ALTERNATE METHODS OF BRIDGE DEAD LOAD SUPPORT FOR CONSTRUCTION

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ABSTRACT

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In the course of railroad bridge repair and reconstruction, it is often necessary to temporarily support the bridge structure while components of the structure are removed and replaced. While supporting the bridge structure from temporary bents, shoring towers, and existing substructures are effective methods of temporary support, situations often arise where site conditions and access needs render these traditional methods unfeasible or exceedingly expensive. This paper explores three alternate methods to temporarily supporting bridges when traditional methods are not feasible for construction, access, or budgetary reasons.

A quick review of traditional techniques of temporary bridge support will be followed by a discussion of three alternate methods. The advantages and disadvantages of each alternate method will be discussed, along with a discussion of track outage requirements for each alternate method. The alternate support methods described are typically more structurally complex than tradition methods so the engineering aspects of design, inspection, and construction will be introduced.

Field application examples will be presented for the shoring methods discussed, including moment resisting brackets, cantilever beams, cantilever trusses, and integrated frames. The examples will briefly cover the conditions that drove the selection of a method, the design of the temporary support, the installation of the temporary support, and the operation of the support.
INTRODUCTION

During the course of conducting repairs on the bearing area or substructure of a railroad bridge the need often arises to temporarily support the superstructure. There are several traditional methods that a bridge crew can use to temporarily support a bridge. However, in some instances these traditional methods are not feasible for reasons including site conditions, access limitations to the work area, and budgetary restraints. In these instances an alternate method of temporary bridge support may need to be employed to conduct the needed repair.

This paper will provide a general introduction into three alternate methods of temporary support for construction. The basic engineering aspects of temporary support design will be introduced after a brief review of the traditional methods of temporary structure support. This will be followed by a discussion of the three alternate methods covered in this paper: integrated frames, moment resisting brackets, and cantilever beams. Each alternate method will be introduced along with one or two examples of the field application of the method.

TRADITIONAL TEMPORARY SUPPORT METHODS

Bridge repair crews have long employed a group of tradition methods for supporting a structure temporarily for construction, examples of which are shown in Figure 1. When an engineer or manager is involved in a project requiring temporary bridge support, these traditional methods should be investigated first. An alternate method should only be pursued after all traditional methods have been eliminated.
These traditional methods are effective in a majority of cases, and are preferred because they are proven to be simple, effective, and safe. Unfortunately, situations arise when these methods cannot easily be utilized as shown in Figure 2. When these situations arise an alternate approach to providing temporary structure support will need to be pursued.

ENGINEERING ASPECTS OF TEMPORARY SUPPORT DESIGN

The alternative temporary support systems can be structurally complex and in some cases failure of the system can be catastrophic. For this reason a stricter level of engineering oversight must be adhered to in comparison to tradition support methods. The design, installation, and operation of the temporary support systems discussed in this paper must be supervised by a licensed professional engineer familiar with railroad bridges and railroad bridge construction and repair. The following are some of the engineering aspects that the engineer in charge should take into consideration:

Codes

The current AREMA Manual of Railway Engineering should be used to design any temporary supports that are subject to railroad live load. For temporary support systems that will be supporting only dead load, the design engineer may decide to use the applicable AISC, ACI, or NDF codes at his discretion and with the approval of the railroad or overseeing agency.
**Loads**

In most cases these alternate methods are intended to support dead load only. In a limited number of cases, a design engineer may be able to utilize an alternate system for live load support, though extreme caution should be exercised in these cases.

Every effort should be made to model the dead load reactions as accurately as possible, taking into consideration the distribution of dead load, modifications to the span that may increase dead load, and an accurate estimation of the amount of ballast. The dead load contribution of ballast is often very significant. In the case of steel and timber bridges ballast typically represents a majority of the load, exceeding the weight of the supporting structure. Besides the magnitude of the ballast load, the frictional forces present in ballast decks should be taken into consideration, especially in those cases where the span to be jacked was adjacent to an abutment or a span that will not be jacked. Applying an additional factor of safety to account for the uncertainties that are inherent with jacking a structure is highly recommended.

**Capacity of Existing Structure**

Many of the alternative support systems discussed in this paper will exert atypical loads onto the existing structure as shown in Figure 3. The stresses resulting from these atypical loads can be quite high because the effected existing structural member is not designed for the atypical applied load. It is imperative that the design engineer check the capacity of the existing structure to resist the atypical loads along with jacking specific
loads applied to it. In many cases the capacity of the existing structure will limit the
capacity of the temporary support system.

