Project: 246 SPRING STREET Date: 7/7/09 Page: 1 of 2

Subject: ACTUAL LOAD ON BEAM FORM TIE Engr: ______ Checked By: ______ Date: ______

SPACING OF BEAM FORM TIE =

USING 1/8 ARCH SCALE

SPACING = 24 UNIT

JOIST WIDTH = 1.75 UNIT = 2.5" ±

$$\text{SPACING} = \frac{24}{1.75} \times 2.5'' = 34'' \pm$$

∴ IT IS CONCLUDED THAT TIE SPACING IS AT THE RANGE OF 2'-6" TO 3'-0".

• TYPICAL LOAD AT SNAPTIES.

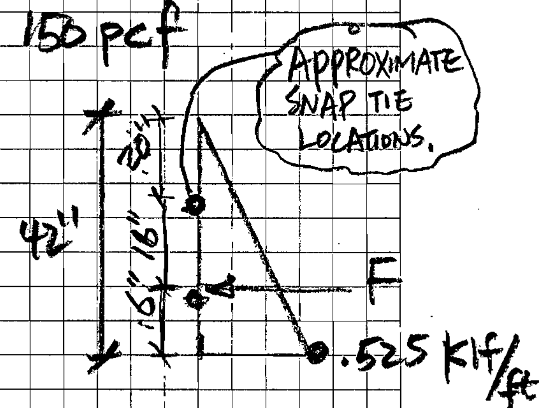
BEAM DEPTH = 42"

$$\text{LATERAL PRESSURE} = \frac{42''}{12} \times 150\text{ pcf}$$

2'-6" SPACING

$$F = .525 \times 2.5' \times \frac{42''}{2 \times 12}$$

= 2.3 kips



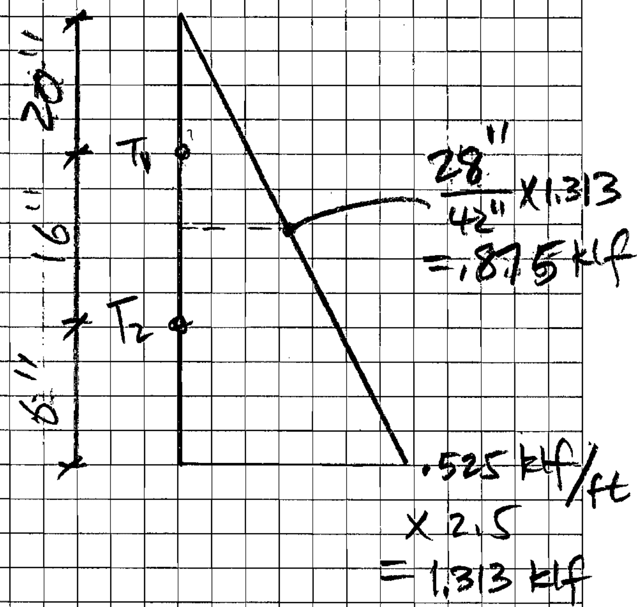
LOADS AT TIES : TYPICAL =

$T_1 = .875 \times \frac{28''}{12 \times 2}$

$= 1.02$ kips

$T_2 = (.875 + 1.313) \times \frac{14''}{2 \times 12}$

$= 1.28$ kips



∴ SNAPTIE STANDARD =

T_2 < SAFE WORKING LOAD = 2.25 kips

$T_2 < 2.25$ kips (OK)

∴ THE SNAPTIE FOR BEAM FORMWORK DESIGN IS ADEQUATE.

- LOAD AT TIES (WORST CASE SCENARIO) WHEN ONE TIE IS LOOSE AND RESULTED SPACING OF 5'-0".

$T_1 = 2 \times 1.02 = 2.04$ kips

$T_2 = 1.28 \times 2 = 2.56$ kips

SAFETY FACTOR IS 2.

$T_{ULTIMATE} = 2 \times 2.25 = 4.5 \text{ kip} > T_2$ (OK)

∴ TIES @ 5'-0" O.C IS ADEQUATE FOR ULTIMATE FAILURE CHECK.

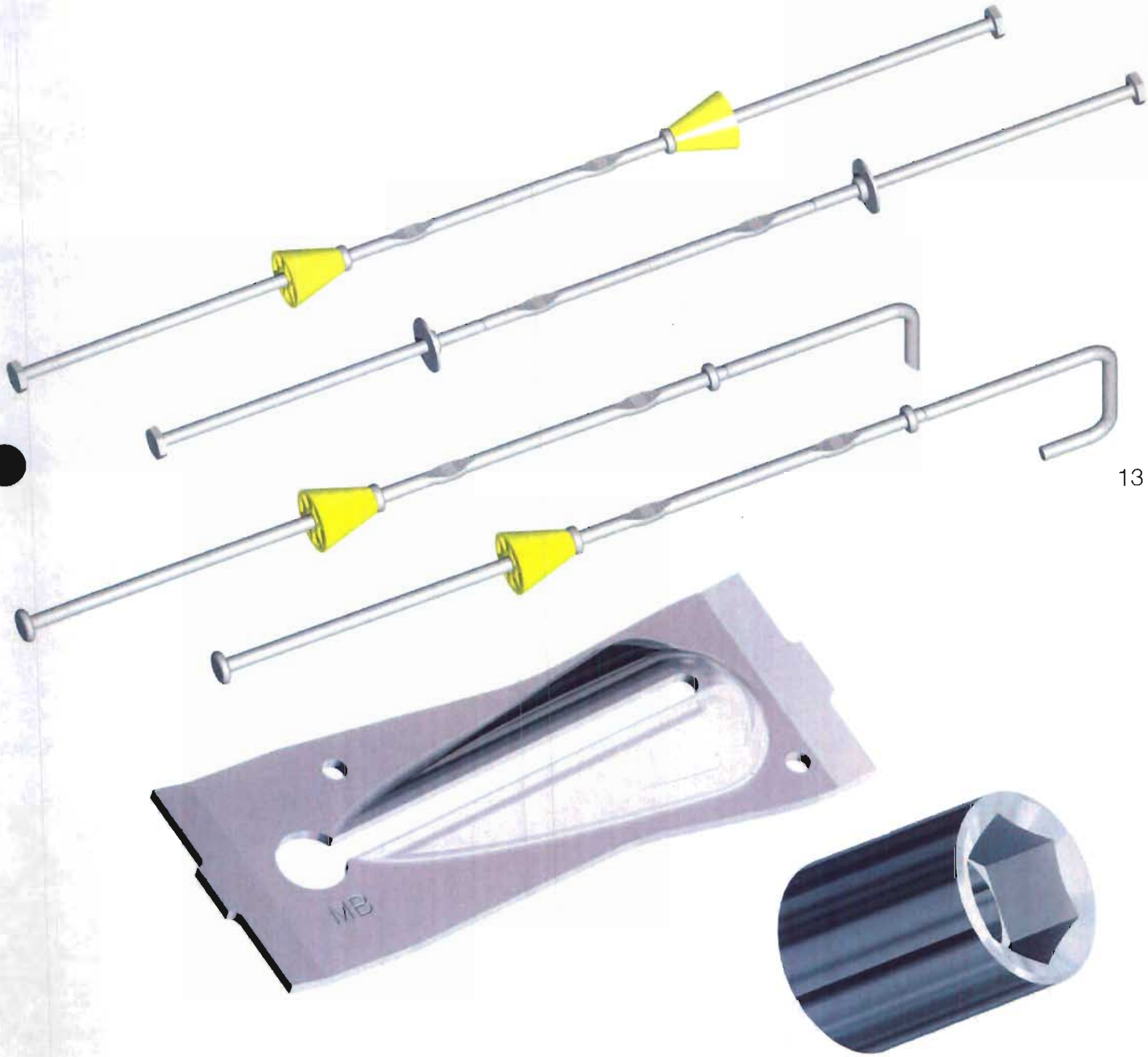

Feldman
LUMBER
Feldman
LUMBER


Feldman
LUMBER

MeadowBurke Concrete Forming Manual

Meadow Burke Snapties

13 – 18



13

Meadow Burke Snapties

(1001) ST-1 SNAPTIE - STANDARD

The ST-1 Standard Snaptie has round heads, anti-turn deformations and 1" breakback. A 1/2" breakback is available on special order. The Snaptie is available equipped with either plastic spreader cones or loose metal washers. For additional rust and corrosion resistance, the Standard Snaptie is available in stainless steel as an ST-8.

NOTE: The plastic cones, furnished from high impact polystyrene, are available in the sizes 1x1, 1x1-1/2 and 1x2. Cones are preferred over a loose washer tie since it covers the break back portion of the tie. Such guarantee of break back is not available with the loose washer tie. When removed the plastic cone also provides a better cavity for grouting purposes. Attempting to breakback any tie, before the concrete has been allowed to properly set, may result in the entire tie turning freely in the wall, making the normal breakback procedure no longer possible. Washer style snapties should be removed before 24 hours of concrete pour.

SAFE WORKING LOAD	
TYPE	SWL (lbs)
ST-1	2,250

Safe working load is based on an approximate 2:1safety factor.

To Order, Specify: quantity, type, L&W, wall thickness, plastic cone or metal washer and breakback.

(1003) ST-3 SNAPTIE - HEAVY

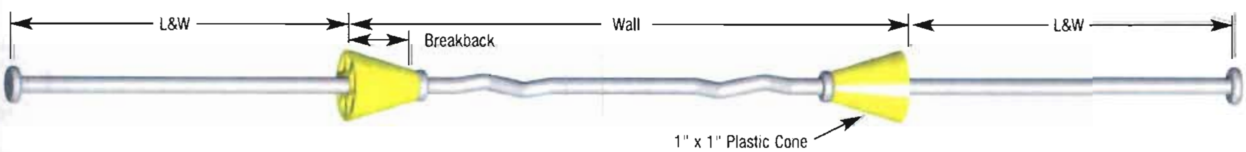
The ST-3 Heavy Snaptie incorporates all of the same design features of the standard snaptie but is fabricated from high carbon steel to produce a higher safe working load. It is available with plastic cones or loose metal washers.

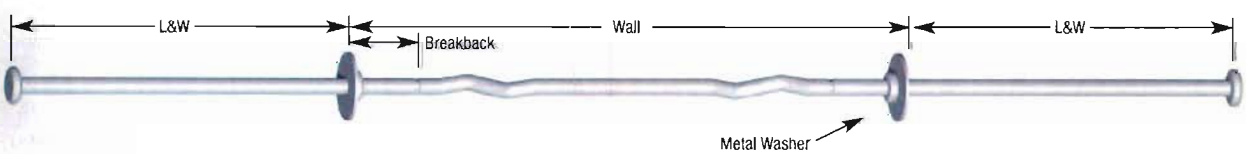
SAFE WORKING LOAD	
TYPE	SWL (lbs)
ST-3	3,250

Safe working load is based on an approximate 2:1safety factor.

To Order, Specify: quantity, type, L&W, wall thickness, plastic cone or metal washer and breakback.

(L&W = Lumber & Wedge)





13 – 18

SNAPTIE DON'TS

- Do not climb on Snapties in the form.
- Do not over-tighten the tie wedges. This can cause severe pre-loading and premature failure.
- Do not place concrete in just one area of the form and allow it to exceed the design pour rate.
- Do not attempt to move the concrete laterally in the form with a vibrator.
- Do not drop the wet concrete more than 30" when placing into the form. This will result in aggregate segregation and unnecessary dangerous impact loading.
- Do not install bent or damaged ties.
- Do not allow Snaptie ends to remain in the wall beyond 24 hours. Remove the breakback portion of the tie as soon as reasonably possible.
- Do not skip or omit any studs or wales. This will likely cause a premature form failure.
- Do not weld Snapties to any object.

SNAPTIE WATERSEAL

All Meadow Burke Snapties are available with a neoprene washer to aid in preventing moisture seepage along the tie wire. Specify this feature when ordering a snaptie product.

(1005) ST-4 SNAPTIE – HEX HEAD – 6 SIDED

The ST-4 Hex Head Snaptie, (previously known as Wrench Head) provides an effective way to breakback snapties before the formwork has been stripped. The head of the snaptie is grasped by the Hex Head Socket (on Page 18) and with a simple turning motion, breaks off the end of the snaptie. Removing the snaptie ends in this manner increases the ease and speed of the form stripping operation.

Hex Head Snapties are available with 1" x 1" plastic spreader cones and 1" breakback.

Metal washers available on special order only.

SAFE WORKING LOAD	
TYPE	SWL (lbs)
ST-4	2,250

Safe working load is based on an approximate 2:1safety factor.

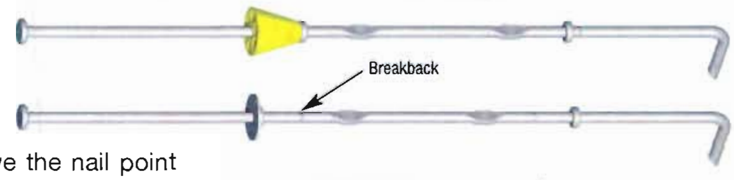
(1008) ST-5 SNAPTIE – THREADED ONE END

The ST-5 Threaded One End Snaptie is manufactured with 1/4"-20 threads x 2" length on one end and a standard hot forged head on the opposite end. This tie has a metal washer and is used when walls have a variable thickness. A small channel can be installed on either end and then used as a welding tie.

SAFE WORKING LOAD	
TYPE	SWL (lbs)
ST-5	250

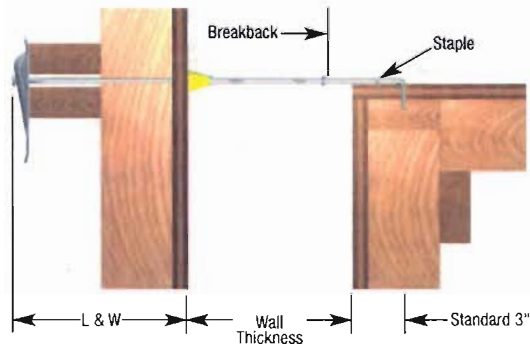
Safe working load is based on an approximate 2:1safety factor.

Meadow Burke Snapties



(1010) ST-6 SNAPTIE – NAIL POINT

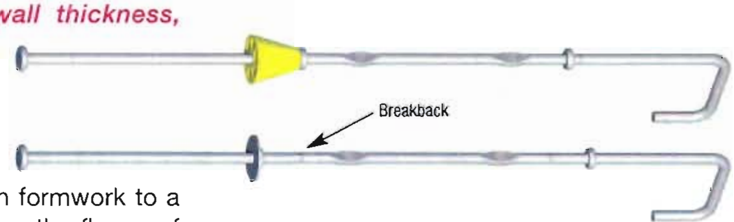
The ST-6 Nail Point Snaptie is designed to have the nail point driven into the formwork and secured with a fence staple. The tie is available with either a plastic spreader cone or a loose metal washer. The plastic cone snaptie is furnished with a standard 1" breakback and the loose metal washer application has a 1/2" breakback.



SAFE WORKING LOAD	
TYPE	SWL (lbs)
ST-6	250

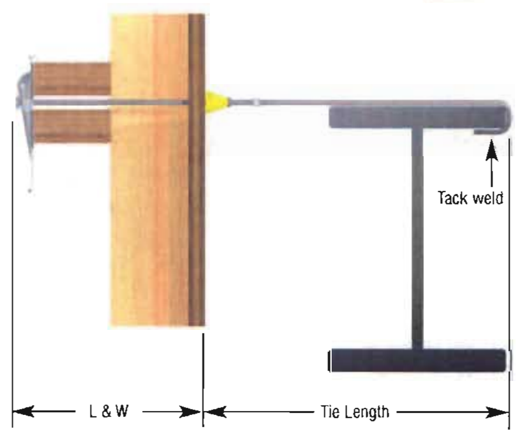
Safe working load is based on an approximate 2:1safety factor.

To Order, Specify: quantity, type, L&W, wall thickness, plastic cone or metal washer.



(1012) ST-7 SNAPTIE – HOOKED

The ST-7 Hooked Snaptie is designed to attach formwork to a structural beam. The hook end of the tie fits over the flange of the beam and should be tack-welded on the underside of the beam flange for added security. Hooked snapties are available with plastic cone or loose metal washer.



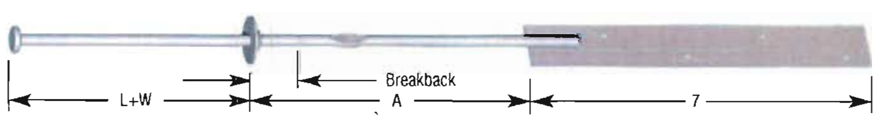
SAFE WORKING LOAD	
TYPE	SWL (lbs)
ST-16	250

Safe working load is based on an approximate 2:1safety factor.

To Order, Specify: quantity, type, plastic cone or metal washer, length, flange thickness and form thickness L&W.

(1014) ST-9 SNAPTIE – SPANDREL PLATE

The ST-9 Spandrel Plate snaptie is manufactured with a 16 gauge steel plate with four 1/8" nail holes for nailing direct to formwork. This tie used similarly as the ST-6 nail-point tie. Available with metal washers or plastic cones.



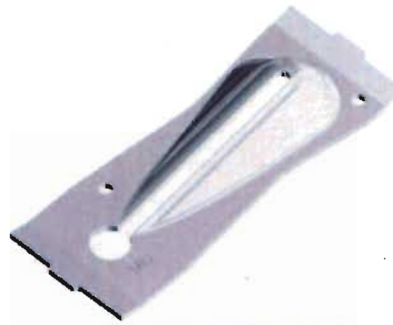
SAFE WORKING LOAD	
TYPE	SWL (lbs)
ST-9	250

Safe working load is based on an approximate 2:1safety factor.

To Order, Specify: quantity and type, L+W, and A.

13 – 18

(1020) ST-15 STEEL WEDGE

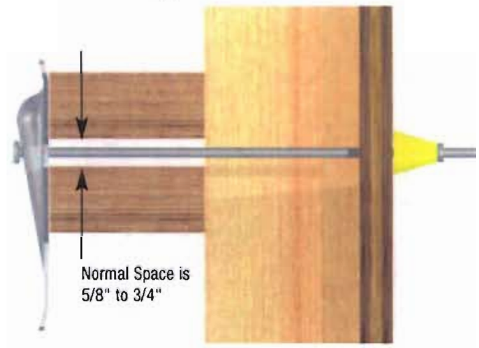


The ST-15 Steel Wedge accommodates either standard or heavy snapties and is designed with sufficient strength to distribute the form loads to the wales.

SAFE WORKING LOAD	
TYPE	**SWL (lbs)**
ST-15	3,250

Safe working load is based on an approximate 2:1 safety factor.

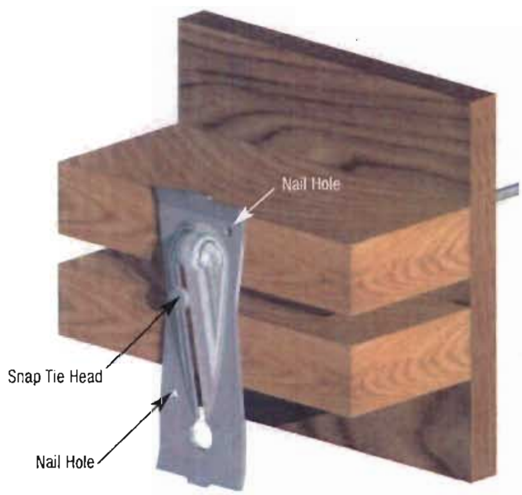
To Order, Specify: quantity and type.



Caution: The safe working load of the Steel Wedge can be affected by the position of the wedge on the tie end. Reference Steel Wedge Assembly Precautions below.

17

Steel Wedge Assembly Precautions:



Excessive spacing between the walers may cause the steel wedge to bend and result in the cone or washer on the snaptie to become embedded in the concrete. Breakback of the snaptie would be made difficult to accomplish.

Over-tightening the wedge may damage the head of the snaptie, the wedge slot and/or the plastic cone and result in a premature failure.

The Steel Wedge is designed to carry the load at the upper 2/3 of the wedge slot. Load applied too low on the wedge slot may cause the wedge to deform or break.

Nail holes are provided to allow the wedge to be firmly secured to the wales to prevent loosening during vibration.

(1030) ST-21 SNAPTIE WRENCH

The ST-21 Snaptie Wrench is used to quickly and easily breakback snapties. After the forming has been stripped the Snaptie Wrench captures the snaptie end. The tie is bent down to a position nearly parallel to the face of the concrete and a subsequent clockwise rotation of the wrench breaks the tie at the breakback point.

