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Rehabilitation of Transit Authority Structures in New York

Rénovation des structures du réseau urbain à New York
Sanierung von New Yorks Transportsystem

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SUMMARY

The New York City Rapid Transit, the largest and oldest system of its kind in the United States of America, is being restored to a state of good repair. The capital investments in the rehabilitation of its infrastructure, is the only viable alternative to ensure that the system will continue to serve its 3.5 million daily customers. This article describes some of the more important rehabilitation work performed in the past several years.

RESUME

L'administration du réseau urbain de New York – le plus ancien et le plus grand système de son genre aux Etats Unis – est en train de remettre en état son réseau routier. Les investissements pour la rénovation de l'infrastructure sont la seule alternative possible qui permette au système de continuer à desservir 3, 5 millions d'utilisateurs quotidiens. Cet article décrit quelques-uns des travaux de rénovation les plus importants réalisés au cours des dernières années.

ZUSAMMENFASSUNG

New York Citys' Rapid-Transit-System, das grösste und älteste öffentliche Transportsystem der Vereinigten Staaten, wird gegenwärtig in einen guten Unterhaltszustand zurückversetzt. Die Kapitalinvestitionen zur Sanierung seiner Infrastruktur sind die einzige mögliche Alternative, um die Gebrauchstüchtigkeit für seine täglichen 3, 5 Millionen Benützer sicherzustellen. Der Beitrag beschreibt einige der wichtigeren Sanierungsarbeiten aus den vergangenen Jahren.

1. INTRODUCTION

The New York City Rapid Transit System, the largest and oldest in the United States and one of the oldest in the world, consists of elevated, and subway track spread over the four boroughs of Brooklyn, the Bronx, Queens, and Manhattan. It carries an average of 3.5 million passengers per day. Over 5,000 subway cars carry one million passengers during every rush hour period, guided, controlled, and powered by 10,000 signals, 1,400 switches, 70 power substations, and 700 miles of track. Simply put - the New York City Transit Authority moves the people of New York.

The system was built in stages since 1885, bringing it to the present day level of completion. Considering the age, the system has maintained its status as one of the foremost systems in the world and has served the New York metropolitan area whose demands and expectations are diverse. This is probably the only system in the world that operates 24 hours a day, 365 days a year. The successful operation of a system of this magnitude and age requires viable solutions to the numerous problems encountered during its service life. The replacement cost of the system, in 1990 dollars, is estimated to be around 200 billion, not including the value of the real estate. Total replacement would be, therefore, out of the question. The only alternative is rehabilitation and properly scheduled maintenance.

We are moving towards a 21st century technology in terms of communications, signal systems, and cars. In order to readily accept this technology for operational use, all the tunnels and structures need to be rehabilitated and brought into a state of good repair.

The system comprises of a total of 230 route miles. Out of these 230 route miles, 123 miles or 54% of the system is underground. Another 37 miles or 16%, is in open cut, on embankment or on grade, while 70 miles or 30% is on elevated structures, which can properly be classified as continuous bridges. These 70 route miles include 181 track miles and 155 stations.

2. ELEVATED STRUCTURES

Some of the problems we face today on the elevated structures stem from the fact that most of the elevated lines were originally privately owned and operated. As a result we have structures of different size, of varying construction details, designed for lighter loads and less frequent operation, and meant to meet different social and environmental conditions. These factors compound the common maintenance concerns such as normal wear, corrosive attack by the elements, foundation settlement, fatigue failure, and obsolesence.

In order to understand the rehabilitation work, acquaintance with the nomenclature and the basic design elements of the elevated structures is necessary.

Foundations supporting the columns of the elevated structure are normally unreinforced concrete pedestal type footings, approximately ten feet deep, which support the elevated columns. Older columns are generally built-up sections. Today we use single wide flange members.

Rigidly connected by brackets to the tops of the columns are built-up members called cross girders. Attached to these, running parallel to the tracks, are built-up members called track stringers.

Clamped on top of the stringers are the cross ties which support the tracks. In addition to these basic elements, bracing, stiffeners, and expansion joints are provided as required. Design loads include a combination of dead load, live load, impact, wind, and traction loads.

