



Lessons Learned from a Master in Concrete Repair – Tony Murray

Presentation by Gene Stevens – J. R. Harris & Company



American Concrete Institute

Always advancing

Concrete Repair Session to Honor the contributions of Tony Murray

Contributions of Tony to me extend far beyond our work on projects.

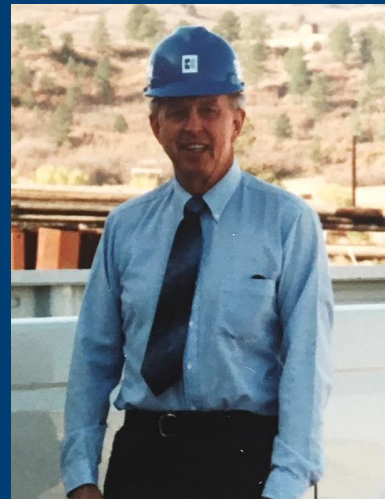
He would always greet me with a smile and a handshake.

We trusted each other and had faith that we could depend on one another.

He inspired me to reach further and to go further with my engineering.

He made me a better engineer, but he also made me a better person.

Here is to Tony with many thanks



Las Animas – Prestressed Concrete Water Tank.

Dia. – 130 ft.

12 Interior Cols. 16 in. sq.

7-1/2 in. P.T. slab

20 ft. Exterior wall

Built in late 70's

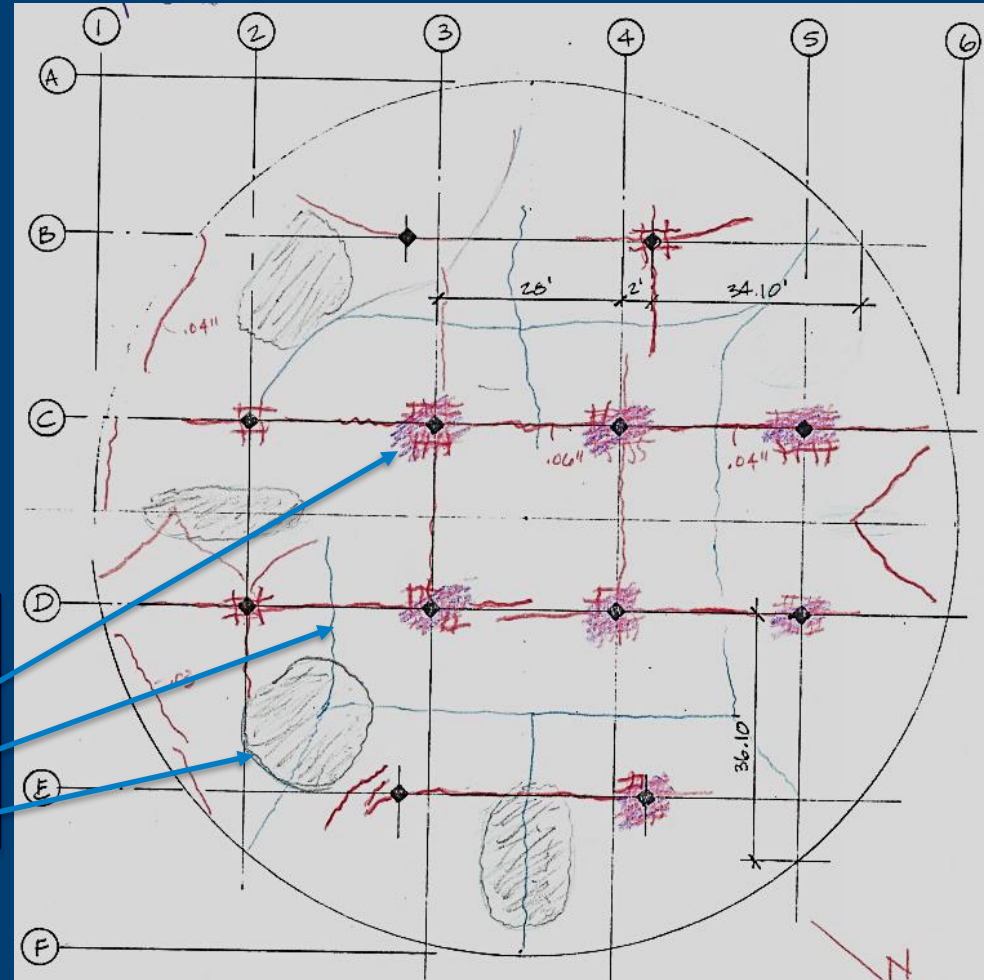
Roof slab distress: 1986

Spalling in underside of slab at columns

Cracks in the slab top

Low spots

- Design was very thin
- Distress over the interior columns and top crack - unusual



Engineering Needs & Construction Techniques

JRH assessment in 1986

- Some top cracks closed
- Others top cracks open (0.06 in.)

What are the Engineering Needs?
Define what is damaged, deteriorated,
or distressed and why.



Underside of slab is spalled at the bent
column bars. Why?

The slab was lifted by water inside the
tank.

Design did not anticipate upward
pressure pushing on the slab.