To Order, Specify: quantity and type.

(1015) ST-16 HEX HEAD SOCKET – 6-SIDED

The 3/8" drive ST-16 Hex Head Socket - 6 Sided fits securely over the head of the Hex Head Snaptie. Used primarily on the Single Waler System's short end snap-ties, a small turn of the socket snaps the tie end at the breakback point before the formwork is removed.

To Order, Specify: quantity and type.

(1022) ST-17 RESIDENTIAL SNAPTIE – PLASTIC CONES
(1023) ST-18 RESIDENTIAL SNAPTIE – METAL WASHERS

The ST-17 and ST-18 Residential Snapties are designed to be used on stem-type footing walls, foundation walls, and basement walls.

The ST-17 and ST-18 Residential Snapties are available with fixed 1-1/4" washers for a flush break back. This breakback routinely results in the wire being flush with the surface of the concrete or slightly protruding outside the surface. When a finished wall is desired, this tie is also available with in a 1" cone and a 1" breakback.

With an end dimension of 1-5/8", the Meadow Burke Residential Snapties can be used with ST-15 Steel Wedges. Frequently used with our Quick Cleat (see page 32).

SAFE WORKING LOAD

TYPE	SWL (lbs)
ST-17 / 18	2,250

Safe working load is based on an approximate 2:1safety factor.

To Order, Specify: quantity, type, L&W, wall thickness, plastic cones or metal washer and breakback.

12

FIELD MEASUREMENT
FOR SNAP TIE

GuoZhan Wu

From: Dan Eschenasy

Sent: Wednesday, July 22, 2009 12:59 PM

To: GuoZhan Wu

Subject: ties

30 inch on center
16 oc vertical
6" from ply edge (would say bottom edge)

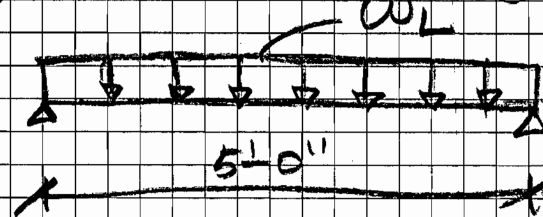
Dan Eschenasy, PE
Chief Structural Engineer
NYC Buildings
280 Broadway, NY, NY 10007
(212) 566 3845
deschenasy@buildings.nyc.gov

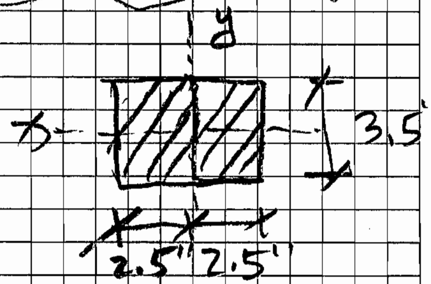
Project: 246 Spring Street Date: 7/22/09 Page: ____ of ____

Subject: BEAM FORMWORK Engr: ________ Checked By: ________ Date: ________

JOIST CHECK

- JOIST SPAN = 5'-0"
  (ASSUMING SNAP TIE @ 5'-0")

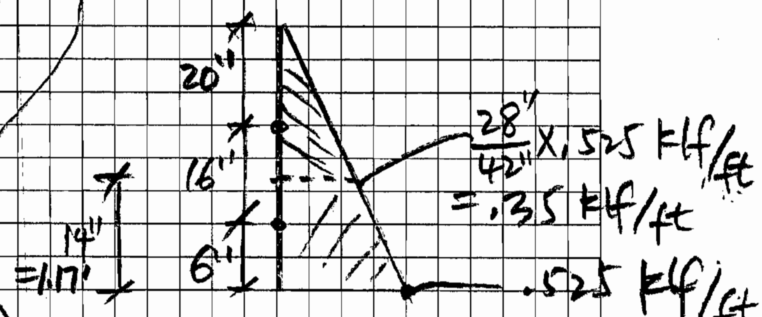




CROSS-SECTION

$W_L = \left(\frac{.35 + .525}{2}\right) \times 1.17'$

$= .52$ klf



$M = \frac{W_L \times 5^2}{8}$

$= 1.625$ k-ft

$= 19.5$ k-in

$S_x = (2.5 \times 2) \times 3.5^2 / 6 = 10.2 \text{ in}^3$

$f_b = \frac{M}{S_x} = \frac{19.5 \text{ k-in}}{10.2} = 1.91$ ksi

ULTIMATE STRENGTH $F_b = 3132$ psi $= 3.13$ ksi

$f_b < F_b$ (ok)

4 Validity of Computer Analysis

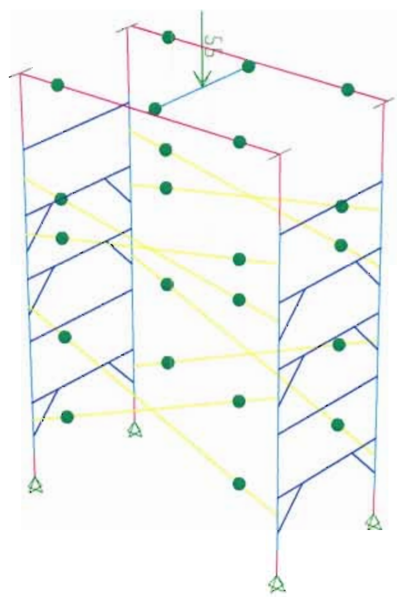
the following calculations compare the valuers obtained by computer analysis with test results.
It considers dead weight only. The overall frame is made of 5'-3" bottom frame and 3'-6" top frame, and the frame is 8'-0" apart. Two loading conditions have been considered and studied.

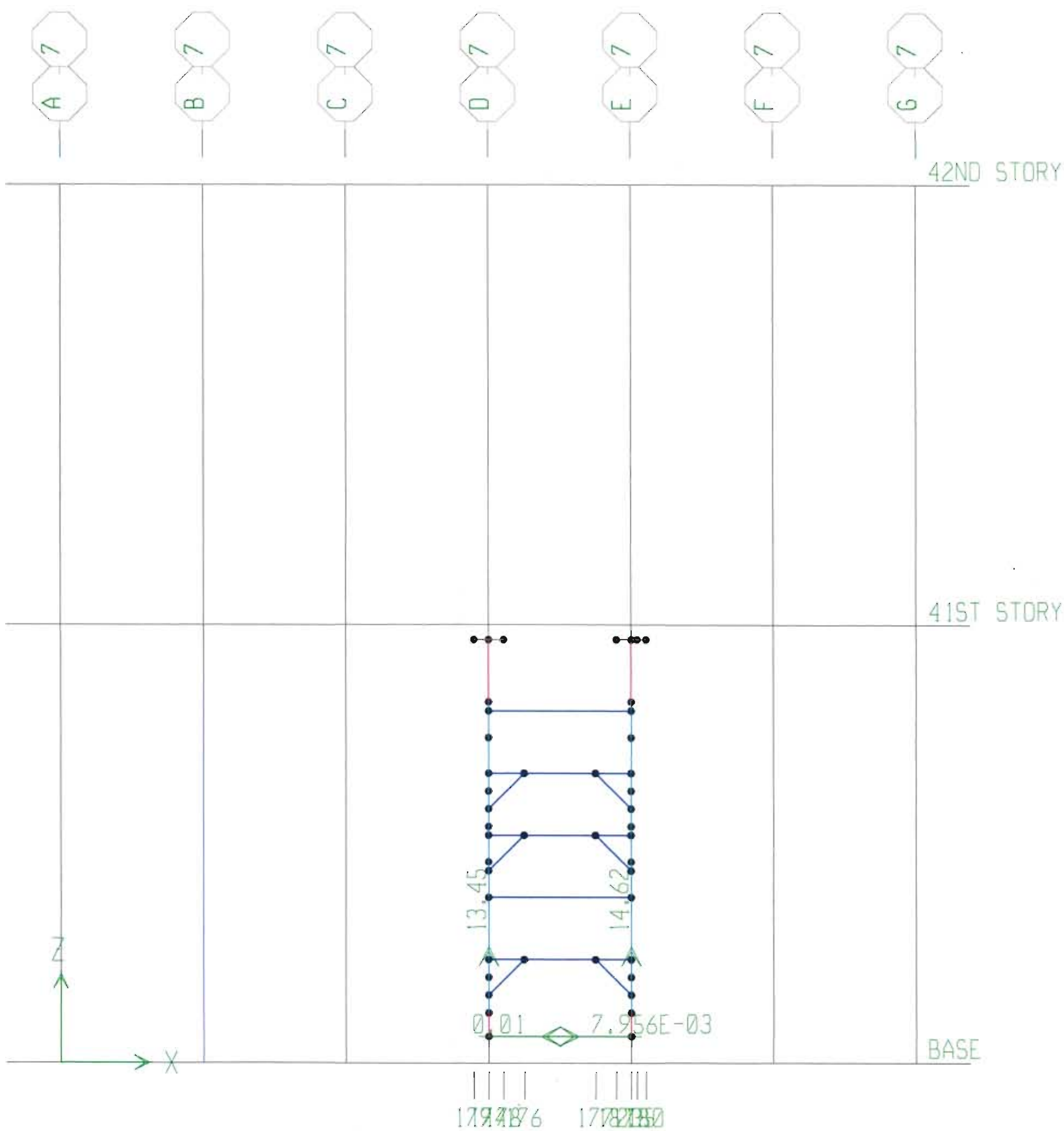
4.1.1 On One Side Of Frame, Load Case B. The Total Weight Is In The Order Of 55 Kips In The Middle Of the Shoring Tower.

- The model file is "246SpringST_2009_05_08_singleTowerDL_1sideECC55KipsTestLoadedinMiddle"

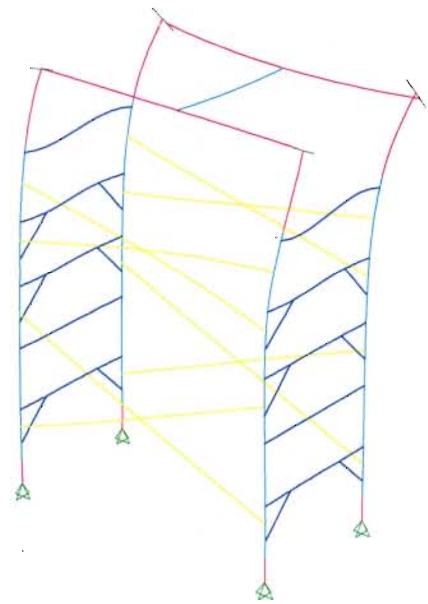
Result: shore failure

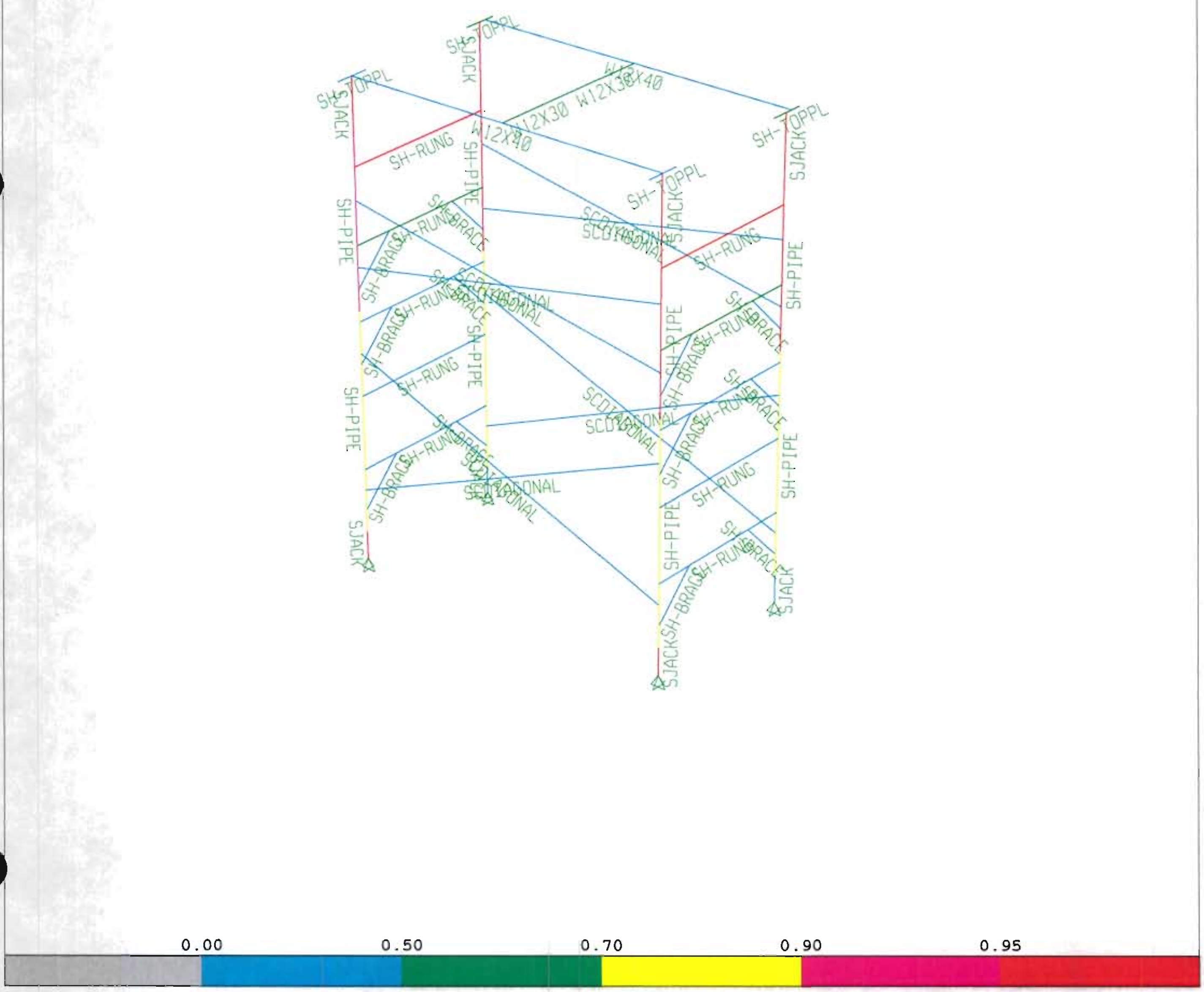
- Screw jacks on the 2" loaded sides buckles and has large deflection.
- All 4 Shoring legs do not fail in buckle or bending.
- **The connection from the top horizontal members to the legs fail in weldment.**
- Knee brace does not fail in compression, tension or bending.
- **The horizontal top deflection is in the order of .8", and the deflection from Lehigh Testing Lab for the similar condition is in order of .6". The results are comparable.**




A 7
B 7
C 7
D 7
E 7
F 7
G 7
42ND STORY
41ST STORY
BASE
13.45
14.62
0.01
7.956E-03
Z
X

3





ETABS v9.0.7 - File: 246SpringST_2009_05_08_singleTowerDL_1sideECC55KipsTestLoadedInMiddle - June 10,2009 18:32
3-D View Steel Design Sections (AISC-ASD89) - Kip-in Units

ETABS Steel Design

Engineer___________________
Project___________________
Subject___________________

```
AISC-ASD89 STEEL SECTION CHECK    Units: Kip-in  (Summary for Combo and Station)
Level: 41ST STORY  Element: B390  Station Loc: 48.000  Section ID: SH-RUNG
Element Type:  Moment Resisting Frame   Classification:  Compact

L=48.000
A=0.503  i22=0.133  i33=0.338
s22=0.213  s33=0.300  r22=0.515  r33=0.820
E=10100.000  fy=35.000
RLLF=1.000

P-M33-M22 Demand/Capacity Ratio is  1.205 = 0.230 + 0.947 + 0.028

STRESS CHECK FORCES & MOMENTS
                          P          M33         M22          V2          V3
    Combo  DSTLS2      -0.692      -6.386       0.113       0.267      -0.005

AXIAL FORCE & BIAXIAL MOMENT DESIGN    (H1-1)
                           fa          Fa          Ft
                       Stress   Allowable   Allowable
    Axial               1.377       5.987      21.000

                           fb          Fb          Fe        Cm        K        L       Cb
                       Stress   Allowable   Allowable    Factor   Factor   Factor   Factor
    Major Bending      21.279      21.000      15.165     0.850    1.000    1.000    2.300
    Minor Bending       0.528      21.000       5.987     0.850    1.000    1.000

SHEAR DESIGN
                           fv          FV      Stress
                       Stress   Allowable       Ratio
    Major Shear         0.790      14.000       0.056
    Minor Shear         0.025      14.000       0.002
```

ETABS Steel Design

Engineer

Project

Subject

```
AISC-ASD89 STEEL SECTION CHECK    Units: Kip-in  (Summary for Combo and Station)
Level: 41ST STORY  Element: C102-3  Station Loc: 42.000  Section ID: SH-PIPE
Element Type:  Moment Resisting Frame   Classification:  Compact

L=42.000
A=1.343  i22=1.367  i33=1.367
s22=0.912  s33=0.912  r22=1.009  r33=1.009
E=10100.000  fy=35.000
RLLF=1.000

P-M33-M22 Demand/Capacity Ratio is  1.300 = 0.495 + 0.805 + 0.002

STRESS CHECK FORCES & MOMENTS
                          P         M33        M22         V2         V3
    Combo  DSTLS2    -13.970     16.950     -0.043     -0.746     -0.003

AXIAL FORCE & BIAXIAL MOMENT DESIGN   (H1-2)
                         fa          Fa          Ft
                     Stress   Allowable   Allowable
    Axial            10.402      19.050      21.000

                         fb          Fb          Fe       Cm       K       L      Cb
                     Stress   Allowable   Allowable   Factor  Factor  Factor  Factor
    Major Bending    18.594      23.100     120.071    0.850   1.000   0.500   1.315
    Minor Bending     0.047      23.100     163.430    0.850   1.000   0.429

SHEAR DESIGN
                         fv          FV      Stress
                     Stress   Allowable       Ratio
    Major Shear       1.029      14.000       0.074
    Minor Shear       0.004      14.000       0.000
```

ETABS Steel Design

Engineer____________________
Project____________________
Subject____________________

```
AISC-ASD89 STEEL SECTION CHECK    Units: Kip-in  (Summary for Combo and Station)
Level: 41ST STORY  Element: C19-1  Station Loc: 21.000  Section ID: SJACK
Element Type:  Moment Resisting Frame   Classification:  Compact

L=21.000
A=1.279  i22=0.509  i33=0.509
s22=0.509  s33=0.509  r22=0.631  r33=0.631
E=29000.000  fy=55.000
RLLF=1.000

P-M33-M22 Demand/Capacity Ratio is  2.095 = 0.331 + 1.764 + 0.000

STRESS CHECK FORCES & MOMENTS
                           P         M33         M22          V2          V3
    Combo  DSTLS2    -13.963      32.621       0.017      -0.746      -0.003

AXIAL FORCE & BIAXIAL MOMENT DESIGN    (H1-2)
                          fa          Fa          Ft
                      Stress   Allowable   Allowable
    Axial             10.917      29.179      33.000

                          fb          Fb          Fe       Cm       K       L      Cb
                      Stress   Allowable   Allowable   Factor  Factor  Factor  Factor
    Major Bending     64.051      36.300     134.847    0.850   1.000   1.000   1.285
    Minor Bending      0.033      36.300     134.847    0.850   1.000   1.000

SHEAR DESIGN
                          fv          FV      Stress
                      Stress   Allowable       Ratio
    Major Shear        0.986      22.000       0.045
    Minor Shear        0.004      22.000       0.000
```

ETABS v9.0.7 File:246SPRINGST_2009_05_08_SINGLETOWERDL_1SIDEECC55KIPSTESTLOADEDINMIDDLE Units:Kip-in June 10, 20

