Why Most Crane Runway Girders Fail, Why?

John Fong (馮永康) . Bill Vanni
Structural Design Corporation
1133 Claridge Dr., Libertyville, IL 60048

Not every Crane Runway Girder (CRG) will fail unless there are serious structural deficiencies. However, without repair CRG's can buckle creating a large boom that can be heard throughout the building. Without properly resolving torsion- and fatigue- related issues then most Crane Runways Girders may fail for these two reasons:

– Torsion

Many engineers fail to recognize that **the Shear center** (**SC**) is the soul of torsion. It deserves to be the most respected section property when it comes to studying how an open sectioned member behaves under torsion.

What affects **CRG** engineering design the most is the location of the **SC.** If it is not correctly located all other torsion-dependent properties will be wrong such as:

- Other sibling properties like the warping constant ($\mathbf{C_w}$).
- The magnitude of applied torque.
- Global structural behavior and response to the applied torque,
- Local stresses
- Design qualification, etc.

As in a chain reaction, every torsional property and design stress would be wrong. On searching the public domain for **SC** treatment, there are resources aplenty for reference including application examples. However, we largely see the copycat-like coverage for an I-beam, channel, angle, etc. being recapitulated over and over and there seems to be nothing new beyond that.

SC as typically posed in the public domain are mostly good for (1) symmetrical shaped members, (2) structures free from torsion's influence or (3) applications where **SC** or $\mathbf{C_w}$ is irrelevant, etc. The problem is, it creates a false notion as if every structural member existed in this world is either symmetrically shaped or can be treated as being symmetrical.

In **CRG** applications for practical reasons, we can't make every girder symmetrical. There are way too many unsymmetrical **CRG's** installed in most crane runways for the longer spans.

Regardless of profile configuration, these two **SC**-related issues can severely affect any **CRG's** life span:

- The biggest engineering error is assuming that the "Crane Rail Base" is the location of the **SC.**

- One then needs to understand clearly that the true location of **SC** for a generic profile must begin with (1) a correctly located **Elastic Centroid** and (2) a properly oriented **Elastic Principal Axis**. Only then the SC can be developed by way of a correctly predicted shear-flow path that then passes through a correctly executed numerical integration process.

There is absolutely no room for error. Depending on how "wrong" the shear flow path is and how "wrong" it has gone off course with the numerical integration process, the end result would be detrimental. For instance, the moment arm for the applied torsion is not merely 6" (rail depth) but much longer as sometimes the true **SC** is at a radius more than 20" away from the rail.

Some could argue; there's no guarantee even from taking the correct approach that we could still run into unexpected issues. It is necessary to identify if it's a physical error, logical error or a conceptual error. Then make the proper correction. In any event, don't fall too easily too soon into assuming the "Crane Rail Base" theory unless, by chance that happens to be the correct location of **SC.**

Another very popular but flawed theory for addressing torsion is the method of using Flexural Analogy. It has severe shortcomings in justifying the design that meets serviceability requirements and qualifying the design that meets the stress mandate.

So we can "see" the reason why a **CRG** may fail if it were designed using a faux SC or Flexural Analogy especially with **CRGs** having unsymmetrical sections.

– Fatigue

The most important part of a design review after the SC is located is proof of whether the **CRG** is qualified against metal fatigue. It is our experience that the engineering effort that should be made to perform a fatigue analysis has not been addressed.

It is very rare to come across engineering-design documentation comprehensive enough to make a fair judgement on the structure's adequacy against metal fatigue. The worst of all is making no mention of the subject in many engineering calculations. This is a major engineering issue that needs to be addressed by academia. A proper fatigue analysis needs to performed at each weld and bolt hole. The issue is even more complex since the wheel loads are also at different locations as the crane bridges down the girder.

Qualifying a structure as being fatigue-proof is more difficult than most engineers know. The fatigue analysis must be based on the fatigue stress range. The lateral loads need to be applied in both directions to determine the stress range.

Sorting out the maximum and minimum tensile fluctuation-related stress and reversal in shear stress involves moving information in and out of the data files for as many wheel load combinations. It is a big challenge of both engineering and data management skills to track data for many load cases at each node for each wheel.

CRG's are unique structural members that must address so many inherent "man-made defects" via bolting and welding. Those "defects" could be located near the mid-span, support ends or anywhere in between, in the webs, flanges or stiffeners and attachments, etc.

Over time, every "defect" is a potential fatigue stress hot spot susceptible to fatigue failure. The calculated fatigue stress range needs to be compared against the corresponding fatigue stress threshold for both tension and shear. The location(s) of fatigue hot spots can only be verified through extensive calculation to determine if a CRG is fatigue resistant.