Slope and Rounding Design

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It is generally recognized that relatively flat slopes with liberal rounding of tops and toes of slopes and drainage channels are desirable for economy of maintenance, erosion control, ease of establishment and maintenance of vegetation, and improved appearance. However, the limitations imposed by cost of right-of-way and construction must be considered. This study was made to determine the critical slope ratios and the minimum roundings required for economical operation of typical mowing equipment presently available.

There is a general lack of standards and of data on which standards might be based for the design of ground forms which can be maintained most economically with due consideration for right-of-way and construction costs. For example, in the AASHO "A Policy on Geometric Design of Rural Highways" there are found only general phrases such as "relatively flat side slope", "liberally rounded", and an indication of lack of definiteness in relation to slope ratio.

Considering the large acreages of roadsides characteristic of highways such as the Interstate System, an extra pass of a mower could add significantly to the mowing time and effort required. It was assumed for the purpose of this study that the cross-section where mowing was to be expected should not present a ground form which would limit the operation of mowing equipment. For example, it was assumed that it might be desirable to operate equipment with the center of the mower over the low point of the drainage channel. This seemed reasonable to prevent the possibility of an extra pass of the mower which might be necessitated by a V-shaped drainage channel mowed by a separate pass on each side of its center.

Four mower sizes were considered in this study. The gang-type reel mower had individual units with a span of 41½ in. between centers of wheels. The rotary and the hammer knife mowers had 48-, 60-, and 72-in. spans between wheels. The sickle-bar mower was not considered because of its slow speed of travel.

A field study was made of the operation of a tractor drawing a gang-type reel mower along the contour of various degrees of slope. This tractor was a model in general use having a 52½-in. rear wheel spacing

Figure 1.

and single rear wheels with 10 x 28 tires. The turf cover, composed mostly of red fescue, was excellent and quite high (Fig. 1). When the mower operated on slopes steeper than 3:1, the wheel on the high side spun so that traction was lost. Operation on slopes flatter than 3:1 was satisfactory. This performance might vary with several factors such as the model of equipment, the type and condition of vegetative cover, the kind of soil and the moisture conditions.

Although it is possible to mow 2:1 slopes or steeper by running the mower down the slope crossing the contours, this is a time consuming operation and is not to be considered by the premise that ground forms should not limit the use of mowing equipment.

It is generally recognized that a height of cut of 3 in. in highway mowing is desirable. This height was used as the normal distance of the cutter above the ground. It was also assumed arbitrarily that a minimum height of cut of 1 in. and a maximum height of cut of 5 in. would be the extremes acceptable on roundings. Thus, a mower operating at a top of slope rounding should clear the theoretical grade by 1 in. where the cutter was nearest that grade, and when operating in a drainage channel or at toe of slope the cutter element should be no more than 5 in. above the theoretical grade at any point (Fig. 2).

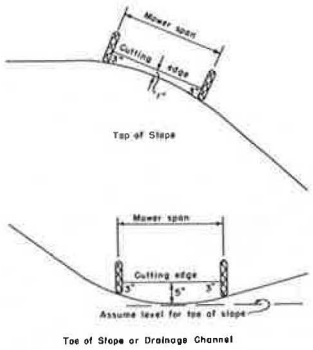


Figure 2. Mowing clearances.

A study was made of the rounding of drainage channels necessary for various combinations of side slopes and mower spans to provide the maximum height of cut specified. A circular curve was selected for use because of its ease in construction. A curve was developed for each of the conditions by computation and graphically, and the radius of curve and the projected horizontal distance that each curve covered was determined. The data developed are given in Table 1 and Figures 3 and 4. The curves developed conformed closely to parabolic curve.

The curves can also be used for the data necessary for minimum rounding of tops of slopes for a minimum cut of 1 in. by turning the cross-sections of Figure 3 upside down for reference.

Although this study has been limited to the determination of the minimums of slope ratios and roundings for mowing requirements, it is believed that these may be assumed to satisfy other factors. Experience

