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Abridgment

Single-Lane Capacity of Urban Freeway During Reconstruction

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Lane capacities of an urban freeway under various traffic-flow configurations during reconstruction are determined. The urban freeway studied was the Penn-Lincoln Parkway, Interstate 376, located in Pittsburgh, Pennsylvania. The study locations on the freeway were in the vicinity of the entrance and exit portals of the Squirrel Hill Tunnel. Traffic flows were studied in the right lane of a two-lane section of the highway for three distinct operating conditions. The first condition consisted of both lanes traveling in the same direction. For the second condition, the left lane was closed because of construction, which left only a single lane open to traffic. In the third condition, the left lane had a single lane of traffic traveling in the opposite direction. The results of this study determined the flow, average speed, and density at capacity for each of the operating conditions. A comparison of the data indicated that the single-lane capacity of both sides of the tunnel was significantly lower during the second and third operating conditions; during the third condition, the lowest level of capacity was attained. Generally, for a two-lane, two-way facility under forced flow, the sustained capacity for a single lane was about 1200 vehicles/h. With both directions under forced flow, a two-way flow of 2400 vehicles/h could be sustained.

Various procedures have been published through the years to evaluate the capacity of a roadway. These include, in the United States, the 1950 Highway Capacity Manual (1), the 1965 Highway Capacity Manual [Highway Research Board Special Report 87 (2)], and, most recently, Interim Materials on Highway Capacity [Transportation Research Circular 212 (3)].

These evaluations of capacity, however, do not consider the effect on traffic flow of construction work zones adjacent to a roadway. Within the past several years, the trend of constructing new highways has decreased, and the trend of reconstructing inadequate highways has increased. Unfortunately, the development of the evaluation of traffic flow through construction work zones has not developed at the same rate. The main examination of the subject has been by Dudek (4), who reports on capacity studies at urban freeway maintenance and construction work zones in Houston and Dallas, Texas, for five-, four-, and three-lane freeway sections.

CONSTRUCTION WORK-ZONE EVALUATION

A study was conducted to compare lane capacities of an urban freeway while it was under various traffic-flow configurations during reconstruction. The urban freeway studied was the Penn-Lincoln Parkway, Interstate 376, located in Pittsburgh, Pennsylvania. The locations chosen for comparison were in the vicinity of the entrance portal (site A) and exit portal (site B) of the Squirrel Hill Tunnel.

The parkway is a four- to six-lane divided urban freeway traversing east and west. It has an average daily traffic volume of 92 000 vehicles. The Pennsylvania Department of Transportation embarked on a 2-year safety improvement project to update the facility for a length of 6 miles; this consisted of the placement of a new 8-in concrete overlay road surface, new shoulders and concrete median barrier for the entire length of the project, and the rehabilitation of both tubes of the Squirrel Hill Tunnel.

The construction phasing consisted of reconstructing the westbound lanes during the 1981 construction season and the eastbound lanes during the 1982 construction season. The construction required that the westbound and the eastbound lanes be completely closed during various stages of their reconstruction. Since no convenient alternative route was available to detour parkway traffic, it was necessary to maintain two-way opposing traffic on the lanes opposite those being reconstructed.

Traffic flows were studied for the two locations in the right lane of a two-lane section of the highway for three distinct operating conditions. The first condition was for both lanes traveling in the same direction (two lanes, one way). For the second condition, the left lane was closed to traffic because of construction, which left only a single lane of traffic (one lane, one way). In the third condition, the left lane had a single lane of traffic traveling in the opposite direction (two lanes, opposing). Figures 1, 2, and 3 depict the three traffic conditions.

The horizontal alignment at the sites consisted of horizontal curves that were designed for vehicle speeds of more than 65 mph. The vertical alignment, traveling west to east, consisted of 0.5 mile of +4.5 percent grade approaching site A and 1 mile of -2.5 percent grade approaching site B.

The roadway section for sites A and B varied for each condition. During the two-lane one-way condition, two lanes, each 12 ft wide, existed. The right edge of pavement was paralleled by a curb 6 in high and a beam guardrail. The left edge of pavement was paralleled by a 6-in mountable curb and a grass median.

For the one-lane one-way condition, one lane 12 ft wide existed. The right edge of pavement remained unchanged for the two-lane, one-way condition. The left edge of roadway was paralleled by 55-gal drums spaced 100 ft center to center.

