Bridge Load Rating Practices for Cranes

By Thomas North, P.E.

Oversized and overweight Rough Terrain (RT) and All Terrain (AT) commercial cranes are used extensively at dam projects, and continuously cross bridges that serve the requirements of the public agencies or private utilities that own them. Depending on the state jurisdiction, these cranes will be trailored or driven under a variety of local and multistate permit programs. The effects of crane loads on bridges are a frequent concern due to the variability in age, design, construction, and condition of the bridges. Currently, the only guidance available for analysis is criteria outlined in AASHTO *Load and Resistance Factor Design* (LRFD) *Bridge Design Specifications* and AASHTO *Guide Manual for the Condition Evaluation and Load and Resistance Factor Rating of Highway Bridges* (LRFR).

The information presented in this article will help determine safe loading capacity and placement of several types of classifications of oversized cranes on a bridge. It is based on vehicular loading and requires an analysis methodology that extrapolates an allowable crane permit loading from the bridge design or legal loading. The differences between vehicular & crane live and static loads, axle configurations and load placements are discussed. There are recommendations for making informed decisions on adjustments in impact loads, live load distributions and lane loading based on the strength and service requirements outlined in the evaluation and rating procedures in the AASHTO LRFR and LRFD specifications. This article will also present an outline for planning a crane operation on a bridge that includes consideration of working loads, placement and minimizing risks.

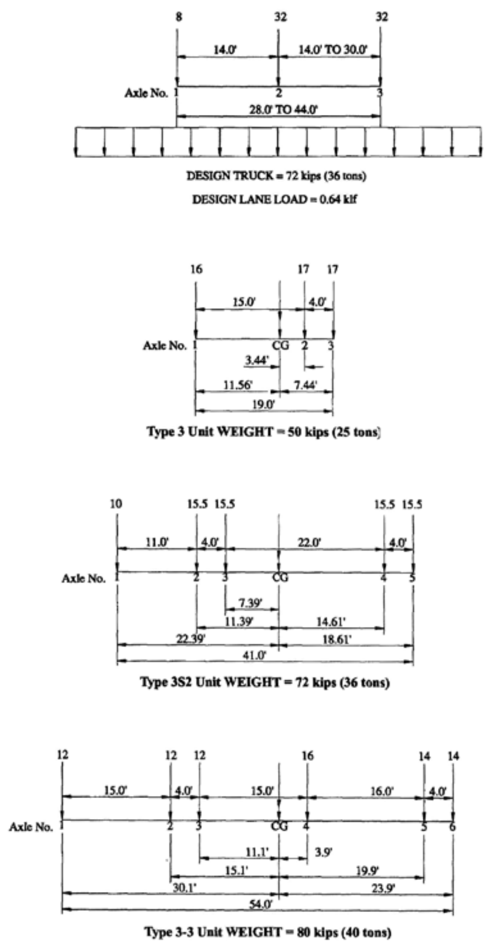

Figure 1: AASHTO design and legal loads.

Current Design Philosophy

The current bridge design criteria adopts a conservative reliability index that imposes checks to ensure serviceability and durability without incurring a major cost impact. Bridges are initially screened for strength and serviceability limit states based on LRFD design level of reliability. If a bridge does not meet these requirements, the current LRFR rating procedures are used and intended to balance safety and economics. In most cases, a lower target reliability is chosen for load rating at the strength limit state.

Basic Rules & Assumptions

Bridge load ratings have some basic rules and assumptions. All load ratings are based on existing structural conditions, material properties, loads, and traffic conditions. The bridge is assumed to be subject to inspections at regular intervals. The past performance of an existing bridge is also considered a good indicator that it has adequate capacity. Most bridges are likely to have experienced a more extreme load than what is considered during evaluation. And finally, any changes in existing structural conditions, material properties, loads, or site traffic conditions may require a re-evaluation of capacity.

Design Loads-Trucks vs Cranes

There are several major and minor differences between crane and truck loading on a bridge. For a standard truck load rating, three different types of loads are considered (*Figure 1*). The first is a design loading and is considered a first-level assessment. This is an HL-93 load per AASHTO LRFD requirements and is outlined in LRFR 6.1.7.1.

