Thornton Crossroads at 104th Avenue Station
90% Design Submittal

Structural Calculations –

Parking Garage

CDRL 03-037.11.06

June 2, 2017

Prepared by:

Regional Rail Partners

For:

North Metro Rail Line Project

RTD CONTRACT No. 13DH008

Having checked this item of Contract Data, I hereby certify that it conforms to the requirements of the Agreement in all respects, except as specifically indicated.

______________________________
David Trent, RRP Project Director
NORTH METRO RAIL LINE PROJECT

QA CERTIFICATION OF CONFORMANCE

DESIGN SUBMITTAL

CDRL No. 03-037.11.06

THORNTON CROSSROADS AT 104TH STATION
PARKING GARAGE

90% Submittal

QA STATEMENT

Upon examination of the documents of this submittal, I find that:

The Quality Assurance process was completed and meets the requirements identified in the Design Quality Management Plan.

______________________________
Quality Assurance Manager

06/02/2017
Date
NMRL 104th Parking Garage
104th and Colorado
Thornton, Colorado

Structural Calculations

Prepared by: KL&A, inc
Date: 5/24/2017
Calculation Package

TABLE OF CONTENTS

100. BASIS OF DESIGN
200. FOUNDATIONS
300. FLOOR AND ROOF FRAMING
400. COLUMNS AND WALLS
500. LATERAL SYSTEM
600. MISCELLANEOUS DESIGN

A-200. FOUNDATION APPENDIX
A-300. ROOF AND FLOOR FRAMING APPENDIX
A-400. COLUMNS AND WALLS APPENDIX
A-500. LATERAL SYSTEM APPENDIX
A-600. MISCELLANEOUS DESIGN APPENDIX
This project consists of (5) levels of above grade and (1) level below grade parking structure. The foundations consist of spread footings. The superstructure consists of post-tensioned slabs with concrete columns. The lateral system is concrete shear walls. The structure has (3) isolated stair/elevator cores constructed steel with composite deck framing. The stair/elevator cores utilize steel moment frames for their lateral systems. This project was designed in accordance with 2015 International Building Code with local updates in accordance with the Thornton Building Department and RTD design standards.

The following is an overview of the loading used in the design of the structure and the key parameters used to derive the loads.

A. Dead Loads

A detailed plan summary of the dead loads can be found in the load keys in the drawing documents. Loads include self-weight of the structure as well as allowances for superimposed loading (e.g. MEP, finishes, insulation, etc). The following typical dead loads were used in the structural calculations.

- Concrete self weight: 135 psf
- Concrete over run: 15 psf
- MEP allowance: 5 psf
- Stair Core self weight: 80 psf
- Stair Core roof self weight: 80 psf

B. Live Loads

The loads keys in the drawing documents show a detailed plan summary of the design live loads for the project. The following typical live loads were used in the design of the structure.

- Parking Garage: 40 psf
- Stair Loading: 100 psf

C. Snow Loads

Snow loads were calculated based on ASCE7-10:

- Ground snow load: 30 psf
- Typical flat roof snow load: 25 psf
- Snow Importance Factor: 1.0

The locations of snow loading and drift on the structure can be seen in the load keys in the drawing documents. See Appendix A-100 for detailed snow load calculations.
Calculation Package

D. Wind Loads:
Wind loads were calculated based on ASCE7-10 based on the following:

<table>
<thead>
<tr>
<th>Enclosure Classification</th>
<th>Enclosed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Category</td>
<td>II</td>
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<tr>
<td>Wind Speed</td>
<td>117 mph (ultimate)</td>
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<tr>
<td>Wind Directionality Factor, Kd</td>
<td>1</td>
</tr>
<tr>
<td>Exposure Category</td>
<td>C</td>
</tr>
<tr>
<td>Topographic factor, Kzt</td>
<td>1</td>
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<tr>
<td>Building flexibility</td>
<td>Rigid</td>
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<tr>
<td>Gust effect factor, G</td>
<td>0.85</td>
</tr>
<tr>
<td>Internal Pressure Coefficient</td>
<td>+/- 0.18</td>
</tr>
</tbody>
</table>

Resulting wind loads:
Wind base shear:
- East/West: 313 k
- North/South: 183 k

Components & cladding loads (based on 50sqft effective area):
- Interior roof zone: 28.2 psf
- Roof end zone: 38.0 psf
- Corner roof zone: 38.0 psf
- Interior wall zone: 27.0 psf
- Wall end zone: 34.2 psf

See Appendix A-100 for detailed wind load calculations.

