

The maximum clear vertical opening between succeeding rails or posts shall be as specified in Articles 13.8, 13.9, and 13.10.

### A13.1.2—Anchorages

The yield strength of anchor bolts for steel railing shall be fully developed by bond, hooks, attachment to embedded plates, or any combination thereof.

Reinforcing steel for concrete barriers shall have embedment length sufficient to develop the yield strength.

### A13.2—TRAFFIC RAILING DESIGN FORCES

Unless modified herein, the extreme event limit state and the corresponding load combinations in Table 3.4.1-1 shall apply.

Railing design forces and geometric criteria to be used in developing test specimens for a crash test program should be taken as specified in Table A13.2-1 and illustrated in Figure A13.2-1. The transverse and longitudinal loads given in Table A13.2-1 need not be applied in conjunction with vertical loads.

The effective height of the vehicle rollover force is taken as:

$$H_e = G - \frac{12WB}{2F_t} \quad (\text{A13.2-1})$$

where:

- $G$  = height of vehicle center of gravity above bridge deck, as specified in Table 13.7.2-1 (in.)
- $W$  = weight of vehicle corresponding to the required test level, as specified in Table 13.7.2-1 (kips)
- $B$  = out-to-out wheel spacing on an axle, as specified in Table 13.7.2-1 (ft)
- $F_t$  = transverse force corresponding to the required test level, as specified in Table A13.2-1 (kips)

Railings shall be proportioned such that:

$$\bar{R} \geq F_t \quad (\text{A13.2-2})$$

$$\bar{Y} \geq \frac{H_e}{12} \quad (\text{A13.2-3})$$

in which:

$$\bar{R} = \sum R_i \quad (\text{A13.2-4})$$

$$\bar{Y} = \frac{\sum (R_i Y_i)}{\bar{R}} \quad (\text{A13.2-5})$$

### CA13.1.2

Noncorrosive bonding agents for anchor dowels may be cement grout, epoxy, or a magnesium phosphate compound. Sulfur or expansive-type grouts should not be used.

Some bonding agents on the market have corrosive characteristics; these should be avoided.

Development length for reinforcing bars is specified in Section 5.

### CA13.2

Nomenclature for Eqs. A13.2-1 and A13.2-2 is illustrated in Figure CA13.2-1.

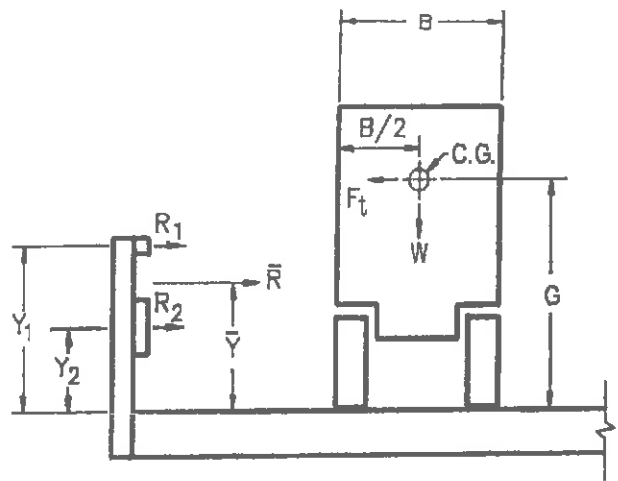


Figure CA13.2-1—Traffic Railing

If the total resistance,  $\bar{R}$ , of a post-and-beam railing system with multiple rail elements is significantly greater than the applied load,  $F_t$ , then the resistance,  $R_i$ , for the lower rail element(s) used in calculations may be reduced.

The reduced value of  $\bar{R}$  will result in an increase in the computed value of  $\bar{Y}$ . The reduced notional total rail resistance and its effective height must satisfy Eqs. A13.2-2 and A13.2-3.

where:

$R_i$  = resistance of the rail (kips)

$Y_i$  = distance from bridge deck to the  $i$ th rail (ft)

All forces shall be applied to the longitudinal rail elements. The distribution of longitudinal loads to posts shall be consistent with the continuity of rail elements. Distribution of transverse loads shall be consistent with the assumed failure mechanism of the railing system.

Eq. A13.2-1 has been found to give reasonable predictions of effective railing height requirements to prevent rollover.

If the design load located at  $H_e$  falls between rail elements, it should be distributed proportionally to rail elements above and below such that  $Y \geq H_e$ .

As an example of the significance of the data in Table A13.2-1, the length of 4.0 ft for  $L_t$  and  $L_L$  is the length of significant contact between the vehicle and railing that has been observed in films of crash tests. The length of 3.5 ft for TL-4 is the rear-axle tire diameter of the truck. The length of 8.0 ft for TL-5 and TL-6 is the length of the tractor rear tandem axles: two 3.5-ft diameter tires, plus 1.0 ft between them.

