STATE OF CALIFORNIA
TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

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TRAFFIC BULLETIN NO. 15

A METHOD FOR CHECKING THE INTEGRITY OF CABLE AND BEAM BARRIERS

APRIL 25, 1967

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SUBJECT: Method for Checking the Integrity of Cable and Beam Barriers.

The effectiveness of the cable barrier is extremely sensitive to the height of the cable; to the differences in cross slopes within the median, the adjacent traffic lanes and shoulders; and to the varying designs and heights of impacting vehicles. Curbs, dikes, and ditches in the median or adjacent to the median can also cause difficulties with the cable barrier. The above factors can also cause vehicles to overtop the beam barrier.

In general, curbs and dikes close to the barrier will launch vehicles over the cable (or beam barrier) when impacting the barrier at a flat angle and high speed. Because small foreign cars, especially when braking, have a low profile, a cable should never be more than 28 inches above the ground. Yet it should never be less than 27 inches above the ground because standard cars will vault over the cable at lower heights.

To provide a wider range of protection than the 27 to 28 inch band, many configurations of several cables at different heights were tested. It was found that in flat angle, high speed collisions the vertically separated cables act as a ramp and the vehicle will climb over the barrier. Therefore, the two cables that are used with this barrier must be placed at the same height.

Convex configurations of pavement and median slopes cause vehicles running into the median to leave the ground. For this reason, it is necessary to ascertain whether the vehicle is back on the ground at the cable barrier location or whether it is necessary to raise one or both beams at beam barrier locations.

When the cable barrier is considered for installation in medians whose cross slopes are not in the same plane as the adjacent pavement slopes, it is necessary to determine whether the trajectory of the impacting vehicle from either side is within the 27 to 28 inch critical height of the cable. (See Figure 1.) An angle of attack of 30° at 60 miles an hour, which gives a transverse trajectory velocity of 30 miles per hour, should be used. Of course, in many cases, it is possible to strike the barrier at higher speeds and more obtuse angles; but generally this criteria should suffice. Fortunately, the angle of attack usually decreases as the speed increases. (A transverse velocity of 30 miles per hour is also attained at 70 miles per hour and $25\frac{1}{2}$°, 80 miles per hour and 22°, and 100 miles per hour and $17\frac{1}{2}$°.)

When using the method outlined above, it is quite possible that there may be no convenient location within the median that would meet the criteria of the cable being no more than 28 inches above the ground for vehicles colliding from the low side and yet at least 27 inches above the vehicle trajectory for vehicles colliding from the high sides. In these cases, a staggered beam barrier as shown in Figure 2 should be used or a beam barrier should be placed at the top of the slope. If the amount of required beam staggering exceeds 12 inches, the beam barrier should be placed at the top of the slope instead. A sample calculation is shown in Figure 3.

A graphic analysis can also be made by plotting the bottom of the vehicle trajectory on plotted cross sections. The vertical scale should be exaggerated since the vertical distances are relatively small and critical. Table 1 gives vertical offset distances "Y" (the amount the vehicle has dropped) from the initial line of trajectory (pavement or shoulder cross slope extended) for each foot of transverse distance "X" from the pavement or shoulder hinge point. The values shown in Table 1 are based on the formula, $S=\frac{1}{2}at^2$, using a transverse velocity of 44 feet per second (30 mph) to compute the time to each transverse distance "X" shown.

Sample applications of the graphic solution are shown in Figures 4A to 4D.

<u>Figure 4A</u>

This is a normal tangent alignment cross section with five-foot median shoulders. Notice that the vehicle leaves the ground at the edge of pavement and stays airborne for 12 feet with 10:1 median cross slopes, 14 feet with 8:1 and over 18 feet with 6:1 slopes.

Figure 4B

This is the same situation as Figure 4A except median shoulders are eight feet wide. The vehicle is airborne for nine feet with 10:1 median cross slopes, 11 feet with 8:1 and 15 feet with 6:1 cross slopes.

