



## **Limiting the Fallout: A Proactive Response to a CoMET Snafu**

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**Is it just me?**

# MAJOR POINTS

- Project
- Problem
- Investigation
  - 5 Stages
- Resolution
- Lessons Learned (Relearned)

# The Project

- \$600 million
- 7 Story structural steel building
- Partial basement
- Steel columns, metal decks, concrete floor slabs
- Total Plan Area – 738,000 s.f.
- Accelerated schedule/penalties
- Client: General Contractor

- Non shrink (expansive) grout
- Bagged product
- Mixed on site
- Hand placed beneath column base plates
- Submittal Information
  - 8000 psi minimum at 28 days
  - 2x2x2 inch cubes
  - ASTM C109 Modified; C1107









# Problem

- 11 sets of 4 cubes
- Represented 85 columns
- Only 1 set met specified strength



# Table 1

## Summary of Test Data for Base Plate Grout

Sample No.	Date Cast	Report No.	Base Plate	Average 28-day Strength Cube Compressive Strength, psi	Proposed Test Locations	Current Edge Condition
1	10/29/09	90091071.0827	U-2,J.9-2,N-5.7,N-6, R-6,S-5 (Total:6)	4220	J.9-2,N-5.7,R-6	Condition 1 (with Overbuild)
2	10/30/09	90091071.0831	U-3,W-2,W-3,X-2, X-3,BB-2,BB-3, GG-3,GG-4,GG.1-2 (Total:10)	4310 (Set 1)	W-3,BB-3,GG-4	Condition 1 (with Overbuild)
3	10/30/09	90091071.0831	HH-2,HH-3,HH-4,HH-5 (Total:4)	3840 (Set 2)	HH-2,HH-4,HH-5	Condition 1 (with Overbuild)
4	10/31/09	90091071.0833	F-2,F-3,F-4,U-4,W-4, K-4,P-2, S-2,S-3,S-4 (Total:10)	2990	U-4,W-4,S-2	Condition 1 (with Overbuild)
5	11/1/09	90091071.0840	W-5.7,W-6,X-4, BB-4,BB-5,K-3, K-5,P-3,P-4,P-5 (Total:10)	7200	BB-4,K-3,P-4	Condition 1 (with Overbuild)
6	11/3/09	90091071.0864	R-5.7,J-6 (Total:2)	6440	R-5.7,J-6	Condition 1 (with Overbuild)
7	11/10/09	90091071.0920	GG-5,BB-5,GG. 5-5,GG.5-5.7, DD-6,BB.5-6,Z-6,AA-5.7 (Total:8)	7450	GG-5,BB.5-6,Z-6	Condition 1 (with Overbuild)

# Table 1

## Summary of Test Data for Base Plate Grout (continued)

Sample No.	Date Cast	Report No.	Base Plate	Average 28-day Strength Cube Compressive Strength, psi	Proposed Test Locations	Current Edge Condition
8	11/11/09	90091071.0932	E-7,N-7,J-7,R-7,U-7, E-8, J-8,N-8,R-8,U-8 (Total:10)	6500 (Set 1)	N-7,J-7,R-8	Condition 2 (w/o Overbuild)
9	11/11/09	90091071.0932	E-9,J-9,N-9,R-9,U-9, E-10, J-10,N-10, R-10,U-10 (Total:10)	6560 (Set 2)	N-9,R-9,U-10	Condition 2 (w/o Overbuild)
10	11/11/09	90091071.0932	E-11,J-11,N-11,R-11, U-11 (Total:5)	8090 (Set 3)	--	Condition 2 (w/o Overbuild)
11	11/24/09	90091071.1052	KK-6,W-7,Z-7,DD-7, KK-7, W-8,Z-8, AA-8,EE-8,KK-8 (Total:10)	6280	W-7,Z-7,AA-8	Condition 2 (w/o Overbuild)

Total: 85

**Range: 2990-8090**

*Notes: All 2x2x2 inch cubes made with plastic molds.*

# Mistakes in Test Procedures

Cube mold material	Plastic/metal
Restraint	No cover plate
Lab	Uneven faces of cubes

**Results Questioned!!**

# INVESTIGATION (Attack Mode)

## STAGE 1

- Input from manufacturer
- Plastic molds removed from service
- Testing procedures clarified
- Quantify effects of mold material/top restraint
- Field trial – Strength potential



## STAGES 2, 3, 4, 5

- Determine in-place strength
- Plan of Action
- Good News/Bad News
- Field Sampling
- **Construction continued!!**

# Mold Type/Top Restraint

Avg. Cube Compressive Strength, psi

<u>Age, Days</u>	<u>Plastic Molds</u>	<u>Brass Molds</u>	<u>Difference</u>
1	3300	3800	500
3	4570	5540	970
7	5710	6670	960
28	7350	8370	1020

- NOTE: Mixed in lab according to producer's specifications/proportions.

