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"Rehabilitation of the Manahattan Bridge Travelers"

THE REHABILITATION OF THE MANHATTAN BRIDGE TRAVELERS

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INTRODUCTION

The Manhattan Bridge crosses the East River and connects the Boroughs of Manhattan and Brooklyn in New York City. The bridge is of the suspension type with steel suspender ropes supporting four stiffening trusses from each of four parallel main cables.

The Manhattan Bridge Travelers are electrically powered maintenance platforms which are suspended from track beams and move along the underside of the bridge. They are used to carry personnel, materials and equipment to any desired locations under the bridge deck for the purposes of inspection, maintenance, painting and repairs. The rehabilitated Manhattan Bridge Travelers are particularly important in that they will facilitate future major reconstruction work on the bridge.

HISTORY

The Manhattan Bridge was the third and last suspension bridge built to cross the East River in New York City. Construction of the bridge began in 1900 and ended in 1909 when the bridge was formally opened to traffic. The first traffic on the bridge consisted of pedestrians, horse drawn carriages and carts, gasoline and diesel powered vehicles, and light rapid transit. Full rapid transit service was introduced in 1918.

Today, the Manhattan Bridge carries two upper roadways for passenger cars and one lower roadway for mixed traffic, together with two sets of transit tracks which are located on each side of the lower roadway.

The original travelers were installed as part of the original bridge construction. The mechanical and electrical systems were first rehabilitated in the 1930's and again in 1982 after years of chronic unsatisfactory operation. Additionally, the platform floors of the travelers were corroded, the railings were broken, and the track beams were severely corroded. The 1982 rehabilitation was to include replacement of the existing platforms, mechanical and electrical systems, and track beams and hangers. It was not completed, however, partly due to the inordinate difficulties encountered during erection of the replacement track beams. Specifically, continuous track beams were being installed on the underside of stiffening trusses which exhibited great flexure, leading to failed hanger and track beam connections during construction. As a result, a new design of the traveler support system was undertaken in 1987 which took into account the significant live load and thermal deflection and lateral tilting of the bridge superstructure.

Rehabilitation of the redesigned support system commenced in 1990. The work performed under this rehabilitation contract consisted of replacement of the existing track beams, replacement of the existing hangers with new or modified partially fabricated hangers, installation of new traveler support yokes and mechanical drive systems, and installation of electrical control and distribution systems.

<u>SUSPENSION BRIDGE DEFLECTION</u>

Suspension bridge deflection due to live load and temperature is of greater amplitude than that for other types of bridge structures. Increases in temperature cause the stiffening trusses on a suspension bridge to expand and deflect downward, as well as causing the main cables and suspenders to increase in length. As the main cables and suspenders lengthen, the stiffening trusses deflect further. The lenthening of the main cables provides the main contribution to span deflections. Live load on the span produce similar effects. The superstructure behaves in the opposite manner for decreases in temperature.

The track beams, if made continuous and rigidly attached by hangers to the stiffening trusses, experience induced strain and longitudinal displacement relative to the truss displacement due to their location below the bottom chord of the truss. This displacement was detrimental to the fixed hangers and their connections in the 1982 rehabilitation. The problem was overcome during redesign of the traveler support system by limiting the track beam lengths to 36 feet (or approximately 2 truss panels) except at the parking area, and by using two expansion hangers and one fixed hanger at the three support locations on each track beam. Designing the mounting system for the track beams was the most challenging aspect of the traveler rehabilitation design.

The heaviest live loads carried by the Manhattan Bridge consist of sets of subway trains which are carried outboard of the lower roadway, each set between two stiffening trusses. The stiffening trusses work independently of each other because their lateral connections are not rigid enough to transfer the live load to the opposite hand cables. Lack of torsional stiffness of the truss system in the longitudinal direction contributes to the differential outer truss deflections of up to eight feet together with tilting of the four truss system.

For these reasons, the mechanical support system was designed to equalize loads and allow for movement in the lateral direction.

DESCRIPTION OF THE NEW TRAVELER SYSTEM

The Manhattan Bridge Traveler System consists of six travelers, two on each main span and two on each of the two side spans. Each traveler spans half of the bridge width and travels the entire length of the span on which it is installed. Each traveler platform is 62 feet long and at least four feet wide throughout its entire length. It has an empty weight of 45,000 pounds and a gross weight of 120,000 pounds, leaving a useful load of 75,000 pounds. Full running speed ranges from 50 to 60 feet per minute. A creep speed of 13 feet per minute may also be used.

