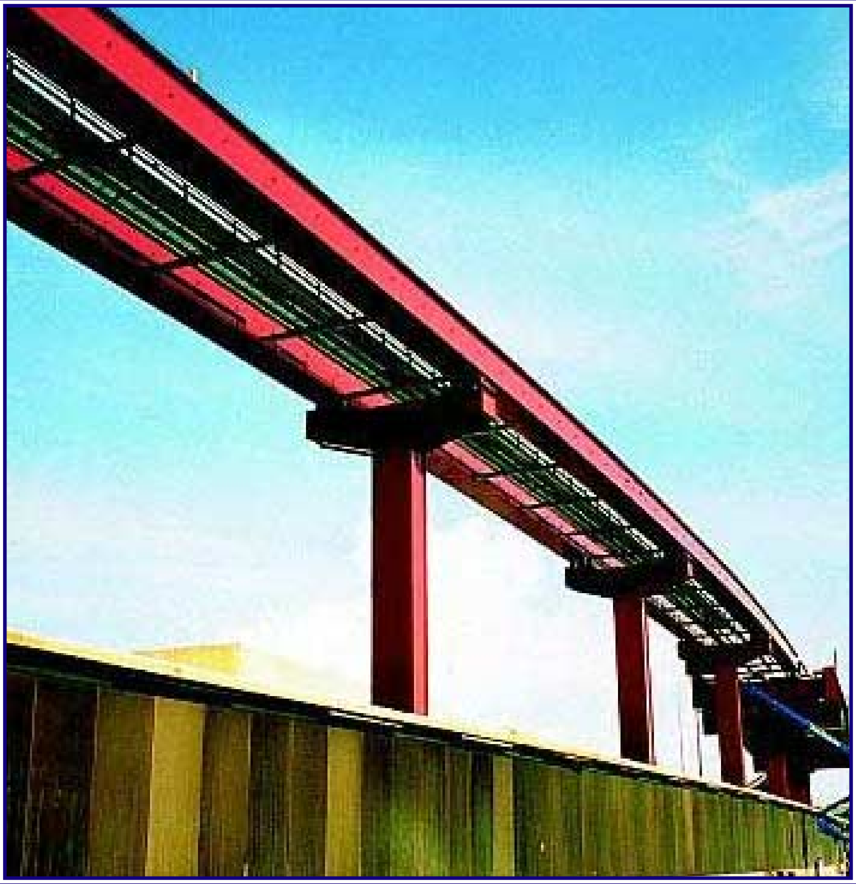
Prize Bridge Award: Special Purpose

MONORAIL NEWARK AIRPORT



About 35 years ago, The Port Authority of N.Y. & N.J. had the foresight to design the three main terminals at Newark International Airport with an additional –and unnecessary at the time – feature. At roughly the second level of each terminal (about 45' above the tarmac), they included a notch, or right of way, on the airside of each building to accommodate a future "people mover" system.