# Table 2

## Summary of Test Data for Base Plate Grout

Sample No.	Date Cast	Report No.	Base Plate	28-day Strength Cube Compressive Strength, psi	28-day Strength Cube Compressive Strength + 1020, psi
1	10/29/09	90091071.0827	U-2,J.9-2,N-5.7,N-6,R-6,S-5 (Total:6)	4220	5240
2	10/30/09	90091071.0831	U-3,W-2,W-3,X-2,X-3, BB-2,BB-3, GG-3, GG-4,GG.1-2 (Total:10)	4310 (Set 1)	5330
3	10/30/09	90091071.0831	HH-2,HH-3,HH-4,HH-5 (Total:4)	3840 (Set 2)	4860
4	10/31/09	90091071.0833	F-2,F-3,F-4,U-4,W-4,K-4, P-2, S-2,S-3,S-4 (Total:10)	2990	4010
5	11/1/09	90091071.0840	W-5.7,W-6,X-4,BB-4, BB-5,K-3, K-5,P-3,P-4,P-5 (Total:10)	7200	8220
6	11/3/09	90091071.0864	R-5.7,J-6 (Total:2)	6440	7460

# Table 2

## Summary of Test Data for Base Plate Grout (continued)

Sample No.	Date Cast	Report No.	Base Plate	28-day Strength Cube Compressive Strength, psi	28-day Strength Cube Compressive Strength + 1020, psi
7	11/10/09	90091071.0920	GG.5-5.7, DD-6,BB.5-6, Z-6,AA-5.7 (Total:8)	7450	8470
8	11/11/09	90091071.0932	E-7,N-7,J-7,R-7,U-7,E-8, J-8,N-8,R-8,U-8 (Total:10)	6500 (Set 1)	7520
9	11/11/09	90091071.0932	E-9,J-9,N-9,R-9,U-9,E-10, J-10,N-10,R-10,U-10 (Total:10)	6560 (Set 2)	7580
10	11/11/09	90091071.0932	E-11,J-11,N-11,R-11,U-11 (Total:5)	8090 (Set 3)	9110
11	11/24/09	90091071.1052	KK-6,W-7,Z-7,DD-7,KK-7, W-8,Z-8,AA-8,EE-8,KK-8 (Total:10)	6280	7300

Total: 85

Range 2990-8090

**Range: 4010-9110**

*Notes: All 2x2x2 inch cubes made with plastic molds.*



# Field Trial

Average Unconfined  
Compressive Strength, psi

<u>Age, Days</u>	<u>OR</u>	<u>Lab X</u>	<u>Terracon</u>
1	---	---	1810
3	---	5450	5160
7	---	---	7230
28	9170	8790	9610

*2x2x2 inch cubes; brass molds*

Cause: Testing Procedures

# In-Place Strength

- 2 inch thick layer of grout beneath steel base plate
- 12 to 16 inch base plates
- Industry standards
- Owner's Representative /Engineer of Record (EOR)

# Preparing a Plan of Action

- Experts
- Technical documents
- Peers/ Colleagues/GBA Network
- No straight forward “tried and true” method

- Rebound Hammer – Space and orientation constraints; Not definitive
- Windsor Probe Pin – Only good up to 5300 psi; Not definitive
- Windsor Probe – Destructive; space and orientation constraints; Not definitive



# Construction Continued!!

# PLAN OF ACTION

- Condition 1 – With Grout Overbuild
- Condition 2 – No Grout Overbuild

# CONDITION 1



# Condition 1 – With Grout Overbuild

- Remove portion of the triangular shaped overbuild
  - Cut to form cubes/cores
  - Expected lower strength than beneath grout base plate
  - Overbuild would not be replaced
- 
- **Client: Granted permission to sample Condition 1 locations**





















