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3.3 Vertical Lift Bridges

3.3.1 Introduction

The movable span of a vertical lift bridge is raised in order to provide clearance for the passage of vessels. The lift span is usually balanced (nominally) by counterweights connected to wire ropes that pass over sheaves at the piers of the movable span. The sheaves are usually located atop towers but they may be located inside the piers. The purpose of the counterweights is to minimize the force required to move the span. This type of bridge is known as a balanced vertical lift. Vertical lift bridges are categorized by the arrangement of the span drive machinery. Figure 3.3.1-1 shows simplified diagrams of some sub-types of balanced vertical lift bridges: the span drive, the tower drive, the connected tower drive, and the pit drive.

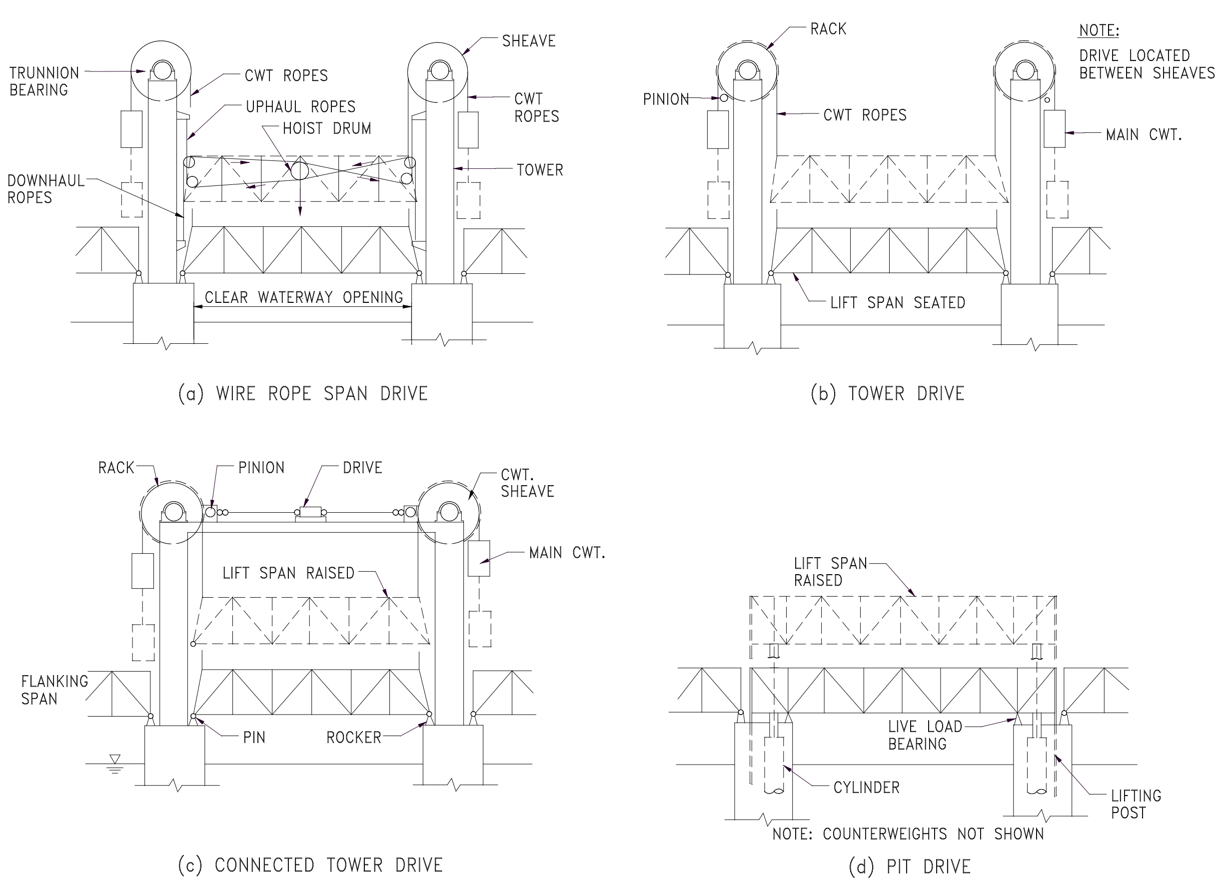

Figure 3.3.1-1: Types of Vertical Lift Bridges.