TRACK BEAMS AND HANGERS

Each track beam is a two span continuous member supported by one fixed hanger and two expansion hangers, which connect to the bottom chord of each stiffening truss. Each track beam is approximately 36 feet long and consists of an American Standard (S12 x 50) section with a welded 8 x 1/2 inch top cover plate. In order to ensure proper alignment of transverse and longitudinal adjacent track beams, the contract specifications contained special requirements for fabrication and installation tolerances. Specifically, both the rolling and welding tolerances were established to minimize sweep and out-of-square distortions of the member. In addition, an installation gap of 1/4 inch was specified between the ends of adjacent track beams, based on an ambient temperature range of 50°-60°F. A tolerance in the gap of -0,+1/16 inch was also required. Adjustments were subsequently made in the installation gap to correlate with varying ambient temperatures. The contract specifications also required the gap to be measured with no transit live load on the bridge, due to the longitudinal motion of the stiffening trusses supporting the track beams.

The expansion and fixed hangers consist of both new and modified partially fabricated members from the previous contract. Fixed hangers are rigidly connected to the web plates of the existing bottom chord of the stiffening truss. Expansion hangers are connected to the top of the bottom chord and hang inside the web plates to support the track beam below. Erection of the hangers was challenging, in that there were numerous interferences between the existing steel and new connections. In addition, the hangers created a potential conflict with structural elements to be added to the stiffening truss under future construction, namely, horizontal gusset plates to be installed as part of a new wind bracing system.

MECHANICAL SUPPORT SYSTEM

Each traveler is supported by a total of 32 8-3/4 inch diameter steel wheels, comprising eight at each corner. The wheels are mounted on fixed spindles with tapered roller bearings and ride on the bottom flanges of the track beams.

The axes of the support wheels are tilted 9.6° from the horizontal to match the slope of the track beam flange. This slope develops equal and opposite horizontal force components in the wheels which center the support carrier assemblies about the track beam , thereby eliminating the need for flanges on the wheels. The weight of the traveler is distributed to the wheels using a system of links, plates, pins and bolsters arranged in a manner to equalize the loads between wheels.

DRIVE SYSTEM

Each traveler is driven, stopped and held in position through the use of four independent motor drive systems mounted on two drive frames, with one drive frame on each track beam. The drive frame is a 27 foot long simple span supported at each end by a pair of wheels bearing on the track beam flange. It consists of two back to back rolled channel sections separated by 1 foot, which support a motor drive system at each end together with a hand brake assembly near the center. In addition, for each traveler there is a collector pickup system supported by one drive frame and an overspeed switch assembly and anti-skew device supported by the second drive frame.

At each end of the drive frame, the motor drives a double reduction speed reducer. The single drive wheel is driven from the speed reducer through a double reduction chain drive. The double reduction speed reducer is driven by the motor through the use of a roller chain.

The drive wheel uses a polyurethane tire to contact the underside of the track beam and transmit the motive force to the track beam. Each drive wheel is held against the track beam with a force of approximately 5,000 pounds provided by four springs. The reaction from this force is transmitted to the track beam through the drive frame support wheels which are mounted directly above the drive wheel. The drive wheels are free to move vertically as they cross irregularities in the riding surface of the track beam.

ELECTRICAL SYSTEMS

The electrical power originates from existing Consolidated Edison Service, 208 V.A.C., Three Phase, 60 HZ from the Boroughs of Manhattan and Brooklyn. The power is stepped up by transformers to 480 V.A.C., Three Phase, 4 Wire for power distribution to the travelers. Each borough provides power to three travelers (six travelers total) and each source has the capacity to drive three travelers at a time.

In the event of a power failure in one borough, power may be transferred from the other borough using a power transfer system controlled at mid span. This system disconnects the three travelers from the failed incoming power source and connects the three travelers to the alternate source.

Power is distributed across the span through copper wire in conduit to a collector type conductor rail system which distributes the power to the travelers.

Each traveler load consists of platform lights and four five (5) horsepower D.C. motors driven through solid state drives.

The collector system consists of collectors attached to the travelers and copper conductor rails, which are supported by the track beams and run the length of each span. There are four collectors per phase on each of the travelers which ensure constant contact with the rails so that power interruptions and arcing which may disturb the solid state drives are prevented.

The power distribution system is connected to each collector system at powerfeeds located at specific points along the conductor rails. Conductor rails are installed in the same discrete lengths as the track beams. During construction, a request was made by the Contractor to change the specified locations of the conductor rails. Specifically, the original Contract Drawings indicate the conductor rails to be supported by the track beams from the two outside trusses. Due to easier access and less required demolition work, it was agreed to relocate the conductor rails to the two inside trusses.

At the gaps between ends of conductor rails, an expansion joint consisting of flexible conductors is used to allow for both motion of the bridge and thermal expansion and contraction of the conductors. All current carrying components are covered with a PVC jacket.

