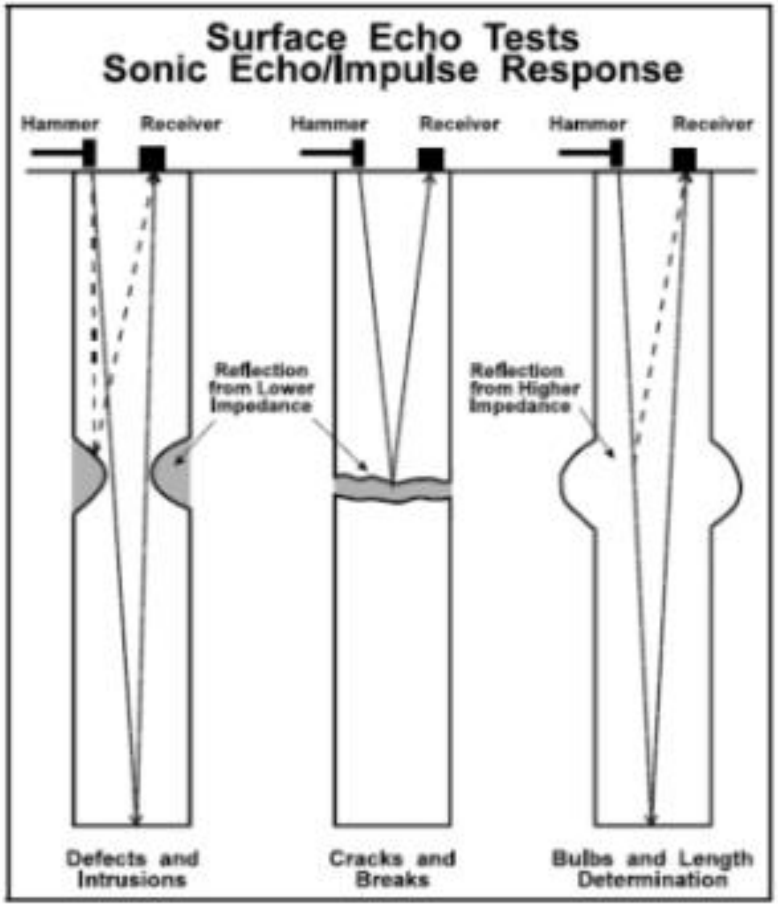
Completed Repair – Drop in beam soffit installed to provide additional cover for reinforcing (not in drive aisle)

EVALUATION FOR CONSTRUCTION DEFECTS

- Structure built in 1990s
- Expansive soils, with significant cracking and damage
- Suspected improper foundation construction
- Evaluated using Sonic Echo (SE) methods – similar to Impact Echo methods for determining slab/wall thickness
- Method can be used for identifying defects, and determining pier lengths in most soils (can be difficult in hard bedrock)
- Shafts were intended to be approximately 28 to 34 feet deep and embedded into claystone bedrock

