

Transferring Forces through a Sheet Metal Curb

Sheet metal curbs must be considered as non-structural items. The sides of a sheet metal curb have no load-carrying capability unless they form a closed section in the plan view. The sides must be fully attached to one another for the full height of the curb in order to generate full strength in the individual sides. Figure 6.2.3-1, shown below, presents one side of a typical sheet metal curb and the loads that the curb may be expected to carry.

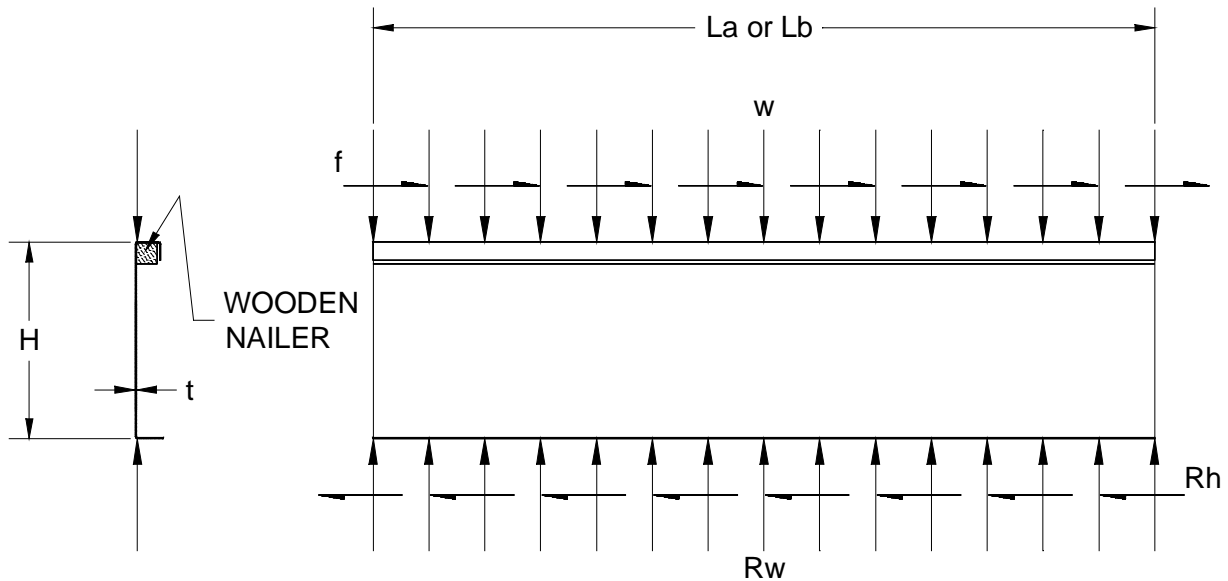


Figure 6.2.3-1. Loading on a Sheet Metal Curb.

H is the height of the curb, and t is the thickness of the sheet metal used in the construction of the curb. The lengths represented by L_a and L_b are the inside lengths of the long sides and the short sides of the curb, respectively. For the sake of simplicity, assume that the weight of the equipment is evenly distributed around the perimeter of the curb. This is close enough to the truth for our purposes assuming that the CG of the equipment is more or less, located at the geometric center of the plan view of the curb. This distributed weight load is denoted by w . The value of w may be determined by considering a typical plan view for a rectangular curb as in Figure 6.2.3-2. The distributed weight load will be given by the following equation.

