Nonconventional girder reinforcement can permit field work below a crane runway and minimizes downtime, avoids crane rail removal, reduces labor requirements, and significantly reduces girder vertical bending stresses.

Nonconventional crane runway girder reinforcement

Raymond S. Milman, Chief Structural Engineer, Middough Associates Inc., Cleveland, Ohio

UPGRADING of overhead traveling crane capacity requires, in most cases, replacement or reinforcement of the existing crane runway girders.

Replacement of the girder is the most expensive alternative. It can only be implemented when the girder reinforcement is physically impossible or more costly than the girder replacement.

Crane girder reinforcement is a challenging task for the design engineer. It involves not only a girder reinforcement design to meet strength and serviceability criteria, but also problems such as downtime in the crane operation to construct the reinforcement, interference with existing structures and equipment, and modifications of elements attached to the girder (eg, walkways, hot rails, piping, electrical conduit supports, etc).

Conventionally, an increase in the crane lifting capacity requires an increase of the crane runway girder vertical and horizontal section properties to satisfy biaxial bending criteria under the action of the increased crane vertical and horizontal loads. In addition, if vertical web shear design stresses exceed allowables, the girder web shall be reinforced.

Reinforcement of the girder top and bottom flanges is labor and time-consuming. The top flange reinforcement, in most cases, requires the removal of the crane rail, which means an extended downtime in the crane operation. A continuous-welded or bolted attachment of the reinforcement parts to top and bottom flanges is extremely costly from a labor point of view.

If a substantial increase in the crane lifted load is considered, the total cost (fabrication and field work) of a conventional method of crane girder reinforcement could exceed the cost of girder replacement.

A nonconventional approach, described in this article, includes two alternative methods of crane girder reinforcement. They allow a substantial increase in the crane lifted load and a significant reduction in the scope of the field work required to install the girder reinforcements. The two alternative methods are:

- Girder conversion into a truss-type structure.
- Crane load sharing between a crane girder and a beam installed below the crane girder.

Both of these methods are based on the concept of breaking the girder span into two or more continuous spans that are then supported by the elastic spring in the girder sections. In both cases, a design engineer can determine the optimum stiffness of the elastic spring to achieve both the desired crane girder vertical bending moment and shear reduction necessary to satisfy the strength and deflection criteria under the action of increased crane loads.

An installation of the truss-type modification also has a positive effect on crane columns. It increases column stability against out of plane buckling which could govern the crane column design. In addition, it also reduces the crane maximum vertical load on the girder seat as a result of a shear redistribution effect. This approach to crane girder reinforcement is extremely effective for small and medium-span girders 20 to 40 ft long. The only deficiency of the girder into truss conversion method is a requirement of available space below the crane girder bottom flange to install reinforcement details. If the space below the girder bottom flange is limited, the alternative approach—the girder load sharing method—is applicable.

Sizing of the reinforcement diagonals, lower chord members and support beams is performed based on an analysis of the modified girder system as an elastic frame. Utilization of a computer program with moving load features can be a convenient tool to determine a force envelope for each member of the system. By changing member sizes of new reinforcement members, the designer can achieve a desirable force distribution between the existing crane girder and new reinforcement members.

The following examples illustrate a design application of the nonconventional crane girder reinforcement approach.

Example 1

It is proposed to replace an existing 50-ton crane with a new 80-ton crane. The crane wheel vertical loads will increase from the present 64 to 89.5 kips, and the horizontal side thrust wheel loads will increase from 5 to 8 kips (*AISE* Technical Report No. 13, 1997 edition).

The existing crane runway 25 ft-0 in. girder is a built-up riveted design. It is constructed of steel with yield strength, $F_y = 33$ ksi.

The results of an analysis of the existing crane girder (Fig. 1a) follow.

Allowable bending stresses:

Top flange, $-F_{bx} = 0.66\ F_y = 21.8$ ksi

$F_{by} = 0.6\ F_y = 19.8$ ksi

Bottom flange, $-F_{bx} = 0.6\ F_y = 19.8$ ksi

Allowable shear stress:

$$-F_s = 0.4\ F_y = 13.2 \text{ ksi}$$

Design stresses in the existing girder resulting from action of the 80-ton crane:

Top flange, $f_{bx} = 22.4$ ksi, with impact, $f_{by} = 6.1$ ksi.

Checking the combined biaxial bending limit in accordance with *AISE* Technical Report No. 13, 1997 edition, for the top flange:

$$\frac{22.4}{21.8} + \frac{6.1}{19.8} = 1.03 + 0.31 = 1.34$$

Since 1.34 > 1.0, the limit is exceeded.

