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The Effect of Thickness of Stroke on the Legibility of Letters

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PROBLEM

This is part of a study dealing with the optional characteristics for greatest efficiency of highway signs. Because there is still considerable room for improvement in the legibility of signs and only a limited amount of experimental data available, this investigation was undertaken. This present project is based on work done before by Lauer, (1932) Aldrich, (1937) Forbes, (1939) and deals on the whole with the separate variables of letter legibility such as stroke, height-width ratio and spacing, each variable being isolated for experimentation. In this paper, however, the discussion will deal only with the isolation of the stroke as a factor in legibility.

METHOD

Two sets of experiments were conducted to determine the optimal stroke for three-inch block letters. Other experiments are being conducted to study letters other than the block type.

A block letter is one whose height and width are equal and whose stroke is the thickness of its individual members. A series of four representative block letters painted dull black on a mat white background, having strokes varying from eight per cent to 32 per cent of the height or width by four per cent intervals, were constructed as recommended by the Public Roads Administration.

A block letter using an eight per cent stroke is equal to a .4 minute angle of the separate members of the letter and a 20 per cent stroke to a one minute angle. The angle notation makes use of a trigonometric relationship between the object to be seen and its legibility distance. The Snellen criterion of 20/20 vision is a five minute angle for the height or width of the letter and a one minute angle for its individual members as seen from the standard distance.

Series I: In this series sixteen subjects made a total of 1344 observations. Each one made three observations for each variety of stroke and letter combination, two of the readings being "in" or approaching observations and the third being an "out" or withdrawing observation. The visual acuity was first measured by the

Clason Acuity Meter in the laboratory and then by the Snellen chart under outdoor conditions of illumination. All observations were made outdoors by daylight with illumination levels ranging from 250 to 550 foot candles. The letters were placed on a special easel, painted flat white, which was located in a plane approximately parallel to the rays of the sun and in such a position that the letter on the screen remained constantly in the shade. A 350-foot reel of tape was used to measure the legibility distances in order to expedite the observations and assure accuracy.

Series II: The results of the first experiment indicated that the theoretical optimal stroke was 18.3 per cent for the representative block letters used. To verify this result experimentally eight letters with strokes of 16, 18 and 20 per cent were employed in a second series of investigations. The procedure described in the former study was again used with 15 subjects making a total of 1080 observations.

RESULTS

Series I: 1. As shown in Table I there is a highly significant variation between the strokes.

Table I. Analysis of Variance of Legibility Distances for 7 sizes of Stroke Observed by 16 subjects in Series I Experiment. Strokes 8% to 32%. 4% intervals.

Source of Variation	Degrees of freedom	Sum of squares	Mean Square
Total	111	74,550.8	671.6
Subjects— (after correction)	15	4,768.0	317.9
Stroke treatments	6	48,612.1	8,102.0**
Error	90	21,170.7	235.2

** highly significant (F. = 34.4) Greater than 3.04 F at 1% F. test from Fisher (4)

2. Figure I shows the comparison between the actual points and a fitted parabola which takes the form of either of the following equations within the limits of the present observations.

$$y = 116.227 + 12.361\, x_P - .337\, x_P^2 \quad (1)$$

or

$$y = 116.227 + 247.265\, x_A - 134.925\, x_A^2 \quad (2)$$

where:

y = legibility distance in feet

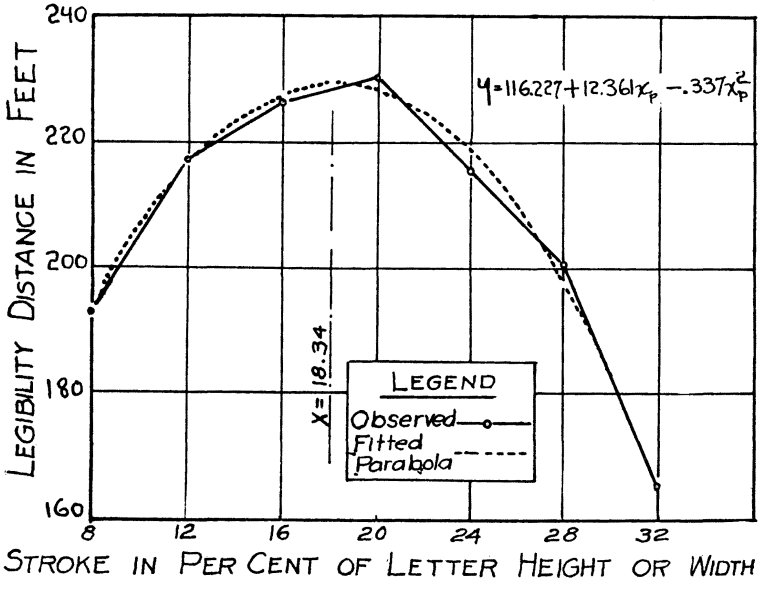
$x_P = \dfrac{\text{thickness of stroke in inches}}{\text{letter height or width in inches}} \times 100$

x_A = minutes angle of the size of stroke required for 100 per cent vision by the normal eye

By differentiating y with respect to x the optimal stroke was found to be 18.34 per cent, equal to .916 minutes angle for 100 per cent vision.