There are two five (5) horsepower 240 V.D.C. shunt wound electric motors mounted on each drive frame, comprising a total of four per traveler. The two motors on each drive frame are connected in series and controlled by a single ten

(10) horsepower four quadrant, regenerative, digital, D.C. programmable drive controller.

The drive controllers provide constant load sharing between the two motors on the same drive frame and are interconnected to provide speed synchronization between drive frames.

Each motor is equipped with a 15 foot-pound solenoid released disc brake mounted opposite the drive end with a hand release.

ANTI-SKEW SYSTEM

The anti-skew device is designed to prevent excessive skew between the two drive frames of each traveler. Skew is the amount of misalignment between the longitudinal axes of the traveler and the track beam, which results from one drive frame moving ahead of the other drive frame on the same traveler. The anti-skew system consists of a mechanical linkage system made up of arms, bearings, links and a shaft, and four limit switches connected to the control system.

The anti-skew device mechanically senses lateral motion at each end of a drive frame relative to the traveler structure. This is translated to skew by mechanically subtracting lateral motion at one end of the frame from the lateral motion at the other end. This eliminates the effects of uniform lateral motion from the skew sensing system. The mechanical portion of the anti-skew device inputs to the control system by tripping a limit switch arm. The minor skew limit switch causes the programmable controller to reduce the speed of the leading drive frame motors to 90 percent of normal speed. After the skew has been corrected sufficiently to release the limit switch, the motors return to 100 percent of normal speed. Should the skew not be corrected and continue to worsen, the major skew limit will then be tripped which will stop the traveler. The traveler cannot be operated until the skewed condition is corrected.

SHOP TESTING

Before any drive frames were delivered to the site they were shop tested on an 80 foot length of track beam mounted on a 3 percent grade. A load was applied to the drive frame using a roller chain which was connected to an air powered disc brake. The test was required to show that the traveler would track properly on the track beam, produce a 5,000 pound tractive force at 100 percent full load motor torque, and operate with that load for one hour without any excessive heating or binding. The tractive force was measured with a load cell and the temperatures of all journal type bearings and the speed reducer were measured with thermocouples. The shop tests proved to be successful.

The actual D.C. motors were not used in this test. A pair of AC squirrel cage motors of the same horsepower and rpm was substituted to avoid having the motors and control system shipped to the machinery supplier. The motors were load tested independently by the motor manufacturer.

FIELD TESTING

Set up testing commenced once the first traveler was completely assembled on the bridge with the drive wheels not in contact with the track beam. The drive systems were operated at both normal and creep speeds. All switches including end-of-travel, near end-of-travel, major skew, minor skew, brake-set, brake-released, dead man and emergency stop switches were tripped to verify the proper response from the control system. Operational testing began after successful completion of the above tests.

The operational testing consisted of running the traveler up and down the existing grade and performing normal and emergency stops, while recording running speeds and creep speeds in both directions. Additionally, the traveler was intentionally skewed while running by tripping a minor skew limit switch. As the skew worsened, it was verified that the opposite minor skew limit switch had tripped and as a result, the speed of the leading drive frame was reduced.

The travelers were then loaded to attain a total weight of 90,000 pounds by using 55 gallon drums filled with water. The operational tests listed above were then performed with the traveler loaded. Additionally, the traveler was run on the entire length of track beam in each location in order to verify proper overall operation.

After successful completion of the operational testing of the first traveler, work on the other travelers was completed and testing was performed in the same manner.