8

POINT DISPLACEMENTS

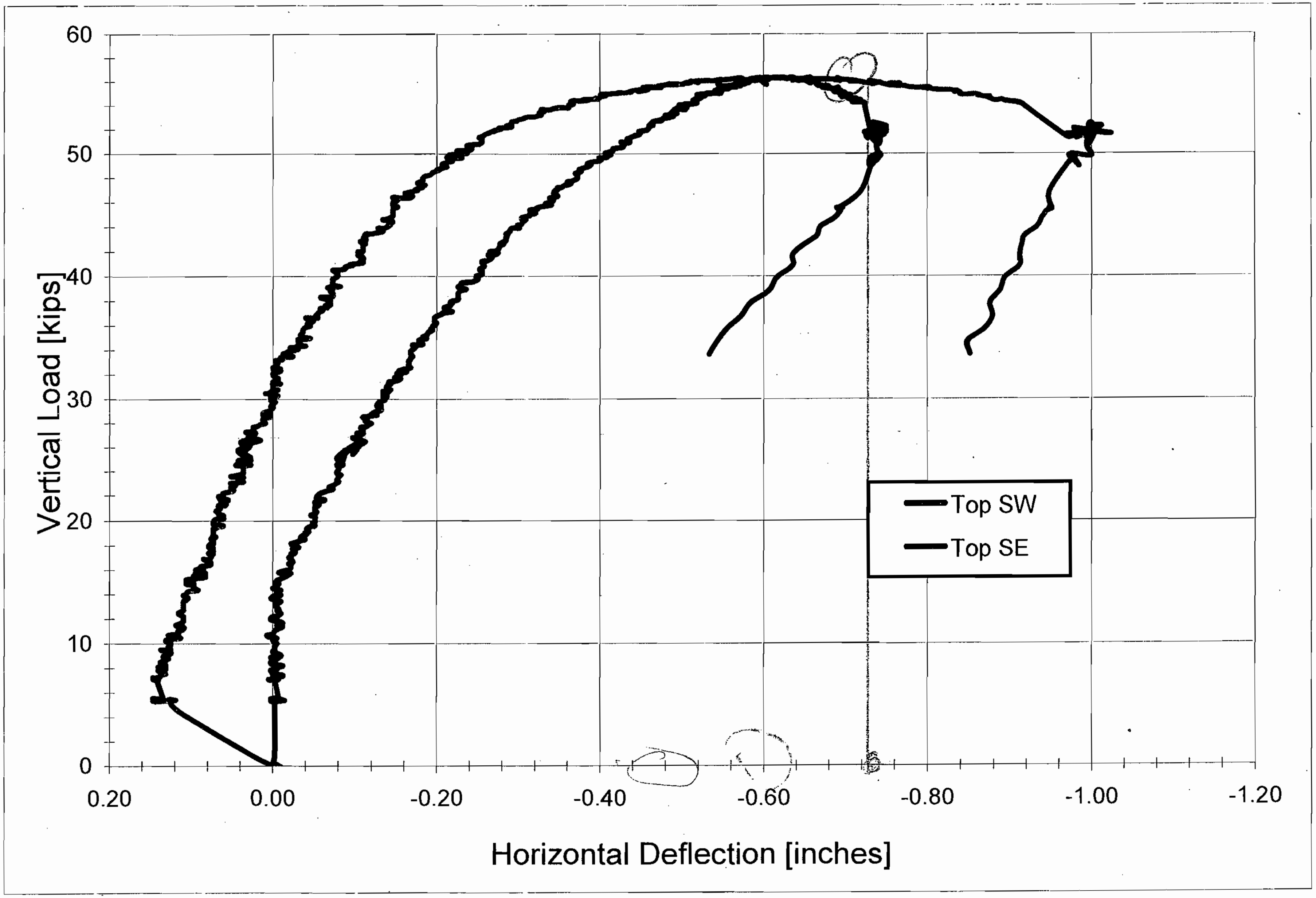
STORY	POINT	LOAD	UX	UY	UZ	RX	RY	RZ
41ST STORY	87-5	DEAD	0.8087	0.0937	-0.0623	-0.01574	0.02223	0.00000
41ST STORY	174-1	DEAD	0.8046	-0.0937	-0.0623	0.01574	0.02165	0.00000
41ST STORY	233-1	DEAD	1.0561	-0.0001	-0.1756	0.00001	0.05538	0.00000
41ST STORY	235-1	DEAD	1.0529	0.0001	-0.1744	-0.00001	0.05478	0.00000

Test	Test Type	Bottom Screw Jack [in]				Top Screw Jack [in]				Total Height [in]				Max Load [lbs]	Failure mode
		NW	SW	NE	SE	NW	SW	NE	SE	NW	SW	NE	SE		
1	Concentric Load Tower "A"	12	12	12 1/8	12 1/16	17 13/16	18	17 7/8	17 15/16	135 3/4	135 3/4	135 7/8	135 7/8	159,000	Racking
2	Concentric Load Tower "C"	11 5/8	11 13/16	11 5/8	11 3/4	18 3/16	18	18 1/8	17 15/16	135 5/8	135 3/4	135 3/4	135 3/4	154,500	Racking
3	Concentric Load Tower "B"	-	-	-	-	18	18	18	18	129 7/16	129 7/16	129 5/16	129 1/4	152,100	Racking
4	Eccentric Load (Various Components)	12	12 1/8	12 1/16	12 1/16	18	18	18 1/8	18	135 7/8	135 15/16	135 7/8	135 7/8	61,300	Screw jack buckling
5	Eccentric Load (Various Components)	-	-	-	-	21	21	21 1/16	21	132 7/16	132 7/16	132 7/16	132 7/16	52,100	Screw jack buckling
6	Eccentric Load (Various Components)	12 3/16	12	12	12	21 1/8	21 1/8	21 1/8	21 1/4	139	139	138 7/8	139	56,400	Top plate fractured

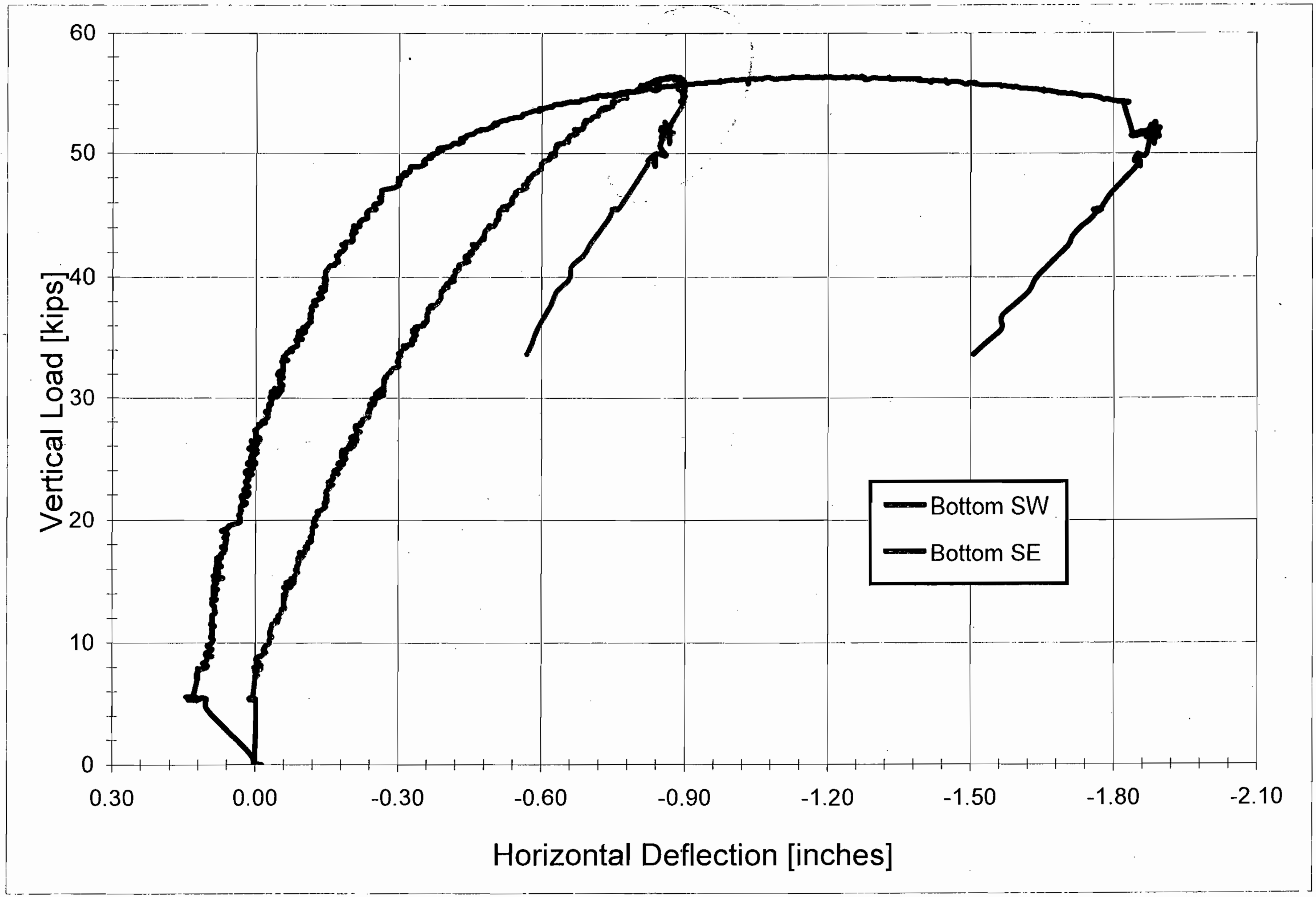
All specimens loaded at a rate of 6-8 kips/min
Load was held for 1 minute at 30-60-90-120 kips
All specimens were plumb to 1/8" in 3" except for Test 2

Test Name = Ecc Test 3
Test Date = 14:55:31 May 05 2009

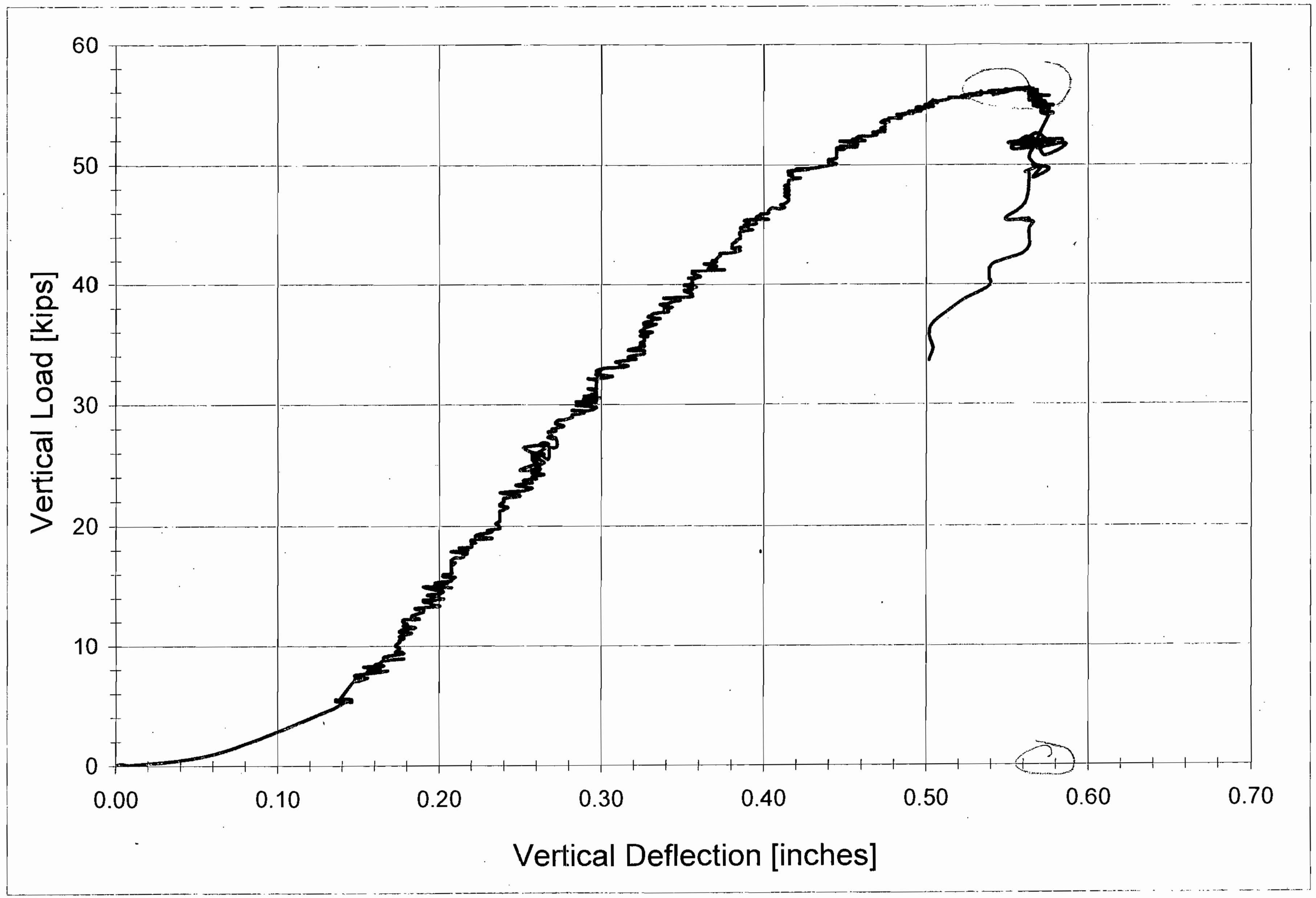
	CH #'s	CH-01	CH-02	CH-03	CH-04	CH-05	CH-00
	NAME	SW Top	SW Bot	SE Top	SE Bot	Zero Vert	Load
	UNITS	Inches	Inches	Inches	Inches	Inches	Kips
10	15:43:55	0.00	0.00	0.00	0.00	0.01	-0.04
11	15:43:56	0.00	0.00	0.00	0.00	0.00	-0.03
12	15:43:57	0.00	-0.01	-0.01	0.00	0.00	0.02
13	15:43:58	0.00	0.00	0.00	0.00	0.00	0.04
14	15:43:59	0.00	0.00	0.00	0.00	0.00	-0.16
15	15:44:00	0.00	0.00	0.00	0.00	0.00	0.13
16	15:44:01	0.00	0.00	0.00	0.00	0.01	0.02
17	15:44:02	0.00	0.00	0.00	0.00	0.00	0.00
18	15:44:03	0.00	-0.01	0.00	0.00	0.00	0.02
19	15:44:04	0.00	0.00	-0.01	0.00	0.00	-0.05
20	15:44:05	0.00	0.00	0.00	0.00	0.01	0.03
21	15:44:06	0.00	0.00	0.00	0.00	0.00	-0.09
22	15:44:07	0.00	0.00	0.00	0.00	0.00	-0.12
23	15:44:08	0.00	0.00	0.00	0.00	0.01	-0.08
24	15:44:09	0.00	0.00	0.00	0.00	0.00	0.00
25	15:44:10	0.00	0.00	0.00	0.00	0.00	-0.02
26	15:44:11	0.00	-0.01	-0.01	0.00	0.01	0.03
27	15:44:12	0.00	0.00	0.00	0.00	0.00	-0.02
28	15:44:13	0.00	0.00	0.00	0.00	0.00	0.07
29	15:44:14	0.00	0.00	0.00	0.00	0.00	-0.02
30	15:44:15	0.00	0.00	0.00	0.00	0.00	-0.02
31	15:44:16	0.00	-0.01	-0.01	0.00	0.01	0.04
32	15:44:17	0.00	0.00	0.00	0.00	0.00	0.03
33	15:44:18	0.00	0.00	0.00	0.00	0.00	-0.05
34	15:44:19	0.00	0.00	0.00	0.00	0.01	-0.06
35	15:44:20	0.00	0.00	0.00	0.00	0.00	-0.04
36	15:44:21	0.00	0.00	0.00	0.00	0.00	0.00
37	15:44:22	0.00	0.00	0.00	0.00	0.00	-0.05
38	15:44:23	0.00	0.00	0.00	0.00	0.00	-0.01
39	15:44:24	0.00	0.00	0.00	-0.01	0.00	-0.06
40	15:44:25	0.00	0.00	-0.01	0.00	0.00	-0.08
41	15:44:26	0.00	0.00	-0.01	-0.01	0.00	-0.01
42	15:44:27	0.00	0.00	0.00	-0.01	0.01	-0.02
43	15:44:28	0.00	-0.01	0.00	0.00	0.00	-0.06
44	15:44:29	0.00	0.00	0.00	0.00	0.00	0.03
45	15:44:30	0.00	0.00	0.00	0.00	0.00	0.05
46	15:44:31	0.00	0.00	-0.01	0.00	0.00	-0.13
47	15:44:32	0.00	0.00	0.00	0.00	0.00	0.12
48	15:44:33	0.00	0.00	0.00	0.00	0.00	-0.09
49	15:44:34	0.00	0.00	0.00	-0.01	0.00	-0.02
50	15:44:35	0.00	0.00	0.00	0.00	0.01	-0.01
51	15:44:36	0.00	0.00	-0.01	0.00	0.00	-0.04
52	15:44:37	0.00	0.00	0.00	0.00	0.00	-0.02
53	15:44:38	0.00	0.00	0.00	0.00	0.00	0.00
54	15:44:39	0.00	0.00	0.00	0.00	0.00	-0.03
55	15:44:40	0.00	0.00	0.00	0.00	0.00	0.00
56	15:44:41	0.03	0.00	0.00	0.01	0.06	0.98
57	15:44:42	0.12	0.00	0.00	0.10	0.13	4.52
58	15:44:43	0.13	0.00	0.00	0.10	0.14	5.42



60
50
40
30
20
10
0
Vertical Load [kips]
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
-1.20
Horizontal Deflection [inches]
Top SW
Top SE



60
50
40
30
20
10
0
Vertical Load [kips]
0.30
0.00
-0.30
-0.60
-0.90
-1.20
-1.50
-1.80
-2.10
Horizontal Deflection [inches]
Bottom SW
Bottom SE



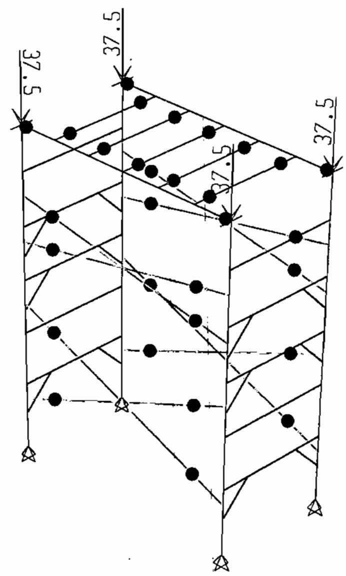
Vertical Load [kips]
60
50
40
30
20
10
0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Vertical Deflection [inches]

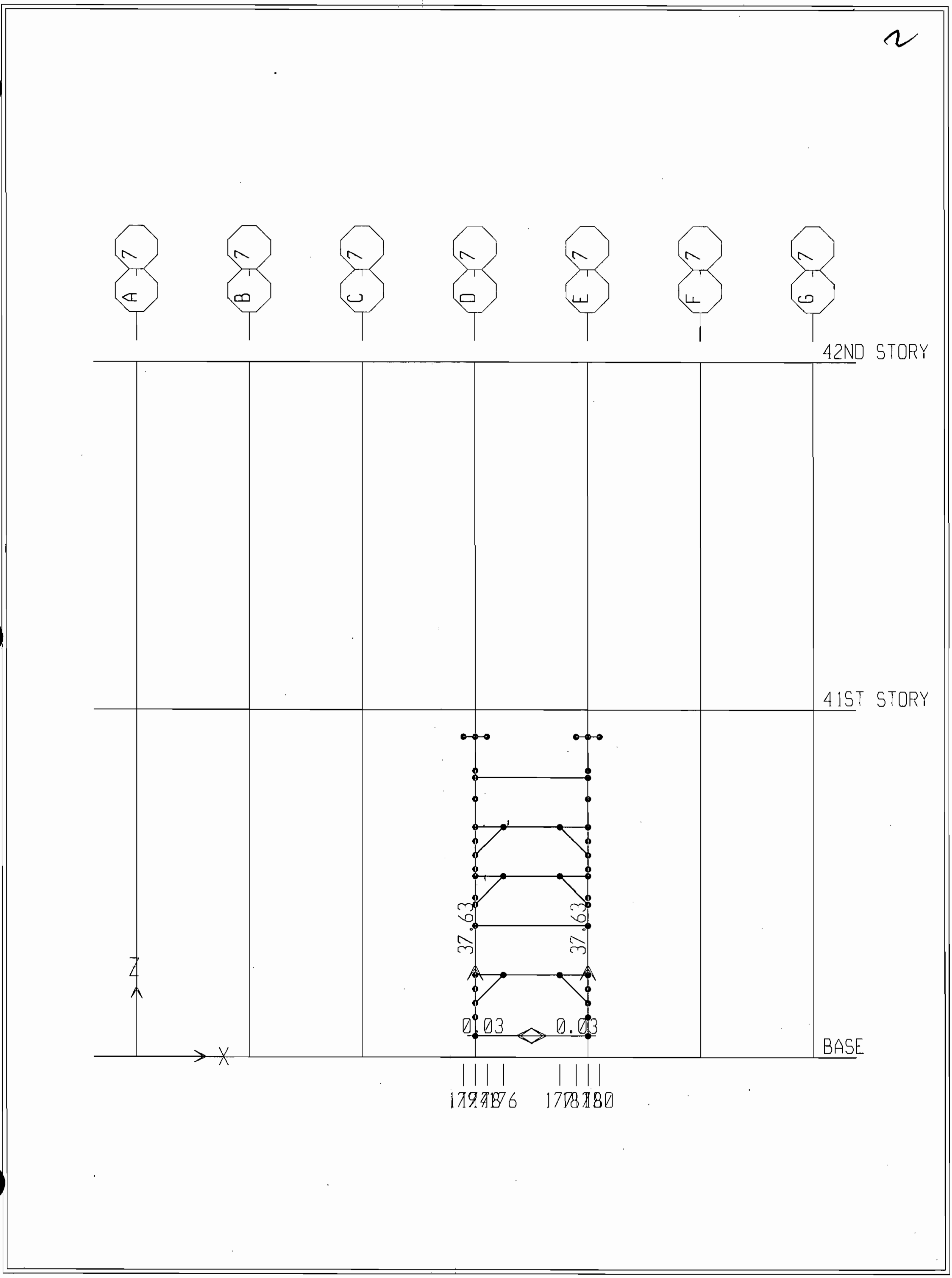
4.1.2 Load Case A. The Total Weight Is In The Order Of 150 Kips (150 Kips / 4 Top Plates = 37.5 Kips On Each Top Plate).

