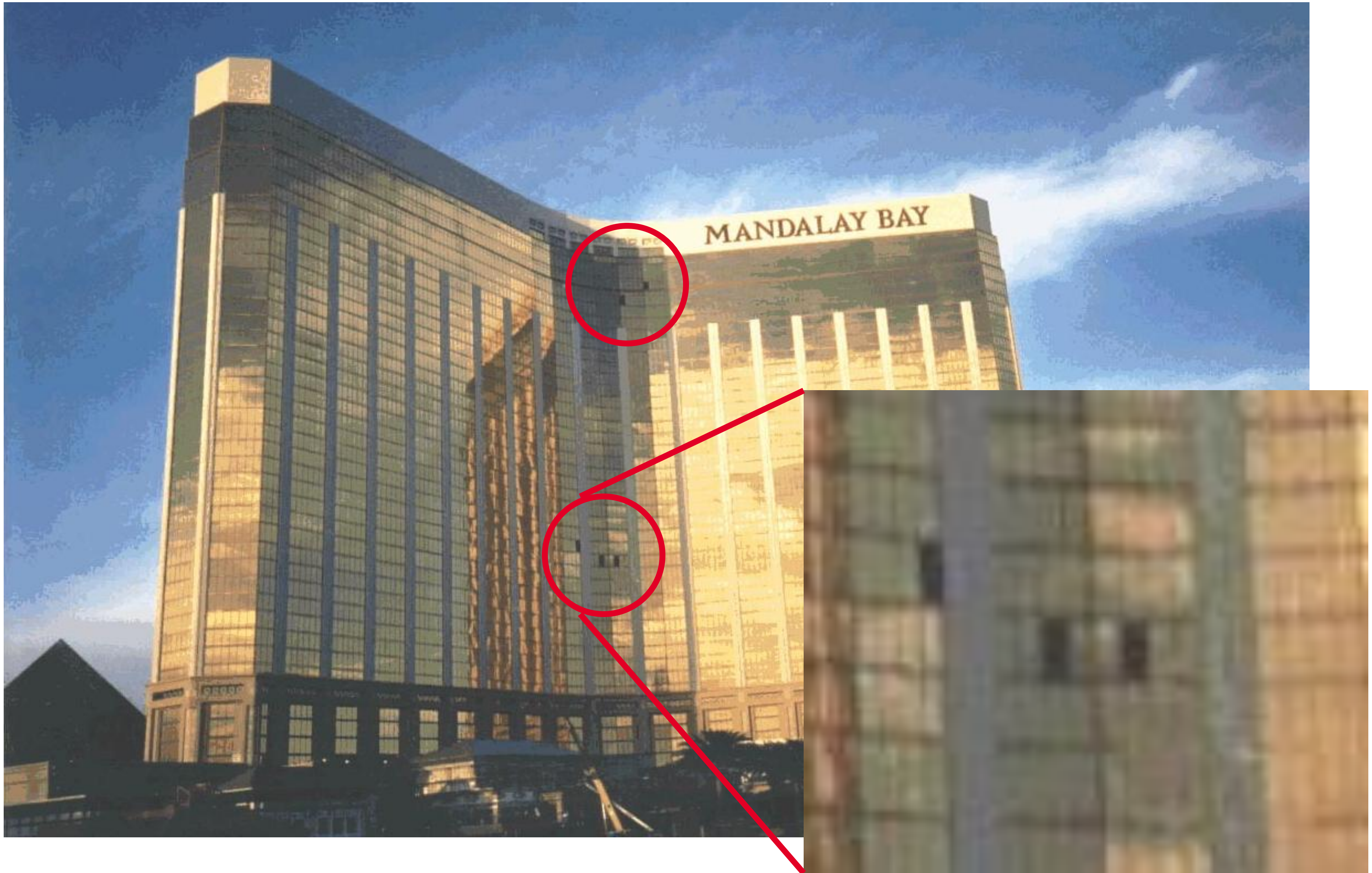
Build on us

You've Lost that Sinking Feeling: Nicholson Looks Back at Mandalay Bay Project

International Society for Micropiles - 12th Lizzi Lecture
Tom Richards, PE, BC.GE Retired Chief Engineer
September 2025

Mandalay Bay Casino, Las Vegas



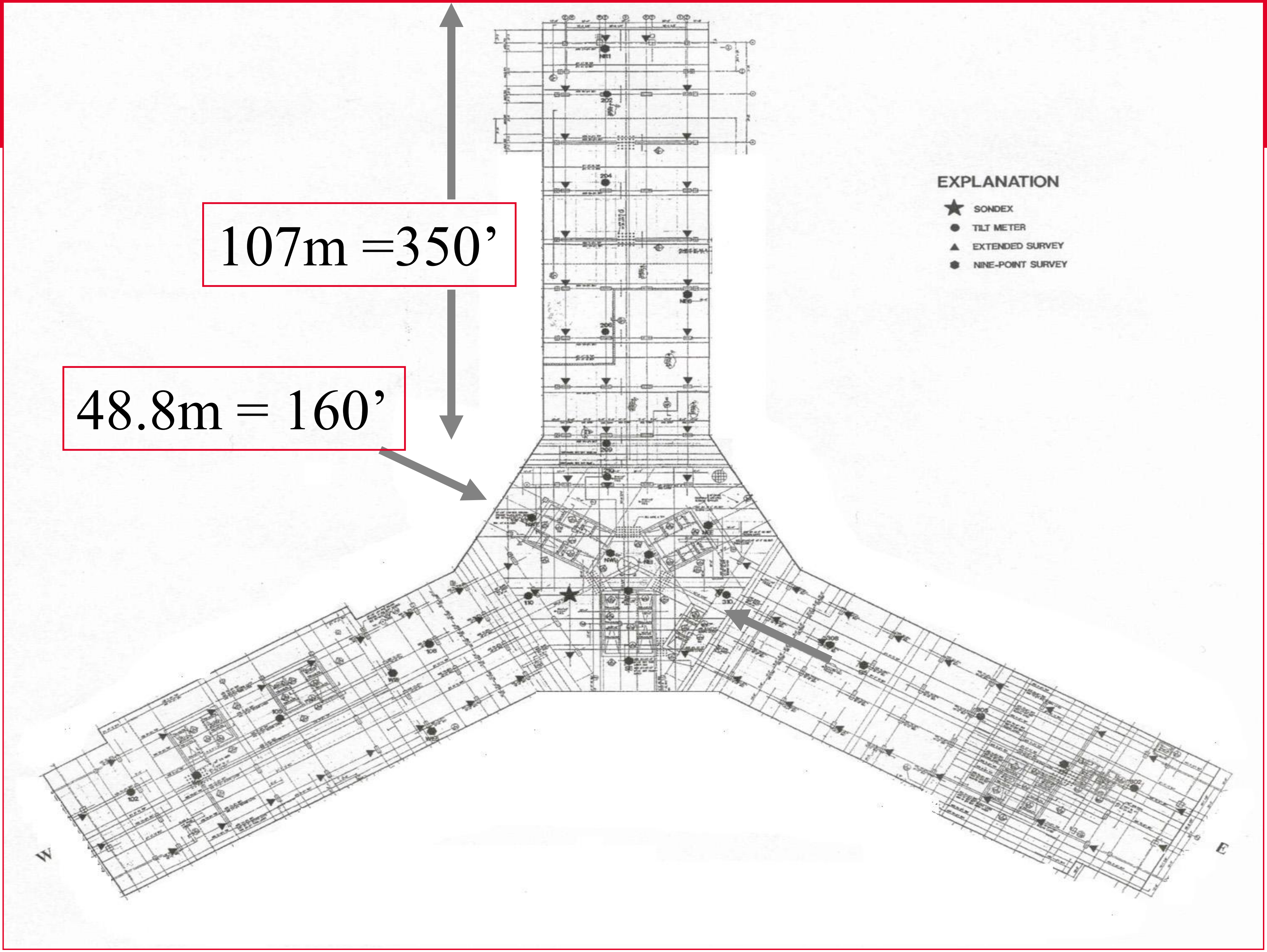
Problem Statement

- 380 mm to 460mm (15 to 18 inch) settlement at core and 150mm (6 inches) in wings.
- Differential settlement across structure up to 300mm (12-in)
- Settlement rate of 19mm (¾ in) per week when Nicholson contacted
- Structural damage a concern; but….Schedule Ruled

Showed Team other Jacking Jobs

Geotech Dream Team

- Kleinfelder LV office
- Jim Warner
- Donald Bruce
- Mike Duncan – first settlement estimate 610mm more (24 in)
- Fred Kulhawy
- Clyde Baker


107m =350’
48.8m = 160’
EXPLANATION
SONDEX
TILT METER
EXTENDED SURVEY
NINE-POINT SURVEY
W
E

Las Vegas Geology

- Sediment Filled basin in desert environment
- Interbedded Caliche and sandy clay
  - Caliche – Typically a cemented layer a few inches to many feet in thickness containing impurities of clay, sand or gravel. Cementing material typically calcium carbonate.
  - Compressible clayey sands and sandy clay extend to depths exceeding 76 meters (250 feet).