TABLE 1
RADII AND PROJECTED HORIZONTAL DISTANCES OF ROUNDINGS

Slope Combinations	Project Horizontal Distance, ft			
	Mower Span 41½ in.[1]	Mower Span 48 in.[2]	Mower Span 60 in.[3]	Mower Span 72 in.[4]
Level vs 2:1[5]	4.1	5.4	8.4	12.1
Level vs 3:1[5]	2.9	3.8	6.0	8.6
Level vs 4:1[5]	2.2	2.9	4.6	6.6
Level vs 6:1[5]	1.5	2.0	3.1	4.5
2:1 vs 1:1	10.5	14.0	21.8	31.3
2:1 vs 1¼:1	9.7	12.9	20.2	29.1
2:1 vs 2:1	8.1	10.8	17.1	24.3
2:1 vs 3:1	6.9	9.2	14.4	20.5
2:1 vs 4:1	6.2	8.4	13.1	18.7
2:1 vs 6:1	5.5	7.4	11.4	16.6
3:1 vs 1:1	9.3	12.4	19.2	27.7
3:1 vs 1¼:1	8.6	11.4	18.0	25.4
3:1 vs 3:1	5.7	7.6	11.8	17.1
3:1 vs 4:1	5.1	6.8	10.5	15.2
3:1 vs 6:1	4.3	5.8	9.1	12.9
4:1 vs 1:1	8.7	11.6	18.1	26.1
4:1 vs 1¼:1	7.8	10.5	16.4	23.6
4:1 vs 4:1	4.4	5.9	9.2	13.1
4:1 vs 6:1	3.7	5.0	7.7	11.1
6:1 vs 1:1	7.9	10.6	16.5	23.7
6:1 vs 1¼:1	7.1	9.6	14.9	21.3

[1]Radius of rounding, 9.05 ft.
[2]Radius of rounding, 12.08 ft.
[3]Radius of rounding, 18.83 ft.
[4]Radius of rounding, 27.08 ft.
[5]For top and toe of slope roundings.

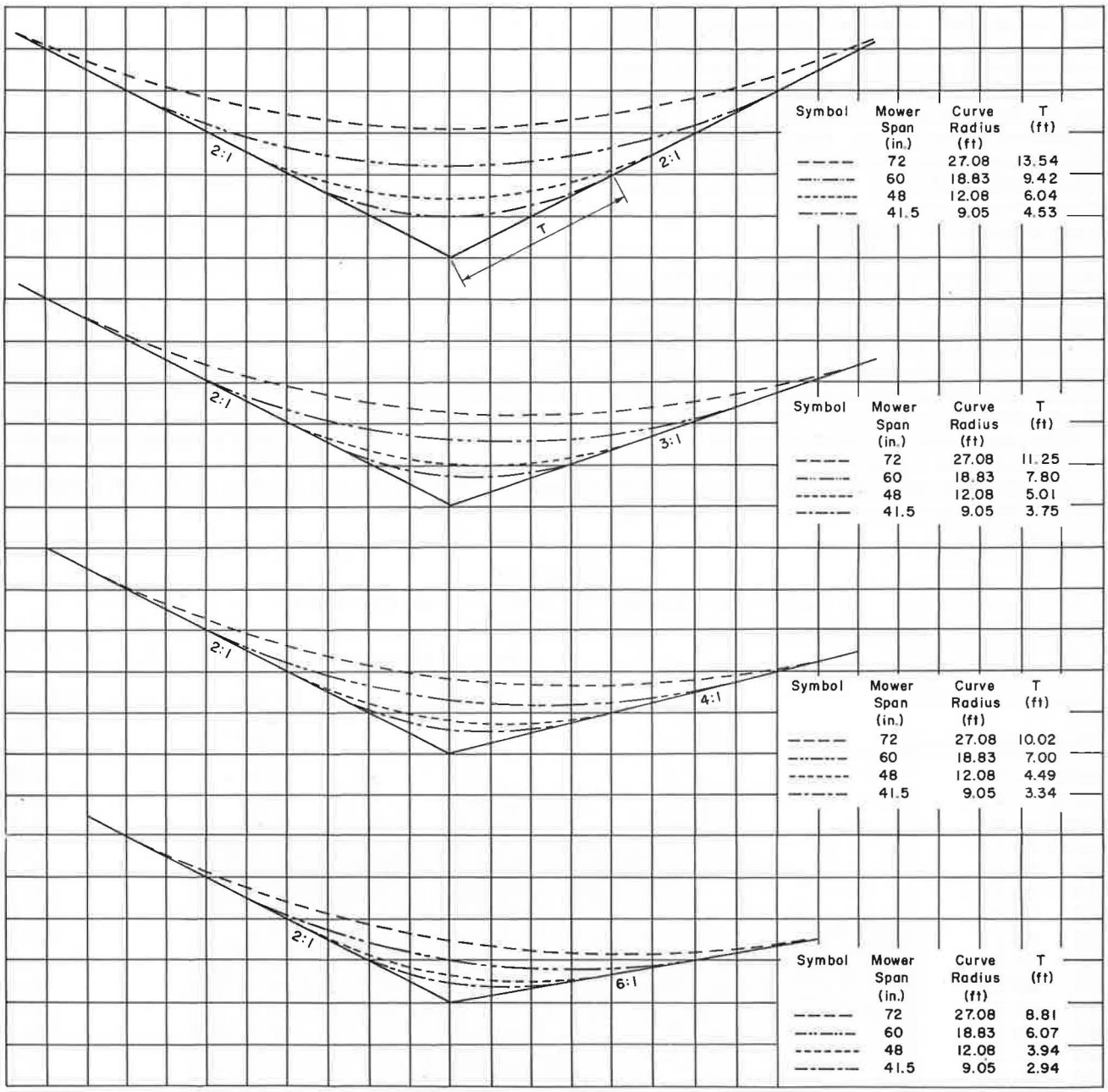


Figure 3. Rounding for clearances on various slope combinations.