- The model file is "246SpringST_2009_05_08_singleTowerDL_NoECC150KipsTestLoad".

Result: shore failure

- Screw jacks do not fail in combination of compression and bending.
- **All 4 Shoring legs fail in combination of compression and bending.**
- All horizontal members and connections do not fail.
- Knee brace does not fail in compression, tension or bending.
- Test and computer analysis are comparable


37.5
37.5
37.5
37.5


7 A
7 B
7 C
7 D
7 E
7 F
7 G
42ND STORY
41ST STORY
BASE
37.63
37.63
0.03
0.03
Z
X

ETABS Steel Design

Engineer________________
Project________________
Subject________________

```
AISC-ASD89 STEEL SECTION CHECK    Units: Kip-in  (Summary for Combo and Station)
Level: 41ST STORY  Element: C25-8  Station Loc: 18.000  Section ID: SH-PIPE
Element Type:  Moment Resisting Frame   Classification:  Compact

L=63.000
A=1.343  i22=1.367  i33=1.367
s22=0.912  s33=0.912  r22=1.009  r33=1.009
E=10100.000  fy=35.000
RLLF=1.000

P-M33-M22 Demand/Capacity Ratio is  1.788 = 1.696 + 0.020 + 0.090

STRESS CHECK FORCES & MOMENTS
                           P         M33        M22         V2         V3
    Combo  DSTLS2    -37.605      -0.372     -0.436     -0.022     -0.003

AXIAL FORCE & BIAXIAL MOMENT DESIGN   (H1-1)
                          fa          Fa         Ft
                      Stress   Allowable  Allowable
    Axial             28.000      16.510     21.000

                          fb          Fb         Fe       Cm       K        L       Cb
                      Stress   Allowable  Allowable  Factor  Factor  Factor  Factor
    Major Bending      0.408      23.100    120.071    0.850   1.000   0.333   1.000
    Minor Bending      0.478      23.100     34.813    0.850   1.000   0.619

SHEAR DESIGN
                          fv          FV     Stress
                      Stress   Allowable      Ratio
    Major Shear        0.030      14.000      0.002
    Minor Shear        0.005      14.000      0.000
```

ETABS Steel Design

Engineer__________
Project__________
Subject__________

```
AISC-ASD89 STEEL SECTION CHECK    Units: Kip-in  (Summary for Combo and Station)
Level: 41ST STORY  Element: C92-11  Station Loc: 0.000  Section ID: SJACK
Element Type:  Moment Resisting Frame   Classification:  Compact

L=14.500
A=1.279  i22=0.509  i33=0.509
s22=0.509  s33=0.509  r22=0.631  r33=0.631
E=29000.000  fy=55.000
RLLF=1.000

P-M33-M22 Demand/Capacity Ratio is   0.926 = 0.917 + 0.000 + 0.009

STRESS CHECK FORCES & MOMENTS
                            P          M33          M22           V2           V3
    Combo  DSTLS2     -37.575        0.017       -0.189        0.001       -0.013

AXIAL FORCE & BIAXIAL MOMENT DESIGN    (H1-1)
                           fa          Fa          Ft
                       Stress   Allowable   Allowable
    Axial              29.379      32.025      33.000

                           fb          Fb          Fe        Cm        K         L        Cb
                       Stress   Allowable   Allowable    Factor    Factor    Factor    Factor
    Major Bending       0.033      36.300    1213.622     0.850     1.000     0.483     1.281
    Minor Bending       0.371      36.300    1213.622     0.850     1.000     0.483

SHEAR DESIGN
                           fv          FV      Stress
                       Stress   Allowable       Ratio
    Major Shear         0.002      22.000   6.934E-05
    Minor Shear         0.017      22.000       0.001
```

+1695

Appendix:

Aluminum Shoring Test Report From "ATLSS Multidirectional Laboratory of LeHigh University"

LEHIGH
UNIVERSITY.

Structural Testing Laboratories
Fritz Engineering Laboratory
13 East Packer Avenue
Bethlehem, PA 18015-4729
(610) 758-5498 Fax (610) 758-5902

June 15, 2009
FL2009.1208.1

Dan Eschenasy
Department Chief Structural Engineer
NYC Buildings
280 Broadway, 7th Floor
New York, NY 10007

Subject: Testing of Shoring Towers for NYC Buildings

Dear Mr. Eschenasy,

On May 4th and 5th, 2009, six shoring towers were tested in the Fritz Lab Baldwin-Lima-Hamilton 5,000K testing machine. The 5,000K machine was calibrated on April 8, 2009. Three towers had concentric axial force applied, and three towers had eccentric axial force applied. Five string pot type displacement transducers were used to measure deflections for the eccentric load tests. The test types and results are summarized in Table 1. Before and after photos of the six test specimens are shown in Figures 1-12.

Load was applied to the towers using an H frame arrangement. A spherical bearing block was affixed to the bottom of the sensitive crosshead which loaded on a spreader beam which in turn loaded on two load beams. The concentric test specimens were loaded directly through the four columns using spacer blocks on top of the screw jack feet. The three eccentric load tests were performed by moving the south load beam so that the center of the load was 2" outboard of the centerline of the screw jack. The North load beam was centered over the screw jacks. Stringer beams were also placed on top of the screw jack feet for the eccentric tests. The bottom screw jack extensions were 12" for all tests except Tests 3 and 5, which had no bottom screw jacks. The top screw jack extensions were either 18" or 21".

Table 1: Summary of Test Results

Test	Test Type	Btm SJ [in]	Top SJ [in]	Total Height [in]	Max Load [lbs]	Failure mode
1	Concentric Load Tower "A"	12	18	136	159,000	Racking
2	Concentric Load Tower "C"	12	18	136	154,500	Racking
3	Concentric Load Tower "B"	None	18	130	152,100	Racking
4	Eccentric Load (Various Components)	12	18	136	61,300	Screw jack buckling
5	Eccentric Load (Various Components)	None	21	133	52,100	Screw jack buckling
6	Eccentric Load (Various Components)	12	21	139	56,400	Top plate fractured