OPERATION

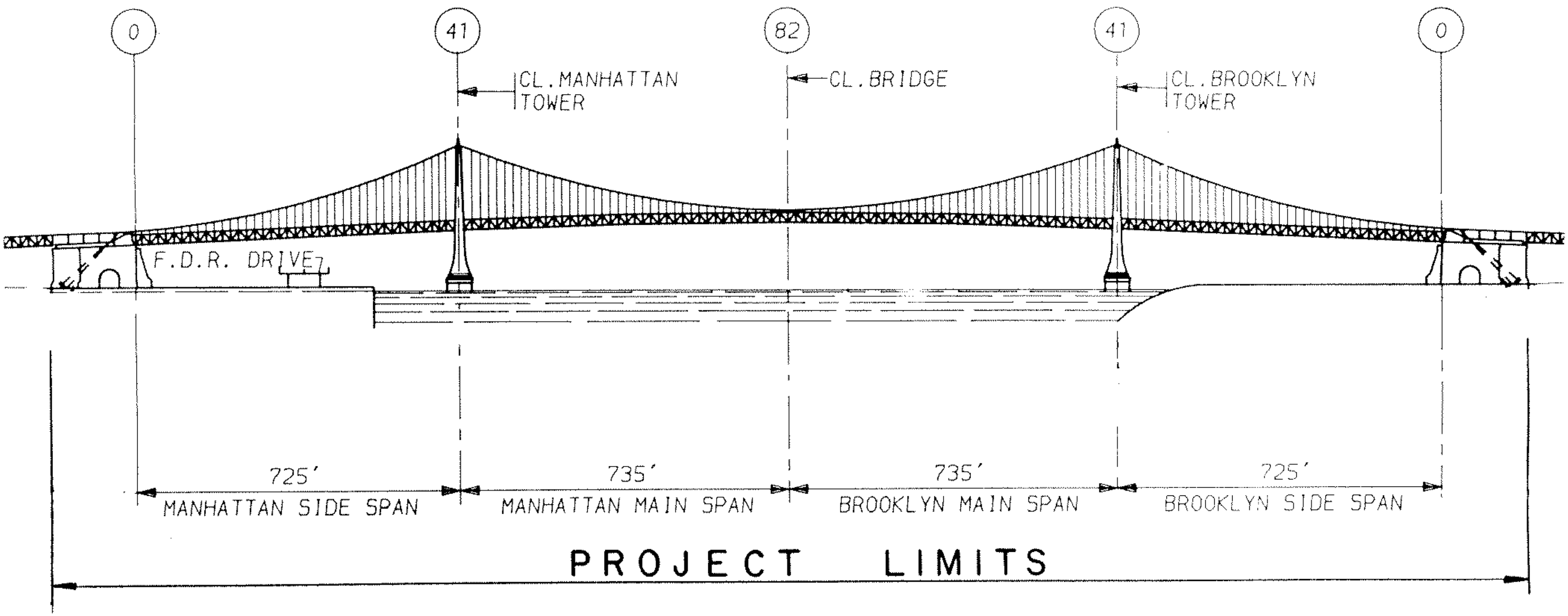
The traveler is boarded and its gates are closed. Then the parking brakes are released, power is turned on, and the dead man switch is installed and depressed. As the drum switch is moved in the running direction, the horn sounds and the traveler accelerates to full speed. When the desired destination is reached, the drum switch is moved to the neutral position and the traveler slows to a stop. To return to the same parking area, the drum switch is moved in the opposite direction and the traveler moves toward the parking area. As the traveler approaches the parking area at full speed, the near-end-of-travel limit switch is tripped by the trip plate and the traveler decelerates to creep speed. It then travels the remaining distance at creep speed until the end-of-travel limit switch is tripped, and then it stops.

If use of the travelers is finished, then the power is turned off, the dead man switch is removed, the parking brakes are set, and the traveler is exited.

The traveler will not move unless the dead man pushbutton switch is depressed. If this switch is released while the traveler is moving, the traveler will come to an emergency stop. The tripping of the motorbrake hand released limit switch, the parking brake engaged limit switch and the overspeed switch will result in shutting down the traveler.