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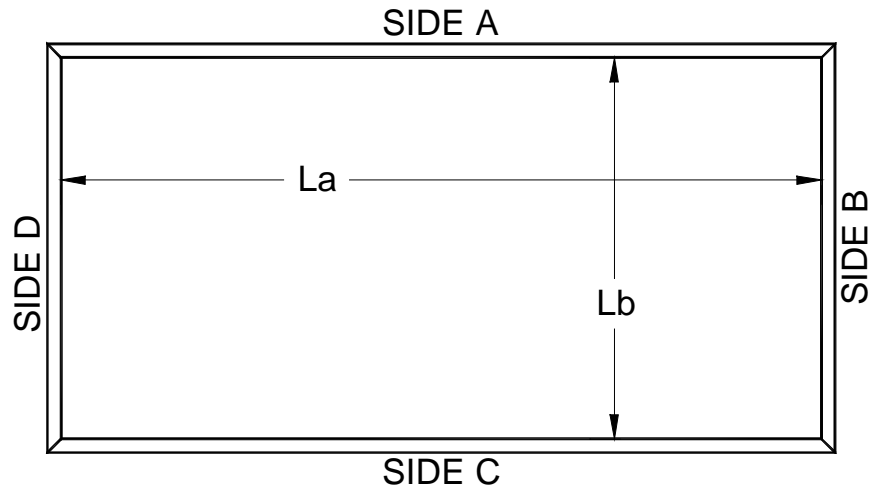


Figure 6.2.3-2. Plan View of a Rectangular Sheet Metal Curb.

$$w = W / (2(L_a + L_b)) = W / L_p \quad \text{(Eq. 6.2.3-1)}$$

where W is the weight of the equipment, and L_p is the length of the inside perimeter of the curb.

The horizontal seismic force acting on the curb is shown as a uniformly distributed shear load (f) acting along the top of the curb. The terms R_w and R_h are the reactions for the distributed weight load, and distributed seismic force respectively.

It is very important to realize that the walls of the curb can only carry loads in the plane of the wall. The curb wall can not effectively resist forces that act perpendicular to the wall of the curb. This is especially true if the sides of the curb are long. The walls of the curb are very thin plates that are loaded in compression on the top and bottom edges by the distributed weight load of the equipment. The horizontal seismic load will be a distributed shear load along the top and bottom edges.

Failure of the curb wall will generally be by buckling. Buckling is a very dangerous and catastrophic failure mode. It is dangerous because it occurs at a stress that is well below the yield point of the materials. It is catastrophic because the collapse is usually complete.

For a given curb height and material thickness there is a critical equipment weight in the absence of a seismic load that will buckle the curb. Table 6.2.3-1 identifies the variation in the critical equipment weight on the curb wall with the height of the curb (H) and the thickness of the curb material (t). Again the critical equipment weight (w') is in terms of the

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distributed weight of the equipment. Note that the load carrying ability of the curb will

Table 6.2.3-1. Critical Equipment Weight (w') (lbs./in.).

CURB HEIGHT (H) (in.)	w' FOR MATERIAL THICKNESS 14 GAGE $t = 0.0747$ in.	w' FOR MATERIAL THICKNESS 16 GAGE $t = 0.0598$ in.	w' FOR MATERIAL THICKNESS 18 GAGE $t = 0.0478$ in.
14.0	57.66	29.58	15.11
15.0	50.23	25.77	13.16
18.0	34.88	17.90	9.14
21.0	25.63	13.15	6.71
24.0	19.62	10.07	5.14
27.0	15.50	7.95	4.06
30.0	12.56	6.44	3.29
33.0	10.38	5.32	2.72
36.0	8.72	4.47	2.28

decrease by approximately 70% as the thickness of the curb material decreases from 14 gage to 18 gage. In addition, there is an 80% decrease in the load-carrying capability of the curb as its height is increased from 14 inches to 36 inches. Thus great care must be exercised when placing large pieces of equipment on curbs fabricated from the lighter gages of steel or when placing large pieces of equipment on extended-height curbs.

As one might expect, there is a critical horizontal seismic distributed load (f') that, when applied to the top edge of the curb, will cause the curb to fail in buckling. The critical seismic load will be a function of the height of the curb, the material thickness, and the weight of the equipment being supported by the curb. For ease of use, the equipment weight can be represented as an evenly distributed load (w). The variation of this critical seismic load with the variables mentioned above is shown in Tables 6.2.3-2, 6.2.3-3, and 6.2.3-4.

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Table 6.2.3-2. Critical Seismic Load for a 14 Gage Curb ($t = 0.0747$ in.).

