Steel-Framed Parking Garages

Take Off

at JFK and Newark International Airports

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The steel framed parking garages constructed and planned by the Port Authority of New York and New Jersey are a significant part of the multibillion dollar capital redevelopment programs at JFK International Airport in Queens, NY, and at Newark International Airport, NJ. The recently constructed 1,800 parking space Green Garage at JFK International Airport and the 3,300 parking space Lot E Garage under construction at Newark International Airport, designed and constructed by the Port Authority, meet the dramatic increases in passengers at the airports.

Aerial view of the Green Garage at JFK Prior to AirTrain Construction.

Both garage structures use steel frames with precast double tee concrete floor systems selected for economy, appearance and the ability to meet tight design and construction schedules. Both structures also use architecturally exposed painted structural steel and double-threaded steel framed helices for entrance/exit ramps. The Port Authority of New York and New Jersey chose steel because of the lower life-cycle costs involved. The Green Garage at JFK International will be integral with the new AirTrain JFK light rail system stations at Terminals 1 and 3, while the Lot E Garage at Newark International will tie in to the existing AirTrain Newark system station.

Both structures had unusual foundation conditions. At JFK, existing underground utilities and an exit plaza were bridged-over with longer spans and grillage beams, while a large portion of the Lot E Garage spans over an open drainage waterway. Design details to achieve resistance to seismic and wind forces using semi-rigid connections were also a main design feature. At JFK, two additional steel-framed parking garages accommodating a total of 3,800 more vehicles (2,300 at Terminal 8 and 1,500 at Terminals 5 & 6) are in the preliminary design phases. The economy and efficiency of the architectural and structural systems for the Lot E garage were validated through a formal value engineering analysis by outside experts.

JFK Background

JFK, one of the first major international airport hubs in aviation history, celebrated its fiftieth anniversary in 1997. The original airport master plan, developed more than 55 years ago, created a Central Terminal Area (CTA) loop roadway network around which nine "individually expressed" terminal buildings were constructed. With the 1998 opening of Terminal 1, along with the upcoming 2001 construction completion of Terminal 4 (International Arrivals Terminal or IAT), the airport's flagship terminal, the original design premise of individual terminal expression and function can be considered history repeating itself, except on a larger scale. British Airways at Terminal 7 and American Airlines at Terminals 8 and 9 are both constructing major individually expressive and functionally different airline terminals. Other airline terminal developments are on the way. To establish uniformity at JFK through an urban CTA plan that could visually and functionally link the nine unique terminal sites into a cohesive environment, the Port Authority developed the JFK "Landside Access Roadway Program." The roadway concept establishes four, color-coded CTA terminal quadrants (Green, Blue, Orange and Red), allowing passengers to move directly to their terminal precinct without passing through the entire CTA loop configuration. This planning idea further develops the notion of individuality by creating four discrete "airport precincts" within the CTA.

As the roadway program was being implemented, a significant parking shortfall was identified within the CTA, resulting in the construction of a new parking garage in the "Green Area" and the proposed renovation of the "Blue Area" Garage located within the Terminal 4 (IAT) Quadrant. As previously mentioned, major parking garages will be constructed along with the American Airlines Terminal 8 redevelopment in the "Red Area" and United Airlines Terminal 5/6 development in the "Orange Area."

Green Garage

At the end of 1996, as a result of steady growth in air passenger traffic, The Port Authority of New York and New Jersey evaluated existing and future parking needs of John F. Kennedy International Airport. It determined that a significant number of new parking spaces were needed immediately in the Green quadrant of the Central Terminal Area. Subsequently, the Port Authority Engineering Department designed and constructed a parking structure within 18 months

Erection of steel frames for Green Garage.

(soft opening) to accommodate this increased demand. The primary design and program considerations were as follows:

Provide parking capacity to meet the projected parking demand for year 2005;

Integrate parking with the planned AirTrain light rail system;

Serve Terminal 1 and Terminals 2 and 3 (Delta Airlines)

Complete the ground and first deck level by May 1998 for partial occupancy to coincide with the opening of Terminal 1;

Provide a cost effective design and construction solution;

