Gannett Fleming

Excellence Delivered As Promised

The City College Of New York
Grove School of Engineering

Civil Engineering Department

Mechanics of Deformable Bodies

New Jersey Transit Authority
Beam Design Project

Applicant:

Aydin Hasan Pekoz, PhD, PE, LEED AP

Gannett Fleming Engineers and Architects, PC

Group Members:

Josue Criollo

Ahmed Heiba

Bryan Gonzales

1. BACKGROUND

New Jersey Transit Authority has hired your company to provide engineering services for a new Substation Service Building that is to be located in Borough of Bay Head, Ocean County, NJ. As the structural engineer of record, you have performed your preliminary analysis and design work. In accordance with your design contract and the schedule of the deliverables, you submitted 30% design package to the client (SEE APPENDIX A – DESIGN PACKAGE). As you can see in Appendix A, the design package includes the conceptual renderings of the service building, a site plan, architectural drawings, and structural drawings.

As spot-check of your work, the client has asked you to provide calculations regarding the design of some components of the building. In addition, they are planning on adding a new generator on the roof (which you did not consider before as it was not included in the proposal stage), and they want you to investigate the effect of adding this equipment on some of the structural components.

2. DELIVERABLES REQUESTED

The client specifically wants you to provide answers (including detailed analysis and design calculations) for the following questions in an academic format. You can team up with another engineer to accomplish these tasks. Make sure to go thru the whole design package, increase your familiarity with the building, and accomplish the followings tasks. Assume all beams are simply supported for simplicity, assume steel has elasto-plastic stress-strain characteristics, ignore any lateral load, and ignore any composite action between the concrete slabs and steel beams.

2.1. Provide <u>flexural design calculations</u> for the <u>lightest W-shapes for</u> beams designated as **B1** and **B2** on 1st Floor (see drawings S-102) and for beams designated as **B3** and **B4** on Roof (see drawing S-104). Use a Factor of Safety of 2.0, and ignore deflection considerations.

2.2. If <u>a max deflection limit</u> of L/360 under live loads (where L is the clear span of the beam), revise the flexural design calculations for the lightest W-shaped **B3 and B4 beams in Question 2.1**.

2.3. If <u>a maximum span-to-depth ratio of 16</u> and the <u>deflection criteria in Question 2.2</u> are enforced, revise the flexural design calculations for the lightest W-shaped **B3 and B4 beams in Question 2.1**.

2.4. Provide design calculations for <u>lightest W-shaped column</u> at **axis B/4** and **axis D/4** under axial loads. Ignore deflection limits in Questions 2.2 and 2.3, and ignore column buckling. Assume that column loads have an eccentricity of 12" with respect to each principal centroidal axis of the column, and use a factor of safety of 2.0.

2.5. Determine <u>the minimum size</u> of the <u>18" thick square footings</u> **under Column B/4** and **Column D/4** using allowable bearing pressure concept only. Use the sections you used/found in Question 2.4. Assume an ultimate bearing pressure of 7,000 psf between the soil and the footing, and a Factor of Safety of 2.0. Make sure to consider the self-weight of the footing.

2.6. The client is planning on putting a new generator on roof. The equipment shall be located between Axes B, D, 3 and 5. Assume that the equipment shall apply a uniform live load pressure of 250 psf on the roof slab. Investigate the impact of this equipment on the structure by revising your calculations for Questions 2.1 thru 2.5.

2.7. How would you expect your results in Question 2.1 to change if you had assumed composite action between the concrete slabs and steel beams? Do not perform any calculations. Just provide a discussion.

3. DUE DATE

Your calculations are due 12/03/2018.

PERSPECTIVE VIEW LOOKING NORTHWEST - SAND DUNE BRICK

NJ TRANSIT
Engineering and Construction

One Penn Plaza East, Newark NJ 07105

CONTRACT NO. 13-006

NJ TRANSIT
BAY HEAD YARD SUBSTATION
30% SUBMITTAL

BOROUGH OF BAY HEAD, OCEAN COUNTY, N.J.

APRIL 15, 2014

Gannett Fleming

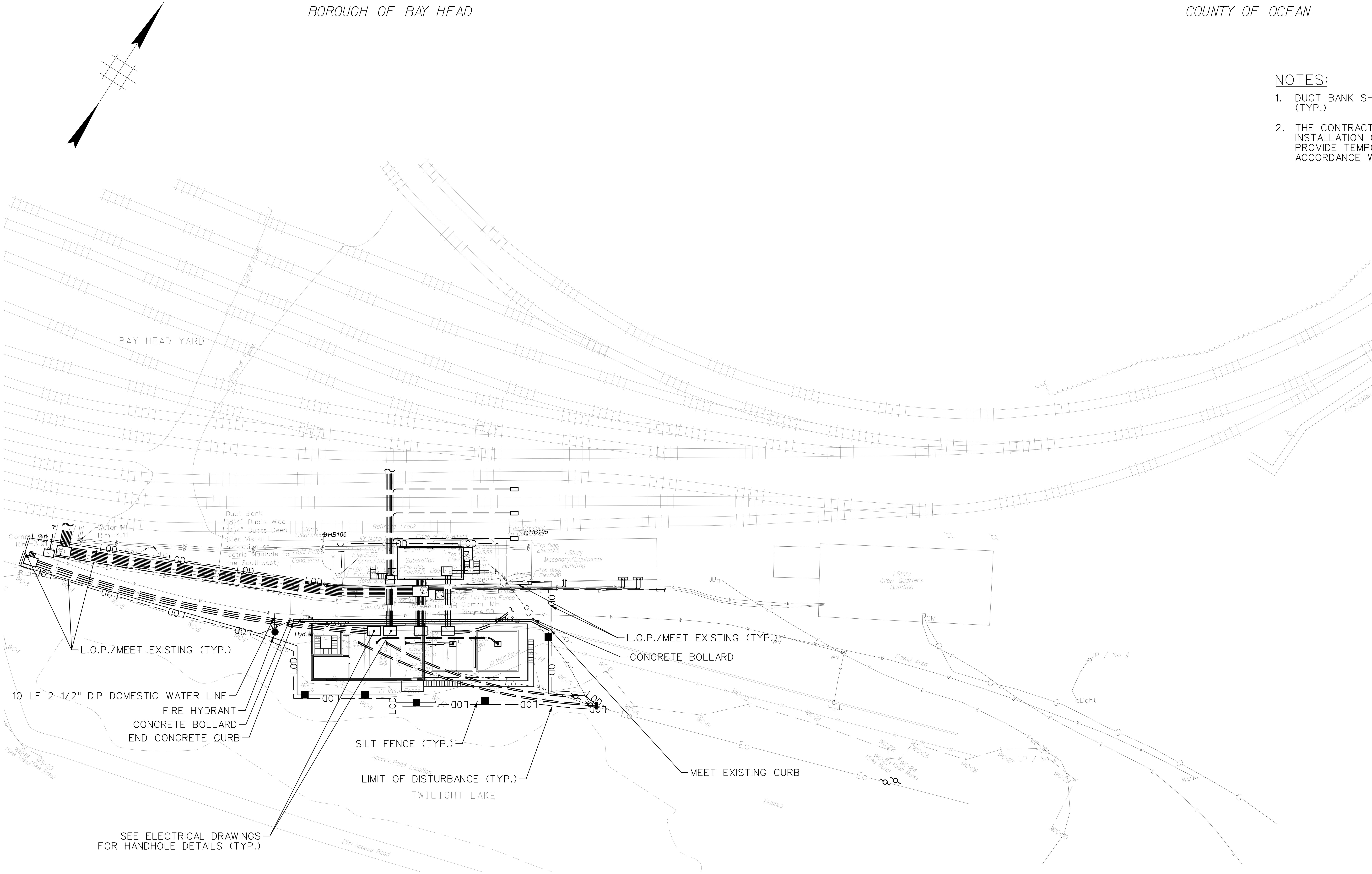
LOCATION MAP
N.T.S.

BOROUGH OF BAY HEAD

COUNTY OF OCEAN

NOTES:

1. DUCT BANK SHALL HAVE A MINIMUM OF 30" OF COVER (TYP.)
2. THE CONTRACTOR IS RESPONSIBLE FOR THE DESIGN AND INSTALLATION OF ANY NECESSARY SHORING SYSTEMS TO PROVIDE TEMPORARY SUPPORT OF THE EXCAVATIONS IN ACCORDANCE WITH THE SPECIFICATIONS.



CIVIL - SITE PLAN

0 30' 60'

No.	Date	Chkd.	Revision Notes
A	04-15-14		30% - ISSUED FOR REVIEW

Date	
Des.	
Dwn.	
Chkd.	
Apprvd.	
Scale	1"=30'

GANNETT FLEMING, INC.
1000 ATRIUM WAY, SUITE 300, MOUNT LAUREL, NJ 08054
CERTIFICATE OF AUTHORIZATION NO. 24GA28032500

DATE

NJ TRANSIT The Way To Go.

BAY HEAD YARD

CIVIL
SITE PLAN

Contract No. 13-006

Drawing C-010

Sheet 2 of 18

4/11/2014 9:57:14 AM SZAPOTICZNY
C:\PWWORKING\GFPW01\SZAPOTICZNY\D0209047\BAY_BH_C_010.DGN

CONTRACTOR NOTES

1. DIMENSIONS TAKEN FROM EXIST SITE ELEMENTS ARE FOR GENERAL REFERENCE ONLY. CONTRACTOR SHALL COORDINATE ACTUAL DIMENSIONS WITH CIVIL DRAWINGS.
2. SEE CIVIL AND ELECTRICAL DRAWINGS FOR LOCATION OF EXISTING AND PROPOSED UTILITIES.

1 / A-010 SITE PLAN
SCALE: 3/32"=1'-0" 1'0 6' 12' 24'

FILE: C:\pwworking\gfpw01\cfernandez\d0209215\BAY_BH_A_010.dwg
DATE: Apr 14, 2014 - 9:34am

No.	Date	Chkd.	Revision Notes
A	04/15/14	H.I.	30% – ISSUED FOR REVIEW

Date	–
Des.	–
Dwn.	–
Chkd.	–
Apprvd.	–
Scale	AS NOTED

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD, SUITE 205,
SOUTH PLAINFIELD NJ, 07080

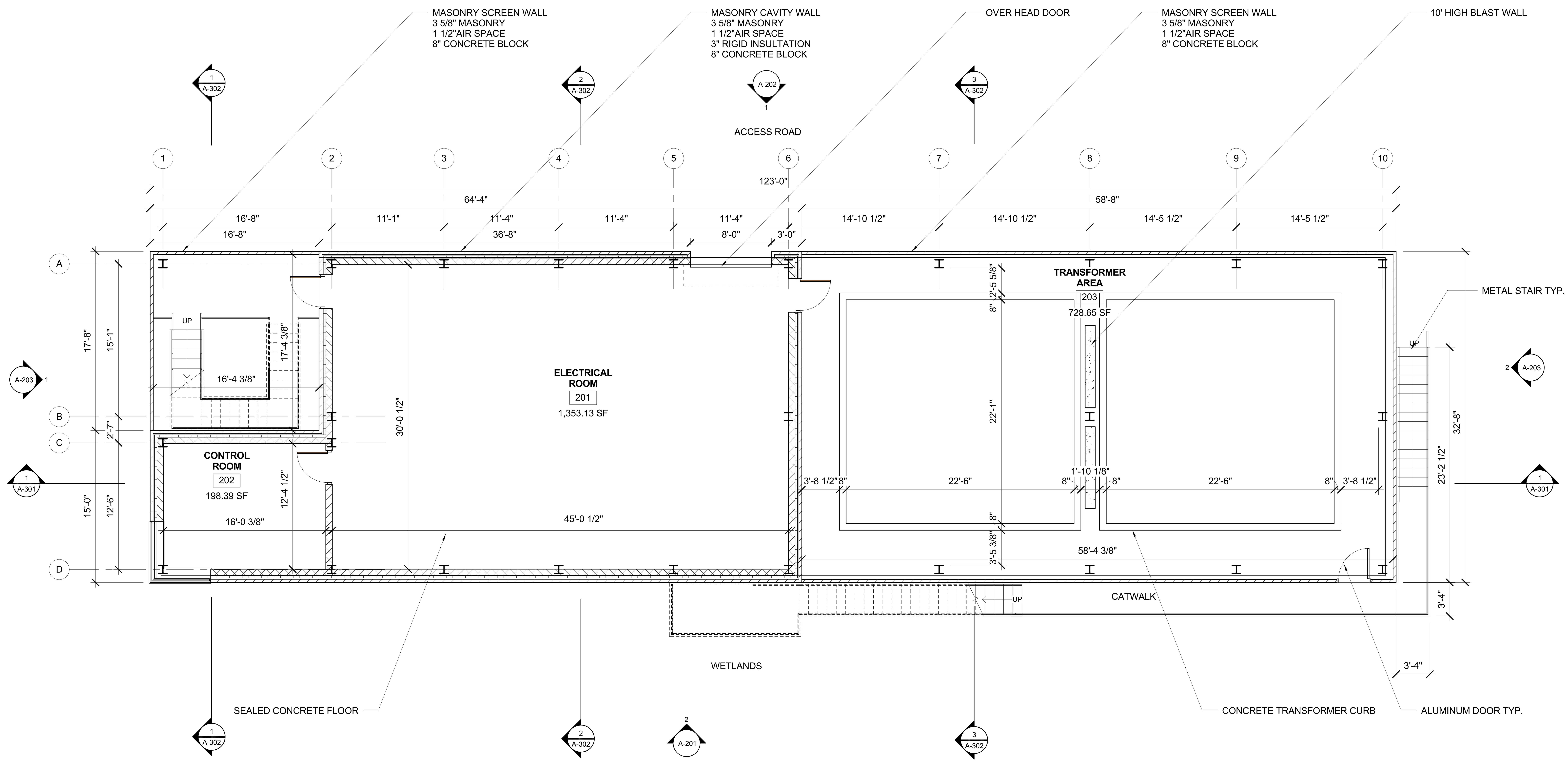
DATE

NJ TRANSIT The Way To Go.

BAY HEAD YARD

ARCHITECTURAL SITE PLAN

Contract No. 13–006
Drawing A–010
Sheet 3 of 18



1 A-102 FIRST FLOOR PLAN

SCALE: 3/16" = 1'-0"

				Date	
				Des.	
				Dwn.	
				Chkd.	
				Apprvd.	
A	04-15-14	HI	30% - ISSUED FOR REVIEW	Scale	AS NOTED
No.	Date	Chkd.	Revision Notes		

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

DATE

NJ TRANSIT
The Way To Go.

