CHAPTER 3

Introduction to Physical Design of Transportation Facilities

PROBLEMS

3.1. Determine the minimum stopping sight distance on a - 2.5% grade at a design speed of 90 km/h.

Total required stopping sight distance

$$s = d_r + d_b$$

Reaction distance

$$d_r = vt_r = (90\text{km/h})\left(\frac{1{,}000\text{m/km}}{3{,}600\text{s/h}}\right)(2.5\text{s}) = 62.5\text{m}$$

Braking Distance

$f = 0.30$ (Table 3.3)

$G = -\ 0.025$ (given)

$$d_b = \frac{v^2}{2g(f \pm G)} = \frac{\left[(90\text{km/h})\left(\frac{1{,}000\text{m/km}}{3{,}600\text{s/h}}\right)\right]^2}{2(9.8\text{m/s}^2)(0.30 - 0.025)} = 116.0\text{m}$$

Total sight distance

$$s = d_r + d_b = 62.5 + 116.0 = 178.5\text{ m}$$

3.2. Determine the minimum stopping sight distance on a +1.5% grade at a design speed of 100 km/h.

Total required stopping sight distance

$$s = d_r + d_b$$

Reaction distance

$$d_r = vt_r = (100\text{km/h})\left(\frac{1{,}000\text{m/km}}{3{,}600\text{s/h}}\right)(2.5\text{s}) = 69.4\text{m}$$

Braking Distance

f = 0.29 (Table 3.3)

G = + 0.015 (given)

$$d_b = \frac{v^2}{2g(f \pm G)} = \frac{\left[(100\text{km/h})\left(\frac{1{,}000\text{m/km}}{3{,}600\text{s/h}}\right)\right]^2}{2(9.8\text{m/s}^2)(0.29 + 0.015)} = 129.1\text{m}$$

Total sight distance

$$s = d_r + d_b = 69.4 + 129.1 = 198.5\text{ m}$$

3.3. Determine the minimum stopping sight distance on a - 4.0% grade at a design speed of 70 km/h.

Total required stopping sight distance

$$s = d_r + d_b$$

Reaction distance

$$d_r = vt_r = (70\text{km/h})\left(\frac{1000\text{m/km}}{3600\text{s/h}}\right)(2.5\text{s}) = 48.6\text{m}$$

Braking Distance

f = 0.31 (Table 3.3)

G = − 0.04 (given)

$$d_b = \frac{v^2}{2g(f \pm G)} = \frac{\left[(70\text{km/h})\left(\frac{1{,}000\text{m/km}}{3{,}600\text{s/h}}\right)\right]^2}{2(9.8\text{m/s}^2)(0.31 - 0.04)} = 71.4\text{m}$$

Total sight distance

$$s = d_r + d_b = 48.6 + 71.4 = 120.0 \text{ m}$$

EXERCISES

3.1. Design standards link vehicle characteristics, human characteristics, and the characteristics of the transportation facility. What features of human and vehicle characteristics are important in the derivation of design standards?

Human characteristics that are important in the derivation of design standards include visual ability, ability to hear, reaction times, gap acceptance behavior, steering behavior, and the subjective sense of comfort. Vehicular characteristics that are important in the derivation of design standards include physical dimensions (length, width, height, and wheelbase), weight (gross weight and wheel loads), acceleration and deceleration characteristics, maximum speed, and (for aircraft only) lift.

3.2. List and briefly describe at least five transportation facility characteristics typically specified by design standards.

Any five of the following:

Minimum radius of horizontal curve. For a given design speed, minimum curve radius is limited by maximum allowable side friction, which is usually based on a comfort standard; maximum superelevation rate (or banking) for the curve; and the necessity to maintain stopping sight distance.

Maximum rate of superelevation. For highways, maximum superelevation rate is limited by side friction and by presence of roadside features such as driveways. For railways, it is limited by the need to limit imbalances in the loads on the rails.

Maximum grade. Maximum upgrades are limited by vehicle power/weight ratios and vehicle traction. Maximum downgrades are also limited by stopping distances and sight distances.

Minimum grades for some types of highway are limited by the need to provide drainage.

Minimum cross-slopes for highways, runways, and taxiways are limited by the need to provide drainage.

Minimum length of vertical curve. For highways minimum length of vertical curve is limited by stopping or passing sight distance requirements, vertical acceleration, and appearance standards. For railways, minimum length of vertical curve is also limited by the need to prevent jerk on couplings in sag vertical curves. For runways and taxiways, minimum length of vertical curve is limited by sight distance requirements.

Edge radii in roadway and taxiway intersections are limited by vehicle turning radii. These, in turn, are related to vehicle wheelbase dimensions.

Minimum intersection setbacks (minimum distances to obstructions to vision) are limited by stopping sight distance and driver gap-acceptance behavior.

Freeway ramp junction details are limited by gap-acceptance behavior, steering behavior in entering or exiting lanes, and vehicle acceleration and deceleration capabilities.

Horizontal and vertical clearances are limited by vehicle dimensions and in the case of horizontal clearances for highways, by the need to provide clear recovery zones for vehicles that run off the road.

3.3. Four basic elements of facility plans document the geometry of linear transportation facilities such as highways and railways. List and briefly describe these four elements.

1. The *plan view* (or simply "plan"). This is a drawing of the facility as it would look to an observer directly above it.

2. The *profile*. This drawing has elevation as its vertical axis, and horizontal distance, as measured along the centerline of the facility (or other recognized reference line), as its horizontal axis.

3. The *geometric cross-section*. This view has elevation as its vertical axis and horizontal distance, measured perpendicular to the centerline, as its horizontal axis.

4. The *superelevation diagram*. This applies to curved facilities, such as highways or railways, only. It consists of a graph with roadway or railway cross-slope (vertical axis) versus horizontal distance (horizontal axis). The cross-slope is measured relative to the centerline or some other axis of rotation for the facility. Alternatively, the diagram may show the elevation of the edge of pavement on the vertical axis.

COMPUTER EXERCISE

3.1 *Spread sheet*. Use a spread sheet to construct a table of stopping sight distances for design speeds ranging from 30 km/h to 120 km/h in increments of 10 km/h and grades ranging from -6% to +6% in 2% increments.

Worksheet

km/h -> m/s factor =	0.277778
Acceleration of gravity =	9.8
Reaction time =	2.5

		Grade						
Speed, km/h	f	-0.06	-0.04	-0.02	0.00	0.02	0.04	0.06
30.00	0.40	31.25	30.68	30.16	29.69	29.27	28.89	28.54
40.00	0.38	47.46	46.30	45.27	44.35	43.52	42.77	42.09
50.00	0.35	68.66	66.47	64.55	62.84	61.32	59.96	58.73
60.00	0.33	94.16	90.54	87.38	84.61	82.16	79.97	78.01
70.00	0.31	125.77	120.06	115.13	110.84	107.07	103.73	100.75
80.00	0.30	160.54	152.46	145.54	139.54	134.29	129.66	125.54
90.00	0.30	195.37	185.15	176.38	168.79	162.15	156.29	151.08
100.00	0.29	240.61	226.91	215.25	205.19	196.44	188.74	181.92
110.00	0.28	292.91	274.87	259.60	246.51	235.17	225.25	216.49
120.00	0.28	341.01	319.54	301.37	285.80	272.30	260.49	250.07

Notes

Cell names

D1	fac
D2	grav
D3	t

Column names for table

Speed column	v
F column	f
Grade columns	G

Formula for cells in table is

```
=v*fac*t+((v*fac)^2/((2*grav)*(f+G)))
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