W lbs./in.	0.00	5.00	10.00	20.00	30.00	40.00	50.00	55.00
H (in.)	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.
14.0	326.2	320.8	315.1	302.6	288.3	271.0	247.1	227.9
15.0	284.2	278.7	272.9	260.1	244.9	224.8	181.8	N/A
18.0	197.3	191.8	185.8	171.5	150.2	N/A	N/A	N/A
21.0	145.0	139.4	133.0	115.7	N/A	N/A	N/A	N/A
24.0	111.0	105.3	98.4	N/A	N/A	N/A	N/A	N/A
27.0	87.7	81.9	74.3	N/A	N/A	N/A	N/A	N/A
30.0	71.0	65.0	56.2	N/A	N/A	N/A	N/A	N/A
33.0	58.7	52.5	40.5	N/A	N/A	N/A	N/A	N/A
36.0	49.3	42.9	N/A	N/A	N/A	N/A	N/A	N/A

Table 6.2.3-3. Critical Seismic Load for a 16 Gage Curb ($t = 0.0598$ in.).

W lbs./in.	0.00	2.50	5.00	10.00	15.00	20.00	25.00	30.00
H (in.)	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.
14.0	167.4	164.6	161.8	155.6	148.5	140.0	128.7	N/A
15.0	145.8	143.1	140.2	133.8	126.3	116.6	99.4	N/A
18.0	101.2	98.5	95.5	88.4	78.2	N/A	N/A	N/A
21.0	74.4	71.6	68.4	60.0	N/A	N/A	N/A	N/A
24.0	56.9	54.1	50.7	36.8	N/A	N/A	N/A	N/A
27.0	45.0	42.1	38.3	N/A	N/A	N/A	N/A	N/A
30.0	36.4	33.5	29.2	N/A	N/A	N/A	N/A	N/A
33.0	30.1	27.0	21.4	N/A	N/A	N/A	N/A	N/A
36.0	25.3	22.1	N/A	N/A	N/A	N/A	N/A	N/A

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Table 6.2.3-4. Critical Seismic Load for an 18 Gage Curb ($t = 0.0478$ in.).

W lbs./in.	0.00	2.50	5.00	7.50	10.00	12.50	15.00	20.00
H (in.)	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.	f' lbs./in.
14.0	85.5	82.7	79.6	76.1	71.9	66.4	55.3	N/A
15.0	74.5	71.7	68.5	64.8	60.0	52.3	N/A	N/A
18.0	51.7	48.8	45.3	40.4	N/A	N/A	N/A	N/A
21.0	38.0	35.0	30.9	33.8	N/A	N/A	N/A	N/A
24.0	29.1	26.0	19.8	N/A	N/A	N/A	N/A	N/A
27.0	23.0	19.7	N/A	N/A	N/A	N/A	N/A	N/A
30.0	18.6	15.0	N/A	N/A	N/A	N/A	N/A	N/A
33.0	15.4	11.2	N/A	N/A	N/A	N/A	N/A	N/A
36.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note that no safety factor has been applied to any of the values in Tables 6.2.3-1, 6.2.3-2, 6.2.3-3, or 6.2.3-4. These values should not be used for design or certifying sheet metal curbs for seismic applications unless a factor of safety of not less than 2:1 is applied to them. Values listed as "N/A" indicate combinations of equipment load, curb height, and material thickness that are absolutely not viable for seismic applications. They indicate that a thicker gage of material must be used for the construction of the curb. In the case of Table 6.2.3-2, the combinations that are marked "N/A" indicate that a structural seismic curb is required.

An obvious conclusion drawn from Tables 6.2.3-2, 6.2.3-3, and 6.2.3-4 is that if the equipment load could be carried by components other than the wall of the curb, the seismic load-carrying capacity of the curb could be maximized. The most cost-effective method of providing vertical reinforcement to carry the equipment weight load is to use treated wood 2 X 4's or 2 X 2's. This is usually the same material that is used for the nailer at the top of the curb. A typical view of the side of a curb that has been vertically reinforced with 2 X 2's is shown in Figure 6.2.3-3. This figure shows the minimum number of vertical reinforcements. A vertical reinforcement is required on each end of the side of the curb with at least one additional member located in the middle. Table 6.2.3-5 gives the maximum allowable vertical reinforcement spacing (S) as a function of the curb height, and the equipment weight load. These reinforcement members must be cut to fit tightly between the underside of the nailer or curb lip and the top of the structural support member at the base of the curb. If a gap exists they will not function properly. The controlling failure mode is buckling. For selection purposes in the table below, a factor of safety of 4:1 was applied to the vertical reinforcements to account for the variation in grade and structure of the treated wood 2 X 2's. Table 6.2.3-5 indicates that for many cases the minimum number of vertical reinforcements will be sufficient to carry the weight

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of the equipment.

