LRFD, ASD, Crane Runway Girders and Building Design

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

We all knew this is a very interesting subject to Structural Engineers designing steel structures. The focus herein is simple: What should we do or not do when dealing with not only **Crane Runway Girder** (**CRG**) but also with its surroundings.

1. Crane Runway Girder as an Independent Structure

At this early stage of our conversation, whether to follow **LRFD** or **ASD** in executing a particular plan is not the point of debate here since each standard had its respective status in normal practices.

> But at the project level, picking out a proper method as basis to qualify the design of a specific class of structure should be the most important commitment any responsible project personnel has to make before going about engineering business as usual
>
> In the meantime one shouldn't gloss over the fact that a great number of Structural Engineers designing **CRG** and a variety of many other structural objects had elected **ASD** for various reasons even though **LRFD** was endorsed officially for quite a while

Since **AISC** (since the Black Book edition as of this writing) is so well articulated in integrating the strategy of treating **LRFD** and **ASD** in parallel, apart from the loading combination details, it makes little difference going either way once the "Nominal Design Strength" is obtained through common sets of Code Equations that are equally applicable to **LRFD** and **ASD**. Among others, some of the familiar distinctions between the two paradigms were:

(a) Respective load combination definition:

LRFD deals with load combination factors specific to strength limit states while **ASD** deals with a separate set of combination load factors applicable to design based on allowable strength

(b) Application rule in defining relevant "Required Strength":

Applying a resistance factor (Phi **Φ**) for **LRFD** and safety factor (Omega **Ω**) for **ASD** (see **AISC Chapter B**)

Like in everything else we do, judgment applies:

> As of this writing per Commentary of **AISC** Section **B3.4**, **the typical relationship between Φ and Ω is mostly based on a live load-to-dead load ratio of 3 for "*braced compact beams in flexure and tension members at yield* …"**
>
> On stopping by the phrase "**mostly based on a live load-to-dead load ratio of 3**," it makes one wonder does that mean there are exceptions to the ratio of 3 albeit that is not the point of argument here but can't help to ponder
>
> Nevertheless, there are situations if not entirely in defilement to the above but may well be drastically different from what were based per **AISC** commentary − even though the stipulation was as ordinary and aptly as for most other applications' sake – but take that and see if it fits for generalized **CRG** interests, for instances:

- For structures supporting Material Handling Operations, one can easily get a feel from comparing the dead weight of a girder against the lifted capacity in tonnage it has to carry, and can immediately conclude that the *live load-to-dead load ratio* in normal **CRG** practice – typical **CRGs** bear an **L/D** ratio of ±15 – which is **always much too much greater than 3**

- In most Mill production processes, for which the service live loads can approach from all **X/Y/Z** directions that hardly stay still but rather move about more actively − with varying load magnitude in tow − thus the load resultants are of the "travelling" kind that may "dynamically" point into "any" orientation; trouble is they "always" trigger **flexural** and **torsional** events concurrently. The harsh ambience a **CRG** has to withstand and how it experiences the effect from the loads goes way beyond "*pure flexure and tension at yield*"

- For practical matter-of-fact reasons, the cross sections of **CRG** were seldom or could never be braced at each and every load point for the loads always move about so randomly and does not stay in fixed location(s) for long

- And besides, some of the profile components could be non-compact and were vulnerable to local buckling under compression (or shear), etc. thus the application of ***"braced compact beams in flexure and tension members"*** becomes impracticable

Then a few questions came up;

(1) Aren't those inferences reasonable enough that using **LRFD** − if only **Φ** value is accurately applies − may turn out a much heavier or lighter **CRG**? (2) Or that doesn't make any difference at all? (3) Or what if it really does? …

Readers interested in the subject should "see and feel" it for themselves if any of these are true by running some calculation on their own; but *don't be in a hurry giving strong-armed answers to those interesting questions without trying*

In general practices though, it is not a good idea mixing **LRFD** and **ASD** − or switching back and forth − in the same design session unless the Practitioners didn't get confused first and then understood the pros and cons of doing so.