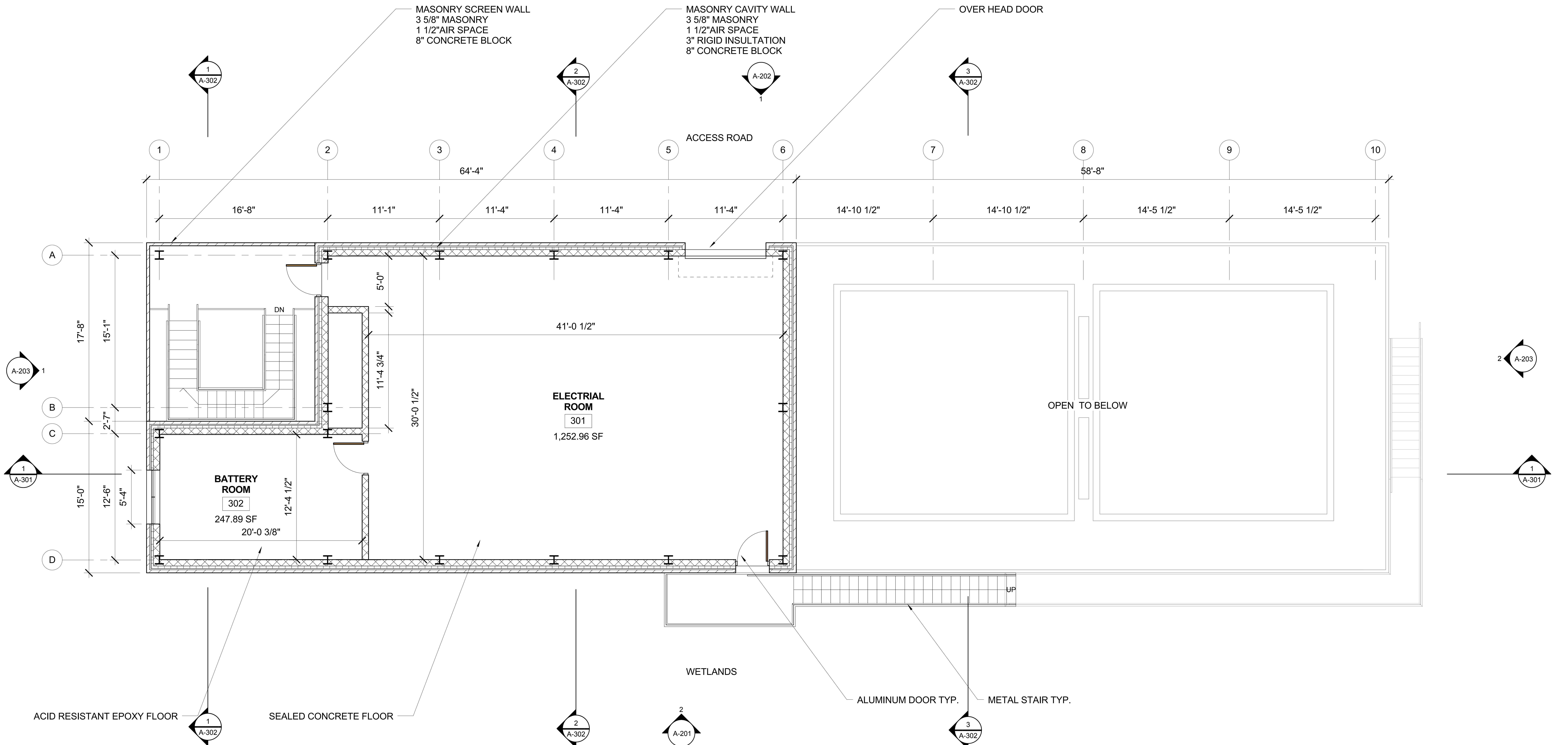
BAY HEAD YARD

SUBSTATION FIRST FLOOR PLAN

Contract No. 13-006

Drawing A-102

Sheet 5 of 18



1 A-103 SECOND FLOOR PLAN

SCALE: 3/16" = 1'-0"

0' 2' 4' 8' 16'

No.	Date	Chkd.	Revision Notes
A	04-15-14	HI	30% - ISSUED FOR REVIEW

Date	
Des.	
Dwn.	
Chkd.	
Apprvd.	
Scale	AS NOTED

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

DATE

NJ TRANSIT The Way To Go.

BAY HEAD YARD

SUBSTATION SECOND FLOOR PLAN

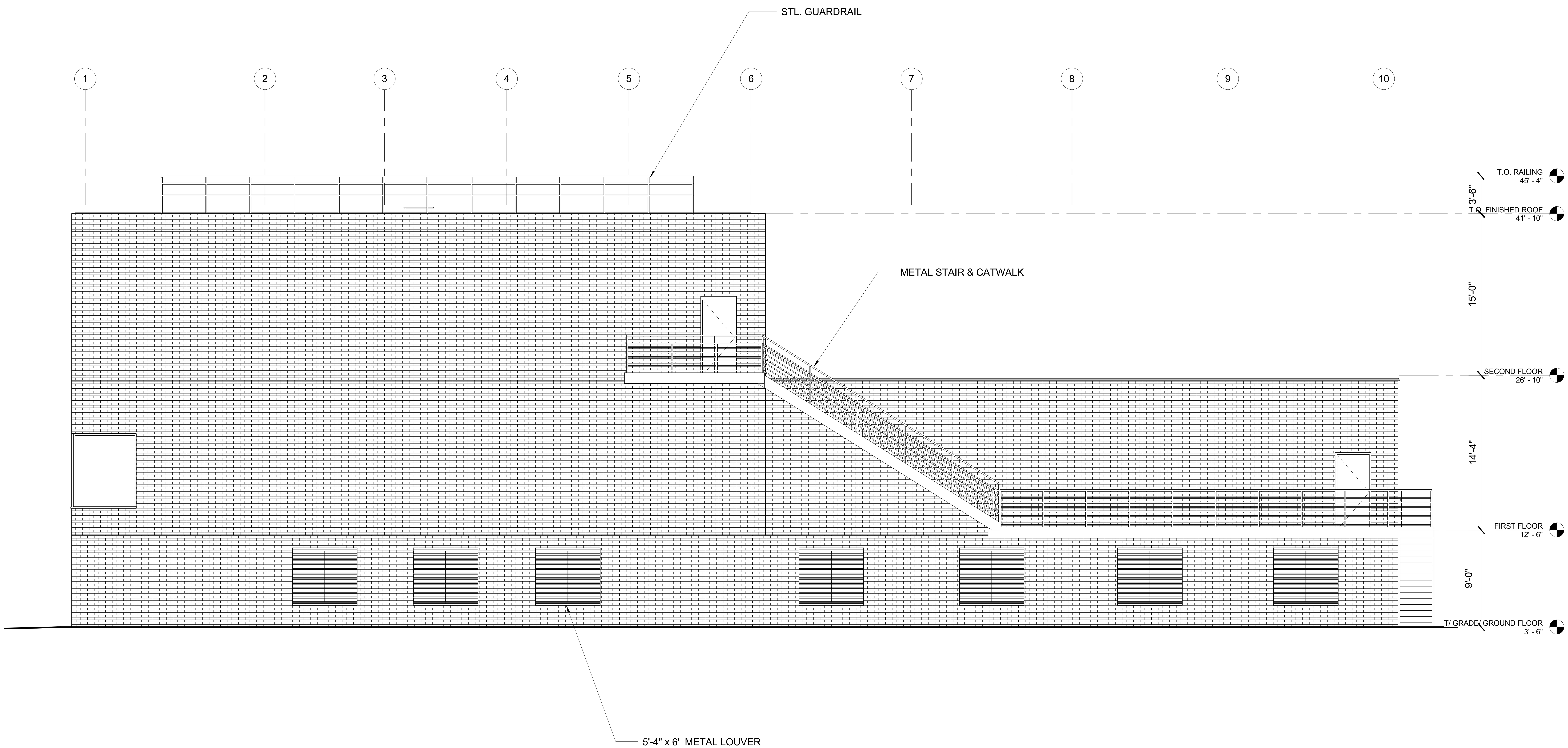
Contract No. 13-006

Drawing A-103

Sheet 6 of 18

ELEVATION NOTES

1 ELEVATION DATUMS ARE RELATIVE TO NAVD88



2
A-201
SOUTH ELEVATION
SCALE: 3/16" = 1'-0"
0' 2' 4' 8' 16'

No.	Date	Chkd.	Revision Notes
A	04-15-14	HI	30% - ISSUED FOR REVIEW

Date	
Des.	
Dwn.	
Chkd.	
Apprvd.	
Scale	AS NOTED

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

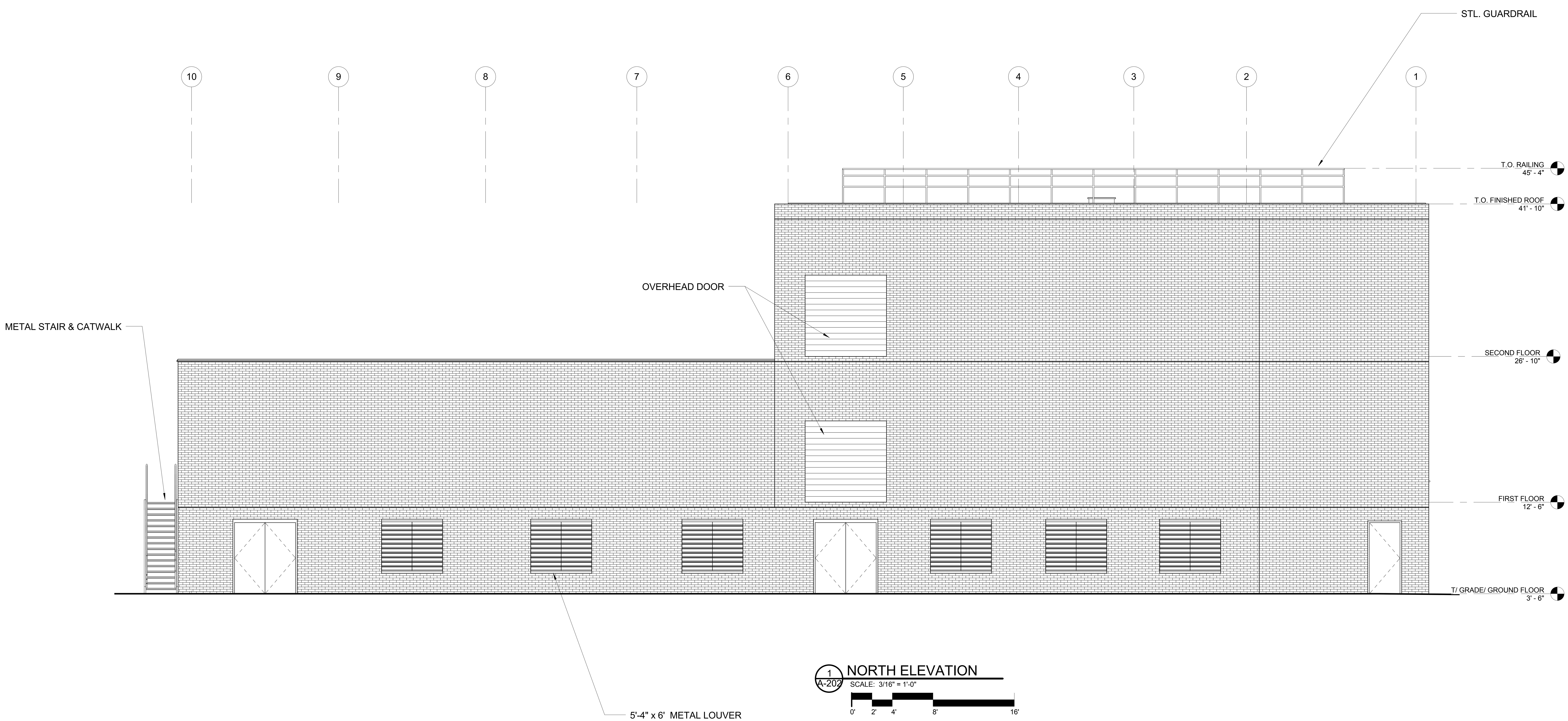
DATE

NJ TRANSIT
The Way To Go.

BAY HEAD YARD

SUBSTATION SOUTH ELEVATION

Contract No.
13-006
Drawing
A-201
Sheet
8 of 18



1
A-202
NORTH ELEVATION
SCALE: 3/16" = 1'-0"

0' 2' 4' 8' 16'

No.	Date	Chkd.	Revision Notes
A	04-15-14	HI	30% - ISSUED FOR REVIEW

Date	
Des.	
Dwn.	
Chkd.	
Apprvd.	
Scale	AS NOTED

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

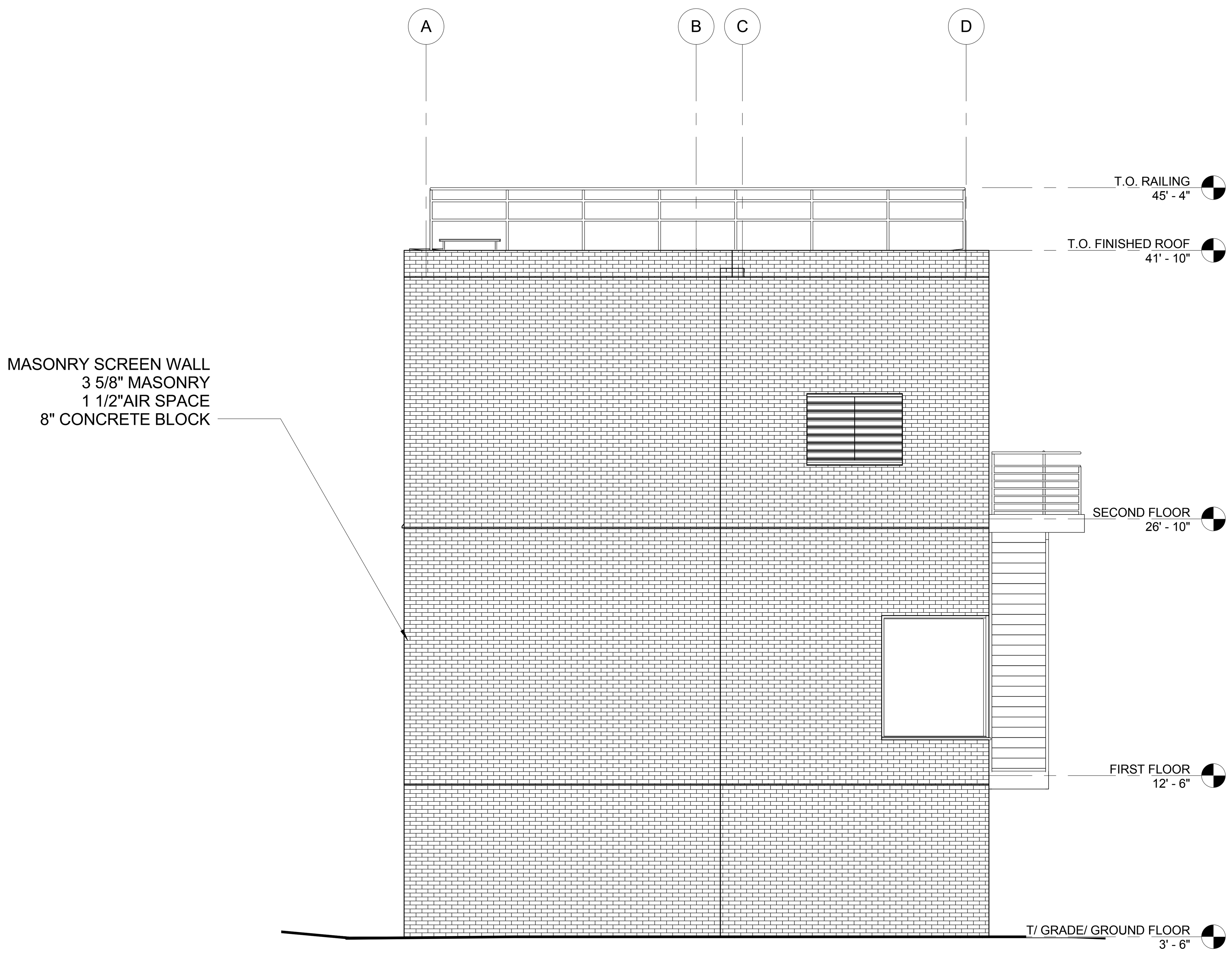
DATE

NJ TRANSIT
The Way To Go.