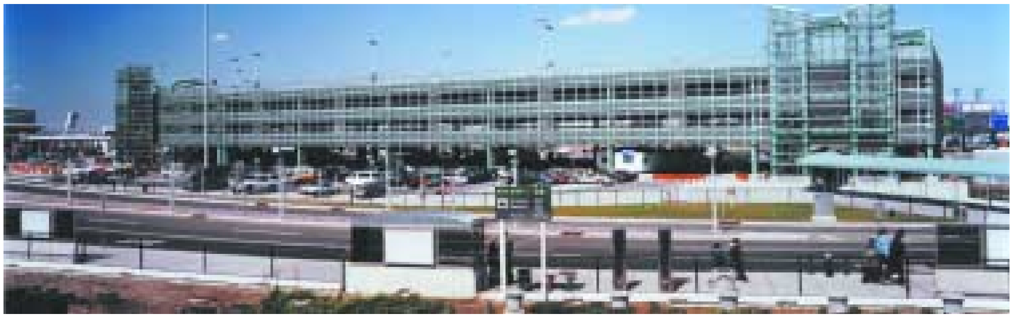
Complement visually and functionally the new Terminal 1;

Minimize disturbance to existing underground utilities;

Provide a high level of service, safety and security;

Span over the existing at-grade parking entrance and exit plazas.

To accomplish these objectives, a fast-track design and construction process was adapted. The design evolved into a cost-effective three-story, 950′ by 120′ boomerang-shaped structure with a single double threaded helical ramp conveniently located opposite the three terminals. Parking is provided at grade and on three elevated levels with a total of 1,850 parking spaces. The structural system is a hybrid of exposed high strength structural steel frames, pre-topped double tees and high-strength cast-in-place concrete. The structure was also consistent with the New York City Building Code seismic provisions adopted in 1996. The parking structure features an architectural screen facade of aluminum extrusions and framed stainless steel wire mesh, six glass-enclosed passenger elevators and five stairs located to link with the future elevated walkways to the terminals and AirTrain stations. The resulting design addressed all of the above criteria to produce a garage that was subsequently considered to be the prototype for stand-alone garages in the Port Authority's three-airport system.



View of Green Garage helix looking from inside the helix itself.

Function and Expression

Functionally, clear span rather than short span construction is a desirable feature for parking structures. Optimized bay sizes of 58′ by 58′ were selected to permit patrons parking at grade to be oriented to the Terminal 1 frontage and minimize the interference of the pile foundation with the numerous existing in-service underground utilities. Due to height restrictions on the second and third levels, a precast concrete girder could not be used due to its deeper cross-section. Comparative studies were made of various floor slab systems, and long-span pre-topped precast/prestressed double tees were selected over post-tensioned cast-in place slabs for the 336,900-sq. ft. parking deck because of the following advantages: economy, speed of erection, durability, less weight and the elimination of on-site winter deck construction. By using the 58′ long precast double tees, large column-free deck areas were achieved, and less columns and foundation were needed. The limited depth of the garage (120′) locates vehicles and passengers in close proximity to the terminals. This aids in orientation, provides natural light, and in conjunction with the generous headroom of 8′-2″ to the bottom of the precast concrete double tee floor structure, creates a spatial configuration that relates to the needs of pedestrians as well as the functional requirements for vehicles.

The lighter-weight double tee floor construction and lighter steel frames translated into less seismic design forces. Due to the site-specific presence of thick layers of seismically liquefiable organic soil, steel monotube piles filled with concrete and reinforcing bars increased the pile flexural capacity to resist the lateral seismic forces. They proved to be a cost-effective foundation system.

View of parking structure ramps.

Vertical circulation consisting of glass-enclosed elevator cabs and metal stairs is strategically placed at the most appropriate pedestrian access points to the adjacent terminal buildings and AirTrain station platforms. Vehicular pick-up/drop-off curbs and passenger amenities are integrated at these locations. Floors are level to allow for the use of baggage carts. The arrangement of the parking aisles was based on pedestrian circulation. At grade, the drive aisles are oriented to the terminal buildings and extend beyond the perimeter of the elevated structure to surrounding at-grade parking. On the elevated decks, drive aisles are oriented to the vertical circulation cores.

The architectural expression of the garage takes its cue from Terminal 1 by creating the extruded aluminum screen facade treatment working in concert with the glass and aluminum garage elevator cores. This building facade approach acknowledges the terminal building's metal and glass curtain wall. The screen facade can be considered as a curtain wall without the glass, acting as the exterior layer to the exposed painted structural steel and precast concrete decks that comprise the overall structural system. The stainless steel wire mesh grille is placed behind the extrusions to function as a code-required guardrail, while a steel box girder is used as a vehicle stop. At the elevator cores, the triangular extrusions used in the screen wall are used in conjunction with clear glazing to provide a unified design expression.