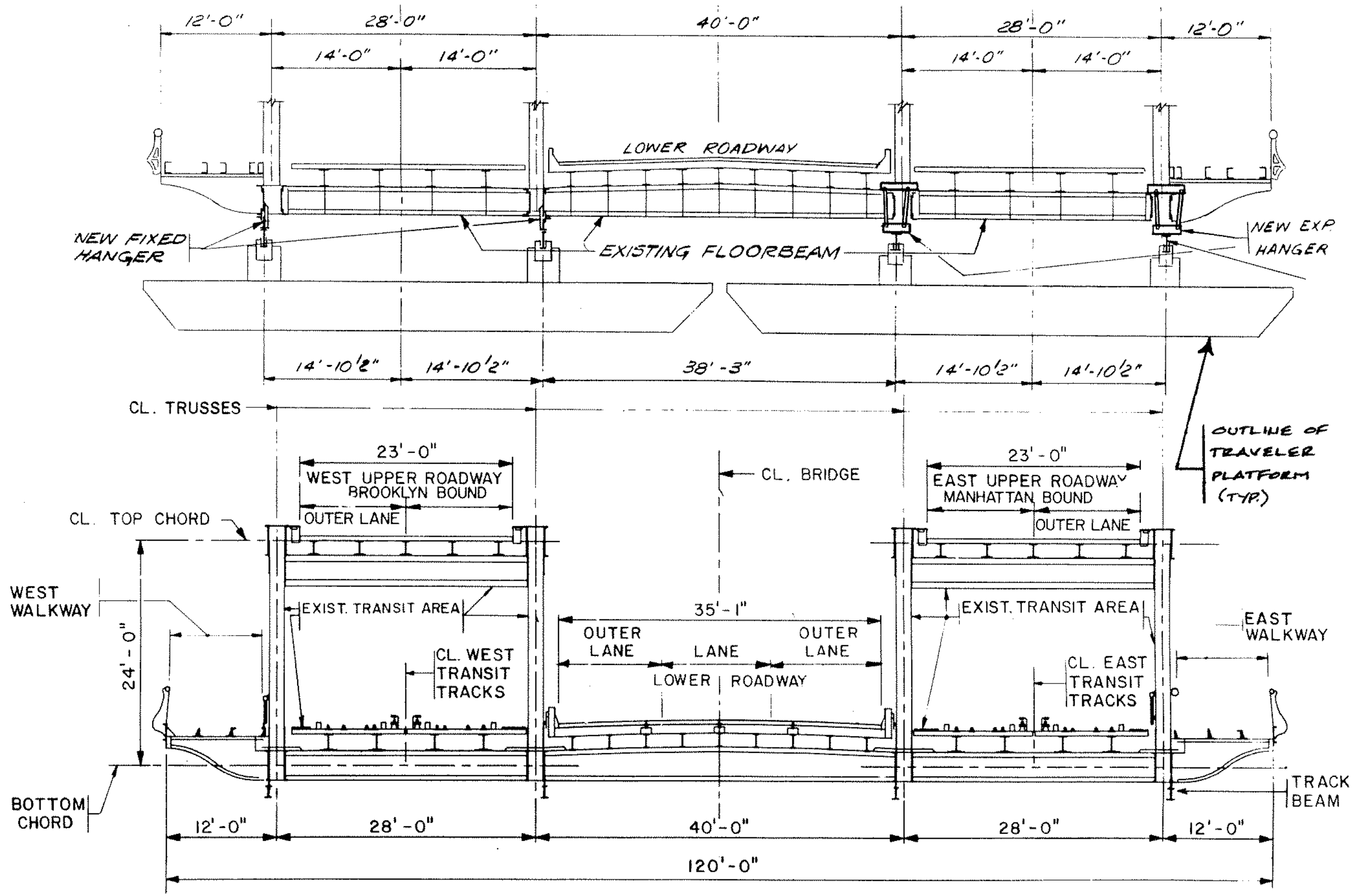
CONCLUSIONS

The Manhattan Bridge Traveler System provides access to all locations under suspension spans for inspection, construction and maintenance. The total cost for all work performed on the travelers during this rehabilitation was approximately $13 million. The traveler system increases the dead load on the superstructure by approximately 420 pounds per linear foot and reduces the navigational vertical clearance by approximately two and one half feet. This data is presented in order to compare the physical effects of a traveler system present on the bridge versus no traveler system present. Travelers are well suited for suspension spans and through trusses, as physical access with underbridge inspection units is restricted by both suspenders and truss members.