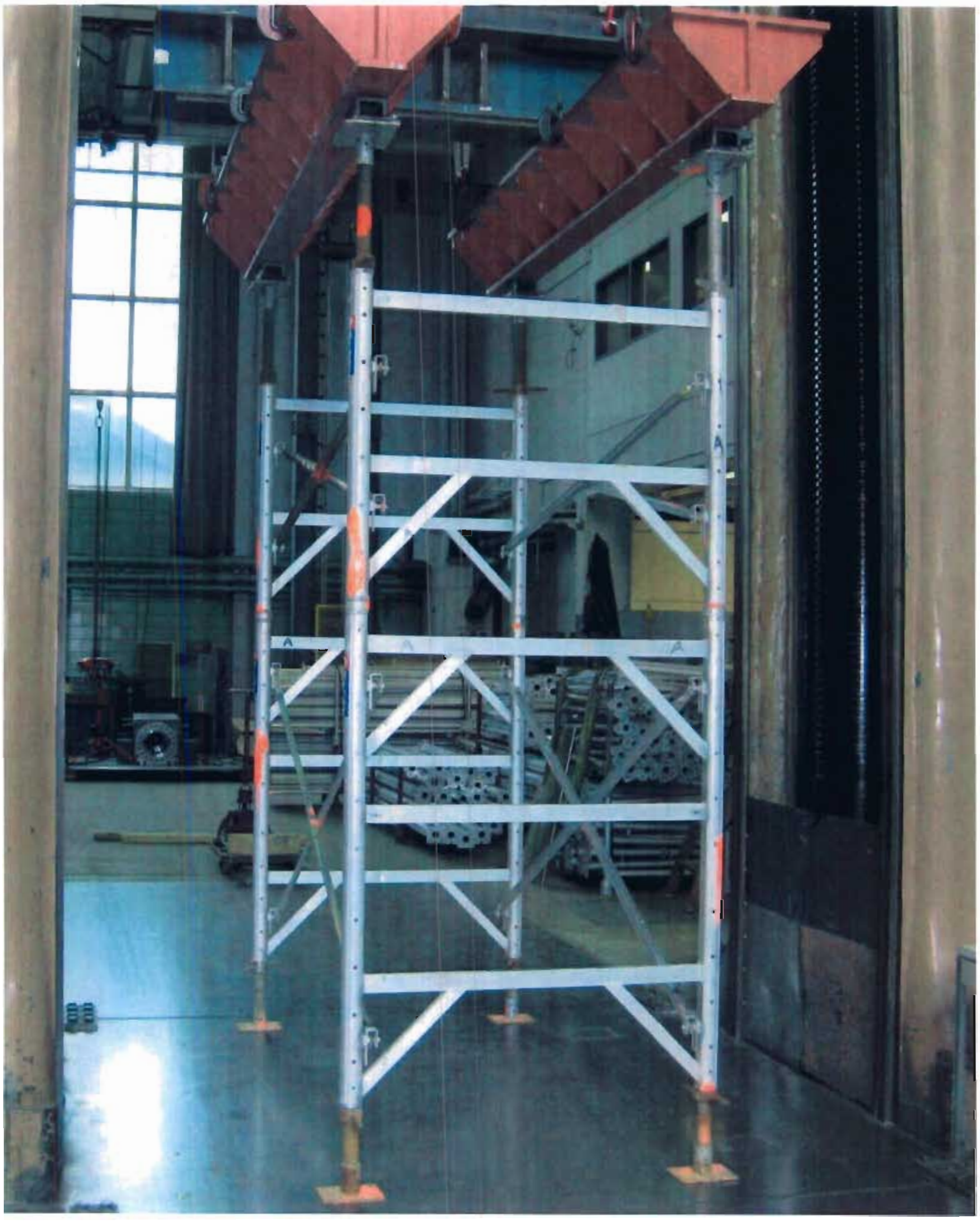


Figure 1: Tower 1 Pretest

Figure 2: Tower 1 Post Test

Figure 3: Tower 2 Pretest

Figure 4: Tower 2 Post Test

Figure 5: Tower 3 Pretest

Figure 7: Tower 4 Pretest

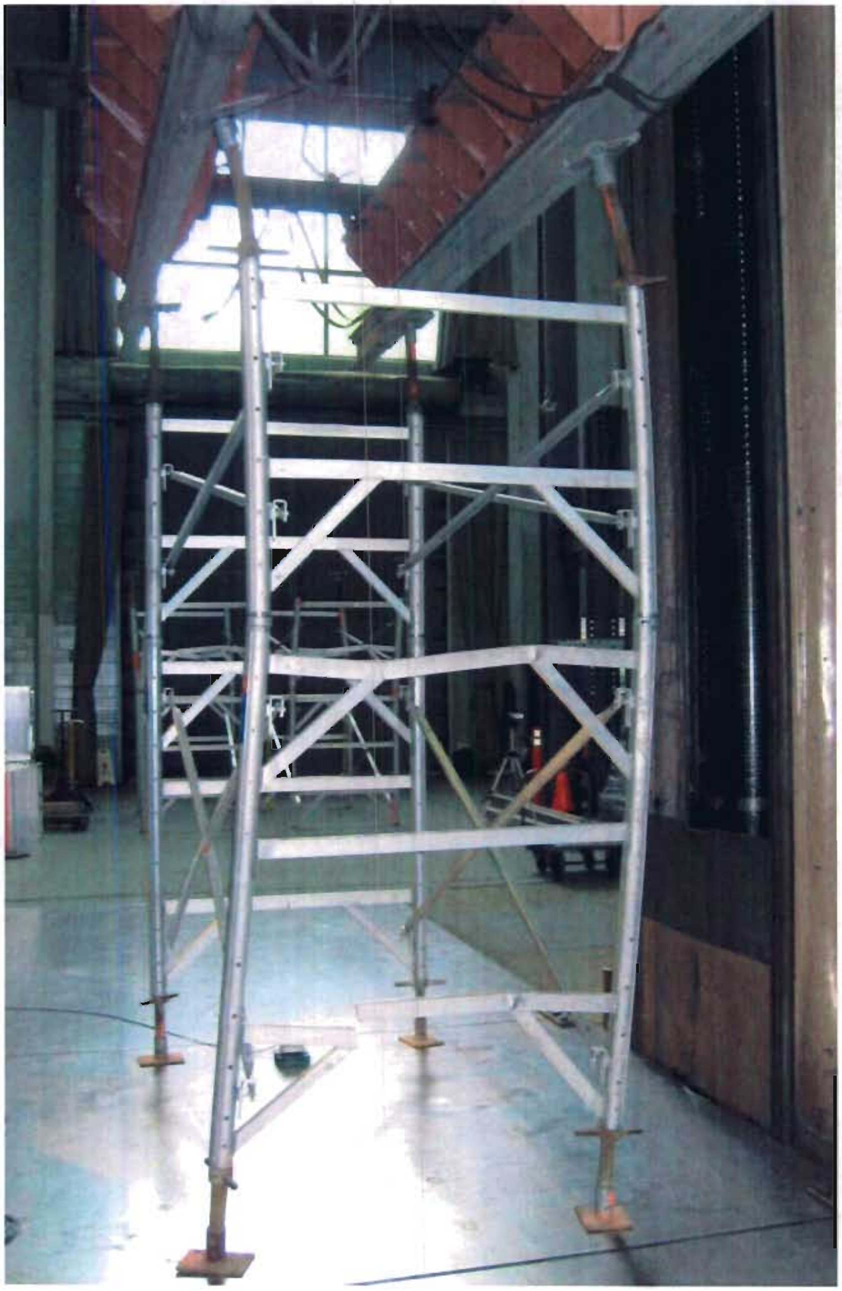


Figure 8: Tower 4 Post Test

10

Figure 9: Tower 5 Pretest

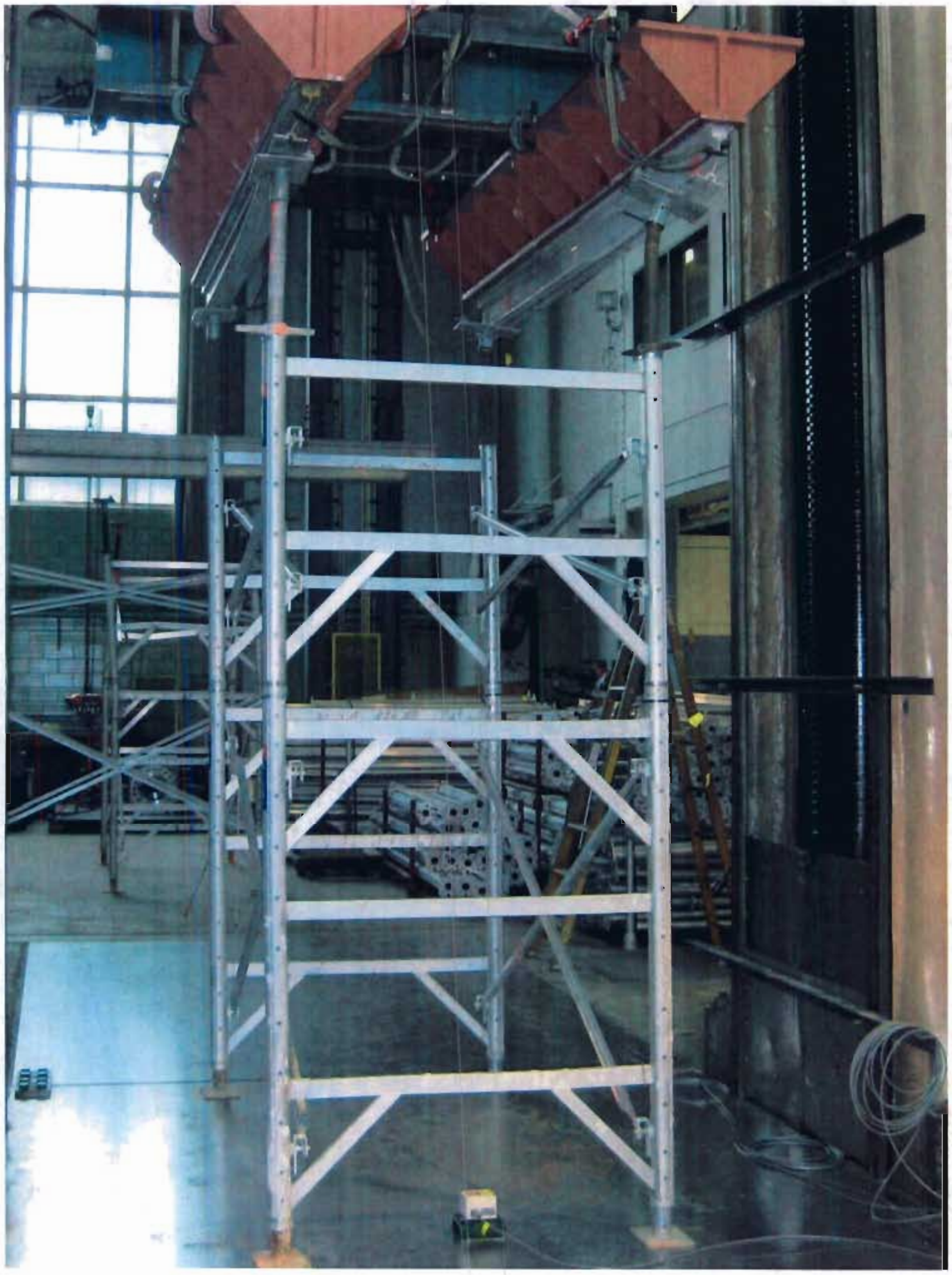


Figure 10: Tower 5 Post Test

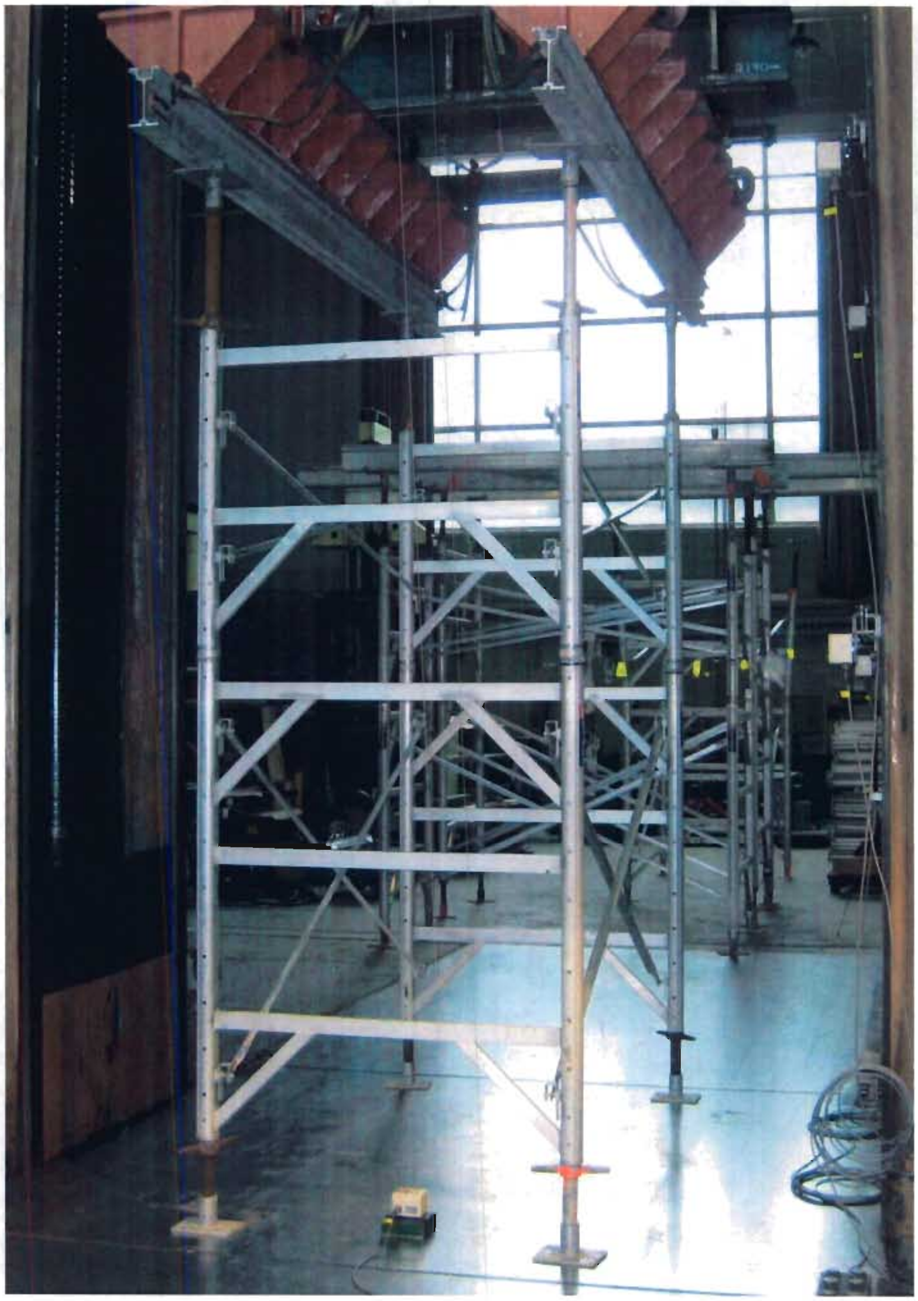


Figure 11: Tower 6 Pretest

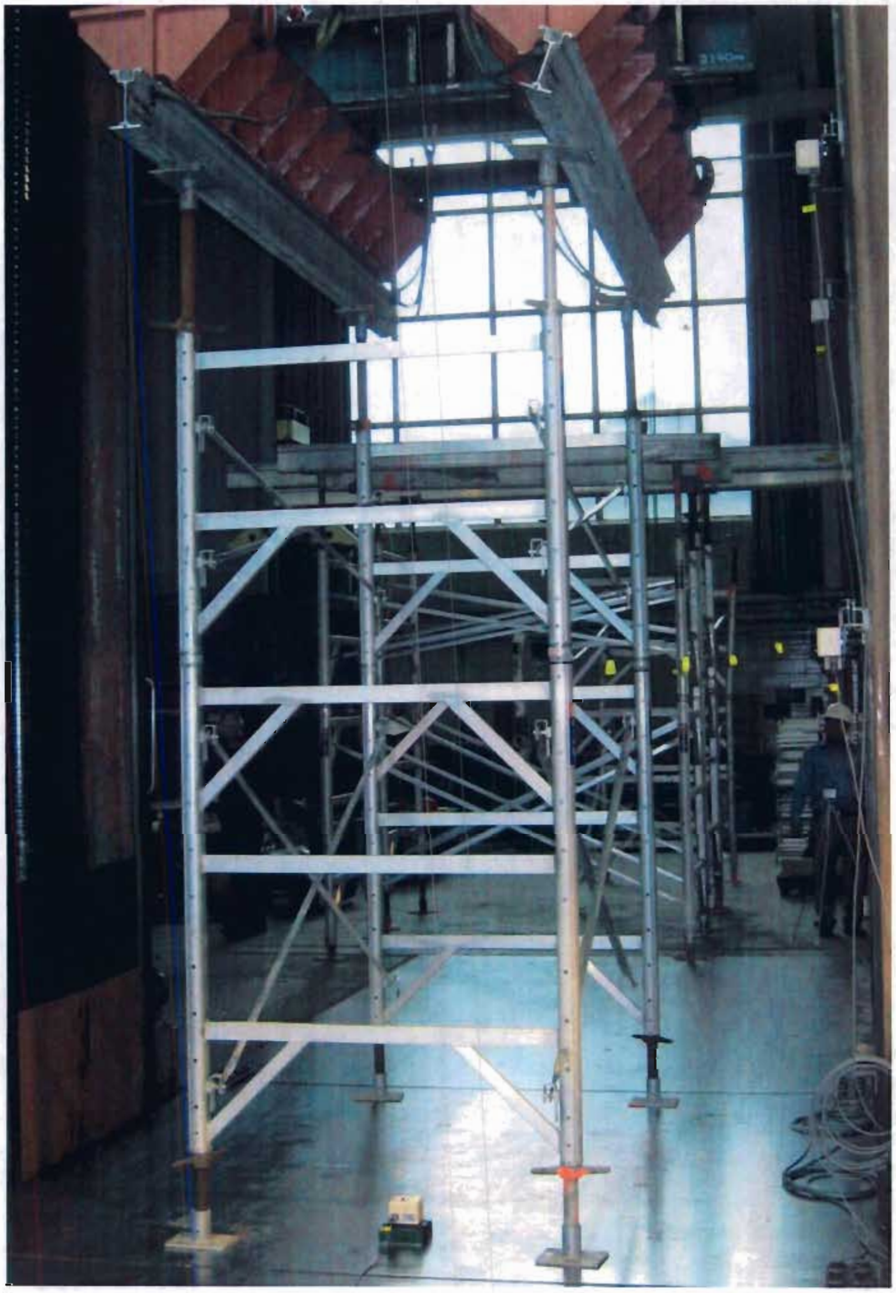


Figure 12: Tower 6 Post Test

The locations of the sensors used for the testing are given using the cardinal directions. Figure 13 Shows the North and South directions relative to the 5,000K testing machine. Figure 14 shows the five string pots and their designations.

Figure 13: 5,000K Machine with Columns Labeled N for North and S for South West is in front of the machine, and East is in the back

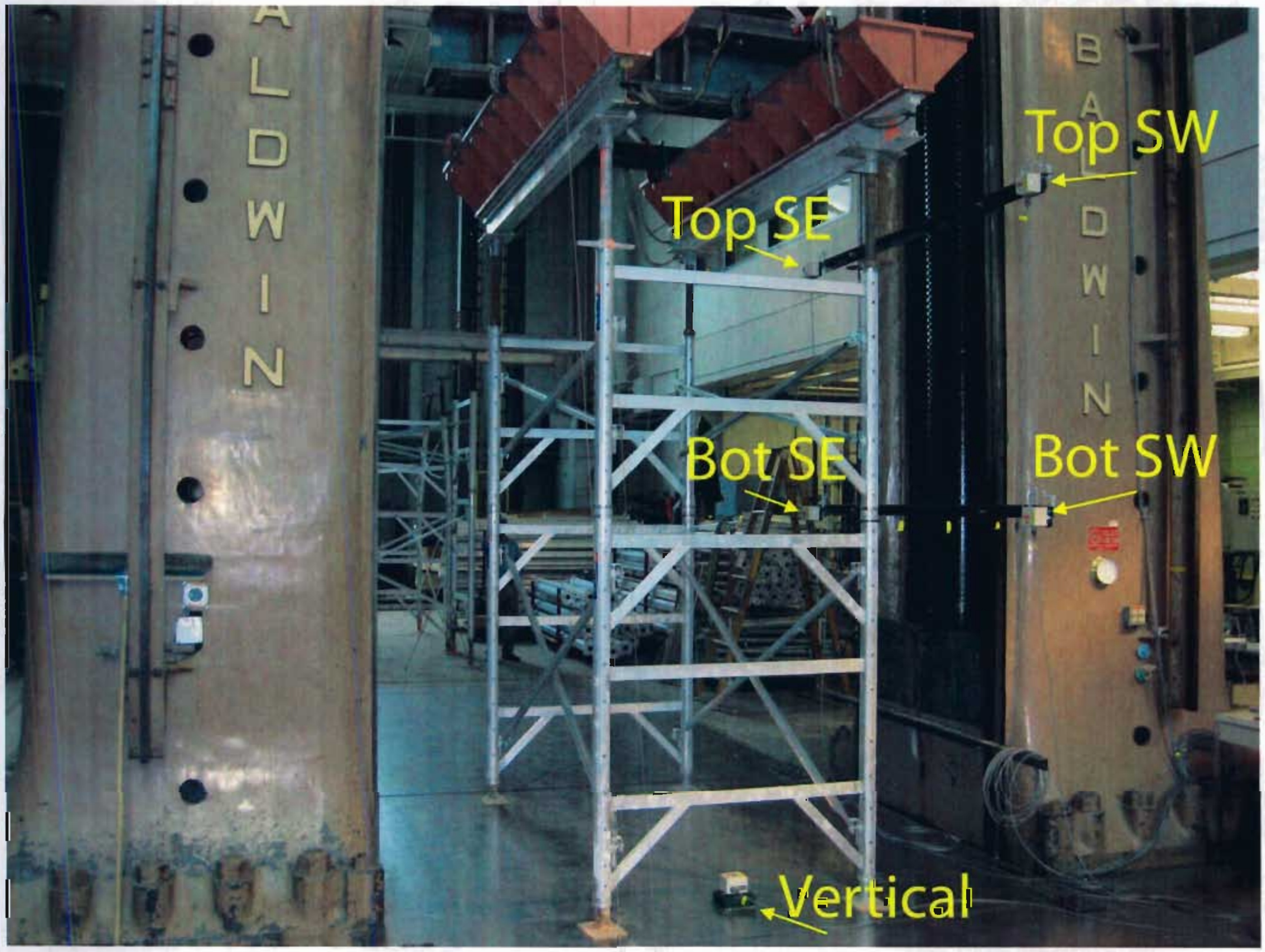


Figure 14: Location of String Pots

Included with this report is a CD containing the 5,000K testing machine calibrations certificate, additional test pictures, load deflection plots for the three eccentric load tests and an electronic copy of this report.

Sincerely,

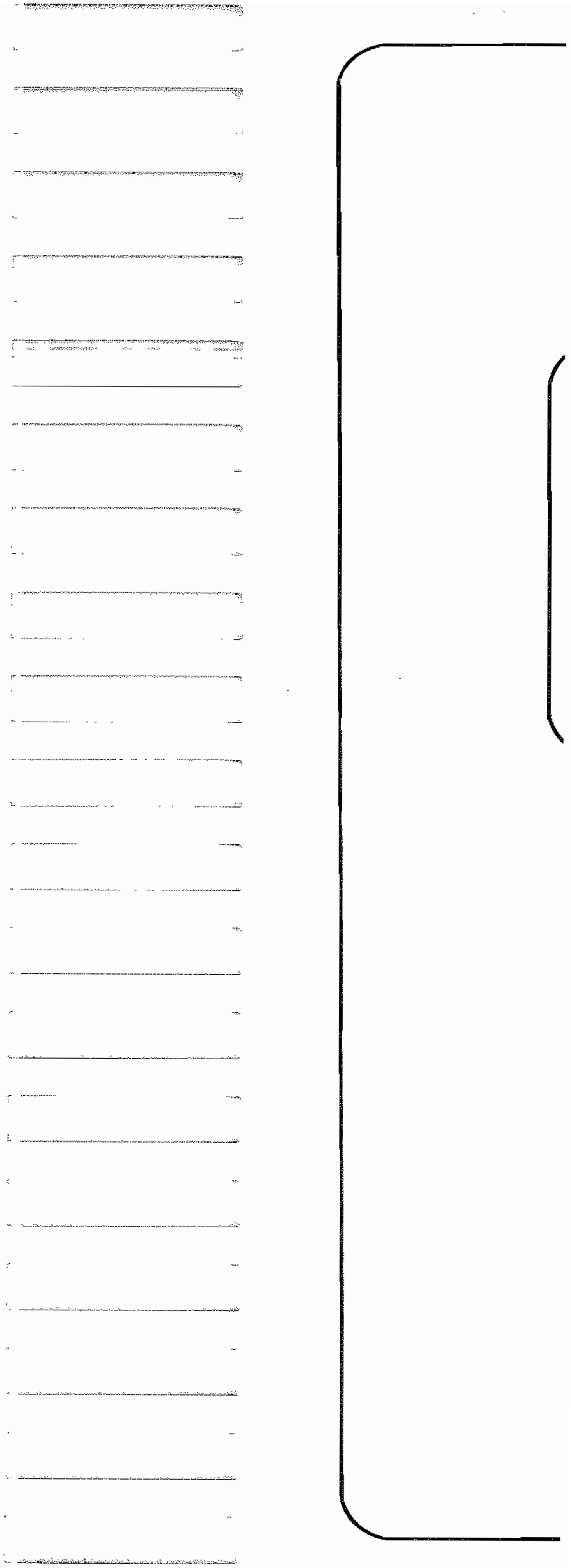
Robin J. Hendricks

Cc: Frank E. Stokes – ATLSS

The following disclaimer belongs on the back of the first page:

The results of the project presented in this report are provided on an "AS IS" basis. University makes no warranties of any kind, express or implied, as to any matter whatsoever, including, without limitation, warranties with respect to the merchantability or fitness for a particular purpose of the project or any deliverables. University makes no warranty of any kind with respect to freedom from patent, trademark, copyright or trade secret infringement arising from the use of the results of the project, deliverables, services, intellectual property or other materials provided hereunder. University shall not be liable for any direct, indirect, consequential, punitive, or other damages suffered by Sponsor or any other person resulting from the project or use of any deliverables. Sponsor agrees that it shall not make any warranty on behalf of University, express or implied, to any person containing the application of the results or any deliverables of this project.

APPENDIX "B"
Wood Formwork Testing and Report
Wood Advisory Services



ces, Inc.

Submitted to:

Mr. Dan Eschenasy, PE

Chief Engineer

NYC Department of Buildings

280 Broadway • 7th Floor

New York, NY 10007

Evaluation of Concrete Formwork Associated with the 42nd Floor Collapse at 246 Spring Street • New York, NY

August 12, 2009

WOOD ADVISORY SERVICES, INC.

PO Box 1322

3700 Route 44

Millbrook, NY 12545

08.125.01

TABLE OF CONTENTS

1. Scope

Evaluate the lumber and plywood associated with the 42nd floor concrete formwork collapse at 246 Spring Street, New York, NY. Inspect and determine the visual grades of the lumber, document grade stamps observed, perform microbiological analyses to verify the presence or absence of wood decay, and perform mechanical testing to determine residual property values. Provide current allowable working stresses for the lumber and the estimated ultimate strength of the lumber at the time of the collapse.

Additionally, inspect and document any grade stamps on the plywood formwork and perform appropriate mechanical testing on the plywood based on the visual inspections. Provide summaries and conclusions of our evaluation of the plywood formwork.

2. Introduction

Wood Advisory Services, Inc. (WAS, Inc.) was retained by the New York City Department of Buildings (NYCDOB) to evaluate the lumber and plywood concrete formwork associated with the 42nd floor collapse at 246 Spring Street, New York, NY. On-site inspections were performed by WAS, Inc. under the supervision of the NYCDOB on three different days. Other parties present during the WAS, Inc. inspections included representatives from Thornton Tomasetti and Bovis Lend Lease. The WAS, Inc. inspection dates and personnel present were as follows:

Inspection Date:	Representative Present:
May 28, 2008	Mr. Matthew Anderson
June 2, 2008	Mr. Matthew Anderson, Dr. Albert L. De Bonis
June 4, 2008	Mr. Matthew Anderson, Dr. Albert L. De Bonis

3. Inspections

During three separate on-site inspections, representatives from WAS, Inc. inspected all of the lumber and plywood which was being stored on the 40th floor, as well as, all of the lumber and plywood stored in two separate shipping containers at street level. The visual characteristics of all the plywood and lumber stored were documented. Any grade stamps observed were documented and as much of the lumber was visually graded as possible. Photographs were taken at the time of inspection and those photographs referenced in this report are provided in Appendix I.

3.1 Dimension Lumber

The lumber was visually graded according to the National Grade Rule for Dimension Lumber, also referred to as the NGR. All of the accredited lumber agencies in the United States and Canada, visually grade dimension lumber according to the NGR, regardless of species. A majority of the lumber inspected at Spring Street were nominal 3x4s with actual dimensions of approximately 2-1/2" x 3-1/2". Occasionally, a nominal 4x4 (i.e. 3-1/2" x 3-1/2"), or a scaffold plank, 2 x10 (i.e., 1-1/2" x 9-3/4"), was observed. In total, during the inspection, nearly 400 fragmented pieces of broken lumber were inspected.

In order to determine the visual grade of a single piece of dimension lumber, all four sides of the lumber, the full length, and at least one end must be visible. This is the only way, following the NGR, that a piece of lumber can be assigned a visual grade. However, most of the material inspected at Spring Street was in fragmented, broken pieces, essentially making the visual grading process impossible by industry standards. Therefore, whenever WAS, Inc. representatives inspected a piece of broken material, the grade controlling defect (such as knots or slope-of-grain), also referred to as the GCD, of that piece was documented and the grade of that fragmented piece was assigned based on that GCD. If no GCD was visible, then no visual grade was assigned to that piece and the piece was classified as no GCD, or "NGCD." Of the 396 fragmented pieces of lumber inspected, 184 were classified without a grade controlling defect. One could argue that these unclassified pieces should have been classified as select structural. However, it was our intent to determine the approximate distribution of actual grade characteristics and assign grades based on the worst characteristic observed. Therefore, arbitrarily assigning these pieces a grade of select structural would have no benefit to the objectives of this project.

Following the completion of this project, WAS, Inc. was provided Patent Construction Systems Drawing Number 4607K070 which appears to be the lumber and plywood specifications for the project at 246 Spring Street. A copy of this document is provided in Appendix V. A review of the lumber design values in this document and published allowable stresses for structural lumber indicated that the dimension lumber (3x4 and 4x4) should have been at a minimum No. 1 & Better (BTR) grade of a species grouping such as Douglas fir-larch, or a No. 2 dense southern pine. The current allowable stresses for these species groupings are published in the Supplement to the National Design Specification for Wood Construction. The published size adjusted base values are provided below. The inclusion of the spruce-pine-fir species grouping here will become evident subsequently in this report. In summary. the dimension lumber used on this project was spruce-pine-fir mill run quality. However, even select structural spruce-pine-fir will not meet the specifications.

Property	Drawing No. 4607K070 Required Design Values	Douglas fir - Larch No.1 & BTR	Southern Pine No. 2 Deuse	Spruce - Pine - Fir Select Structural
F_b	1,640 psi	1,800 psi	1,700 psi	1,875 psi
F_v	180 psi	180 psi	175 psi	135 psi*
$C_\perp$	625 psi	625 psi	660 psi	425 psi*
$C_{//}$	1,350 psi	1,783 psi	1,850 psi	1,610 psi
MOE	1,600,000 psi	1,800,00 psi	1,700,00 psi	1,500,00 psi*

* Values more than 5% below specified allowable property

3.2 Lumber • 3x4

A detailed list of the lumber visual grades observed during our inspection is provided in Appendix II. The 3x4 lumber was graded as "Structural Light Framing" and also as "Light Framing." These two visual grade classifications have slightly different allowable characteristics and size adjustments for design calculations. A summary of the visual grading results are provided below, however, this data is not directly applicable for use in design calculations due to the fact that wood decay was observed in many fragmented pieces and due to the levels of the resulting strength reductions found during mechanical testing. Both of these issues are discussed in sections 5.2 and 6.1 of this report.