E. Seismic Loads for Parking Garage:
Seismic loads were calculated based on ASCE7-10 based on the following:

<table>
<thead>
<tr>
<th>Ss</th>
<th>0.177</th>
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<tbody>
<tr>
<td>S1</td>
<td>0.057</td>
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<tr>
<td>Site Class</td>
<td>D</td>
</tr>
<tr>
<td>Period</td>
<td>.568 Sec</td>
</tr>
<tr>
<td>Period determination</td>
<td>Approx per ASCE 7</td>
</tr>
<tr>
<td>Long Period Tl</td>
<td>4</td>
</tr>
<tr>
<td>Seismic Force resisting System</td>
<td>Ordinary Reinf Conc Shear Wall</td>
</tr>
<tr>
<td>Response Modification Factor, R</td>
<td>5</td>
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<tr>
<td>Overstrength Factor, Ωo</td>
<td>2.5</td>
</tr>
<tr>
<td>Deflection Amplification Factor</td>
<td>4.5</td>
</tr>
<tr>
<td>Importance Factor, Ie</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Resulting Seismic Base Shear:
- East/West: 1264 K
- North/South: 1264 K

See Appendix A-100 for detailed seismic load calculations.

F. Soil Loads:
Calculation Package

Soil loads calculated based on the values stated in the geotechnical report are shown below:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Equivalent Fluid Pressure</td>
<td>50 psf/ft</td>
</tr>
<tr>
<td>At-Rest Equivalent Fluid Pressure</td>
<td>70 psf/ft</td>
</tr>
<tr>
<td>Passive Equivalent Fluid Pressure</td>
<td>325 psf/ft</td>
</tr>
<tr>
<td>Sliding Friction Coefficient</td>
<td>0.53</td>
</tr>
</tbody>
</table>
Calculation Package

200. FOUNDATIONS

The foundation system for this structure is spread footings for the gravity columns and mat foundations for the lateral system based on the criteria found in the geotechnical report provided by Yeh and Associates, dated 10/18/2016. A copy of the geotechnical report can be found in appendix A-200. The following is a summary of the soil parameters:

- Footings:
  - Footing allowable bearing pressure: 6000 psf
- Continuous Footings:
  - Footing allowable bearing pressure: 4000 psf
- Retaining Walls and Basement Walls:
  - Active soil pressure: 50 psf/ft
  - At rest soil pressure: 70 psf/ft
  - Passive soil pressure: 325 psf/ft

This parking garage sits on a sloping site, creating one corner the building retaining two stories of soil while the other corner is flush with the exterior grade. This grading across the site created unbalanced soil loading on the structure. At the elevated slab levels, the basement walls engage the floor diaphragms to distribute the hydrostatic force into the shear walls. To accommodate this large hydrostatic force at the ground level basement walls tie into the slab on grade to use the slab on grade as a diaphragm. From a global stability standpoint, the large hydrostatic force was resolved from sliding resistance of the building.

Gravity and lateral loads to the foundation were determined using Etabs, a 3-D analysis and design program, based on loads as prescribed in section 100. The Etabs model was also validated through the use of hand calculations.

An in house spread sheet was used to design the gravity foundation elements of the building. A representative design of the foundations is provided in Appendix section A-200.

Ram Concept was used to design the lateral foundation elements of the building. The Ram Concept output can be found in in Appendix section A-200.
Calculation Package

200 Foundation Calculation Index:
Gravity Loading Summary 201
Lateral Load Summary 202
Gravity Footing Design 203
Lateral Matt Foundation Design 204
Basement Wall Design 205
Floors for the structure are composed of cast-in-place post-tensioned concrete slabs over post tensioned slab beams. The following is a discussion of the design of these elements.

Garage Floor Framing:
A typical floor of this structure consists of a 7 ½” cast-in-place post tensioned slab over 14” deep x 7’-0” wide post tensioned slab beams. The design of this floor system was done through Ram Concept following all ACI requirements.

Stair Core Floor and Roof Framing
The floor and roof decks for the stair cores structure are 3VLI composite deck with 2” of normal weight concrete over non-composite wide-flange steel framing. The design of this system is detailed below.
A. Decks
The floor and roof deck was selected using Vulcraft tables. For the maximum typical span of 12'-10”, a 18 gage deck was selected.
B. Framing
Beams were designed using RAM Structural Systems based on LRFD in accordance to AISC 14. Typical beams are wide flange beams, with deflections limited to 1/2” but not less than L/360 live load and L/240 total load. A representative design of the framing is provided where indicated in this index below.

Connections
Typical steel beam connections are based on the LRFD design reactions calculated in RAM Structural Systems. Typical connection details are found in the typical details in the drawing documents. Any unusual connections, based on the varied geometry of the structure, were designed using the reactions from RAM in accordance with AISC. Connection design calculations can be found in Appendix A-300.
Calculation Package

300 Floor and Roof Framing Calculation Index:

[Steel, Wood...] Framing Size Summary Plans 301
[Steel, Wood...] Loading Summary 302
[Steel, Wood...] Framing Number Key Plans 303
[Steel, Wood...] Beam Design 304
[Steel, Wood...] Deck Design 305

[Conc Slab, PT Slab] Layout Summary 306
[Conc Slab, PT Slab] Load Summary 307
[PT Slab] Tendon Layout 308
[Conc Slab, PT Slab] Reinforcing Layout 309
[Conc Slab, PT Slab] Deflection Summary 310
[Conc Slab, PT Slab] Moment Plan 311
[Conc Slab, PT Slab] Design Strip Key Plan 312
[Conc Slab, PT Slab] Design Strip Design 313
[Conc Slab, PT Slab] Punching Shear Key Plan 314
[Conc Slab, PT Slab] Punching Shear Design 315

[Other...]  Section....
Calculation Package

400. COLUMNS AND WALLS

The columns for this structure are typically 16”x24” CIP columns. Typical structural walls are 12” ordinary reinforced concrete shear walls. See Section 500 for information pertaining to the lateral design of the columns and walls.

Garage Column Design
Gravity columns were designed based on factored loads using Etabs. Typical columns are 16”x24” columns. The typical unbraced lengths of the columns was 10’-0” feet at each level.

Stair Column Design
The gravity columns in the stair core were based on factored loads using the Ram structural system analysis. The typical column size was an HSS 12“x12”, with an unbraced length of 10’-0” for each level.
Calculation Package

400 Columns and Walls Calculation Index:

<table>
<thead>
<tr>
<th>Column Size Summary Plans</th>
<th>401</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column Numbering Key Plans</td>
<td>402</td>
</tr>
<tr>
<td>Column Design</td>
<td>403</td>
</tr>
</tbody>
</table>
Calculation Package

500. LATERAL SYSTEM

The lateral system consists of Ordinary Reinforced Concrete Shear Walls. The floor and roof diaphragms consist of post tensioned concrete slabs as described in section 300.

The main lateral force resisting system was analyzed using ETABS a 3D analysis/Design software program. P-delta effects were included in the lateral analysis accounting for reduction of member stiffness considering cracked section properties per ACI318. Floor and roof diaphragms were modeled considering Semi-rigid behavior.

Seismic:
The seismic force resisting system was designed per ASCE7 consisting of Ordinary Reinforced Concrete Shear Walls in the both the north-south direction and in the east west direction. The equivalent lateral force procedure was used to determine design seismic forces. The seismic base shear was calculated using the parameters as indicated in section 100 and validated through hand calculations. The building period was determined by the approximate period calculation per ASCE7. Seismic irregularities were checked and no irregularities were found.

Wind:
The wind force resisting system was designed per ASCE7 consisting of Ordinary Reinforced Concrete shear Walls in both the north-south direction and in the east west direction. The directional procedure for buildings of all heights was used to determine design wind forces. The wind base shear was calculated using the parameters as indicated in section 100.

Soil:
The soil force resisting system was designed per ASCE 7 consisting of Ordinary Reinforced Concrete shear wall in both the north-south and east-west direction. The soil forces were determined using the values given in the geotechnical report. The soil pressures were analyzed in Etabs concurrently with the seismic and wind forces. The basement walls use the floor diaphragms to transfer the soil forces into the concrete shear walls.
Calculation Package

500 Lateral System Calculation Index:
Wind and Seismic Base Shears and Story forces  501
Soil loads  502
Story drift and deflections  503
Main Lateral Force Resisting System Design  504
Diaphragm Design (Stiffness, flexure, shear, deflections, collectors, etc.)  505
## 600. MISCELLANEOUS DESIGN

### 600 Miscellaneous Design Calculation Index:

<table>
<thead>
<tr>
<th>Component</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevators</td>
<td>601</td>
</tr>
<tr>
<td>Stairs</td>
<td>602</td>
</tr>
<tr>
<td>Mechanical supports</td>
<td>603</td>
</tr>
<tr>
<td>Handrails and Guard Rails</td>
<td>605</td>
</tr>
</tbody>
</table>