**Monitoring Operation**

The engineer supervising the operation must be able to monitor the load being applied to
the temporary support system during the jacking operation. If synchronized hydraulic
jacks are used pressure gauges must be utilized so the load on the jacks can be monitored.
If the jacking system to be utilized cannot be fitted with pressure gauges then the
maximum rating for the jacks should not exceed the design capacity of the support
system or the capacity of the existing bridge to resist the jacking load. Prior to jacking
the bridge the engineer should calculate the gauge pressure that corresponds to design
jacking load and communicate to the crew that this pressure should not be exceeded. As
much as possible the engineer should communicate to the crew what components of the
support system and existing structure are critical. In the cases where the system cannot be
observed fully by one individual, the engineer should position competent individuals in
critical areas to observe operation.

**ALTERNATIVE METHODS OF TEMPORARY SUPPORT**

Three basic alternate methods are discussed in this paper; integrated frames, moment
resisting brackets, and cantilevered beams and trusses. Each alternative method has
particular advantages and disadvantages that make it more effective in some situations
and less effective in others. For instance, the simple and compact nature of the moment
resting bracket make it an excellent means of supporting a difficult to access tower leg of
an open deck tower bridge. However, the limited capacity of these brackets make them less effective at supporting long span ballast deck bridges, that would be better addressed by cantilever beam or integrated truss frame. Also, a temporary support system can utilize more than one alternate method of support to maximize the advantages of each system. The Tallahatchie River Bridge project discussed on Page 13 is an example of this, utilizing arguably all three methods in a single system.

**Integrated Frames**

Integrated frames are essentially a more complex version of the traditional shoring tower or bent. Integrated frames are primarily compression structures with some elements in bending that redirect the load of the structure out to a safe jacking point. Integrated frames are effective at providing access to a high capacity jacking point when the configuration of the superstructure does not provide a safe jacking point directly above the existing substructure.

A primary advantage of integrated frames is that they can be designed to be structurally robust systems and capable of resisting larger jacking loads. In many cases they can be configured to avoid atypical loading of the existing structure. For these reasons, they possibly can be used in live load applications if properly designed.

The primary disadvantage of integrated frames is their geometric complexity, which limits the ease of their application. The designer has to take into careful consideration how the frame will fit in and around the existing structure and design the frame so that it
does not interfere with the bridge during the jacking process. It is also important that the designer avoids placing components of the frame in the way of the repair work to be performed. Since each frame is complex and utterly unique to its particular application, a practical engineer should explore every available traditional and alternative method prior utilizing an integrated frame.

The track time requirements for the installation and operation of an integrated frame would vary depending on the configuration of the bridge and frame. As a rule the designer would need to avoid having any section of the integrated frame foul the track so track time is not consumed with assembly and disassembly of the integrated frame. Components of the frame are heavy enough that installation and removal of the frame will require a track outage for access to the bridge by on-rail handling equipment if site conditions prevent off-rail access. Operation of the frame would require a track outage to conduct the repairs unless the frame was designed as a live load structure.

*Integrated Frame Example Project:*

*Salmon Falls Bridge*

This project involved replacing the expansion bearings on a deck truss bridge that contained wrought iron lattice truss planes dating back to the 1887 (Photo 1). There was room on the existing bearing seat to place jacks directly under the trusses, unfortunately structural checks revealed that the lower chord of the trusses did not have sufficient capacity to resist the required jacking load of up to 200 kips. To support the structure safely and avoid damage the wrought iron components of the bridge, jacking brackets
were attached to the end post of the trusses in such a manner to avoid applying any atypical loading to the post (compression only). Beneath the jacking brackets an integrated frame of continuous beams and braced columns was used to direct the load to bearing area of the pier as shown in Figure 4. The integrated frame was configured to support three 121’ ballast desk truss planes simultaneously, and was designed to resist an estimated total jacking load of 380 kips plus an additional safety factor of 1.4. In the case of this structure the design load of ballast and the frictional forces within ballast were underestimated and nearly all of the 40% additional capacity was utilized in order to raise the bridge.

**Moment Resisting Brackets**

Moment resisting brackets can be utilized to provide a safe jacking point just outside the bearing area of the structure to be supported. As the name implies, this alternative method of support utilizes a moment resisting bolted connection to resist the eccentricity of the jacking load.

The primary advantage of moment resisting brackets is that they are typically compact and easy to install. They can provide a jacking point just outside the bearing area and can be used to move the jacking point away from the work area to allow for improved access.

The primary disadvantage of moment resisting brackets is that they are limited by the capacity of the bolted connection that secures the bracket to the existing structure. These connections become large and impractical as the eccentricity of the jacking load
increases. For this reason moment resisting brackets can typically provide only 2-3’ of offset for the jacks.