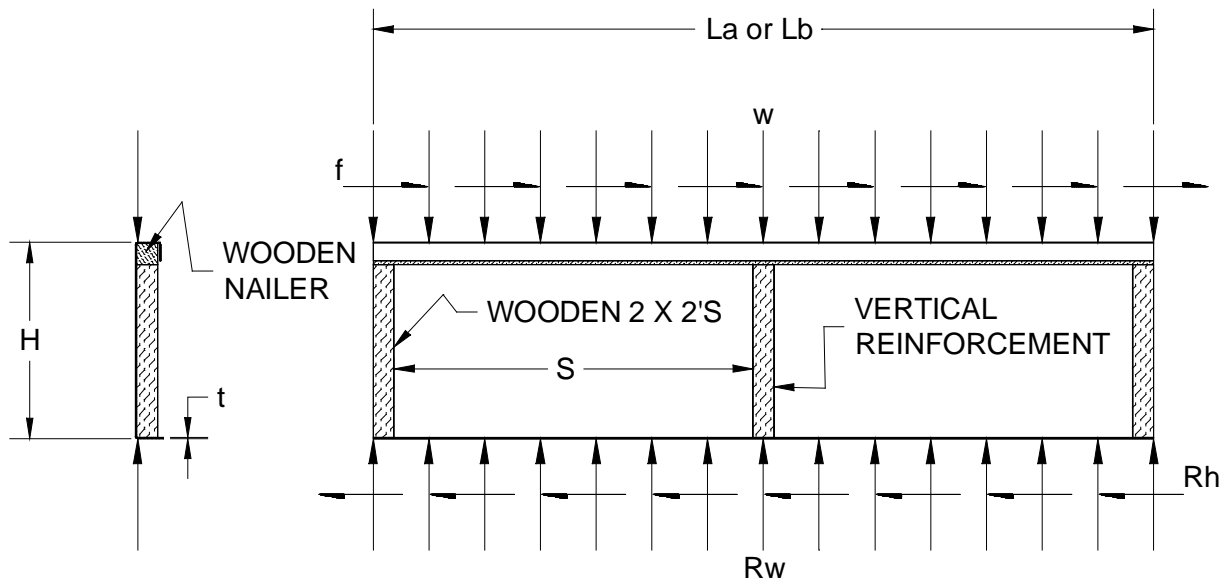


Figure 6.2.3-3. Typical Vertically Reinforced Curb.

Table 6.2.3-5. Maximum Spacing for Vertical Reinforcements – Treated Wood 2x2's – Factor of Safety = 4:1 with Respect to Buckling.

w lbs./in.	0.00	5.00	10.00	20.00	30.00	40.00	50.00	55.00
H (in.)	S (in.)	S (in.)	S (in.)	S (in.)	S (in.)	S (in.)	S (in.)	S (in.)
14.0	2,762	1,381	690	345	230	173	138	126
15.0	2,406	1,203	601	401	200	150	120	109
18.0	1,671	835	418	209	139	104	84	76
21.0	1,227	614	307	153	102	77	61	56
24.0	940	470	235	117	78	59	47	43
27.0	743	371	186	93	62	46	37	34
30.0	601	301	150	75	50	38	30	27
33.0	497	249	124	62	41	31	25	23
36.0	418	209	104	52	35	26	21	19

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In the course of a seismic event, the most significant vertical seismic loads occur at the corners of the curb. This type of load will put the curb wall in bending. In the presence of a horizontal seismic load, a vertical seismic load will cause the load-carrying ability of the curb to drop to an unacceptable level. Thus vertical seismic loads should be transferred from the equipment to the building structure in as direct a manner as possible. The mode of transfer must minimize the bending moments in the curb wall to maintain the ability of the curb to carry the equipment weight load and the horizontal seismic load.