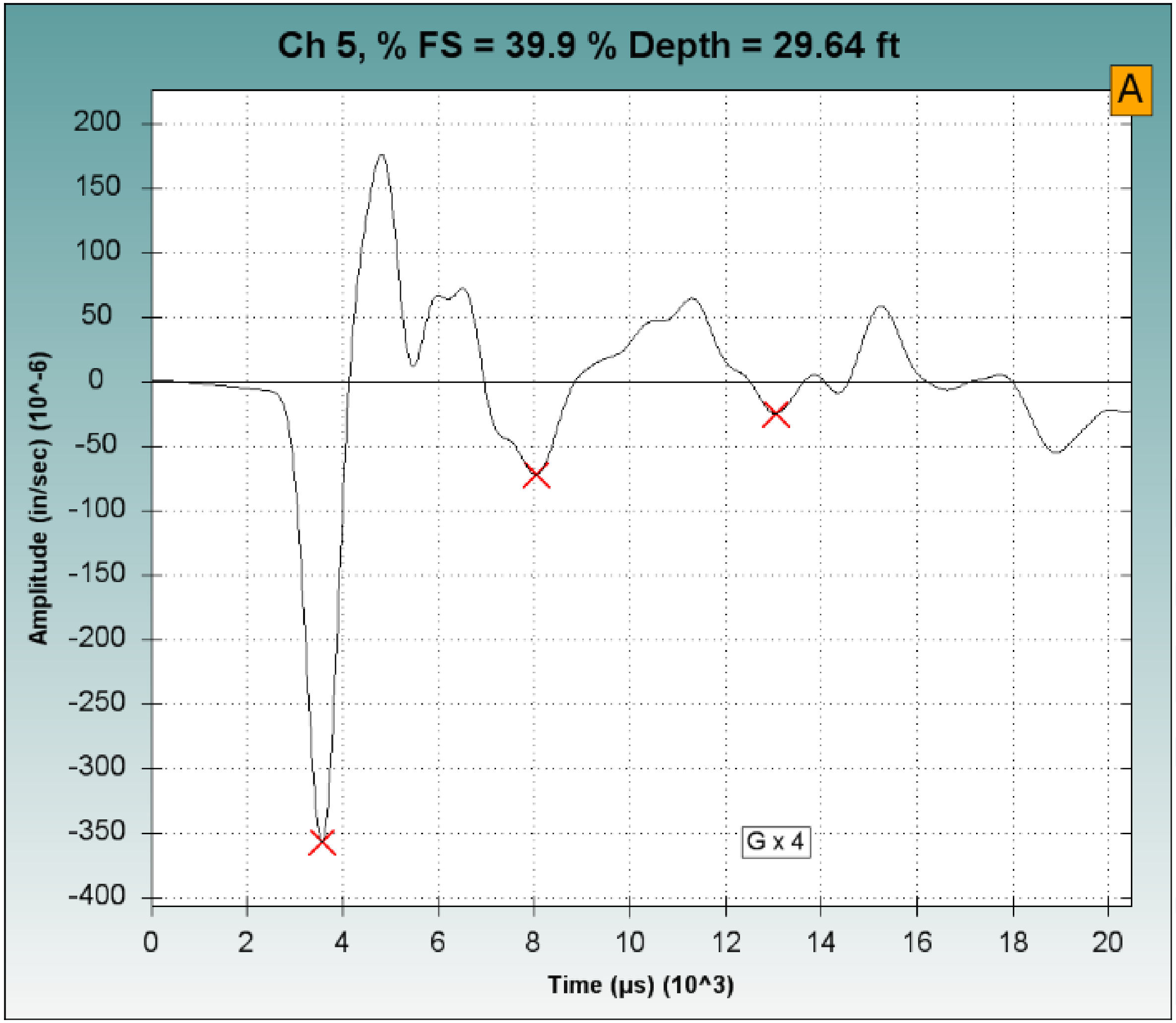
SONIC ECHO METHODOLOGY

- Impact the top of the pier with a 3-pound impulse hammer with a built-in load cell
- A receiver (accelerometer) is mounted on the top of the shaft and connected to a Data Acquisition System (DAQ)
- The energy wave travels to the bottom of the foundation and reflects off irregularities

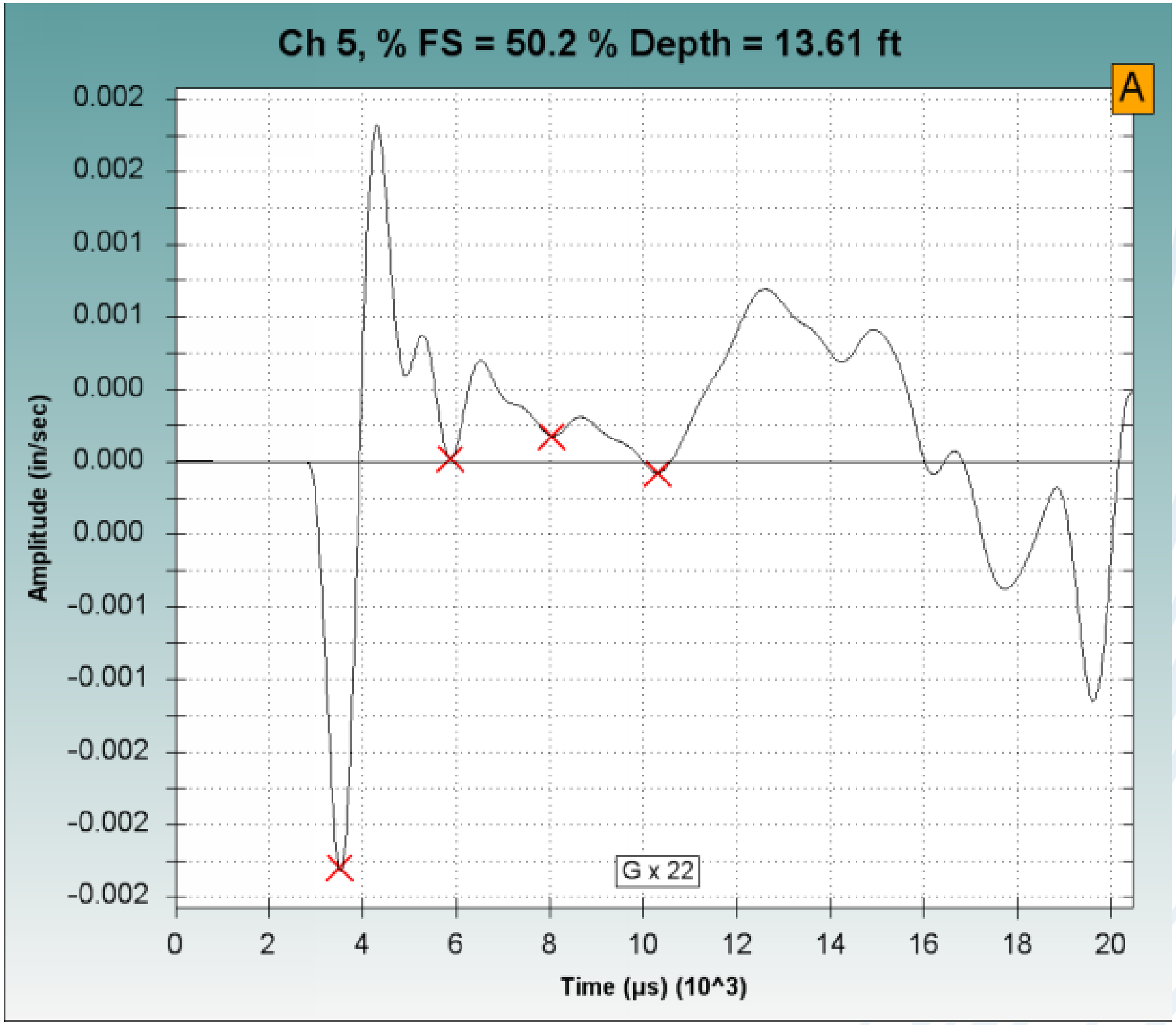


Images and Graphs Courtesy of Olson Engineering, Wheat Ridge, Colorado

SE Test being Performed on a Drilled Pier



Sound pier, depth based on wave velocity in concrete = 12,500 fps



Defective Pier – Short, Broken or Cold Joint at a depth of 13.6 feet
Recommended replacement with a micropile

Thank you!

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