Figure 4C

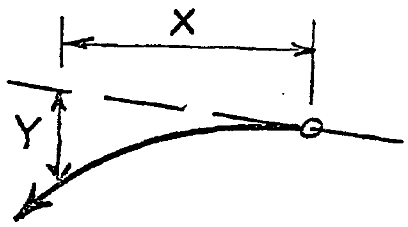
This is a curve to the right situation with 5% superelevation. Notice that, even with 20:1 median cross slopes, the vehicle is airborne for 12 feet beyond the shoulder hinge point.

Figure 4D

This figure depicts a curve to the left situation with a 3% superelevation on the pavement and the normal 5% cross slope on the median shoulder. Notice that the 2% convex break in slopes between pavement and shoulder causes a slight airborne condition, but that the vehicle is on the ground as it leaves the shoulder. The shoulder slope extended, therefore, becomes the control line for measuring (plotting) the "Y" distances. The vehicle is airborne for considerably shorter transverse distances in this case than in Figure 4C because the initial vehicle velocity is downward for a curve to the left.

TABLE 1

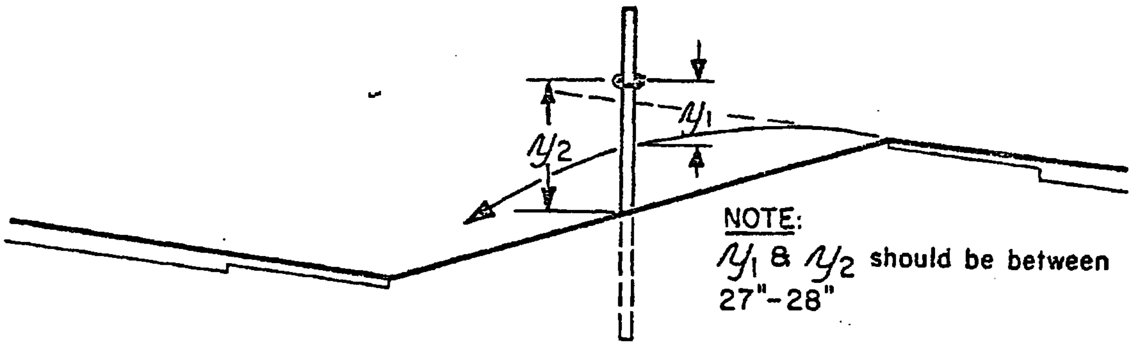
X (feet)	Y (feet)
1	0.01
2	0.03
3	0.07
4	0.13
5	0.21
6	0.30
7	0.41
8	0.53
9	0.67
10	0.83
11	1.01
12	1.20
13	1.41
14	1.63
15	1.87
16	2.13
17	2.41
18	2.69
19	3.01
20	3.33



Based on $s = \frac{16.1x^2}{(44)^2} = 0.00833x^2$

FIGURE 1

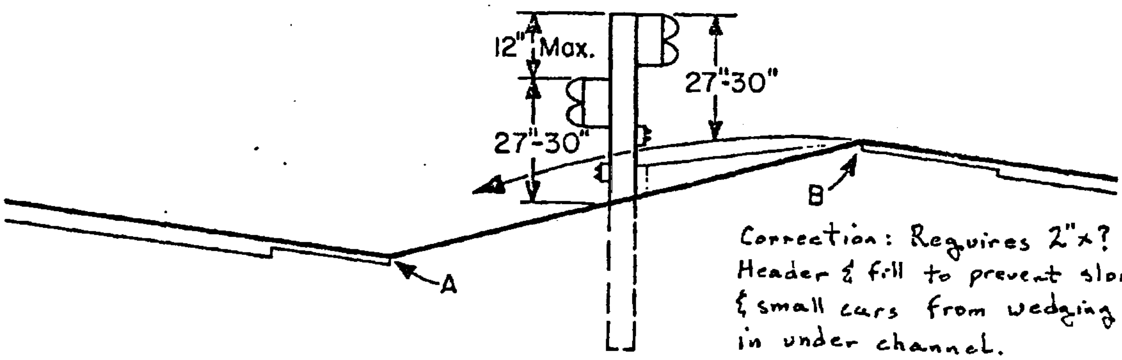
CRITICAL DIMENSIONS OF CABLE BARRIER



NOTE:
y_1 & y_2 should be between 27"–28"

