engineering new zealand
te ao rangahau

DISCIPLINARY COMMITTEE – UPHELD COMPLAINTS
LESSONS TO BE LEARNT

CASE STUDY
SEPTEMBER 2022 – TRUCK AND TRAILER

INTRODUCTION

Engineering New Zealand receives around 50 concerns and complaints about Chartered Professional Engineers and members each year.

Not all complaints are upheld, but they typically relate to:

- miscommunication,
- inattention to client care,
- a misunderstanding over what the engineer has been engaged to do (or what they can't do),
- serious issues of competence, or
- ethical conduct.

Reflections on past complaints that an Engineering New Zealand Disciplinary Committee has upheld can offer valuable lessons for engineers.

We will review an upheld complaint from a past Disciplinary Committee decision every two months. The purpose of this project is not to name and shame, but to provide information so we can learn and grow. Wherever possible, we have anonymised the case.

We invite you to reflect on the lessons to be learnt.

Background

The initial complaint was made against the respondent (a Chartered Professional Engineer) and was initiated by an incident in 2017 where a truck and trailer were travelling at speed on a highway when the draw beam separated from the truck, causing the trailer to collide with the bank on the side of the road.

The respondent was engaged by the client to provide the design and certification for the truck trailer draw beam towing connection (draw beam) to comply with New Zealand Standard 5446:2007 Heavy vehicle towing connections – Draw beams and drawbars (the Standard). The draw beam was certified by the respondent as road-safe.

Key points

- Did the respondent meet the competency standards expected of a reasonable engineer in preparing and certifying the design of the draw beam?
- Did the respondent meet the competency standards expected of a reasonable engineer in certifying the draw beam as road-safe?

Decision

The Disciplinary Committee found that the respondent engineer had acted negligently when designing the draw beam, checking their analysis, and subsequently in their certification of the draw beam.

The respondent engineer demonstrated a serious lack of due care and attention to their draw beam design and analysis, and a failure to check whether all requirements had been met before they certified the draw beam.

The respondent engineer breached the Code of Ethical Conduct to the extent they acted negligently.

CAN YOU IDENTIFY THE PROBLEM?

A key part of the analysis of any draw beam is assessment of the bending stresses induced in the beam by the longitudinal load cases.

In calculating the bending moment, it is common practice to make the conservative assumption that the draw beam is a beam with a central point load with pinned conditions at each end. Once the bending moment and beam section properties are known, the bending stresses can be calculated.

Suggestion

Look at the load case table below and the drawings provided. Draw out the load path, use big arrows for big forces and small arrows for small forces. For these connections, the allowable stress is normally 0.6.

Estimate the demand and capacity of the connections.

- Where do you think the failure occurred?
- Why do you think that?

Table 1 – Load cases

LOADCASE	FORCE
Longitudinal static force (FL)	260kN
Vertical static force (FV)	39kN
Lateral static force (FS)	78kN
Longitudinal fatigue force range (FFR)	220kN

DRAWINGS

Figure 1 – Anonymised manufacturing drawing of draw beam from the certifying engineer's file.