3.3.2 Span Drive Vertical Lift

The span drive vertical lift bridge is almost always a balanced vertical lift. The ends of the lift span are connected to wire ropes that pass over sheaves at the tops of the towers. The main counterweights are connected to the other ends of the wire ropes. These counterweights balance (or nearly so) the weight of the lift span. For large lift bridges with high lifts the weight of the counterweight ropes is so large that the ropes themselves are usually counterweighted by an auxiliary system in order to minimize power requirements for operation. The auxiliary counterweight systems are not shown in the figures of this section, for clarity.

3.3.2.1 Wire Rope Span Drive

As shown in Figure 3.3.1-1 (a), the feature defining a span drive bridge is the wire rope drive mounted on the lift span that hauls the span upward or downward. The directions of rope travel shown in the diagram are for the lift span being lowered. An advantage of this type of mechanical drive is that only negligible skewing of the span in the longitudinal direction can occur if the haul rope lengths are properly adjusted. As used here, the word skew refers to the difference in elevation between the two ends of the lift span (for a particular vertical position of the span). In the figure the hoist drum is located at midspan, but span drive bridges exist for which the primary drive machinery is at midspan and the secondary machinery and hoist drums are located at the ends of the span.

3.3.2.2 Rack and Pinion Span Drive

Instead of using haul ropes to raise and lower the balanced lift span, bridges have been built with a rack and pinion drive (not shown in Figure 3.3.1-1). They are balanced lift bridges. The primary machinery is located at the middle of the span and secondary machinery (terminating with pinions) is located at each end. The pinions engage racks mounted vertically on the towers and rotation of the pinions raises or lowers the span. This type of drive prevents significant longitudinal skewing of the lift span.

3.3.3 Tower Drive Vertical Lift

Tower drive vertical lift bridges, as in Figure 3.3.1-1 (b), are usually balanced bridges with the span drive machinery located at the towers, either atop the towers or below the roadway level, but above high water level. There are two basic types; the traction drive and the winch drive. The distinguishing feature of tower drive vertical lifts is that the machinery in one tower is mechanically independent of that in the other tower. Hence, non-uniform raising of the span end-to-end has to be limited, and compensated, by the motor controls.

3.3.3.1 Wire Rope Traction Drive

Figure 3.3.1-1 (b) is a diagram of a tower drive vertical lift bridge with a traction drive. There is drive machinery in each tower that rotates the counterweight sheaves. The forces necessary to raise the span are transmitted from the sheaves to the counterweight ropes by friction. The action is similar to that of a traction drive passenger elevator in a building. Both ends of the lift span should raise and lower at the same rate so that the lift span remains horizontal and does not wedge itself between the towers during motion. There are various electrical/electronic means of controlling the drives in the two towers so that the skew is kept within permissible limits. It should be noted that the force necessary to raise the lift span at each end may differ due to unequal machinery friction, unequal ice loading, etc.

3.3.3.2 Winch Drive

Tower drive lift bridges have been built with winch drives located atop the tower or, more commonly, in the tower base. The lift spans are balanced in the usual fashion but raised and lowered by wire rope winches. The haul ropes are connected to either the lift span framing or to the counterweights. Because the mechanical machinery on one side of the channel is independent of that on the other side, skewing has to be controlled.

Winch drives with the machinery located below roadway level are considered suitable for lift bridges with four independent counterweights.

3.3.4 Connected Tower Drive

A connected tower drive vertical lift bridge is shown in Figure 3.3.1-1 (c). Longitudinal and lateral framing connects the tops of the towers and serves as support for machinery and access walkways. The lift span is balanced by counterweights. However, because this type of lift bridge is most suitable for short spans of low to moderate lift, the counterweight ropes are usually not balanced by auxiliary counterweight systems. The span drive machinery is mounted on the structure connecting the towers. Primary machinery is located in a machine room at midspan from which line shafts extend to speed reducers at the towers, midway between the counterweight sheaves. From the reducers, shafts extend to pinions that engage curved racks fastened to the counterweight sheaves. The force necessary to move or hold the lift span is transmitted between the sheaves and the counterweight ropes by friction.

Because all the span drive machinery is directly connected (normally without any torque equalizers in the system) no major skewing of the lift span in either the longitudinal or transverse direction occurs. However, minor skewing due to differential counterweight rope stretch, different sheave diameters, and rope slip in the counterweight sheave grooves can cause skewing over time. The mechanical system is usually designed with features to permit angular adjustments in order to compensate for these effects. The bridge carrying East Wisconsin Avenue over the U.S. Canal in Kaukauna is a connected tower lift bridge.

