**Heavy Movable Structures, Inc.**

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Clearwater Beach, Florida

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# *The George P. Coleman Bridge Reconstruction, Yorktown, Virginia*

by

Michael J. Abrahams, P.E., Parsons Brinckerhoff Quade & Douglas, Inc.

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## Introduction

This May, in a 9-day period, the Tidewater Construction Company was able to remove and replace six truss spans of the Coleman Bridge - a feat that made the cover of Engineering News-Record. An integral part of that project was that two of the truss spans form one of the largest swing bridges in the world and that within weeks after they were installed, the two swing spans had been made operational, and shipping was using channel.

## Project History

Work on a highway crossing began in 1939, when complete design plans were prepared for a suspension bridge. This bridge was to accommodate the U.S. Navy's requirement of a 1,200-foot-wide navigation channel to bridge the Atlantic Fleet into a fueling station upstream from the bridge site. Construction was postponed due to the onset of World War II.

When the project was reviewed after the war, local interests (particularly the Daughters of the American Revolution) voiced their concern that the construction of the high-level suspension bridge would intrude on the colonial setting of the Colonial National Historical Park, the site of the last major battle and surrender of much of the British Army during the Revolutionary War.

At this juncture, a unique design a solution was proposed, comprising twin 500-foot swing spans, set so that the top of the structure was below the Park's sight lines, and high enough (65-foot vertical clearance) to clear almost all vessels except those of the U.S. Navy, which would require an opening. The Coleman Bridge was completed in 1952.

The entire bridge is 3,750 feet long with 4.5 percent grades. Except for girder spans of 450 feet on the south approach and 720 feet on the north approach, the bridge utilizes deck truss spans as shown in Figure 1. The substructure includes six river piers founded on large hollow caissons, which spread the

[1]Vice President, Parsons Brinckerhoff Quade & Douglas, Inc.

bridge load across the relatively soft marl soils that underlie the river bed and limit differential settlement between piers.

The bridge had two lanes and was designed to accommodate 15,000 vehicles daily. However, due to removal of tolls on the bridge combined with regional growth, the bridge was carrying approximately 30,000 vehicles each day; and traffic delays due to the bridge's limited capacity were increasing resulting in extensive rush hour delays.

After a study of a wide range of alternatives, the widening of the Coleman Bridge was selected in March 1989 as it had the fewest impacts, the lowest cost, and was able to solve the traffic capacity restriction caused by the existing two-lane bridge. A contract for the construction was awarded to Tidewater Construction Company, a Virginia-based firm, in October 1993. Tidewater's price for the work was $72.7 million. Construction of the replacement started in 1994 and was completed this year.

The new bridge is 74 feet wide, with two lanes in each direction together with a median divider between the opposing roadways, a 2-foot shoulder on the inside lane, and a 10-foot shoulder on the outside lane. The existing bridge carries two lanes, and its roadway is only 26 feet wide. Thus there will be twice as many lanes as on the existing bridge and the outside shoulders will provide enough room for disabled vehicles to pull over and get out of the flow of traffic. Figure 2 shows how the new roadway will look in comparison to the original roadway.

To minimize the visual impact of the new structure, the general configuration of the trusses and control house was not changed. The new approach truss and swing span truss spans are similar to, but wider than, the new existing trusses. However, a number of changes were made to reflect current practice. The deck of the truss spans utilizes lightweight concrete. Open grating was previously used on the swing spans and normal weight concrete on the other truss spans. This solid type of deck surface was selected because it is a better driving surface, particularly in wet or freezing weather. The truss members are welded grade 50 and 70 steel and the deck is composite with floor system. While the traffic control features are similar to the original structure, closed circuit television and variable message signs, controlled from the operator's house, have been added to assist in traffic control. The original girder approach spans consisted of two riveted steel girders with a system of floorbeams and stringers to support the roadway deck slab. These were replaced in a staged construction sequence, with prestressed concrete girders and composite concrete deck.

For the river piers, only the tops of the piers were widened and this was a key element in reducing the project's costs. The added weight of the wider superstructure has only a small effect on the overall bearing pressure of the caissons. As a result, the factors of safety exceed the minimum acceptable values for all loading combinations using very conservative assumptions.

Since the new bridge is wider, it reduced the channel opening in the open position from 450 feet to 420 feet. This 30-foot reduction in width occurs at the level of the roadway. The channel clearances in the closed position (when the bridge is open to highway traffic) did not change. This reduced channel clearance was reviewed with the U.S. Navy and river pilots, and found acceptable.

Another key element of the project was the need to quickly replace the truss spans as traffic had to detour 30 miles upriver to the nearest crossing. The truss spans were replaced using float-in construction by removing the existing trusses and installing new trusses.

The project documents provided for two 2-week shutdowns to replace the truss spans with an $8,000/hour penalty for not meeting this schedule and a $4,000/hour bonus for bettering it. The shutdown time was critical because the nearest crossing was a two-lane bridge 30 miles upstream.