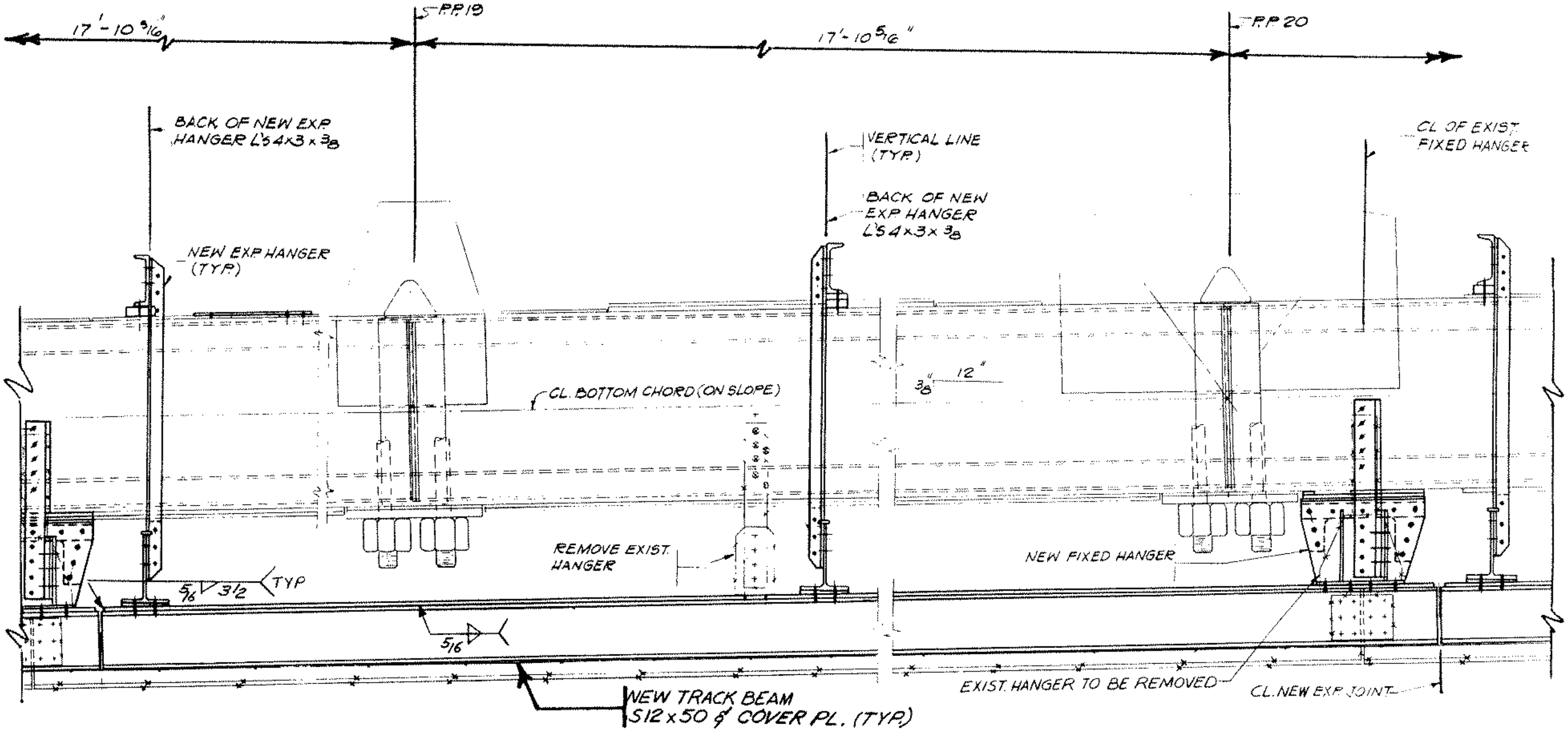
ELEVATION

MANHATTAN BRIDGE

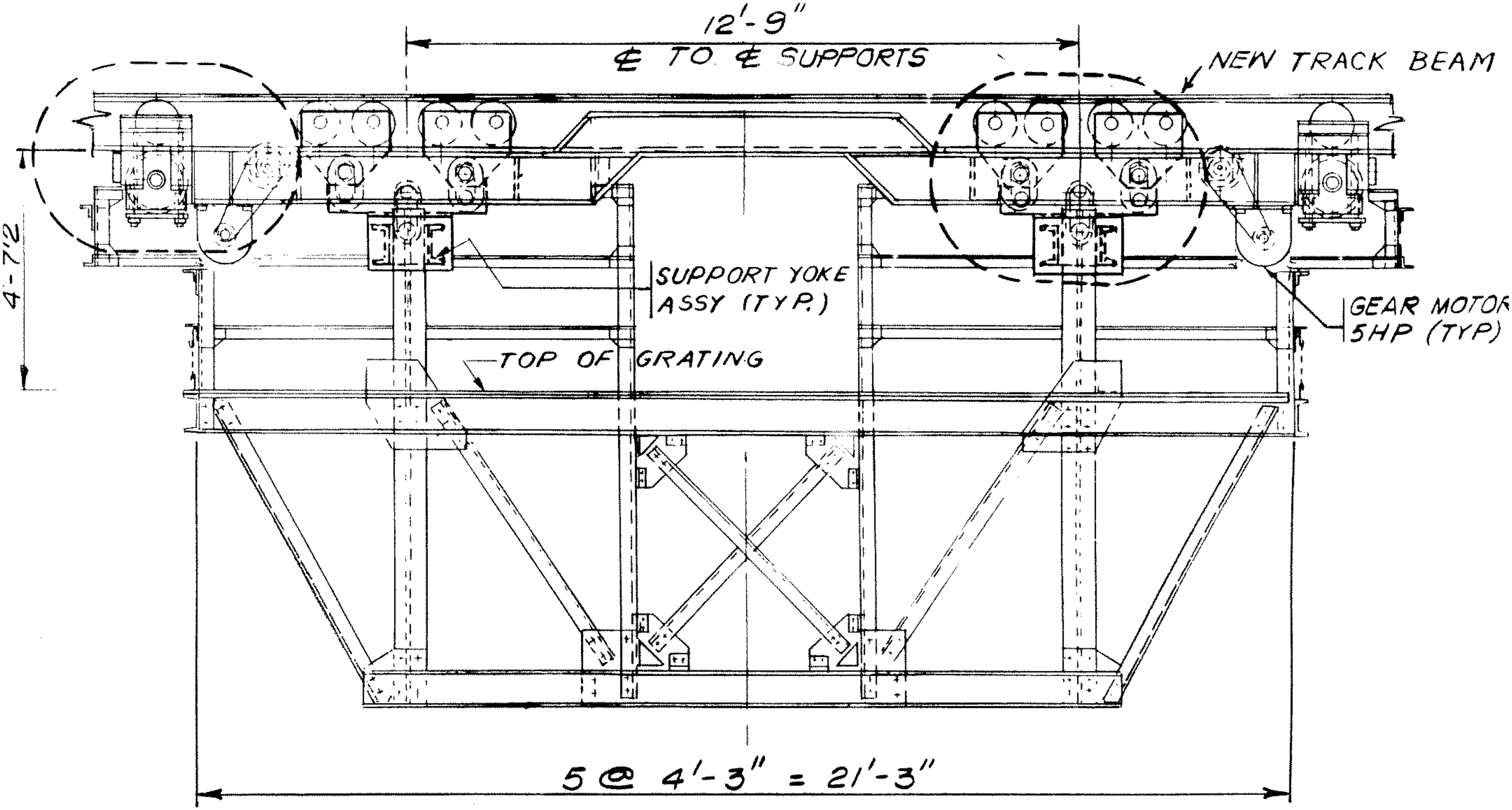