- Depth of spall is about $\frac{1}{2}$ the slab thickness
 - Shear capacity ≈ 79 k ($\phi = 0.85$)
 - Shear demand 74 k for service weight of slab (load factor of 1.0)
- Using current load factors and $\phi = 0.75$, $D/C = 1.5$

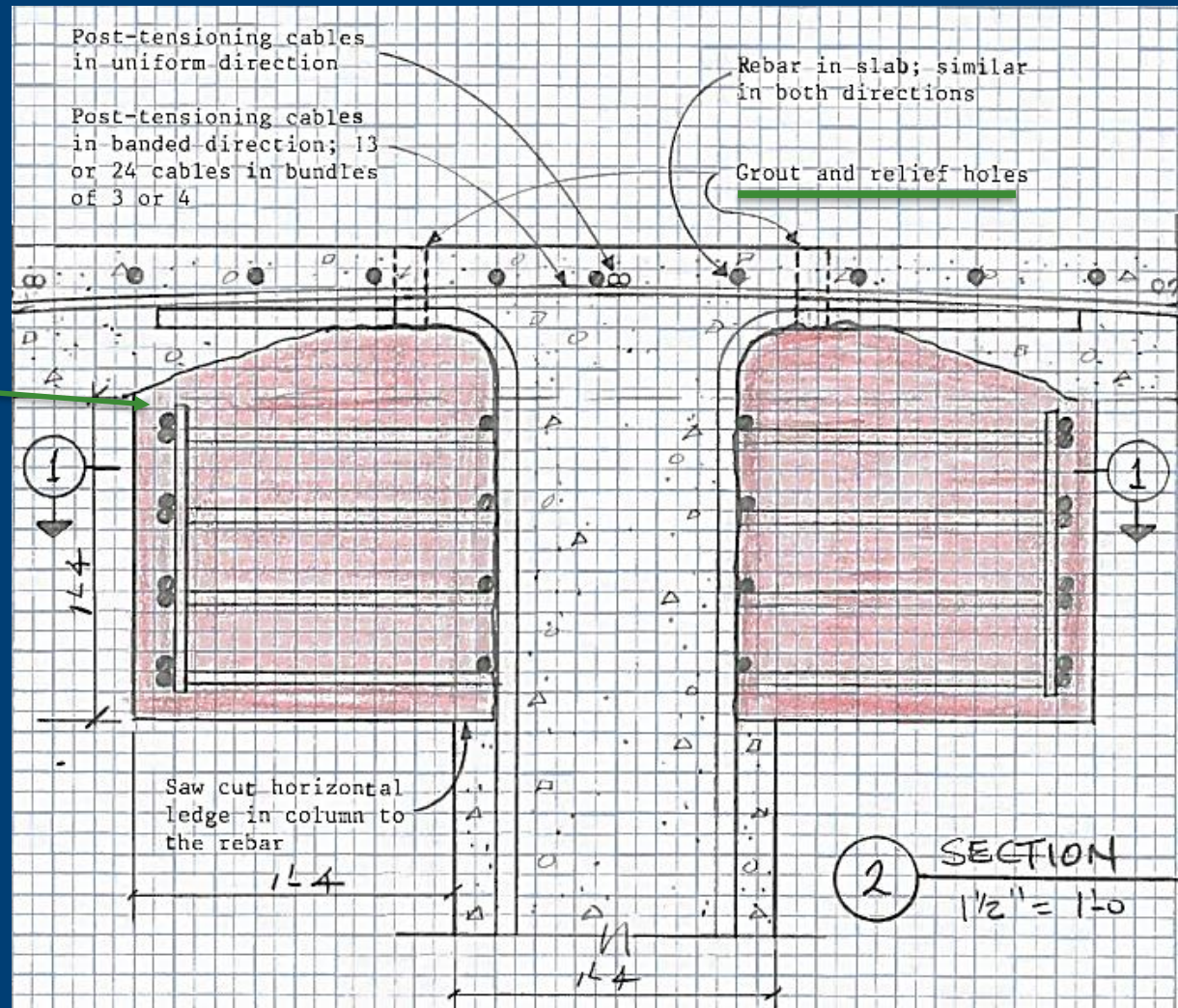
Seriously unsafe condition as a result of lack of system redundancy to resist the slab dead load



Repair of slab spalls at columns:

Add column capitals to restore punching shear strength.

Use preplaced aggregate concrete to reduce the potential for shrinkage causing gaps between the (E) slab and the (N) capital