The second is AASHTO legal loads described in LRFR 6.1.7.2. These include Type 3, Type 3S2 and Type 3-3 vehicular loading and are intended as a second level rating that provides a single safe load capacity for a given truck configuration applicable to AASHTO and State legal loads. The live load factors are based on the truck traffic

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conditions at the site. Strength is the primary limit state for load rating, with service limit states being selectively applied.

The third type is a permit loading and is outlined in LRFR 6.1.7.3. Permit loading is primarily a check for safety and serviceability for passage of vehicles over a bridge that are above legally established weight limitations. The permit rating should only be applied to bridges having sufficient capacity for AASHTO legal loads.

The types of cranes that may see service on a bridge are classified as All Terrain (AT), Rough Terrain (RT), and Crawler (track) cranes. AT or RT cranes will have outriggers for increased capacity that extend between 20-24 feet and may be spaced 20-25 feet apart. Most of these cranes require the addition of counterweights to develop full capacity. The gross vehicle weight (GVW) for a standard design truck is 72,000 lbs. For comparison, an AT crane with a routine or annual permit or an RT crane will have a GVW that varies from 50,000 to 160,000 lbs. The GVW of a crawler crane can vary from 50,000 to 230,000 lbs.

AT cranes have a multi axle configuration, a telescoping cantilevered boom and can have a rated capacity of up to 300 tons (*Figure 2*). The center-to-center wheel spacing can be about 8 feet, with axles typically spaced 5-6 feet apart. These types of cranes combine the road speeds of truck carriers with off road capabilities. They can have features that may include large pick and carry ratings, all axle drive and steering, and can have suspension systems that equalize axle loading on uneven surfaces while the crane is moving or static. Because of their multiple axle configurations, most AT cranes are road legal or may require permits with a specialized boom trailer.

RT cranes are two axle carriers with a telescoping cantilevered boom and can have a rated capacity of up to 100 tons (*Figure 3*). These types of cranes have oversized tires that make travel easier on unimproved construction site roads. The center-to-center wheel spacing can be about 8-9 feet, with axles typically spaced 15 feet apart. Cranes of this type can travel an operating speed of about 30 mph. RT cranes typically have a high center of gravity and are not considered road legal due to higher axle weights.

Crawler cranes are propelled by two treads mounted on an extremely stiff base. The tread configurations may be about 17 feet long by 3 feet wide (*Figure 4*). Each has a separate clutch, brake and lock for independent control of travel and turning. Crawler cranes are not road legal and

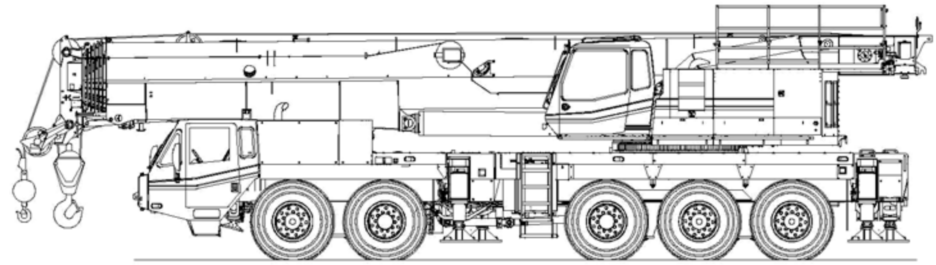

Figure 2: All Terrain (AT) crane.