Tidewater utilized only one two-week shutdown period to accomplish the changeout of the trusses. By so doing, Tidewater received a substantial incentive bonus for eliminating one two-week outage period, while those who use the bridge benefited by only having one outage. As the shutdown included two weekends, only 5 working days were impacted. As the Department had conducted an extensive public awareness program in anticipation of the shutdown, the traffic generally flowed smoothly during this period. This was another key element of the project as had the program not been effective, extensive traffic backups were predicted at the detour route.

The construction of the truss spans, including the installation of the machinery and controls, took place off-site prior to the float-in so that once the new swing spans were installed, they would be quickly put back in operation. Thus almost all the controls and machinery were fully operational before the closure.

The operating machinery of the new Coleman Bridge is a combination of features from the original bridge as well as a new design for portions of the machinery that proved troublesome in the original bridge. The drive machinery in particular is very different from the original. As reported in a previous Symposium of this organization [Strain Gauge Testing of Movable Bridge Brakes, Michael J. Abrahams, HMS 3rd Biennial Symposium, 1990] the original electrical/mechanical drive proved to be prone to failure of the drive pinions, particularly when stopping the bridge due to the high torsional stresses developed in the pinion shafts. This is a problem that has been observed at other large swing bridges as well and is not a surprise when one considers the angular momentum associated with a swing span in motion.

As the mass of the bridge was about to double with the replacement, any problems being experienced with the original bridge would only be that much worse with a similar drive system. Therefore a decision was made to use a hydraulic drive that would not require any mechanical braking.

Initially consideration was given to both hydraulic cylinders and to hydraulic motors. But it became readily apparent that hydraulic cylinders would not be suitable due to the large sizes required, their large space requirements on top of the pivot piers, the complicated brackets and framing required to secure the cylinders, and the inability of cylinders to accommodate any overtravel that it was believed could occur due to a control system malfunction or due to a vessel striking the swing span.

The use of hydraulic drive motors with planetary reducers was adopted as it was found to be a much better solution (to obtain the desired speed and torque characteristics). It had none of the problems cited above and furthermore offered the opportunity to design a system with multiple redundancy. There are numerous examples of hydraulic motors with planetary reducers. For example conveyors and ski lift drives use hydraulic motors with reducers - and these are systems that need very high starting torque, as does a swing bridge, slow motion and the ability to brake. And, like movable bridges there are applications that require arduous duty. The other aspect favoring hydraulics was that the bridge site is close to the many shipyards in the Norfolk, Virginia area where there is considerable expertise available in servicing hydraulic machinery.

Each swing span was designed with four hydraulic drive motors (Figure 3) although they were sized to operate on three motors and could operate without problems on two drive motors. Each drive can be removed and interchanged and a spare drive unit has been provided for future maintenance. As shown in Figure 3, the mounting bolt circle is eccentric to allow adjustment of the pinion teeth backlash.

There are two fully redundant pumps provided to drive each swing span, with a spare pump available for maintenance. And while the bridge is operated remotely from the control house, local push-button control is provided at the hydraulic power unit and is available for both maintenance and emergency use. In addition if this local control system should fail, the proportional value can be operated manually so that provided there is power for the pump, the span can be swung.

The tubing and fittings are all Type 316 stainless steel to guard against corrosion. A vegetable based hydraulic fluid, Mobil EAL 224 H, is used for the hydraulic machinery so that if a spill or leak should occur there is no danger to the marine environment. However, as this oil will break down over time, Mobil does recommend that it be replaced yearly.

The pivot bearing (Figure 4) and balance wheels (Figure 5) are similar to those used on other center pivot bearing bridges, although the size of the pivot bearing, 60 inch diameter, is certainly larger than usually found on a swing span. Also, the live load wedges at each pivot pier are typical of those found at swing spans (Figure 6).

There are lock bars and a movable grating section at each swing span joint. These are shown in Figure 7. The lock bars are ASTM A668 Class G forged alloy steel and each bar weighs 14 tons, as they need to be designed for the live load of three lanes of traffic on each side of the median.

The roadway joint section (Figure 8) was also taken from the original design, although its size had to be adjusted for the larger gap at each swing span associated with the wider span. The movable joint and lock bars are driven by the same reducer and thus their motion is linked. Redundant motors are provided, so that if one fails the second motor is available.

The bridge controls use parallel PLCs; if one fails the other is available. In addition, if both PLCs fail the bridge can be operated from the motor control centers and if all the controls fail or if the links between the controls fail, local push buttons are available at each motor or hydraulic drive.

The piers are linked together and to land with fiber optic cable so that in the future, additional features can be added. Due to the exposed position of the bridge and need to protect the electronic equipment from lightning, lightning arrestors and surge protectors are provided.