The two-lane opposing condition consisted of one lane 12 ft wide for the eastbound traffic and one

Figure 1. Two-lane one-way condition.

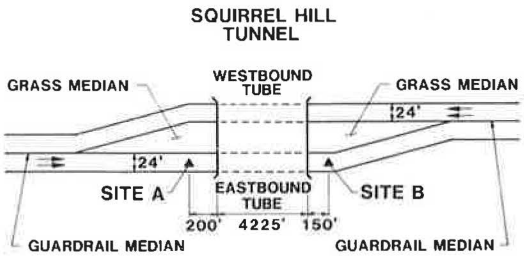


Figure 2. One-lane one-way condition.

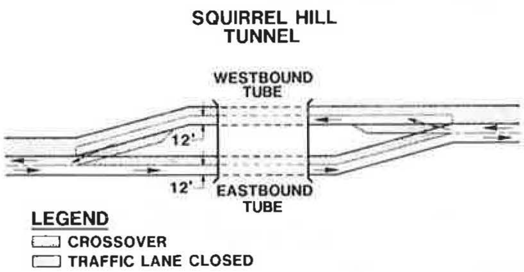
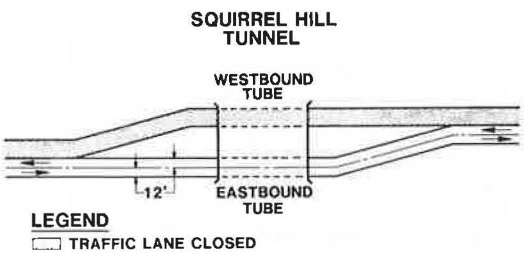


Figure 3. Two-lane opposing condition.



lane 12 ft wide for the westbound traffic. The two-way opposing traffic was separated by a 4-in double yellow center line, raised pavement markers, and traffic guideposts 18 in high.

The section for the 4225-ft-long eastbound tube of the tunnel consisted of two lanes 12 ft wide. The right edge of pavement was paralleled by a curb 8 in high and a parapet 1.5 ft high. The left edge of pavement was paralleled by a curb 8 in high and a parapet and pedestrian walkway 1.5 ft high. The vertical clearance was 19 ft at the face of the portal. Inside the tunnel 92 ft, the vertical clearance dropped to 14 ft 2 in. The same traffic control devices used for the roadway during each traffic condition were the same ones installed in the tunnel for each of the same traffic conditions.

The data were collected by a Stevens PPRII print punch traffic classifier. Volume, speed, and vehicle classifications were monitored. The speed data were reduced to space mean speed and the counts were reduced to flow. From the space mean speed and flow, density was then determined and the relationships of flow versus density, speed versus density, and speed versus flow were plotted.

Usually, data were collected for each day from about 6:00 a.m. to about 7:00 p.m. Two days of data collection were carried out at each site for each traffic condition.

RESULTS AND ANALYSIS

Total data results are summarized in Table 1, which shows the maximum 5-min flow rate along with the speed and density conditions for each site and traffic condition. Also given are the observed maximum sustained 1-h traffic flows. All maximum flow rates were monitored during forced-flow conditions with approximately 9 percent trucks. A comparison of the data indicated that the single-lane capacity for sites A and B was significantly lower during the one-lane one-way and the two-lane opposing conditions; during the two-lane opposing condition the lowest level of capacity was attained.

The data show that for normal operating conditions during the two-lane one-way condition, the maximum lane flow was about 1550 vehicles/h for 5 min and about 1350 vehicles/h for 1 h. This gives a peak hour factor of 0.87.

Under the one-lane one-way condition, the maximum 5-min flow was slightly more than 1400 vehicles/h, whereas the sustained 1-h flow was about 1200 vehicles/h. These volumes represent the maximum throughput of a single lane of traffic through the construction zone and are about 90 percent of the normal volume.

The two-lane opposing condition provided a further reduction of traffic flow to a 5-min flow of 1350 vehicles/h and a 1-h flow of just less than 1200 vehicles/h, which represented a further reduction of about 5 percent in maximum throughput.

The overall results of the study can be seen in Figures 4 and 5, which show the speed-flow envelope curves for these traffic conditions. Observation of

Table 1. Summary of traffic-flow data.