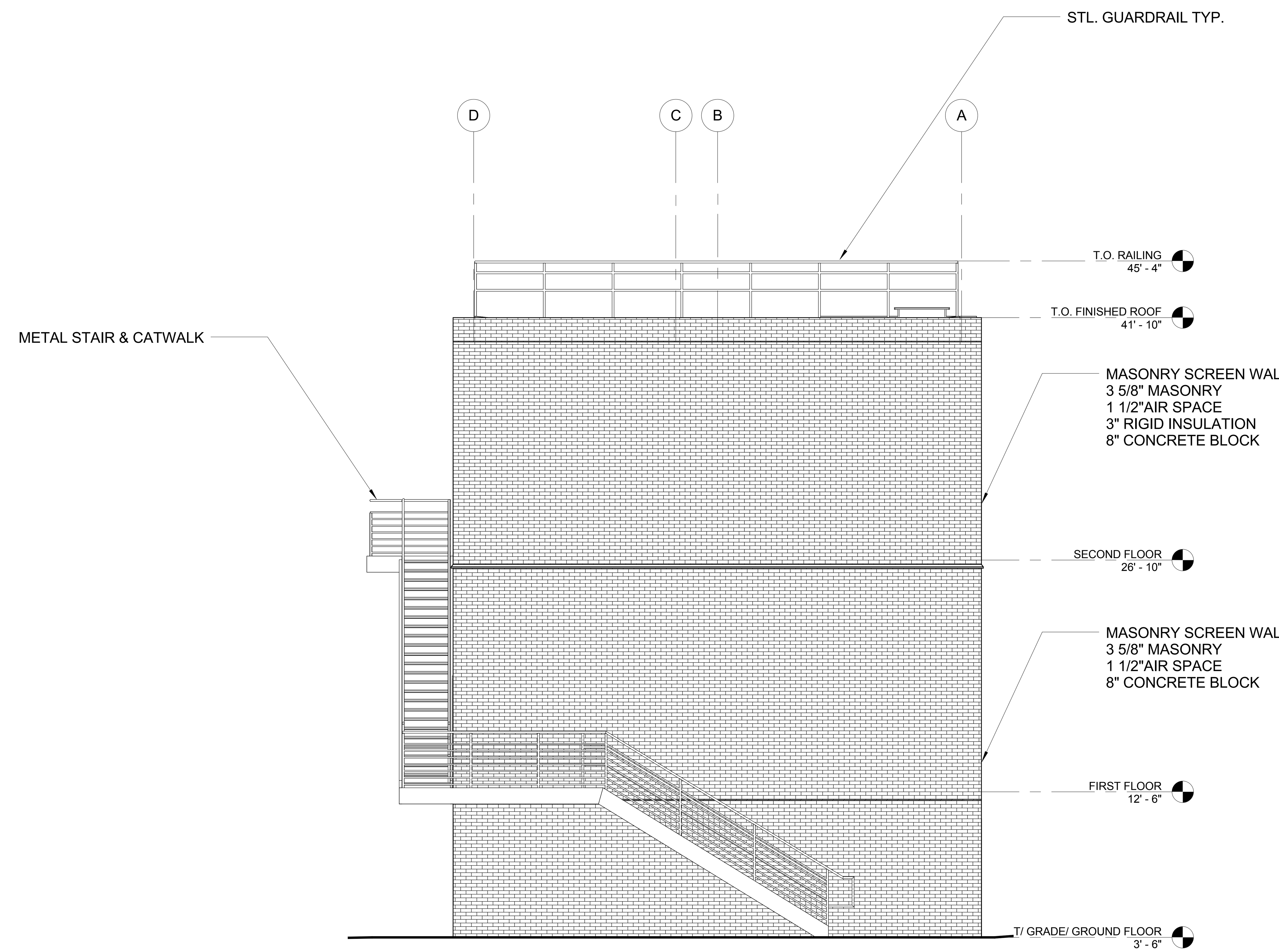
BAY HEAD YARD

SUBSTATION NORTH ELEVATION

Contract No.
13-006
Drawing
A-202
Sheet
9 of 18



1 A-203 WEST ELEVATION
SCALE: 3/16" = 1'-0"



2 A-203 EAST ELEVATION
SCALE: 3/16" = 1'-0"

0' 2' 4' 8' 16'

No.	Date	Chkd.	Revision Notes
A	04-15-14	HI	30% - ISSUED FOR REVIEW

Date	
Des.	
Dwn.	
Chkd.	
Apprvd.	
Scale	AS NOTED

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

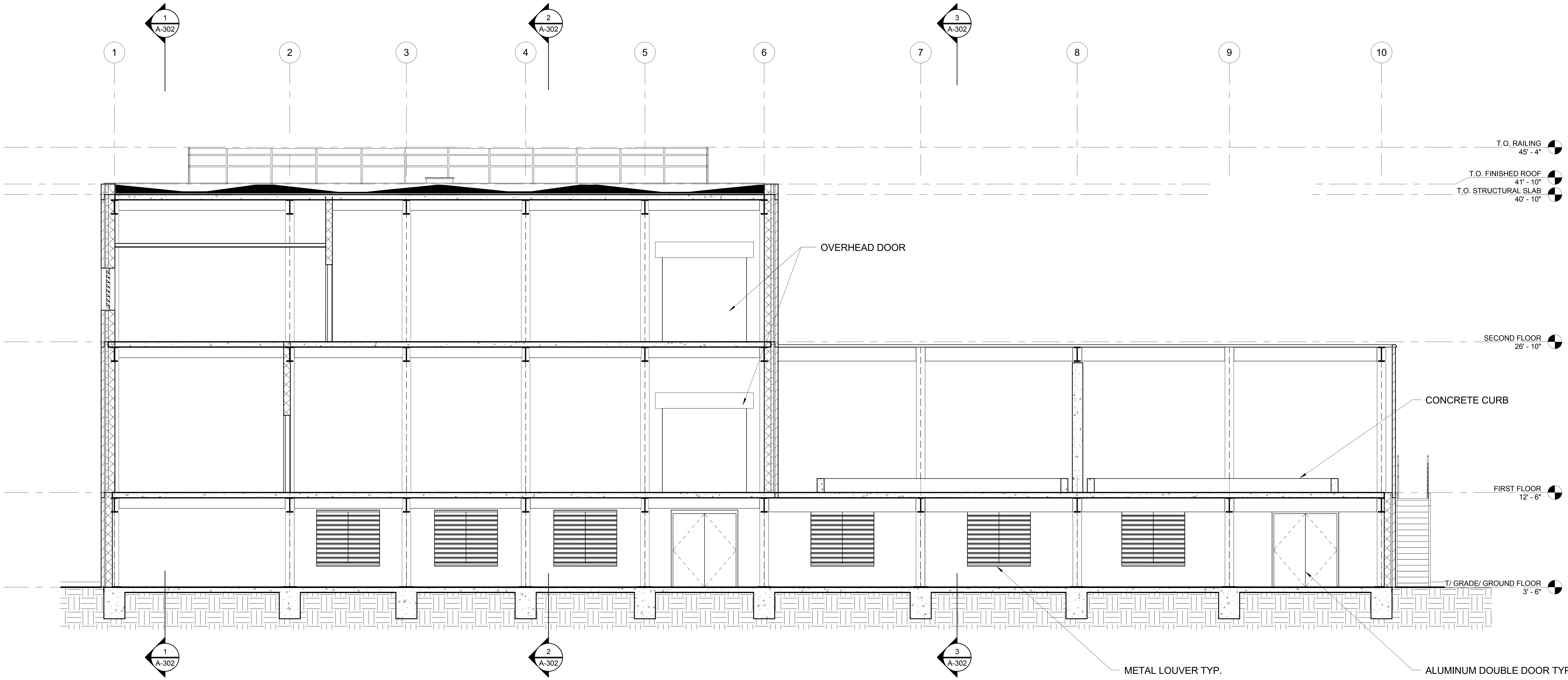
DATE

NJ TRANSIT
The Way To Go.

BAY HEAD YARD

SUBSTATION EAST & WEST ELEVATION

Contract No. 13-006
Drawing A-203
Sheet 10 of 18



1
A-301
SUBSTATION SECTION A
SCALE: 3/16" = 1'-0"

0' 2' 4' 8' 16'

No.	Date	Chkd.	Revision Notes
A	04-15-14	HI	30% - ISSUED FOR REVIEW

Date	
Des.	
Dwn.	
Chkd.	
Apprvd.	
Scale	AS NOTED

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

DATE

NJ TRANSIT
The Way To Go.

BAY HEAD YARD

SUBSTATION SECTION A

Contract No.
13-006
Drawing
A-301
Sheet
11 of 18

GENERAL NOTES

CODES AND STANDARDS

1 ALL WORK SHALL CONFORM TO THE REQUIREMENTS OF THE LATEST CODES EDITION, WITH THE SPECICFICATIONS

2 INTERNATIONAL BUILDING CODE (IBC) NEW JERSEY

3 WHERE MORE STRINGENT, THE LATEST EDITION OF THE FOLLOWING CODES SHALL APPLY TO WORK:

A ACI 301, LATEST EDITION, WITH THE SPECIFICATION AND WITH THE REGULATIONS OF ALL GOVERNMENTAL AGENCIES HAVING JURISDICTION. FOR STRUCTURAL CONCRETE FOR BUILDINGS"
B AISC "SPECIFICATION FOR THE DESIGN, FABRICATION, AND ERECTION OF STRUCTURAL STEEL FOR BUILDINGS
B1 ALLOWABLE STRESS DESIGN, NINTH EDITION
B2 LOAD RESISTANCE FACTOR DESIGN, THIRD EDITION
C AISC "CODE OF STANDARD PRACTICE FOR STEEL BUILDINGS AND BRIDGES" LATEST EDITION EXCEPT THAT SECTION 6, 7, 8, AND 10 ONLY, SHALL APPLY TO THE WORK
D "STRUCTURAL WELDING CODE-STEEL" ANSI/AWS D1.1, BY THE AMERICAN WELDING SOCIETY
E "BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE" ACI 318
F "STRUCTURAL WELDING CODE-STEEL", ANSI/AWS D1.3, BY THE AMERICAN WELDING SOCIETY
G "BUILDING CODE REQUIREMENTS FOR CONCRETE MASONRY STRUCTURES", ACI 53 AND "SPECIFICATIONS FOR MASONRY STRUCTURES"

4 AMERICAN SOCIETY FOR TESTING OF MATERIALS (ASTM)

GENERAL CONSTRUCTION NOTES

CONTRACTOR RESPONSIBILITY WILL CONSIST OF BUT NOT BE LIMITED TO THE FOLLOWING:

1 ALL WORK SHALL BE PERFORMED IN ACCORDANCE WITH THE REQUIREMENTS OF BUILDING CODES SHOWN ABOVE.

2 THE CONTRACTOR SHALL REVIEW THE REQUIREMENTS OF THE BUILDING WITH THE OWNER TO DETERMINE THE USE OF AREA, RAMPS, ETC. ANY RELATED COSTS OR CHARGES THERE TO SHALL BE INCLUDED IN THE COST OF THE WORK.

3 THE CONTRACTOR SHALL BE SOLELY RESPONSIBLE FOR ALL CONSTRUCTION MEANS, METHODS, TECHNIQUES, SEQUENCES AND PROCEDURES, AND FOR THE COORDINATION OF ALL PORTIONS OF THE WORK.

4 THE CONTRACTOR IS RESPONSIBLE FOR THE PROTECTION AND SAFETY OF ALL PERSONS, EXISTING FACILITIES AND EXISTING EQUIPMENT AND DISPLAYS AT THE CONSTRUCTION SITE AND THROUGHOUT ALL AREAS AFFECTED BY THE NEW CONSTRUCTION.

5 THE CONTRACTOR SHALL THOROUGHLY VERIFY ALL DIMENSIONS AND FIELD CONDITIONS AT THE JOB SITE. ANY AND ALL DISCREPANCIES SHALL BE REPORTED TO THE ENGINEER; OTHERWISE, THE CONTRACTOR SHALL BEAR ALL COSTS TO COMPLETE THE WORK AS INTENDED ON THE DRAWINGS.

6 MAINTAIN, PROTECT AND RELOCATE (IF REQUIRED) LIGHTING AND POWER CONDUITS, DUCTS, PIPES, WIRES (EXPOSED AND CONCEALED), DURING CONSTRUCTION. INSULATE ALL CONSTRUCTION EQUIPMENT FROM THE GROUND TO AVOID ACCIDENTAL GROUNDING.

7 THE STRUCTURAL DRAWINGS SHALL BE USED IN CONJUNCTION WITH THE PROVISIONS OF ALL CONTRACT DOCUMENTS (THE SPECIFICATIONS, ARCHITECTURAL, MECHANICAL AND ELECTRICAL DRAWINGS ETC.)

8 THE CONTRACTOR SHALL MAKE NO DEVIATION FROM THE DESIGN DRAWINGS WITHOUT PRIOR WRITTEN APPROVAL OF THE ENGINEER.

9 IT IS THE CONTRACTOR'S RESPONSIBILITY TO MAKE SURE THAT EXISTING ADJOINING STRUCTURES ARE NOT DISTURBED AND UNDERMINED DURING ENTIRE CONSTRUCTION PERIOD. TEMPORARY BRACING AND/OR SHORING SHALL BE INTRODUCED WHERE NECESSARY TO SUPPORT ALL LOADS TO WHICH THE STRUCTURE MAY BE SUBJECTED. SUCH BRACING SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR AND SHALL BE LEFT IN PLACE AS LONG AS REQUIRED FOR SAFETY AND IS SUBJECT TO CONTROLLED INSPECTION. CONTRACTOR SHALL SUBMIT PROCEDURE, DESIGN CALCULATIONS AND DETAILED DRAWINGS FOR THE COMPLETE PROPOSED SUPPORT SYSTEM TO ENGINEER FOR APPROVAL.

10 COORDINATE WITH ARCHITECTURAL, MECHANICAL AND ELECTRICAL DRAWINGS FOR CLEARANCES, DIMENSIONS, EQUIPMENT LOCATIONS, OPENING LOCATIONS AND PIPE PENETRATIONS PRIOR TO COMMENCING CONSTRUCTION WORK.

CAST-IN-PLACE CONCRETE

1 ALL CONCRETE DETAILS AND CONSTRUCTION ARE TO COMPLY WITH THE LATEST EDITION OF ACI 301, ACI 318, ACI 614.

2 CONFORM TO ACI 305R WHEN CONCRETING DURING HOT WEATHER.

3 CONFORM TO ACI 306R WHEN CONCRETING DURING COLD WEATHER.

4 CEMENT - ASTM C150 TYPE I.

5 JOINT FILLER TYPE ASTM D1752; PRE MOLDED SPONGE RUBBER, FULLY COMPRESSIBLE WITH RECOVERY RATE OF MINIMUM 95 PERCENT.

6 MIX CONCRETE IN ACCORDANCE WITH ACI 304. DELIVERY CONCRETE IN ACCORDANCE WITH ASTM C94.

7 PROVIDE CONCRETE TO MEET THE FOLLOWING CRITERIA:

a) COMPRESSIVE STRENGTH 28 DAYS: 5000 PSI.
b) SLUMP: 3 TO 4 INCHES.
c) MAXIMUM WATER/CEMENT RATIO: 0.45

8 ENSURE REINFORCEMENT, INSERTS, EMBEDDED PARTS, FJOINT FILLERS AND ANCHORS ARE NOT DISTURBED DURING CONCRETE PLACEMENT.

9 VERIFY REQUIREMENTS FOR CONCRETE COVER OVER REINFORCEMENT.

10 NOTIFY THE ENGINEER MINIMUM 24 HOURS PRIOR TO COMMENCEMENT OF OPERATIONS.

11 VERIFY THAT ANCHORS, SEATS, PLATES, REINFORCEMENT AND OTHER ITEMS TO BE CAST INTO CONCRETE ARE ACCURATELY PLACED, POSITIONED SECURELY, AND WILL NOT CAUSE HARDSHIP IN PLACING CONCRETE.