2.1 Structural Rehabilitation

The Transit Authority utilized the services of a consulting firm to perform a study of the condition of our elevated structures. This study was completed in 1978 with the conclusion that the structures were generally in a good condition, but identified need for specific rehabilitations. This study complimented the Authority's periodic in-house inspection. Based on the in-house inspection and the consultant study, the following specific needs for rehabilitation were identified:

- o Column Replacement (Jamaica Line).
- o Rehabilitation of Steel (over mezzanines).
- o Rehabilitation of Track Supporting Members.
- o Rehabilitation of Expansion Joints.

2.1.1 Column Replacement

On the Jamaica Line the Consultant found that, in an area near Crescent Street, the columns are overstressed by as much as 50% due to the loading from heavier cars used in the 1920s and 1930s. The original cars used on the Jamaica Line were constructed of wood, and were lighter in weight.

This line was constructed between 1888 and 1918, with several modifications made over the years. As a result, the line is not of uniform construction. In the section between the Van Siclen Avenue and Cypress Hills stations, a two track structure is supported on latticed columns comprised of four angles held together by lacing plates. In 1980 and 1982 the Authority awarded contracts totalling $8.5 Million for the repair and modernization of this section. including the replacement of 192 columns.

The replacement procedure of columns was fairly simple. After suitable traffic barricades were placed, a timber grillage was laid on the street adjacent to the old column, to serve as a temporary footing.

Two 14" wide flanged columns were secured between this grillage and the cross girder above, to temporarily take the column load. Working from mechanized scaffolds, ironworkers removed the old column connections. Utilizing a telescoping crane the old column was removed, and a new wide flange column put in place and connected.

Following the removal of temporary supports, the column base was cast in concrete.

2.1.2 Rehabilitation of Steel (Over Mezzanines)

At stations on the elevated lines, the control areas and mezzanines are often hung from the structure, below the trackways. In lieu of track stringers in these areas we use thru-span girders, so called because the trains run between them. These thru-span girders rest on the top flanges of the cross girder.

In a thru-span area a system of floor beams support the concrete and steel track decks, which also serve as the roof of the mezzanine. While elevated lines generally avoid drainage problems by the use of open decks, these solid decks require a drainage system, which in turn requires maintenance in order to avoid the problems of clogged drains, ponding water, leakage, and corrosion. Areas where steel members protrude above the concrete deck are particularly susceptible to water intrusion and its attendant problems.

The drainage system which presently exists in many thru-span areas is largely dependent upon a series of short pipes which pass through the webs of existing beams. Being beneath the track and ties, these pipes are difficult to access and have tended to clog. Water backing up from these blocked drains has caused corrosion of the structural members and leakage along these members to the mezzanines below.

The new design being used at thru-span section consists of a structural slab, supporting the track concrete. The separation plane is waterproofed. Drainage is into the track troughs, to an inlet at the end of the thru-span section, and then by drains and leaders into the City sewers. Note that this is a much simpler system, much easier to maintain.

The corrosion of the thru-span girders caused by the malfunctioning drainage system is repaired by adding web plates to restore the strength of these members.

2.1.3 Rehabilitation of Track Supporting Members

Another problem we have on elevated structures involves the top flange angles of the track stringers. Between stations the track is supported on wood ties which rest directly on these top flange angles. Moisture, which is absorbed by or trapped under the wood ties, causes corrosion of the top flange angles. This corrosion is generally not visible until the ties are lifted. Depending on the extent and frequency of the corrosion, top flange angles are either spliced in the corroded area or completely replaced. New material is connected to existing using high strength bolts.

2.1.4 Rehabilitation of Expansion Joints

At approximately every 100 feet along the elevated structure, the connection of the track stringers to the cross girders provides for expansion. The seat bracket is composed of two angles with plates in between them and is attached to a cross girder. The rocker pin, a 4 inch diameter half round steel pin, slides on this seat bracket to allow for expansion. The track stringer is supported on the round part of the pin, allowing for rotation of the stringer. The constant sliding and rotating at this connection, coupled with corrosion, results in wear of the rocker pin and seat bracket. As this wear occurs, the top of this stringer will drop, causing a difference in elevation of adjacent stringers. This in turn results in excessive wear of the tracks. Under the Authority's continuing inspection program, these stringer elevations are recorded. When the difference in elevation exceeds1/4 inch, replacement of the rocker pin is indicated.