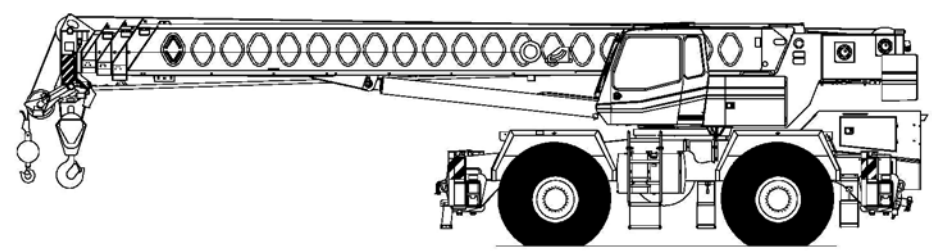

Figure 3: Rough Terrain (RT) crane.

must be transported with a crawler carrier. Crawler cranes have a lower cost and rental rate than other types of cranes, but their transit costs are higher.

Dynamic Loads

For vehicles, the dynamic load allowance is primarily a function of pavement surface conditions. It is defined in LRFR 6A.4.4.3 and outlines the required impact factor as 33% of the live load. For an approach with minor surface deviations and depressions, it can be adjusted to 20%. For smooth riding surfaces at approaches, deck and expansion joints, the impact factor can be adjusted to 10%. For legal loads, the dynamic load allowance per LRFR 6A.4.5.5 can be applied for permit load rating. This means that for slow moving permit vehicles (10 mph or less), the dynamic load allowance may be eliminated.

The live-load factors for permit loads were derived for the possibility of simultaneous presence of non-permit trucks on the bridge when the permit vehicle crosses the span. An adjustment can be made on the live load factor depending on vehicle type and traffic conditions. For permit loads, Table 6A.4.4.2.3a-1 allows an adjustment of live load factors from 1.8 to 1.4 for routine commercial traffic.

If traffic can be closed in the opposite lane, Table 4.6.2.2.2b-1 in the LRFD specifications provide specific reductions in live load distribution for single lane loadings of interior beams.

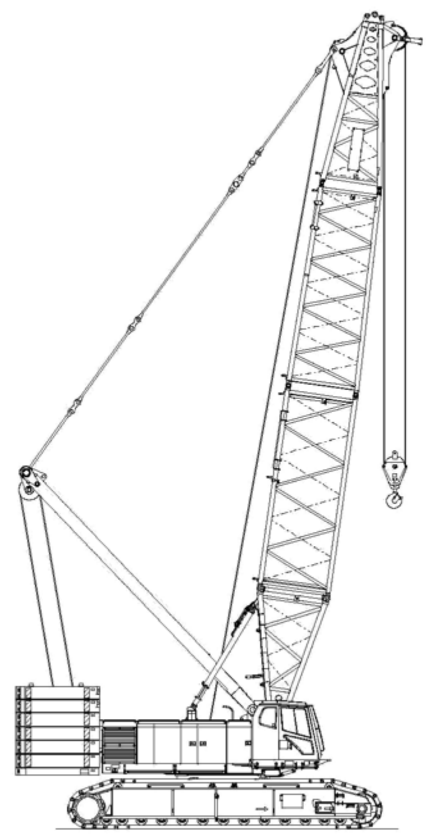

Figure 4: Crawler crane.

Cribbing and Shoring

For most instances, cribbing is required to distribute the outrigger loads on the bridge deck (*Figure 5*). Overloading from improperly placed outriggers can initiate cracking due to general or punching shear failure. Cribbing and shoring can be made from timber, steel or a combination of both with an effective width “b” and length “c”. Maximum design efficiency can be obtained when b = c; however, the existing bridge geometry, width, girder spacing and type of loading will control the shape of the cribbing. For timber, a check for horizontal shear stress needs to be made. Although the typical practice is to allow some increase in allowable stress for short duration loads, a more rational approach is to forgo these increases because the outrigger loads are calculated without consideration for wind and other dynamic effects. For steel, shear is not as critical condition to check. Cribbing members that are oversized and stiffer will deflect less and provide a more even load distribution; however, the cribbing needs to be checked to verify that members bear uniformly on the base. Filling, leveling or blocking may need to be added.

Loading Near Slopes and Abutments

The effects of surcharge loading need to be taken into account when operating heavy cranes near slopes and abutments. Surcharge loading decreases with added distance; therefore, to determine a safe position for crane set up, a check for stability may be required. If stability is an issue, surcharge loading may be eliminated or resisted with the placement of pontoon shoring on top of the abutment and placement of diagonal shoring along the abutment wall.