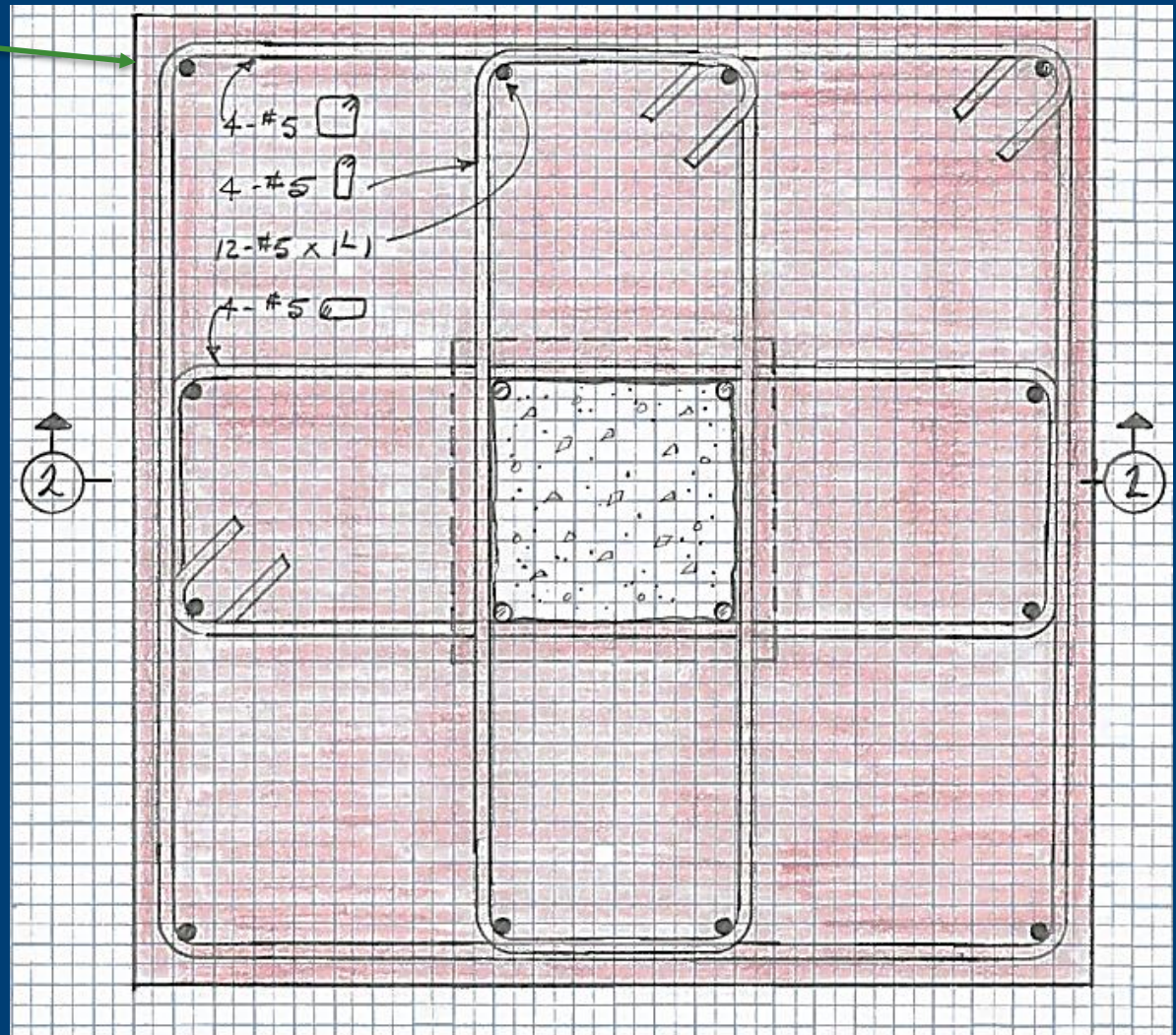
Construction Technique

Section of the (N) column capital

Preplaced aggregate concrete has to a large extent been replaced with shrinkage compensating self-consolidating concrete, but not in 1986.

Tony consulted with J. R. Harris & Company on the repairs for this project. Tony's firm, Restruction Corporation did the repairs.