Condition	Site A (tunnel entrance) Day 1	Site A (tunnel entrance) Day 2	Site B (tunnel exit) Day 1	Site B (tunnel exit) Day 2
Two lanes one way				
Maximum 5-min flow (vehicles/h)	1512	1560	1596	1644
Mean speed (mph)	25.6	37.0	45.3	42.4
Density (vehicles/mile)	59	42	35	39
Maximum 1-h flow (vehicles/h)	1355	1359	1402	1414
One lane one-way				
Maximum 5-min flow (vehicles/h)	1428	1416	1536	1488
Mean speed (mph)	27.2	26.1	39.1	36.4
Density (vehicles/mile)	53	54	39	41
Maximum 1-h flow (vehicles/h)	1169	1208	1264	1258
Two lanes opposing				
Maximum 5-min flow (vehicles/h)	1368	1308	1344	1356
Mean speed (mph)	25.9	28.8	39.6	39.5
Density (vehicles/mile)	53	45	34	34
Maximum 1-h flow (vehicles/h)	1188	1153	1187	1223

Figure 4. Speed-flow relationship, entrance portal, for all three conditions.

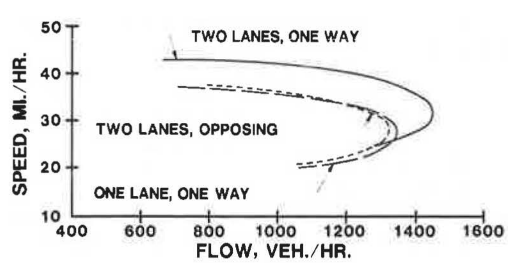
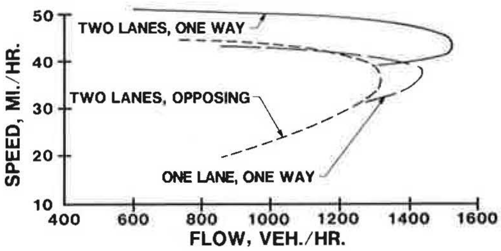


Figure 5. Speed-flow relationship, exit portal, for all three conditions.



the curves provides the following conclusions for site A (tunnel entrance):

1. The shape of the curves for each condition delineates wide envelopes, which is an indication that the entrance of the tunnel was a bottleneck location.
2. The curves were influenced by the reduction in the number of lanes available for traffic. The plot for the one-lane one-way condition and the two-lane opposing condition resulted in a shift of the curves down and to the left.
3. The opposing traffic during the two-lane opposing condition had a slight influence on the speed-flow curve. The curve moved left from the curve for the one-lane one-way condition.

The conclusions for site B (tunnel exit) were as follows:

1. The shape of the curves for the two-lane one-way condition and the one-lane one-way condition delineates narrow envelopes, which is an indication of free flow. The wide envelope of the two-way opposing condition indicates a bottleneck location.
2. The speed-flow curves were influenced by the reduction in the number of lanes available for traffic. The plot for the one-lane one-way condition and the two-lane opposing condition resulted in a shift of the curves down and to the left of the two-lane one-way condition. The overall traffic flows were controlled, however, by the discharge past the tunnel entrance.

CONCLUSIONS

The study was mainly concerned with determining the single-lane capacity of an urban freeway while under various reconstruction configurations, but it also gives some quantitative insight into capacity flows of a two-way two-lane highway.

The study shows that single-lane traffic flow through a construction zone is significantly less than single-lane traffic flow as part of a multilane flow under normal conditions. Single-lane flow alongside an opposing traffic stream has a somewhat lower capacity than single-lane flow with no opposing traffic stream.

Generally, it seems that for single-lane traffic flow under the given geometric conditions and 9 percent trucks, a flow of only 1200 vehicles/h can be sustained; short-term flow rates go up to 1350 vehicles/h. These agree reasonably well with the Texas study conducted by Dudek (4). During forced-flow conditions, however, traffic flow is very variable and follows no particular speed-flow relationship.

During the two-way opposing traffic condition, forced flow existed from both directions. Some manual-count samples showed that with two-way traffic, similar flows were being achieved in the opposite lane. This would indicate that the capacity of two-way two-lane sections of roadway with the given geometrics under forced-flow conditions can reach 2400-2500 vehicles/h.

Comparison of the data for each of the traffic-flow configurations indicates that the tunnel entrance was a restraint to traffic flow during the two-lane one-way condition and for the one-lane one-way condition. However, during the one-lane opposing condition, the opposing traffic caused the restraint to the traffic flow.

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