FIGURE 2

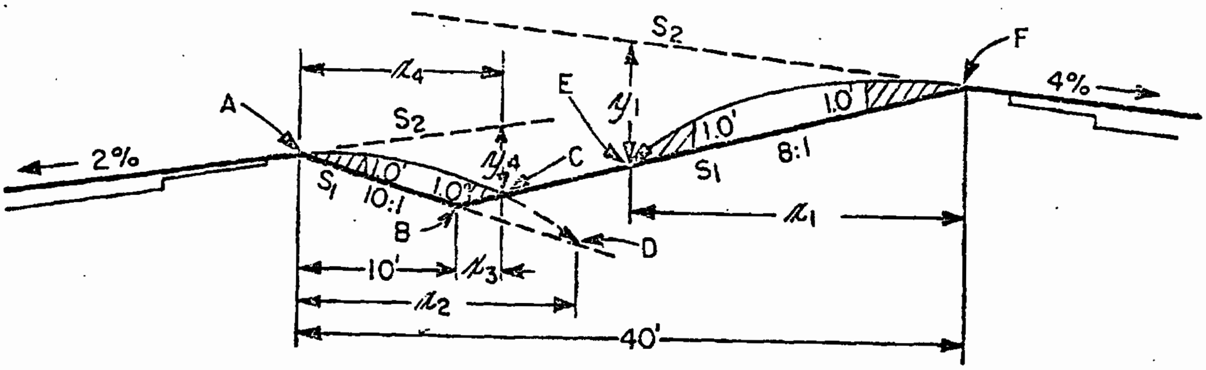
CRITICAL DIMENSIONS OF BEAM BARRIER



Correction: Requires 2"x? Header & fill to prevent slow & small cars from wedging in under channel.
SJT.

FIGURE 3

SAMPLE CALCULATION TO CHECK BARRIER EFFECTIVENESS



$y = 1/2\,at^2 = 16.1\,t^2$

$t = \dfrac{x}{44 \text{ ft/sec}}$ (based on 30° angle of attack at 60 mph)

Substituting, $y = 0.0083\,x^2$ ①

Also, $y = x\,(S_1 - S_2)$ ②

Substituting, $x\,(S_1 - S_2) = 0.0083\,x^2$

Therefore, $x = \dfrac{(S_1 - S_2)}{0.0083}$ ③

STEP NO. 1 : Determine where in median the trajectory from right roadway intercepts ground. Using ③, $x_1 = \dfrac{[0.125-(-0.04)]}{0.0083} = 19.8'$

(Cable barrier cannot be installed between points E and F.)

STEP NO. 2: Determine where in median the trajectory from left roadway intercepts ground. Using ③, $x_2 = \dfrac{[0.02-(-0.10)]}{0.0083} = 14.5'$

Since 14.5' is beyond point B (10'), an adjustment is necessary to determine actual intercept of line BF.