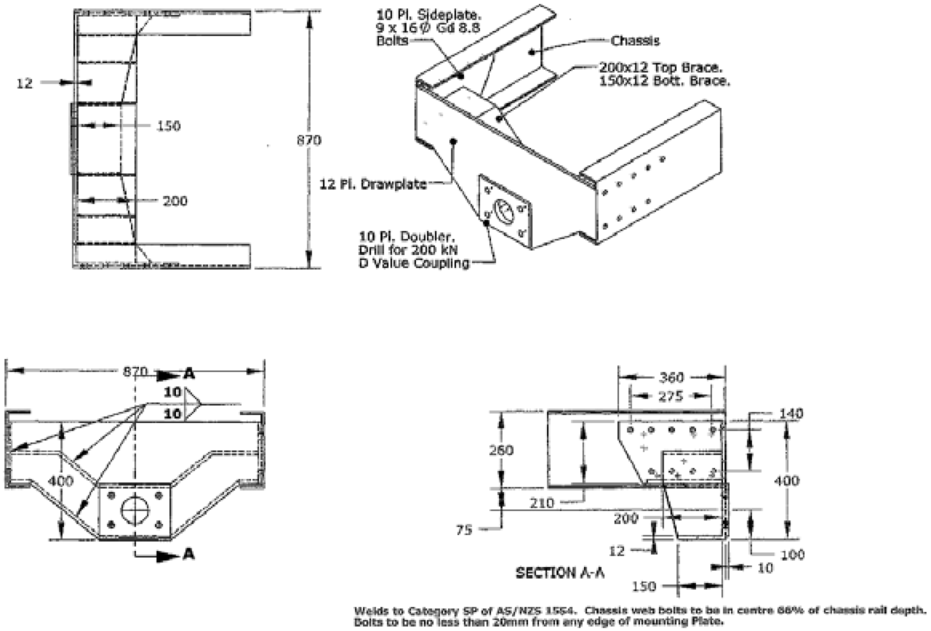


Figure 2 – Draw beam at time of certification. View is of the rear of the truck, with draw beam bolted to the inside of the chassis rails.

YOUR REFLECTION

Based on the information provided, consider your answers to the following three questions.

What do you identify as the problem?

Consider the load path, sketch it onto the drawings. Approximately how long would you expect welds to be to resist the load? If you were going to model the structure, how would you model the connections?

If you were engaged to resolve the problem, how would you do so? Sketch on the drawings and describe your thought process.

How could you ensure a robust load path? How much redundancy is there in the design?

How would you have stopped this from occurring in your own company? What are your quality control and assurance procedures?

AN EXPERT'S VIEW

Background on draw beam design

A draw beam is a type of towing connection that is fitted to trucks to allow them to tow heavy trailers. An example is shown in Figure 3, and this shows how a coupling is attached to a draw beam, which in turn is bolted to the chassis of a truck.

Draw beams can be fitted with several different types of coupling, each of which gives a mechanical connection to a matching coupling on the trailer to allow transmission of towing forces between truck and trailer whilst also allowing for some articulation.

Figure 3 – Example draw beam (tsgl.nz/wp-content/uploads/2019/09/Drawbeam-Certification-2.jpg)

Draw beam assessment considerations

The mandatory standard for draw beams in New Zealand is NZS 5446. This standard gives a series of static and fatigue load cases that a draw beam must be designed for. The static load cases (longitudinal, lateral, and vertical) are typically assessed against the allowable stress limits of AS 3990, which essentially gives an allowable stress of 0.6 x yield.

The draw beam, in this case, was rated for a maximum towed mass of 30,000kg, which results in load cases from NZS 5446 as summarized in Table 1.

Design life

The longitudinal fatigue force load case is typically designed to either AS 3990 or BS 7608 such that a recommended design life of two million cycles is achieved, representing a 20-year design life.

The fatigue assessment would consider the stress range at all relevant fatigue features (e.g. welds, bolted connections etc.) and compare these to an applicable S-N curve from one of the above standards. Often the limiting feature will be a transverse weld (e.g., at the edge of the central doubler plate) which would have effective allowable stress of 55/49MPa (depending on which standard is used).

Draw beam design

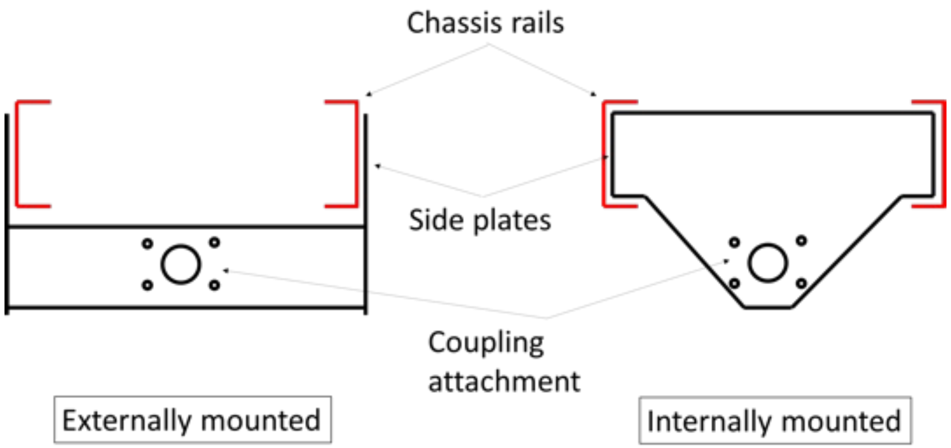
Draw beams are usually bolted to the truck chassis through a pair of side plates, with the side plates being welded to either end of a central beam section.