# Table 1

## Summary of Test Data for Base Plate Grout

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1	10/29/09	90091071.0827	U-2,J.9-2,N-5.7,N-6, R-6,S-5 (Total:6)	4220	J.9-2,N-5.7,R-6	Condition 1 (with Overbuild)
2	10/30/09	90091071.0831	U-3,W-2,W-3,X-2, X-3,BB-2,BB-3, GG-3,GG-4,GG.1-2 (Total:10)	4310 (Set 1)	W-3,BB-3,GG-4	Condition 1 (with Overbuild)
3	10/30/09	90091071.0831	HH-2,HH-3,HH-4,HH-5 (Total:4)	3840 (Set 2)	HH-2,HH-4,HH-5	Condition 1 (with Overbuild)
4	10/31/09	90091071.0833	F-2,F-3,F-4,U-4,W-4, K-4,P-2, S-2,S-3,S-4 (Total:10)	2990	U-4,W-4,S-2	Condition 1 (with Overbuild)
5	11/1/09	90091071.0840	W-5.7,W-6,X-4, BB-4,BB-5,K-3, K-5,P-3,P-4,P-5 (Total:10)	7200	BB-4,K-3,P-4	Condition 1 (with Overbuild)
6	11/3/09	90091071.0864	R-5.7,J-6 (Total:2)	6440	R-5.7,J-6	Condition 1 (with Overbuild)
7	11/10/09	90091071.0920	GG-5,BB-5,GG. 5-5,GG.5-5.7, DD-6,BB.5-6,Z-6,AA-5.7 (Total:8)	7450	GG-5,BB.5-6,Z-6	Condition 1 (with Overbuild)

# Table 1

## Summary of Test Data for Base Plate Grout (continued)

Sample No.	Date Cast	Report No.	Base Plate	Average 28-day Strength Cube Compressive Strength, psi	Proposed Test Locations	Current Edge Condition
8	11/11/09	90091071.0932	E-7,N-7,J-7,R-7,U-7, E-8, J-8,N-8,R-8,U-8 (Total:10)	6500 (Set 1)	N-7,J-7,R-8	Condition 2 (w/o Overbuild)
9	11/11/09	90091071.0932	E-9,J-9,N-9,R-9,U-9, E-10, J-10,N-10, R-10,U-10 (Total:10)	6560 (Set 2)	N-9,R-9,U-10	Condition 2 (w/o Overbuild)
10	11/11/09	90091071.0932	E-11,J-11,N-11,R-11, U-11 (Total:5)	8090 (Set 3)	--	Condition 2 (w/o Overbuild)
11	11/24/09	90091071.1052	KK-6,W-7,Z-7,DD-7, KK-7, W-8,Z-8, AA-8,EE-8,KK-8 (Total:10)	6280	W-7,Z-7,AA-8	Condition 2 (w/o Overbuild)

Total: 85

**Range: 2990-8090**

*Notes: All 2x2x2 inch cubes made with plastic molds.*















# CONDITION 2



# Condition 2 – No Grout Overbuild

- Locate shim packs
- Core Grout – Method A, B, C
  - Method A
    - Center of base plate
    - Core base plate and grout
    - Patch hole with grout
    - Reflects confinement
    - Same Test Orientation with Respect to Confinement
    - Near neutral axis of base plate