Using ①, $y_4 = 0.0083\,x_4^2$

Also from median geometry,

$y_4 = 0.10\,(10) - 0.125\,(x_3) + 0.02\,(x_4)$ and $x_4 = 10 + x_3$

Substituting and symplifying,

$0.0083\,x_4^2 + 0.105\,x_4 - 2.25 = 0$ and $x_4 = 11.2'$

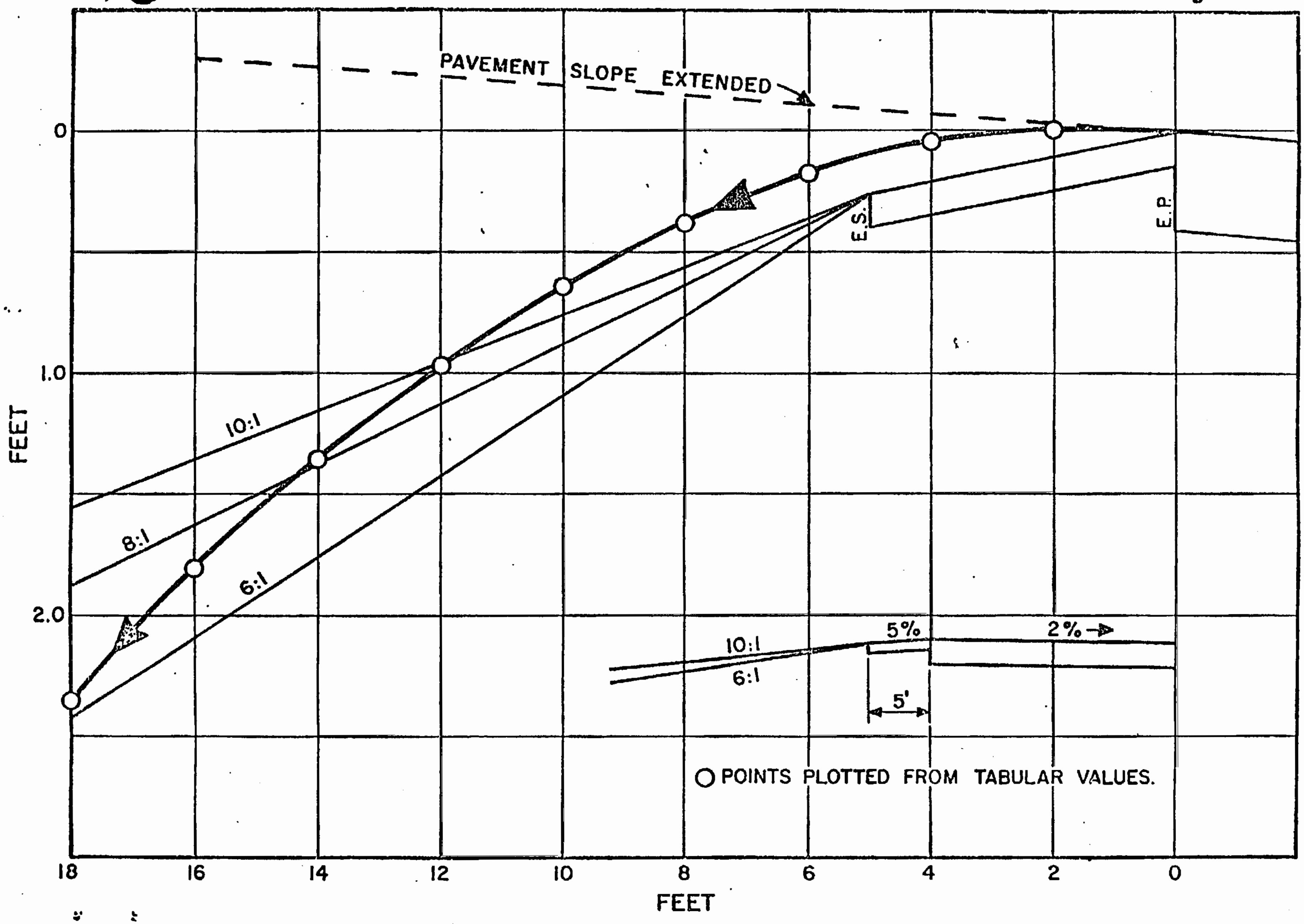
(Cable barrier cannot be installed between points A and C).

(Cable barrier can be installed between points C and E only).