The track time requirements for the installation and removal of moment resisting brackets can be relatively small because of the compact nature of most moment resisting brackets. The compact size of the brackets allows the designer to locate the bracket so that it does not foul the track. Some brackets are small enough to be handled without the use of cranes, allowing them to be installed and removed by hand, or with the use of lightweight chain hoists. Even those brackets that require handling equipment to install typically take less time to install because they consist of only one or two components that can be quickly placed, opposed to an integrated frame or cantilever beam that can contain several components requiring more time to place. However, because they are limited in load capacity and therefore impractical for live load support, a track outage is typically required while the bridge is supported by the bracket.

*Moment Resisting Bracket Example Project 1:*

*Pine River Bridge*

This project involved raising an open deck girder tower bridge and installing precast blocks under the bearings. Overall four towers supporting six spans of lengths varying from 46’ to 77’ needed to be jacked. The base of the existing towers did not provide a safe location to place a jack so a set of brackets was designed to provide safe jacking points (Photo 2). The simple and compact design of the moment resisting brackets
allowed the towers to be jacked simultaneously with a relatively small budget for temporary support material.

The brackets consisted of a W18x76 wide flange beam secured to the base of tower with a combined tension and shear connection. The brackets were designed to resist an applied jacking load of 48 kips with an additional safety factor of 1.5. The connection was designed using a method typically used to design a bolted seated beam connection. The capacity of the tower leg to resist the applied bending moment in the loaded axis was checked as well. The 168 ft-kip capacity of the connection allowed the jack to be placed approximately 28” from the centerline of the tower leg. This offset allowed the jacks to be placed on the tower leg pedestal just outside of the work area.

**Moment Resisting Bracket Example Project 2:**

**Saco River Bridge**

This project required the replacement of a large concrete riser with a series of steel bolsters on a 66’ ballast deck girder bridge. The bridge spanned a deep, rapidly flowing river that made the use of a shoring tower or bent impractical. The only direct jacking point was located on the concrete riser that was to be removed.

With the traditional temporary support methods eliminated an alternate method of two moment resisting brackets secured to adjacent girders was utilized to provide a safe jacking point above the work area as shown in Figure 5. Each bracket consisted of a pair of MC18x58 channels secured to the girders with a shear type moment resisting
connection. The brackets were designed for a jacking load of 56 kips plus an additional safety factor of 1.4. The moment resisting connection was designed for a maximum moment of 520 kip-in, allowing for an eccentricity of 6⅞”. The torsion loads resulting from the loading of the channels were addressed with a tie plate placed under the jacks so that the bolted connection was not subjected to a tension load. This simple alternate support system relocated the jacks from the work area and safely supported the 66’ span while the concrete riser was removed as shown in Photo 3.

**Cantilever Beam**

A cantilever beam method provides a jacking point outside of the bearing area of a bridge utilizing a beam is placed with a cantilever off the end of the bridge as shown in Figures 3 & 6. The jack is placed under the cantilevered end of the beam and the load is transferred into the bridge by the upward reaction within the span of the cantilevered beam. At the opposite end of the cantilever beam a downward reaction is directed into existing structure to provide the moment couple required to maintain the stability of the cantilever. This method is very effective at lifting through type bridges where the beam can be secured to the main structure outside the clearance envelope or where floorbeams can be utilized to provide anchor points.

The primary advantage of the cantilever beam method is that, like moment resisting brackets, they can provide a jacking point outside of the work area. Unlike moment resisting brackets they are not limited by a bolted moment resisting connection, so they are capable of supporting much larger loads and greater eccentricities. Very large beams,
even trusses, can be utilized for cantilever beams and the tension connections to the existing bridge can be sized to take very large loads. This allows the jacks to be placed farther away from the work area and heavier structures such as long span ballast deck bridges to be supported.

The greatest disadvantage of cantilever beams is the amplification of the jacking load that occurs as a result of the cantilever configuration (See Figure 3). The effect of this load amplification on the existing bridge is often very significant and in many cases the capacity of the existing bridge to resist this load amplification will be the limiting factor in the design capacity of the system. To gain higher capacities the existing bridge would need to be reinforced, which is expensive and impractical in most cases. For this reason it is typically not practical to design a cantilever beam system to support live load.