The rocker pins presently are of carbon steel. We have switched to stainless to minimize corrosion, and to provide a smooth sliding surface.

Where the seat brackets have significant wear, we are replacing them with a newly designed seat bracket with stainless steel wearing surface.

3. SUBWAYS

The New York City Transit Authority's underground system includes the subway tunnels and other auxiliary structures. The subway tunnel sections are primarily of the following types:

a) Circular cast iron tunnel.

b) Concrete bent construction (Rectangular open cut section.)

c) Steel bent construction (Rectangular open cut section.)

Auxiliary subway structures associated with the operation of the railroad and contiguous to the tunnels include vent shafts, emergency exits, equipment rooms, crew quarters, etc. The underground structures are generally waterproofed to an extent that depends on the elevation of the ground water at the time of construction. The structures partially below the water table are provided with waterproofing under the invert and along the sides to a height above the ground water level. When the structures are totally below ground water and constructed in earth, they are completely waterproofed. If the invert is constructed in rock, the waterproofing is omitted and a non-structural slab is used with weep holes to relieve the water pressure.

In general, two types of waterproofing were used in the construction of the Transit Authority tunnels. The brick and mastic waterproofing was used for the most severe situations and consisted of bricks laid with a mastic mortar. The second type was the ply waterproofing which was originally made out of a coal tar product and a cotton fabric. The coal tar product later evolved into a petroleum based product. The tunnels presently in use by the Authority date back to the turn of the century. Due to age, deferred maintenance and changed conditions surrounding these tunnels, cracks have developed in the tunnel envelope. The presence of water outside, coupled with waterproofing that, in many instances, has become ineffective due to the passage of time, has resulted in water leaking into the tunnels.

The water infiltration corrodes reinforcing bars, structural steel, deteriorates line equipment, undermines the invert, overloads the drainage systems, deteriorates tracks, creates hazardous conditions for maintenance personnel and finally impacts on the operation of the railroad.

3.1 Water Remedy Work In Subways - History and Methodology

The extent of water infiltration depends on the causes and therefore, the approach to remedy the water condition must be tailored to suit the conditions. Substantial amounts of water infiltrating into the tunnels has required lowering the ground water level outside the subway tunnel. A number of contracts were awarded to install dewatering wells and well point systems to remedy the severe water infiltration problems on the Nostrand Avenue and Lenox Avenue Lines and at the Essex Street Station.

In locations where the invert has been undermined, cement grouting of voids as well as replacement of structural inverts have been utilized as remedies. Cement grout was utilized to fill voids below the invert at Essex Street Station in 1982. A 275 foot length of structural invert replacement north of 42nd Street on the 8th Avenue Line was completed in 1987. A combination of cement grouting and invert replacement was completed in 1990 between 110th Street and 116th Street on Lenox Avenue.

Actively leaking cracks and damp patches of tunnel surfaces must be treated using methods that stop the water by filling in the cracks. Several products and methods were utilized over the last ten years. A summary of products used on various contracts is provided in Table 1. The early attempts to stop water leaks were within the limits of the stations. These stations were part of the station modernization program. These projects utilized various types of cementitious repair products, such as Sika-set Plug, Master Builder Set-45, Five-Star waterproofing and Vulchem Sealant. To a large extent, these products were not very successful in sealing leaks. For example, the Contract for the rehabilitation of Bergen Street Station in 1982 utilized a combination of Sika cementitious plugs and a Five-Star cementitious coating to treat a severe water condition. This approach was not effective and Bergen Street Station was subsequently redone, years later, using chemical grout as part of the Culver Line Rehabilitation Contract. The original design of the first large water remedy contract on the 4th Avenue Line, while never awarded, specified cementitious grout and was subsequently changed to chemical grout by addenda.

3.1.1 Use of Chemical Grout

The Transit Authority's first exposure to chemical grouting was in 1968 when following the advice of Professor Chebetorial, approximately 200 ft of track invert north of Newkirk Avenue Station was granted using AM9 grout. The objective was to grout the soil beneath the invert. The contract was terminated halfway through due to failure of the grout to stop the water inflow.