The distribution of the horizontal seismic load is addressed through a rational analysis. Figure 6.2.3-4 shows the plan view of a curb with the equipment CG at the center of

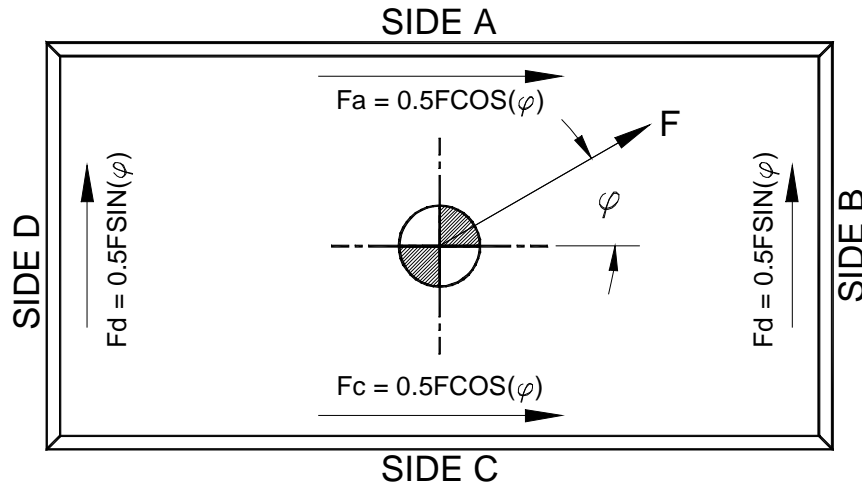


Figure 6.2.3-4. Seismic Loading of Curb.

the curb. In this figure F is the horizontal seismic force. The angle ϕ represents the direction of motion for the seismic wave front. Since the curb wall can transfer forces only in the plane of the wall as previously discussed, the forces carried by the individual curb walls will be as shown in Figure 6.2.3-4. The resulting distributed seismic force acting on the long sides of the curb will be equal to

$$f_a = (0.5/L_a)F \cos \phi. \quad \text{(Eq. 6.2.3-2)}$$

In a similar fashion, the distributed seismic force acting on the short sides of the curb will be

$$f_b = (0.5/L_b)F \sin \phi. \quad \text{(Eq. 6.2.3-3)}$$

Note that the ability of a sheet metal curb to resist a horizontal seismic load depends on

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the length of the curb available to carry the loads. Thus, the worst-case scenario for a curb would occur when \bar{f} was equal to 90 degrees. The seismic load is parallel to the short sides of the curb, which means that the short sides of the curb must be able to resist the entire horizontal seismic load. So, for calculation purposes, the distributed seismic load on the short sides of the curb would be as follows.

$$f_n = 0.5F/L_b \quad \text{(Eq. 6.2.3-4)}$$

Equations 6.2.3-1 and 6.2.3-4 with Tables 6.2.3-1 through 6.2.3-4, along with a healthy factor of safety, allow us to determine the suitability of a given curb in a specified seismic application. Since the curb walls are very thin compared to any other dimensions, any dents, creases, or other defects will drastically lower the critical buckling loads, a factor of safety in the range of 3:1 or 4:1 is considered appropriate to account for the possibility of such minor damage. Major damage must be corrected.

The last issue that must be addressed is the presence of large-scale penetrations in the curb walls. Screw and pop rivet holes are not considered to be large-scale holes. Large-scale penetrations are those that are made for ducts, pipes, or conduits. Figure 6.2.3-5 shows a rectangular penetration for a duct.