FIG. I. DAYLIGHT LEGIBILITY, BLACK ON WHITE, OF FOUR BLOCK LETTERS (E,N,C,P) AVERAGED AND CORRECTED TO 100% CLASON AND SNELLEN VISION

16 SUBJECTS- 1344 OBSERVATIONS; 192 PER POINT.



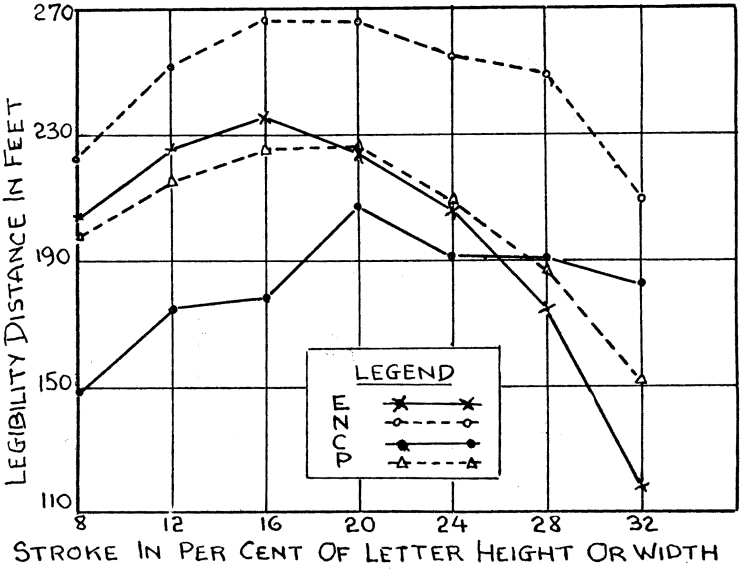
3. Table II shows the computed values from the equation and the deviations from the actual values.

Table II. Comparison Between Actual and Theoretical Values From Equations (1) or (2).

x stroke in per cent	x minutes of the Angle	Observed Legibility Distance in Feet	Theoretical values y . . . from (1)	Deviations Actual-Theoretical
8	.4	193.1	193.5	− .4
12	.6	217.3	216.0	1.3
16	.8	226.3	227.7	−1.4
18.3	.916	—— *	229.6	—
20	1.0	230.3	228.6	1.7
24	1.2	215.6	218.7	−3.1
28	1.4	200.6	197.9	2.7
32	1.6	165.6	166.4	− .8

* No letters having that stroke were studied in Series I.

FIG II. LEGIBILITY CURVES OF FOUR INDIVIDUAL LETTERS CORRECTED TO 100 PER CENT CLASON AND SNELLEN VISUAL ACUITY. 16 SUBJECTS.



4. Figure II shows the individual curves for each of the four letters.

Series II: 5. As seen in Table III the variations between 16, 18 and 20 per cent strokes for the means of the eight letters were found to be significant. It will be noted that the subjects varied more than in the first series even after correction to 100 per cent vision.

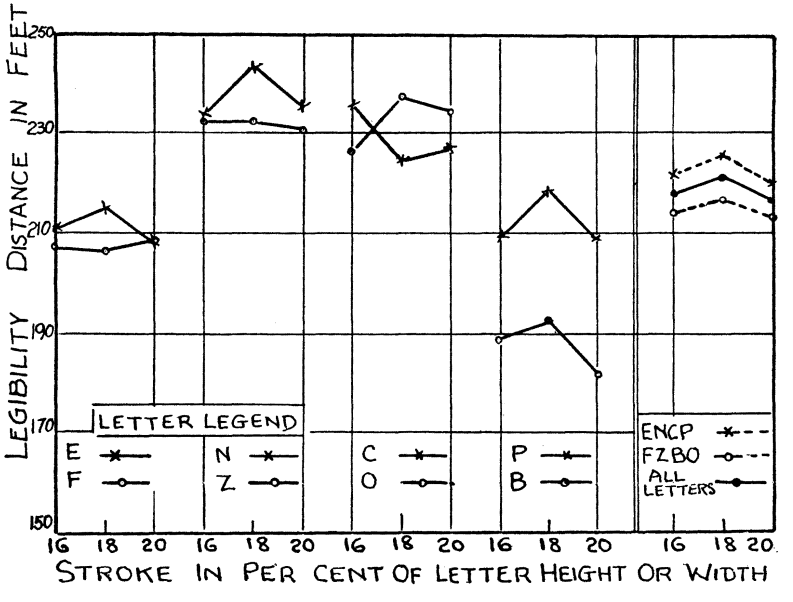
Table III. Analysis of Variance of Legibility Distances for 3 Sizes of Stroke Observed by 15 Subjects in Series II Experiment. Stroke 16, 18, 20 Per Cent.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	44	15,728.6	
Subjects— (after correction)	14	14,993.1	1,670.9**
Strokes	2	154.6	77.3*
Error	28	580.9	20.75

* Significant (F. = 3.73) **highly significant (F. = 51.61)
F. for strokes greater than 3.34 at 5%
F. for subjects greater than 2.80 at 1%
F. test from Fisher

FIG III. DAYLIGHT LEGIBILITY, BLACK ON WHITE, OF EIGHT BLOCK LETTERS CORRECTED TO 100 PER CENT CLASON AND SNELLEN VISUAL ACUITY.

15 SUBJECTS- 1080 OBSERVATIONS



6. Figure III shows the relationship between the 16, 18 and 20 per cent strokes for each of the representative letters, for two groups, and for the total.

CONCLUSIONS

1. The results of these experiments would seem to indicate that the optimal stroke of three-inch block letters is, on the average, closest to 18 per cent of the width or height of the letter.

2. The general acceptance of constancy of angle should make this applicable to any size block letter.

3. The legibility distances obtained for letters having a stroke of 16 and 20 per cent are fairly close due to the parabola at this section of the curve.

4. A 16 per cent stroke, on the average, gives a higher legibility distance than a 24 per cent stroke.

5. These data are presented with a full knowledge of the limits of application to letters of other characteristics. Further experiments are in progress at this time which suggest the need for reduction in the width of stroke with the reduction of the height-width ratio to assure maximum legibility.

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