Background Info

- Typical building foundations in LV were mats supported on caliche layer with 240 to 335 kPa (5 to 7 ksf) bearing pressure
- Tallest building at 43 stories, largest footprint, largest mat pour in Nevada at the time.
- As structure was built, settlement was occurring and accelerated as building was topped out.
- Thicker caliche in other parts of Las Vegas

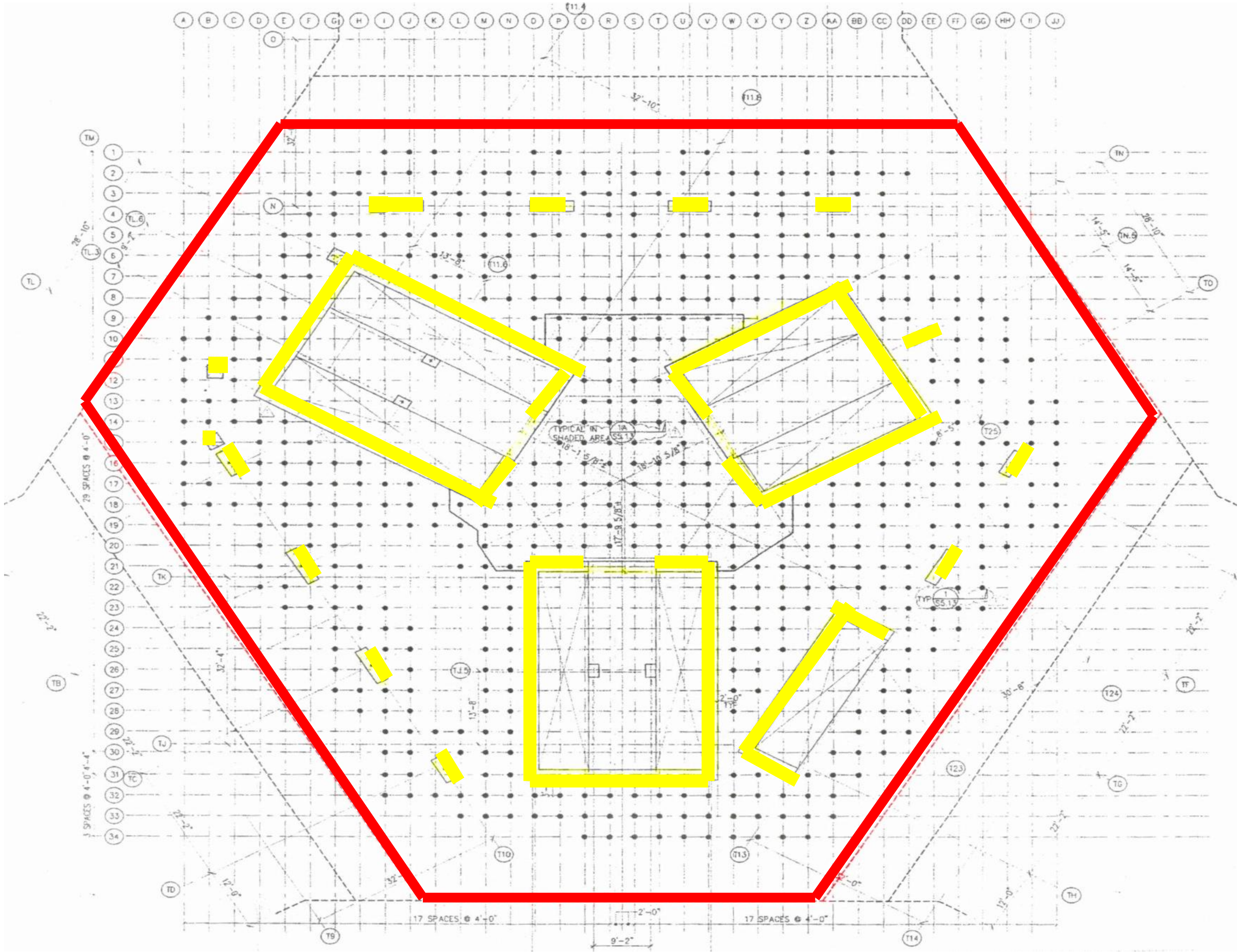
Geotech Details

- Groundwater at micropile mat elevation
- Predominantly cohesive soils
- 15% gravel, 39% sand, 46% silt/clay
- LL = 36, PL = 17, w = 24%
- s_u as low as 20 kPa = 0.4 ksf (from CPT)
- q_u as high as 47.6 MPa = 6900 psi (from N size core)

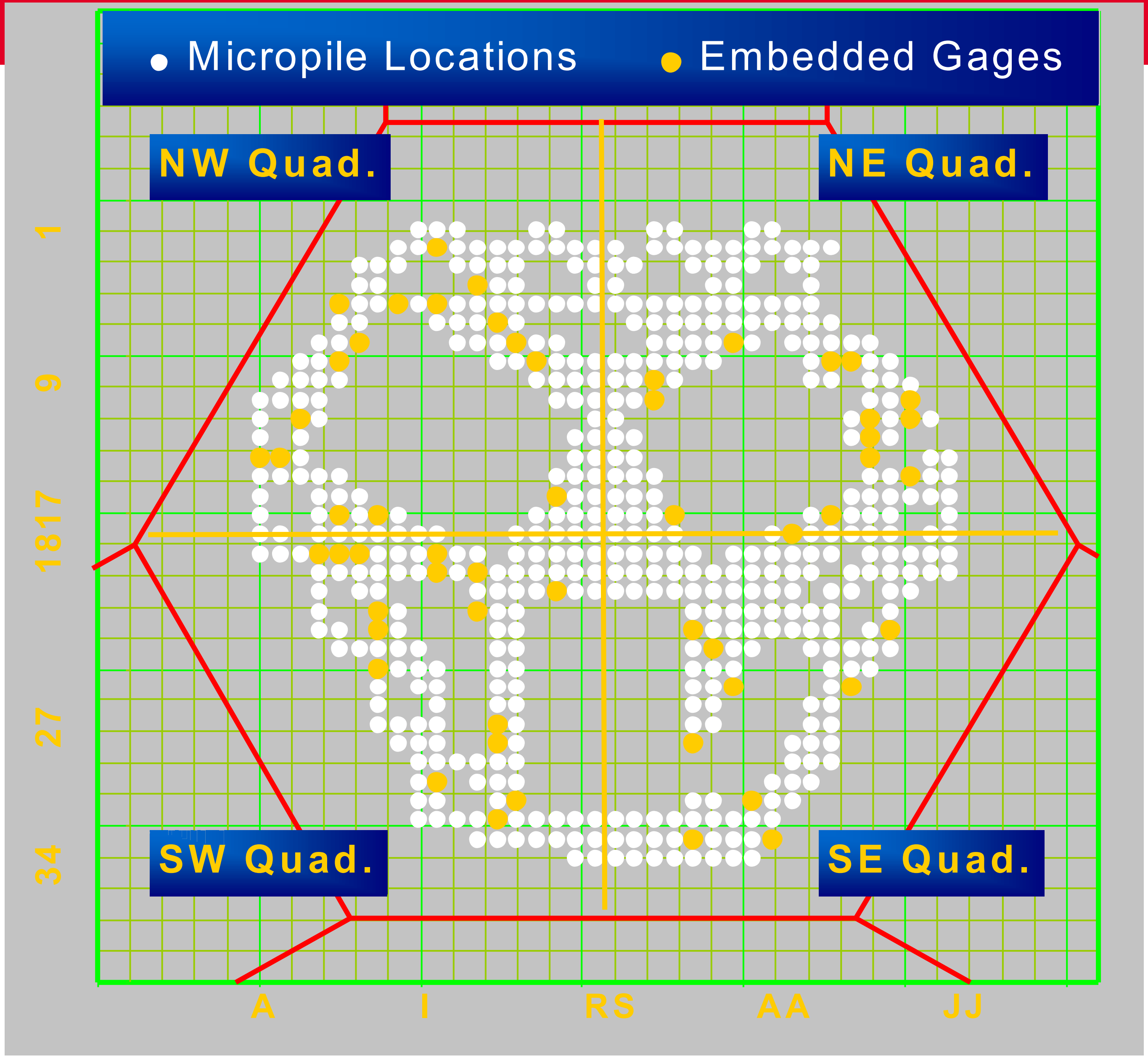
Overview – Pile Design

- Design Load: 1780 kN (400 kips)
- Test Load: 2670 kN (600 kips)
- Each Pile Individually Tested
- Heavily Instrumented and Monitored
- Converted Mat to a Large Structural Pile Cap