Double-Threaded Helix

Vehicular vertical circulation is accomplished through a steel-framed double-helix ramp on the garage's landside opposite from pedestrian vertical circulation. The double helix incorporates lanes for both ascending and descending vehicles within the same 120′ diameter footprint, minimizing the amount of site utilized for this efficient vehicular network. Vehicles circle only one-half revolution of the helix between floors.

The continuous curved rising slab with exposed concrete soffit is of high strength cast-in-place concrete and was aesthetically more acceptable than the other systems under consideration. Support of the spiral-slab formwork was simplified with the use of an exposed steel helical frame resulting in speedier construction. Use of precast beams and columns for this same type of ramp geometry would have proved impractical.

To ensure a long life for the helical ramp, fly ash, silica fume, a corrosion inhibitor and a high range water reducer were included in the mix to produce a 7,000 PSI-28-day compressive strength with a low water/cement ratio of 0.38. These measures along with epoxy coated reinforcing with a 2″ cover enhance the durability and service life. Silica fume was also specified for the precast/prestressed double tees and was incorporated as a mixture

Erection of steel frames with precast deck in progress.

of pre-blended cement and silica fume at a ratio of 85/15%.

Construction of the ground floor and first level were completed in time to meet the project milestone of May 1998 for initial occupancy and total completion was achieved in the spring of 2000. The helix structure design was by Severud Associates, New York City. The general contractor for the project was Turner Construction Com pany, New York City. Steel and precast concrete erection was by Metro Steel Construction Company, Inc., Whitehouse, NJ.

Newark International Airport Background

At Newark Airport, where a unified CTA plan was incorporated into the overall 1960s airport master plan, the need for garage uniformity is expressed in the long-term parking areas outside of the CTA. Newark's AirTrain light rail system, formerly known as the Monorail, has enhanced passenger level of service in the long-term parking areas with the development of four stations in parking lots E and D. The passenger services programming of these stations includes consolidated rental car facilities and public pick-up/drop-off zones. Because the AirTrain Newark system has dramatically increased airport operational efficiency by linking all airport passenger-related functions, the need for increased structural parking that would be linked to light rail was a natural outgrowth of the overall airport master plan.

The Lot E Garage, the first garage to be constructed in the long-term areas, is adjacent to the Lot E AirTrain station on the airport's north side. A large portion of the existing at-grade Lot E parking area site to the north of the AirTrain station will be developed as new aircraft apron for Terminal C. The area to the south of the station is the location of the new parking structure. The peripheral drainage ditch also bisects the site. The Lot E Garage under construction at the site will accommodate over 3,200 cars within five levels of structural parking plus parking at grade.

Lot E Garage Design

The design of the Lot E Garage was based on providing an efficient operation that would link its patrons to all three terminals via the AirTrain. The garage incorporates both long-term parking and valet parking within the same structure. The customer interfaces with the valet operation at the front and lobby of the AirTrain station. Long-term parking customers enter the garage through a dedicated entry plaza. After patrons access their parking space, they proceed to one of four glass-enclosed elevators located directly across from the AirTrain station lobby. The compact plan configuration of the garage at 345′ by 525′ minimizes walking distances to the lobby destination. A metal and glass canopy provides weather protection as passengers cross the frontage road to the lobby.

As with the JFK prototype, the facade of the parking structure is greatly influenced by its proximity to the light rail station. In this garage, the screen was further refined through the use of a steel truss backup to the extruded aluminum rails, providing an added layer of articulation within the context of a more horizontal expression. The façade of the building, also carved away at the entry and exit plazas, provides architectural cues to these functions, as well as giving visual relief on the two sides of this massive structure. Similar to the Green Garage at JFK, the Lot E Garage has a double threaded helical ramp and an exterior elevator core with four glass-enclosed passenger elevators and five interior stairs. Metal and glass will also be used for the entry/exit plaza canopies, frontage canopies and crosswalk canopies, thereby creating a metal/steel and glass vocabulary outside the Newark CTA, a thematic link to the prototypical environments created in the JFK CTA.