Construction Technique
Reconfigure Bars



Plan of the (N) column capital

Empire Park @ 3801 E. Florida Ave.,
Denver, CO

Exposed Concrete Deck:
Double Tees & Structural Slab

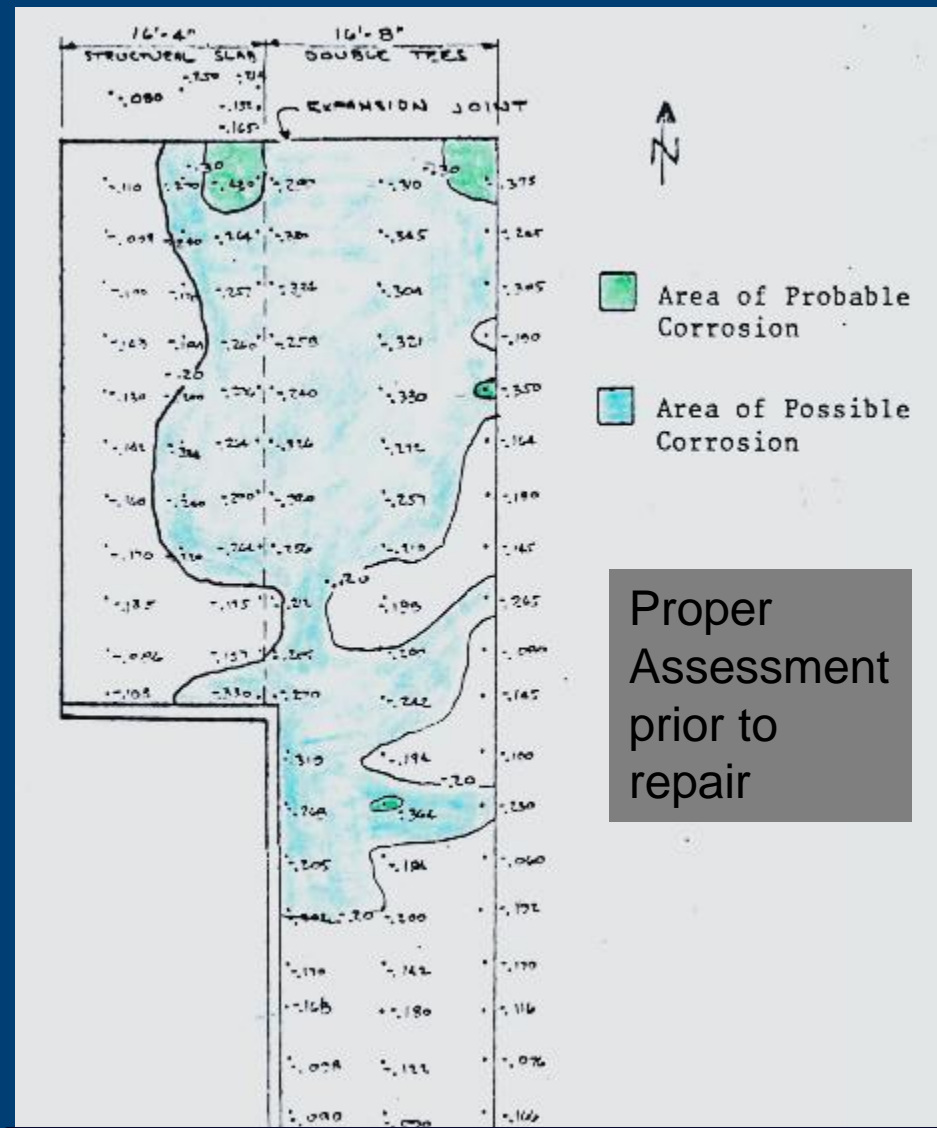
Restruction Corp. repairs:
Crack repairs with epoxy injection

Expansion Joint Repair

Remove existing concrete below top
bars on structural slab & R/R
corroded bars

Remove and replace concrete
topping on DT's and replace bars w/
#5 epoxy coated bars.

Perhaps the more typical repair
project.



Half-Cell Test Results from J.R. Harris & Company

Proper
Assessment
prior to
repair

Terminal Garage @ 1730
Glenarm Place, Denver,
CO

Interior & Exposed
Concrete Parking Garage
Deck:

- 10-1/2 in. Structural
Slab
- 2-way slab system

Design based on 1928
provisions

Remove 3 to 3-1/2 in. of
existing concrete to below
top bars on structural slab

Add top bars and replace
concrete



Investigation of concrete & top reinforcement at columns

Tony insisted on
proper assessment prior to repair
& proper construction techniques



Owner is seeking
20 years of safe life

Using the full bar areas, the
existing construction provides
2 to 3.5 times the required
reinforcement

Shear is not an issue as a
result of the column capitals

Concrete proved to be solid
below the top layer of bars

Limit the repairs to isolated
areas of high distress as
determined in our survey

Used 1/4 " ϕ SS screws into
(E) concrete for Horizontal
Shear.



Asphalt overlay conceals concrete spalls at columns



Two to four layers of bars for positive bending.

Assessment by JRH 2008+

Bottom reinforcement with
Existing distress is adequate.

Repairs 2009 – 2010
Some by Restruction Corp.

Reviewed performance in
2015

Replacement concrete is solid

- No cracks
- No bonding separation

Next check in 2020



Carrara Place Garage in Greenwood Village, CO

2004 assessment by JRH & investigation help and concrete repairs by Restruction Corp.

Two-way P.T. slab

- Evidence of one strand fracture
- Cracked and spalled concrete in underside of pour strip
- Corrosion on bottom bars of the pour strip
- Distress in concrete supporting P.T. slab edge



Support for P.T. slab repaired

Per Tony - proper assessment to determine the proper repair. One needs to resolve the cause of the distress prior to designing repairs

Repair for top reinforcement of the P.T. slab is not required.



Top reinforcement in good condition in P. T. slab areas checked. No evidence of probable distress.

Restruction Corp. Repairs:

- Removed and replaced pour strips in the garage
- Removed and replaced support ledge of the Plaza Level
- Replace a P.T. strand

2004 design by JRH



Proper assessment prior to repair &
Construction Technique

Grosvenor Arms Apartment
Court Yard Repairs
333 East 16th Avenue,
Denver, CO

Initial assessed by J. R. Harris & Co.
1995

Repaired by Restruction 1996

Court Yard deck exposed – concrete
paved with stone

Remove pavers and review concrete

Underside of the slab shows
significant bar distress and water
leaking through the slab

Assessment completed as repairing
the project per the owner's request -
make changes to repairs as needed



Distress in underside of concrete resulting from leaking water evident prior to repairs

Slab and beam bars corroded

Chip out areas of unsound concrete and remove – some partial and some full depth.

Replace reinforcement as necessary and replace concrete

Add protective membrane on top surface



Add epoxy coated bars
in patched areas

New slab and reinforcement in
stair ramp area

Exits from building solve by
wooden ramps.



Collaboration on projects was
endorsed by Tony.