For the bottom flange:

$f_{bx} = 27.7$ ksi, with impact > 19.8 ksi, which is too high.

For the vertical web shear:

$f_s = 16.2$ ksi > 13.2 ksi, which is too high.

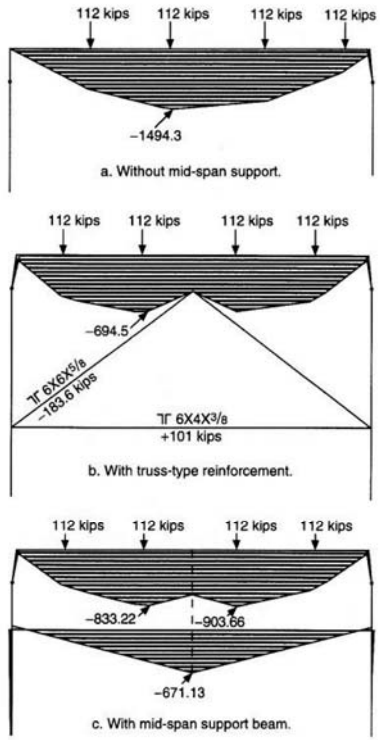

Fig. 1 — Example No. 1—Crane girder bending moment diagrams for alternative reinforcements associated with new 80-ton crane: a. Without mid-span support; b. With truss-type reinforcement; and c. With mid-span support beam.

The crane girder reinforcement analysis was performed using STAAD-III "Structural Analysis and Design Software." The crane runway was modeled as a longitudinal frame loaded with moving crane wheel loads.

Truss-type girder reinforcement — After several computer program runs with various member properties for diagonals and struts, the optimal diagonals 2L 6 x 6 x 5/8 and struts 2L 6 x 4 x 3/8, in ASTM 572, Grade 50 steel were chosen for design.

The results of the analysis illustrated in Fig. 1b are:

$M_{max.\ vertical}$ = 694.5 ft–kip, which compares with 1494.3 ft–kip for single-span girder (Fig. 1a).

$V_{max.\ vertical}$ = 212.6 kips, which compares with 291 kips for a single-span girder.

For the top flange, f_{bx} = 10.3 ksi, with impact f_{by} = 5.6 ksi

Checking the combined biaxial bending limit

$$\frac{10.3}{21.8}+\frac{5.6}{19.8}=0.47+0.28=0.75$$

Since 0.75 < 1.0, limit is not exceeded.

Vertical shear stress, F_s = 11.8 ksi < 13.2 ksi, is also within limits.

Crane load-sharing with mid-span support beam — Crane girders located over the entrance door and electrical room do not have sufficient space to install the truss-type reinforcement. Installation of a load-sharing beam requires substantially less space below the girder.

The results of a stress analysis are illustrated in Fig. 1c. A proper size support beam was determined, by trial and error, to be W33 x 152.

The load distribution in the existing girder and the W33 support beam are shown in Table I.

TABLE I **Load distribution in existing girder and support beam**

Load	Existing girder	Support beam
Vertical bending, M_{max}, ft–kip	904	671
Vertical shear, V_{max}, kip	228	54

Checking the reinforced girder:

Top flange, f_{bx} = 13.5 ksi, with impact, f_{by} = 5.6 ksi

Combined axial bending,

$$\frac{13.5}{21.8}+\frac{5.6}{19.8}=0.62+0.28=0.9$$

Since 0.9 < 1.0, limit is not exceeded.

Vertical shear stress, fs = 12.7 ksi < 13.2 ksi, is also within limits.

Checking W33 support beam:
$-f_{bx}$ = 16.5 ksi < 21.6 psi, ie, within limits.

Reinforcement details are shown in Fig. 2.

Example No. 2

It was proposed to replace an existing 15-ton crane with a new 25-ton crane. The design crane wheel load is increased from 39.5 to 56 kips. The 42 ft–3in. crane girder consists of

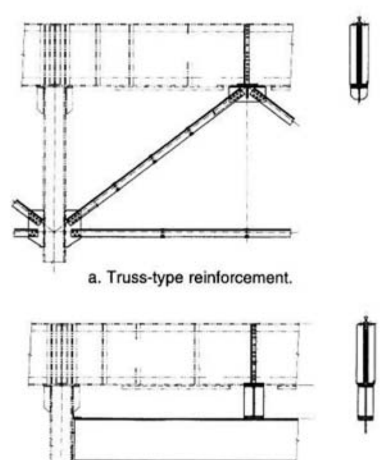

Fig. 2 — Example No. 1—Crane girder alternative reinforcement details associated with new 80-ton crane: a. Truss-type reinforcement; and b. Mid-span support beam.