Raising the Bar on Bridge Jacking

By Matthew G. Yerkey, E.I.T

Structural engineers are involved in many aspects of bridge construction including jacking (or structural lifting operations as it is commonly specified). In general, each state DOT has its own structural lifting operation specification. When acting on an owner's behalf, engineers may specify the jacking, or at times, acting on the contractor's behalf, they develop the plans and details for the contractor to implement.

There are several reasons why existing bridge structures may require jacking and or shoring, including:

- Strengthening existing bridge members, such as adding a cover plate.
- Replacing a deteriorated member or an existing bearing.
- Replacing a damaged or failed member.
- Structure erection (e.g., to maintain the superstructure in the "no-load" position).

Some spans can be jacked quite easily, and in some cases their original design accounts for this. One example of this is a steel multi-girder bridge that has extra heavy end diaphragms to jack from. Other stubborn spans are reluctant to be jacked and require a more elaborate design and procedure.

Know the Loads

Quite often shoring loads are provided in the contract documents. Many questions must be answered regarding these loads, such as:

- Are these loads factored or unfactored?
- Were new asphalt-wearing surfaces included?
- Were existing or new utilities included?
- Was live-load impact considered?

In other words, these shoring loads should be taken with a grain of salt. They could be used as a starting point or for bidding purposes, but they should be verified or even recalculated by the shoring designer.

In general, there are two load cases to commonly consider:

1. The loads that occur during actual jacking;
2. The loads that occur when the bridge is in the shored position.

Global photo of structural lifting operations of Dam 6 at Lock E10 on the Erie Canal; Town of Florida, NY

Steel towers for structural lifting operations of Dam 6 at Lock E10 on the Erie Canal; Town of Florida, NY

During jacking, vehicular live loads are normally not permitted on the bridge whereas in the shored position they may be. For the case when vehicular live load is not on the shored bridge, the two load cases are essentially the same.

The engineer should also be familiar with the contractor's intended work sequence. A crane or a stockpile of temporary concrete barriers located on the shored structure can easily consume factors of safety if those loads are not accounted for in the jacking and shoring design.

Consider Existing Utilities and Geometry

It is important to make note of existing utilities. Depending on their connection to the existing structure, they may need to be temporarily moved or disconnected if they are not capable of resisting differential movement. As an example, consider a multiple-span bridge with a continuous gas line supported by each span. If jacking one span at a pier while its sister span remains fixed, differential movement of the gas line could perhaps cause a pipe joint to fail.

The engineer should verify existing geometry since skews, curved girders, and cross slopes can prevent the jacking system from being installed properly, which in turn could lead to eccentric loads or second order stresses.

Check Stability

Who needs to worry about stability? It's only in the raised position for a day, right? Wrong! Stability is one of the most important aspects of structural lifting. Often times, the jacking procedure can be used to limit instability, such as only lifting one end of a girder at a time or

Structural lifting of multi-girder bridge at the abutment; Cobleskill, NY. Photo courtesy of D.A. Collins Construction Company, Inc.

only lifting half of the girders of any particular span. Blocking of an expansion bearing may be needed if the fixed end of the superstructure is to be raised.

Evaluate the Existing Structure

The means of shoring may cause existing truss members to undergo stress reversals or may cause excessively high shear and flexural stresses in an end diaphragm. The existing bridge members must be checked for the loading condition it will experience in the jacked and shored positions. Although each state DOT has their finer nuances, the bridge members are generally checked in accordance with AASHTO's *Manual for Condition Evaluation of Bridges*. In general, the proposed jacking and shoring system should not be placed at locations where the existing members are deteriorated.

Develop Temporary Foundations

Perhaps the biggest misconception is that since the proposed jacking and shoring system is temporary, one can afford to skimp on the foundation. The most robustly designed shoring towers or heavily braced shoring posts are moot without an adequate foundation to support the intended loads. Imagine jacking the existing structure a quarter of an inch to do bearing rehabilitation, only to find that the soil beneath the temporary foundation has settled that same quarter of an inch. What has the contractor accomplished?