Pile Layout



Micropile Instrumentation

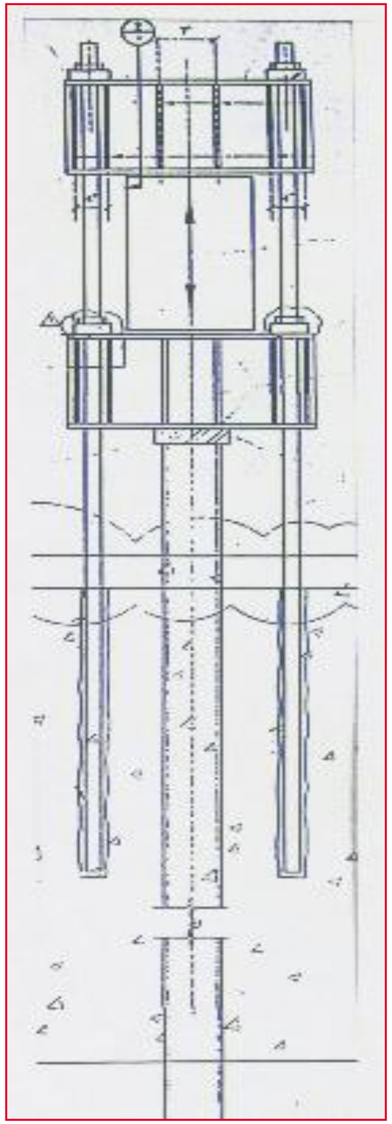


Overview – Pile Design

- 536 piles installed in the core of the structure
- Each pile was 60.9 m (200-ft) long determined by demonstration drilling since no borings that deep yet.
- 177.8 mm diameter 12.7 mm wall casing (7 x 0.5 in) full-length
- Pressure grouted with a cement grout

Exposure of the Existing Mat for Pile Installation Required Excavation of Soil Fill

Reaction Frame



< Jacking Beam

< 350 Ton Jack

< Permanent Reaction Beam

< Micropile

< Reaction Bars Grouted into Mat

< Bond Breaker in Mat

Reaction Frame – Calculator Error

- Beam size calculated by structural engineer using hand calculator
- Beams and fab details ordered on Day 2
- They did check calculations and found shear not adequate
- Added web plate for shear strength before many fabricated
- Lesson Learned: use MathCAD for calculations or at least write them down

Micropiles Work Sequence

1. Core drill existing concrete mat

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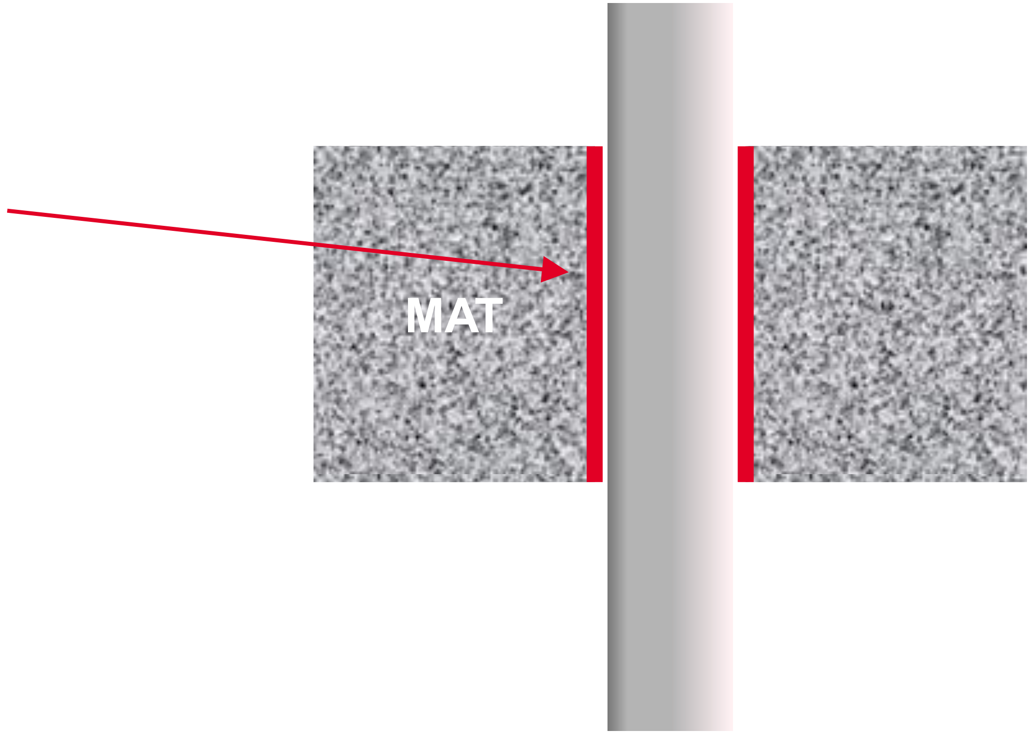

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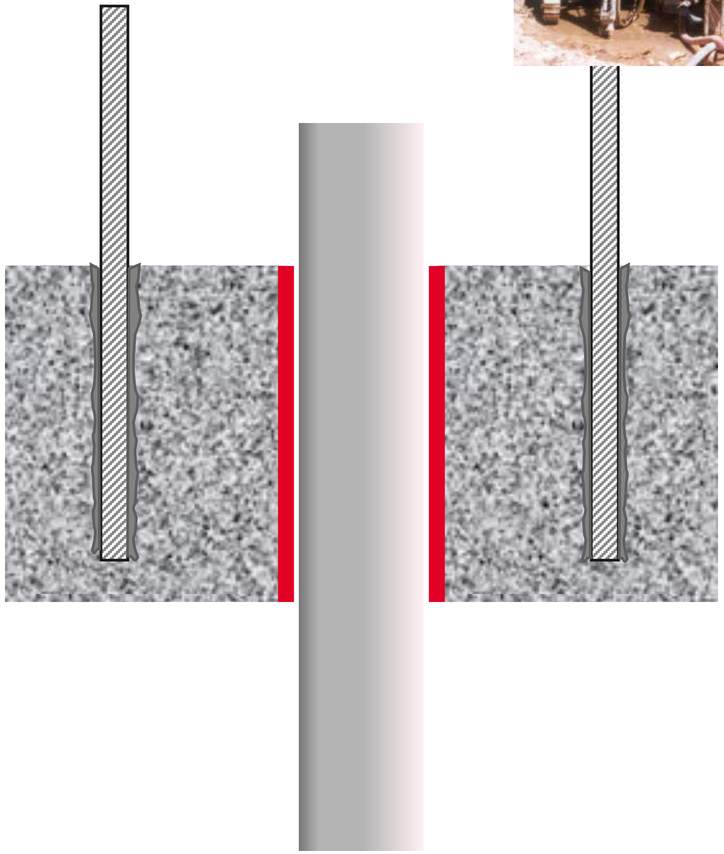

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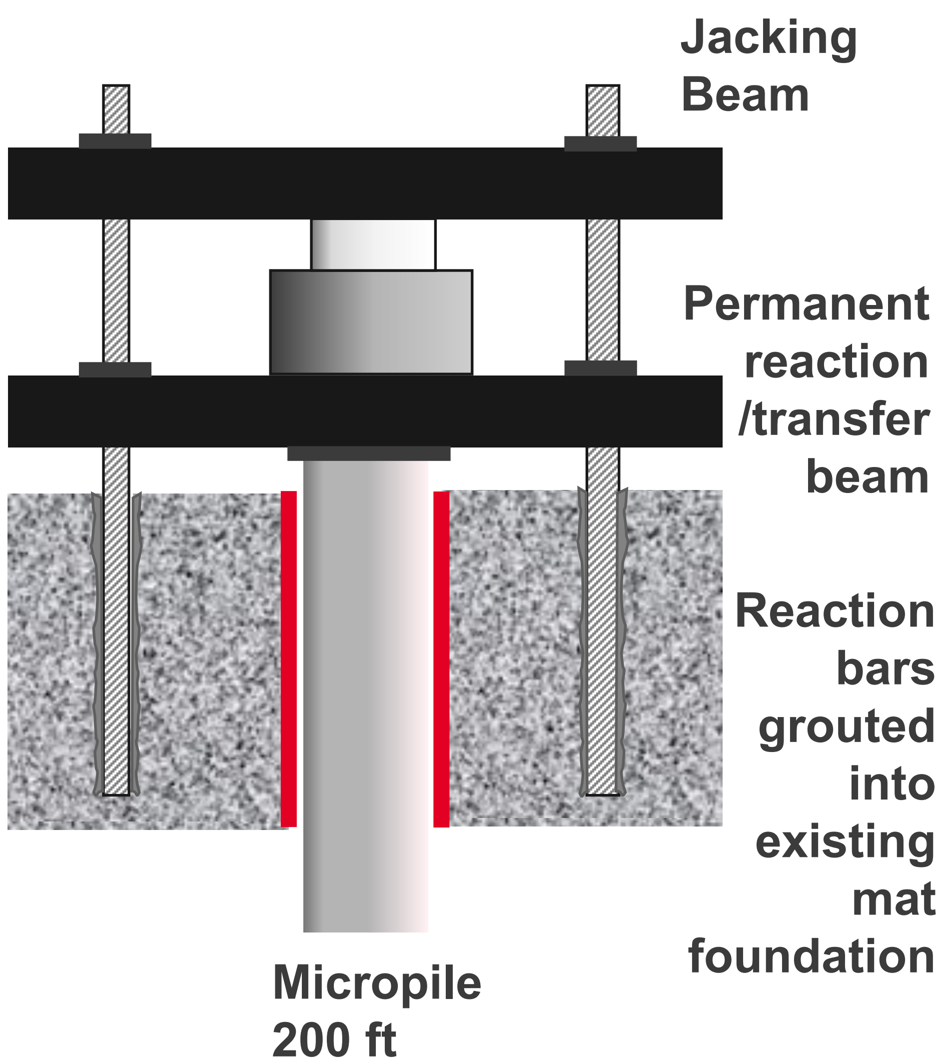