- Total number of lumber pieces inspected = 396
- Visual grade summary of 3x4s - Structural Light Framing (2"- 4" thick, 2"- 4" wide)

Visual Grade	Pieces	Percentage
Select Structural	59	28%
No. 1	50	23%
No. 2	41	19%
No. 3	48	23%
Economy	14	7%
TOTAL	212	100%

- Total number of pieces inspected = 396
- Visual grade summary of 3x4s - Light Framing (2"- 4" thick, up to 4" wide).

Visual Grade	Pieces	Percentage
Construction	159	75%
Standard	39	18%
Utility	----	----
Economy	14	7%
TOTAL	212	100%

In addition to determining the visual grade of each piece of lumber, the failure characteristics of all the pieces, if present, were documented. Additionally, we documented factory cuts, field cuts, and holes when present even though they are not failure characteristics. The characteristics were defined as follows:

B	= Brash; consistent with decay or low specific gravity,
BK	= Brash (w/saw kerf),
T	= Tension, or typical bending failure,
BT	= Brash/tension; combination of B and T,
F	= Factory cut end (not an actual failure),
FC	= Field cut end (not an actual failure),
C	= Compression failure, and
H	= Hole cut into the lumber (not an actual failure).

Two summaries are provided below. The first summary represents all of the documented characteristics and the second summary represents only the failure characteristics (i.e., B, BK, T, and BT).

Summary of All 3x4 Lumber Characteristics Observed

Characteristic	Count	Percentage
B	86	11.5%
BK	3	0.5%
BT	182	25%
F	188	25.5%
FC	96	13%
T	168	23%
C	1	0%
H	10	1.5%
TOTAL	734	100%

Summary of all the 3x4 Failure Modes Only

Characteristic	Count	Percentage
B	86	20%
BT	182	42%
T	168	38%
TOTAL	436	100%

When the results from the previous 3x4 data were examined, two observations became apparent. First is the high percentage of low grade material (i.e., numerous economy pieces, No. 3, and Standard) and second is the high percentage of brashness present in the material examined (i.e., B and BT classifications). Brashness in wood is characterized by a fracture which progresses more or less across the grain (see photos 1 - 3) as opposed to failures that follow the grain. The presence of a brash failure is often associated with wood decay and/or pieces of wood with low specific gravity values. Brash failures are not typical in normal wood.

Two different visual grade classifications were provided in the summary tables for the 3x4 lumber. Visual grades were provided for Structural Light Framing, which includes Select Structural (SS), No. 1, No. 2, and No. 3, and apply to lumber that is 2 to 4 inches thick and 2 inches and wider. The use of visual grade design values for these grades requires a size adjustment be applied to the basic values which can be found in Table 4A of the National Design Specifications (NDS) for Wood Construction. The factors listed in Table 4A would be used to adjust the published characteristic value for 12" wide lumber to the 4" nominal width of the 3x4 lumber. The other visual grade classification provided in this report is Light Framing, which includes of Construction, Standard, and Utility grades for dimension lumber 2 to 4 inches thick and up to 4 inches wide. Use of these visual grades does not require an adjustment for size.

Dimension lumber which does not meet the minium requirements for either No. 3 (Structural Light Framing) or Utility (Light Framing) were classified as Economy grade, and have no published design values. One of the most distinct grade controlling characteristics documentcd during our inspections was slope-of-grain (SOG). We observed severe SOG in numerous pieces (photos 4 - 6) which resulted in down grading the lumber to either a No. 3 or Economy grade.

During our inspection, we did not observe any grade stamps on any of the 3x4 lumber examined. However, the name "LAUZON" (photo7) was observed on one single piece. This stamp appears to be associated with Marcel Lauzon, Inc., a Canadian company which produces lumber, including 3x4 lumber, just north of the Vermont border in Quebec. Additionally, numerous pieces of the 3x4 lumber were examined microscopically and two distinct species were identified, spruce and eastern-fir. Therefore, the lumber inspected may be classified as SPF since it appears to be manufactured in Canada. If the material were manufactured in the US, it would be classified as SPF-s which is assigned different design stresses then SPF. Additionally, since no grade stamps were observed on any of the fragmented pieces of lumber and the grading characteristics were so variable, the material was most likely "mill-run" lumber.

Even after classifying the visual grades for the 3x4 lumber population, the published design values would not apply to this material due to the presence of wood decay. Evidence of wood decay was visually observed in the lumber by the presence of brash failures and surface mycelium (photos 8, and 9). Verification of the presence of wood decay is provided and discussed in section 5.1 of this report, and the reductions in strength properties, as a result of the wood decay, are discussed in section 5.2. The overall allowable design stresses and the estimated ultimate stresses in the 3x4 lumber at the time of the collapse are also provided and discussed in section 6.1.

3.3 Lumber • 4x4s

Twenty pieces of nominal 4x4 lumber were inspected. Two grade stamps were observed on two different pieces. The stamps were as follows:

1. STAND&BTR, D-FIR, S-GRN, PLIB (photo 10), and
2. NO. 2, S-GRN, WWPA, D-FIR, MILL 266 (photo 11).

For 13 of the 4x4s, we were able to determine the visual grades. The results were as follows:

Visual Grade	Pieces	Percentage
Select Structural	1	7%
No. 1	3	23%
No. 2	8	63%
No. 3	1	7%
TOTAL	13	100%

All of the characteristics observed would have qualified for the STAND&BTR grade, including the sample graded as a No. 3. The No. 3 had a SOG of 1:7, which also qualifies as STAND&BTR.

Similar to the 3x4 lumber, WAS, Inc. personnel documented the characteristics of each 4x4. Nearly 60% of the material had factory cut ends or field cut ends. The actual failure modes included 3 brash, 8 combination brash/tension, and 4 tension only. The results are similar to the 3x4 lumber, with nearly 75% of the failures exhibiting brashness or a combination of brash and tension. These numbers are based on a significantly smaller population than the 3x4s, but never the less, indicate there may be decay present in some of the 4x4s, although we did not visually observe any mycelium on the surface of any of these members when we performed our inspection.

Summary of all the 4x4 Lumber Characteristics Observed

Characteristic	Count	Percentage
B	3	8.3%
BK	----	----
BT	8	22.2%
F	18	50%
FC	3	8.3%
T	4	11.1%
C	----	----
H	----	----
TOTAL	36	100%

Summary of all the 4x4 Failure Modes Only

Characteristic	Count	Percentage
B	3	20%
BT	8	53%
T	4	27%
TOTAL	15	100%

3.4 Other Lumber

There were two nominal 2x10 planks and two nominal 1x4s inspected as well. One of the 2x10 planks qualified as a No. 2, and the second plank was an on-grade scaffold plank; SPIB, DI-65, MEETS SCAFFOLD KD 19 OSHA 1910.28, #350. Neither of the 1x4s were visually graded since they do not qualify as dimension lumber. No evidence of wood decay was observed on either 2x10 or either 1x4.

3.5 Moisture Content of Lumber

The NYCDOB had requested that WAS, Inc. personnel provide an opinion regarding the storage conditions of the lumber prior to our inspection, and if that storage had any impact on our findings. Moisture content (MC) levels during our on-site inspection were consistently below 20%, which is generally considered the minimum threshold required to facilitate the growth of wood decay. During our three day inspection, we recorded nearly 60 MC values and only eight were above 20%, with the highest value recorded at 24.5%. The lumber we inspected was stored in clean shipping containers from February through May. The months of February and March consistently have temperatures below 60°F, whereas April and May would have temperatures more favorable to wood decay growth. However, most of the lumber testes exhibited MC values below the 20% threshold. In addition to adequate moisture levels, wood decay also requires an optimal temperature of approximately 60°F or greater. Below 60°F growth slows significantly. Wood decay can occur between 32°F and 60°F, but growth is limited particularly at the lower temperature levels. Storage in the containers would have significantly restricted drying of the lumber since the containers were enclosed with little ventilation or air circulation. Therefore, we wouldn't anticipate a significant difference in MC levels between February, when the lumber was initially stored, and May, when we inspected the lumber. Relative humidity values of 59% and 62% were recorded in both containers during our inspection which is equivalent to a MC level of approximately 12% at 70°F.

One final and critical piece of evidence we observed was the presence of wood decay on 3x4 lumber ribs which were still in use on the job site during our inspection. These ribs had not been kept in storage for four months (photos 12 and 13), and yet contained some mycelium growth on the surface similar to some of our observations of stored material.

Based on all the evidence discussed above, it is our professional opinion that the storage of the material between February and May had no effect on the dimension lumber with respect to promoting wood decay. The evidence gathered during our inspection and scientific literature do not warrant any reason to suggest otherwise.

3.6 Plywood

During our three day inspection, we inspected over 100 broken pieces of plywood of varying sizes. All of the concrete formwork was 5-ply plywood with melamine overlays on both faces which were marked either "Feldman Lumber" (photo 14), or "Mid-South Lumber Company" (photo 15). No visible grade stamps could be documented for this material since both faces were covered with a melamine overlay. One grade stamp was documented on several panels which did not have melamine overlays. The stamp read; Futter, Mill 332, Uni-Form, B-B Class (photo 16).
Several of the broken formwork panels had consistent linear failures which appeared to be punch-through failures (photos 17 - 19). Based on this consistent pattern, it appeared that these failures were caused by the steel column base plates (6" x 8") which had punched through the plywood panels. As a result of this observation, the NYCDOB requested that a concentrated load test be performed on the plywood to examine the load carrying capacity of the plywood formwork using a 6" x 8" steel column base plate retained from the site, and 3x4 framing at 16" on-center spacing.

Following the completion of this project, WAS, Inc. was provided Patent Construction Systems Drawing Number 4607K070 which appears to be the lumber and plywood specifications for the project at 246 Spring Street. A copy of this document is provided in Appendix V. A review of this specification indicates that the plywood, in order to conform to the specification, needed to meet the requirements of the APA, The Engineered Wood Association specifications for plyform class I, with B-B grade face & back veneers, and exterior adhesive and meet the requirements of PS1-95.

4. Laboratory Procedures

During our on-site inspection, we randomly selected some samples and systematically selected other representative samples for mechanical testing, microbiological analyses, and wood species identifications. At the request of the NYCDOB some of the 3x4 pieces were randomly selected for analysis using a random number generator. Other samples were specifically selected by WAS, Inc. personnel based on the presence of brashness and evidence of wood decay. Two groups of test specimens were selected for the laboratory analyses; the 3x4 lumber ribs and plywood. The plywood selected was neither randomly selected nor systematically selected. They were simply the only non-damaged full size sheets available for testing. All the samples retained were marked by representatives from the NYCDOB and Thornton Tomasetti. Each sample was returned to our laboratory by representatives form WAS, Inc. and were marked as follows:

3x4 Lumber Ribs	**Plywood**
TP1-A	TP8-A
TP2-A	TP9-A
TP3-A	TP10-A
TP4-A	PW4055
TP5-A (randomly selected)	
TP6-A (randomly selected)	
TP7-A (randomly selected)	
TB40215	
TB40146	
TB40244	
TB40189	
TB40143	

4.1 Microbiological Analyses

At WAS, Inc., microbiological activity, including evaluation of the presence of wood decay fungi, evidence of bacterial attack and the presence of sap stain fungi, and the condition of the wood cellular structure are conducted using a light microscope and the deterioration is documented using two simple classification systems.

Wood decay (i.e., the levels of hyphae observed microscopically) is classified as one or a combination of the following six categories: "none", "occasional", "light", "moderate" , "heavy", or "very heavy."

Category	**Definition of Classification**
None	Describes the lack of wood decay hyphae or evidence of wood decay in any view. Hyphae are root-like structures of wood decay fungi. The category "none" does not mean that no hyphae or evidence was present in the entire sample. The category "none" simply means that none were observed in the limited sections viewed microscopically.
Occasional	Describes the observation of hyphae in limited regions of the wood cells, but they were not observed in every view.
Light	Describes the observation of a limited network of hyphal growth or evidence of deterioration, but was not observed in every view.
Moderate	Describes an organized network of hyphae or evidence which was observed in most views but is limited to certain cells.
Heavy	Describes an organized network of hyphae or advanced evidence which was observed in every view and in practically all cells.
Very Heavy	Describes an extremely advanced network of hyphae or evidence which was observed in every view and in all cells.

Bacterial attack is difficult to analyze with a light microscope because of the extremely minute size of bacteria and their effects. However, some limited evidence of their attack can sometimes be observed and the evidence is classified as either present or absent. Sap stain fungi do not cause cellular degradation and they are classified as either present or absent.

A second simple classification system, used at WAS, Inc., describes the wood cellular structure of the microbiological samples. Four classes are used: "good", "fair", "poor", and "very poor."

Class	**Definition of Classification**
Good	Represents typical wood cellular structure.
Fair	Represents a condition where the structure of some wood cells has been compromised.
Poor	Represents the condition where the structure of most wood cells has been compromised.
Very Poor	Represents the most compromised level of cellular structure in which many types of wood cells are unrecognizable.

There are times when sectioning difficulties can occur during the preparation of microbiological samples and results in a "fair" classification of cellular structure, which may not indicate actual cellular deterioration. However, sectioning difficulties can also be indicative of the presence of wood decay. All analyses were conducted using a compound light microscope at magnifications of 100 to 400x.

All results from the microbiological analyses will be presented in Section 5.1 of this report.

4.2 Mechanical Testing

4.2.1 Lumber • 3x4

The mechanical testing methodology for evaluating the 3x4 lumber was performed in accordance with ASTM D 143, "Standard Test Methods for Small Clear Specimens of Timber." The mechanical properties evaluated, as directed by the NYCDOB and Thornton Tomasetti, were:

1. Modulus of Rupture (MOR) or bending strength,
2. Modulus of Elasticity (MOE),
3. Shear Parallel-to-Grain, (F_v) and
4. Compression perpendicular-to-grain ($C_{\perp}$).

Determination of MOR and MOE was performed in accordance with Section 8, "Static Bending." Shear parallel-to-grain was performed in accordance with Section 14, "Shear Parallel-to-Grain," and the compression tests were performed in accordance with Section 12, "Compression perpendicular-to-grain." All the tests were conducted on a Tinius Olsen, 10,000 lb. capacity universal bench top test machine which is calibrated annually and has not required any load cell adjustment in over 10 years (all certifications are available at our offices upon request).

During the week of September 15, 2008, numerous parties were present to witness the fabrication and testing of all the small clear test specimens. Microbiological analyses and wood species identifications were performed on September 18 and 19, 2008. The parties present and the dates they were present are as follows:

Name	**Dates Present**	**Company**
Mr. Matthew Anderson	09/15, 09/16, 09/17, 09/18, 09/19	Wood Advisory Services, Inc.
Dr. Albert De Bonis	09/15, 09/16, 09/17, 09/18, 09/19	Wood Advisory Services, Inc.
Ms. Caitlin Kevins	09/15, 09/16, 09/18, 09/19	Thornton Tomasetti
Mr. Perides Stivaros	09/15, 09/16	Feld, Kaminetzky & Cohen
Mr. Luis Valderruten	09/15, 09/17	Thornton Tomasetti
Mr. Guo Zhan (John) Wu	09/15, 09/16, 09/17	NYCDOB
Mr. Carl Schoenberger	09/17, 09/18, 09/19	Feld, Kaminetzky & Cohen
Mr. Walter Karon	09/18	R.L. Grunos
Mr. Ari Bauer	09/18	Dillinger, Miller & Torallo

All the results for the small clear tests were compared to historical small clear data published for spruce and eastern-fir grown in Canada as published in ASTM D 2555, "Standard Practice for Establishing Clear Wood Strength Values." Residual properties were determined by comparing the mean value of the test results to the mean value of the published data for that particular species. The test data obtained using the procedures described in this section will be discussed in Section 5.2 of this report

4.2.2 Plywood Concentrated Load Testing

Four 4' x 4' plywood samples were selected during our inspections to evaluate the capacity of the material when a load was applied to the plywood using one of the 6" x 8" steel column base plates. The panels were selected because they were the only large size panels we inspected which exhibited no apparent visible damage. A consistent and unique failure pattern was observed in several of the broken plywood panels inspected which was consistent with a punch through failure of the steel base plates (photos 17 - 19). Therefore, we elected to perform a modified ASTM test procedure to apply a concentrated static loading specific to the observed failure characteristics of the concrete formwork associated with the collapse at 246 Spring Street. This test method was designed to be used in conjunction with the APA - The Engineered Wood Association (APA-EWA) concentrated load requirements which require the application of a static concentrated load through a 3" diameter disk to minimum failure loads of 400 - 550 lbs. for roof and floor sheathing, not for concrete formwork panels. Therefore, our in-house plywood test assembly was modified to simulate the particular concentrated loads applied to the plywood concrete formwork assembly constructed at 246 Spring Street. Additionally, using the APA-EWA test standard, deflections are measured up to a 200 lb. concentrated load level. The NYC DOB requested deflection be measured up to and including punch through failure. Therefore, our in-house equipment also needed to be additionally modified to accomplish deflection measurement throughout the duration of each test.

The load was applied manually using a hand pump. The hydraulic capacity of the ram was rated to 10,000 lbs. maximum capacity. A test frame was constructed to imitate the 3x4 concrete formwork framing used at 246 Spring Street. Nominal 4x6 lumber was bandsawed at WAS, Inc. to a width of 2-1/2" which was the actual width of the 3x4 lumber ribs used at 246 Spring Street. Two types of loading conditions were evaluated as follows:

1. Base plate located at center of 16" span, interior edge of plate 11" from panel edge.
2. Base plate located at center of 16" span, interior edge ~24-26" from panel edge.

To calibrate the test assembly, a 10,000 lb. proving ring was used which was calibrated prior to the testing. Using the proving ring, we were able to develop an accurate linear correlation between the digital meter output display and the proving ring increments. Therefore, we were able to convert the digital meter outputs to actual failure loads.

Deflections were measured by projecting a laser beam on an engineering scale which was attached to the concentrated load base plate. Deflections were recorded at various load levels throughout the test until punch through occurred.

The concentrated load testing was performed at the laboratories of WAS, Inc. on January 21, 2009, and the following parties were present:

Name	**Company**
Mr. Matthew Anderson	Wood Advisory Services, Inc.
Dr. Albert De Bonis	Wood Advisory Services, Inc.
Mr. Luis Valderruton	Thornton Tomasetti
Mr. Carl Schoenberger	Feld, Kaminetzky & Cohen
Mr. Walter Karon	R.L. Grunos
Mr. Guo Zhan (John) Wu	NYCDOB

The test data obtained using the procedures described here will be subsequently discussed in Section 5 of this report and specifically in Section 5.3.

5. Results

The results of the microbiological analyses, wood species identifications, and the mechanical testing, are discussed in the following three sections (5.1, 5.2, and 5.3). Summaries of the laboratory analyses are provided in Tables 1, 2, 3a - 3f, and 4a - 4b, and the detailed results are provided in Appendices III and IV.

5.1 Microbiological Analyses & Wood Species Identifications

A total of twelve, 3x4 lumber cross sections were microscopically evaluated for wood species and the presence of wood decay. Each sample was evaluated using a cross sectional grid with 11 different locations. This provided the opportunity to evaluate the entire cross section. A schematic of the cross sectional grid and the 11 locations examined for each sample is provided in Appendix III. A summary of the microbiological analyses and wood species identifications is provided in Table 1.

Locations 1, 2, 3, and 4 (Schematic 1, Appendix III) were first evaluated during each microbiological analysis. If wood decay was observed at any of those locations, then we proceeded to the next depth of ½", or locations 5, 6, 7, and 8. If wood decay was present at any of these locations, we proceeded to locations 9 and 10, or a depth of 1". If applicable, we proceeded to the center, location 11. If no wood decay was documented at any surface location, then we did not evaluate the sample at the next depth. For example, if wood decay was observed at location 1, then location 5 was also examined, and so on. If no wood decay was observed at location 2, then a classification of "none" was provided for location 2 in Table 1, and locations 6 and 9 were marked "N/A" (i.e., not applicable or not analyzed).

A total of twelve cross sections were microscopically evaluated for wood species and microbiological wood decay. Seven of the samples were identified as spruce and five were identified as eastern-fir. There is a distinct microscopic characteristic present in western fir which can be used to differentiate these species from eastern-fir. Dark brown crystal-like extractives are visible in specific cells of western-fir but not eastern-fir. That distinct characteristic was not observed in any of the five samples identified as fir, therefore, each sample was further classified as eastern-fir. There are no distinct characteristics which can be used to differentiate the eastern and western spruce species. As was previously discussed in section 3.2, a "LAUZON" stamp was observed on one of the 3x4 lumber ribs. Research that we conducted found that Lauzon is actually a lumber company in Quebec, Canada and the full name is Marcel Lauzon, Inc. Based on our laboratory analyses and research, all evidence indicates that the 3x4 lumber ribs would be classified as SPF (Canadian design values) and not SPF-s (US design values).