- Method B

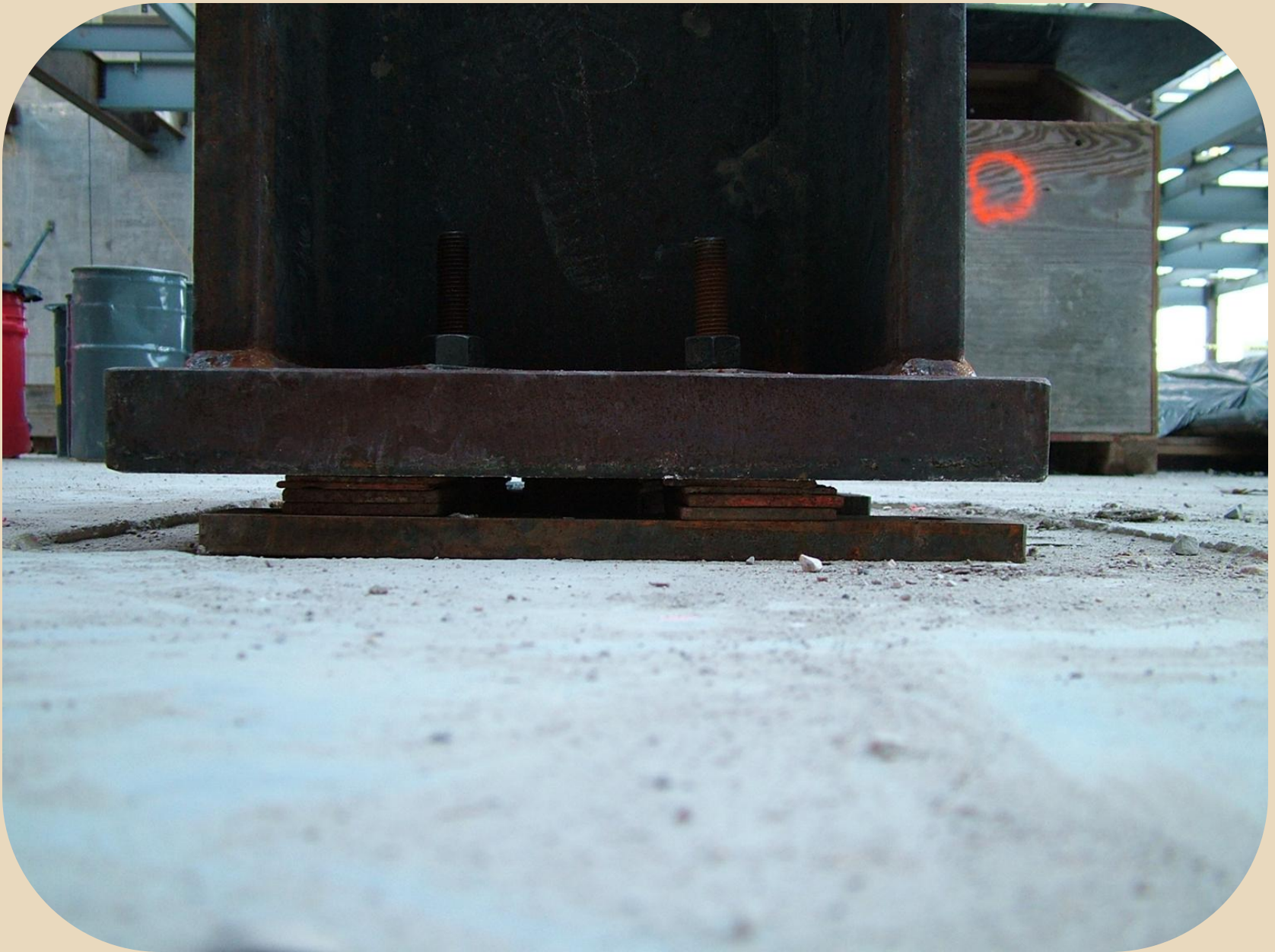
- Core grout horizontally
- 1/3 to 1/2 dimension of base plate
- Orientation differences – Lower strength than Method A

- Method C

- Drill, saw, chip grout from beneath base plate
- Prepare test specimen









# 3<sup>rd</sup> Party Oversight

- Independent
- USCOE Validated Laboratory
- Professional Engineer

# Preliminary Structural Analysis

- Remove/replace base plate grout
- Shoring
- Needs EOR approval

**CONSTRUCTION CONTINUED!!**









# Field Sampling

## Condition 1 Sampling

- Trimmed field samples to 1:1:1 Ratio
- Sealed in plastic bags 5 days
- Weigh, measure, cap, test
- 15 of 17 sets exceed 8000 psi
- Other 2 sets exceeded 85% of 8000 psi



**Table 3****Summary of Compressive Strength Test Results for Cubes Cut from Field Samples**

Sample No.	Column Line	Sample I.D.	Length (in.)	Width (in.)	Surface Area (sq. in.)	Maximum Load (lbs.)	Compressive Strength of Cube (psi)	Average Compressive Strength (psi)
1	J.9-2	A	1.000	0.972	0.972	7930	8160	8460
		B	0.991	0.971	0.962	8050	8370	
		C	0.974	1.000	0.974	8620	8850	
1	N-5.7	A	0.903	0.886	0.800	6930	8660	8330
		B	0.876	0.904	0.792	6220	7850	
		C	0.873	0.912	0.796	6750	8480	
1	R-6	A	0.976	1.010	0.986	6980	7080	9000
		B	0.966	1.020	0.985	10480	10640	
		C	0.978	1.010	0.988	9170	9280	
2	W-3	A	0.999	1.030	1.029	10650	10350	9100
		B	1.010	1.040	1.050	9370	8920	
		C	1.010	1.040	1.050	8420	8020	
2	BB-3	A	0.893	0.876	0.782	7350	9400	8550
		B	0.868	0.919	0.798	6320	7920	
		C	0.879	0.894	0.786	6540	8320	