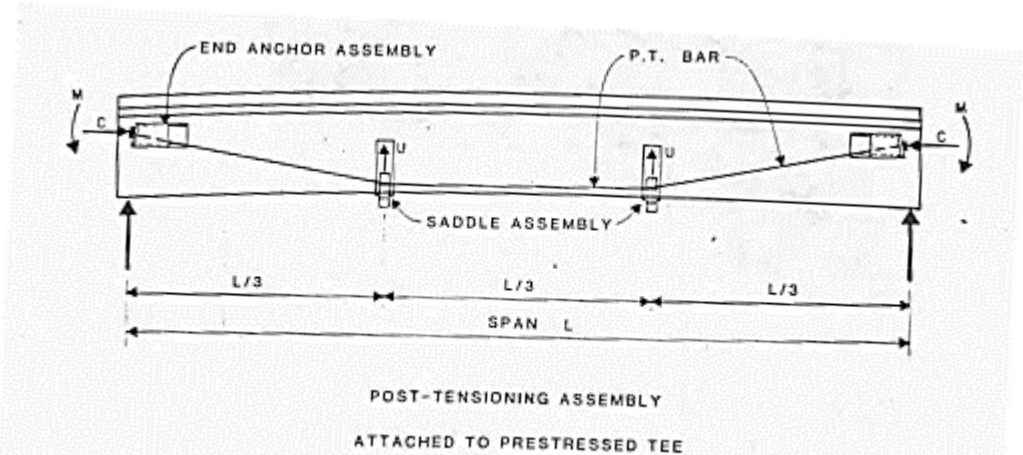
Span = 50 ft.
24 in. deep Dbl. Tee slabs
Live Load increase from 50 psf
to 83 psf

Add (2) 5/8 in. diameter
Dywidag bars at each leg

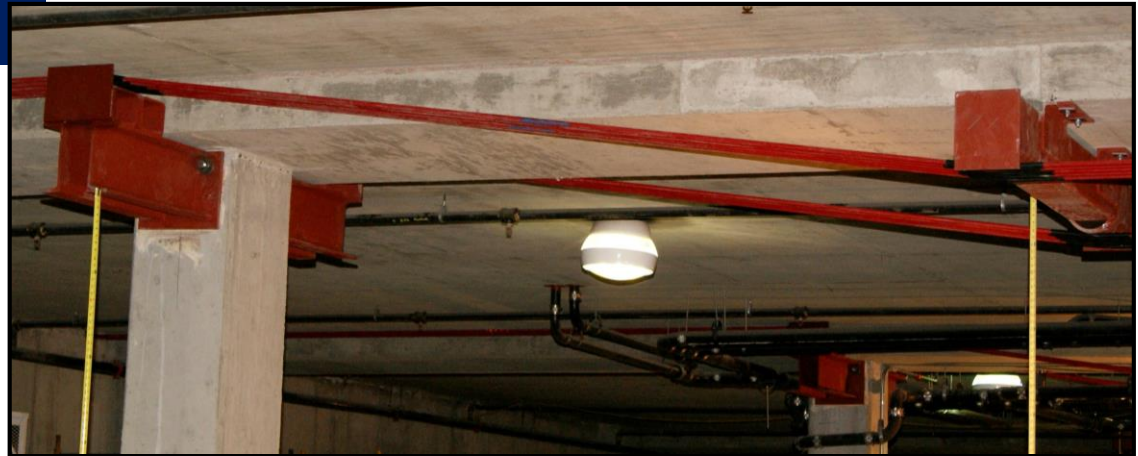
Design 1986 by Stanley Smith
Checked by J.R. Harris & Co.

Remedial work installed by
Restruction Corporation

This project provided the
Inspiration for our
development of other
External P.T.
Reinforcement projects.



#2 Denver Highlands: Structural Strengthening
of Double Tee floor members with external P.T.



1986 External P.T. Repairs
To 2014 External P.T. repairs

JRH 2009 assessment found

- Several beams with deficient reinforcement for positive bending
- Most cost effective repair external P.T. reinforcement
- 2013 JRH repair design using ACI 562-13
- 2014 repairs by Restruction Corp.



Construction Technique – bolt on corbels

Village Lofts Condominiums
Steel Corbel Added to (E) Concrete Column
for External Post-tensioned Reinforcement



Steel corbel fabricated off site and fastened to (E) concrete columns with two 1" ϕ ASTM A354 , Grade BD, $F_u = 150$ ksi threaded rods

Problem was exactly locating the column reinforcement and positioning the anchoring rods