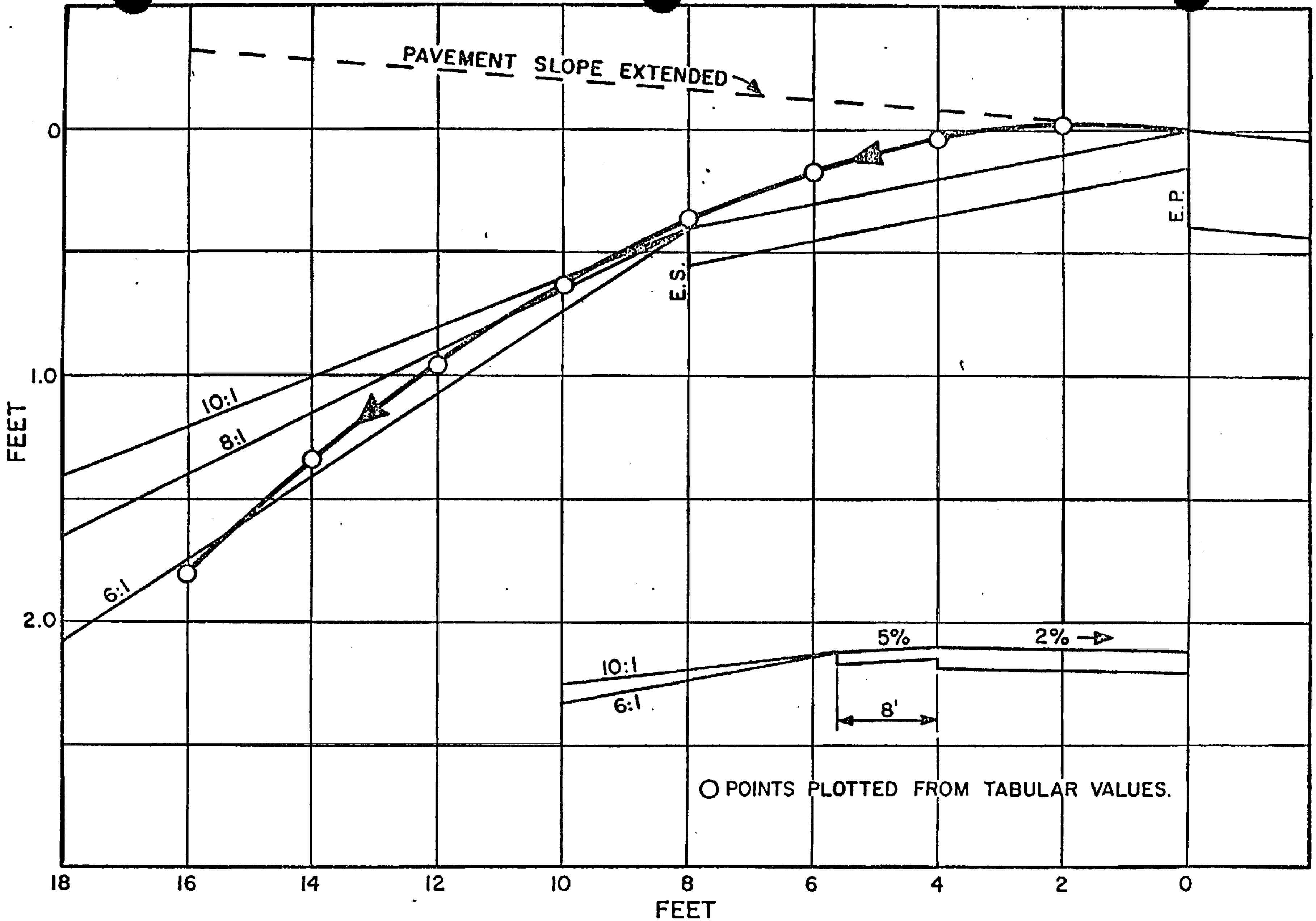
STEP NO. 3: If the trajectories overlap, the cable barrier cannot be used. A beam barrier must be used.

STEP NO. 4: If beam barrier is required, a staggered rail system as shown in Figure 2 can be used in any area where both trajectories are no more than 1.0 foot above the ground (shaded area in above figure). The upper rail should be 27" to 30" above the trajectory at the rail and the lower rail should be 30" above the ground at its rail. An alternative is to place the standard beam barrier at Points A or F or between Points C and E.

Fig. 4A


PAVEMENT SLOPE EXTENDED
0
1.0
2.0
FEET
10:1
8:1
6:1
E.S.
E.P.
5%
2%
10:1
6:1
5'
O POINTS PLOTTED FROM TABULAR VALUES.
18
16
14
12
10
8
6
4
2
0
FEET

F[illegible] 4B



PAVEMENT SLOPE EXTENDED
E.P.
E.S.
10:1
8:1
6:1
5%
2%
10:1
6:1
8'
O POINTS PLOTTED FROM TABULAR VALUES.
FEET
0
1.0
2.0
18
16
14
12
10
8
6
4
2
0
FEET