12 MAINTAIN CONCRETE WITH MINIMAL MOISTURE LOSS AT RELATIVELY CONSTANT TEMPERATURE FOR PERIOD NECESSARY FOR HYDRATION OF CEMENT AND HARDENING OF CONCRETE.

13 DO NOT PATCH, FILL, TOUCH-UP, REPAIR, OR REPLACE EXPOSED CONCRETE EXCEPT UPON EXPRESS DIRECTION OF ENGINEER FOR EACH INDIVIDUAL AREA.

14 REPAIR OR REPLACEMENT OF DEFECTIVE CONCRETE WILL BE DETERMINED BY THE ENGINEER.

STRUCTURAL STEEL NOTES

1 THE DESIGN, FABRICATION AND ERECTION OF STRUCTURAL STEEL SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AISC MANUAL OF STEEL CONSTRUCTION, ALLOWABLE STEEL DESIGN, 13TH EDITION. ALL WELDING SHALL CONFORM TO THE REQUIREMENTS OF AMERICAN WELDING SOCIETY

2 STRUCTURAL WELDING CODE (AWS D1.1). WELDING ELECTRODES SHALL BE E70XX.

3 STRUCTURAL STEEL SHALL BE NEW STRAIGHT AND CLEAN. IT SHALL CONFORM TO THE REQUIREMENTS OF ASTM DESIGNATION AS FOLLOWS, UNLESS OTHERWISE NOTED:

A ROLLED SHAPES: ASTM A922, FY = 50.0 KSI
B TUBING: ASTM A500 - GRADE B, FY = 46.0 KSI
C BASE PLATES AND BEARING PLATES: ASTM A36, FY = 36.0 KSI
D FASTENERS

ANCHOR BOLTS	ASTM A36, GRADE (GALVANIZED)
ANCHOR BOLT NUTS & WASHERS	ASTM A307 (GALVANIZED)
SHOP AND FIELD BOLTED CONNECTIONS	ASTM A325
HIGH STRENGTH NUTS	ASTM A563
HIGH STRENGTH WASHERS	ASTM F436

E CONNECTIONS:

E1 SHOP CONNECTIONS SHALL BE MADE WITH HIGH STRENGTH BOLTS OR WELDS.
E2 FIELD CONNECTIONS SHALL BE MADE WITH HIGH STRENGTH BOLTS UNLESS OTHERWISE NOTED.
E3 CONNECTION CAPACITY: FULL SHEAR CAPACITY OF THE MEMBER.

4 ALL BOLTED CONNECTIONS, UNLESS OTHERWISE NOTED, SHALL BE MADE WITH A325 HIGH STRENGTH BOLTS.

5 CONTRACTOR SHALL PROVIDE ALL TEMPORARY BRACING REQUIRED MAINTAINING PLUMBNESS AND STABILITY OF STRUCTURAL SYSTEM DURING ERECTION.

6 ALL ANCHOR BOLTS AND EMBEDDED PLATES/INSERTS TO ESUPPLIED BY STEEL CONTRACTOR, AND SHALL BE SET AT THE PROPER LOCATION BY GENERAL CONTRACTOR.

7 APPROVAL OF SHOP DRAWINGS SHALL NOT RELIEVE CONTRACTIOF HIS RESPONSIBILITIES AND CONTRACT OBLIGATIONS.

DESIGN LOADS

1 SUPERIMPOSED DEAD LOADS

UNIFORM LOADS	
CRAWL SPACE	0 PSF
ELECTRICAL ROOM	75 PSF
ROOF	25 PSF
LINE LOADS	
EXTERIOR FACADE	150 PSF OVER HEIGHT

2 LIVE LOADS

UNIFORM LOADS	
CRAWL SPACE	40 PSF
ELECTRICAL ROOM	100 PSF
ROOF	40 PSF (UNREDUCIBLE)

3 SELF WEIGHT
AS REQUIRED

ABBREVIATIONS

T.O.S.	TOP OF STEEL
T.O.C.	TOP OF CONCRETE
B.O.S.	BOTTOM OF STEEL
B.O.F.	BOTTOM OF FOOTING
T.O.C.	TOP OF CONCRETE

No.	Date	Chkd.	Revision Notes
A	04-15-14	KGF	30% - ISSUED FOR REVIEW

Date	
Des.	
Dwn.	
Chkd.	
Apprvd.	
Scale	AS NOTED

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

Issue Date
DATE

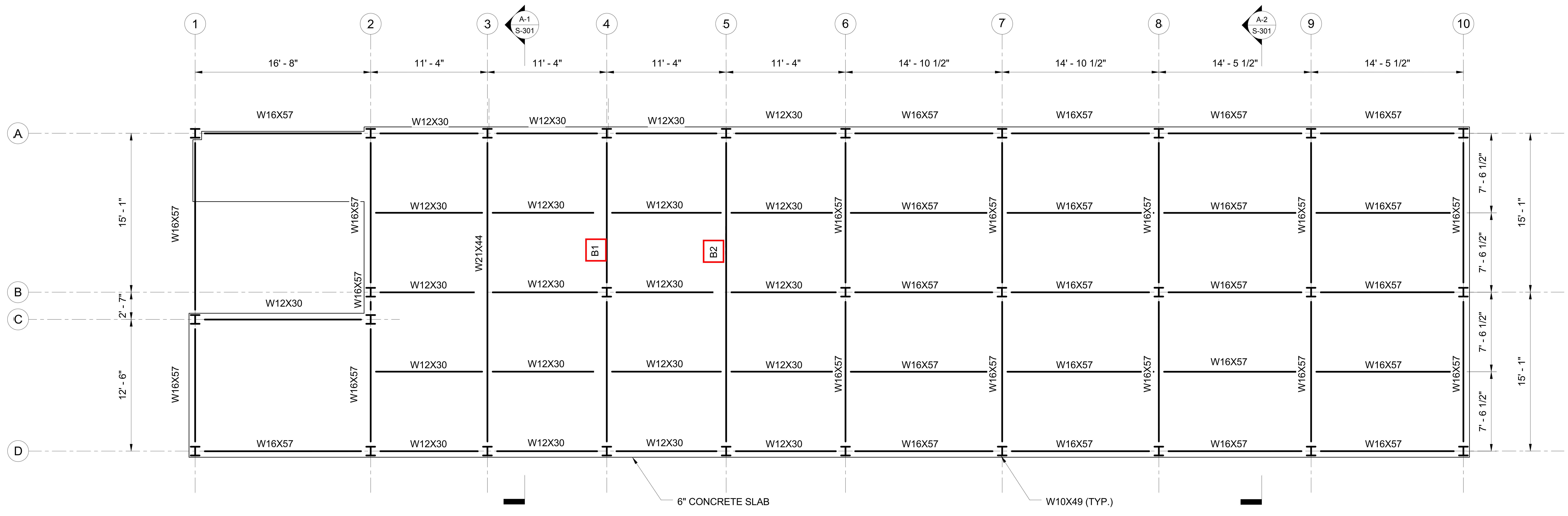
SJH ENGINEERING, P.C.
3700 ROUTE 27, SUITE 201, PRINCETON, NJ 08540
SJH ENGINEERING, P.C.

NJ TRANSIT
The Way To Go.

BAY HEAD YARD

GENERAL NOTES, LEGEND & ABBREVIATIONS

Contract No. 13-006
Drawing S-001
Sheet 13 of 18



1 FIRST FLOOR SUBSTATION FRAMING PLAN - EL. 12.5'

3/16" = 1'-0"

0' 2' 4' 8' 16'

NOTES:

1. ESTIMATED CONCRETE SLAB THICKNESS 6" UNLESS OTHERWISE NOTED.

No.	Date	Chkd.	Revision Notes
A	04-15-14	KGF	30% - ISSUED FOR REVIEW

Date	
Des.	
Dwn.	
Chkd.	
Apprvd.	
Scale	AS NOTED

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

Issue Date
DATE

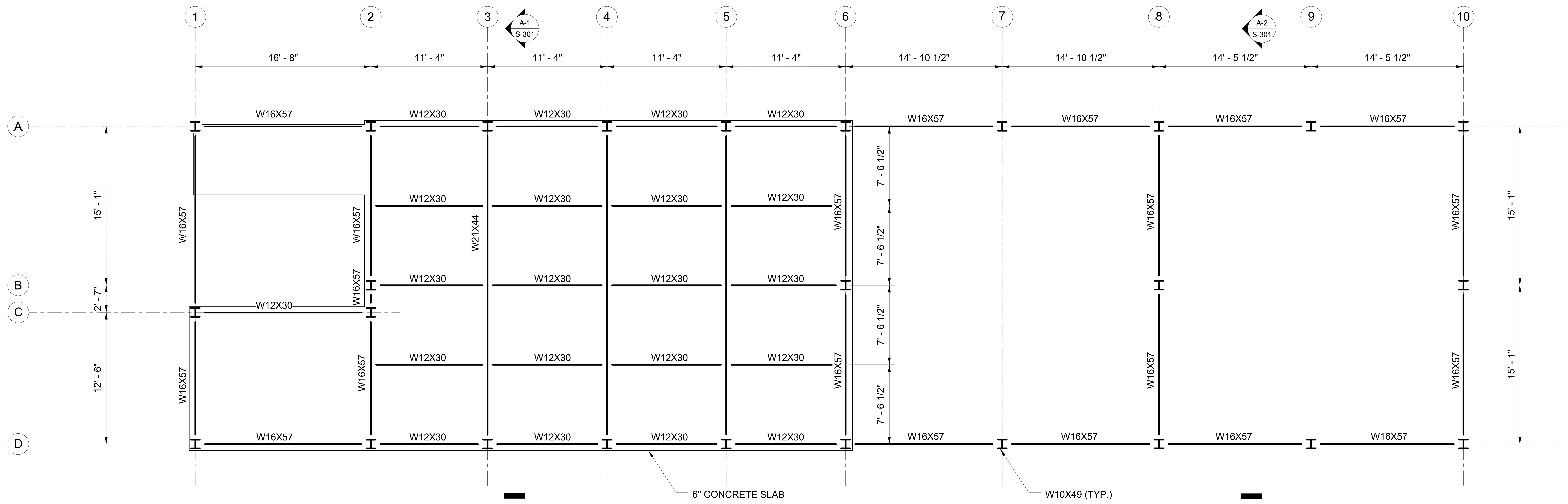
SJH ENGINEERING, P.C.
3700 ROUTE 27, SUITE 201, PRINCETON, NJ 08540
SJH ENGINEERING, P.C.

NJ TRANSIT The Way To Go.

BAY HEAD YARD

SUBSTATION FIRST FLOOR FRAMING PLAN

Contract No. 13-006
Drawing S-102
Sheet 15 of 18



1 SECOND FLOOR SUBSTATION FRAMING PLAN - EL. 26.83'

3/16" = 1'-0"

0' 2' 4' 8' 16'

NOTES:

1. ESTIMATED CONCRETE SLAB THICKNESS 6" UNLESS OTHERWISE NOTED.

No.	Date	Chkd.	Revision Notes
A	04-15-14	KGF	30% - ISSUED FOR REVIEW

Date	
Des.	
Dwn.	
Chkd.	
Apprvd.	
Scale	AS NOTED

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

Issue Date
DATE

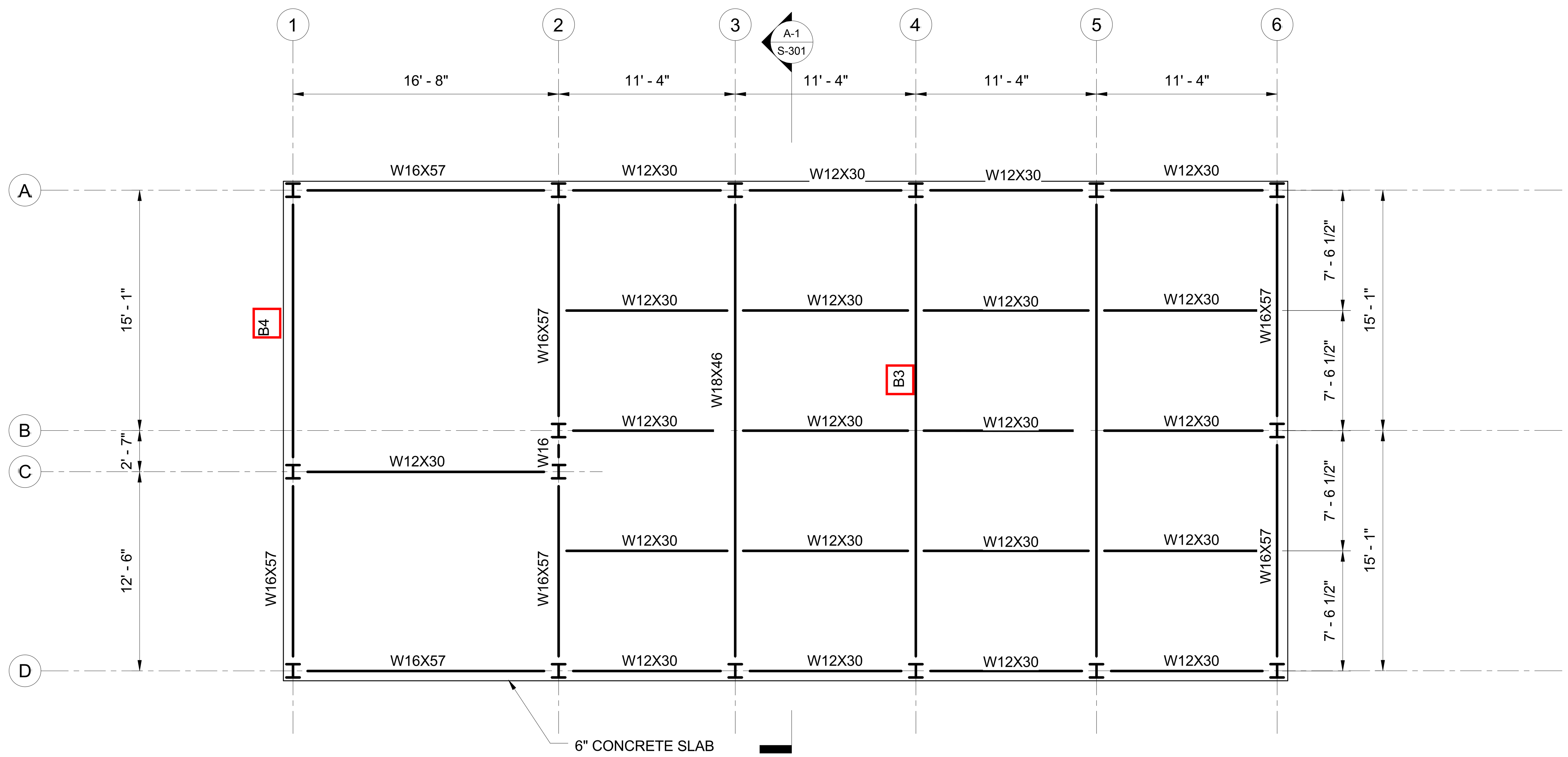
SJH ENGINEERING, P.C.
3700 ROUTE 27, SUITE 201, PRINCETON, NJ 08540
SJH ENGINEERING, P.C.