Anyhow, although the project-level criterion had already committed to **LRFD** load combinations per **ASCE-7 LRFD** intent, but on individual occasion, one may still need to decide if it's more (or less) practical by (1) staying with or (2) taking exception from the implications per committed **LRFD**. A decision should be made whenever allowing for **CRG's** interaction with or participation in the local and/or global framing performance evaluation as seem fit

*Nevertheless, except for situations in conflict with the Project Requirement or Corporate Standard Commitment, whether adopting **LRFD** or **ASD** should be an individual preference as to qualifying **CRG** as standalone members but do make sure the design is properly qualified accordingly*

While comparing **CRG** with **non-CRG** applications in an overview, the difference is not much in the procedures involving general structural response/stress analysis or in the methods employed for such purposes, instead it is in (1) the specific qualification process in meeting both the strength (or the stress) and the serviceability (or deflection) requirements and (2) the logistics and handling of the ancillary services needed in taming the offshoot database maintenance issues

Regardless to how it's been done or not been done per **LRFD** or **ASD**, in the context of a full-fledged qualification session for a typical **CRG**, **serviceability** issue must be attended to under all circumstances for functional and practical reasons – no excuse whether its importance was downplayed as if second banana by many Engineers

In addition to **serviceability** matter, it is equally important to keep in mind that **CRG** design assignment is never ever "completed" or "finished" without addressing both "**non-fatigue**" and "**fatigue**" issues, i.e. for meeting performance requirements, there are basically two processes underlying a typical **CRG** strength design qualification session − one for fatigue strength assessment and the other for non-fatigue design mandate

Many among us who were enthusiastic at meeting the challenge on hand know it well, but not all do. The overoptimistic and/or unprepared ones might not realize what diving deep into **LRFD** on behalf of **CRG** at the deep end feel like. The goal is simple, the hard part is in how to sort it all out and consolidate from a swamp of information; the key is in how to come up with an effective strategy geared toward separating out the data in order to meet all design qualification intents.

Herein the swamp is the mixture of *torsion*, *fatigue, non-fatigue, **LRFD** and **ASD*** and that is where it hits − since all seemed joining hands together and churning things up all at same moment.

Let's say it was already opted for **LRFD** (not **ASD**) in meeting the "**non-fatigue**" qualification intent (using applicable factored load terms with applicable load factors, etc.) as the primary process, but to complete the job, there is still a need to conduct the **non-LRFD** counterpart (using service loads with suitable load factors) to fulfill both the "**serviceability**" and the "**fatigue**" related obligations as the companion process. Kind of confusing for those not familiar with the situation but here is a clearer message yet somewhat simplified:

*We may choose either **LRFD**- or **ASD**- based qualification procedures for non-fatigue assessment but we only need **ASD**- based procedures for serviceability and for fatigue assessment*

Even so, the two processes are as if the two sides of the same coin and are equally important in qualifying any **CRG** and its components therefore the usage of words primary and companion as the modifier here has no implication in signifying which one process is more or less important than the other

How to reach our goal of shooting for a **functional and fatigue-proof CRG** meanwhile expending minimum "data processing energy" becomes our next focus. Ideally, it is best not to duplicate the numerical efforts but to apply the same basic numerical processing logic across the board. The reason for that is quite obvious unless if not so obvious from the scenario depicted as follow:

If (1) **LRFD** were committed for General Structural Engineering purpose for the entire project and (2) **ASD** were applied only for **CRG** structures with limited subordinate project scope then the "same basic numerical processing routine" for the "loading combination" portion would have to be executed twice as we learned a couple of paragraphs ago − once for the **LRFD** non-fatigue assessment and the other for the **non-LRFD** "serviced load-based" process intended for both serviceability and fatigue strength evaluations