The track time requirements for the installation and operation are typically greater than the requirements for moment resisting brackets. On through type structures the cantilevered beams can be secured to the main structure of the bridge in an area outside the clearance envelope of the bridge (Photo 4). On deck structures it is more difficult to place the beams outside the clearance envelope and in the case of these structures some of the track outage dedicated to performing the repairs will be consumed by the installation and removal of components of the temporary support system. Unless the cantilever system is a very simple design, it may not be feasible to use a cantilever system on deck structures located on corridors with high traffic volumes and limited duration track outages. Components of cantilever beams are heavy enough that
installation and removal of the beams will require a track outage for access to the bridge by on-rail handling equipment if site conditions prevent off-rail access. Operation of this type of temporary support would require a track outage to conduct the repairs since the cantilevered beams are typically only capable of supporting dead load.

*Cantilever Beam Example Project:*

*Elm Street Bridge*

The Elm Street Bridge project involved the installation of new expansion bearings and precast blocks under the ends of a 127’ through truss. Access to the bearing areas was limited and there was no way to place a jack on the bearing seat and still be able to conduct the specified repairs. The bridge spanned a busy roadway containing a large sewer line buried too close to the surface to allow a shoring tower or bent to be used.

A cantilevered beam temporary support was utilized to support the 165 kip dead load reaction of the bridge along with an additional safety factor of 1.33 (Figure 6). The cantilevered temporary support, shown in Photo 4, consisted of two W24x117 beams connected by a series of diaphragms and attached to the end of the truss by a bolted shear connection. The jacks for lifting the structure were placed on the headwall and acted against the cantilevered end of the beam. The cantilever action resulted in a 260 kip upward force on the shear connection that secured the beam to the truss, and a 94 kip downward force acting down on the lower chord at the far end of cantilevered beam. The shear connection consisted of two ¾”x13½” plates secured to the bridge with A490 bolts and welded to a MC10x41.1 channel whaler resting on top of the cantilevered beams.
To reduce their incursion into the clearance envelope, the upper and lower flanges on the truss side of the cantilevered beams were coped to allow the beams to be placed closer to centerline of the truss chord. This allowed the cantilevered beams to be installed prior to the repair outage and to remain in place immediately after the repair was completed so that the duration of the outage could be kept at a minimum. The beams were sized for a moment of 825 ft-kips based on this coped section.

**Combinations:**

In some cases the design engineer may find it advantageous to combine the aspects of two or more alternate support methods. The effectiveness of this combined approach is best illustrated by the Tallahatchie River Bridge Project discussed below.

*Combination of Alternate Methods Example Project:*

*Tallahatchie River Bridge*

The repairs to the Tallahatchie River Bridge involved the replacement of most of the end post, a part of the end floorbeam, and a section of the lower chord on a 150’ truss span. Traditionally a driven pile bent placed under the first intermediate floorbeam would be the simplest and most effective means to support the bridge while the end post was removed. Unfortunately, the remote location of the bridge made the construction of a temporary pile bent exceedingly expensive and impractical.
In lieu of a pile bent, a temporary support system utilizing a cantilevered truss and moment resisting brackets was used to support the truss span while the end post was removed (See Photo 5 & Figure 7). To allow trains to pass through the structure with the temporary support system in place, the jacking truss was integrated into the span so that the incursion of the jacking system into the clearance envelope was kept to a minimum.

The integrated jacking truss was designed to withstand a cantilever moment of 3650 ft-kips with an impressive 24’3” foot moment arm. This allowed a dead load jacking force of 107 kip with an additional safety factor of 1.4. To counteract this cantilevered load, a moment resisting bracket was utilized to attach the cantilevered truss to the second intermediate floorbeam. The 104 kip resultant force from the cantilevered truss was transferred into the moment resisting brackets by four 1” diameter, 150 ksi threaded rods. The 7½” eccentricity of this load resulted in a 397.5 kip-in applied moment that was resisted by a combined tension and shear connection. The bracket itself was a weldment built up out of plate and designed using the method typically applied to the design of seated beam connections.

The cantilevered truss itself was an integrated frame that was built around the first intermediate floorbeam. The integrated frame design allowed trains to pass through the bridge while the frame was in place, though as a dead load only system the integrated truss was not designed to carrying the weight of the train.
The use of a large cantilever truss did impart a significant atypical load onto the existing bridge. When loaded the integrated truss imparted a compression load of 211 kips on the U1-L1 hanger. This compression load was significant because this member was designed as a tension member, not a compression member, so the section of the hanger was not optimal for this atypical compression load. This existing U1-L1 member was checked for a design load of 295 kips of compression and was found to be sufficient, however the compression capacity of this member ultimately proved to be the limiting factor in the capacity of the entire system.