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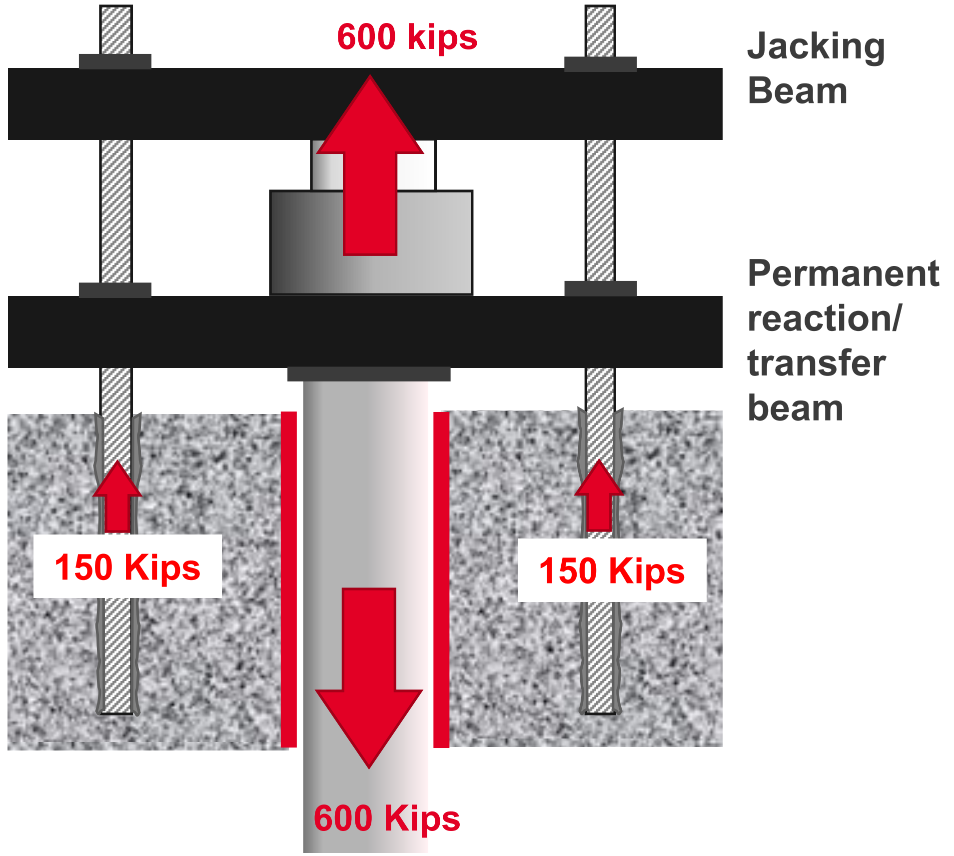

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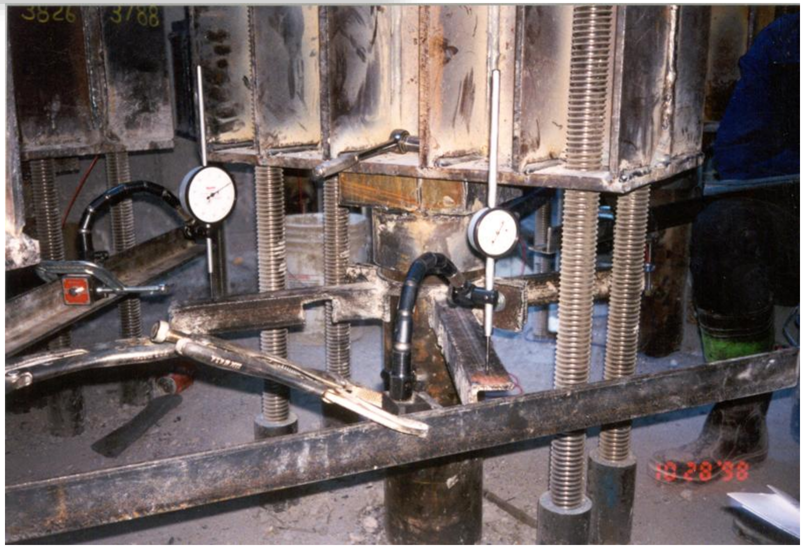

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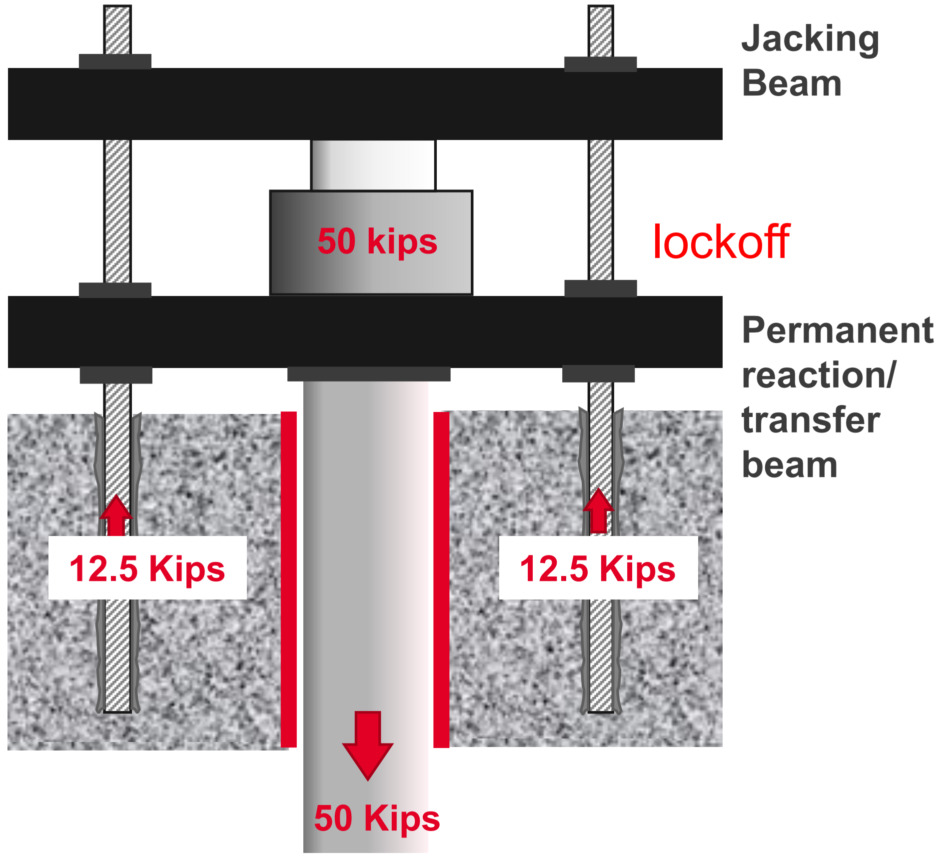
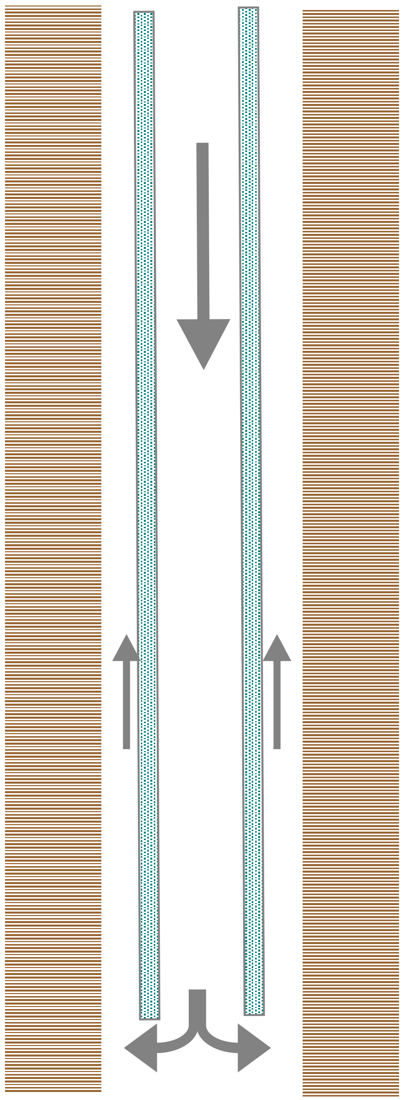
7. Lock-off at 50 Kips



Installation Method



- External Flush with a lost bit (time)
- Tremie grout casing
- Pressure grout through drill head until grout return on outside of casing

Lost Rerun Oil Field Bits

Installation Method Test Pile

Piles were pressure grouted until grout returned to the surface around the outside of the piles.