TYPICAL CROSS SECTION

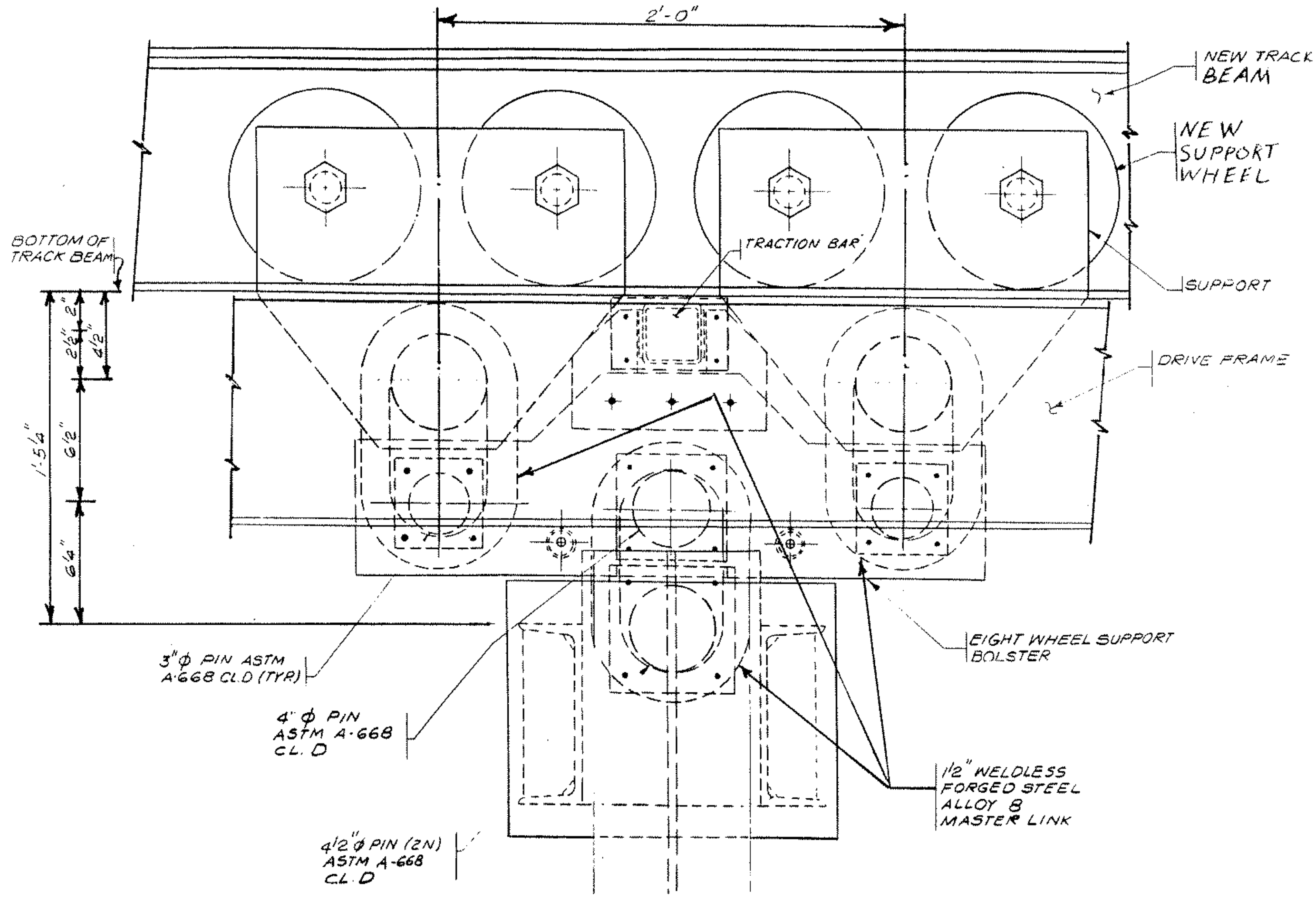
(LOOKING NORTH)



SECTIONAL ELEVATION OF BOTTOM CHORD

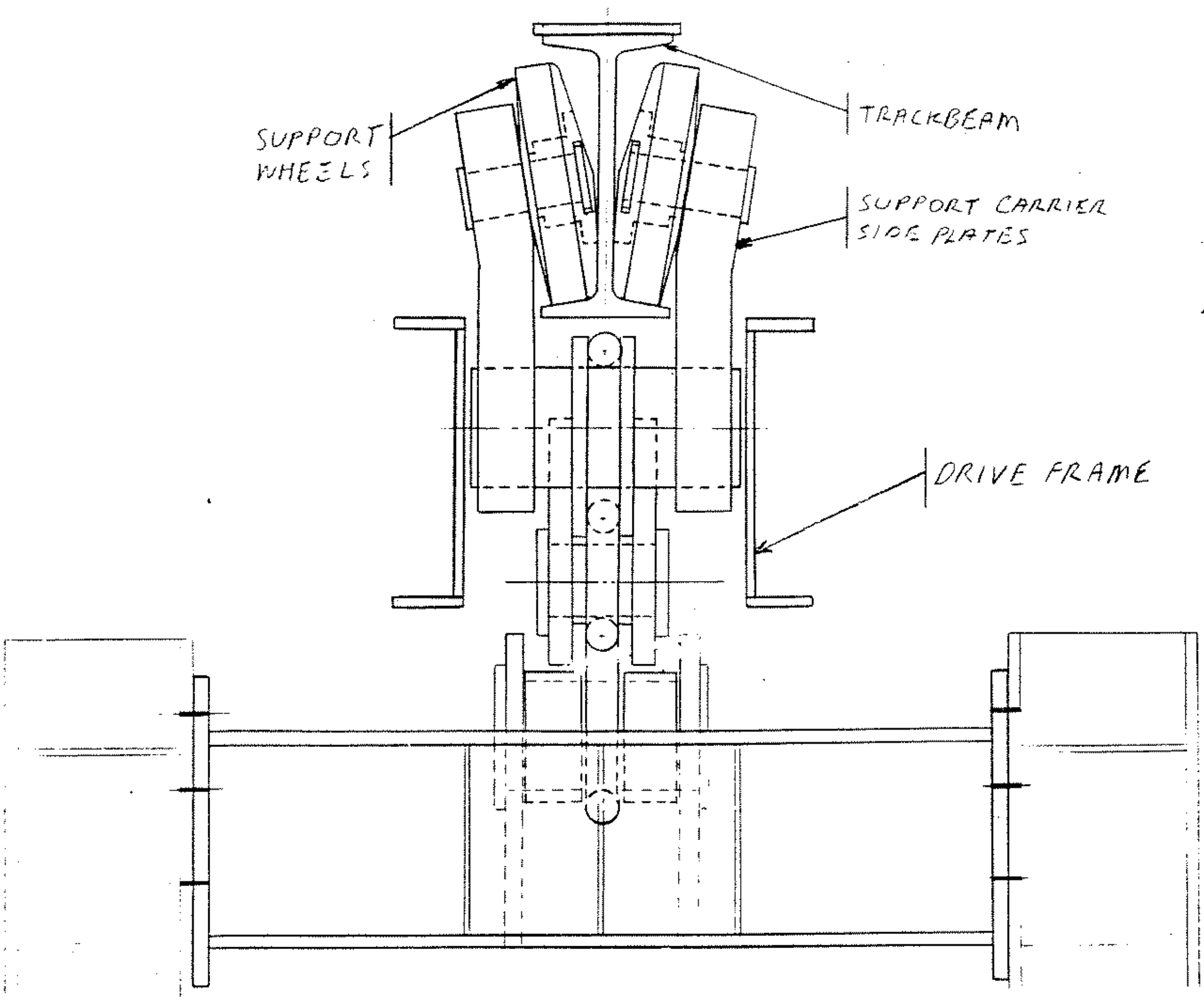


TRAVELER DRIVE & SUPPORT ASSEMBLY



ELEVATION

TRAVELER SUPPORT ASSEMBLY



SECTION

TRAVELER SUPPORT ASSEMBLY