**CONCLUSION:**

The alternative methods for temporary structure support described in this paper can be effective tools for addressing those projects where traditional methods for temporary structure support are not feasible or cost effective. However, great care should be exercised in the design, installation and operation of these alternate systems to ensure the safety of the bridge crew and general public. At all times a professional engineer that is familiar with railroad bridge construction should be supervising the design, installation, and operation of these alternate systems.

The alternate methods discussed here are meant to supplement, not replace, the traditional methods of temporary bridge support. By safely and appropriately applying an alternate method such as an integrated frame, moment resisting bracket, or cantilevered beam a qualified engineer can solve difficult structure support problems and reduce the costs associated with temporary structure support.
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Figure 1 – Three of the common temporary support methods used by bridge repair crews.
Figure 2 – A few examples of situations where traditional methods of temporary support may not be feasible and an alternate method may be required.
Figure 3 – One example of an atypical load on an existing structure resulting from the use of an alternate support system. The nature and magnitude of these atypical loads vary greatly, so the design engineer must investigate the possibility of atypical loads closely.
Figure 4: Salmon Falls Bridge Integrated Frame

The integrated frame utilized on the Salmon Falls Bridge consisted of two parallel braced frames running perpendicular to the centerline of the bridge. Three whaler beams passed through the end post of the trusses and rested on jacks placed on top of the frames. The load of the truss was transferred to the whaler beams by a bracket secured to the web of the end post. These brackets were installed in line with the centroid of the end post so that no eccentric loads were imparted to the existing truss members.

Figure 4 – The integrated frame system used to support the Salmon Falls Bridge.
Figure 5 – Saco River Moment Resisting Brackets

SACO RIVER BRIDGE
MOMENT RESISTING BRACKET

MOMENT RESISTING BRACKET
The moment resisting brackets utilized on the Saco River Bridge consisted of two channels bolted to either side of the girder web. One bracket was placed low on the girder that was to remain in place, and another bracket was placed high on the girder to be supported. Two jacks were placed between the channels to provide the required jacking force. This simple system allowed the riser under the jacked span to be completely removed without fear of upsetting the jacks.

Figure 5 – The moment resisting bracket system used to support the Saco River Bridge.
Figure 6 – The cantilever beam system used to support the Elm Street Bridge.
The temporary support system utilized on the Tallahatchie River Bridge was a combination of the three alternative temporary support systems discussed in this paper. The bridge was supported by a cantilevered truss that allowed an impressive 24'-3" cantilever off of the first intermediate floorbeam. The cantilever truss frame was integrated into the existing bridge so that this relatively large and complex system would not need to be removed to allow for the passing of trains. A moment resisting bracket was utilized to secure the cantilevered truss to the second intermediate floorbeam.

Figure 7 – The combined alternate system used to support the Tallahatchie River Bridge.
Photo 1 – The Salmon Falls Bridge included three double track 121’ ballast deck trusses. Each span contained five lines of trusses, three of which were wrought iron trusses dating from 1887. The lower chord of the 1887 trusses did not have sufficient capacity to resist the jacking load from a traditional direct jacking method. To address this situation an integrated frame was installed at the pier to support the bridge while the truss bearings were replaced, see Figure 4.
Photo 2 – The Pine River Bridge was supported temporarily utilizing sets of moment resisting brackets applied to the base of each tower. The moment resisting connection that secured the bracket to the tower leg allowed for a large enough eccentricity to place the jack outside the bearing area (arrow) and away from the work location. The relatively inexpensive nature of the brackets made it cost effective to apply brackets to all the tower legs, reducing the time required to raise the bridge.
Photo 3 – The Saco River Bridge was supported temporarily utilizing a set of moment resisting channel brackets attached to the ends of the girder spans. These moment resisting brackets (a portion of which is visible in the upper right hand corner) relocated the jacks away from the work area to a point safely above it. With jacks safely relocated, the concrete riser the span rested on could safely be removed in its entirety without the possibility of upsetting the jacks.
Photo 4 – The Elm Street Bridge was supported by a cantilevered beam system that was secured to the main truss plane. Cantilever beam systems are effective for bearing repairs on through type bridges because they can be installed to the main structure of the bridge without fouling the clearance envelope (dashed line). This allows the system to be in place before and after a track outage so that no time within the repair track outage is lost to installing and removing the temporary support system.
Photo 5 – The Tallahatchie River Bridge was supported by a temporary support system that used a combination of alternate methods, including an integrated truss frame, a cantilevered truss, and a set of moment resisting brackets. This system allowed the end post of the truss to be removed and replaced without the use of a temporary support bent. The shoring truss is visible just above the work platform in the photo above.