$F_v$ , the weight of the vehicle lying on top of the bridge rail, is distributed over the length of the vehicle in contact with the rail,  $L_v$ .

For concrete railings, Eq. A13.2-1 results in a theoretically-required height,  $H$ , of 34.0 in. for TL-4. However, a height of 32.0 in., shown in Table A13.2-1, was considered to be acceptable because many railings of that height have been built and appear to be performing acceptably.

The minimum height,  $H$ , listed for TL-1, TL-2, and TL-3 is based on the minimum railings height used in the past. The minimum effective height,  $H_e$ , for TL-1 is an estimate based on the limited information available for this test level.

The minimum height,  $H$ , of 42.0 in., shown in Table A13.2-1, for TL-5 is based on the height used for successfully crash-tested concrete barrier engaging only the tires of the truck. For post and beam metal bridge railings, it may be prudent to increase the height by 12.0 in. so as to engage the bed of the truck.

The minimum height,  $H$ , shown in Table A13.2-1, for TL-6 is the height required to engage the side of the tank as determined by crash test.

**Table A13.2-1—Design Forces for Traffic Railings**

Design Forces and Designations	Railing Test Levels					
	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6
$F_t$ Transverse (kips)	13.5	27.0	54.0	54.0	124.0	175.0
$F_L$ Longitudinal (kips)	4.5	9.0	18.0	18.0	41.0	58.0
$F_v$ Vertical (kips) Down	4.5	4.5	4.5	18.0	80.0	80.0
$L_t$ and $L_L$ (ft)	4.0	4.0	4.0	3.5	8.0	8.0
$L_v$ (ft)	18.0	18.0	18.0	18.0	40.0	40.0
$H_e$ (min) (in.)	18.0	20.0	24.0	32.0	42.0	56.0
Minimum $H$ Height of Rail (in.)	27.0	27.0	27.0	32.0	42.0	90.0



- $L_t$  = longitudinal length of distribution of impact force  $F_t$  (ft)  
 $R_w$  = total transverse resistance of the railing (kips)  
 $M_b$  = additional flexural resistance of beam in addition to  $M_w$ , if any, at top of wall (kip-ft)  
 $M_c$  = flexural resistance of cantilevered walls about an axis parallel to the longitudinal axis of the bridge (kip-ft/ft)  
 $M_w$  = flexural resistance of the wall about its vertical axis (kip-ft)

For use in the above equations,  $M_c$  and  $M_w$  should not vary significantly over the height of the wall. For other cases, a rigorous yield line analysis should be used.

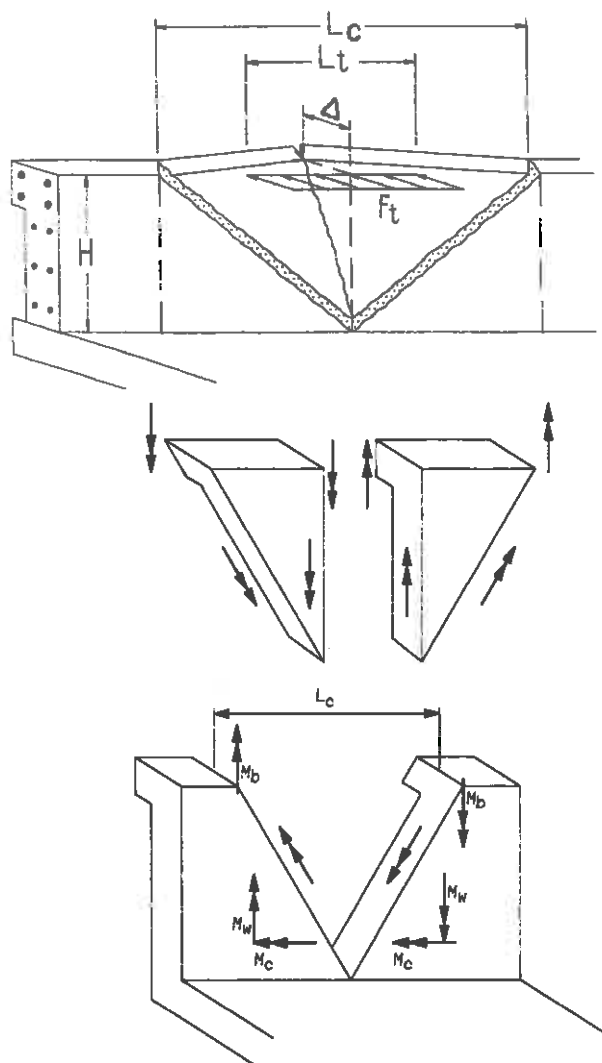


Figure CA13.3.1-1—Yield Line Analysis of Concrete Parapet Walls for Impact within Wall Segment