Sample No.	Column Line	Sample I.D.	Length (in.)	Width (in.)	Surface Area (sq. in.)	Maximum Load (lbs.)	Compressive Strength of Cube (psi)	Average Compressive Strength (psi)
2	GG-4	A	0.999	0.989	0.988	6980	7070	7580
		B	0.975	0.995	0.970	8440	8700	
		C	0.997	1.000	0.997	6940	6960	
4	U-4	A	0.739	0.707	0.522	5360	10260	10240
		B	0.756	0.724	0.547	6330	11570	
		C	0.750	0.726	0.545	4840	8890	
4	W-4	A	0.890	0.911	0.811	7130	8790	8280
		B	0.874	0.915	0.800	6820	8530	
		C	0.885	0.921	0.815	6140	7530	
4	S-4	A	0.736	0.755	0.556	4900	8820	7880
		B	0.702	0.744	0.522	3910	7490	
		C	0.741	0.713	0.528	3880	7340	
5	BB-4	A	0.877	0.920	0.807	7450	9230	8160
		B	0.918	0.875	0.803	6590	8200	
		C	0.903	0.884	0.798	5620	7040	
5	K-3	A	0.985	1.000	0.985	8970	9110	8280
		B	0.985	1.000	0.985	7740	7860	
		C	0.981	1.010	0.991	7810	7880	

Sample No.	Column Line	Sample I.D.	Length (in.)	Width (in.)	Surface Area (sq. in.)	Maximum Load (lbs.)	Compressive Strength of Cube (psi)	Average Compressive Strength (psi)
5	P-4	A	1.020	1.080	1.102	8430	7650	8270
		B	1.070	1.030	1.102	9220	8370	
		C	1.030	1.070	1.102	9690	8790	
6	R-5.7	A	0.878	0.899	0.789	6460	8180	8200
		B	0.891	0.879	0.783	6430	8210	
		C	0.887	0.889	0.789	6480	8220	
6	J-6	A	0.761	0.715	0.544	5510	10130	10120
		B	0.733	0.711	0.521	5060	9710	
		C	0.717	0.735	0.527	5550	10530	
7	GG-5	A	0.713	0.753	0.537	4940	9200	10030
		B	0.714	0.717	0.512	5840	11410	
		C	0.727	0.719	0.523	4960	9490	
7	BB.5-6	A	0.759	0.728	0.553	4940	8940	10250
		B	0.753	0.720	0.542	6110	11270	
		C	0.742	0.720	0.534	5630	10540	
7	Z-6	A	0.840	0.902	0.758	6920	9130	9880
		B	0.880	0.870	0.766	8270	10800	
		C	0.878	0.888	0.780	7570	9710	

# Good News/Bad News!

- EOR / OR / Table 1

Samples 3, 5, 6, 7, 8, 9 and 10 are acceptable as the actual strength for each column will not be exceeded.

Samples 1, 2, and 4 do not meet strength requirements. The grout for the 26 associated columns shall be removed and replaced.

Provide documentation as to how the grout will be removed, replaced and the intended shoring methods for the columns and supporting structures above the columns.

- Client

“...Terracon may be responsible for any and all costs associated with remedial actions required at these locations.” **RISK!**

- Columns in Question

26 instead of 85

- Submitted test data from cubes cut from field samples

# Resolution!

## 2 weeks later

“...is satisfied that the strength under the base plates has been evaluated by an Engineer and the Engineer has **certified** the grout meets the required strength; therefore the grout under the columns will not have to be removed and replaced as stated in the letter...”

2 ½ month process

No delays or changes to construction schedule

# Lessons Learned/Relearned

- Read and review submittals carefully and in a timely manner.
- Read the fine print! Don't use plastic cube molds.
- Be careful what you ask for!
- Restraint critical for strength development of non-shrink grout
- Work through proper channels
- Independent 3<sup>rd</sup> Party verification
- Run towards your problems – **CONFRONT THE RISK!!**



**Construction continued without  
delay!!**

# Questions?