The Planning Process

A crane loading plan is needed to assess the loads, establish how the crane will be positioned in place, determine the crane motions and what special equipment will be required. The load information needs to include the combined gross vehicle weight, counterweights, blocks, slings, lifting beams and other lifting accessories. The movement and positioning of a crane on a bridge deck has to be a controlled operation where travel paths have to be predetermined and adhered to. Operating positions and crane motions must be controlled, and all loads, operating radii and horizontal boom angles must be known in advance. The crane motions to be considered are hoisting, swinging, booming (in or out), traveling (if allowed) and sufficient allowance for some deviation in position and maneuvering. A lower risk crane operation employs a minimum of control and control engagements, low motion speeds and durations, as well as shorter boom lengths and picking radii.

The crane loading plan should be reviewed and approved by a licensed professional Engineer who is charged with the overall responsibility for bridge-capacity evaluation and has a minimum of five years of bridge design and inspection experience. The following is a sample specification requirement for a crane loading plan on a bridge:

1) Crane Loading Requirements

- A loading diagram shall be submitted and approved prior to operating any equipment or vehicles in excess of 72,000 lbs GVW and axle loads of 32,000 lbs.
- The loading diagram will include, but not be limited to, providing information on the following:
  1) A typical section and plan view of the bridge, the position of the wheel loads and wheel spacing of the crane.
  2) Crane gross vehicle weight (GVW), required counter weights and center of gravity from the axis of rotation.
  3) Location and weight of axles before and after counter weights are installed.
  4) All outrigger loads.
  5) Required crane boom length, weight and location of center of gravity. This should also include the effects of guy lines, upper spreader and jib mast.
  6) If using a jib, the length, weight and location of the center of gravity.
- Prior coordination and approval for such loads shall be obtained before proceeding. No exclusion trucks, multi-axle specialized hauling vehicles (SHV) or mobile cranes will be allowed on the bridge deck without prior review and approval.
- Any SHVs authorized to drive on the bridge deck will at all times be required to have all lift axles lowered and fully engaged while the vehicle has any load. For cranes, all specialized boom trailers will be required to be engaged until a final set up with the outriggers are made and approved.

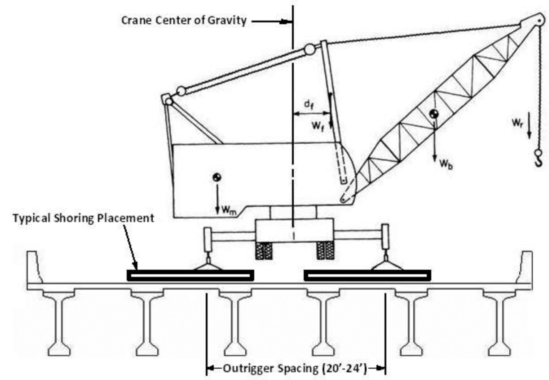

Figure 5: Typical outrigger & shoring placement.

- No vehicular traffic will be allowed in the opposite lane or in the same span that the crane is positioned on.
- Crane speeds will be limited to 5 mph or slower. There will be no sudden stops or starts.

2) Shoring Requirements

If using timber, call out the required grade, Fc, Fb and Fv values.

- If using steel, call out the required grade and any weldments.
- Shoring and blocking must be accurately aligned as shown on the plan.
- Crane operations may cause the shoring to work loose. All wedges, shims and position of the shoring shall be checked daily.
- All wedges, shims or fillers must be made of hard wood or steel. No soft wood materials will be allowed.

Conclusion

The response of crane loads on bridges is a function of the variability in the age, design, construction, and condition of the bridge. By knowing the differences between vehicular and crane live loads, what the axle configurations are and where the loads are being placed, the effects of crane loads can be quantified using a combination of adjustment of live load impact, load factors, load distribution and removal of lane load requirements based on Strength II design permit load criteria in the AASHTO LRFD and LRFR specifications.▪

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