6. Design Procedure

6.1. Design for strength

Structural design codes give standardised design procedures for verifying the bending and lateral buckling strength, web shear strength and stability and connection strength. The design procedures stipulated in, AS 1418.18 should be regarded as complimentary with AS 4100 rules. With a view to minimise the design effort, AS 1418.18 categorises the runways into Light Duty for structural classes S1 to S7 and Heavy Duty for structural classes S8 and S9. The intention of the code committee was that full local detail checks for the top flange region are only necessary for Heavy Duty category runways. The author believes all crane runways should be checked.

There will be situations where a runway classified as S4 to S7 should be treated as the Heavy Duty category (heavy maintenance, steel mills, potroom service and general warehouse cranes). This is because the local stresses interact with the global stresses and this may lead to overstress.

AS 1418.18 standard covers some of the specialised design aspects of runway girders, such as: -

- Direct bearing stress distribution under the rail and in loaded flange to web junction.
- Local torsion in the upper flange region induced by lateral forces and wheel loads acting eccentrically with respect to the mid-plane of the web.
- Material type and thickness to avoid brittle fracture at low operating temperature. Already at +5 degrees C, plates in tension thicker than 20 mm should be of a steel exhibiting enhanced notch ductility, for example grades 300 -L0 and -L15, known as fully killed steels.
- Strict manufacturing and erection tolerances specified in the steel and runway codes must be achieved in practice because the code provisions are only valid for members fabricated and erected within those tolerances. Of special importance are the dimensional and alignment tolerances.
- Fatigue resistance should be considered in parallel with the detail design because in the majority of cases, the fatigue considerations govern the design of crane runways of structural classes S4 and over. It is best to specify details having the highest practicable fatigue detail category.
- Serviceability requirements such as deflections and twists should be checked against the specified limits as the design progresses.

Bending capacity is adequately covered in AS 4100. Interaction between bending and shear is covered in AS 4100, Section 5.12, which basically reduces the bending moment capacity when accompanied with relatively large shear forces. This starts to operate where M^* is larger than $0.75M_S$.

6.2. Torsion

Torsion arises from lateral loads applied at the top of rail level and the eccentric application of vertical loads, that is, from the couples $N_w e_y$ and $H h_t$, see Figure 12(c). The eccentricity e_y has been specified in AS 1418.18 as consisting of two parts:

$$e_y = \frac{B_{te}}{k} + \frac{L}{1000}$$

where B_{te} is the effective railhead width,
k is an eccentricity factor;
k = 8 for rails with convex heads and
k = 4 for crane rails with flat head and rectangular bars.
This is a variation on the traditional $0.25B_{te}$ allowance.

The second term, L/1000 is for the lateral camber induced eccentricity based on tolerance for camber. AS 1418.18 allows the designer to neglect the second term when designing Light Duty runways. The author's opinion is that the camber induced eccentricity should be applied to all runways.

The torsion moment is a summation of ($N^*_{wi}\, e_y + H^*_{yt}\, h_T$) terms. Using the 'twin beam' analogy the lateral forces in flanges counteract the torsion moment alone and the contribution from pure torsion is neglected, see references 6, 55, 84 and 87.

Lateral forces acting on the top flange at each wheel (see Fig. 12) are given by

$$H^*_{ti} = \frac{M^*_{Ti} + N^*_{yi}\, c_1}{h}$$

and the bottom flange forces:

$$H^*_{bi} = \frac{-\, M^*_{Ti} + N^*_{yi}\, c_2}{h}$$

where $M^*_{Ti} = N^*_{wi}\, e_y + N^*_{yi}\, h_t$

These forces, applied laterally to the flanges, result in lateral bending moments, M^*_{yt} and M^*_{yb} as shown in Figure 12. It only remains to check the critical sections for combined actions.

$$\frac{M^*_x}{\phi M_{bx}} + \frac{M^*_{yt}}{\phi M_{sty}} \le 1.0$$

where M^*_x is the major axis moment in vertical plane; M^*_{yt} is the lateral bending moment in the top (compression) flange; M_{bx} is the design moment capacity in vertical plane and M_{sty} is the lateral moment capacity of the top flange alone. M_{bx} is determined in accordance with member capacity of monosymmetric beams in AS 4100.

6.3. Torsion Capacity by rigorous method

Torsion induced by the lateral loads and rail contact eccentricity is not covered in AS 4100 at this stage. Rigorous methods of torsional analysis are described in references 49, 54, 55, 57, 80, 82, 84 but these tend to be cumbersome for practical application.

6.4. Lateral stability of the runway girder

Runway girders are normally restrained in the lateral direction at the supports only and usually have no intermediate lateral restraints. Intermediate lateral restraints can be beneficial but not easy to detail.

AS 4100 specifies an effective length factor of 1.40 where the loads are applied to the top of the girder flange. The fact that the loads are actually applied some distance above the top flange need not be considered because of the beneficial influence of linkage between the opposite side girders via the crane bridge. The verification of the lateral stability is to be carried out in accordance with AS 4100, as modified below. .

The usual construction of light duty, low capacity runway girders is in form of a compound girder consisting of a UB section and Inverted top channel. This type of girder is termed monosymmetric girder. The warping constant used for symmetric and monosymmetric girders is given in AS 4100, Appendix H -

$$I_w = I_{cy} d_f^2 \left(1 - \frac{I_{cy}}{I_y}\right)$$

where

I_{cy} = minor axis second moment of area of the top flange alone.
I_y = minor axis second moment of area for the whole section.
d_f = distance between centroids of flanges.

Recent research reported in Ref 88, Woolcock et al shows that AS 4100 method for monosymmetric girders can be unconservative. Neither method makes allowances for the beneficial effect of coupling via the crane bridge girders, such that the side carrying larger load receives some lateral support by the side under lower load.

As indicated in section 6.3 there is an interaction between the torsion and lateral buckling, and this is currently taken into consideration by using the effective length factor k_e = 1.4.

6.5. Box Sections

The method of stress analysis for box girder is described in Bennets and Grundy, ref 21. The dilemma is how to position the rail. Eccentric, over the web rail position is preferred in spite of imposition of large eccentricity. That should not be a problem because the box section has a relatively high resistance to torsion. The other option is to position the rail onto the centreline of the girder and cross stiffen the top plate at close centres. The latter method is costly and introduces a large number of fatigue prone welded connections.

The most important thing with box girders is the prevention of sectional distortion by means of diaphragm plates, stiff cross frames or cross bracing. The spacing of diaphragms can be as little as the depth of the girder or as much as one third span. Once diaphragms are provided the box girder will behave very much as an I-girder, but will have very much larger torsional stiffness.

Crane Runway Girders

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