The Transit Authority initiated a program to perform structural rehabilitation of the subway tunnels in the early 1980's. These early contracts included water remedy work. In these contracts, an attempt was made to seal all cracks in the structure, leaking and non-leaking. The Transit Authority has utilized a number of consultants in developing and evaluating the use of various types of products to seal leaks.

In December 1982, a successful demonstration was performed at Metropolitan Avenue Station in Brooklyn utilizing a chemical grout to seal leaks. The product used was TACSS 020 polyurethane grout manufactured by DeNeef Construction Chemicals.

Transit Authority design projects subsequently specified the use of chemical grout. The contract for the rehabilitation of the 8th Avenue Line, advertised in 1985, was the first major line contract which utilized the TACSS 020 chemical grout. The contract for the rehabilitation of the Culver Line was awarded with TACSS 020 specified as the chemical grout. The contractor requested approval of Scotch Seal 5600, a polyurethane grout manufactured by 3M Construction Products in lieu of the specified product. The use of Scotch

CONTRACT NUMBER	DESCRIPTION	YEAR	PRODUCTS USED
C 30399	Rehab. of Bergen Street Station Borough of Brooklyn	1982	'Hey' Di Powder X 'Hey' Di Special Five Star Waterproof Plug Five Star W.P. Coating ('8")
T 31563	Repl. Tracks W8 St. To W32 St. 6th Ave. Borough of Manhattan	1983	Five Star Waterproofing Sika Set Plug Sika Top 123 Gel Mortar Hey Di K-11 Cement W.P.
Z 32271	Structural Improvement 4th Ave. BMT Line, Borough of Brooklyn	1984	Master Builder Set-45 Sika Set Plug Vulkem 116 Sealant
A 35553	Station Mod. of Kings Highway Station Borough of Brooklyn	1982	Sika Flex 1A
A 35522	Station Mod. of Church Ave. Station Borough of Brooklyn	1982	Sikadur 52 Epoxy Sealer Sikadur 33
C 20786	Archer Ave. Wrap Up Borough of Queens	1987	Acrylate AC 400
C 20167	Route 131A, Sect. 1 thru 7 63rd St. Tunnel Wrap Up Boroughs of Manhattan and Queens.	1988	Acrylate AC 400

Table 1 Record of Water Remedy Products

Seal 5600 was approved after a successful demonstration test at the Bergen Street Station. When the Authority was introduced to Scotch Seal 5600, the preparation of the new routes wrap-up contracts for the Archer Avenue and 63rd Street was under way. In these contracts, polyurethane grouts (3M Scotch Seal 5600 and DeNeef Flex 44LV) for large joints and cracks and acrylate grouts (Geochemical AC-400 and Celtite Terragel 55-31/32) for finer cracks were specified. Construction on these two contracts was completed utilizing both the polyurethane and acrylate grouts. Post construction feedback on both the 63rd Street and Archer Avenue contracts indicated that the acrylate grouts did not withstand the effects of wet-dry cycles and movements caused by seasonal changes. It was a result of this information that a decision was made in 1990 to utilize polyurethane grouts on all contracts.

3.1.2 Current Approach

At the present time, Transit Authority water remedy contracts are aimed primarily at sealing only active water leaks within the subway structures. The current specifications for chemical grouting to seal active water leaks designates the use of a polyurethane grout. These polyurethane grouts contain mainly urethane prepolymer and acetone. The polyurethane grout is pumped under pressure into the crack through drilled holes, reacts with water by foaming to form a flexible closed void solid which seals the leaking cracks within the structure.

This flexible closed void solid is capable of withstanding the movements of the subway structures caused by seasonal changes and train operations. In evaluating polyurethane grout, physical properties such as viscosity, solid content, density, tensile strength, elongation, shrinkage, etc. are considered. Two examples of the products currently being used are Scotch Seal 5600 manufactured by 3M Construction Products, St. Paul, Minnesota and Hydro-Active Flex LV manufactured by DeNeef Construction Chemical, Waller, Texas.