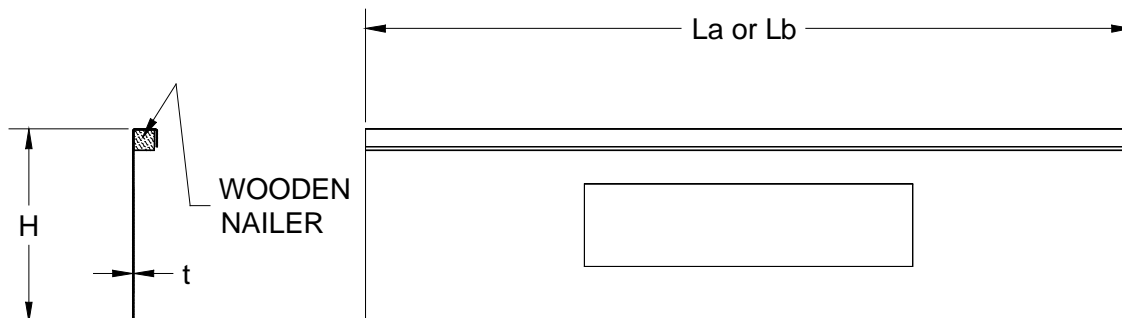


Figure 6.2.3-5. Typical Duct Penetration.

If left un-reinforced, this penetration would eliminate any significant seismic load-carrying ability for that side of the curb. However, in some case an appropriate reinforcement scheme for a duct penetration, similar to that shown in Figure 6.2.3-6, can be added. In

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this scheme, the reinforcement “ring” made out of sheet metal is placed around the hole.

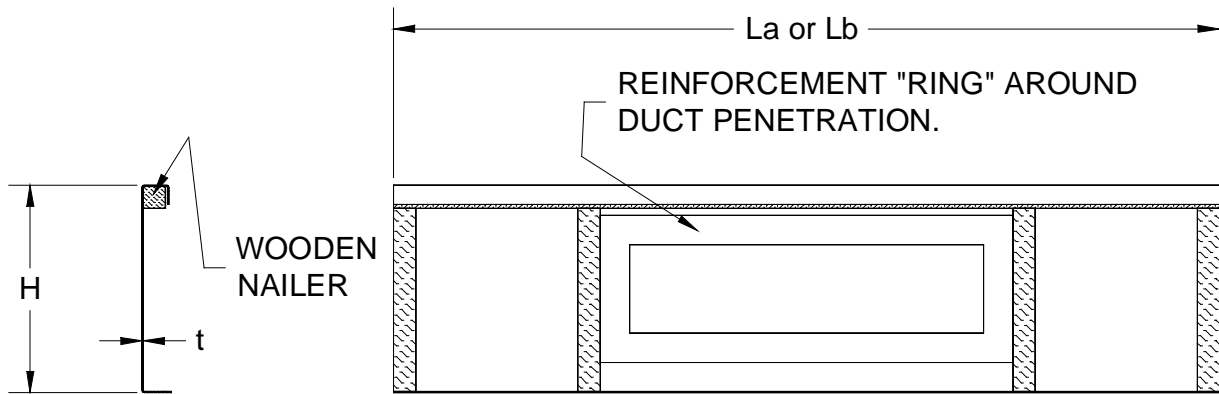


Figure 6.2.3-6. Reinforcement of Duct Penetrations.

The ring must have a thickness equal to or greater than that of the curb wall and extend at least 2 inches beyond the penetration. The “ring” must be pop riveted, screwed, or spot welded in place. Enough fasteners should be used to ensure that the loads are transferred to the “ring.” In addition to the ring, vertical restraints made up of treated wood 2 X 2’s should be placed as shown in Figure 6.2.3-6. The total seismic load carrying ability of this side of the curb should be reduced as follows:

$$f_{ap} = 0.5F / (L_a - L_h) \quad \text{(Eq. 6.2.3-5)}$$

and,

$$f_{bp} = 0.5F / (L_b - L_h) \quad \text{(Eq. 6.2.3-6)}$$

In these two equations, f_{ap} and f_{bp} are the distributed horizontal seismic loads carried by the long and short sides, respectively, of a curb with a duct penetration in one of the walls. The term L_h represents the length of the duct penetration. Another type of penetration is a circular penetration for either a pipe or a cable conduit. This type of penetration is shown in Figure 6.2.3-7. These penetrations are much smaller than the one for a duct. “Ringing” these penetrations as shown in Figure 6.2.3-8 should provide sufficient reinforcement without the loss of seismic load-carrying capacity. The “rings” should have the same thickness as the walls of the curb and extend at least 2 inches beyond the penetration. The attachment may be by pop rivet, screw, or spot weld. A sufficient number of fasteners