First Production Pile – 75mm (3 inch) deflection at test load

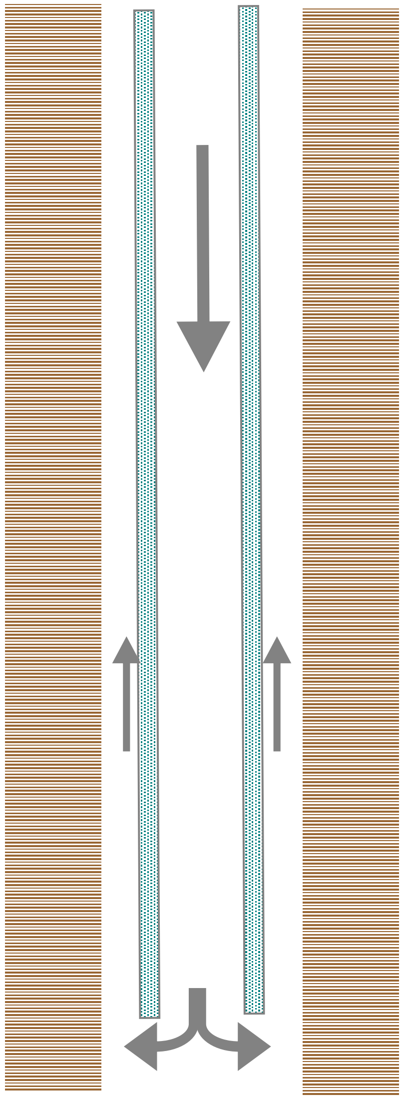
Grout Temp Issues

- Las Vegas in hot in July
- Initial mixes were hot and very thick
- Move grout mixing and cement storage to shade
- Tried several Master Builders (now BASF) admixtures including hydration control and superplasticizer
- Chose naphthalene sulfonate Rheobuild1000 and got a dosing pump from supplier

Driller called on radio – “I think I hit artesian”

Not a real job photo. Source: daleswater.co.uk

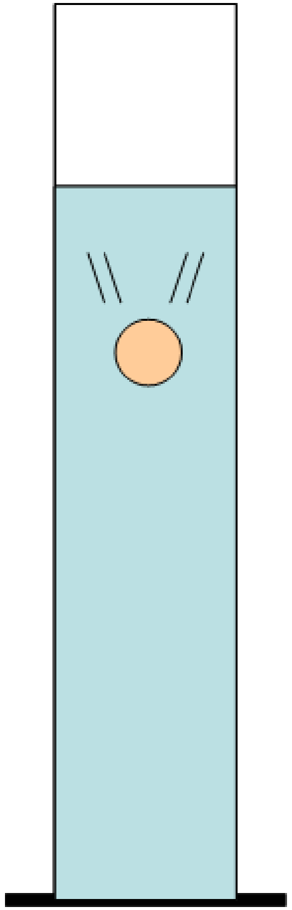
Installation Method – when driller said “artesian”



- External Flush with a lost bit (time)
- **Polymer additives ensured spoils were lifted from drill hole**
- Tremie grout casing
- Pressure grout through drill head until grout return on outside of casing

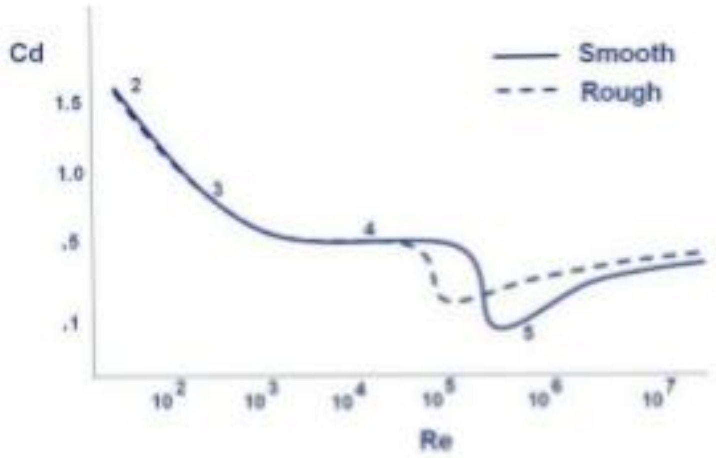
Removing Drill Cuttings

- Drill fluid carries the spoil out of the hole
- What fluid velocity is enough?
- What does it depend on?



Removing Drill Cuttings – what does it depend on?
Per NASA

Drag of a Sphere



The aerodynamic drag on an object depends on several factors, including the shape, size, inclination, and flow conditions. All of these factors are related to the value of the drag through the drag equation.

$$D = \frac{1}{2} C_d \rho V^2 A$$

Where D is equal to the drag, ρ is the air density, V is the velocity, A is a reference area, and C_d is the drag coefficient.

Drag Coefficient

The drag coefficient is a dimensionless number that characterizes all of the complex factors that affect drag. The drag coefficient is usually determined experimentally using a model in a wind tunnel. In the tunnel, the velocity, density, and size of the model are known. Measuring the drag then determines the value of the drag coefficient as given by the above equation. The drag coefficient and the drag equation can then be used to determine the drag on a similar shaped object at different flow conditions as long as several flow similarity parameters are matched. In particular, Mach number similarity insures that the compressibility effects are correctly modeled, and Reynolds number similarity insures that the viscous effects are correctly modeled. The Reynolds number is the ratio of the inertia forces to the viscous forces and is given by:

$$Re = \frac{1}{\eta} V \rho$$

where l is a reference length, and η is the viscosity coefficient. For most aerodynamic objects, the drag coefficient has a nearly constant value across a large range of Reynolds numbers.

But for a simple sphere, the value of the drag coefficient varies widely with Reynolds number as shown on the figure at the top of this page. To understand these variations, we are going to look in some detail at the flow past a cylinder. The two dimensional flow past a cylinder is very similar to the three dimensional flow past a sphere, but is a little easier to compute and understand because of the reduced dimensionality. Flow past a cylinder and a sphere goes through a number of transitions with velocity as shown in this figure:

UHV Calculations

REQUIRED FLOW RATES

JOB:	Mandalay					
BY:	TDR	DATE :	8/26/2025			
ANNULUS DIMENSIONS	OD =	8.535	in =	216.8	mm	Hole Diameter or Casing ID
	ID =	7	in	177.8	mm	Rod Diameter
FLOW AREA	A =	18.73	in^2 =	12083.06	mm^2 =	0.130 ft^2

FLUID	REQUIRED VELOCITY			REQUIRED FLOW				
	ft/sec	m/sec	ft/min	CFM	liter/min	gal/min		
Air	60	18.3	3600	468	1772	3503		Star calcuator says 4000 fpm
Foam	15	4.6	900	117	443	876		
Water	2.5	0.8	150	20	74	**146**		Star calculator says 150 fpm
Polymers	1.5	0.5	90	12	44	**88**	**60%**	
Cement Bentonite *	1	0.3	60	8	30	58		

* conservative for grout with w/c=0.44

A Testimony To Uphole Velocity

Written by TDR 12/7/2012

SUPER: Tom I need your help to get done with …….. We can not clean the bottom of this redrilled grout hole. The core driller drilled with roller bit and tried to flush for 2 days. Now we have tried with a tremie for days. Can we grout though the cuttings?

TDR: I will work on Engineer, send me a photo of your cuttings.

What is your water flow?

SUPER: 100 psi when dead end

TDR: Not pressure - flow rate? What pump do you have?

SUPER: Guys hook up that flow meter. Mission pump.

TDR: Tremie pipe size? Hole size?

SUPER: 1 inch tremie and hole is 4.25 inch and 6 inch at top. Hey we are pumping 48 GPM.

Hey we are pumping 48 GPM.

The Wonders of Uphole Velocity

TDR: Lets give flushing another try with more flow. Get a proper Nicholson Moyno and larger tremie pipe from Cuddy. Get some polymer too. I will work on the Engineer too.

SUPER: OK I think their field rep will want one more try, but then go for grout through cuttings.

SIDE NOTE:

TDR runs standard Nicholson uphole velocity spreadsheet and gets 97 GPM for 4.25" and 207 GPM for 6" using water. Sends to field engineer and PM.

TDR thought Nicholson Moyno pump ~150 GPM or so from measuring one time.

A DAY OR TWO LATER

EMAIL FROM SUPER IN AM

Subject: The wonders of up hole velocity!