Table 1
Results of the Microbiological Analyses & Wood Species Identifications of Twelve, 3x4 Lumber Cross Sections from the Concrete Formwork Collapse at 246 Spring Street, New York, NY.

Sample	Location	Wood Decay	Cellular Structure	Species
TP1-A	1	None	Good	Spruce
	2	None	Good	
	3	Light	Good	
	4	Modcrate-Light	Good	
	5	N/A	----	
	6	N/A	----	
	7	Light	Good	
	8	Occasional	Good	
	9	N/A	----	
	10	N/A	----	
	11	N/A	----	
TP2-A	1	Occasional-Light	Good	Spruce
	2	Occasional	Good	
	3	Occasional	Good	
	4	N/A	----	
	5	None	Good	
	6	None	Good	
	7	None	Good	
	8	N/A	----	
	9	N/A	----	
	10	N/A	----	
	11	N/A	----	

Table 1 (Continued)
Results of the Microbiological Analyses & Wood Species Identifications of Twelve, 3x4 Lumber Cross Sections from the Concrete Formwork Collapse at 246 Spring Street, New York, NY.

Sample	Location	Wood Decay	Cellular Structure	Species
TP3-A	1	None	Good	Spruce
	2	None	Good	
	3	Occasional-Light	Good	
	4	Occasional-Light	Good	
	5	N/A	----	
	6	N/A	----	
	7	None	Good	
	8	None	Good	
	9	N/A	----	
	10	N/A	----	
	11	N/A	----	
TP4-A	1	Moderate	Fair	Spruce
	2	None	Fair	
	3	None	Fair	
	4	Light	Fair	
	5	Light	Good	
	6	Light	Good	
	7	Knot - N/A	----	
	8	Light	Fair	
	9	Light	Fair	
	10	Occasional	Good	
	11	Occasional	Good	
TP5-A	1	None	Good	Spruce
	2	None	Good	
	3	Knot - N/A	----	
	4	Light	Fair	
	5	N/A	----	
	6	N/A	----	
	7	N/A	----	
	8	Occasional-Light	Good-Fair	
	9	N/A	----	
	10	None	Good	
	11	N/A	----	

Table 1 (Continued)
Results of the Microbiological Analyses & Wood Species Identifications of Twelve, 3x4 Lumber Cross Sections from the Concrete Formwork Collapse at 246 Spring Street, New York, NY.

Sample	Location	Wood Decay	Cellular Structure	Species
TP6-A	1	None	Good	Eastern-fir
	2	None	Good	
	3	None	Good	
	4	None	Good	
	5	N/A	----	
	6	N/A	----	
	7	N/A	----	
	8	N/A	----	
	9	N/A	----	
	10	N/A	----	
	11	N/A	----	
TP7-A	1	Occasional	Good	Eastern-fir
	2	Light	Good	
	3	Knot - N/A	Good-Fair	
	4	Moderate-Heavy	Fair	
	5	Light	Good	
	6	None	Good	
	7	None	Good	
	8	Light	Fair	
	9	None	Fair	
	10	None	Fair	
	11	N/A	----	
TB40215 (Micro 8)	1	Occasional	Good	Eastern-fir
	2	Occasional	Good	
	3	None	Good	
	4	None	Good	
	5	N/A	----	
	6	N/A	----	
	7	N/A	----	
	8	N/A	----	
	9	N/A	----	
	10	N/A	----	
	11	N/A	----	

Table 1 (Continued)
Results of tbe Microbiological Analyses & Wood Species Identifications of Twelve, 3x4 Lumber Cross Sections from the Concrete Formwork Collapse at 246 Spring Street, New York, NY.

Sample	Location	Wood Decay	Cellular Structure	Species
TB40416 (Micro 9)	1	Occasional	Good	Eastern-fir
	2	Light	Good	
	3	Occasional	Good-Fair	
	4	Light	Good-Fair	
	5	None	Good	
	6	Light	Good	
	7	Occasional	Good	
	8	Occasional	Good	
	9	None	Good	
	10	None	Good	
	11	N/A	----	
TB401244 (Micro 10)	1	Occasional	Good	Spruce
	2	Occasional	Good	
	3	Occasional	Good	
	4	Occasional	Good	
	5	N/A	----	
	6	N/A	----	
	7	N/A	----	
	8	N/A	----	
	9	N/A	----	
	10	N/A	----	
	11	N/A	----	
TB 40189 (Micro 11)	1	Occasional	Good	Spruce
	2	Light	Good	
	3	None	Good	
	4	None	Good	
	5	N/A	----	
	6	Light-Moderate	Good	
	7	Occasional	Good	
	8	N/A	----	
	9	Light-Moderate	Good	
	10	N/A	----	
	11	Occasional	Good	

Table 1 (Continued)
Results of the Microbiological Analyses & Wood Species Identifications of Twelve, 3x4 Lumber Cross Sections from the Concrete Formwork Collapse at 246 Spring Street, New York, NY.

Sample	Location	Wood Decay	Cellular Structure	Species
TB40143 (Micro 12)	1	Light	Good-Fair	Eastern-fir
	2	Light	Good-Fair	
	3	Light	Good-Fair	
	4	Light	Good-Fair	
	5	Occasional	Good-Fair	
	6	Occasional	Good-Fair	
	7	Light	Good-Fair	
	8	Light	Good-Fair	
	9	Occasional	Good-Fair	
	10	Occasional	Good-Fair	
	11	N/A	----	

Evidence of wood decay was documented in eleven of the twelve samples evaluated. Of the 11 samples which exhibited wood decay, five samples contained decay limited to the surface area, and seven samples contained wood decay that ranged from a depth of ½" up to the center, or 1-½" depth.

Sample TP6-A was the only sample which exhibited no evidence of wood decay. Samples TP2-A, TP3-A, TP5-A, TB40215 (micro 8), and TB40244 (micro 10), each exhibited evidence of wood decay which was limited to the surface region (i.e., only locations 1, 2, 3, and 4 exhibited wood decay and no evidence observed at locations 5, 6, 7, and 8). The level of decay documented in the surface region of these five samples was either occasional or light with good cellular structure (see photos 20 and 21).

Seven samples exhibited light to heavy wood decay anywhere from the ½" depth in samples TP1-A, TP4-A, TP7-A, TB40416 (micro 9), and TB40143 (micro 12) (see photos 22 and 23). Evidence of wood decay was observed to depths of 1" and even at the center of samples TP4-A and TB40189 (micro 11).

The presence of wood decay resulted in strength reductions in some of the samples discussed above. Additional discussion of these strength reductions is provided in Section 5.1. Many of the samples chosen by WAS, Inc. personnel were selected because they exhibited evidence of brashness. The presence of wood decay in the samples evaluated, verifies that the brashness observed was due in part to the presence wood decay.

As was previously discussed in Section 3.2, a high percentage of the bending failures documented during our inspection were brash (B) or a combination of brash and typical bending (BT). The laboratory analyses in combination with our inspection observations are important, because the laboratory analyses verified the presence of wood decay in several samples that exhibited brashness. In addition to our inspection of the material in the shipping containers, we also observed brash failures in 3x4 ribs which were currently being used (not a part of the collapse) in the construction formwork system during our on-site inspection of floors 40-42 (see photos 12 and 13). The reduction in strength as a result of the wood decay will be discussed in Section 5.2 and the overall implications associated with the visual grades is provided in Section 6.

5.2 Mechanical Test Results • 3x4 Lumber

Eleven of the 3x4 lumber samples retained by WAS, Inc. were used to fabricate small clear test specimens. The 12th sample (TB40143, or micro 12) was only a short, 12" long section of a failure. Therefore, no test specimens could be fabricated from this sample.

Instead, only microscopic analyses were performed on TB40143 (micro 12) and light levels of wood decay were verified in this sample.

The mechanical properties evaluated for the 3x4 lumber were static bending, MOR or bending strength, MOE, shear parallel-to-grain, and compression perpendicular-to-grain at 0.4" deflection. With each lumber section, we first attempted to fabricate two static bending test specimens (1" x 1" x 16") then, if possible, two shear parallel-to-grain test specimens (2" x 2" x 2-1/2") then, if possible, one compression perpendicular-to-grain test specimen (2" x 2" x 6"). The results of the test specimen fabrication process which includes the numbered and marked test specimens fabricated from each 3x4 lumber sample and for each mechanical properly are provided in Table 2. Missing test specimens are either the result of insufficient material or they were culled due to the presence of strength reducing characteristics.

Table 2
Summary of Fabricated Specimens to be Tested Using
ASTM D 143 Small Clear Procedures & to Undergo Microbiological Analyses.

3x4 Lumber Sample:	Static Bending MOR/MOE	Shear∥	Compression⊥
TP1-A	1-1 1-3	1-1	
TP2-A	2-2 2-3	2-1	2-1
TP3-A	3-1 3-2	3-1 3-2	3-1
TP4-A	4-1 4-2	4-1 4-2	
TP5-A	5-1	5-1	5-1
TP6-A	6-2	6-1 6-2	6-1

Table 2 (Continued)
Summary of Fabricated Specimens to be Tested Using
ASTM D 143 Small Clear Procedures & to Undergo Microbiological Analyses.

3x4 Lumber Sample:	Static Bending MOR/MOE	Shear//	Compression⊥
TP7-A	7-1 7-2 7-3	7-1 7-2	7-1
TB40215 (micro 8)	8-1 8-2	8-1	
TB40146 (micro 9)	9-2 9-3		
TB40244 (micro 10)	10-1		
TB40189 (micro 11)	11-1 11-2	11-1 11-2	11-1

A summary of the small clear test results is provided in Tables 3a - 3f. Since two different species were identified in the lumber samples, then two different comparisons were made for each property. The evidence from our inspections, analyses, and research strongly indicates the lumber was manufactured in Canada. Therefore, it was necessary to calculate, for each species, weighted mechanical properties based on the volume of spruce and fir standing timber in Canada published in ASTM D 2555. There are four species of spruce harvested for lumber in Canada and two species of fir. Based on the volume of standing timber for each species group (i.e., spruce and fir), we calculated weighted means for MOR, MOE, shear//, and compression perpendicular-to-grain at 0.4". Once our tests were completed, we compared our small clear test results to the historical weighted values published for spruce and fir grown in Canada at an adjusted moisture content (MC) level of 12%. Table 3a and 3b, 3c and 3d, and 3e and 3f are the summarized results for MOR and MOE, shear parallel-to-grain, and compression perpendicular-to-grain at 0.4" deflection for spruce and fir respectively.

As was previously discussed in this report, seven samples were identified as spruce and five were identified as eastern-fir. The results discussed herein are for comparison purposes only. The actual tested strength values listed in each summary table are not to be used as design stresses, working stresses, or ultimate loads for design purposes. Those values will be discussed in Section 6.1 of this report.

The mean MOR and MOE values for the spruce test specimens were 9,623 psi, and 1.46 x 10^6 psi respectively (Table 3a). The mean residual values were 0.88 for MOR and 0.92 for MOE. The range of residual values for MOR was 0.71 to 1.00, and 0.70 to 1.00 for MOE. The mean MOR and MOE values for the fir test specimens were 8,640 psi and 1.47 x 10^6 psi respectively (Table 3b). The mean residual values were 0.98 and 0.96. The range of residual values for MOR was 0.93 to 1.00 and 0.88 to 1.00 for MOE.

The mean shear parallel-to-grain for the spruce test specimens was found to be 1,205 psi with a mean residual value of 0.94. The residual values ranges from 0.75 to 1.00. The mean shear strength for the fir test specimens was found to be 1,126 psi, with a mean residual value of 0.99 and a range of residual values from 0.97 to 1.00.

The compression perpendicular-to-grain results varied considerably for the spruce and fir test specimens. The mean compression at 0.4" deflection was 773 psi with a mean residual value of 0.81. The range of residual values varied from 0.69 to 1.00. The mean compression at 0.4" deflection result for the fir test specimens was 495 psi. Only two compression test specimens could be fabricated from the 3x4 fir lumber samples. The residual values were 0.56 and 0.58 which resulted in a mean value of 0.57.

Table 3
Summary of the ASTM D 143 Small Clear Tests Performed on the 3x4 Lumber Samples from 246 Spring Street (all values reported at a MC of 12%).

3a. Static Bendiug (Spruce)

Sample	MOR (psi)	MOE ($x10^6$ psi)	Residual MOR	Residual MOE	SG
1-1 1-3	7,842 9,447	1.36 1.39	0.74 0.89	0.90 0.92	0.36 0.36
2-2 2-3	8,110 8,053	1.28 1.06	0.76 0.76	0.85 0.70	0.32 0.33
3-1 3-2	12,303 11,768	1.55 1.69	1.00 1.00	1.00 1.00	0.48 0.45
4-1 4-2	7,550 8,530	1.43 1.14	0.71 0.80	0.95 0.75	0.40 0.37
5-1	10,561	1.51	0.99	1.00	0.41
10-1	9,693	1.68	0.91	1.00	0.42
11-1 11-2	10,555 11,070	1.79 1.68	0.99 1.00	1.00 1.00	0.47 0.42
Mean	**9,623**	**1.46**	**0.88**	**0.92**	**0.40**

3b. Static Beuding (Eastern-fir)

Sample	MOR (psi)	MOE ($x10^6$ psi)	Residual MOR	Residual MOE	SG
6-2	9,800	1.58	1.00	1.00	0.38
7-1 7-2 7-3	7,823 10,033 10,846	1.26 1.82 1.68	0.94 1.00 1.00	0.88 1.00 1.00	0.35 0.40 0.39
8-1 8-2	8,823 8,180	1.49 1.17	1.00 0.98	1.00 0.82	0.36 0.34
9-2 9-3	8,840 7,779	1.42 1.46	1.00 0.93	0.99 1.00	0.35 0.38
Mean	**8,640**	**1.47**	**0.98**	**0.96**	**0.37**

3c. Shear$_f$ (Spruce).

Sample	Shear Strength (psi)	Residual Value	SG
1-1	1,109	0.94	0.33
2-1	891	0.75	0.31
3-1 3-2	1,573 1,543	1.00 1.00	0.42 0.42
4-1 4-2	1,178 1,162	1.00 0.98	0.35 0.37
5-1	1,286	1.00	0.36
11-1 11-2	1,000 1,165	0.85 0.99	0.37 0.38
Mean	**1,205**	**0.94**	**0.37**

3d. Shear$_f$ (Eastern-fir).

Sample	Shear Strength (psi)	Residual Value	SG
6-1 6-2	1,251 1,244	1.00 1.00	0.36 0.36
7-1 7-2	1,088 1,156	1.00 1.00	0.36 0.37
8-1	889	0.97	0.33
Mean	**1.126**	**0.99**	**0.36**

3e. Compression $_{\perp}$ @ 0.4" (Spruce).

Sample	Compression Strength (psi)	Residual Value	SG
2-1	688	0.69	0.34
3-1	1,110	1.00	0.42
5-1	798	0.79	0.39
11-1	762	0.76	0.42
Mean	**773**	**0.81**	**0.39**

3f. Compression $_{\perp}$ @ 0.4" (Eastern-fir).

Sample	Compression Strength (psi)	Residual Value	SG
6-1	486	0.56	0.36
7-1	504	0.58	0.34
Mean	**495**	**0.57**	**0.35**

A detailed list of all the test results is provided in Appendix III. The results are color coded with various shades of green which represent the levels of wood decay observed in each sample. Bending strength reductions up to 30%, or 0.70 residual values, were observed in three of the spruce test specimens (TP1-A, TP2-A, TP4-A). All of these lumber samples were selected by WAS, Inc. personnel during our first inspection of the material stored on the 40th floor. These samples were specifically selected because they exhibited evidence of wood decay. Wood decay was also observed in TP3-A, however, no reductions were found when compared to the historical data. This result may be somewhat misleading for the following reason. Our comparisons are based on mean values, therefore, it is very possible that the original strength of TP3-A was higher than the published mean (i.e., 50% chance) for spruce, and that the effects of the decay were masked.

Samples TP5-A, TP6-A, and TP7-A were randomly selected from material on the 40th floor by the NYCDOB. Wood decay was verified in two of the three test specimens and strength reductions were found in TP7-A.

The remaining samples were selected by WAS, Inc. personnel during our inspection of the material in both shipping containers. Wood decay and slight strength reductions were found in three of the four samples. The 12th sample was not mechanically evaluated, but wood decay was observed to the center of that sample (TB40189, Table 1).

The results provided within this section and their ramifications will be discussed in section 6.1. Current working design stresses and approximate actual strengths at the time of the collapse will be provided.

5.3 Concentrated Load Testing • Plywood

During our on-site inspection, as was previously discussed in section 4.3.2, we observed a consistent and unique failure pattern which appeared to be a punch through failure of the steel column support base plates (photos 17 - 19). Therefore, it was recommended to perform a modified test procedure following ASTM E 661-88. That ASTM standard was specifically designed for concentrated load testing of floor and roof sheathing using a 3" diameter steel disk. The base plates associated with the concrete formwork at 246 Spring Street were 6" x 8". During our testing, we simply followed the ASTM E 661 test procedures except we replaced the 3" diameter disk with an actual 6"x8" base plate we retained from 246 Spring Street during our inspections. Additionally, the tests were continued until punch through occurred.

One additional request from the NYCDOB for our testing protocol was recording deflection measurements to failure. To measure deflection, we attached an engineers scale to the top of the base plate and set up a laser level to measure the base plate displacement during our load application. Therefore, we were able to provide load/deflection data where the deflection represented base plate displacement and not a direct deflection measurement of the plywood. A summary of the test results is provided in Table 4a and 4b and all the load/deflection data and charts, along with the maximum loads, is provided in Appendix IV.

The test procedure used for the testing and a list of witnesses present were provided previously in section 4.2.2. On the day of the testing, we performed the static concentrated loading on two types of test specimens which was also discussed in section 4.2.2.

Panels TP8, TP9, and TP10 were 5-ply formwork panels with melamine overlays on both faces of each panel, resulting in an average thickness of 0.65 inches. Therefore, the panels are likely 5/8" panels. Sample PW4055 was a 4-ply "UNI-FORM" panel and had a grade stamp that indicated the panel was B-B, Class-1, manufactured by Futter, Mill 332. Test panel PW4055 had no legible thickness on the grade stamp, but the thickness was measured to be 0.60-0.61. Therefore, the manufactured thickness is either 19/32", or 5/8".

For loading condition #1, with the base plate located at the center of the 16" span, and the interior edge of the base plate 11" from the edge of the panel, test specimens TP8-A - #1, TP8-A - #2, and TP9-A - #2 demonstrated maximum failure loads of 4,988 lbs, 5,151 lbs, and 4,857 lbs, respectively. Panel test specimen PW4055 - #2 resulted in a maximum failure load of 3,586 lbs. The failure modes of each panel were punch through failures (photos 24 - 26)and were consistent with the panel failures we observed on several panels during our on-site inspection (photos 17 - 19).

For loading condition #2, with the base plate located at the center of the 16" span and the interior edge of the base plate approximately 20" to 24" from the panel edge, test specimen TP10-A and TP9-A demonstrated maximum failure loads of 8,967 lbs and 6,765 lbs, respectively. The maximum failure load of panel PW4055 - #1 was 3,716 lbs.

Table 4

Summary of the Static Concentrated Load Test Results for Four Panels from 246 Spring Street.

4a. Loading Condition #1 • 2'x4' Test Specimen with Base Plate at Center of 16" Span & Interior Edge of Base Plate 11" from Panel Edge.

Sample	Thickness (in.)	Maximum Load (lbs.) (Punch Through)	Deflection at Maximum Load (in) (Punch Through)
TP8-A #1	0.65	4,988	0.73
TP8-A #2	0.64	5,151	1.70
TP9-A #2	0.65	4,857	1.70
PW4055 #2	0.61	3,586	0.63
Mean	----	4,646	1.19

4b. Loading Condition #2 • 2'x4' Test Specimen with Base Plate at Center of 16" Span & Interior Edge of Base Plate 20"-24" from Panel Edge.

