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HUDSON YARDS - TOWER C
PEER REVIEW REPORT

Prepared for
The Related Companies

Prepared by
DeSimone Consulting Engineers

March 12, 2013

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I. EXECUTIVE SUMMARY

DeSimone Consulting Engineers (DeSimone) performed a Peer Review as required by the New York Building Code Section BC 1627.2.

We relied on drawings that were prepared by the Engineer of Record, Thornton Tomassetti, dated 20 August 2012 with subsequent revisions dated 14 December, 2012 and 01 February, 2013. Additionally we reviewed the Design Criteria, Wind Tunnel Studies and Geotechnical Reports, prepared by others.

Our findings are summarized within the pages of this report and the accompanying spread sheets entitled Review Comments.

The issues presented for discussion have been resolved to our satisfaction and the design as presented is in general conformance with the intent of the New York City Building Code (NYCBC) and referenced standards.

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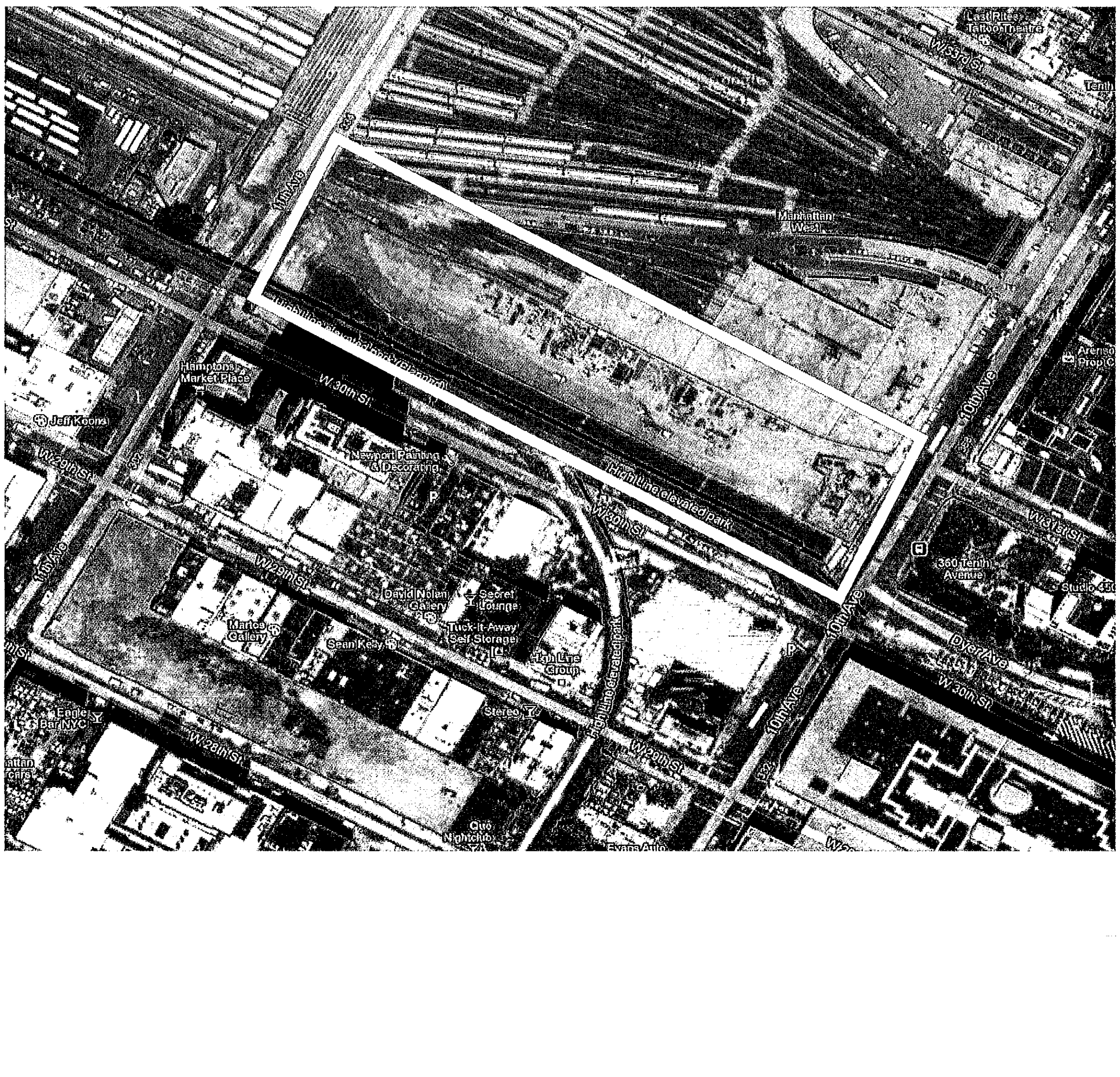
II. PROJECT DESCRIPTION

Site Description

The site is located within the Southeast quadrant of the Metropolitan Transportation Authority (MTA) – Long Island Rail Road (LIRR) Westside Yards. The Westside yard is split by Eleventh Avenue into the Western Rail Yard and Eastern Rail Yard. The Tower C site is located on the southern part of the Eastern Rail Yard. The site has a total footprint of approximately 101,000 square feet and was previously used as a laydown area for the contractor responsible for the No. 7 Subway Line extension.

The elevated railway known as the "Highline" occupies the southern portion of the site. The existing railway will become part of the Highline Park and will be integrated into the project.



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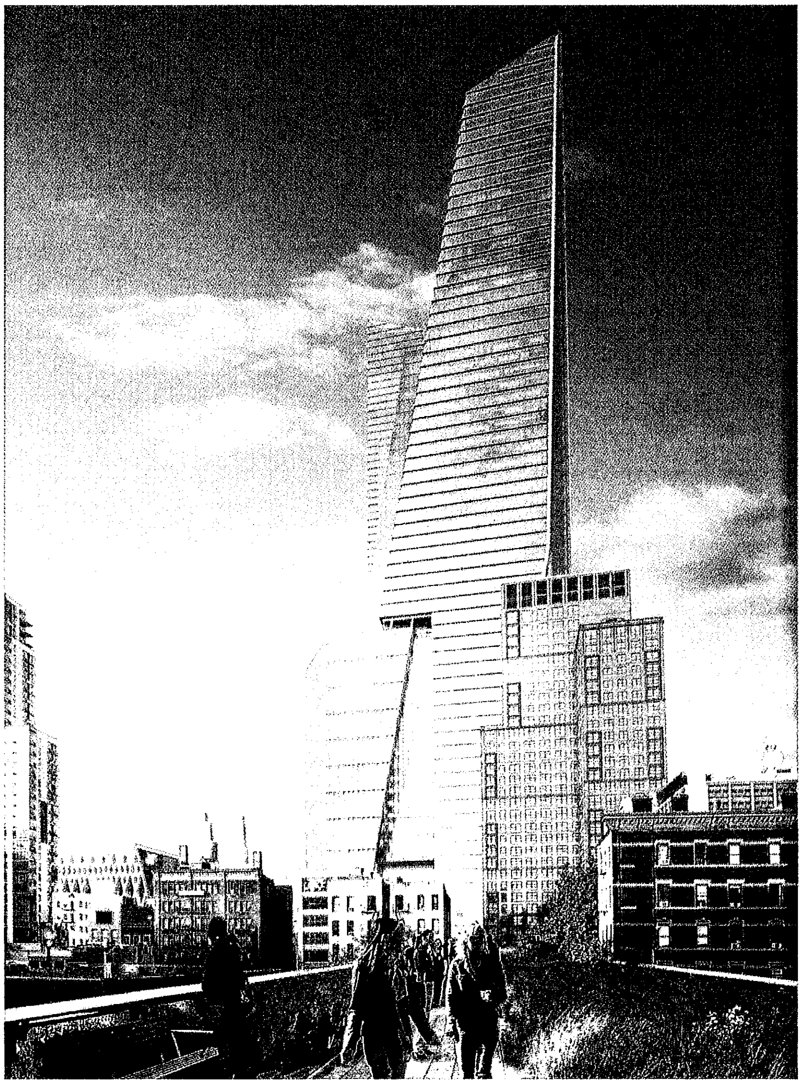
Proposed Construction

The Tower C project will include a 47 story commercial building with a low rise podium. The tower will be located on the eastern portion of the site. The low rise podium will occupy the middle of the site. The building will be constructed on "terra firma", off the proposed platform and will rise to a height of approximately 880 feet. The tower will also straddle the existing High Line structure. The depth of excavation is approximately 20 feet and will have a single basement that will contain parking and mechanical.



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III. SCOPE OF STUDY

DeSimone Consulting Engineers (DeSimone) has been engaged by The Related Companies to perform a code required Peer Review of the Tower C project located in the Hudson Yards Development. The 2008 New York City Building Code (NYCBC) requires a structural peer review be performed based on criteria established in Chapter 16. (see Appendix B, Vol. I)

1627.2 Where required. A structural peer review of the primary structure shall be performed a report provided for the following buildings:

1. Buildings included in Structural Occupancy Category IV as defined in this chapter and more than 50,000 square feet (4645 m^2) of framed area.

2. Buildings with aspect ratios of seven or greater.

3. Buildings greater than 600 feet (183 m) in height or more than 1,000,000 square feet (92 903 m^2) in gross floor area.

4. Buildings taller than seven stories where any element supports in aggregate more than 15 percent of the building area.

5. Buildings designed using nonlinear time history analysis or with special seismic energy dissipation systems.

6. Buildings where a structural peer review is requested by the commissioner.

The peer review scope will include but not be limited to the following:

1627.6 Extent of the structural peer review.

1627.6.1 Scope. The reviewing engineer shall review the plans and specifications submitted with the permit application for general compliance with the structural and foundation design provisions of this code. The reviewing engineer shall perform the following tasks at a minimum:

1. Confirm that the design loads conform to this code.

2. Confirm that other structural design criteria and design assumptions conform to this code and are in accordance with generally accepted engineering practice.

3. *Review geotechnical and other engineering investigations that are related to the foundation and structural design and confirm that the design properly incorporates the results and recommendations of the investigations.*
4. *Confirm that the structure has a complete load path.*
5. *Perform independent calculations for a representative fraction of systems, members, and details to check their adequacy. The number of representative systems, members, and details verified shall be sufficient to form a basis for the reviewer's conclusions.*
6. *Verify that performance-specified structural components (such as certain precast concrete elements) have been appropriately specified and coordinated with the primary building structure.*
7. *Confirm that the structural integrity provisions of the code are being followed.*
8. *Review the structural and architectural plans for the building. Confirm that the structural plans are in general conformance with the architectural plans regarding loads and other conditions that may affect the structural design.*
9. *Confirm that major mechanical items are accommodated in the structural plans.*
10. *Attest to the general completeness of the structural plans and specifications.*

1627.6.2 Structural calculations. The structural calculations prepared by the structural engineer of record shall be submitted to the reviewing engineer, upon the reviewing engineer's request, for reference only. The reviewing engineer shall not be obliged to review or check these calculations. If the design criteria and design assumptions are not shown on the drawings or in the computations, the structural engineer of record shall provide a statement of these criteria and assumptions for the reviewer.

In addition to the general requirements outlined in the NYCBC, we have identified a specific Summary of Services matrix included in our proposal dated March 22, 2012. (see Appendix B, Vol. I)

The objective of this report is to determine "whether or not the structural design shown on the plans and specifications generally conforms to the structural and foundation requirements of the code".

For the purposes of this review, we have broken down our review into four (4) components as follows:

- Basis of Design – Geotechnical Report, Wind Tunnel Study, Design Criteria
- Tower and Podium Foundation Design Review
- Tower and Podium Lateral System Review
- Tower and Podium Gravity System Review

It should be noted that while this peer review is mandated by the NYCBC, the review itself and its acceptance by the NYCBC in no way relieves the Engineer of Record from having sole responsibility for the structural design.

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IV. METHODOLOGY

As part of this review we relied on the lateral model (ETABS) developed by the engineer of record, Thornton Tomasetti. We reviewed the modeling assumptions, loading, and boundary conditions to verify the results presented. We also performed spot checks on members to determine demand (loads) and then checked the capacities of those members against the demands determined.

For the remaining portion of the review, we performed independent demand (load) calculations and element designs to compare against the design information indicated on the drawings.

Additionally, we reviewed any of the other information that formed the basis of the design including the Design Criteria, Wind Tunnel Study and Geotechnical Reports.

Our findings are presented in the form of written observations. Additionally, we have summarized our observations and resolutions in a spreadsheet that allowed the design team to track the issues and resolutions.

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V. FINDINGS

A. BASIS OF DESIGN

Geotechnical Report

Reference: Geotechnical Engineering Study; Hudson Yards – Terra Firma (prepared by Langan Engineering and dated 17 May 2012)

The number of borings taken in 2011-2012 (15 total) is less than required by code. Section 1802.4.2 allows for the use of existing data and previously taken borings in 2008 more than satisfy the requirements of Section 1802.4.1.

The development of the seismic design parameters is in general conformance with the requirements of Section 1802.2.3 and Section 1616. Liquefaction potential was analyzed in accordance with Section 1813.

The values for peripheral bond strength are within acceptable ranges. The safety factor is per the requirements of the NYCBC. Langan also lists alternate bond strengths of up to 300 psi.

The allowable bearing capacity is stated as 40 tsf in Class 1c "or better" rock.

The compressive axial capacity of the driven piles is reasonable and in accordance with the requirements of the NYCBC Section 1808.2.8.1.3.

The Site Investigation and recommendations presented therein are generally in conformance with the intent of the NYCBC.

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Wind Tunnel Study

Reference: Final Report-Wind-Induced Structural Responses (prepared by Rowan Williams Davies & Irwin and dated 15 August 2012)

The study recognizes the phased nature of the Hudson Yards Development and adequately captures the potential impact of future development on the predicted wind load and resulting building accelerations.

The study also recognizes that the design is continuing to evolve and results have been presented for a range of building properties.

The range of building accelerations predicted is within industry recognized and accepted standards.

While we believe the use of torsional velocities in conjunction with existing building acceleration criteria is overly conservative, the results are nonetheless within acceptable ranges.

The wind tunnel study and methodology used for the design of Tower C is generally in conformance with the intent of the NYCBC.

Design Criteria

Reference: HY-Tower C & Terra Firma Design Criteria
(prepared by Thornton Tomasetti and undated))

PT Beam Design Criteria
(prepared by Thornton Tomasetti and dated 3 August 2012)

The codes presented are the governing codes given the project location and nature of construction.

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The uniformly distributed dead and live loads meet and/or exceed the loads given in Section BC 1606 and 1607 of the NYCBC. Live loads are reduced in accordance with Section BC 1607.9.

Snow load calculations are in accordance with Section BC 1608 of the NYCBC.

Impact loads specified meet the requirements of Section 1607.8.1 and 1607.8.2.

Wind loads determined from the Wind Tunnel Studies meet and/or exceed the loads calculated from Section BC 1609.

The load combinations indicated for Working Stress design and Load and Resistance Factor design are in accordance with 1605.2.1 and 1605.3.1.

Ultimate Strength design combinations are in accordance with ACI-318-05.

The lateral drift criteria indicated is not a specific code requirement but is in accordance with industry standards.

The inclusion of second order effects (PΔ) is appropriate given the height, mass and anticipated total deflection of the structure.

Interstory drift under seismic loads is per IBC Table 1617.3.1 and ASCE 7 Table 12.12 -1 which meets the requirements given in Table 1617.3.1 of the NYCBC.

Floor vibration criteria given is not a code requirement but is appropriate given the nature of the project.

The Design Criteria presented references the appropriate codes and reference standards.

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B. TOWER AND PODIUM FOUNDATION DESIGN REVIEW

Piles and pile caps are found to have adequate capacity. Pile spacing should be verified according to pile spacing recommendations in the Geotechnical Report.

Caisson Caps are found to have adequate capacity. Caissons are found to have adequate capacity to resist the loads given in the column schedule.

The foundation design is in accordance with the recommendations presented in the Geotechnical Report and is in general conformance with the intent of the NYCBC.

C. TOWER AND PODIUM LATERAL SYSTEM REVIEW

Reference: 2012-09-10 - Service Model.edb prepared by Thornton Tomasetti

2012-08-31- Strength Model.edb prepared by Thornton Tomasetti

2013-01-30 - Service Model_DeSimone.edb prepared by Thornton Tomasetti

Drawings prepared by Thornton Tomasetti dated 20 August 2012 with revisions to 01 February 2013

Geometry of the lateral force resisting elements in the structural model match the drawings provided to an extent sufficient to properly capture structural behavior. This includes wall lengths and thicknesses, story heights, link beam sizes, and wall penetrations. Material properties in the model including 28 day strength and modulus of elasticity match the specifications and are properly varied over the building height.

There are some discrepancies between wall penetrations shown on the drawings provided and the analysis model, however these discrepancies do not appear sufficient to impact overall structural response.

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The coordinates and orientation of the structural model match those provided to RWDI for wind tunnel analysis.

Building mass is properly accounted for through the 'mass source' definition in Etabs to properly reflect building dynamic properties. Secondary effects are captured with P-Delta analysis using a load combination of 1.2DL + 0.5LL which is standard practice.

Two analysis models are used, one to reflect behavior under service level loads and another for strength level loads. The models use stiffness modifiers on beam and wall elements to account for cracking, rebar yielding, and bond slip. The dynamic properties from the service model match those provided to RWDI for calculation of wind loads.

The service model uses full section properties for all walls, reflecting an uncracked state. The beams use a stiffness of 0.50Ig to reflect a 50% reduction in flexural stiffness under service loads due to cracking. Shear stiffness is not modified.

The strength model uses 0.35Ig for beam elements, representing a 65% reduction in flexural stiffness under design loads. *Shear stiffness is not modified in the beams.* Wall elements are selectively modified for shear and bending stiffness. Where wall elements are modified they use a 0.35 factor on flexural and shear stiffness, all other wall elements use full section properties. The location and extent of modified wall elements appears to follow the general trend of tension areas in the wall under gravity and lateral loads.

The analysis model includes wind and seismic loads. The wind loads match those provided by the August 15th 2012 RWDI report. 24 Wind load combinations are used, the magnitude, direction, and point of application of each combination matching the information provided by RWDI. Earthquake loads are input at the center of mass and include an accidental offset.

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The building features a cap that is created by a structural steel framework. The analysis model does not include this steel frame, rather it uses an extension of the building core in this area to allow for application of wind loads at the cap height.

The building is modeled to the foundation level, with pin supports at the base of the wall elements. Soil structure interaction is not accounted for in the lateral model. There is also no modeling of foundation wall restraint for backstay effects.

The overall lateral response of the model matches expected behavior.

Results for base shear and overturning moment match expected results. Wall stresses match predicted values as calculated by hand. Base reactions match expected values.

A check of approximately 30 link beams shows that link beam designs conform to the requirements of all applicable codes. There are some isolated cases of link beams that appear to have demand to capacity ratios slightly exceeding 1.0, however the values fall within the range of accuracy in modeling and design are isolated to a few distinct beams.

A check of approximately 15 shear wall segments show that wall designs conform to the requirements of applicable codes. Walls were checked using interaction diagrams for axial capacity and standard shear equations for shear capacity. Variations in design assumptions and methodology will provide varying results but in general the shear walls appear to meet strength demands.

The analysis models presented for review were prepared in accordance with accepted industry standards. Loads applied are per the Wind Tunnel Study as well as loading and load combinations outlined in the Design Criteria.

D. TOWER AND PODIUM GRAVITY SYSTEM REVIEW

Reference: Drawings prepared by Thornton Tomasetti and dated 01 February 2013

- **Column Design**

Podium column designs are found to conform to all applicable code. Tower column designs are found to conform to all applicable codes. By inspection, the elements defined as "Key Elements" conform to the requirements of this section.

- **Slab Design**

ACI Chapter 10.15 – Transmission of column loads through floor system limits the maximum concrete strength differential between columns and slabs to 1.4. The code allows the use of puddling or overpouring of column concrete into the slab. The commentary speaks primarily to flat slab construction but by extension its use is allowed in a beam and slab system. The beams are 48" wide perpendicular to the columns and 24" parallel. The beams are typically 21" deep. The 12 ksi and 10 ksi column mixes are highly flowable and the amount of "overpour" will be substantial. In addition, the possibility of developing cold joints is substantial.

Tower slabs are identified in three types, voided filigree, solid filigree and cast-in-place.

Typical office floors 9" voided interior span slab designs are found to comply with all applicable codes. Non typical office floors 9" voided interior span slab designs are found to comply with all applicable codes. M.E.P floors 9" solid interior and exterior span slab designs are found to comply with all applicable codes.

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The extent of cast-in-place slab construction should be clarified.

The slabs as detailed meet the intent of the integrity requirements of Section 1917.2.1.1.

- **PT Floor Beams**

As previously discussed in the methodology section of this report, our office created independent analysis and design models based on the information contained in the project Design Criteria as well as the information contained on the structural drawings.

Due to the time constraints, we modeled a typical floor plan, Level 09 and a Mechanical floor plan, level 34.

The loads used to perform our review of the level 09 beams were provided in the Design Criteria. Live loads were reduced based on the PT Design Criteria. Effective T-beam dimensions were assumed to be 7'-4" wide by 2 ½" thick based on the provided PT beam Design Criteria.

The loads used to perform our review of the level 34 beams were also provided in the Design Criteria. Live loads in excess of 100 psf have not been reduced. Effective T beam dimensions have been assumed to be 7'-4" wide and 2 ½" thick based on the provided PT beam design criteria.

The beam calculations submitted have beam ends "fixed" at the columns. This end condition assumption transfers significant moment into the exterior columns and reduces the amount of effective pre-stress force required. **The PT beam design meets the requirements of all applicable codes.**