The contract specifications provide for grouting to be done in a series of up to three passes. The first pass seals all active leaks, the second pass seals new and migrated leaks and the third pass completes the sealing of any remaining leaks.

The quantity of lineal feet of leaking cracks is established during the design phase on the basis of a comprehensive field survey. The designers walk through the tunnel and record the location and the length of all the cracks. The total is increased to allow for new and migrated leaks. The field survey data which shows the location and length of cracks is made available to the prospective bidders during the bid period. A final inspection is made after the contract is bid by a team made up of Authority and contractor personnel. In establishing grout quantities, it is estimated, based on past experience and input from the manufacturers, that one gallon of grout will seal three lineal feet of leaking crack.

The contract specifications include directions on handling, storage and disposal of the chemical grout as well as safety precautions to be followed during the grouting operation. The cured materials are essentially non toxic.

3.2 Other Rehabilitation Work

In addition to the water remedy work utilizing cement and chemical grouting, other significant rehabilitation work was performed in the subway structures to restore them to a state of good repair. This work can be divided into two categories - Work that is the result of water intrusion over the years and includes such items as repair of corroded structural steel and replacement of track. Work in the other category includes upgrading of the pump rooms, ventilation plants, and tunnel lighting. The work in the later category is also necessary to improve the efficiency, reliability and most of all the safety of the system.

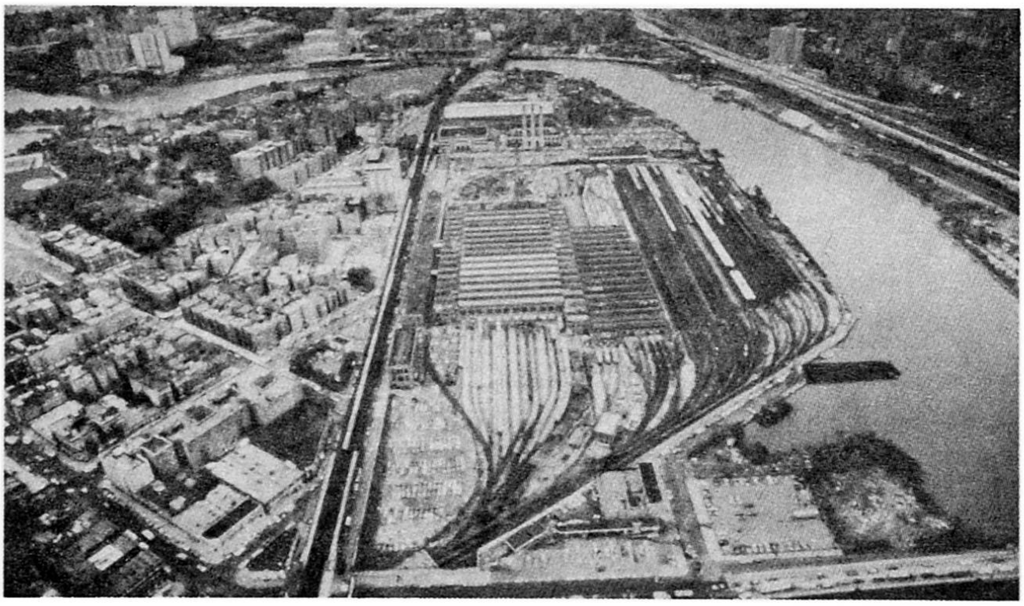
4. CONCLUSION

The mission of the Transit Authority is:

> "To achieve excellence in providing a safe, convenient, comfortable, reliable, cost effective, responsive, and customer oriented transportation system."