NJ TRANSIT
The Way To Go.

BAY HEAD YARD

SUBSTATION SECOND FLOOR FRAMING PLAN

Contract No. 13-006
Drawing S-103
Sheet 16 of 18



1 ROOF FRAMING PLAN - EL. 40.83'

3/16" = 1'-0"

0' 2' 4' 8' 16'

				Date	
				Des.	
				Dwn.	
				Chkd.	
				Apprvd.	
A	04-15-14	KGF	30% - ISSUED FOR REVIEW	Scale	AS NOTED
No.	Date	Chkd.	Revision Notes		

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

Issue Date
DATE

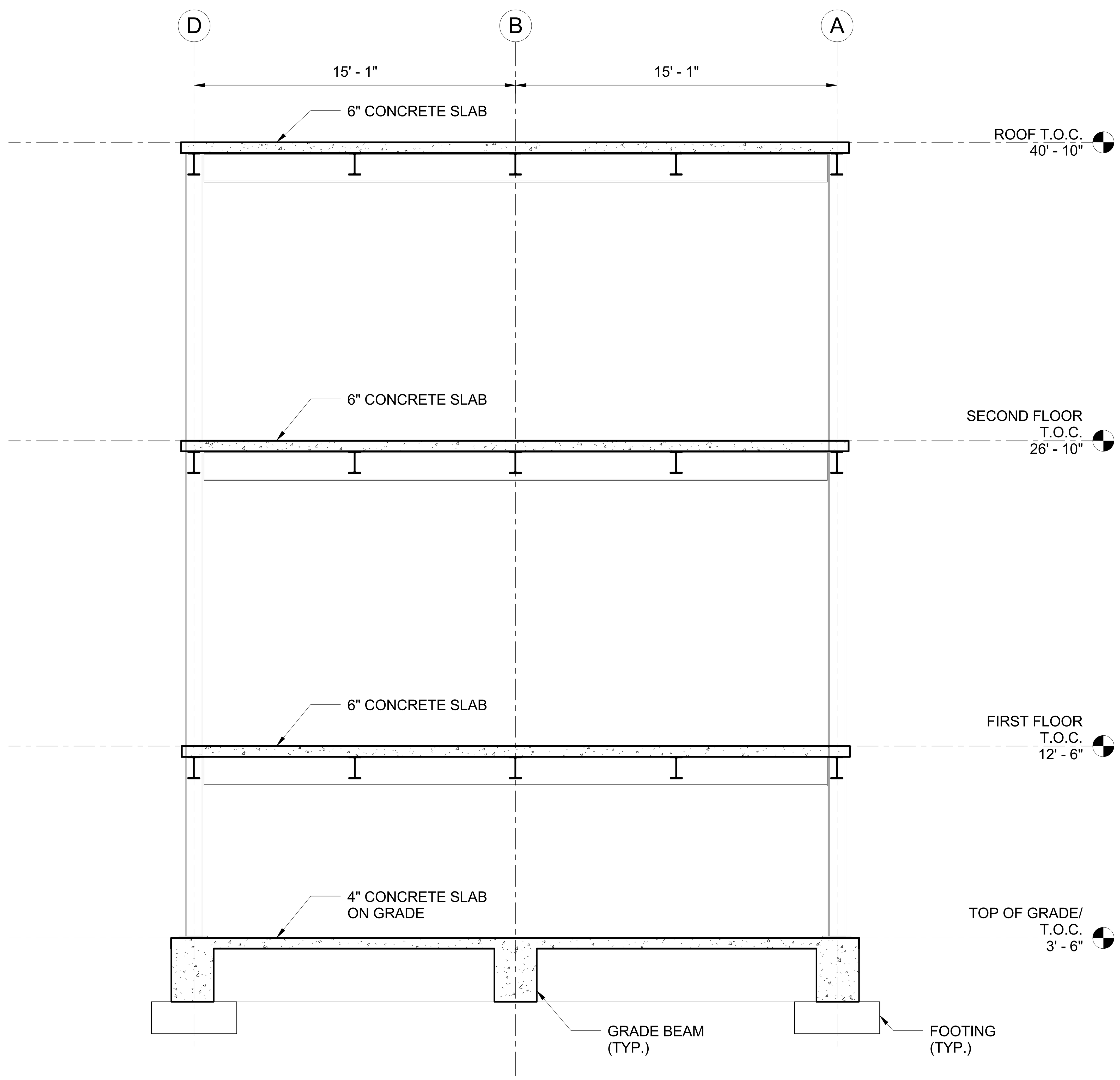
SJH ENGINEERING, P.C.
3700 ROUTE 27, SUITE 201, PRINCETON, NJ 08540
SJH ENGINEERING, P.C.

NJ TRANSIT
The Way To Go.

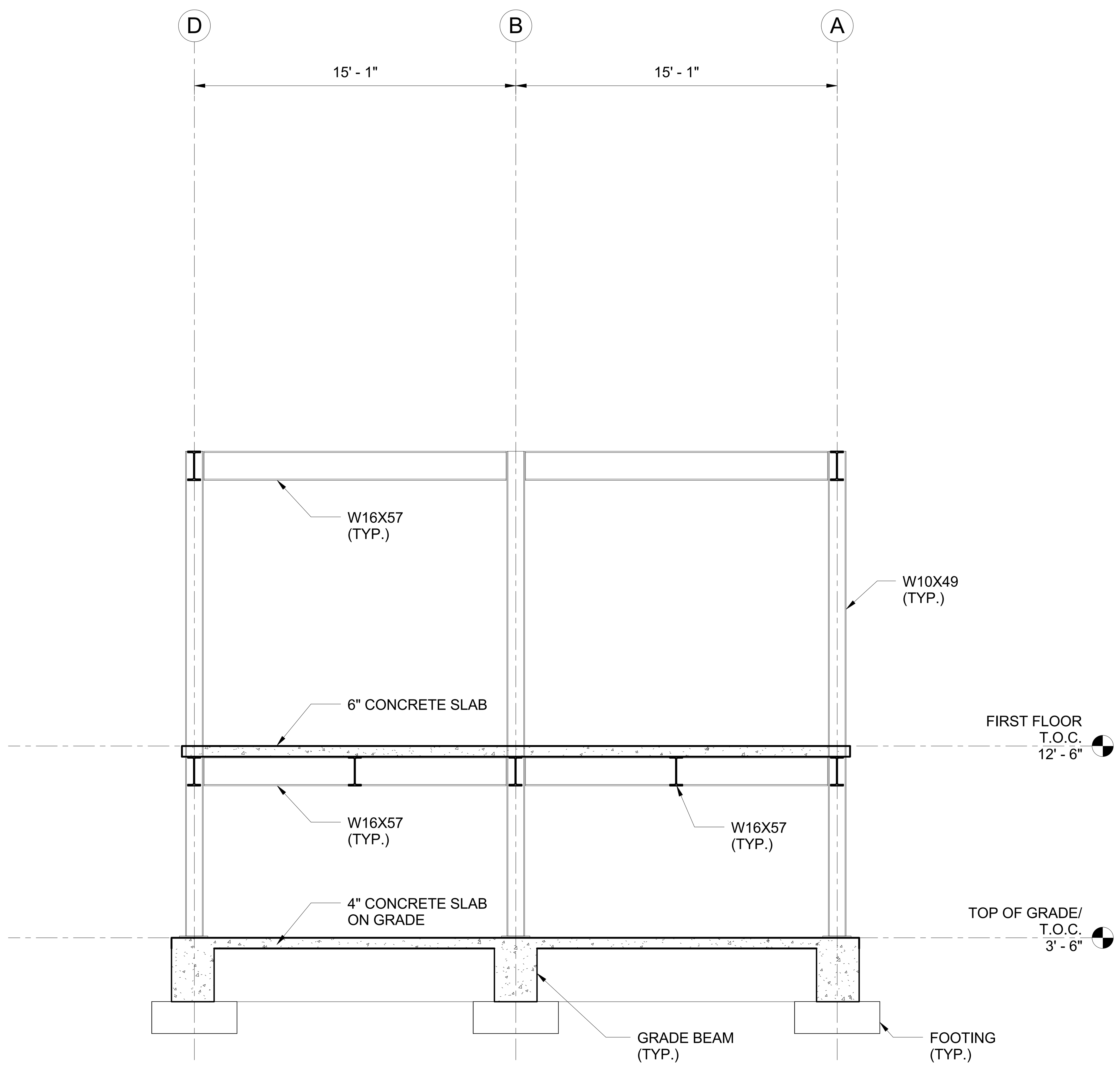
BAY HEAD YARD

SUBSTATION ROOF FRAMING PLAN

Contract No.
13-006
Drawing
S-104
Sheet
17 of 18



A-1 SECTION 1
1/4" = 1'-0"



A-2 SECTION 2
1/4" = 1'-0"

No.	Date	Chkd.	Revision Notes		
A	04-15-14	KGF	30% - ISSUED FOR REVIEW	Date	
				Des.	
				Dwn.	
				Chkd.	
				Apprvd.	
				Scale	AS NOTED

GANFLEC ARCHITECTS & ENGINEERS, INC.
ONE CRAGWOOD ROAD,SUITE 205,
SOUTH PLAINFIELD NJ, 07080

Issue Date
DATE

SJH ENGINEERING, P.C.
3700 ROUTE 27, SUITE 201, PRINCETON, NJ 08540
SJH ENGINEERING, P.C.

NJ TRANSIT
The Way To Go.

BAY HEAD YARD

SUBSTATION BUILDING
SECTION A

Contract No.
13-006
Drawing
S-301
Sheet
18 of 18

Gannett Fleming

Excellence Delivered As Promised

NJ TRANSIT

Engineering and Construction

One Penn Plaza East, Newark NJ 07105

CONTRACT NO. 13–006

NJ TRANSIT

BAY HEAD YARD SUBSTATION

30% SUBMITTAL

BOROUGH OF BAY HEAD, OCEAN COUNTY, N.J.

Table of Content:

Abstract

Our company has been hired by the New Jersey Transit Authority to provide engineering services for their new building project which is located in Borough of Bay Head, Ocean County, NJ. The following report contains calculations regarding the design of specific portions of the New Jersey Transit Authority’s new Substation Service Building design project.

As specified by the client, the flexural design, maximum deflection limit, revised flexural design, lightest W-shaped column, max footing size and revised calculations for all portions of the design are included. As per the request of the client, we have also considered the inclusion of a generator on the roof in our calculations. Explanations are also included along with the calculations in the report so that the client can have a better understanding of the design project.

This report is the next step to the 30% design package submitted and fulfills all of the client’s requirements. Our engineers went through all of the questions and have provided answers with detailed analysis and design calculations.

Known: For lightest W-Shapes on 1st floor.

- The factor of Safety = 2.0 → $\frac{\sigma_{ult}}{\sigma_{all.}}$
- Ignore deflection
- USE "1st Floor Drawings" (S-102) for Beams 1 and 2
- USE "Roof Drawings" (S-104) for Beams 3 and 4

– Location of Beam 1: Electrical Room. (See figure 1)

- Based on Beam Type table: Rolled Shapes: ASTM A922
  → Stress: $\sigma_y = 50000$ psi

– knowing total load; by using General Notes (S-001):

- Design loads for electrical room: Dead load = $75 \frac{lb}{ft^2}$, Live load = $100 \frac{lb}{ft^2}$ → $175 \frac{lb}{ft^2}$ total

$L_{Tot} = L_D + L_L$

Load total $= \left(175 \frac{lb}{ft^2}\right)\left(\frac{1 ft}{12 in}\right)^2 = 1.2152$ psi

- The weight of the concrete itself:

If ρ of concrete is $= \left(150 \frac{lb}{ft^3}\right)\left(\frac{1 ft}{12 in}\right)^3 = 0.08680 \frac{lb}{in^3}$

then, the weight for slab with 6" thickness:

$\left(0.08680 \frac{lb}{in^3}\right)(6\, in) = 0.52083 \frac{lb}{in^2}$

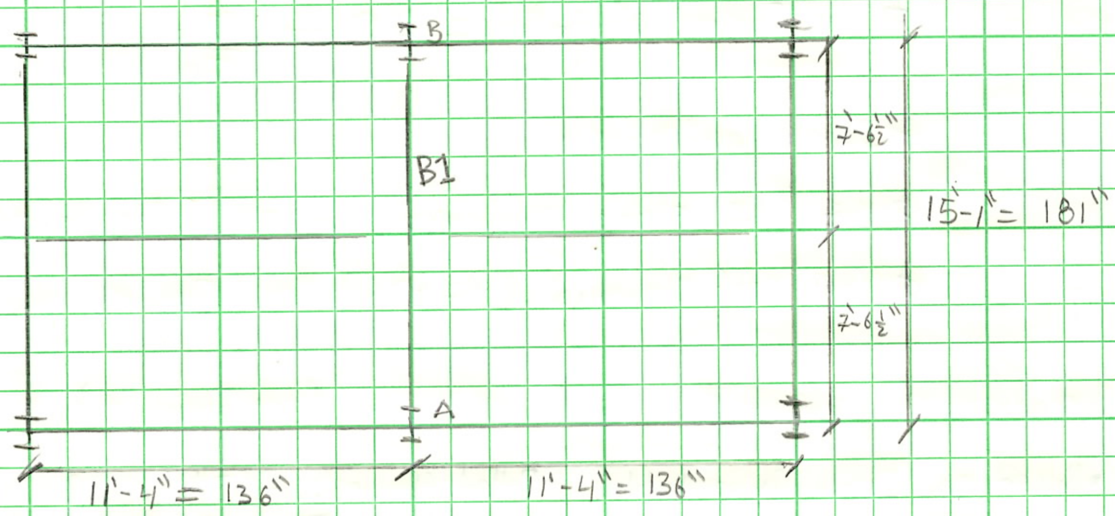
$L_{Tot} = 1.2152\ lb/in^2$ and $L_{self} = 0.52083\ lb/in^2$

– Distributed Load: $W = L_{Tot} + L_{self} = (L_{Tot} + L_{self})$ (Length of section) at B1

- See figure 1 for more details: length of section for B1: 11'-4" = 136"
- $W = (1.2152 + 0.52083) \frac{lb}{in^2} (136\ in) = \boxed{236.100 \frac{lb}{in.} = W}$

– Allowable stress: since $SoF = 2.0 = \frac{\sigma_{ult}}{\sigma_{all}}$ → $\sigma_{all} = \frac{50000\ psi}{2.0} = 25$ ksi

Figure 1: Beam 1 (NTS)



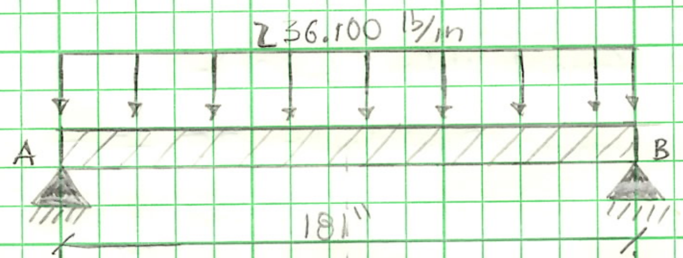


Figure 2: Load Distribution on Beam 1

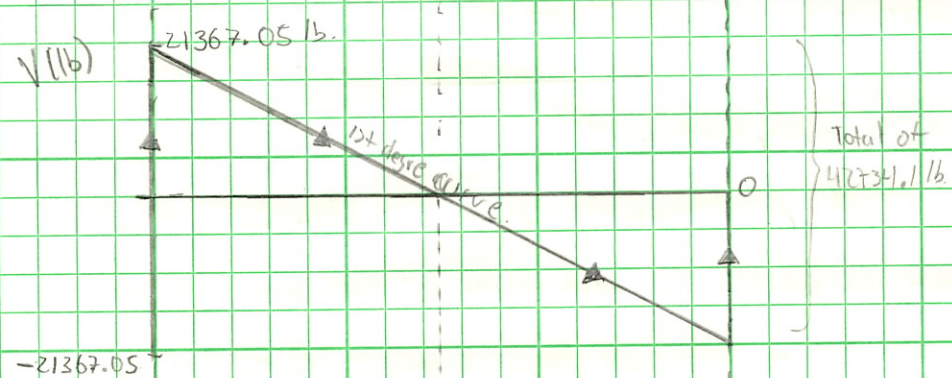


Figure 3: Shear Diagram.