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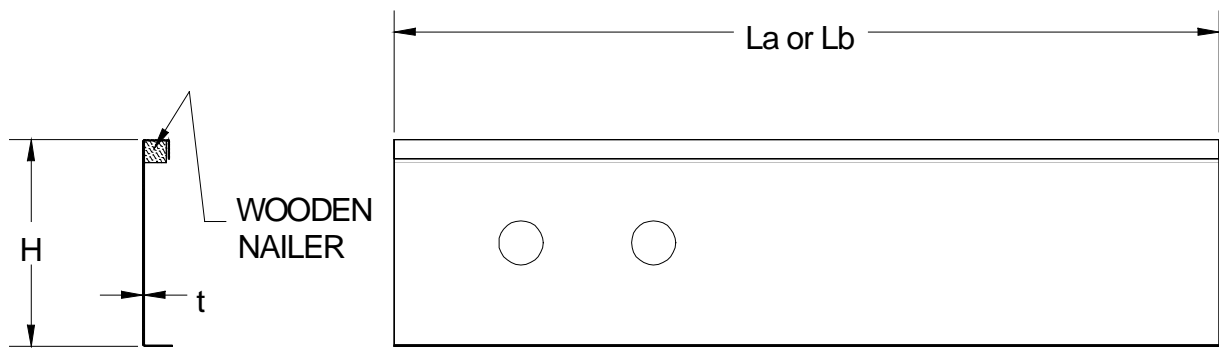


Figure 6.2.3-7. Typical Piping/Conduit Penetrations.

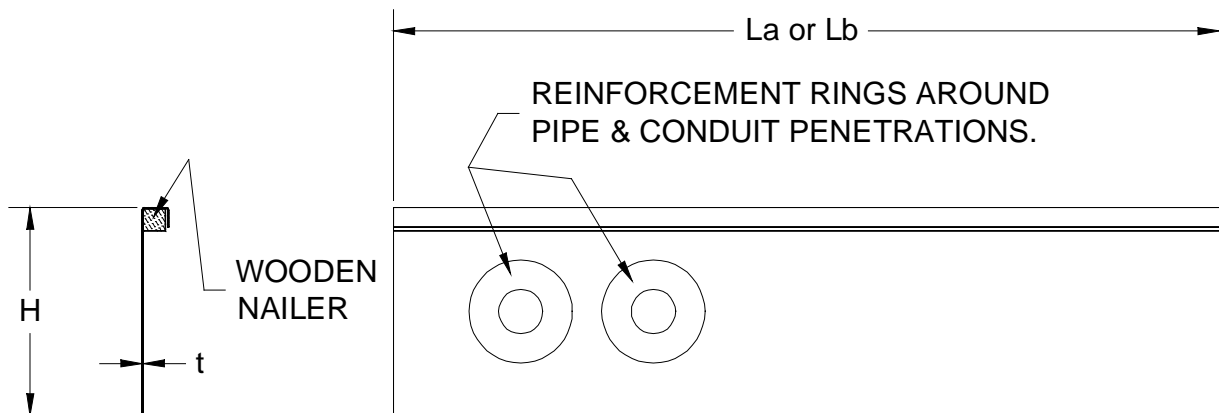


Figure 6.2.3-8. Reinforcement of Piping/Conduit Penetrations.

must be used to ensure that loads are effectively transferred to the reinforcing “rings.”

The intent of this document is to provide input and guidance as to how loads are transferred through a sheet metal curb. The tables and equations presented in this document may be used with factors of safety of 3:1 to 4:1 in order to estimate the performance of a curb for a specific seismic application. However, prior to installation a thorough analysis should be made by the curb manufacturer or KINETICS NOISE CONTROL.

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