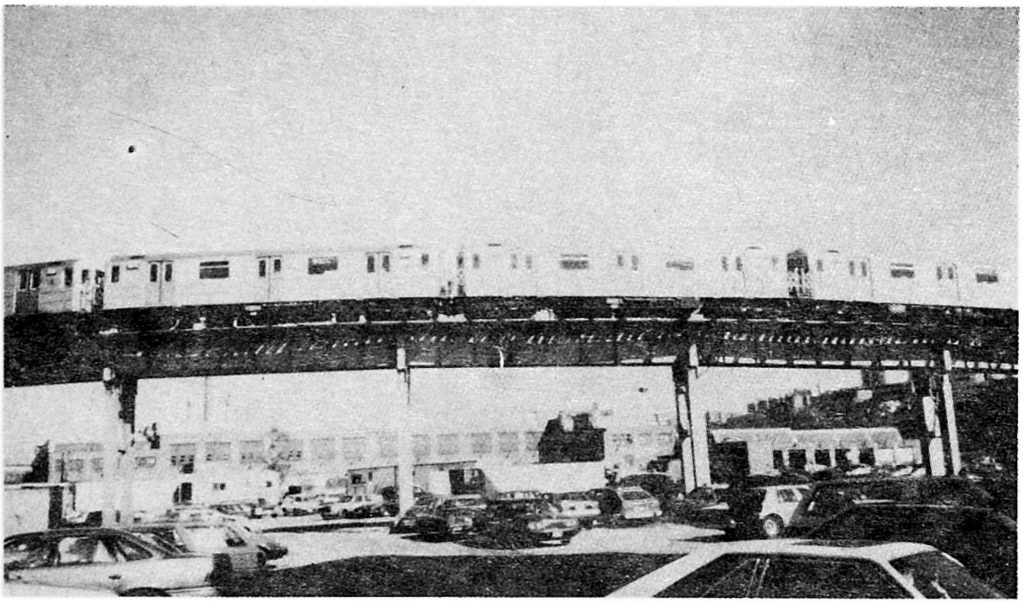
An infrastructure that is sound and in a state of good repair is essential to the safety and the reliability of the system, and would go a long way in accomplishing the mission of the Transit Authority.

Over the last decade, the Authority invested substantial amount of money in the rehabilitation of the infrastructure. The return on investment is visible in a restored, reliable and vibrant system that is being noticed and appreciated by the riding public. More remains to be done to protect the earlier investments, and to retain the gains made to date. The 1992 - 1996 Capital Program, which envisions an investment of over seven and one half billion dollars in the rehabilitation of the line structure, stations, track, shops and bus depots, etc., is vital to the future of public transit operations in New York City.

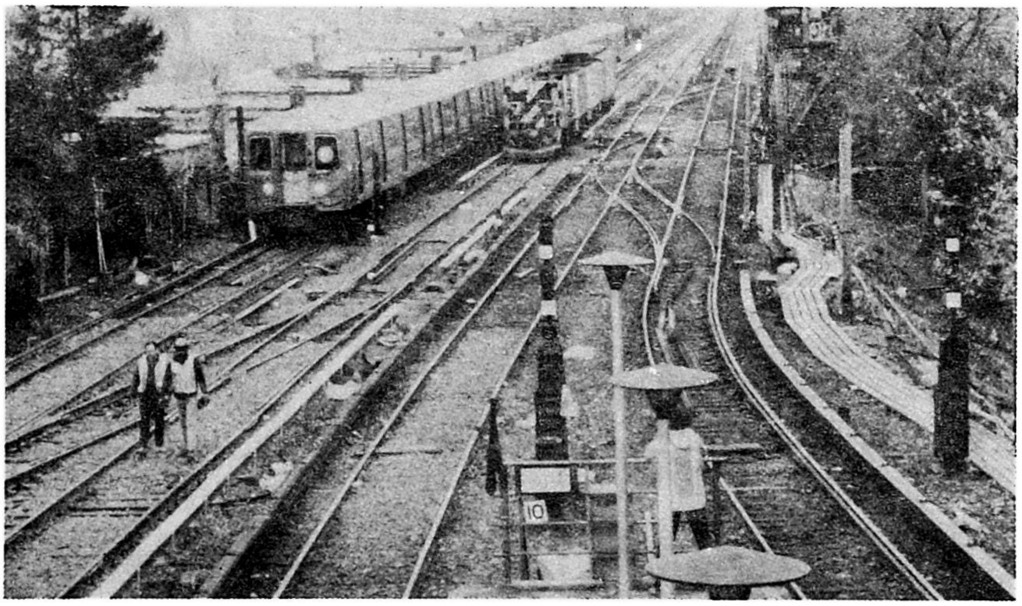


TRAIN STORAGE YARD

SUBWAY STATION



ELEVATED STRUCTURE



TRACK ON EMBANKMENT