9

Fig. 4C

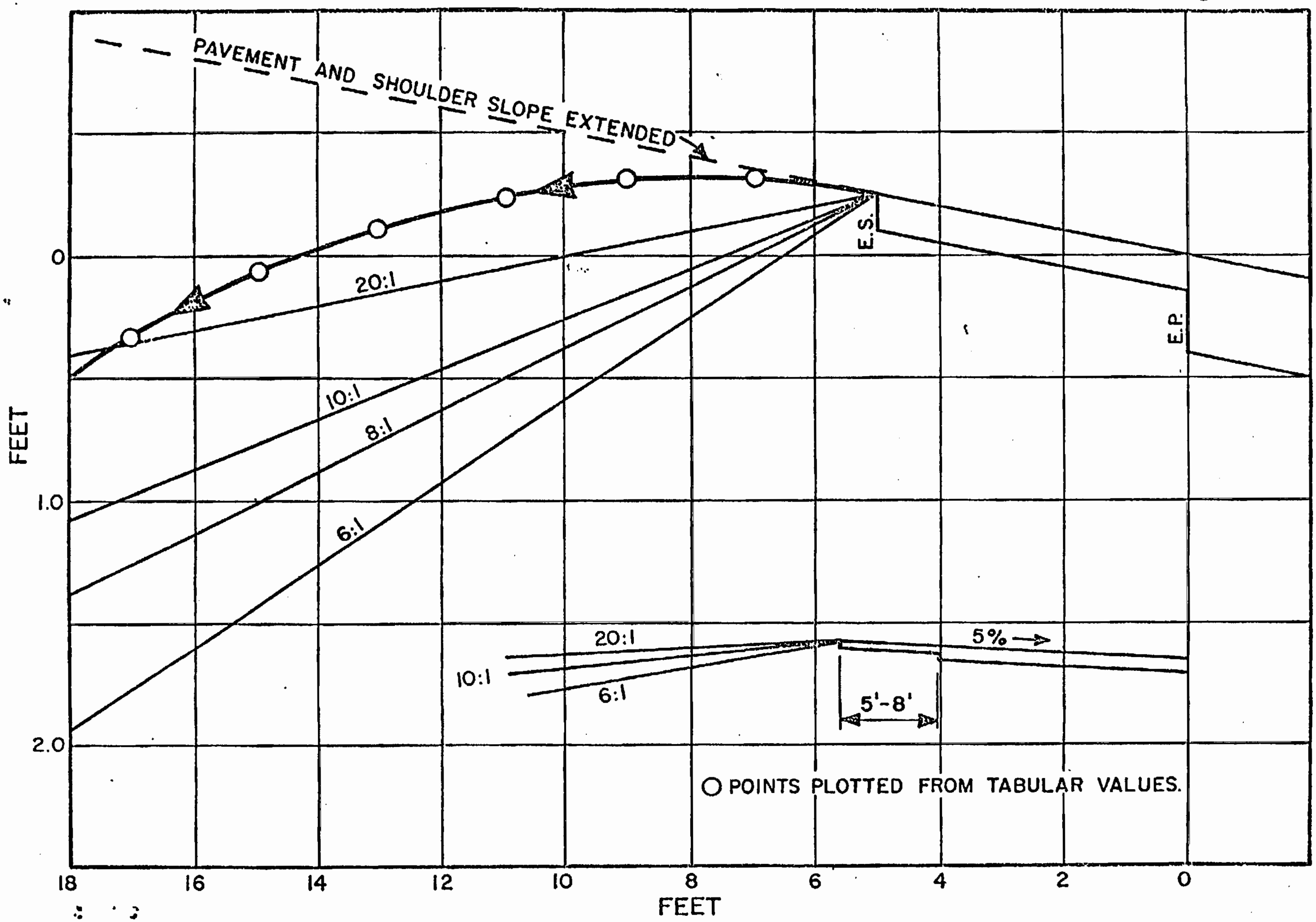
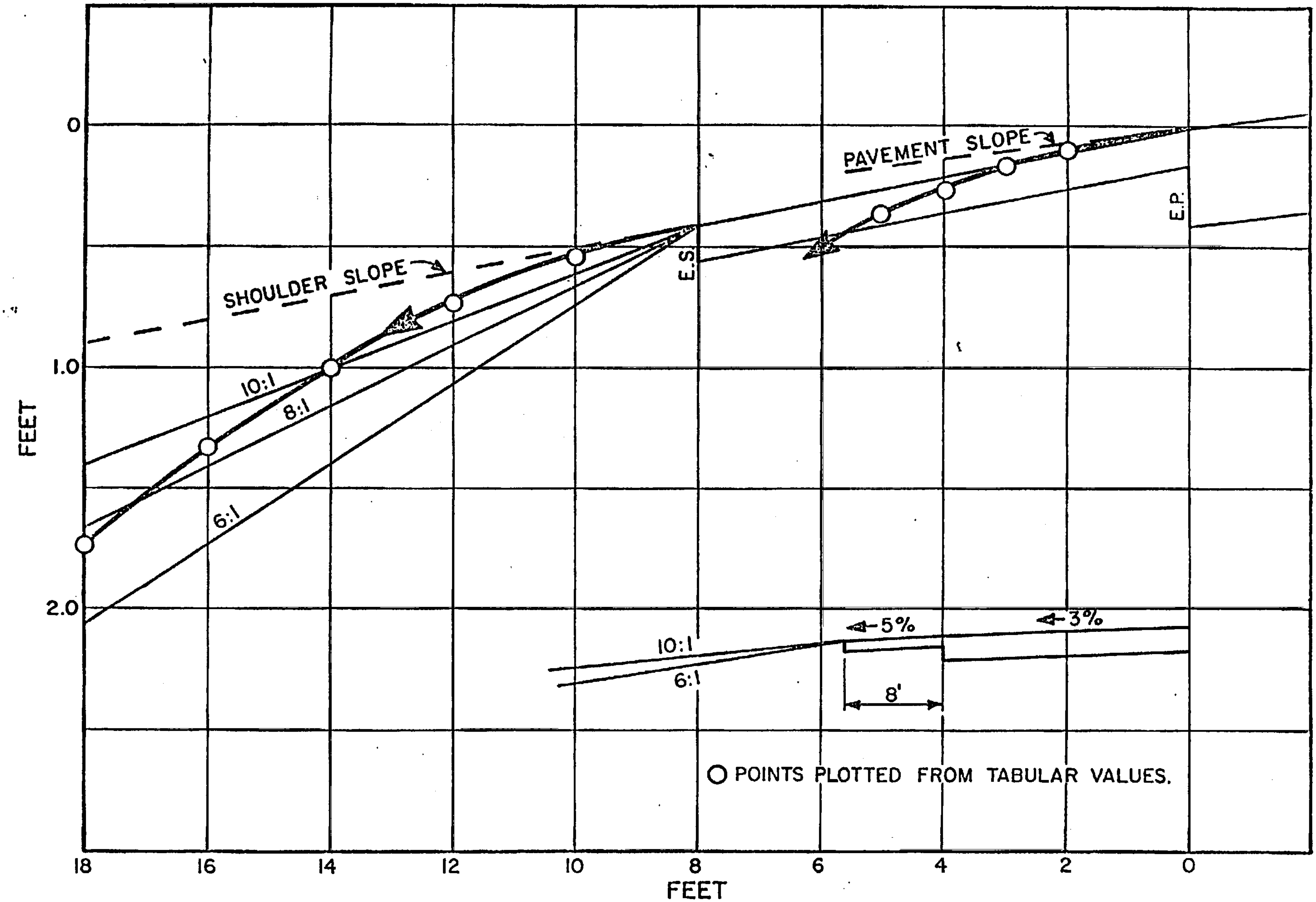

PAVEMENT AND SHOULDER SLOPE EXTENDED
E.S.
E.P.
20:1
10:1
8:1
6:1
20:1
10:1
6:1
5%
5'-8'
O POINTS PLOTTED FROM TABULAR VALUES.
FEET
0
1.0
2.0
18
16
14
12
10
8
6
4
2
0
FEET

Fig. 4D



PAVEMENT SLOPE
SHOULDER SLOPE
E.P.
E.S.
10:1
8:1
6:1
0
1.0
2.0
FEET
-5%
-3%
10:1
6:1
8'
POINTS PLOTTED FROM TABULAR VALUES.
18
16
14
12
10
8
6
4
2
0
FEET