As mentioned above, the controls and power were installed and tested prior to the float-in. At the same time, all power and fiber optic cables were installed and tested in the piers prior to the float-in. This meant that as soon as the new spans were set, the electrical subcontractor, Dorey Electric, could begin to complete the connections. This had a rather spectacular result as spans were lit up, including all the roadway lights, within hours of being installed.

In general, the operation of the new spans has been a noticeable improvement over the original bridge. The PLCs have cut several minutes off the time of operation as there is no longer a need to actuate each operation. In addition the hydraulic drive has proven to be very smooth.

Much credit for the timely accomplishment of this project must go to the contractor, Tidewater Construction Company and owner, the Virginia Department of Transportation all of whom expended considerable effort to make this a successful project. At the start of the construction, the Department invited the project participants to a partnering session that proved to be an important step in setting the tone of the project. In particular the restoration of traffic in 9 days with an operational swing span approximately 2 weeks later was a very significant accomplishment.

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Figure 1

# Coleman Bridge General Plan and Elevation

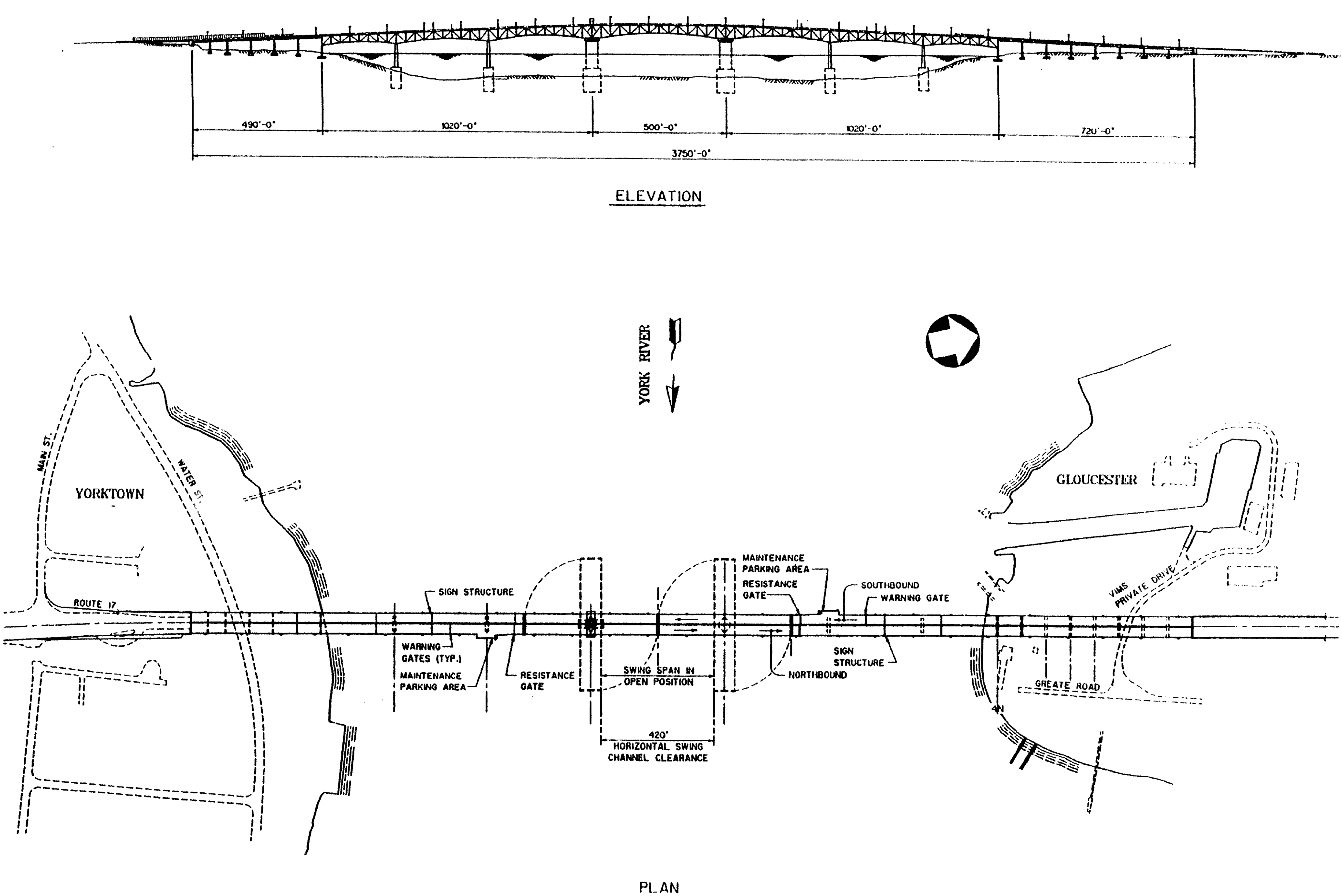


Figure 2
# Roadway Camparison

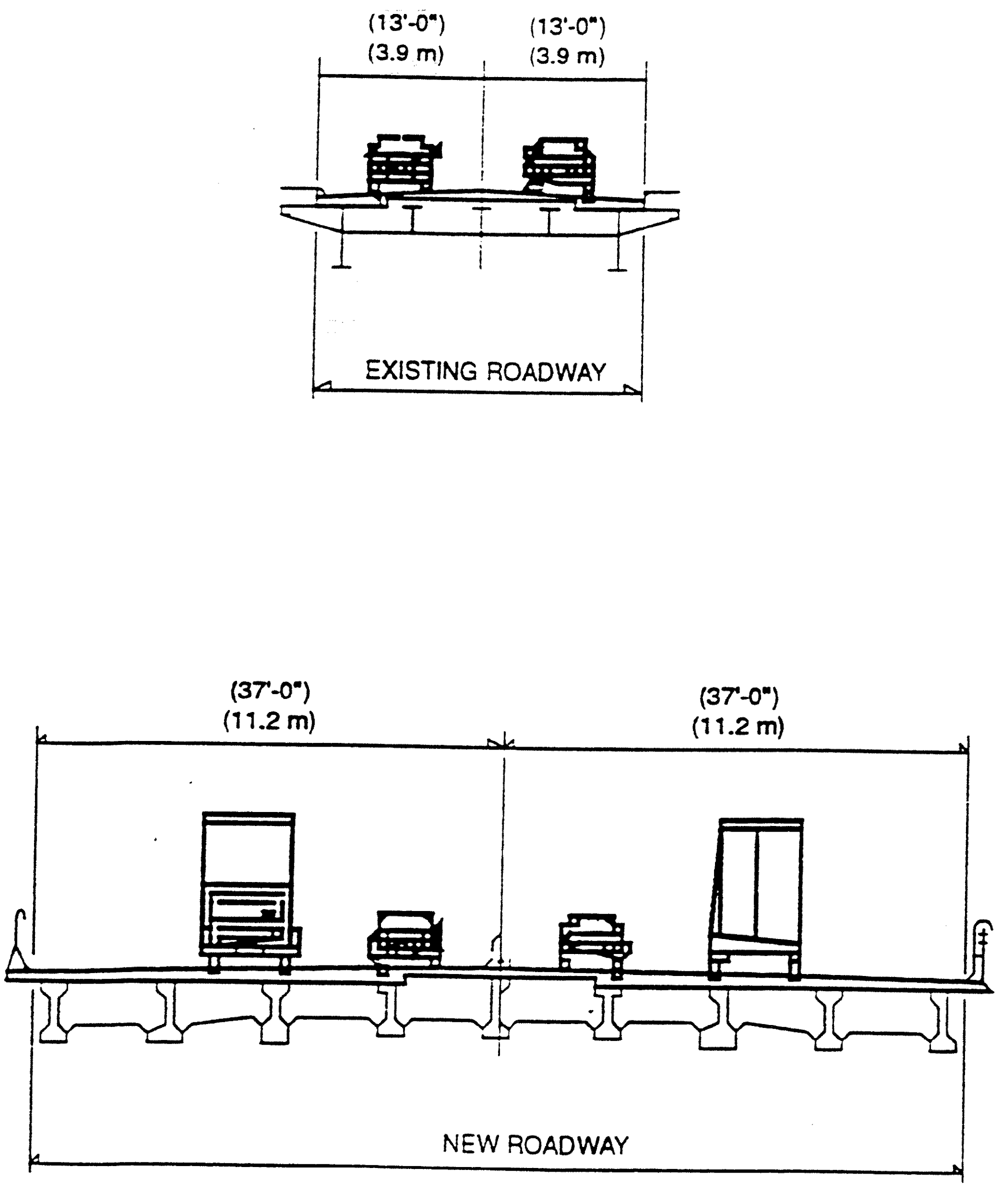
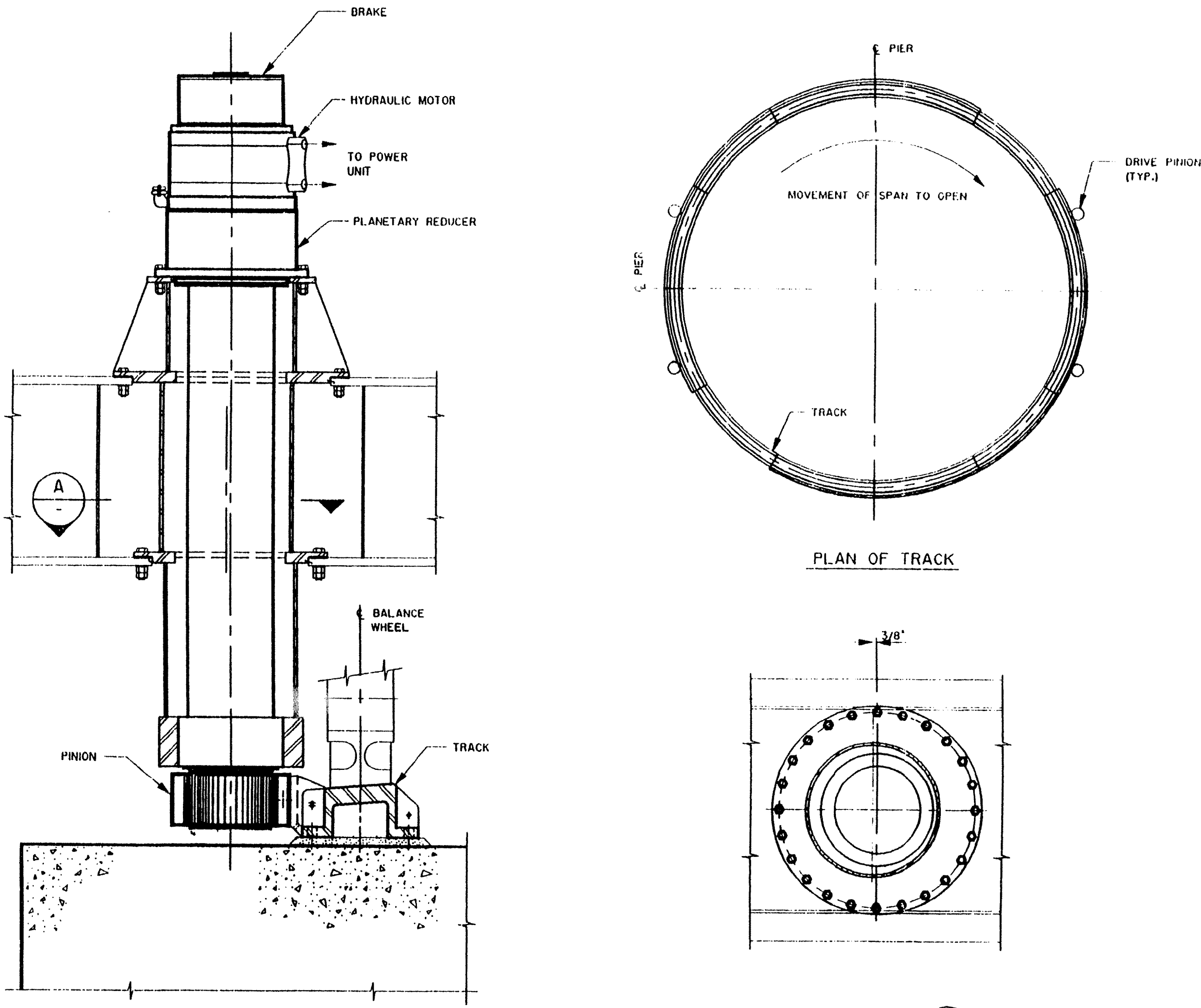