Sample	Thickness (in.)	Maximum Load (lbs.) (Punch Through)	Deflection at Maximum Load (in) (Punch Through)
TP10-A	0.65	8,697	1.00
TP9-A	0.65	6,765	0.90
PW4055 #1	0.61	3,753	0.60
Mean	----	6,393	0.83

4c. Loading Condition #1 and #2 Combined.

Sample	Maximum Load (lbs.) (Punch Through)	Deflection at Maximum Load (in) (Punch Through)
Overall Mean	**5,394**	**1.04**

6. Discussion

6.1 Lumber • 3x4

Allowable Working Stresses & Approximate Load Carrying Capacity at Failure

The NYCDOB had requested that WAS, Inc. provide the allowable working stresses of the 3x4 lumber at the time of failure, and the approximate ultimate load carrying capacity of the lumber at failure.

The allowable design values published in the NDS Supplement for SPF apply to the 3x4 lumber which is the subject of this investigation. For design purposes, a standard requirement of using published design stresses is that the lumber to which these design stresses are applied is free of wood decay. This is due to the fact that strength reductions in lumber caused by decay with varying amounts of decay in that lumber are unknown and the brash behavior of decayed lumber is unpredictable. This project, however, differs from a normal design-build project because attempts are being made here to establish contributing factors to the failure of a structural system rather than designing a new system or building. Thus, we have developed an adjustment for the presence of and degree of decay observed during the microbiological analysis, and the strength reductions found during the mechanical testing performed on the 3x4 samples. Additionally, since we are investigating a structural collapse, we recommend the use of the lowest residual values found for each property evaluated. Therefore, residual factors of 0.70 for F_b, 0.70 for MOE, or E, and 0.75 for F_v should be applied to the 3x4 dimension lumber used in the concrete formwork system that collapsed at 246 Spring Street.

The residual values for the compression perpendicular-to-grain test results appear to have been significantly affected by grain angle in two of the eastern fir test specimens and one spruce test specimen. Reductions of 40% in compression perpendicular-to-grain strength have been found to be associated with a growth ring angle of 45°. Every attempt was made during our testing to fabricate the compression test specimens with growth ring angles at 90°, however, this was not always possible since we were limited by using lumber in commercial size. Test specimens 6-1 and 7-1 had growth ring angles near 45° and test specimen 2-1 had some distorted grain. Therefore, test specimens 6-1, 7-1, 2-1 were removed from the analysis. After accounting for this ring angle anomaly, we recommend using a residual factor of 0.85 for compression perpendicular grain (mean residual values of 1.00, 0.79, and 0.76 for the remaining compression test specimens). Compression perpendicular grain is always reported as a mean value.

A total of 7% of both visual grade populations for the 3x4 lumber were found to only qualify for Economy grade, primarily as a result of excessive SOG (greater than 1:4 as allowed in No. 3 and Standard grades). Slope-of-grain has a significant effect on bending strength. The relationship between SOG and strength is exponential. Significant reductions occur especially at SOG's steeper than 1:8. The strength ratio published for a SOG of 1:8 in ASTM D 245 is 53% of the strength of straight grained lumber for bending strength. A strength ratio is the ratio between the strength of wood containing particular strength reducing characteristics, such as slope-of-grain, and the strength of wood without those strength reducing characteristics. At a SOG of 1:6, the bending strength drops to 40% when compared to straight grain lumber. If this data were extrapolated to 1:4, the ratio would be approximately 25%. During our inspection, we observed SOG's of 1:3 and 1:2 on several pieces we classified as economy which would correspond to strength ratios of approximately 10% - 15% of straight grained lumber. As a result, we can only provide estimates rather then actual computed design stresses and ultimate stresses for the Economy grade lumber. Furthermore, the only data provided in ASTM D 245 on the effects of SOG on strength are for bending strength and compression parallel-to-grain. Therefore, we can only provide data for MOR and F_b in this report for Economy grade material.

Table 5 provides a list of the applicable working design stresses of all the 3x4 lumber graded during our inspection and Table 6 provides an approximate estimate of the ultimate stresses at the time of the collapse. The values provided are F_b, E, F_v, and $Fc_{\perp}$ for SS, No. 1, No. 2, No. 3, CONST, and STAND visual grades. There are no published values for Economy material. However, 14 pieces of lumber were classified as "ECON" because of SOG's greater than 1:4. To provide estimates of design stresses and approximate ultimate stresses for these pieces, we reviewed ASTM D 245, "Standard Practice for Establishing Structural Grades & Related Allowable Properties for Visually Graded Lumber," Table 1, "Strength Ratios Corresponding to Various Slopes of Grain." Additionally, we reviewed the underlying data that was used to develop Table 1 in ASTM D 245, as well as other industry data on the effects of SOG on strength properties. The only strength properties based on SOG provided in Table 1 of ASTM D 245 are applied to bending strength and compression parallel-to-grain. Therefore, we have only provided estimates for F_b in the ECON grade in Tables 5 and 6 of this report.

The working design values listed in Table 5 are provided for Structural Light Framing (i.e., SS, No. 1, No. 2, and No. 3 with a size adjustment to 3x4 lumber) and Light Framing (i.e., CONST and STAND with no size adjustment necessary). The published values in the NDS for SPF are provided in the first set of columns under the heading "Value Published in NDS." The second set of columns under the heading "Adjustments for Decay/Size," lists the adjustment factors for the effects of wood decay (i.e., 0.70 for bending strength and modulus of elasticity, 0.75 for shear, and 0.85 for compression perpendicular-to-grain) and for size (i.e., 1.5 for SS, No. 1, No. 2, and No. 3) since the values published in the NDS for structural joists and planks are at a characteristic width of 12". After applying these adjustments, the allowable design stresses for F_b', E', F_v', and $Fc_\perp'$ are provided in the last four columns of Table 5 for each visual grade. These values are applicable for design purposes based on our laboratory analyses. If this data were to be used to design this system, we would recommend using a visual grade class of ECON & Better. However, the only property that could be provided for the Economy grade would be F_b. The effect of slope-of-grain is only reported for bending strength and compression parallel-to-grain in ASTM D 245. A more reasonable procedure would be to eliminate Economy grade material from the lumber population and use either Standard and Better or No. 3 and Better material.

Table 5
Summary of the Allowable Working Design Stresses for the 3x4 SPF Lumber Associated with the Concrete Formwork Collapse at 246 Spring Street.

Visual Grade	Value Published in NDS (psi)				Adjustments for Decay/Size[1]				Current Allowable Stresses (psi)			
	F_b	E	F_v	$Fc_\perp$	F_b	E	F_v	$Fc_\perp$	F_b'	E'	F_v'	$Fc_\perp'$
SS	1,250	$1.5x10^6$	135	425	0.70x1.5	0.70	0.75	0.85	1,300	$1.1x10^6$	100	350
No. 1	875	$1.4x10^6$	135	425	0.70x1.5	0.70	0.75	0.85	925	$1.0x10^6$	100	350
No. 2	875	$1.4x10^6$	135	425	0.70x1.5	0.70	0.75	0.85	925	$1.0x10^6$	100	350
No. 3	500	$1.2x10^6$	135	425	0.70x1.5	0.70	0.75	0.85	525	$0.8x10^6$	100	350
CONST	1,000	$1.3x10^6$	135	425	0.70	0.70	0.75	0.85	700	$0.9x10^6$	100	350
STAND	550	$1.2x10^6$	135	425	0.70	0.70	0.75	0.85	375	$0.8x10^6$	100	350
ECON	275	----	----	----	0.70	----	----	----	200	----	----	----

[1] Adjustments for decay: F_b x 0.70
E x 0.70
F_v x 0.75
$Fc_\perp$ x 0.85
Adjustment for size: F_b x 1.5
Adjustment for SOG - Economy = STD x 0.5

The values provided in Table 6 are values resulting from calculations which were performed to estimate the ultimate stresses in the 3x4 lumber at the time of the collapse. The first four columns, "Unrounded Stress," represent the unrounded values from the columns under the heading "Current Allowable Stresses" in Table 5. The second four columns in Table 6, "Removal of GAFs," list values for F_b L5%, F_v L5%, E$\bar{x}$, and $Fc_{\perp}\bar{x}'$. The L5% notation is referred to as the lower 5th percentile limit. When calculating wood design stresses for strength, the L5% value is used as the basic strength of that property, rather than the mean ($\bar{x}$). The mean values are only applicable to serviceability properties, such as E and $C_{\perp}$. For simplification and safety, selection of this near minimum value (L5%) insures that approximately 95% of the material is stronger than that level of strength and represents the weakest link in the population of strength values.

Table 6
Summary of the Approximate Ultimate Stresses for the 3x4 Lumber Associated with the Concrete Formwork Collapse at 246 Spring Street[1] (all values reported in psi units).

Visual Grade	Unrouded Stress (from table 5) (psi)				Removal of GAFs Ultimate Stress = L5% or $\bar{x}$ (psi)				Mean Ultimate Stress = $\bar{x}$ (psi)			
	F_b'	E'	F_v'	$Fc_{\perp}'$	F_b L5%	E$\bar{x}$	F_vL5%	$Fc_{\perp}\bar{x}$	$F_b\bar{x}$	E	$F_v\bar{x}$	$Fc_{\perp}\bar{x}$
SS	1,313	1.05x10^6	101	361	2,757	0.98x10^6	202	603	4,683	0.98x10^6	262	603
No. 1	919	0.98x10^6	101	361	1,930	0.92x10^6	202	603	3,278	0.92x10^6	262	603
No. 2	919	0.98x10^6	101	361	1,930	0.92x10^6	202	603	3,278	0.92x10^6	262	603
No. 3	525	0.84x10^6	101	361	1,103	0.79x10^6	202	603	1,873	0.79x10^6	262	603
CONST	700	0.91x10^6	101	361	1,470	0.86x10^6	202	603	2,496	0.86x10^6	262	603
STD	385	0.84x10^6	101	361	809	0.79x10^6	202	603	1,374	0.79x10^6	262	603
ECON[2]	193	----	----	----	405	----	----	----	689	----	----	----

[1] Notations for stresses in chart are as follows:

F_b', E', F_v', and $Fc_{\perp}'$ are each the unrounded values from Table 5.
F_bL5% = is the lower 5th percentile values after removal of the general adjustment factor
F_vL5% = is the lower 5th percentile values after removal of the general adjustment factor
$F_b\ \bar{x}$ = is the approximate mean based on coefficient of variation = 0.25
$F_v\ \bar{x}$ = is the approximate mean based on coefficient of variation = 0.14
E$\bar{x}$ and $Fc_{\perp}\bar{x}$ = is the approximate mean after removal of the general adjustment factor (0.94 for E and 1.67). This property is always reported as a mean value, not based on L5% calculations.

[2] The only SOG data allowable for adjustment of economy lumber is for bending strength.

In order to estimate ultimate properties from published allowable properties in the NDS one must remove certain adjustment factors for items such as duration of load and a true safety factor for unknown job site conditions. These are called the general adjustment factors (GAFs). In the case of bending stresses, the general adjustment factor for F_b, is equal to 2.1. Therefore, to derive an ultimate stress from an allowable design stress in bending, one must remove this GAF by multiplying the published design value by 2.1. For purposes of this report, we multiplied the value in column 1 of Table 6, F_b', by the 2.1 general adjustment factor. Therefore, the value provided in column 5 of Table 6, F_bL5%, is the unrounded ultimate lower 5th percentile stress in bending after adjusting the NDS design value for size and stress the effects of wood decay found during the testing for this project. Similar adjustments for different issues are made to the other properties of interest listed in Table 6. A complete discussion of allowable property development for wood is beyond the scope of this report, thus, rather than going into detail, the second set of 4 columns in Table 6 reflect removal of each of the GAFs from each allowable property resulting in ultimate stresses for each grade of lumber. An additional calculation was then made to estimate the mean ultimate stresses from the 5th percentile stresses for F_b and F_v and are results provided in the last four columns (9 - 12) under the heading "Allowable Mean Ultimate Stresses." The final calculation was performed assuming a coefficient of variation of 25% for bending strength, 14% for shear, and 16% for compression perpendicular-to-grain and applying the standard statistical conversion for equating mean values to standard deviations and coefficients of variation.

For purposes of ultimate stress calculations the weakest link in the group is the L5% value for the ECON grade listed as 405 psi. Again, the L5% values provided in the second set of columns in Table 6, "Removal of GAFs," represent the approximate ultimate stress levels at the lower 5th percentile level of the population. This is the "weakest link" value for all practical purposes, for the Economy grade representing the lowest strength levels of all the material. Mean values are provided in the table, but <u>do not</u> represent the population strength. The population strength for wood is governed by the L5% values.

Although the L5% exclusion value is technically the most important and most appropriate value to use for estimates of ultimate strength for the determination of failure, WAS, Inc. was also requested to provide an estimated mean strength value for the lumber used at 246 Spring Street. As previously described, the estimated mean values are provided in columns 9-12 in Table 6 for each property and grade. Since the lumber supplied was mill run material, an overall mean value can only be estimated by developing a weighted value based on the number of lumber pieces within each visual grade as we observed during the inspection. Therefore, by combining the number of pieces of each grade observed with grade controlling defects (212 in total) from section 3.2 of this report, with the estimated mean ultimate strengths in Table 6, which were adjusted downward based on the mechanical testing performed in our laboratory, an estimated mean ultimate strength of 3,132 psi was computed for F_b, 262 psi for F_v, and 603 for $Fc_{\perp}$ and 916,000 psi for E.

6.2 Plywood - Ultimate Loads & Nailing Pattern

As reported in section 5.3, the plywood failure loads ranged from 3,586 lbs. to 4,988 lbs. with a mean of 4,646 lbs. for loading condition #1, and 3,716 lbs to 8,697 lbs. with a mean of 6,393 lbs. for loading condition #2. The overall combined mean for both loading conditions was 5,394 lbs. In addition to maximum load (punch through), deflections at punch through were also measured. For loading condition #1, the mean deflection at punch through was 6.49". For loading condition #2, it was 6.23" with a combined mean of 6.38". Loading condition #1 consisted of aligning the base plate at the center span between two joists spaced 16" on-center, and the interior edge of the base plate 11" from the panel edge. Loading condition #2 also aligned the base plate at the center span, however, the interior edge of the base plate was located 20" to 24" from the panel edge. The ultimate load results were significantly different for the concrete formwork plywood panels TP8, TP9, and TP10 than for panel PW4055. Many of the concrete formwork panels assessed during our inspection exhibited linear failure patterns consistent with base plate punch through failures (photos 17-19). The testing failure patterns were similar to those observed during our inspection (photos 24-26).

Therefore, it is our professional opinion that the results of our modified concentrated load testing simulates the actual loads to the plywood forms as occurred in service and, thus, the ultimate load carrying capacity of the concrete formwork plywood panels observed during testing are representative of the actual loads to the plywood panels that occurred during the collapse at 246 Spring Street.

The nailing pattern used for the plywood testing was at 12" intervals around the entire panel during our testing, as well as the interior of the panel. The nailing pattern observed during our inspection was not exactly at 12" increments, however, for all practical purposes, this is the pattern selected for the tests to insure that all tests were consistent with each other. The spacing documented during our inspection ranged from 3" to 20" around the panel edges with an average spacing of 9-1/4". Nailing was primarily observed around the edges of the panels and not within the field of the panels.

7. Summary & Opinions

Based on our inspection, testing using consensus based standard procedures, and laboratory analyses performed on the 3x4 ribs and plywood associated with the concrete formwork collapse at 246 Spring Street, New York, NY, our knowledge, education, and experience, as well as documented scientific literature and industry publications, we offer the following summary and opinions:

1. Nearly 400 fragmented pieces of dimension lumber and over 100 fragmented pieces of plywood associated with the collapse at 246 Spring Street were physically inspected. Visual grades of the dimension lumber were documented whenever possible. Failure characteristics of the dimension lumber and plywood were also documented. Twelve, 3x4 lumber ribs were evaluated following ASTM standard test

procedures, and four, 4'x8' sheets of plywood were evaluated following a modified concentrated load ASTM standard test procedure. Additionally, for each 3x4 lumber rib that was mechanically tested, the rib was also microscopically evaluated to document levels of wood decay and to determine the wood species.

2. The visual grades for the 3x4 dimension lumber were found to have a high percentage of low grade material. In fact, numerous pieces did not even qualify as structural material and were, therefore, classified as "Economy" which has no associated published design values. The 3x4 dimension lumber was visually graded using two different classifications; Structural Light Framing and Light Framing. Since no grade stamps were observed in the 3x4 lumber, they were graded using both classifications. Only slight differences exist between these classifications and those differences project through to the published allowable design properties for the grades within these two systems. A summary of the results are as follows, however, the published design values <u>do not</u> apply to these grades without first adjusting for decay which is discussed later in this summary:

- Total number of lumber pieces inspected = 396
- Visual grade summary of 3x4s - Structural Light Framing (2"-4" thick, 2"-4" wide)

Visual Grade	Pieces	Percentage
Select Structural	59	28%
No. 1	50	23%
No. 2	41	19%
No. 3	48	23%
Economy	14	7%
TOTAL	212	100%

- Total number of pieces inspected = 396
- Visual grade summary of 3x4s - Light Framing (2"-4" thick, up to 4" wide).

Visual Grade	Pieces	Percentage
Construction	159	75%
Standard	39	18%
Utility	----	----
Economy	14	7%
TOTAL	212	100%

3. The failure characteristics of the 3x4 dimension lumber were found to have a high percentage of brashness which is associated with wood decay and/or low specific gravity values; both of which are not typical in normal wood. The following is a summary of 436 failure modes observed in the 3x4 dimension lumber (B = brash failure, BT = combination of brash and typical tension failure, T = typical tension failure):

Characteristic	Count	Percentage
B	86	20%
BT	182	42%
T	168	38%
TOTAL	436	100%

4. No grade stamps were observed on any of the 3x4 dimension lumber samples inspected except for the name "LAUZON," which was observed on one piece. Further research was conducted and revealed that this stamp is likely associated with a lumber mill located in Quebec, Canada, just north of the Vermont border. Based on all the characteristics of the lumber inspected, the 3x4 lumber ribs appear to be "mill run" material.

5. The species of the lumber inspected was a combination of spruce and eastern fir. Therefore, the lumber would be classified as S-P-F (spruce-pine-fir) which is manufactured in Canada.

6. The 3x4 lumber does not meet the specification requirements present in Patent Construction Systems Drawing No. 4607K070.

7. Two different grade stamps were documented for the 4x4 dimension lumber; STAND & BTR and No. 2. All the 4x4 dimension lumber examined qualified for both grades. The failure modes of the 4x4 dimension lumber were similar to the 3x4 dimension lumber and are listed below:

Characteristic	Count	Percentage
B	3	20%
BT	8	53%
T	4	27%
TOTAL	15	100%

8. The 4x4 lumber does not meet the specification requirements present in Patent Construction Systems Drawing No. 4607K070.

9. Based on all the evidence collected during our inspection and documented scientific literature, it is our opinion that the storage of the material inside the shipping containers between February and May had no effect on the lumber with respect to wood decay at the time we performed our inspection.

10. Over 100 broken pieces of plywood were inspected. Several failures appeared to be consistent with a punch through of the 6" x 8" steel column base plates. Therefore,

full plywood sheets were retained to perform concentrated static load tests. No grade stamps were observed on most of the concrete formwork panels since they had melamine overlays on both faces. The only markings observed were "Feldman Lumber" and "Mid-South Lumber Company." One grade stamp was observed on several other panels which read: Futter, Mill 332, Uni-form, B-B Class.

11. Only some plywood panels contained grade stamps which could be used to determine conformance to the Patent Construction Systems Drawing No. 4607K070. The plywood panels with Feldman Lumber Company overlays or Mid South Lumber Company overlays could not be verified to be either in compliance or out of compliance with the specifications. Those panels with a Futter Lumber Company stamp were in compliance with the specifications since they were stamped with a Pittsburgh Testing Laboratory stamp illustrating B-B grade veneer, Class 1 with an exterior adhesive.

12. Twelve 3x4 dimension lumber samples were retained for mechanical testing and microbiological analyses. Evidence of wood decay was documented in 11 of the 12 samples. Five of the 11 samples had decay limited to the surface region and seven had wood decay ranging from a depth of ½" to a depth of 1-1/2".

13. Reductions in mechanical properties resulted from the wood decay in the dimension lumber samples. Small clear tests were performed on several test specimens and reductions in MOR, MOE, Shear parallel-to-grain, and C perpendicular-to-grain were found. As a result of the testing, we recommended the following residual value factors for the published design values of the 3x4 dimension lumber: