5 TIMES SQUARE

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The 5 Times Square tower is a 40-story high-rise building located at the intersection of Seventh Avenue and 42nd Street in the “Bow Tie” district of New York City's Times Square. The tower, which is approximately 565' tall, contains 1,000,000 rentable sq. ft. of office space and 100,000 sq. ft. of retail space.

One of the major challenges on this project was the foundation system. Just like many New York City towers, the 5 Times Square site is bordered by the New York City subway. The engineers must be very careful in the design of the foundation system to avoid transferring the tower's foundation loads into the subway structure. The closer the building and the deeper the subway, the more of a challenge this task becomes.

The 41st Street side of the 5 Times Square tower foundation wall is approximately 2'-0" from the adjacent subway structure. The bottom of the subway, in turn, is approximately 60'-0" below grade level and 30'-0" below the second cellar level. Consequently, a deep foundation system was needed to safely transfer the tower loads from the tower columns to a level below the subway structure.

The 5 Times Square Tower is fortunate to sit on Manhattan Shist bedrock. While it is good from a structural perspective, it is very difficult to excavate. Furthermore, the proximity of the site to the subway and a historical landmark building on the west property line dictated that blasting could not be used. Consequently, the system went through three phases of design evolution. In the initial scheme, the intent was to use 24" diameter caissons. Although these large caissons had adequate capacity, it became difficult to efficiently locate them while accounting for New York City code and Transit Authority's placement requirements. The alternative solution was to excavate large concrete piers down to below the bottom of the underground subway structure. While this was a direct engineering solution, the high quality of the bedrock on the site would have made efficient excavation without blasting difficult.

Left: Transfer truss on tower's west side looking north.
Above: View of the west face of the tower looking south.

The final solution consisted of high capacity 10" diameter mini-caissons. These caissons were composed of a 12" diameter steel shell, high strength concrete and a core of reinforcing bars. The small size of the caissons allowed a placement pattern that minimized the eccentricity of each caisson group relative to the line of the load from each tower column. Furthermore, the small caissons allowed the contractor to use faster drilling equipment, which delivered less energy to the surrounding rock.

The caissons are used along the entire 41st Street side with the exception of the southwest corner column adjacent to the New Amsterdam Theater. Due to the high axial loads and its corner location, the placement of an adequate number of caissons under this column was not practical without imposing a large eccentricity on the foundation system. To address this issue, a large concrete pier was built at this location down to the bottom of the subway. This direct load path allowed for the tower's column load to be transferred below the subway, while avoiding the costly construction which would have been required to properly transfer a large additional eccentricity in tight quarters.

Computer Analysis

As with all modern complex projects, the design of 5 Times Square made extensive use of computer analysis and design techniques. A key aspect to this computerized work was to avoid placing complete reliance on a single tool. In addition to finite element based programs such as SAP90 and ETABS, several custom design programs and commercially available structural programs were used. This resulted in a compartmentalized approach to the computer design and analysis and allowed the structural engineer to maintain full control over the design process. This approach also allowed for a method of independent consistency checking where the results of multiple programs and hand calculations can be compared to ensure that the results are reasonable. For example, the preliminary lateral analysis was accomplished through the use of several two-dimensional models using the SAP90 analysis program. The final analysis was done using a three-dimensional model and the ETABS program. The initial two-dimensional analysis provided an excellent benchmark for verifying the overall accuracy of the more complex analysis.

In addition to the various tools used during the design of the structural system, extensive use of the computer was

Above: View of east side elevation.
Left: Caisson installation at south end of tower.

Typical view of perimeter truss system between 2nd and 3rd floor.

also made in the detailing phase of the building. In order to ensure that the building properly "closed" and that the architect's high complex multidimensional geometric parameters where properly achieved, the entire structural frame was modeled in three-dimensions in the computer. This allowed the detailer to identify all complex connections in a virtual environment prior to cutting or drilling a single piece of steel. In the construction of a building with complicated geometry such as 5 Times Square, this approach was extremely beneficial.

The Lateral Load Resisting System

The structural lateral load resisting system selected for this building can be best described as a "modified perimeter tube system." Traditionally, a building of this size would use a central braced core as part of the lateral load resisting. The costs for fabricating and erecting a braced system tend to be much lower than for a comparably performing moment frame system. The down side of such a system is that the amount of usable floor space is reduced due to the large size of the bracing members, which must be installed in the building's core. Since rentable square footage is such a highly prized asset in the New York City office market, minimizing the area needed for the lateral system and therefore reducing the core size became a high priority and challenge to the design team at the initial stage of the project. By moving the lateral system to the perimeter of the building, the design team achieved the goal of maximizing the rentable square footage.

The system itself is a modification of a traditional "tube" system, which uses closely spaced columns, typically 6' to 12' on center, and deep spandrel girders around the entire perimeter of the structure. The north and south faces of the lateral system are composed of W14 columns, which are spaced at 10'-0" on center and are linked by W36 wind girders.

The "modification" to the traditional tube system exists in the east and west faces. These sides of the tower also utilize W14 columns and W36 girders. Since these sides are longer than the north and south faces, it was possible to increase the column spacing on the center three bays to 30'-0". The longer spans allowed the architects to utilize a larger column free viewing area while still retaining many of the structural benefits of traditional tube system.

Some of the columns at the lower floors are large built-up members. These sections ranged from 24" deep by 20" wide I-shapes composed of very thick plate material to four 30" deep by 20" wide "box" columns. The box columns are located at the northeast corner of the site and work in combination with the second floor perimeter truss system to transfer the tower's northeast corner column at the second floor. The transfer makes possible the creation of a column free space, which looks out onto New York's famous Times Square.

The Core and Floor System

The selection of the perimeter lateral system was not the only component, which contributed to the ability to design such an efficient and tight core. To minimize column sizes, the majority of the core columns consist of W14 sections conforming to ASTM A572, grade 65, while the perimeter columns are W14 and built-up sections conforming to ASTM A572, grade 50. Since the tower uses a perimeter lateral system, the controlling factors in the selection of the perimeter moment frame members are lateral loads and drift control.

Foundation excavation looking at southeast corner of site.

View of the north side elevation looking south.

Consequently, the perimeter lateral system columns and the interior gravity columns tend to work at different stress levels. This in turn leads to differential shortening of the columns under load. In order achieve a desired level floor upon the completion of construction, it was necessary to lengthen certain column lifts. This lengthening was designed so that as the building is gradually loaded, the beam-to-column connections at a given floor level will arrive at the same final elevation.

The typical floor system consists of a $2^{1}/_{2}$" of normal weight concrete over 3" composite metal deck, which spans between W18 floor beams. The main interior girders, into which the floor beams frame, were given special consideration in order to produce a cost effective floor design. Since these girders span nearly 44', deep W33 members were selected. In order to properly accommodate the mechanical system, which was installed in the ceiling space, penetrations were provided in the girders. The cost saving was achieved by sizing the girders so that costly reinforcing of the openings would not be required.

In addition to the typical floor construction, there are several areas where a heavier floor system was implemented to meet the specific needs of the building. The most notable area is the Con Edison transformer vaults. Due to the tight nature of the site and the close proximity of the subway lines, it was not feasible to install the transformers in the more typical sidewalk vault spaces. The solution was to construct the six vaults and network protector rooms at the southern end of the third floor. The concrete vaults themselves were specifically designed as per Con Edison requirements, which stipulated that in addition to other design loads, the concrete structure needed to be capable of withstanding a heavy blast load should any of the transformers explode. This resulted in a massive reinforced concrete box structure supported on a cradle of W16 and W21 beams spaced 5'-0" on center. In addition to the reinforced concrete vaults, various sections of the slab needed to be constructed in "layers" to accommodate the installation of electro magnetic shielding and waterproofing. The basic foundation of this multi-layered floor construction consisted of a $2^{1}/_{2}$" normal weight concrete on top of 3" composite metal deck.

The Transfer Truss

Another key aspect of the tower is a full story high transfer truss which spans nearly 90'-0" and picks up the load from three of the towers "bustle" columns, located on the west side of the building. Below the eighth floor, these "bustle" columns would have become interior columns. In order to create a cleaner column free space, a large truss was built into the perimeter moment frame between the eighth and ninth floors. This allows the overall system to continue to benefit from the modified tube system while economically transferring the loads.

This 90'-0" transfer truss was designed almost entirely of W14 wide flange sections. The top chord of the transfer truss consists primarily of heavy W14 sections of ASTM A572 grade 50 steel. The vertical and diagonal members range from small W14 sections to large W14 members. The bottom chord of the truss uses custom built-up reinforced wide flange sections, sized to accommodate the truss's close proximity to the perimeter facade. The nominal section falls within the dimensional parameters of a heavy W14 section. The center span of the bottom chord reinforces this built-up section through the addition of 2" thick flange plates.

A similar system was used between the second and third floors to transfer column loads. At this level diagonal members, typically consisting of four 6x6x$^{3}/_{4}$ thick angles, were added to the perimeter frame to create a belt and suspenders system consisting of moment connections and a typical truss system. The members which create the "bottom" and "top" chords of this hybrid system consisted of the W36 moment frame girders which form the majority of the tower's perimeter frame.

Transfer Floor

In addition to the transfer truss, the tower has an additional transfer system at the 25th structural floor level. At this level, 12 of the tower's perimeter moment frame columns at the southeast corner are transferred through the use of a series of W40 and W36 girders, which average 42" in depth. The largest girder in this system is a W36x848. The horizontal shear forces in the columns are transferred from the upper segment of the modified perimeter tube to the lower segment of the lateral system though the use of a horizontal truss system.

The modified tube system adopted for the 5 Times Square tower serves as a practical structural system for supporting the elegant lines, angles and folds created by the architect while minimizing the impact on rentable square footage. The construction of the 5 Times Square Tower in one of the world's most famous and well known city centers is an example of the marriage between innovative engineering and architectural design.

OWNER & DEVELOPER:
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STRUCTURAL ENGINEER:
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ARCHITECT:
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STEEL FABRICATOR:
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