Government of Western Australia
Department of Mines and Petroleum
Resources Safety

Mines Safety Bulletin No. 105

Subject: Under-design of bridge and gantry crane end connections

Date: 2 July 2013

Background

Various types of cranes are used on mine sites to lift and move loads, commonly plant requiring maintenance during a shut down. This bulletin relates to purpose designed and built cranes, including bridge and gantry cranes. These cranes utilise bridge beams, which distribute the crab loads to the end carriages or support legs (Figure 1).

In the process of registering cranes on mine sites, Resources Safety has established that many designs do not accommodate all load effects on the end connection of the bridge beams. In an attempt to address this design deficiency, crane owners are exchanging crane end connection bolts as required by the designers for higher class (i.e. stronger) items, but this solution may not be adequate.

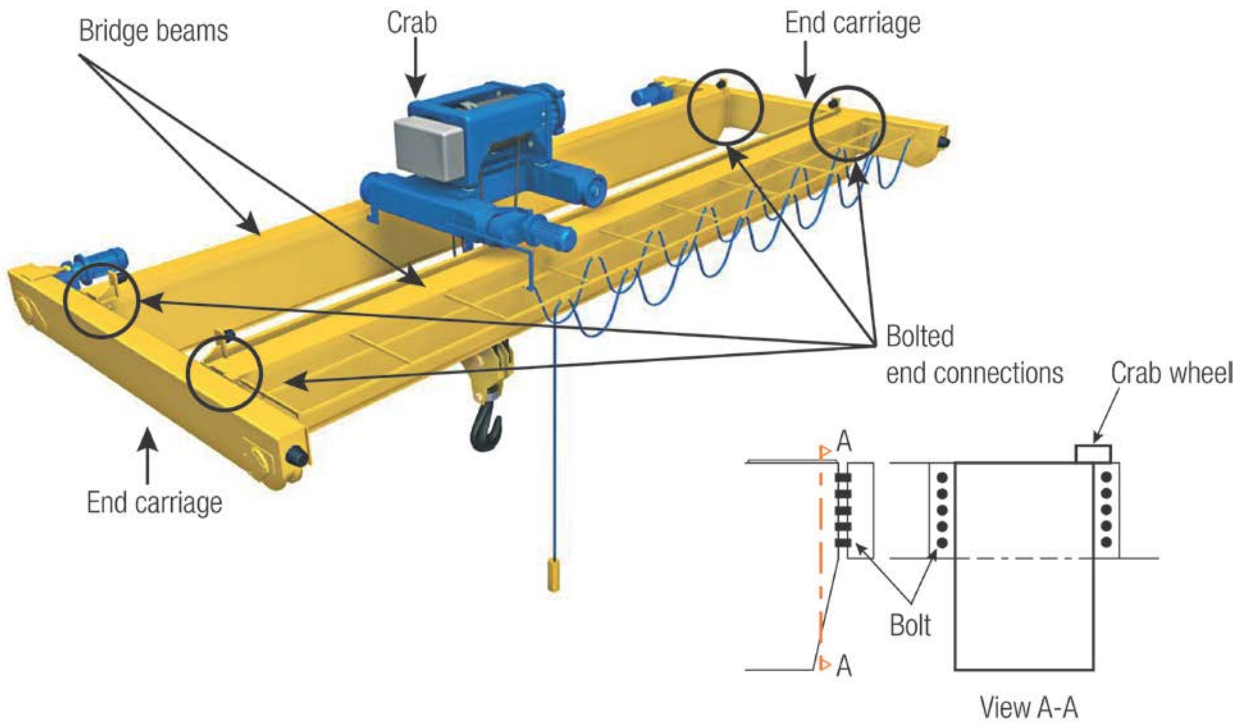

Figure 1 Typical layout of a double bridge crane, with schematic sections showing a bolted end connection (adapted from image at www.podemcrane.com/?p=15&l=2&id=3)

Summary of hazard

Investigations into a number of cranes have found the strength of some bridge beam to end carriage connections to be inadequate. When the loaded crab moves along its rails, these connections experience torsion loads that were not considered in the design checks. This torsion load exists because the crab wheels apply loads eccentrically on many bridge beams. With the torsion loads added, the end connection bolts experience combined forces that exceed the limits in the Australian Standards.

In these cases, the bolted end connections of the double bridge crane require review and possible strengthening due to the design oversight. Without this strengthening, there is the potential for the end connections to fail suddenly, resulting in a collapse.

All cranes with eccentrically loaded bridge beams and end connections with bolts in shear may be at risk.

Contributory factors

- Analysis of the crane structure designs being investigated indicates that computer modelling was simplistic (Figure 2), and there was no modelling of the eccentric loading of the trolley wheels relative to the centreline of the bridge beams (Figure 3).

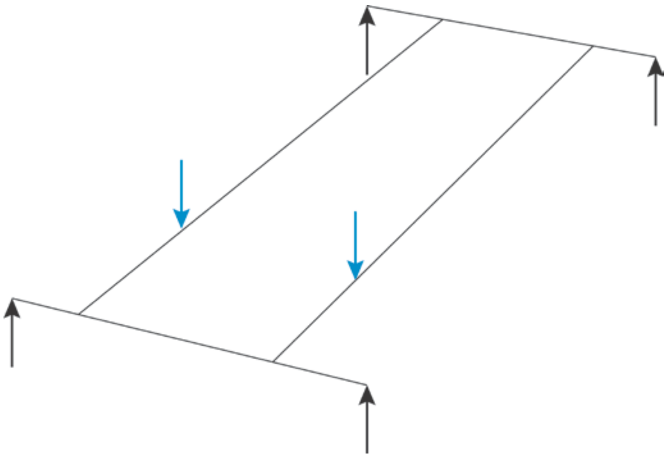

Figure 2 Schematic diagram showing simplistic modelling for bridge beams whereby simple model loads (blue arrows) are applied to the bridge beam centreline.

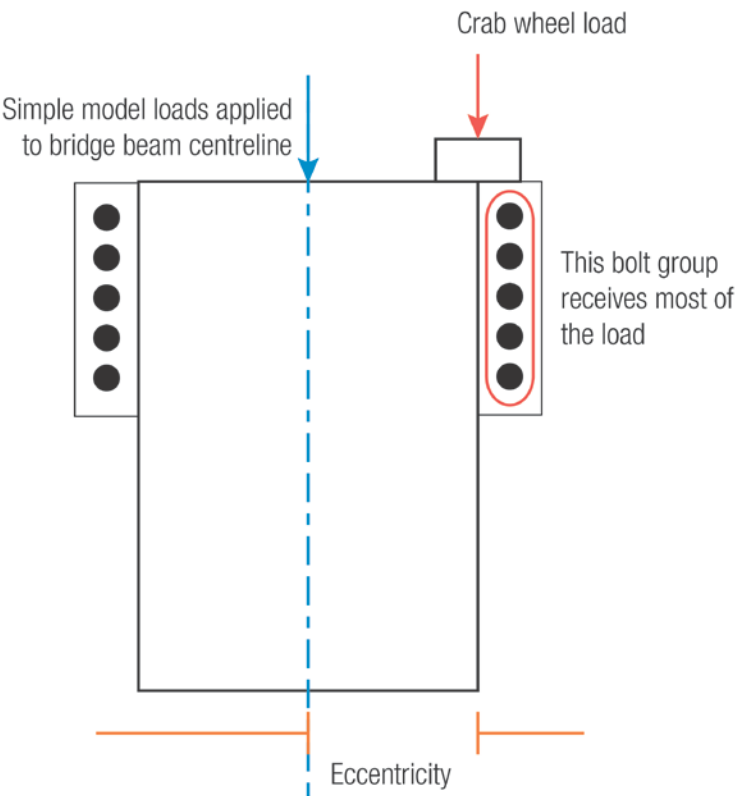

Figure 3 Schematic cross section of bridge beam end connection showing eccentricity resulting from loading of the crab wheel (red arrow) relative to that for a load at the bridge beam centreline (blue arrow).

- Rather than including eccentricity in the analysis model, it is possible to manually add a secondary effect to the calculations. However, this approach can be vulnerable to mistakes because it can be difficult to manage all secondary effects and combinations in complex structures.
- The omission of modelling or calculations accounting for eccentric loading was often not identified by the verifier of the designer's calculations.

Recommendations

Mine management and crane owners

- Registered Managers should establish if any cranes on their sites have eccentrically loaded bridge beams with the potential end connection defect. If so, management should establish from the original equipment manufacturer (OEM) whether the design omission or error exists in the crane.
- If the design omission or error exists, consider an interim short-term operational down-rating. For example, operate the crane in a 75 per cent down-rated load-carrying capacity and limit the crab movement to the central third of the bridge (Figure 4) until the defect is adequately addressed. These load and movement restrictions will produce less force on the bolted end connections than that experienced during load testing.

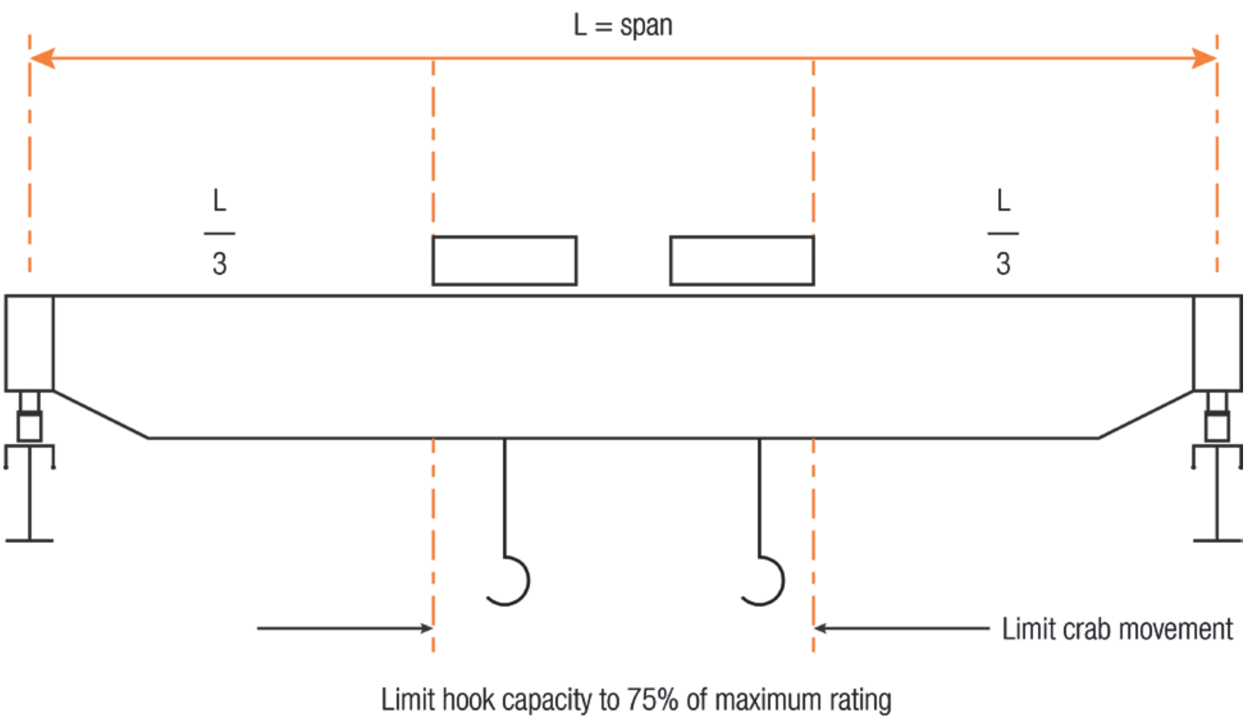

Figure 4 Schematic side view of bridge crane showing recommended short-term operating parameters when eccentricity has not been considered in the design.

- Manage the associated risks of using the down-rated crane through a combination of management systems such as the classified plant register, notices, risk assessments, verification of competency (VOC) programs and high risk work (HRW) protocols.
- A competent person should inspect the end connections without delay and arrange for them to be strengthened if required.

- Ensure all required strengthening is carried out, inspected by a competent person and recorded in the relevant plant registers.
- Be aware that if swapping out class 8.8 bolts with class 10.9 or higher class bolts, the higher class bolts can experience stress corrosion cracking (SCC) and hydrogen embrittlement (HE) failures. These failures occur most often where the bolts are subjected to tri-axial (or combined) stresses, as is the case with the end connections on the bridge beams, and the bolts have not undergone specialised manufacturing processes to counter this.

Designers and verifiers

- Crane designers and crane design verifiers must ensure compliance with relevant clauses in Australian Standards and use sound engineering practice. The analysis and design process must consider all possible load combinations, primary and secondary load effects, and the maximum combined cases.
- Crane designers should consider adopting analysis models that account for all eccentricities, and accurately model end connections to avoid missing secondary effects.

Additional information

Australian Standards, available at www.saiglobal.com

- AS 1418 *Cranes, hoists and winches – General requirements*
- AS 3990 *Mechanical equipment – Steelwork*
- AS 4100 *Steel structures*

Simon Ridge
STATE MINING ENGINEER