indicates that the requirements for erosion control will be satisfied for almost all soils assuming a vegetative cover, and that, in the cool, humid sections of the country, vegetation can be established and readily maintained on the surfaces indicated. No attempt has been made to study the relationship of these designs with snowdrift control. Finally, appearance should, in general, be acceptable using the minimums indicated with one exception—the minimum roundings of tops of cut slopes, particularly where the original surface beyond the cut is in the direction opposite to the cut slope. These forms should be constructed with consideration for the line of sight from all locations to avoid sharp lines and planes not natural to the topography. Transitions between cuts and fills should also be adequate for appearance as well as for maintenance.

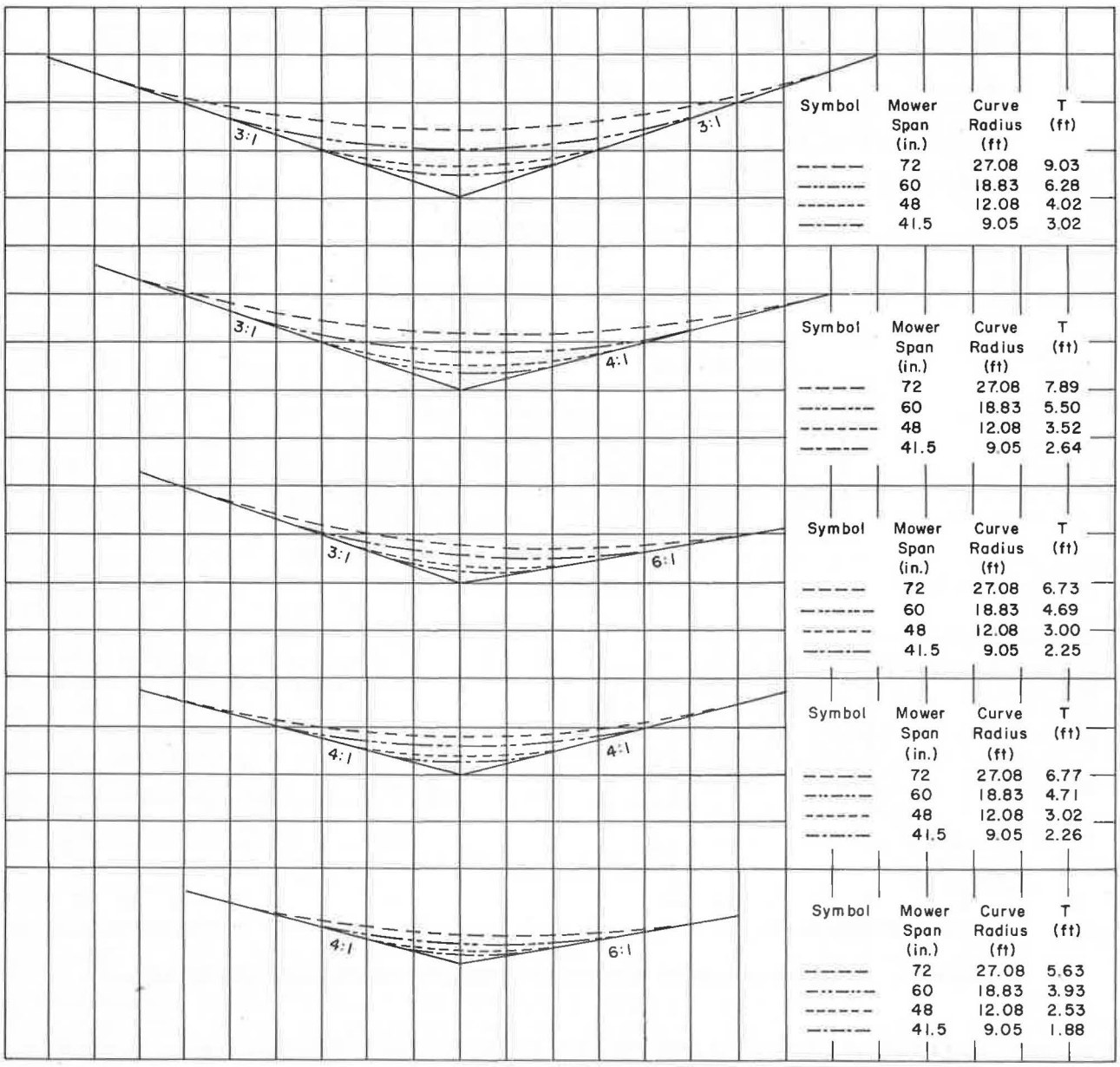


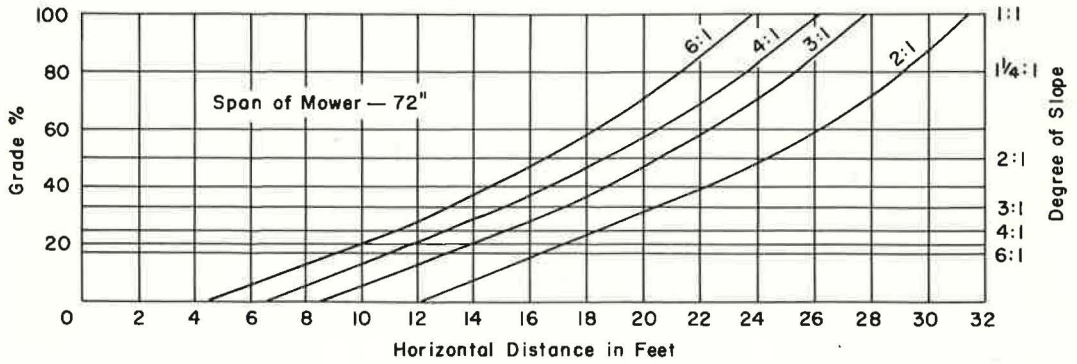
Figure 3. Rounding for clearances on various slope combinations (cont'd.).

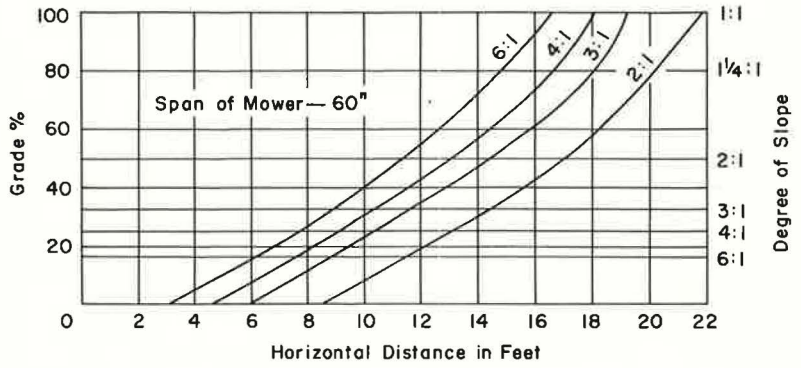