**Figure 3**

# Coleman Bridge Hydraulic Motor and Pinions



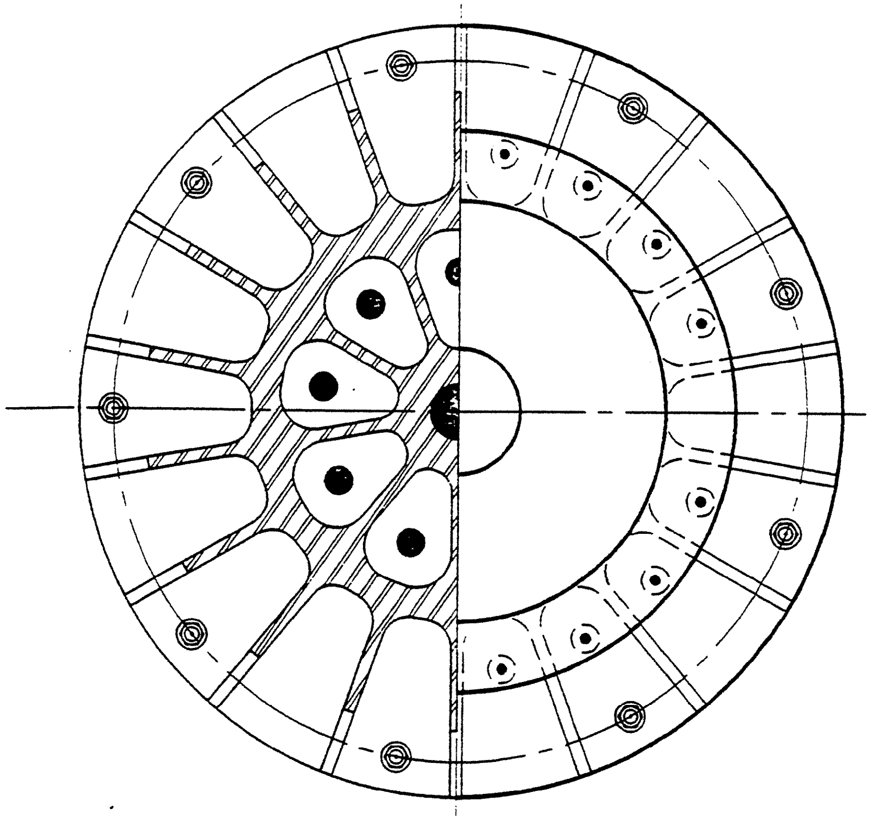

HYDRAULIC MOTOR - ELEVATION

PLAN OF TRACK

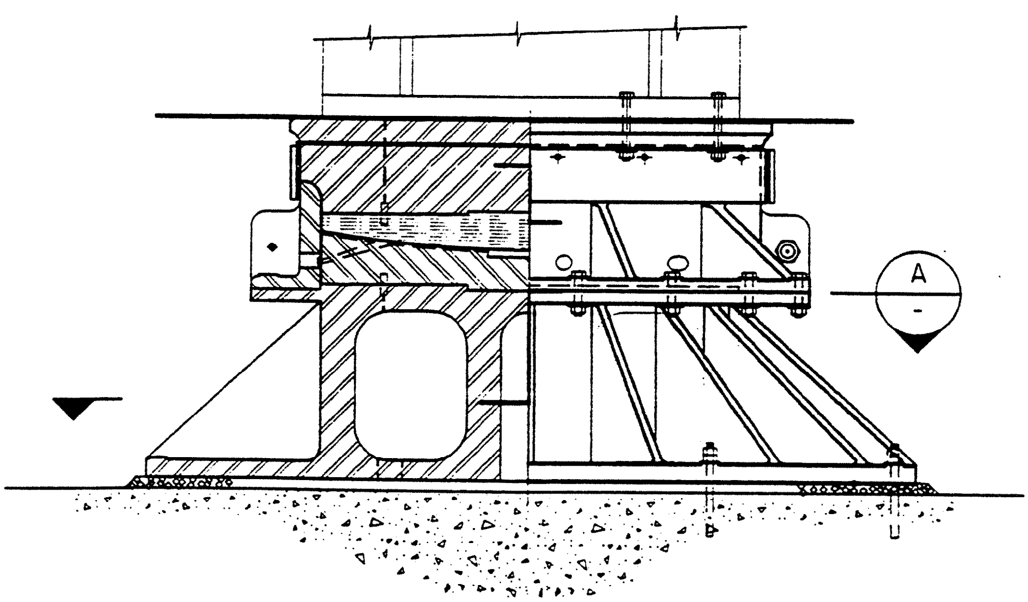
SECTION A
SCALE: 1" = 1'-0"