3.3.5 Pit Drive Vertical Lift

3.3.5.1 Balanced Pit Drive Vertical Lift

Balanced vertical lift spans are raised and lowered by machinery located within pits that are located inside the rest piers. The pits extend downward below the high water level in the channel. The design objective is, of course, to avoid the need for towers above the roadway. This is accomplished by fastening downward extending legs (lifting posts) to the ends of the lift span as shown in Figure 3.3.1-1 (d). The lifting posts guide the movable span during motion and resist horizontal forces applied to the span when it is not seated on its bearings. One or two lifting posts may be provided at each end of the span, depending on the roadway width. Counterweight ropes (not shown in Figure 3.3.1-1 (d)) are fastened to the lower ends of these lifting posts and looped over sheaves located above and connected to the counterweight. This type of vertical lift bridge is suitable for low lift heights - say less than 40 feet.

The lift span may be raised or lowered by mechanical machinery or hydraulic cylinders. Mechanical drives are usually located in one of the two pits. Pinions engage racks mounted on the lifting posts to move the span. Because the pinions are mounted on the same shaft, the vertical motion is automatically equalized side-to-side. Equalization of vertical motion, end-to-end of the span, is accomplished by a wire rope/tension rope equalizing system.

In hydraulic cylinder drives the span is usually moved by one or two cylinders in each pit. Equalization of piston travel is accomplished either by controlling fluid flow to the individual cylinders, based on measurement of the longitudinal and transverse slope of the lift span, or by tying the cylinders together with hydraulic lines to assure equal pressure is applied to all cylinders, supplemented by mechanical equalization. Mechanical equalization may be accomplished using rotary machinery or wire rope equalizing. An example of a balanced pit drive vertical lift bridge with hydraulic cylinders and a wire rope equalizing system is the Michigan Street Bridge over the Milwaukee River in the City of Milwaukee. See Figure 3.3.5.1-1.

Figure 3.3.5.1-1: Balanced Pit Drive Vertical Lift, Michigan Street Bridge in Milwaukee.

The Wisconsin Avenue Bridge, rehabilitated in 2012, uses internal equalization by means of sensors within the hydraulic system. There is no outside mechanical equalization system such as wire rope equalizing. Prior to the rehabilitation the Wisconsin Avenue Bridge, the structure was raised by means of one hydraulic cylinder in each pier and equalized by means of a wire rope system. Refer to Figures 3.3.5.1-2 and 3 for elevation views of the old and current lifting mechanisms.

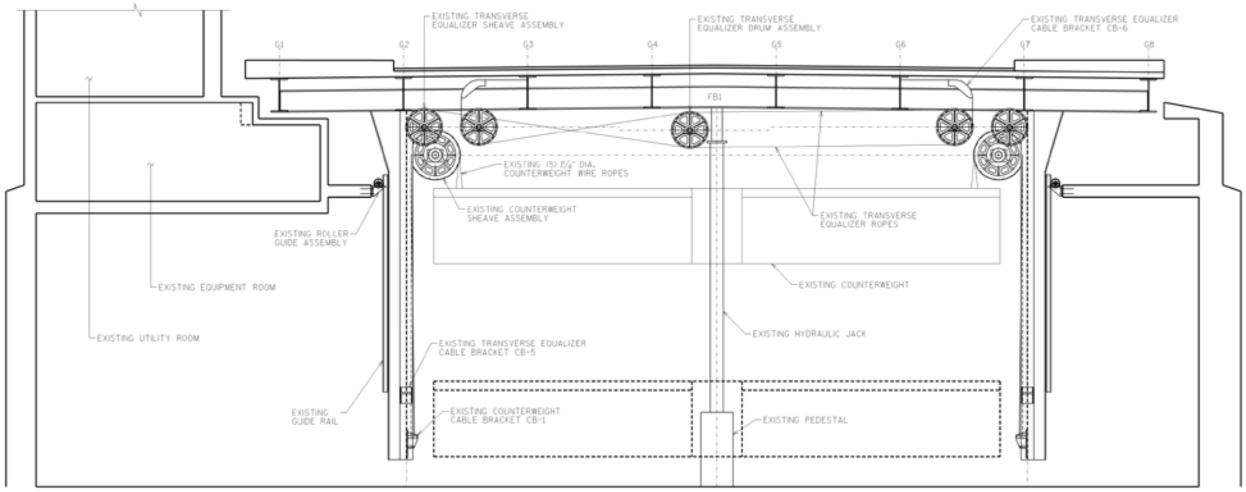

Figure 3.3.5.1-2: Elevation view of previous Wisconsin Avenue Bridge lifting and equalizing components. Note only single hydraulic piston used to lift superstructure.