This study has provided data which may be used quantitatively to design slopes and roundings which will satisfy the requirements of maintenance in relation to mowing. Further consideration should be given to the practical application of the data in design procedure.

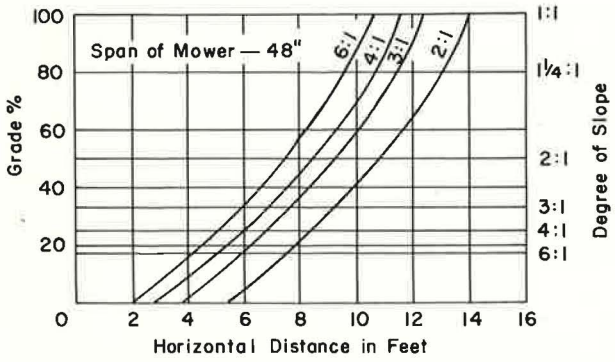
Discussion

Slack: Is a gang mower the only type you use in your work? Do you use rotary mowers at all?

Iurka: Our department uses rotary and hammer knife mowers as well as the reel type. It is the span between wheels of the individual unit and the height of setting of the cutting element rather than the type of mower which governs the minimum rounding indicated.







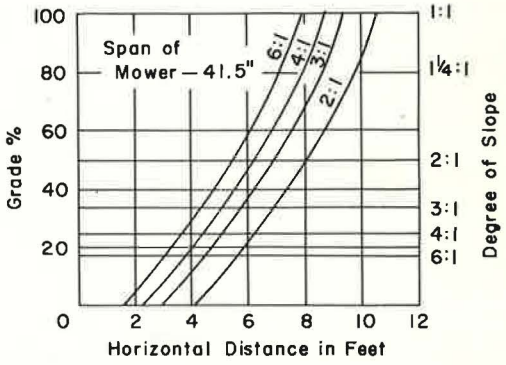


Figure 4. Projected horizontal distance of curves for various slope combinations.

Vanderman: In Florida we find that the gang reel type mowers are safer than other types. Do you have any comparison of costs of gang vs. rotary mower operation?

Iurka: No. Obviously the wider swath covered by gang mowers, other factors being equal, makes for greater economy.

Owens: I understand that Japanese honeysuckle is frequently used on slopes rather than turf. In the southern humid area of the United States this would be quite undesirable because of the rank growth of the plant.