Figure 4

# Coleman Bridge Pivot Bearing




SECTION A/-




PIVOT ELEVATION

Figure 5

## Coleman Bridge Balance Wheels

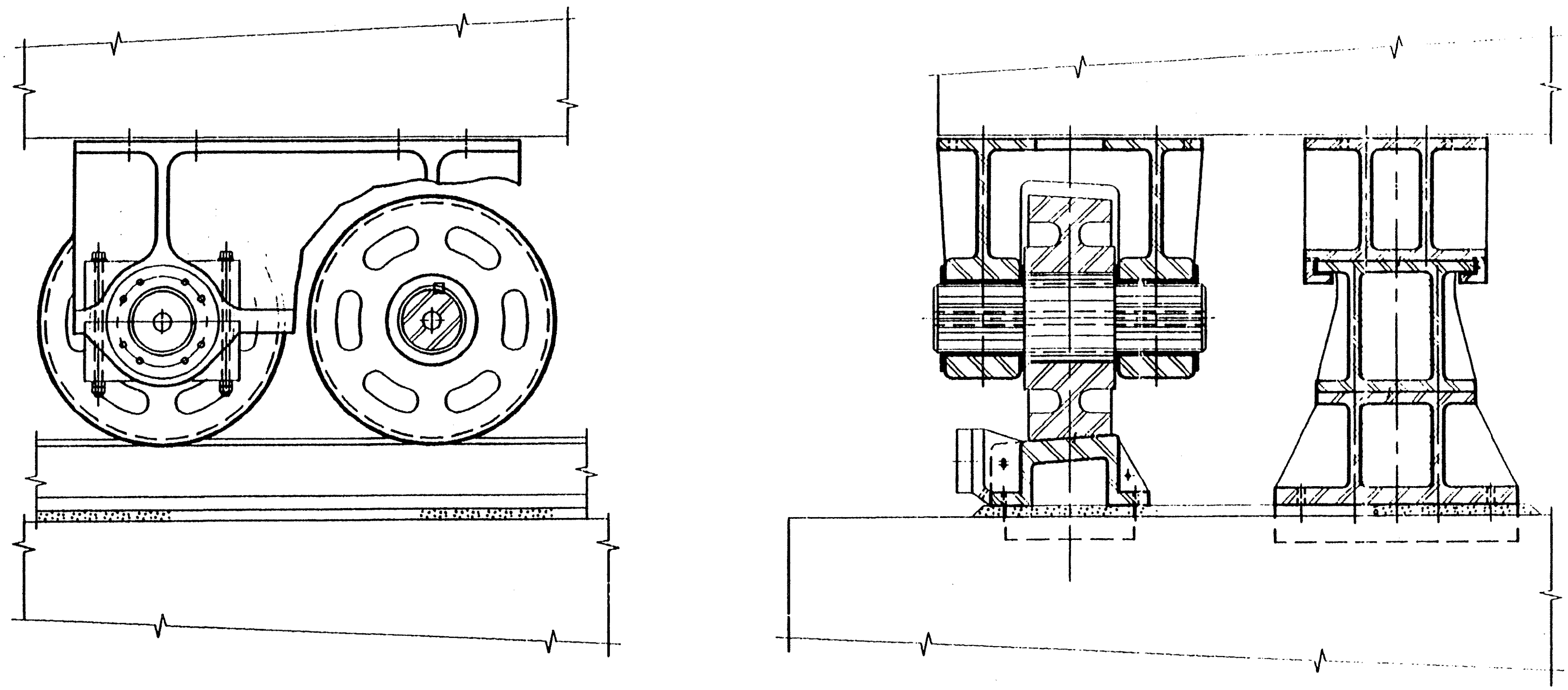


Figure 6