& fitting of surfaces plate to (E) concrete

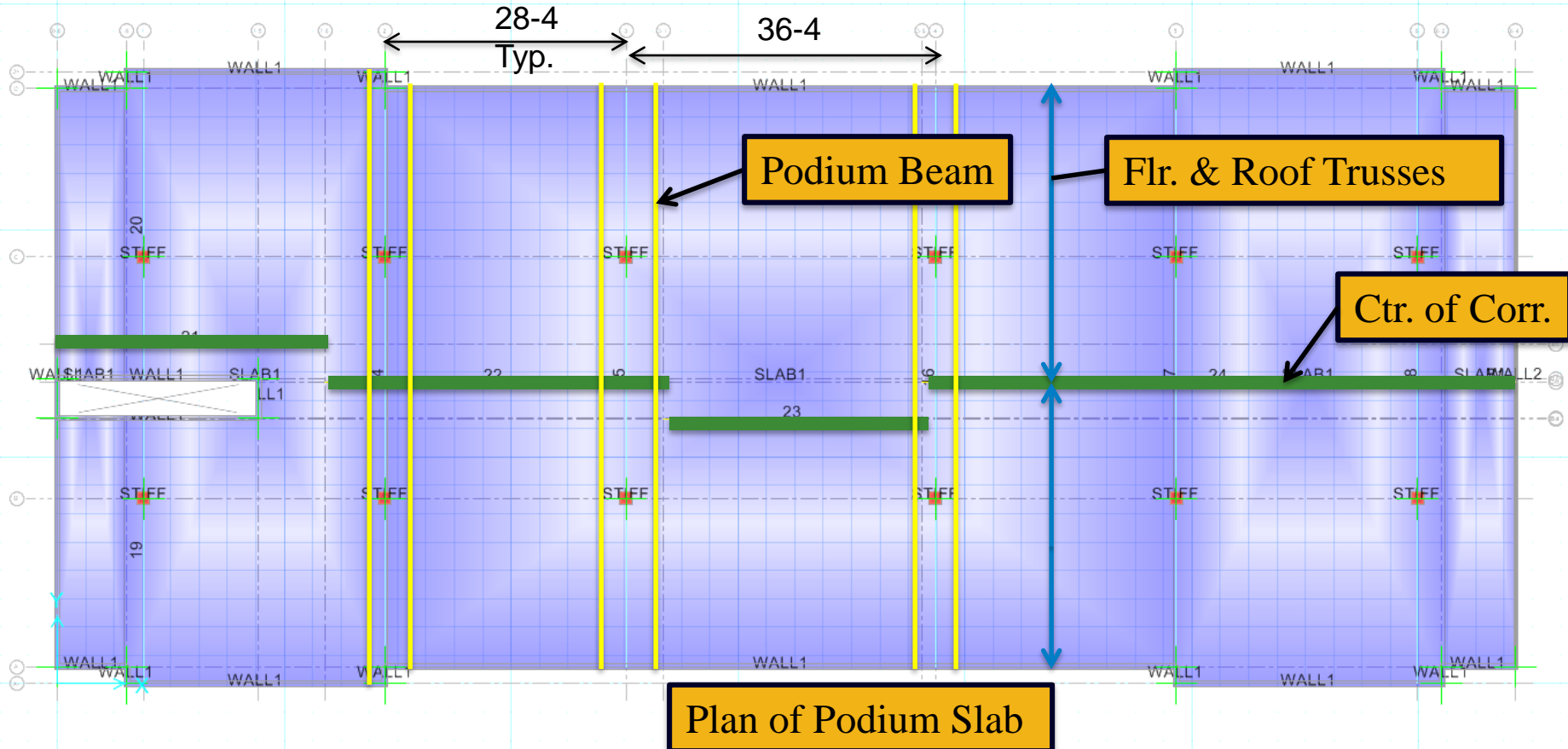


Construction Technique – bolt on corbels

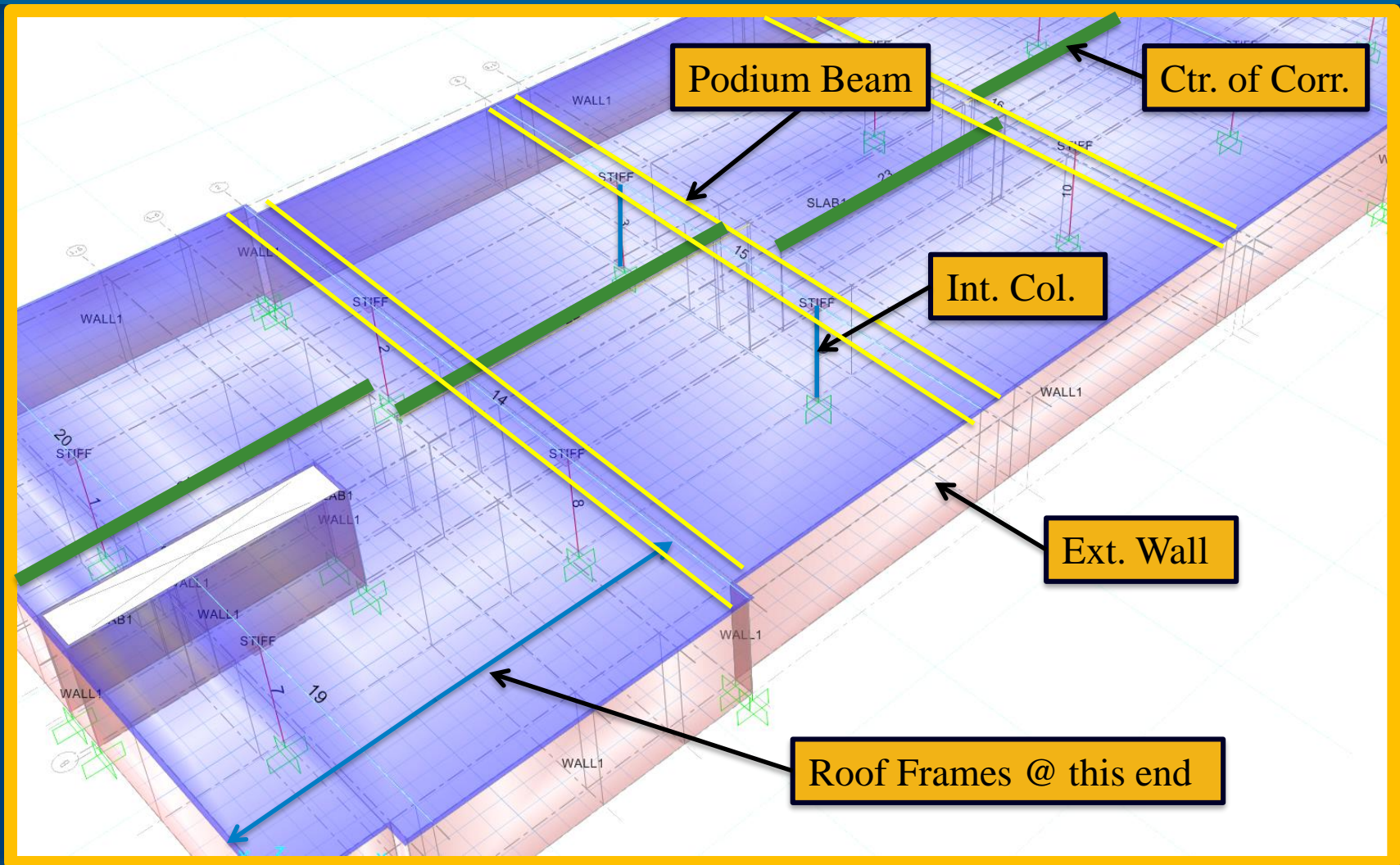


Evaluate data to judge structural adequacy