EMAIL FROM SUPER IN AM

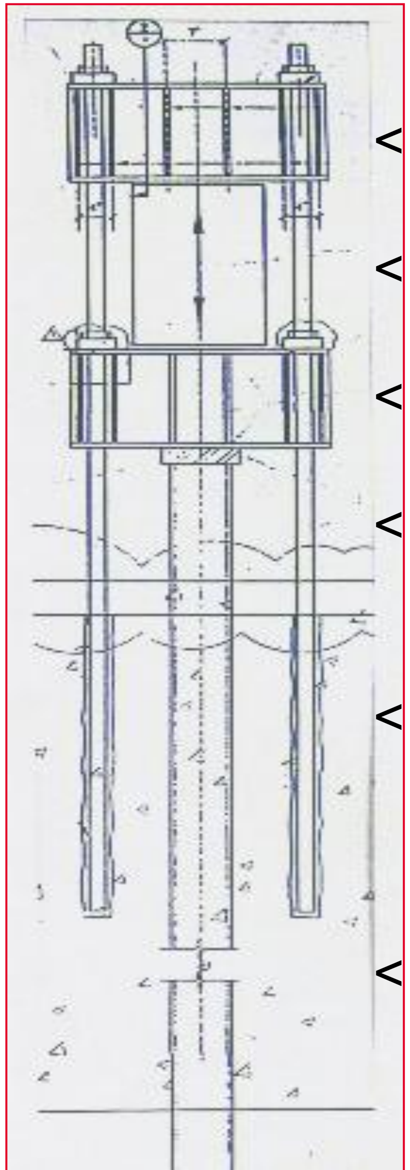
Subject: The wonders of up hole velocity!

Cutting Size Using Polymer

EMAIL FROM SUPER IN PM

Subject: Cutting size using polymer

Reaction Frame



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Thread Issues during Testing

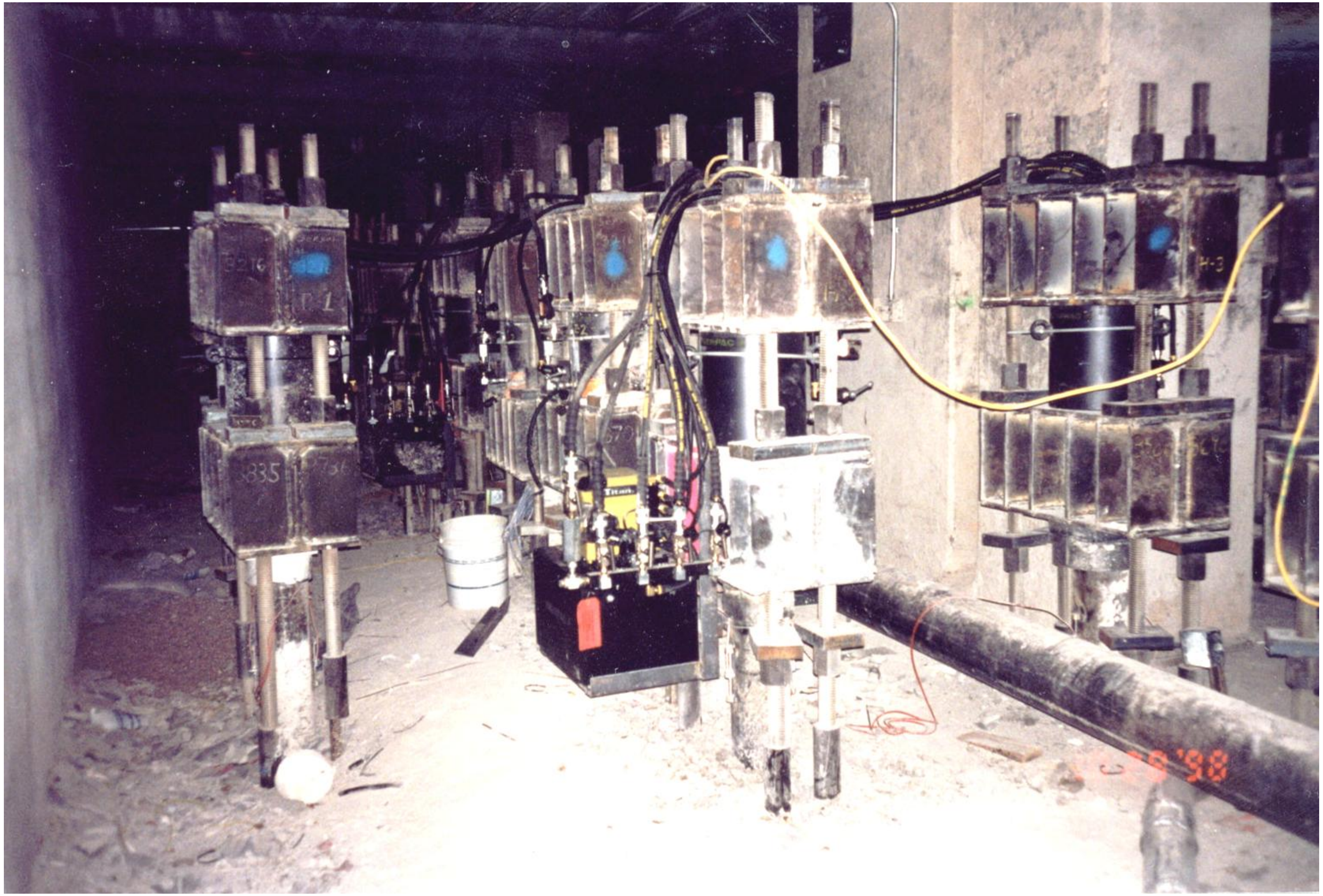
- Used 50mm long pin x blank tops rather than cutting off threads and grinding
- A few early piles with this detail had the thread pop on one side
- Cause was threads not shouldered due to grout laitance and general debris (air track drilling reaction bars)
- Solution was flushing grout vigilance and wrench to tighten

Epoxy Dowel Glue Issues

- After initial orders, every epoxy salesman visited us
- Bar pullout was too frequent (say 1 in 10) during tests even when drilled to bottom mat at 2.7m
- Large bar size of 1.75inch with 50mm/2.0 inch max dimater for dowel epoxy
- Airtrack bit options made larger annulus on order of 10mm
- Epoxies work best as thin layer
- Wet environment with external flush drilling & epoxies do not like wet holes
- Switched to typical bagged nonshrink grout and no more failures