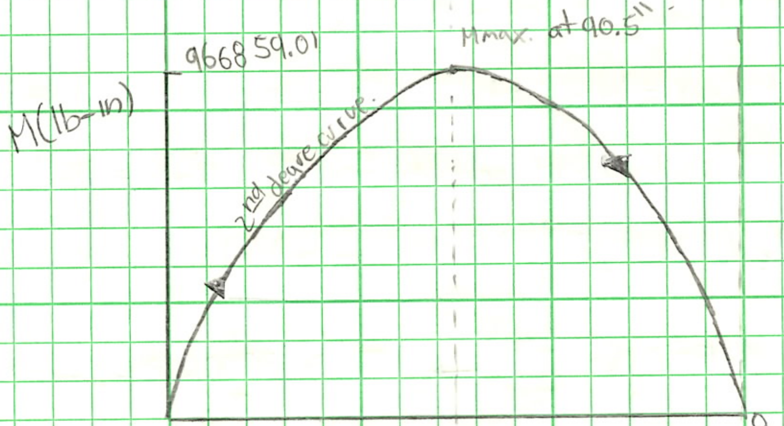
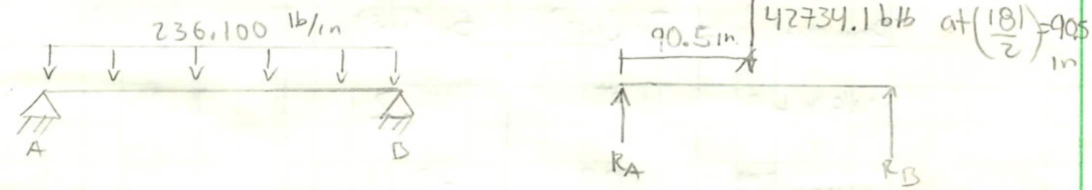


Figure 4: Moment Diagram.

② 2.1) Flexural Design | Calculations for M-V diagrams | Beam 1

- Since our W is Distributed along the Beam (B1). (see figure 2).

FBD:



Distributed load becomes: (236.100 lb/in)(181 in) = 42734.1 lb. at the center

- To Find Reactions: Use Basic Statics Knowledge.

  - Because of symetry: $\frac{42734.1 \text{ lb}}{2} = 21367.05 \text{ lb} = R_A = R_B$.

OR

$\sum M_A = 0 \rightarrow R_B(181 \text{ in}) - (42734.1 \text{ lb})(90.5 \text{ in}) = 21367.05 = R_B$

$\sum F_y = 0 \rightarrow R_A + R_B = 42734.1 \text{ lb} \rightarrow R_A = 21367.05 \text{ lb}$.

- From Reactions: we know $V_{max} = 21367.05$ lb since R_A is pointing upward

  - For Shear Diagram, since the Beam only experiences an evenly distributed load, then our graph will look linear with negative slope until it reaches R_B. which then brings it back to zero.

    (see figure 3)

- In order to graph out Moment Diagram:

  - Max Moment: $\frac{(V_{max})\left(\frac{181}{2}\right)}{2}$ (since its at the center) =

    $M_{max} = \frac{(21367.05 \text{ lb})(90.5 \text{ in})}{2} = 966859.01$ lb·in

  - Because of symetry: Total moment = 0 when we reach to 181"

    (see figure 4)

- We can obtain our section Modulus. by using equation: $\frac{I}{c} \geq \frac{M_{max}}{\sigma_{all}}$

But, $\frac{I}{c} = S$ so $\rightarrow S_x = \frac{M_{max}}{\sigma_{all}}$. $S_x = \frac{966859.01 \text{ lb·in}}{\left(\frac{50000 \text{ lb/in}^2}{2}\right)} = 38.674 \text{ in}.$

- The Beam options based on our S_x, and Based on the W-table: (Choose slightly bigger S_x).

  (see table 1.1).

Table 1.1 - Beam Options.

Designation #	I_x (in^4)	S_x (in^3)	d(in)
W8X48	184	43.3	8.5
W10X39	209	42.1	9.92
W12x35	285	45.6	12.5
W14x30	291	42.0	13.8

* Since Beam 2 is also located in the Electrical Room,

The total load $= 175\ lb/ft^2 = 1.2152\ lb/in^2$

- We know from B1 that: • $\sigma_{yield} = 50{,}000\ psi$ • $\sigma_{all} = 25\ ksi$

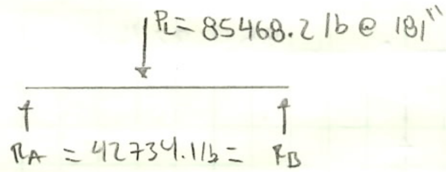
Load 1 $= T_L$(length of section) $= (1.215\ psi)(136\ in) = 165.280\ lb/in$

Load 2 $= (0.5208\ psi)(136\ in) = 70.833\ lb/in.$

$W = L_1 + L_2 = 236.100\ lb/in$

- $P_L = (W)(\text{Span length}) = (236.100\ lb/in)(181\ in + 181\ in) = \underline{85468.2\ lb}$
- If we want to find the reactions: (see figure 5)

FBD



Because of symetry:

$R_A = R_B$ or we can use our statics knowledge:

$R_A = R_B\ \frac{1}{2}(85468.2\ lb) = \underline{42734.1\ lb.}$

- For our shear diagram: (see figure 6).

• $R_A = V_{max} = 42734.1\ lb\ (T)$

- For our Moment diagram (see figure 7).

• $M_{max} = \frac{V_{max}(181\ in)}{2} = \frac{(42734.1\ lb)(181\ in)}{2} = 3867436.05\ lb.in.$

- For our Section Modulus: $S_x = \frac{M_{max}}{\sigma_x} = \frac{3867436.05\ lb.in}{\left(\frac{50000\ lb/in^2}{2}\right)} =$

$\sigma_x \rightarrow \sigma_{all}$

$S_x = 154.601\ in^3.$

- We want to find Beam options: (see table 2.1).

Figure 5: load Distribution on Beam 2.

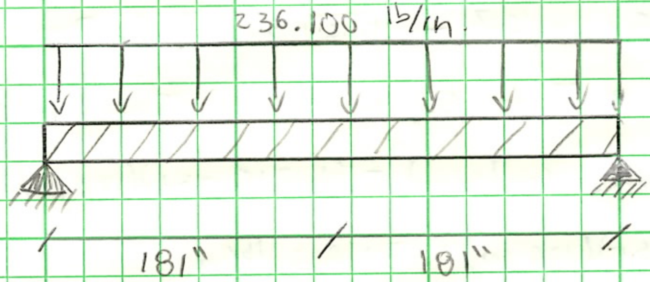


Figure 6: Shear Diagram for Beam 2.

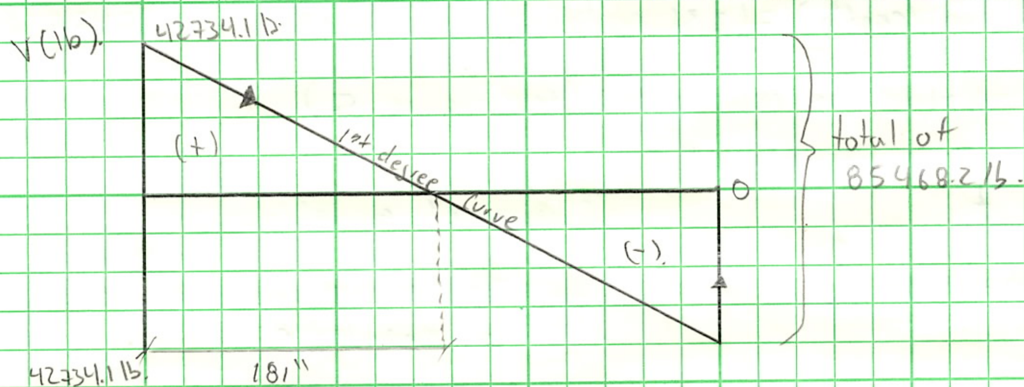


Figure 7: Moment Diagram of Beam 2.

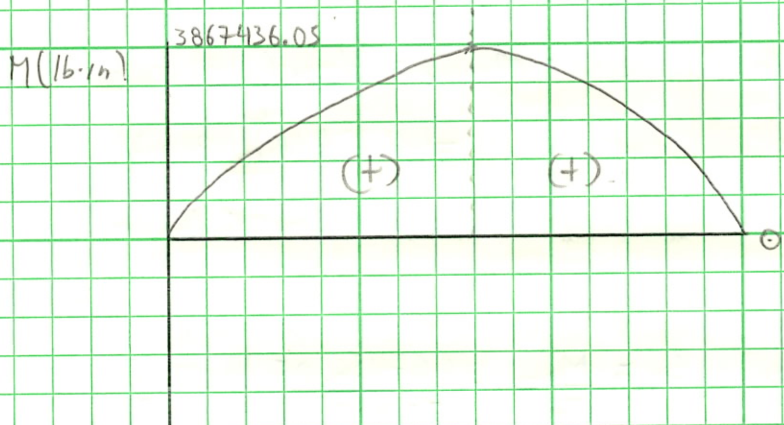


Table 2.1 - Beam options.

Designation #	I_x (in^4)	S_x (in^3)	d (in)
W24X68	1830	154	23.7
W16X89	1300	155	16.75
W14X99	1110	157	14.16
W18X86	1530	166.	18.4
W21X83	1830	171.	21.4

$\sigma_y = 50{,}000$ psi

$\sigma_{all} = 25{,}000$ psi

Loads : Dead $= 25$ lb/ft^2

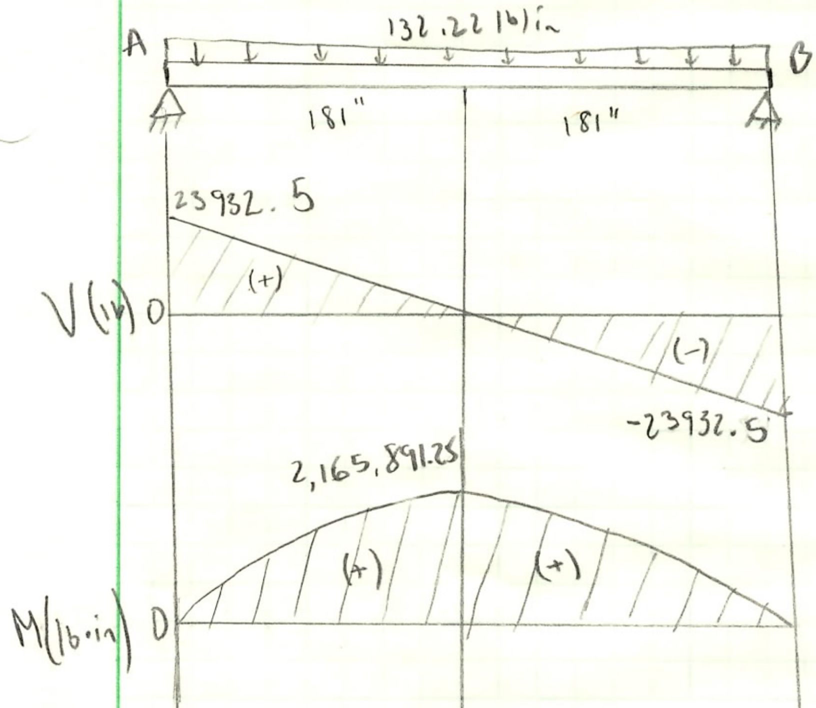
Live $= 40$ lb/ft^2

Total $= 65 \text{ lb/ft}^2 \left(\frac{1 \text{ ft}^2}{144 \text{ in}^2}\right) = 0.4514$ psi

$w_1 = (0.4514)(136) = 61.39$ lb/in

$w_2 = \left(150 \text{ lb/ft}^3\right)\left(\frac{1 \text{ ft}^3}{1728 \text{ in}^3}\right)(6 \text{ in})(136 \text{ in}) = 70.83$ lb/in

$w = w_1 + w_2 = 61.39 + 70.83 = 132.223$ lb/in



$P_L = (L)(w) = (362)(132.224)$

$P_L = 47865$ lb

$R_A = R_B = \frac{P_L}{2}$

$R_{A,B} = \frac{47865}{2} = 23932.5$ lb

$M_{max} = \frac{(V_{max})(181)}{2}$

$M_{max} = \frac{(23932.5)(181)}{2}$

$= 2165891.25$

$S_x = \frac{M_{max}}{\sigma_x} = \frac{2165891.25}{25000}$

$S_x = 86.636 \text{ in}^3$

Table 3.1 – Beam Options

Designation	I_x (in^4)	S_x (in^3)	d (in)
W12x72	597	97.4	12.3
W16x57	758	92.2	16.4
W18x50	800	88.9	18.0
W14x68	722	103	14.0

Total load $= 0.4514\ lb/in^2$

Concrete Density $= 150\ lb/ft^3$

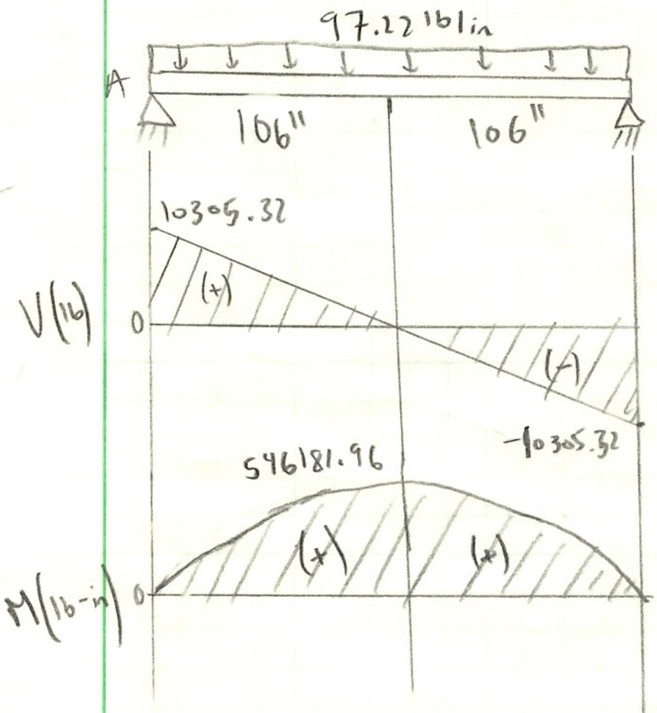
$\sigma_{all} = 25\ ksi$

Distributed loads:

$w_1 = (0.4514)(100) = 45.139\ lb/in$

$w_2 = (150\ lb/ft^3)\left(\frac{1\ ft^3}{1728\ in^3}\right)(6\ in)(100\ in) = 52.0833\ lb/in$

$w = w_1 + w_2 = 45.139 + 52.0833 = 97.22\ lb/in$



$P_L = (L)(w) = (212)(97.22)$

$P_L = 20,610.6\ lb$

$R_A = R_B = \frac{P_L}{2}$

$R_{A,B} = \frac{20610.6}{2} = 10305.32\ lb$

$M_{max} = \frac{(V_{max})(106)}{2}$

$M_{max} = \frac{(10305.32)(106)}{2}$

$M_{max} = 546181.96\ lb\text{-}in$

$S_x = \frac{M_{max}}{\sigma_x} = \frac{546181.96}{25000} = 21.84\ in^3$

Table 4.1 – Beam options

Designations	I_x (in^4)	S_x (in^3)	d (in)
W14 x22	199	29	13.7
W12x22	156	25.4	12.3
W10x22	118	23.2	10.2
W8 x 28	98	24.3	8.06

Live load $= \left(40 \frac{lb}{ft^2}\right)\left(\frac{1 ft^2}{144 in^2}\right)(136 in) = 37.78 \ lb/in$

$$\frac{L}{360} = \frac{362}{360} = 1.0056$$

$$\delta_{max} = \frac{5 w L^4}{384 E I}$$

① W12X72

$$\delta_{max} = \frac{5(37.78)(362)^4}{(384)(29\times10^6)(597)} = 0.488 < 1.0056 \quad \underline{Pass}$$

② W16 x 57

$$\delta_{max} = \frac{5(37.78)(362)^4}{(384)(29\times10^6)(758)} = 0.3843 < 1.0056 \quad \underline{Pass}$$

③ W16 x 50

$$\delta_{max} = \frac{5(37.78)(362)^4}{(384)(29\times10^6)(800)} = 0.364 < 1.0056 \quad \underline{Pass}$$

④ W14 x 68

$$\delta_{max} = \frac{5(37.78)(362)^4}{(384)(29\times10^6)(722)} = 0.4034 < 1.0056 \quad \underline{Pass}$$

✩ We know from our Flexural Design Calculations that:

- The total load = $W = W_1 + W_2 = 97.22$ lb/in. ✩ But we want Live!
- Live load = $\left(40 \frac{lb}{ft^2}\right)\left(\frac{1ft}{12in}\right)^2 (100 \text{ in}) = 27.7778$ lb/in
- Not use Dead Load
- $E = 29 \times 10^6$ psi

✩ If a max deflexion limit of $\frac{L}{360}$ under live loads.

- Live load = $\frac{L}{360} = \frac{181''}{360} = 0.5027$

✩ Use $\frac{5WL^4}{384EI}$ (chart from book).

✩ Usis our Beam options: Our $S_x = 21.84 \text{ in}^3$.

- 1st Beam: W14X22: $I_x(in^4) = 199$, $S_x(in^3) = 29$.

Live load: $\frac{5(\text{Load})(181in)^4}{384(E)(I_x)} = \frac{5(27.7778 \text{ lb/in})(181 in)^4}{384(29 \times 10^6 \text{ lb/in}^2)(199 \text{ in}^4)} = 0.06723$

$0.06723 < 0.5027$ (Good)

- W12X22: $I_x(in^4) = 156$, $S_x(in^3) = 25.4$

Live load: $\frac{5(27.7778 \text{ lb/in})(181 \text{ in})^4}{384(29 \times 10^6 \text{ lb/in}^2)(156 \text{ in}^4)} = 0.0858 < 0.5027$ (Good)

- W10X22: $I_x(in^4) = 118$, $S_x(in^3) = 23.2$

Live load: $\frac{5(27.7778 \text{ lb/in})(181 \text{ in})^4}{384(29 \times 10^6 \text{ lb/in}^2)(118 \text{ in}^4)} = 0.11344 < 0.5027$ (Good).

- W8X28: $I_x(in^4) = 98$, $S_x(in^3) = 24.3$.

Live load: $\frac{5(27.7778 \text{ lb/in})(181 \text{ in})^4}{384(29 \times 10^6 \text{ lb/in}^2)(98 \text{ in}^4)} = 0.13659 < 0.5027$ (Good).

We use our previous tables. (table 3.1).

B3

$$\frac{L}{d} = 16 \Rightarrow d = \frac{L}{16} = \frac{362}{16} = 22.625 \text{ in}$$

① W12x72

$d = 12.3 < 22.625$ fail

② W16x72

$d = 16.4 < 22.625$ fail

③ W18 x 50

$d = 18 < 22.625$ fail

④ W14x68

$d = 14 < 22.625$ fail

New choice : W24x68

$$\delta_{max} = \frac{5(37.78)(362)^4}{(384)(29\times10^6)(1830)} = 0.1592 < 1.005 \quad \text{Pass}$$

$d = 23.7 > 22.625$ Pass

☆ Use table 4.1 with "d" values.

B4

$$\frac{L}{d} = 16 \Rightarrow d = \frac{L}{16} = \frac{212}{16} = 13.25 \text{ in}$$

(1) W14 x 22

$d = 13.7 > 13.25$ Pass

(2) W 12 x 22

$d = 12.3 < 13.25$ fail

(3) W 10 x 22

$d = 10.2 < 13.25$ fail

(4) W 8 x 28

$d = 8.06 < 13.25$ Pass

- Under axial loads, ignore deflection limits in previous questions and no Buckling. - eccentricity of 12". - SoF = 2.0.
- $\sigma_{all} = \frac{50000 \text{ psi}}{2.0} = \frac{\sigma}{SF} = 25 \text{ ksi}$
- From our flexural design calculations: we said that: the load distribution:

$$P_R = R_A = R_B = 21367.05 \text{ lb}, \quad \text{load applied then is } 2 \times R_A.$$
$$= 42734.1 \text{ lb}.$$

- For the column conditions:
  - Total load = Live load + Dead load = W_1

$$= (75 \text{ lb/ft}^2) + (100 \text{ lb/ft}^2) = 175 \text{ lb/ft}^2 \left(\frac{1 \text{ ft}^2}{144 \text{ in}^2}\right) = 1.2152 \frac{\text{lb}}{\text{in}^2}$$

$$W_1 = (1.2152 \text{ lb/in}^2)(90.5 \text{ in}) = 109.985 \text{ lb/in}.$$

  - Concrete: W_2 = (Density concrete)(thickness of slab) x (length of col.) =

$$(150 \text{ lb/ft}^3)(6 \text{ in})(90.5 \text{ in})\left(\frac{1 \text{ ft}}{12 \text{ in}}\right)^3 = 47.1354 \frac{\text{lb}}{\text{in}}$$

(see figure 8). for reference.

$$W_T = 109.985 + 47.1357 = 157.120 \text{ lb}.$$

- From Distributed load:
  - $P_L = W(\text{Span length}) = \left(157.12 \frac{\text{lb}}{\text{in}}\right)(136 \text{ in}) = 21,368.32 \text{ lb}.$
  - $P_{Tot} = P_L + P_R$

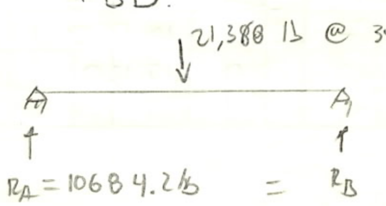
$$P_{tot} = 21368.32 \text{ lb} + 21367.05 \text{ lb} = 42,735.37 \text{ lb}.$$

  - Reactions from a total Force P: $R_A = R_B = \frac{21,368.32 \text{ lb}}{2} = 10684.16 \text{ lb}.$
  - $R_A = V_{max}$. - $M_{max} = 363261.1 \text{ lb·in}.$

(see figure 9) for distributed load.

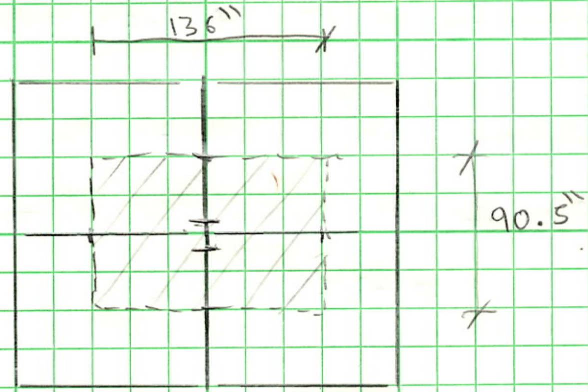
- Shear Diagram (figure 10).
- Moment Diagram (figure 11).

FBD.



$$S_y = \frac{M}{\sigma_{all}} = \frac{(P_{Tot})(12 \text{ in})}{25000 \frac{\text{lb}}{\text{in}^2}} = \frac{(42735.35 \text{ lb})(12 \text{ in})}{25000 \text{ lb/in}^2} = 25.642 \text{ in}^3.$$

Figure 8: Column



Problem states eccentricity of 12"

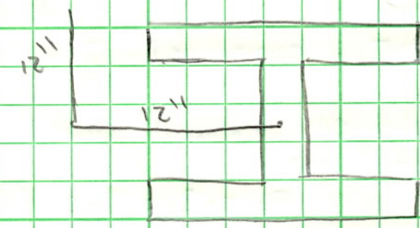


Figure 9: Distributed load.

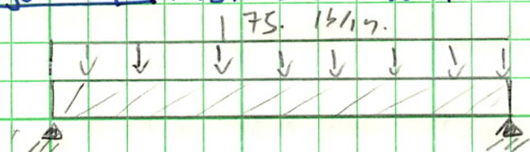


Figure 10: Shear Diagram

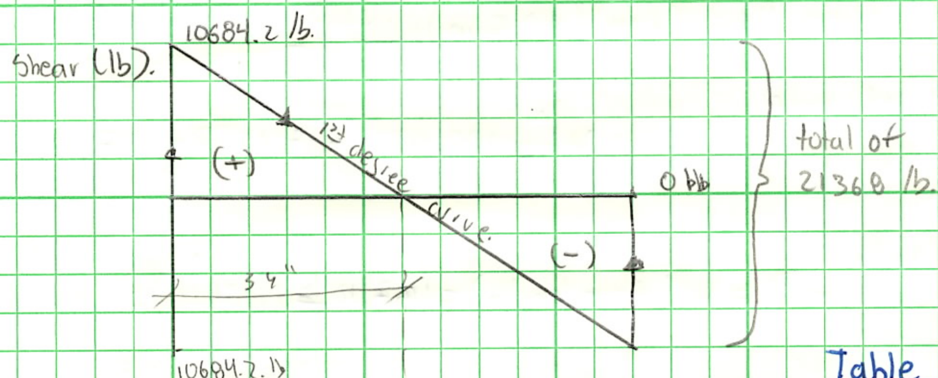
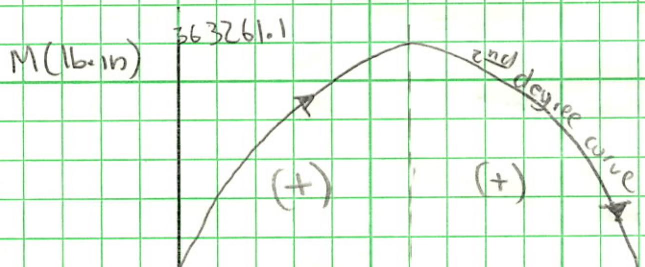


Table 4.1:

Designation #	I_x (in^4)	I_y (in^4)	S_y (in^3)
W16X77	1106	138	26.9
W14X74	796	134	26.6
W10X68	394	134	26.4

d(in)	Area	Width (in)
16.77	22.6	10.295
14.17	21.8	10.070
10.40	20.0	10.130

Figure 11: Moment Diagram



☆ From our table 4.1, test our W shape beams

☆ $\sigma = \frac{P_{tot}}{A} + \frac{M_x(Y_{max})}{I_x} + \frac{M_y(X_{max})}{I_y}$ ☆ $M_x = M_y = (42736.35\,lb)(12\,in) = 512836.2\,lb \cdot in$

- **W16X77** $I_x(in^4) = 1100$, $I_y(in^4) = 138$, $S_y(in^3) = 26.9$, $d = 16.77$, $A = 22.6\,in^2$, width $= 10.295\,in$

☆ $Y_{max} = \frac{d}{2} = \frac{16.77}{2} = 8.385\,in$

☆ $X_{max} = \frac{Width}{2} = \frac{10.295}{2} = 5.147$

$\sigma = \frac{(42735.35\,lb)}{22.6\,in^2} + \frac{(512836.2\,lb \cdot in)(8.385\,in)}{1100\,in^4} + \frac{(512836.2)(5.145)}{138}$

$\sigma = 24{,}920\,\frac{lb}{in^2} < \sigma_{all}(25\,ksi)$ Good

- **W14X74** $I_x(in^4) = 796$, $I_y(in^4) = 134$, $S_y(in^3) = 26.6$, $d = 14.17$, width $= 10.070$

Area $= 21.8\,in^2$

$Y_{max} = 14.17/2 = 7.085$

$X_{max} = 10.070/2 = 5.035$

$\sigma = \frac{(42735.35\,lb)}{21.8\,in^2} + \frac{(512836.2\,lb \cdot in)(7.085\,in)}{796\,in^4} + \frac{(512836.2\,lb \cdot in)(5.035\,in)}{134\,in^4}$

$\sigma = 25{,}794.5\,\frac{lb}{in^2} > 25\,ksi\,(\sigma_{all})$ Failure

- **W10X68** $I_x = 394\,in^4$ $I_y = 134\,in^4$ $S_y = 26.4\,in^3$, $d = 10.40\,in$, $A = 20\,in^2$, width $= 10.130\,in$.

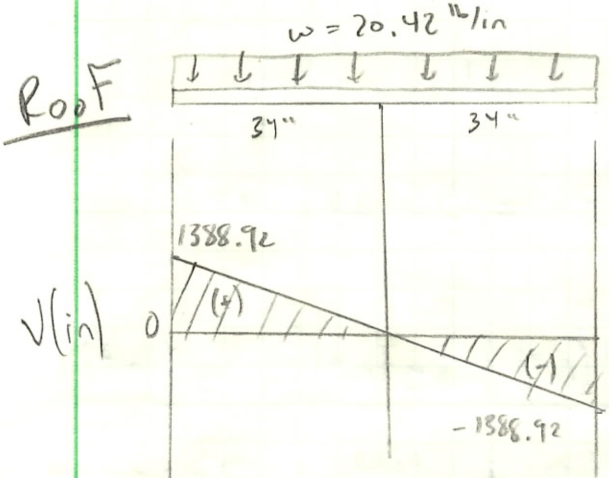
$Y_{max} = 10.40/2 = 5.2\,in$

$X_{max} = 10.130/2 = 5.065\,in$

$\sigma = \frac{(42735.35\,lb)}{20\,in^2} + \frac{(512836.2\,lb \cdot in)(5.2\,in)}{394\,in^4} + \frac{(512836.2\,lb \cdot in)(5.065\,in)}{134\,in^4}$

$\sigma = 28{,}284.6 > \sigma_{all}$ Failure.