Five-Story Structure

The structural system is a hybrid of exposed high strength structural steel frames and precast double tees with high-strength, cast-in-place concrete. The structural steel of the five-story parking structure consists of paired columns and girders at each of the north-south building column lines and supports the parking decks' floor loads and provides lateral stability to the structure during and after construction. The paired columns are tied together by steel plates (battens) at approximately 6′ on center vertically and are shop fabricated at full height of the structure. The paired columns are erected with the girders for the support of the precast double tees spanning in the east-west direction. The ladder frame of the paired columns in the transverse direction and the conventional rigid frame action in the longitudinal direction provides lateral stability.

View of construction of the Lot E Garage progressing over the caisson foundations in the drainage waterway.

An interesting aspect of the parking structure is its location over an existing 90′ wide peripheral ditch drainage waterway that runs at an angle underneath the garage. After an environmental and hydrological assessment, it was determined that widely spaced concrete caissons would provide the foundation support for each of the paired columns and the grade level precast floor construction spanning over the ditch. The garage columns beyond the ditch embankments are supported on concrete-filled, steel pipe pile foundations.

The circular double threaded helical ramp, another interesting feature of the garage, provides a separate up ramp and an exit traffic ramp with the same footprint. The helix ramp (as opposed to traditional slanted ramp construction or dual one-way helices) created more useable parking area. The continuous curved rising slab and curb is high strength cast-in-place concrete on an exposed steel frame structure. The spiral slab formwork was simplified resulting in a speedier construction.

Design of the Lot E helix structure and ancillary canopy structures for the Lot E site was by Weidlinger Associates, New York, NY. The General Contractor is NAB Construction Company, and the precaster is Kenvill Newcrete Products Company.

Structural System

The structural system adopted by the Port Authority is similar to that described in Modern Steel Construction/December 1996, "Hybrid Parking Structure Cuts Cost." The optimum bay size for airport use, as used in the Lot E Garage is a 58′ long bay allowing for two, back-to-back parking stall lengths and a drive aisle between them. The bay width is 35′ in the other direction, allowing for three side-by-side precast concrete double tees each 11′-8″ wide. The framing system consists of a pair of steel columns connected by battens at each floor and halfway between floors. Along the width of the typical bay, a pair of parallel steel girders spans 35′ between the columns. In the latter direction the frame action to resist lateral seismic and wind forces is achieved by framing the girders into the column flanges (strong axis) with semi-rigid connections. Necked down flange connection plates (paddle plates) are provided top and bottom since reversals from seismic forces are possible. In the other direction, precast double tees 58′ in length span between the steel girders. The webs of the tees are notched at the ends to sit on top of the top flange of the steel girder. In this direction (length of tee), the lateral force resistance is provided by the pair of double steel columns (weak axis) connected together with battens providing vierendeel-type frame action as a vertical cantilever frame. Therefore, this system benefits from the ductile behavior of steel frames in both directions to resist seismic forces and displacements. This system also permitted expansion joints (seismic separation joints) to be located farther apart than with a precast concrete framing system.

View of the erection of the Lot E Garage Columns.

Value Engineering

While the use of this hybrid structural system was driven by schedule and longer span length in the JFK Green Garage, the Port Authority decided to perform a value engineering (VE) analysis of the steel framed system for the Newark Airport Lot E Garage in November 1998. The panel of 15 experts was assembled and led by Hill International. They were charged with making recommendations to improve the cost effectiveness relative to initial construction cost, life-cycle costs and schedule considerations. As a result of the VE effort, the structural system was validated to be the most cost-effective given the project siting, constraints and schedule.

EWR Lot E Garage

Software:
STAAD III Structural Analysis & Design Software by Research Engineers, Inc. for frame analysis and steel design code check. Microsoft Office EXCEL spreadsheets for steel members and connection design (supplements hand calcs.).

Engineer:
Port Authority Engineering Department, New York City-Weidlinger Associates, New York City (Double Threaded Helix and other miscellaneous structures)

Architect:
Port Authority Engineering Department, New York City

Garage
designed in 1999

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JFK Green Garage

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Engineer:
Port Authority Engineering Department,New York City Severud Associates, New York City (Double Threaded Helix)

Architect:
Port Authority Engineering Department, New York City

Garage
designed in 1997

Fabricator:
SMI-Owen Steel Co., Columbia, SC

Detailer:
SMI-Owen Steel Co., Columbia, SC