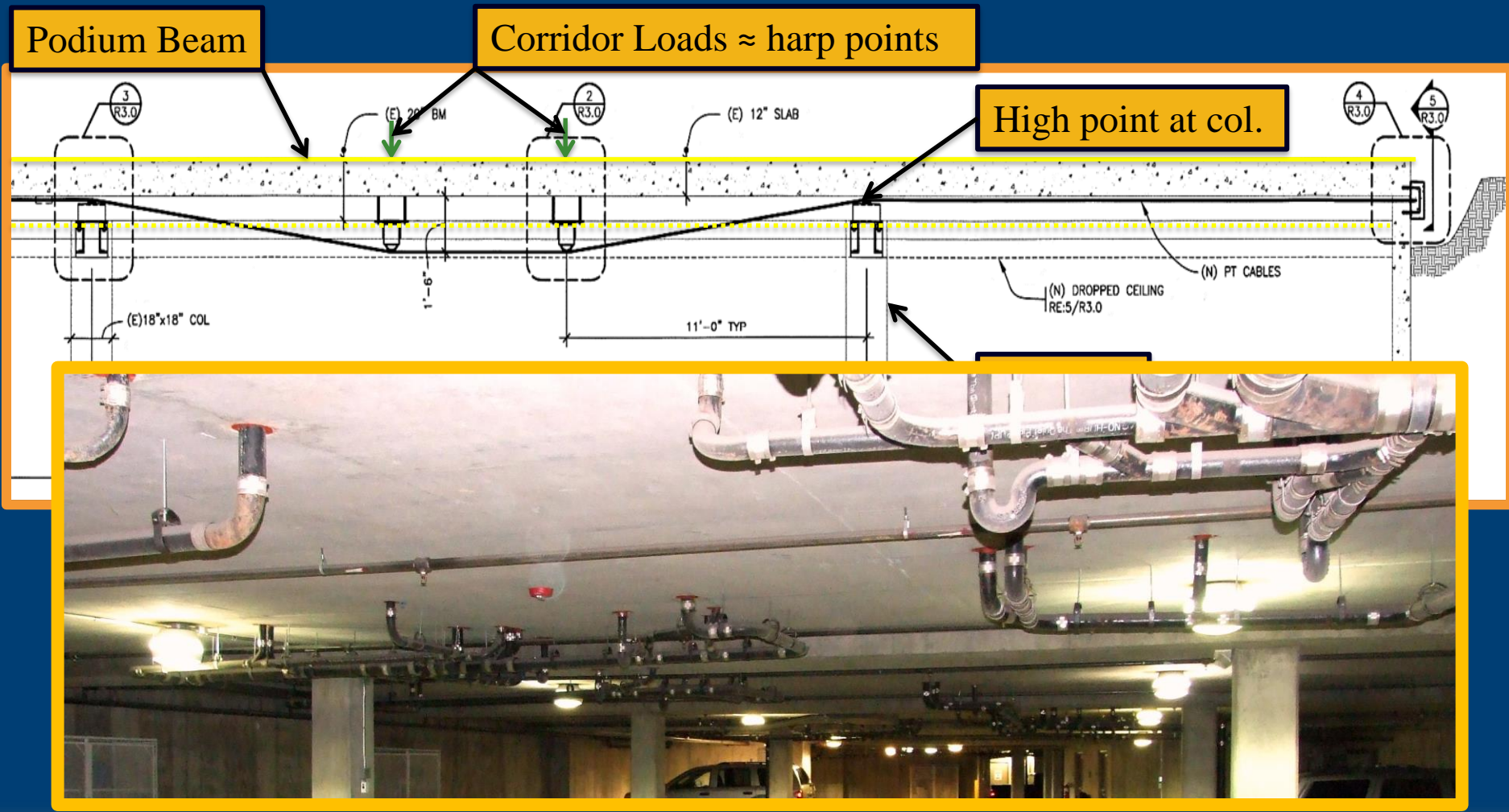
Computer Analysis – SAP & SAFE - CSI



Use ACI 562 for repair design - 3D View from CSi "Safe" Model – Bldg. B



Section of Podium slab beam w/ external P. T.