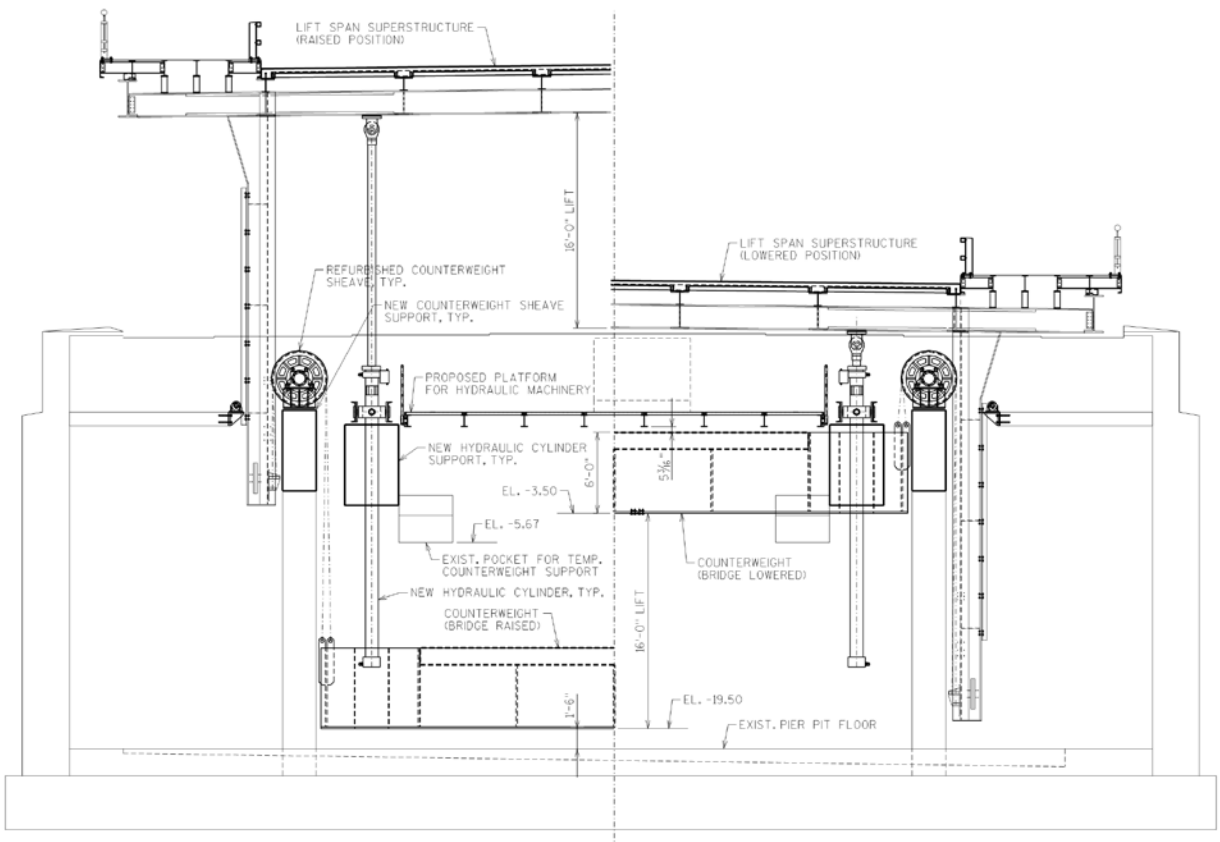

Figure 3.3.5.1- 3: Elevation view of rehabbed Wisconsin Avenue Bridge lifting components. Note two hydraulic pistons used to lift superstructure and absence of equalizing cables.

3.3.5.2 Unbalanced Pit Drive Vertical Lift

Unbalanced vertical lift bridges are constructed when the cost of the greater lifting capacity required (compared to a balanced bridge) is estimated to be less than the cost of counterweights or for reasons of aesthetics. Hydraulic cylinder drives are most suitable for unbalanced lift bridges because large actuating forces can be produced using smaller electric motors than in a mechanical drive. There is less friction between the prime mover and the point of force application in the hydraulic system.