Jack Decision and Jacking forst 60 piles next to the central elevator shafts

Five Jacks attached to Each Hydraulic Pump

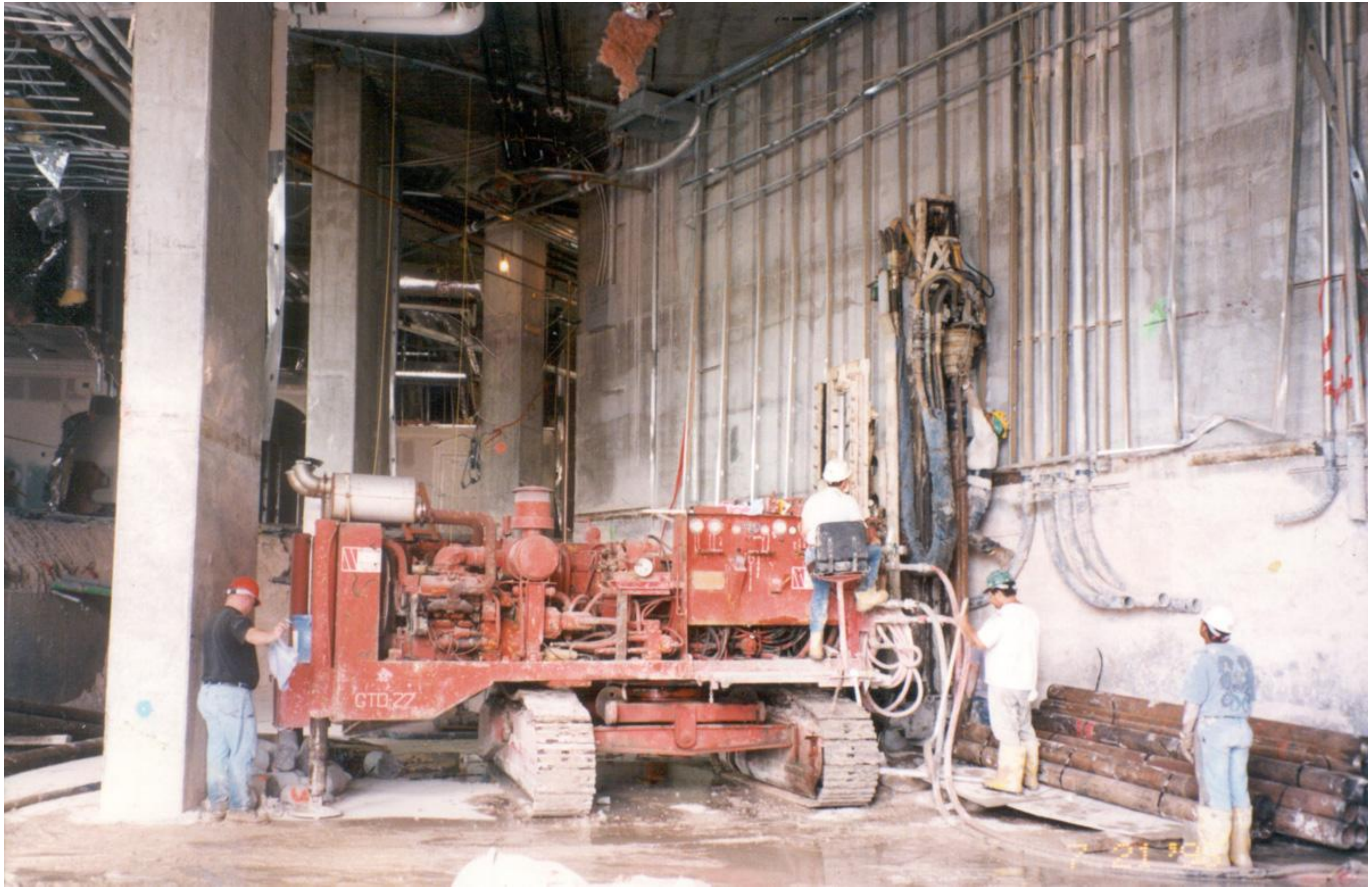


Sea of Piles and Jacks

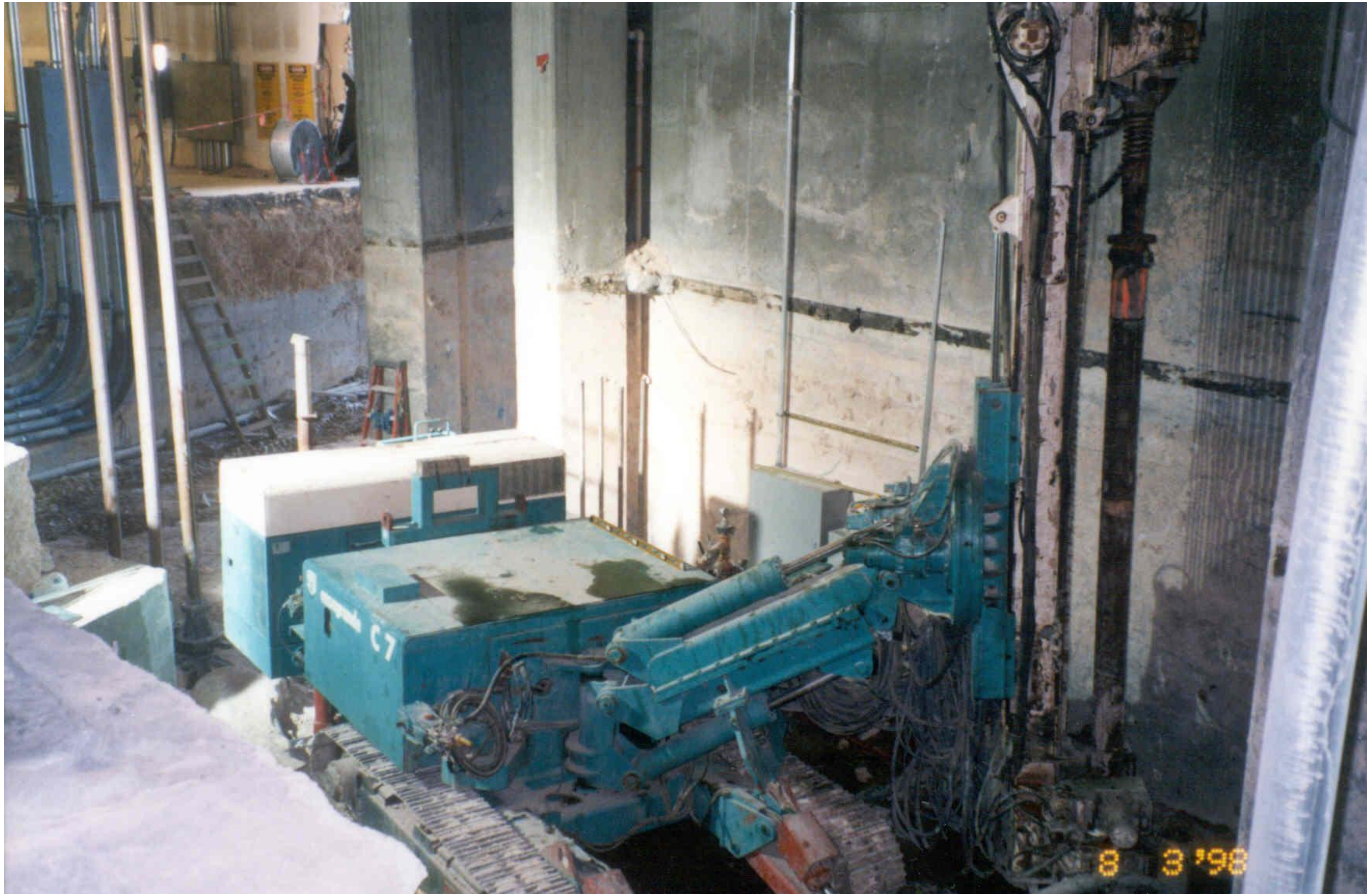
Key Challenges

- Grout Return
- Rapid Mobilization
- Extreme Heat – Affected Grouting and Labor Resources
- Limited Access and Space
- Material Supply Shortages

Low Headroom Drilling (~5.8m = 19')