Construction Technique
As the complexity of
Repairs increases

Details become more
complex

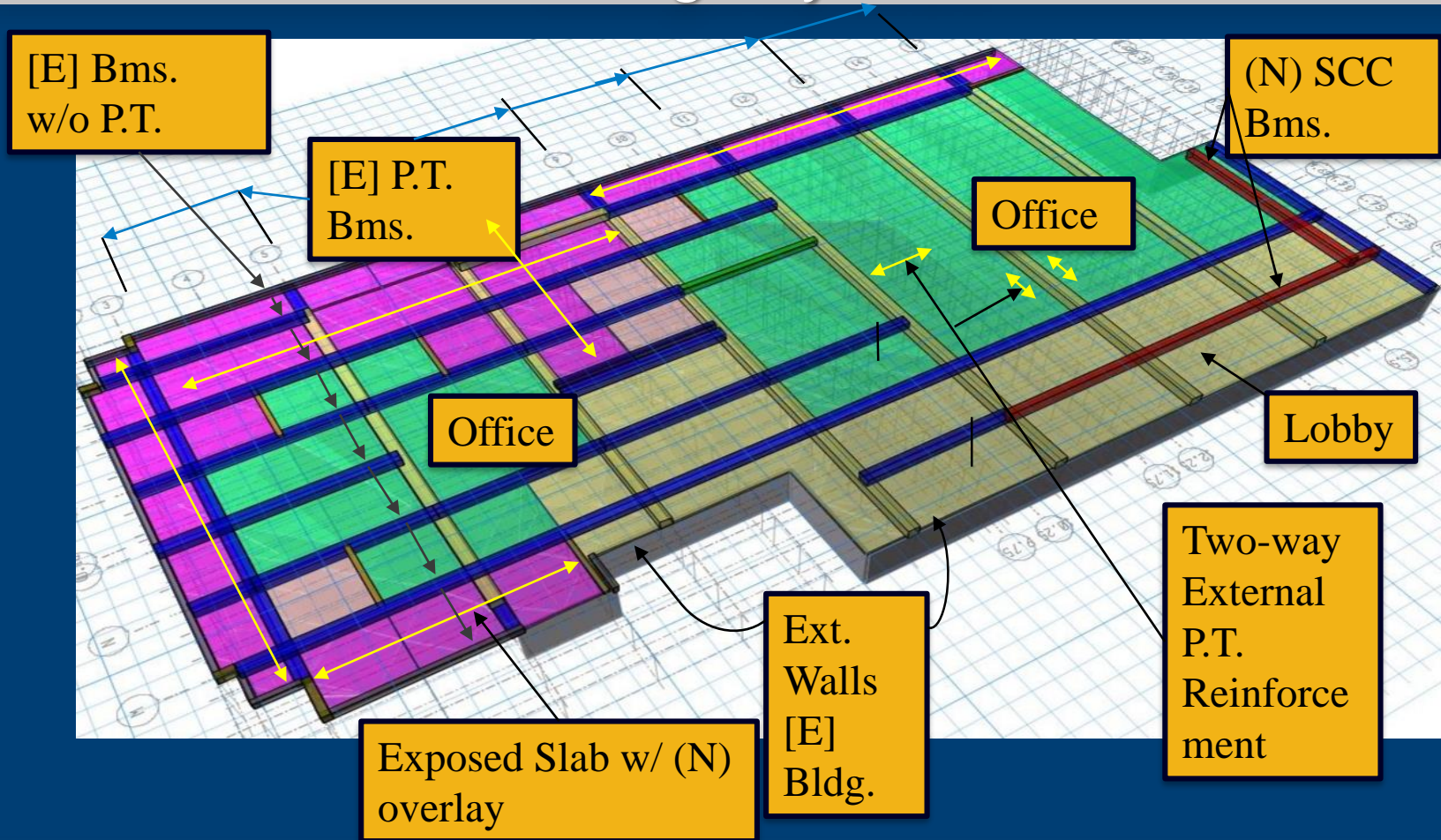
Quality control is more
important

Construction trust is an
absolute necessity

With Tony's firm,
Restruction Corp. I
have this trust.




"Safe" 3D View – Current Project is the next generation of External P.T. – 2016-2018 design by JRH



Tony's inspirations given to others,
construction techniques taught,
knowledge of engineering needs
shared,
and contributes to repair of
concrete structures
continue
with Restruction Corp.,
Documents,
and in my heart.

An ACI Provisional Standard



 American Concrete Institute
Always advancing



American Concrete Institute

Gene Stevens – J.R. Harris & Co.

Always advancing