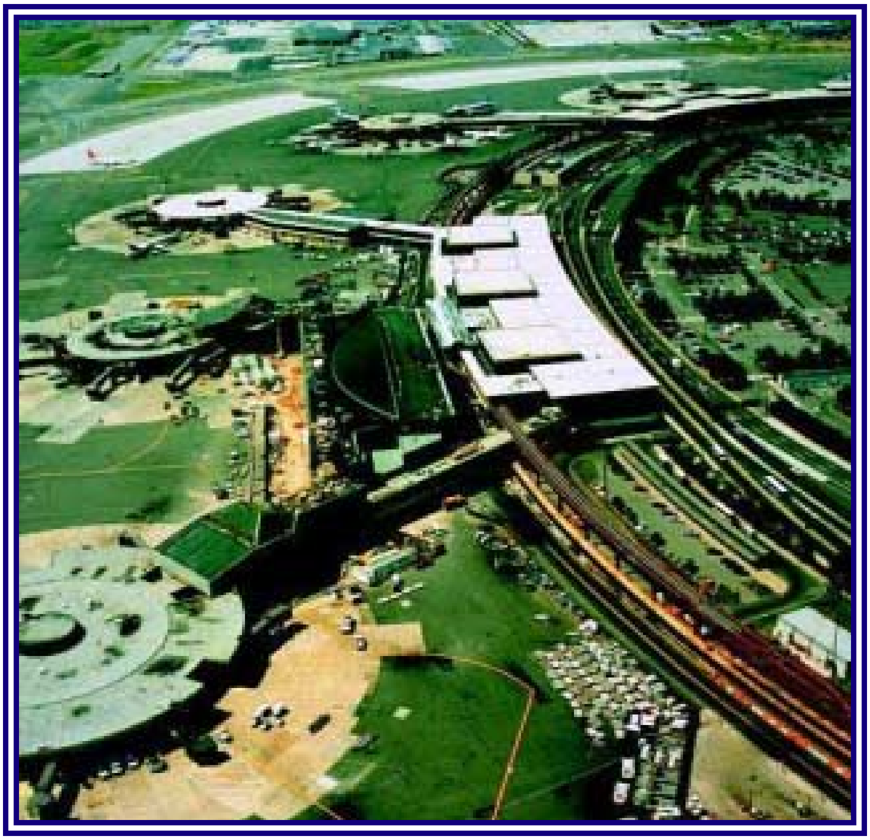
In 1990 a Swiss products manufacturing firm was selected to design and maintain for five years a monorail, people mover system, which would service the terminals and parking areas. Today the people mover system has been so successfully operating since June of 1996 that an extension has been designed to connect with N.J. Transit train system, which will travel to NYC's Penn Station.

The trains travel on elevated tracks varying in height from 18' to 46' above ground. These tracks are composed of welded plated-boxed girders supported by "hammerhead type" welded plated-boxed sections spaced typically at approximately 90' on centers. Trains travel at a maximum speed of 27 mph and during peak periods, trains of six or seven cars will leave one of seven stations along a two-mile run every 90 seconds, completing a round trip circuit in approximately 19 minutes.

The elevated steel guideway is treated as a major design element. Its appearance relates strongly to the passenger stations, which feature exposed steel structural systems. The burgundy color is intended to highlight its presence on the airport as a brightly colored ribbon, unifying all of the airport's public structures. The design of the guideway columns is identical to the existing welded steel box columns built at the time of the original terminals. These original brown columns were painted burgundy to match the new columns, completing the overall system identity. The guideway is equipped with an emergency walkway that will allow safe passenger access to the nearest station in the event of a system malfunction.

Monorail box girders are constructed of ASTM A709 grade 36 or 50 steel; they are 3'-1" wide at the top flange and vary in depth from 2'-3"to 5'-4". Between expansion joints, the tracks form a continuous beam that rides over welded box, T-shaped steel supports known as hammerhead columns. Typically these hammerheads are 15.5' wide and spaced 60' to 90' apart (with some spans up to 155'). The guideway assembly includes power and signal rails mounted on guide-beams and an open-grate steel emergency egress walkway between the double loop tracks. Each box member is continuously welded so that the interior is deprived of oxygen to prevent internal rusting. On the mainline sections of the guideway, the minimum curve radius is 400', precluding the need for super-elevations. This simplifies fabrication and erection significantly. The maximum grade on the system is approximately 2-1/4%. The box girder curves along with the horizontal alignment and has spiral transitions where curve radii change. In all 4,600 tons of steel was used in the guideway superstructure, exclusive of guideway switches. Steel was able to conform to the high tolerances required for the curved guideway box beam and precision switch structures and to provide the resilience and toughness needed for a long fatigue life.

A Swiss firm did the structural design of the guideway, while the Engineer of Record, a NY Consulting Firm, made significant contributions, specifically in the design of the bearings that transfer loads from the girders to the hammerheads, and in the adoption of the European design to American steel detailing and fabrication practice and means and methods of construction. The design also conformed



to AASHTO requirements for highway bridges. Numerous load combinations were analyzed, considering dynamic impact factors of 10% for stress checks and 6% for deflection checks. Dead, live, centrifugal, acceleration/breaking, temperature, friction, snow, wind, and earthquake were the basic loads considered.

Individual girders were fabricated and pre-assembled in the shop. They resembled actual field support conditions as close as possible. Tolerance reports were prepared during the progressive trial assembly to minimize field weld splice incongruities.