Roof

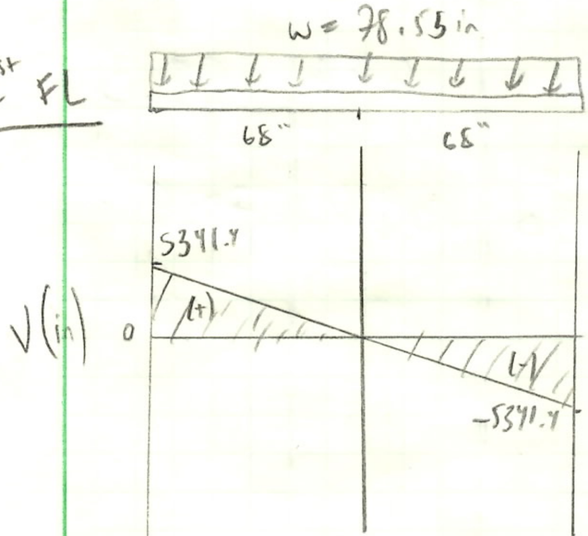


$P_1 = 24021.05$ lb

$P_2 = 2777.8$ lb

$P = P_1 + P_2 = 26799$ lb

1st FL

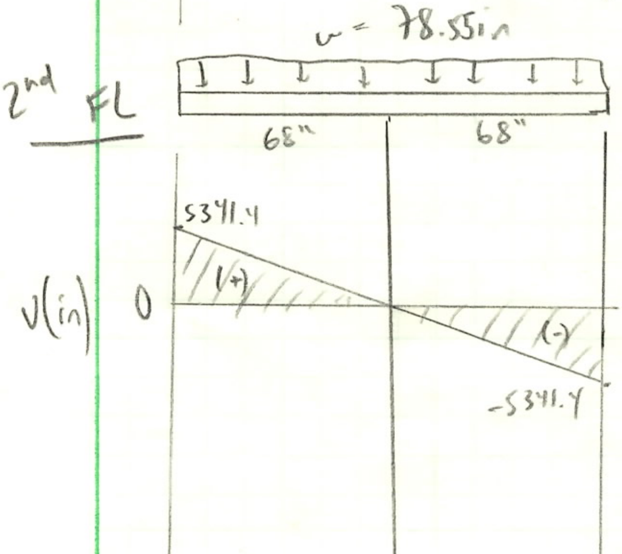


$P_1 = 42735.97$ lb

$P_2 = 10682.8$ lb

$P = P_1 + P_2 = 53418.8$ lb

2nd FL



$P_1 = 21368$ lb

$P_2 = 10682.8$ lb

$P = P_1 + P_2 = 32050.8$ lb

$P_{total} = 112268.5$ lb

$$M_x = M_y = (112268.5)(12) = 1347221.5 \text{ lb-in}$$

$$S_y = \frac{M}{\sigma_{all}} = \frac{1347221.5}{25000} = 53.889 \text{ in}^3$$

Designation	A (in^2)	d (in)	b_f (in)	I_x (in^4)	I_y (in^4)	S_y (in^3)
W27X146	43.1	27.4	14	5660	443	63.5
W14X145	42.7	14.8	15.5	1710	677	87.3
W30X173	51	30.4	15	8230	598	79.8

$$\sigma = \frac{P}{A} + \frac{M_x(Y_{max})}{I_x} + \frac{M_y(X_{max})}{I_y}$$

① W 27x146

$$\sigma = \frac{32050}{(43.1)} + \frac{(1347221.04)(27.4/2)}{(5660)} + \frac{(1347221.04)(14/2)}{443}$$

$$\sigma = 743.62 + 3260.94 + 21287.9 = 25292.48 > \sigma_{all}$$

fail

② W 14x145

$$\sigma = \frac{32050}{42.7} + \frac{(1347221.04)(14.8/2)}{1710} + \frac{(1347221.04)(15.5/2)}{677}$$

$$\sigma = 750.6 + 5830.08 + 15422.4 = 22003 < \sigma_{all}$$

Pass

③ W 30x173

$$\sigma = \frac{32050}{51} + \frac{(1347221.04)(30.4/2)}{8230} + \frac{(1347221.04)(15/2)}{598}$$

$$= 628.43 + 2488.18 + 16896.58 = 20013.2 < \sigma_{all}$$

Pass

Choose $\boxed{W14X145}$ because it is lightest

(14) 2.5) Determine min size of 18" thick sqr footings. B/4 and D/4 columns.

$$\sigma_{all} = \frac{7000}{2} = 3500 \frac{lb}{ft^2}\left(\frac{1}{144}\right) = 24.31\ psi$$

$$\sigma_c = (18")(.15\ lb/ft^3)\left(\frac{1\ ft^3}{1728\ in^3}\right) = 0.156\ psi$$

$$P = 42\,736.6\ lb$$

$$\sigma_{all} = \sigma_c + \frac{P}{A} = 24.31 = 0.156 + \frac{42736.6}{A}$$

B4

$$\frac{42736.6}{A} = 24.15 \Rightarrow A = 1769.36\ in^2$$

$$S = \sqrt{1769.36} = 42.06\ in \approx \underline{42\ in}$$

D4

$$A = \frac{P}{A} = \frac{11268.46}{24.31} = 4618.2\ in^2$$

$$S = \sqrt{4618.2} = 67.95\ in \approx \underline{68\ in}$$

2.6) Investigation of impact | Calculations.

- New Request: 250 psf on roof by adding a new generator

$$\Sigma M_A = \overset{L_{1A}}{(66{,}669\ lb)(96.5\ in)} + \overset{L_{1B}}{(23935\ lb)}(0.75) + R_B\ \ 0$$

$$R_B\ \ 24{,}519\ lb.$$

$$\Sigma F_y = R_B + R_A - (66{,}669\ lb) - (23935\ lb) = 0$$

$$R_A = 55.989\ lb$$

W_1 = total weight = 236.096 lb/in

W_2 = 132.7 lb/in

$$S_{min} = \frac{4.254.775\ lb\text{-}in}{23{,}690\ \frac{lb}{in^2}} = 170.191\ in^3$$

$$\delta_{tot} = \frac{-5 w_2 L^4}{384 EI} + \frac{w_1 y}{24 EIL}\left(a^2 4 l^2 a^2 - 2ax^2\, 2La + Lx^3\right)$$

$$L = 181\ in$$

when, $\frac{dy}{dx} = 0$, $x = 166.4$ in

live last definition

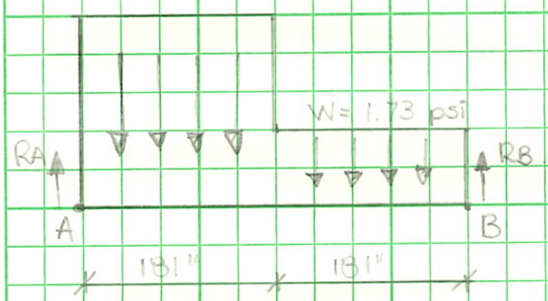
$$\text{total} = \delta = \frac{5 w_2 L^4}{384 EI} + \frac{w_1 (9.79 \times L'')}{24 EIL},$$

$$\text{live} = \delta = \frac{5 w_2 L^4}{384 EI}$$

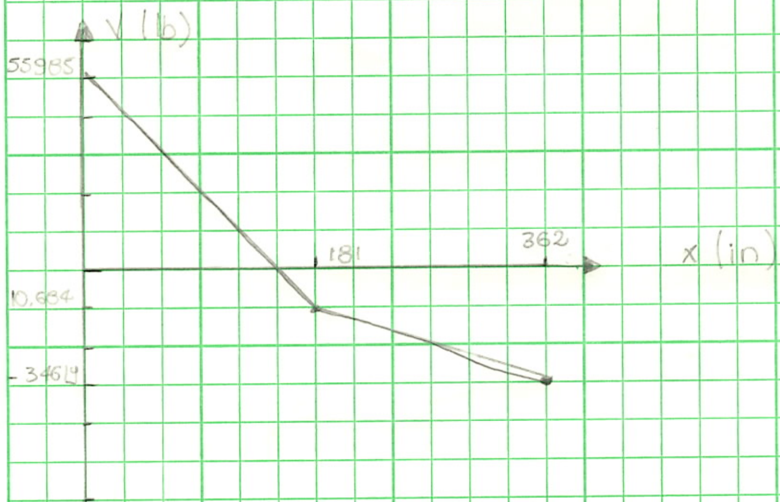
total live load = $274\ \frac{lb}{in}$

- So the lighter beams vertre gring to test are?

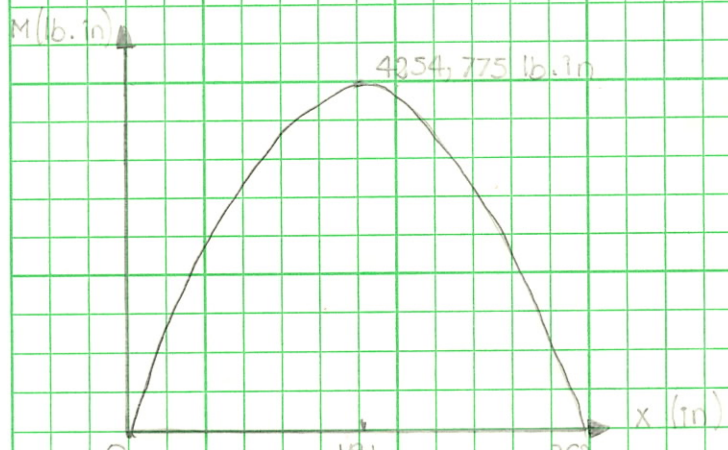
W 18x76
W 24x68
W 27x84



Shear



Moment



2.6) Investigation of Impact Calculations.

Criterio live : $\frac{362 \text{ in}}{360 \text{ in}} = 7{,}005$

total = $\frac{362 \text{ in}}{240 \text{ in}} = 1{,}51$

test.

- W 18 x 75

$I_x = 1330 \text{ in}^4$

$\text{live} = \frac{(5)(229 \text{ lb/in})(362 \text{ in})^4}{384(29 \times 10^6 \text{ lb/in}^2)(1330 \text{ in}^4)} = 1.6 > 1.005$ fail

- W 24 x 68

$I_x = 1830 \text{ in}^4$

$\text{live} = \frac{(5)(274 \text{ lb/in})(363 \text{ in})^4}{384(29 \times 10^6 \text{ lb/in}^2)(1830 \text{ in}^4)} = 1.157 > 1.005$ fail

- W 27 x 84

$I_x = 2850 \text{ in}^4$

$\text{total} = \frac{5(132.7 \text{ lb/in})(362 \text{ in}^4)}{384(29 \times 10^6 \text{ lb/in}^2)(2850 \text{ in}^4)} + \frac{(236 \text{ lb/in})(9.29 \times 10^4)}{24(29 \times 10^6 \text{ lb/in})(2850 \text{ in}^4)} = 68$

$\text{live} = \frac{5(274 \text{ lb/in})(362 \text{ in}^4)}{384(29 \times 10^6 \text{ lb/in}^2)(2850 \text{ in}^4)} = 0.74 < 1.005$ pass

Depth of W 27 x 84

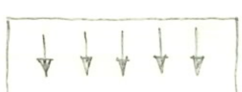
$\frac{362 \text{ in}}{16} \le \text{depth}$

$26.7 \text{ in} \le 22.625 \text{ in}$ pass

- W27x84 ✓

- Columns

B4 unaltered by generator

B4 

136 in

total weight = $(.4514 \text{ lb/in}^2)(45.25 \text{ in})$
$+ (190 \text{ lb/in}^2)(1 \text{ lb}/12 \text{ in})^3 (6 \text{ in})(45.25 \text{ in})$
$+ (1.73 \text{ lb/in}^2)(45.25 \text{ in}) = 122.28 \text{ lb/in}$

$P = (122.28 \text{ lb/in})(136 \text{ in}) = 16{,}630.08 \text{ lb}$

Total depth on all flovel = 158, 121 lb

$$M_y = (158{,}121\ lb)(12\ in) = 1{,}897{,}468.4\ lb.in$$

$$S_y = \frac{1{,}897{,}468.4\ lb.in}{23{,}060\ lb/in^2} = 75.9\ in^3$$

Steel shapes to be examind

- W 30 x 173
- W 14 x 145
- W 33 x 201

<u>tely</u> : $\gamma_{all} = 25{,}000\ lb/in^2$

• W30 x 173

$A = 41\ in^2,\ C_y = 15.2\ in\ \ C_x = 7.5\ in,\ I_y = 8230\ in^4\ \ I_x = 592\ in^4$

$$\gamma = \left(\frac{198121\ lb}{51.0\ in^2}\right) + \left(\frac{1297468.42\ lb.in}{8230\ in^4}\right) + \left(\frac{(1897468.41\ lb.in)(36\ in)}{598\ in^4}\right)$$

$\gamma = 30{,}402.5\ psi > 25{,}060\ psi$ foil

• W14 x 143

$A = 42.7\ in^2,\ C_y = 7.4\ in,\ C_x = 7.76\ in,\ I_y = 1710\ in^4,\ I_x = 677\ in^4$

$$\gamma = \left(\frac{158{,}121\ lb}{42.7\ in^2}\right) + \left(\frac{1897468.416\ lb\ (7.9\ in)}{1710\ in^4}\right) + \left(\frac{18974624\ lb.in\ (7.72\ in)}{677\ in^4}\right)$$

$\gamma = 33{,}635.7\ psi > 25{,}060\ psi$ foil

• W 33 x 201

$A = 59.2\ in^2,\ C_y = 16.85\ in,\ C_x = 7.25\ in,\ I_y = 7495\ in^4,\ I_x = 1466\ in^4$

$$\gamma = \left(\frac{158{,}12\ lb}{59.2\ in^2}\right) + \left(\frac{(187468.4\ lb.in)(16.185\ in)}{744\ in^4}\right) + \left(\frac{(147469.41\ lb.in)(7.85\ in)}{11.800\ in^4}\right)$$

$\gamma = 2015.24\ psi < 25\ 000\ psi$ pass

- W 33 x 201 ✓

<u>footing</u> :

- B/4 is not offerld by generator
- D/4 f_{all} = 24, 31 psi

New area : $A = 7150.75\ in^2$

$$S = \sqrt{7150.75\ in^2} = 84.56\ in \approx 85\ in$$

2.7 – Composite Action

As stated within the instructions of the project, we are to assume all beams are simply supported, steel has elasto-plastic stress-strain characteristics, ignore any lateral load, and ignore any composite action between the concrete slabs and steel beams. However, in a more realistic approach to the design project where the concrete slabs and beams would be connected (by bolts, etc) then you would have to take composite action into consideration.

If the two materials were in composite action, it would result in an overall stronger member because materials that are in composite action are considered as one material. Composite action increases the strength of the beams which increases the yielding stress and allowable stress.

If the member is stronger, it means that it can support a greater allowable load. This greater allowable load would result in a smaller sectional modulus (compared to the one calculated in the report) because allowable stress and section modulus are inversely proportional. As allowable stress increases, section modulus decreases. With a smaller section modulus, we have more choices for beams to choose from for our design. This allows us to choose a beam that is lighter, more economical and supports a greater load.