The Highland Avenue Lift Bridge in Milwaukee is an example of an unbalanced pit drive vertical lift bridge. For this structure, there are two hydraulic cylinders in each of the two pier pits which support the full weight of the span when it is lifted up off its supports. As the span is not balanced by a counterweight, a sudden loss of hydraulic pressure when the span is in a raised position could cause the span to drop. As a safety precaution two spring-loaded rail clamps are provided at each lifting post. The design concept is that they clamp onto rails mounted on the lifting posts and thereby retard motion if the span should descend uncontrolled or at an excessive skew.

The Highland Avenue Bridge, in the city of Milwaukee is an unbalanced pit drive vertical lift pedestrian bridge. The bridge is designed to accommodate either a full pedestrian live load or a single H10-44 live load (an emergency vehicle). It should be noted that a vehicle can only approach the span from the east end since steps and a guardrail and sidewalk are on the west end. Refer to Figure 3.3.5.2-2 for a photograph of the Highland Avenue Bridge.

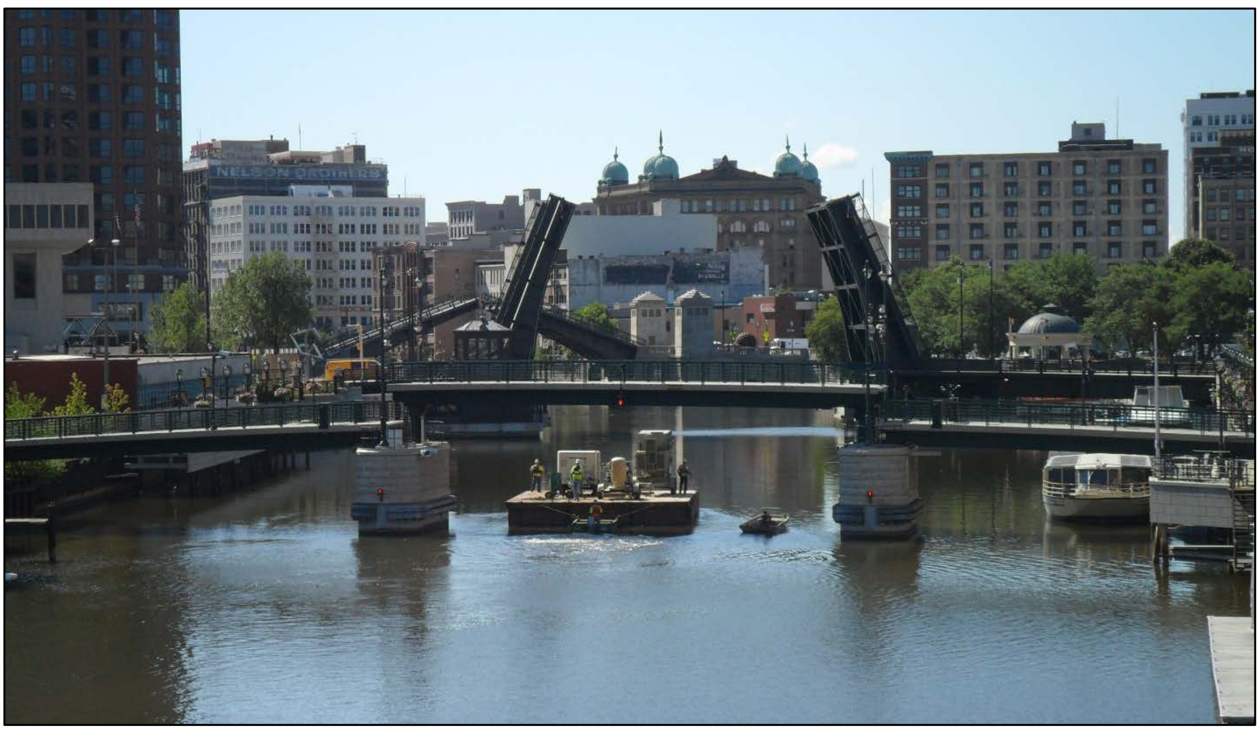

Figure 3.3.5.2-1: Unbalanced Pit Drive Vertical Lift, Highland Avenue Pedestrian Bridge in Milwaukee.