Regardless to whichever standard was chosen, and knowing that there would be stockpile of numbers − spread out in front of us on screen or hidden in read-only memory − if we had not carefully planned for a *data management strategy* for the worst then it could/would be a daunting "numerical" disarray to manipulate a mixed Dataset (a database term) to serve dual data management purposes: (1) factored load based **LRFD** and (2) Service load based process (although not necessary an **ASD** initiative, philosophically speaking)

As long as **LRFD** is being mandated, we could run into the same data management trouble (disarray) whether doing the task on pieces of scratch paper as in the olden days or through serious automation in this modern era. But in contrast if we opted for **ASD** scheme to begin with for the entire **CRG** project then the same "numerical" process based on service loads could be applied universally only once for all purposes, analytical or design, not twice.

Finallybut not the least, if we were fully prepared to (1) avoid clutters in connection with data depository and management issues and to be (2) numerically practical then we should stick with using one universal processing routine that being the most convenient approach, wouldn't that make better sense? *To those **factored-load** enthusiasts insist on applying **LRFD**, make sure the live load to dead load ratio is three before doing it*.

2. Crane Runway Girders as Building Components

Recalling the earlier comment:

> A decision should be made whenever allowing for **CRG's** interaction with or participation in the local and/or global framing performance evaluation as seem fit. *Nevertheless, except for situations in conflict with the Project Requirement or Corporate Standard Commitment, whether adopting **LRFD** or **ASD** should be an individual preference as to qualifying **CRG** as* <u>*standalone members*</u> *but do make sure the design is properly qualified accordingly*

In there the key phrases are (1) framing performance evaluation as seem fit and (2) properly qualified accordingly. Granted, opting for **LRFD** or **ASD** is an individual preference comes to handling load response analysis in general. Certainly, some can always insist on **LRFD** considering applications involving building roof live load, environmental loads such as wind and earthquake, etc., but, as far as **CRGs** and structures supporting **CRGs** are concerned, we should not use **LRFD** when the Live-load-to-dead-load-ratio is different from 3. Anyhow, **LRFD** warrants a yes to those persisting on for argument's sake but no for simplicity's sake.

CRG, together with other components/elements that make up the complete building system, is not a standalone entity; its support reaction must be absorbed by the framing in stages through connections to tie-backs, seat bolts and then spread out to cap plates, crane columns, building columns, roof trusses and foundations, etc.

The passage of load/reaction being transferred from **CRG** to foundation although follows a natural track but with lots of twists and turns; along the load path strictly speaking, any *fluctuation* in tension and *reversal* in shear befell upon one component/element can in turn affect the wellbeing of other elements near and far, not limited in the vicinity of girder. Herein the so-called wellbeing has everything to do with the component's *acquired margin of strength against material yielding, instability and most of all, metal fatigue*.

As documented in a number of inspection reports,

> Often times we see telltale failures within the girder's confine, yet external to which, we also see issues with tie-back bolts, seat bolts, column-to-roof-truss connection bolts, foundation anchor bolts, cracked building column flanges or sheared columns among others. Besides cracks in weld and base metal, the prevalent finding is missing or sheared bolts here and there; the most catastrophic finding is *sheared foundation anchor bolts* that take incessant beating from crane, wind and subbase pumping action, etc. befitting a perfect candidate to experience *fluctuation* in tension and *reversal* in shear

A general question to the Engineers:

> If the support reactions were *accurately* computed, for which if the connections were *properly* qualified then why do we see missing bolts and sheared bolts?

And then whoever designed it should give an honest answer:

> Has the connection been properly qualified against metal fatigue involving tensile force fluctuation and shear force reversal?

Coming back to the key phrases: (1) framing performance evaluation as seem fit and (2) properly qualified accordingly, what that brought to mind is − on behalf of proper **CRG** load transferring − all building components vulnerable to fatigue failure must be carefully assessed by default, for which there is no need of **LRFD**. From a broader perspective in design of structures housing **CRGs**, qualification against metal fatigue should apply to both the traditionally built structures and pre-fabricated buildings.