## Coleman Bridge Live Load Wedges

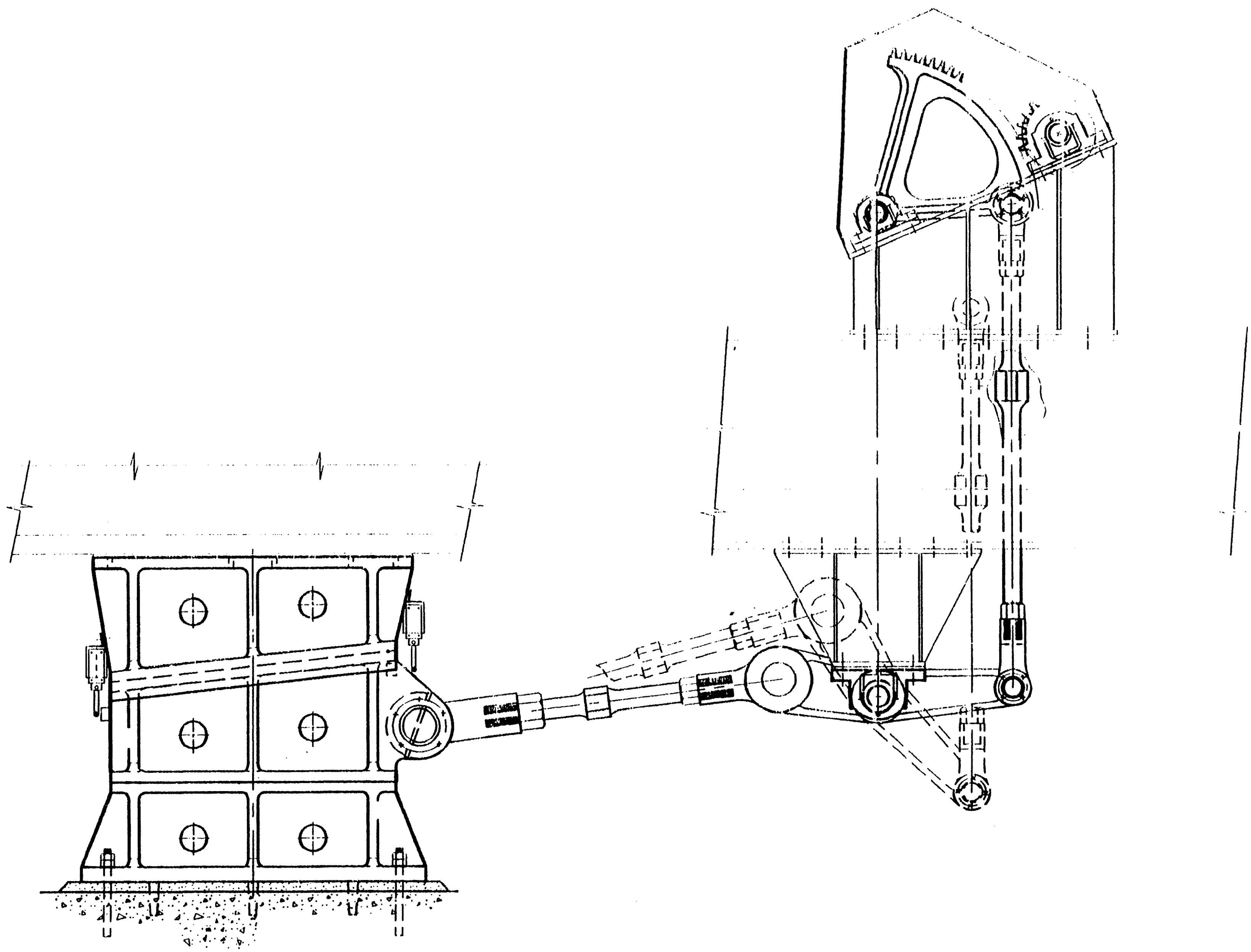


Figure 7

# Coleman Bridge Lock Bar

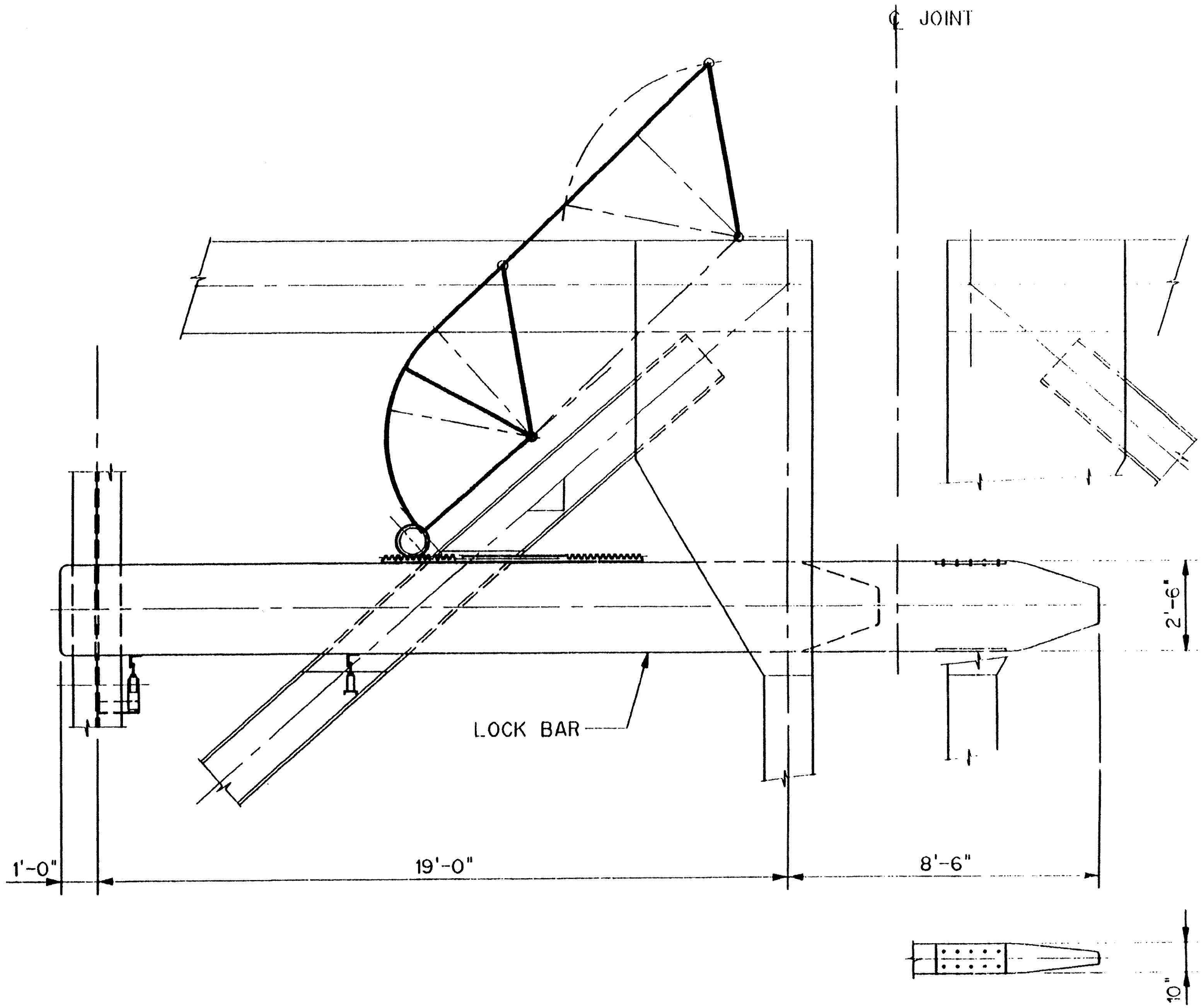


Figure 8

# Coleman Bridge Movable Roadway Joint