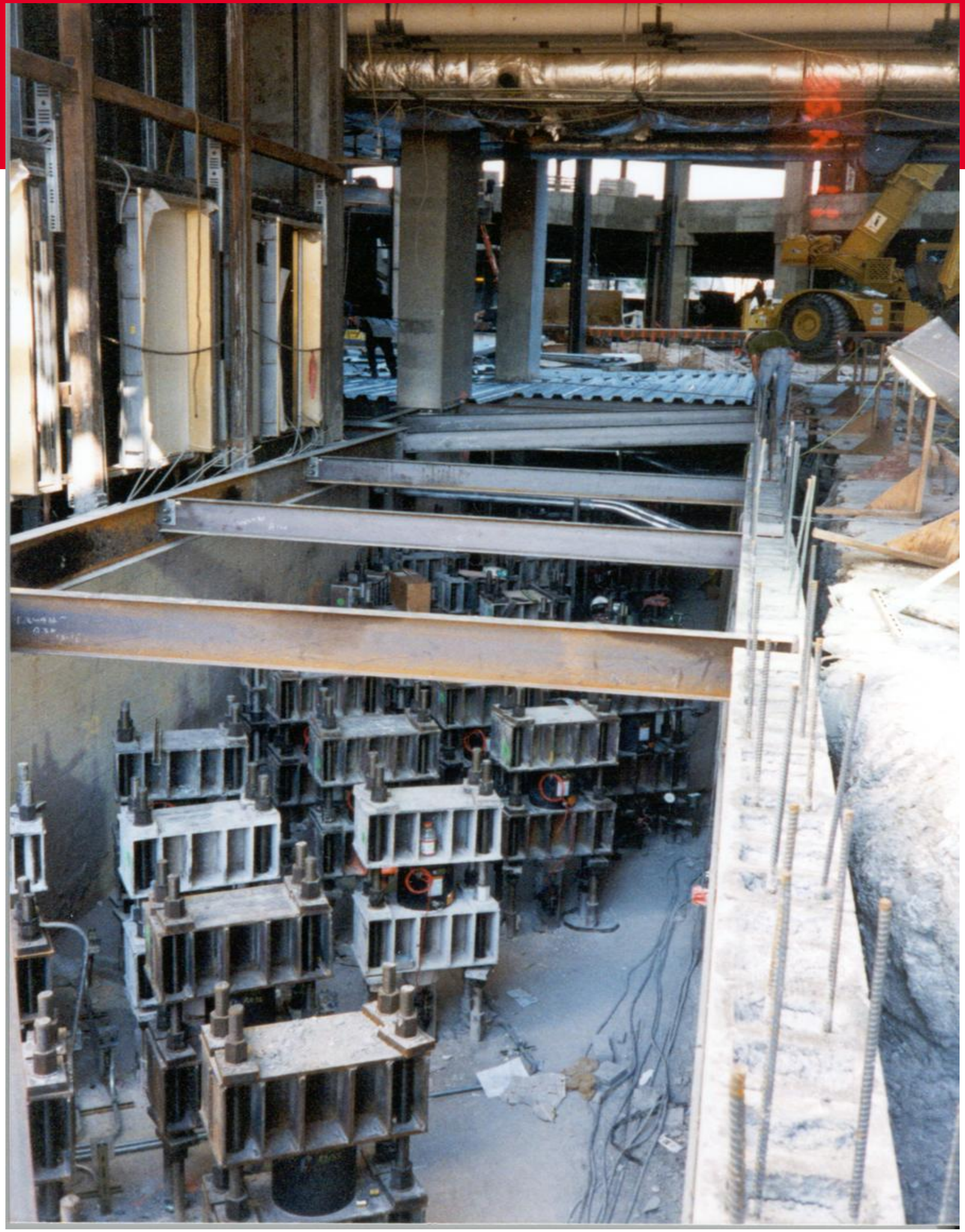
Tight Access



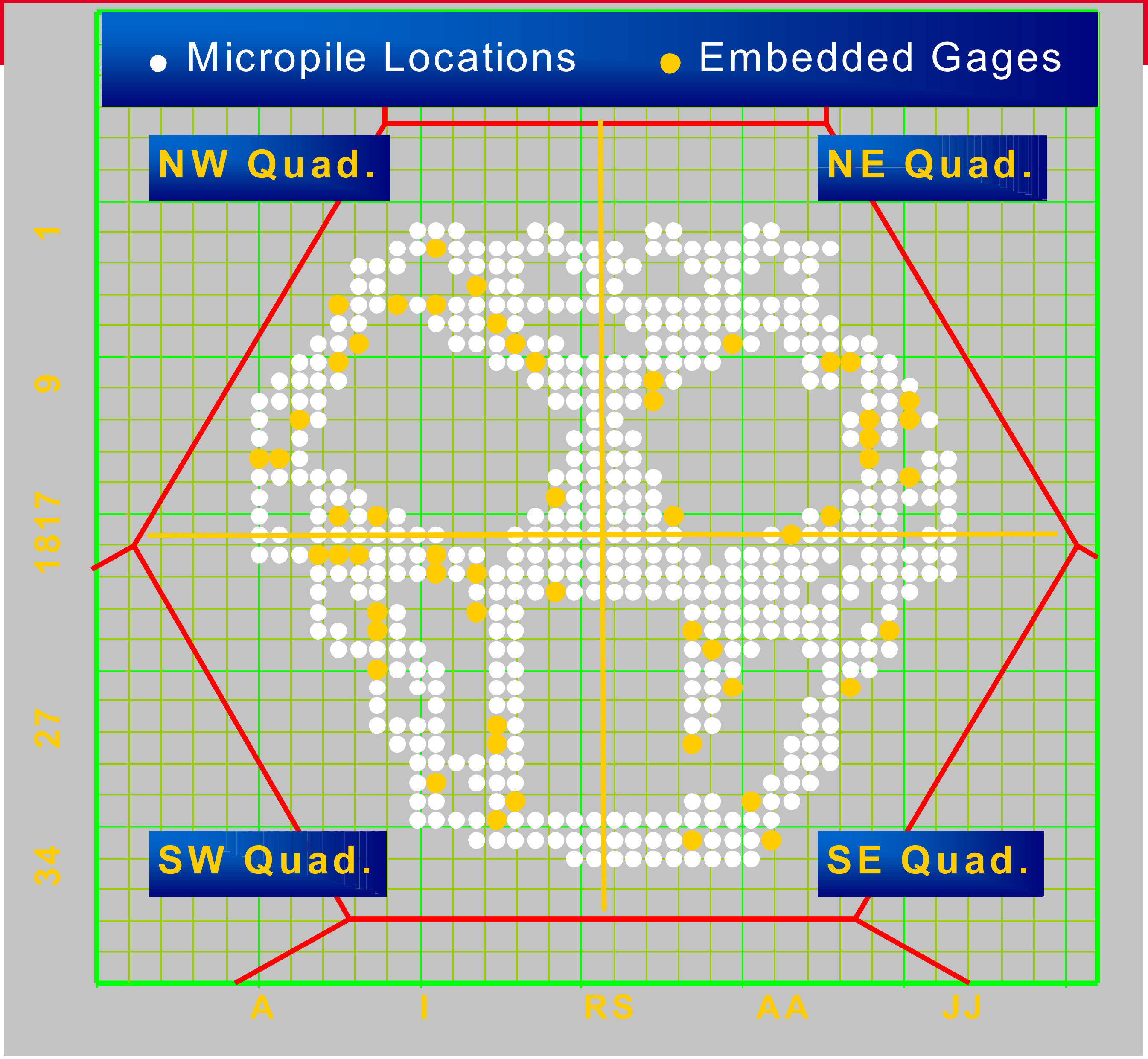
Materials

- Shortages due to accelerated schedule
- 85 truckloads of casing
- 536 drill bits
- 15 truckloads of bar
- 4,300+ hex nuts
- 2,000 Tons of cement by the 94 lb (42 kg) bag
- 536 – 350 Ton Jacks
- 118 Pumps
- ALL IN 3 MONTHS!

Installing the new steel framed deck used to form a new basement above the piles.



Micropile Instrumentation



Strain Gages Installed at Top of Each Pile and Connected to Central Data Collector

Observations

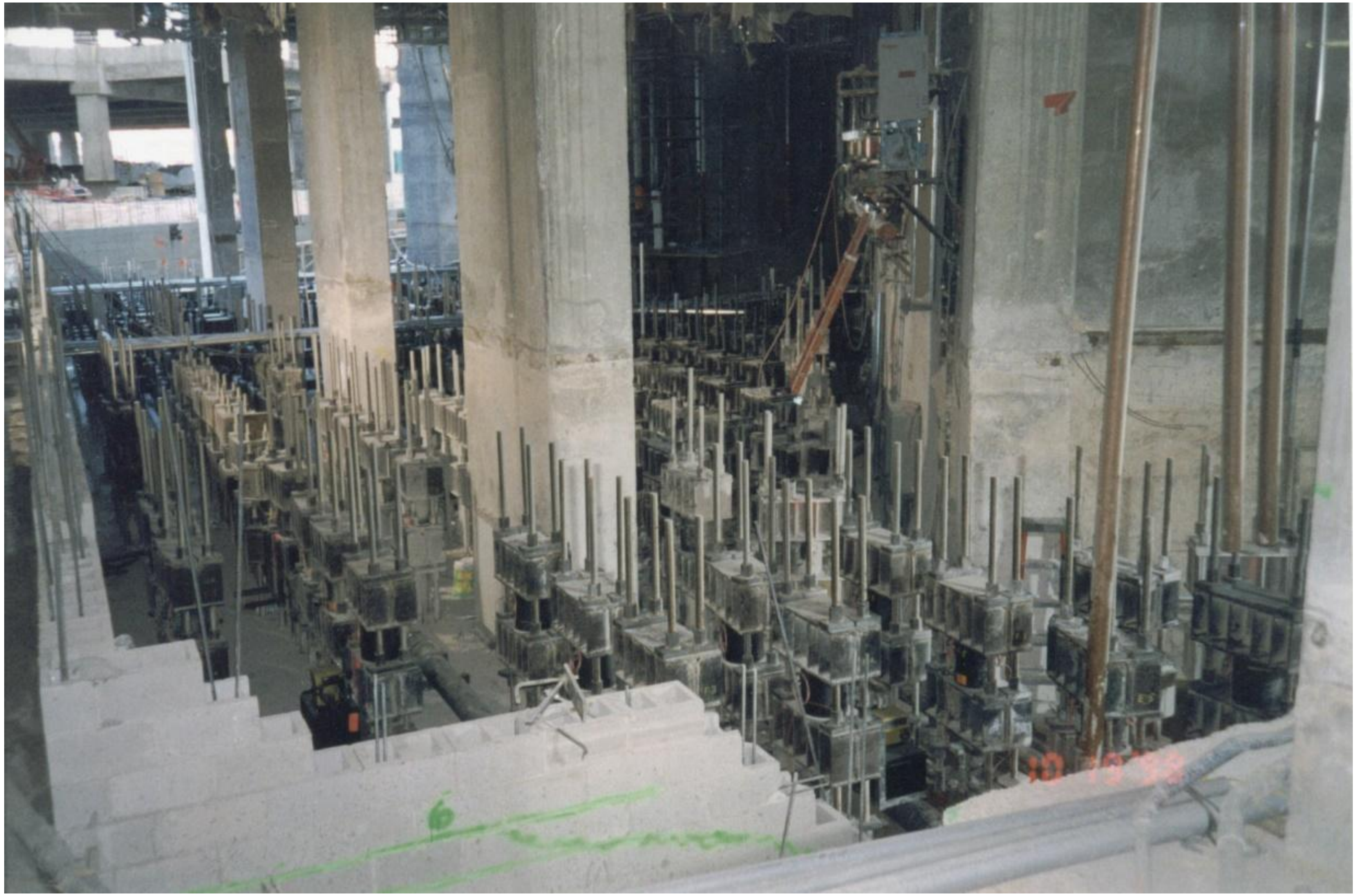
- Movement slowed as piles were installed even though piles were not tied to the mat
- Down-the-hole strain gages indicated piles loaded from soil.
- Mat loading soil, soil loading piles and piles transferred load deeper.

Results

- At completion, only demonstration jacking was performed.
- Nominal 220 kN (50 kips) load applied to all piles
- Rate of vertical movement of core greatly reduced
- Movement of wings continued; however, results in a reduction of differential settlement.
- In ~3 years after completion, piles picked up another 220kN to 330 kN (50 to 75 kips) as continued displacement occurred

Results

- Hector Mine Earthquake October 16, 1999
- Epicenter ≈ 190 km (120 miles) from structure – good performance



Summary - Mandalay Bay Casino

- Hotel Tower topped off - March 14 1998
- Removed fill over core mat - July 1 to July 8
- First micropile installed - July 16, 1998
- First micropile test - July 21, 1998
- First 60 piles (20 at each core) loaded to 1335 kN (300 kips) as jacking demonstration - September 3, 1998
- Completed installation of all 536 micropiles - October 9, 1998
- Completed testing and lock off of all micropiles to 220 kN (50 kips) - November 12, 1998

Casino Opened on Time --- $$$$

The Key to Success

- Emergency Response
- Teamwork Between Owner, Engineers and Contractor
- Allowing Field Verification of Drilling Technique Applicability
- Adapting to grout issues and “artesian”/grout return issues

Questions

Thank You

NICHOLSON