Sometimes the "foundation" can be the top of the existing bridge seat. Other times it may consist of installing crane mats or cribbing on a partially excavated section of the slope protection of an existing abutment. Often times this requires hand digging; however, this is commonly rewarded by being able to use the existing abutment or pier footing toe to aid in the transfer of load into the surrounding soil. Typically material used has to be dragged up the abutment slope by hand because of poor access. Scrap box-beam guide rail, of which contractors seem to have stashes, can often be substituted for the standard 12 x 12 crane-mat timber at about half the weight. One should look closely at the soil bearing pressures under the temporary foundations since often times the soil out in front of an abutment or pier is not compacted "select structure fill", but rather non-compacted "embankment in place." In addition, global stability of the abutment slope needs to be considered.

Prepare Drawings

The proposed shoring design needs to be conveyed to the workers in the field. After all they are the ones performing the work. Standard drawing practices apply with the addition of a jacking table (see *Table 1* for an illustrative example) and a detailed structural lifting operations procedure.

Examples

Most jacks typically work on the principals of hydraulics. On one project, this was taken to the extreme when a series of Flexi-floats™ (with shoring towers already attached) were intentionally filled with water to nearly sink them. The floats were subsequently positioned at specified locations underneath an existing bridge. The water was pumped out of the Flexi-floats and Archimedes took it from there!

Erection of tied-arch bridge in Schoharie, NY. Photo courtesy of D.A. Collins Construction Company, Inc.

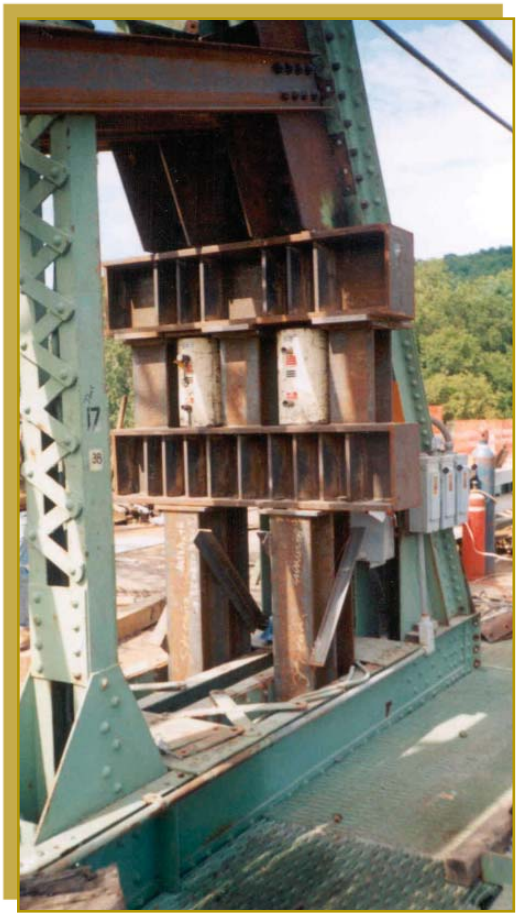
Another unique jacking-type project required the shoring of an existing truss so as to replace portions of the multi-ply bottom chord. Rather than installing 50-foot-long shoring posts into the river bottom, which would have been daunting at best, the bottom chord was post-tensioned to relieve the load while the ply replacements were completed.

In summary, raising awareness of jacking and shoring issues with contractors, owners, and engineers before a project begins will reduce difficulties and setbacks during the project. In turn, at the end of the successful project, the spirits of the parties involved will undoubtedly be lifted.▪

	North Span	South Span
Jacking Load	510 kis	180 kis
Jack Type	Model XXX (300-ton)	Model YYY (100-ton)
Effective Cylinder Area	50.26 square inches	20.57 square inches
Jacking Pressure	10,150 psi	8,750 psi
Maximum Allowable Pressure	11,938 psi	10,000 psi
Outside Diameter	10 inches	6.5 inches
Stroke	2 inches	1.97 inches

Table 1: Jacking Table

Matthew G. Yerkey is a Design Engineer with Ryan-Biggs Associates, P.C., in Troy, N.Y. He has been involved in many types of bridge jacking and shoring projects.



Auxiliary truss member, transfer beam, and jacks for structural lifting operations of Dam 6 at Lock E10 on the Erie Canal; Town of Florida, NY