Option 1: Draw beams are most commonly designed to be mounted externally, that is with the side plates attached to the flat exterior surfaces of the chassis rails and with a typically straight horizontal beam section located below the level of the chassis.

Option 2: Alternatively, a draw beam can be mounted internally, as in this case, with side plates at the ends of the beam bolted to the internal surfaces of the chassis channel sections. To achieve the appropriate coupling position below the level of the chassis, internally mounted draw beams usually need to taper downwards towards the centre.

Figure 4 shows the difference between the internal and external mounted draw beams fitted to a truck.

Figure 4 - Rear elevation of externally mounted (L) & internally mounted (R) draw beams. Red lines are chassis rails.



Design considerations

INTERNAL AND EXTERNAL MOUNTING

Externally mounted draw beams are simpler to design and fabricate, so internally mounted draw beams tend to be used where an external mount isn't practical for a particular vehicle configuration or application.

This is sometimes the case where a vehicle is expected to be used to jack knife a trailer, a low-speed maneuver with the trailer perpendicular to the truck. When jack knifing, the side plates of an externally mounted draw beam protruding beneath the chassis rails could clash with the towing connection of the trailer, so a tapered draw beam may be preferable.

In this case, the vehicle was fitted with a rear-mounted crane, so an internally mounted draw beam may have been chosen to avoid the need to modify existing crane mounts.

DISTRIBUTION OF FORCES

A doubler plate welded to the beam at the coupling attachment location is a common feature of draw beams, as shown in Figure 1. This doubler plate gives local reinforcement of the draw beam around the coupling attachment and ensures proper distribution of the towing forces into the beam can occur without causing localized damage.

The welds attaching doublers to draw beams are sometimes critical fatigue locations as they have a relatively low allowable fatigue stress and occur close to the point of maximum bending moment. However, in this case, the doubler plates and welds weren't relevant to the failure.

CONSIDERATION OF BENDING AND TORSION

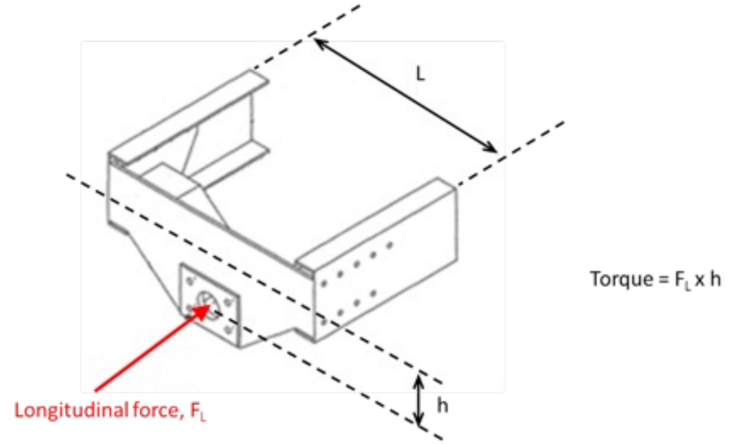
In most applications, the tow coupling needs to be located some distance below the level of the truck chassis, meaning that any longitudinal loads (ie, in the direction of travel) at the coupling will induce a bending moment about the lateral axis in the chassis. In the case of a typical externally mounted draw beam, the longitudinal force at the coupling acts close to the shear centre of the beam.

This means no significant torsion is induced in the beam, with this moment developing in the vertical side plates that connect the beam to the chassis.

However, for an internally mounted draw beam such as in this case, the outer ends of the beam are offset vertically from the coupling, meaning that a longitudinal force induces combined bending and torsion of the beam itself.

This draw beam was made up of a rear plate, with top and bottom plates attached by fillet welds to create an open section. In general, open sections are poor at resisting torsional loads.

Figure 5 – Longitudinal load case sketch



Failure modes of the draw beam in this case

A third-party review of this draw beam following its failure concluded that the draw beam was significantly under-designed, both for the static and the fatigue load cases.

Fatigue analysis carried out as part of the review showed that the stress range in the draw beam adjacent to the end welds was an order of magnitude above the allowable value. Even accounting for conservative assumptions within the analysis, this showed that failure could have been expected significantly earlier than the design life.

The draw beam, in this case, failed after two years in service when a crack developed adjacent to the weld between the side and top plates. This resulted in the central section of the draw beam (Figure 5), complete with the trailer, detaching from the truck. The draw beam side plates remained bolted to the truck chassis.

Figure 6: View from the trailer towards the draw beam.

Figure 7 – Photo showing part of the draw beam after failure. This view is looking from the front of the draw beam, ie towards the trailer. Green lines indicate locations of failed welds to the side plates, and the red line indicates another crack.

WAYS TO REMEDY THE PROBLEM

Use a simpler standard design

One option could be to design a simpler externally mounted draw beam and accept that this may mean modifications are required to other systems (eg crane mounts) to achieve this. However, in many cases, this may not be practical.

Strengthen the existing design

The existing design could potentially be modified such that it meets the requirements. This could include design changes such as increased plate thicknesses, draw beam depth, additional stiffeners on the forward edges of the top and bottom plates etc. The addition of a capping plate over the forward face of the draw beam would also improve its torsional strength by turning the beam into a closed section (see Figure 6).

Figure 8 – Cross section of failed draw beam (L) and possible capping plate modification (R)

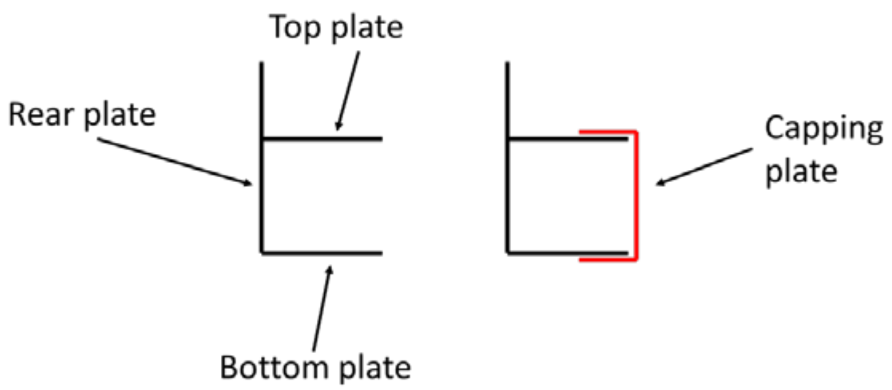
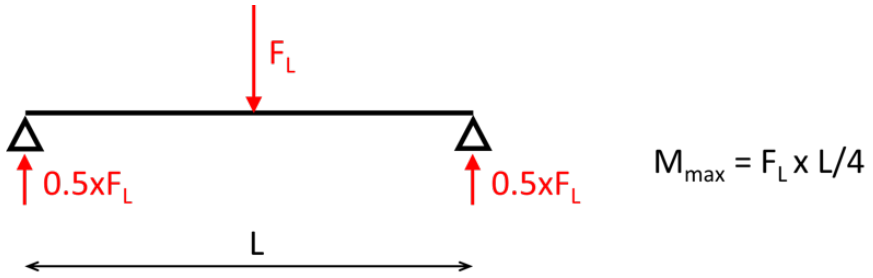


Figure 9 – Free body diagram



In the case of an internally mounted draw beam such as in this case, it would also be necessary to consider the effect of the torsional shear stresses in the beam caused by the torque shown in Figure 7.

Considering combined forces

Combined bending and torsion isn't well catered for by AS 3990 as this standard assumes that beams aren't generally loaded in torsion. A reasonable method would be to calculate the shear stress, bending stress and torsional shear stress distributions along the beam and use these individual stress components to calculate the von Mises equivalent stress, which is a measure of how close the material is to yield considering the overall multiaxial stress state.

This von Mises stress value could then be compared against yield, using the 0.60 factor of safety. As the geometry of this draw beam is relatively complex, it may also be prudent to check these calculations against a simple linear FEA model of the draw beam.

HOW CAN WE STOP THIS HAPPENING?

A double check using hand calculations

The primary reason that this failure occurred appears to be that the draw beam was not properly assessed against the requirements of the standard before certification. Basic hand calculations assessing the draw beam structure against each load case would have shown that the design was inadequate.

Validation of Finite Element Analysis

When using FEA, ensure that this is validated with basic calculations wherever possible, and that boundary conditions, loads, mesh, and all other model features are appropriate.

Ensure standards are met

Ensure that the job file is complete with all relevant information and analysis etc, and at least meets the minimum documentation requirements of the regulator (in this case, Waka Kotahi).

LESSONS TO BE LEARNT

What lessons can be learnt after reflecting on this upheld complaint?

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