Tolerances conformed to the requirements of the AISC "Code of Standard Practice" except where the dynamic interaction of the vehicle with certain areas of the girder called for more stringent tolerances specified by the vehicle manufacturer. As with all automated systems, fabrication and erection tolerances are paramount for the operation and comfort of the passengers. The width of the box girder must be exactly 3'-1" with the edges of the top flange being exactly 4.75" from the exterior face of the vertical webs. These dimensions are required to accommodate the balloon-type tires and the vertical and horizontal adjustment guide wheels for the train bogies.

Since the entire guideway was designed for two million cycles, fatigue was an important consideration in all aspects of the project: from specifications for fracture-critical material and welding to assessment of all structural details to meet the AASHTO requirements of fatigue stress range. Charpy V-Notch impact tests were required for all steel, non-redundant main load carrying components subjected to tensile stress. Welding was in accordance AASHTO/AWS D1.5 and the "Guide Specifications for Fracture Critical Non-Redundant Steel Bridge Members."

As with any automated system, there are strict tolerances and alignments to be maintained. When coupled with camber and temperature requirements, these constraints made the field welded splices of the box girders near the columns a particularly complex problem. Extensive joint fit up measurements were taken to verify its acceptability before executing fracture critical complete joint penetration welds.

Subsequently a skin effect heating system uses a ferromagnetic tube (Carbon Steel Schedule 40 Pipe) welded to the underside of the running surface and a current carrying heat resistant copper conductor passing through the pipes. These conductors are pulled through the heat tubes and are connected to an alternating current power source at one end as well as to the pipe itself (at the other end). The alternating current flows through the conductor and back along the inner surface of the heat tube. The current flowing through the heat tube concentrates only on the inner surface of the pipes. Current or electrical potential does not exist on the outer surface of the pipe.

The structural components of the heating system were fabricated in the form of a three-legged channel for each tire track with a flat running surface formed by a ¼" thick steel plate supported by 1" X ½" bars. These "channels" are welded in a paralleled alignment to the top flange of the guideway steel box girder forming the parallel running surfaces for the train rubber tires. Sections approximately 30' in length are put in place to make up the entire girder. The heating pipes of adjacent sections are spliced at each assembly junction (shop splice), and a cover plate is welded in place over the access space, which is left open at the end of each channel section to accomplish the splicing. The channel plate ends approximately 16" from the end of the girder to accommodate field splicing. The entire beam is transported to the site, complete with the heating pipe system in place. In the field the "field splice" access area was bridged with ¼" plate.

Along the guideway there are 10 crossovers between the two guideway track beams that carry vehicles in opposite directions. To achieve vehicle crossover capabilities, rotating guideway switches supported by an elevated steel frame were used. Typically, the elevated structure has two, 91' spans, with 6'-deep plate girders at the outer edges supported by box column hammerheads or bents on pile foundations. Spanning between the plate girders are the W36 frames, which support the rotating guideway switches and the fixed box track girders. A secondary frame above the W36's supports the emergency walkway. A total of 2,422 tons of steel were used in the guideway switches, walkway, and approch girders.

The switch crossovers comprise structural, mechanical, electrical, and hydraulic components. A single turnout guideway switch is structurally comprised of a rotating equipment switch frame, with box track girders on the top and bottom of the frame positioned for either tangent or turnout alignments. The switching operation consist of rotating the switch equipment frame,

MONORAIL NEWARK AIRPORT

Owner:
The Port Authority of New York and New Jersey

Designer:
Weidlinger Associates, Inc., New York City

Consulting Firm:
Simons-Eastern Consulting Engineers,
Atlanta, GA

General Contractor:
ABB Daimler-Benz Transportation,
Pittsburgh, PA

Detailer:
Dominion Bridge Inc.,
Lachine, Quebec, Canada

Fabricator:
Dominion Bridge Inc.,
Lachine, Quebec, Canada

Erector:
SMI-Owen Steel Company,
Columbia, SC (AISC Active Member)

including the box girders, 180 degrees vertically into alignment with the fixed track box girders. The rotary frame's movement is limited by stops. Once the frame has reached its proper position, lockpins prevent any additional movement and hold the switch in position. The automated switch rotation sequence takes approximately 12 seconds.