Current Collector–Distributor Road Design Practices

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The reconstruction of major urban freeways frequently includes the provision of collector-distributor (C–D) roads. In this paper, design issues are evaluated for C–D roads and slipramps along a 16-mi portion of I-270, located between Washington, D.C., and Frederick, Maryland. Design-year traffic volumes along I-270 are estimated to exceed 8,000 vehicles per hour in the peak direction. A literature review indicated that only minimal information was available concerning slipramp and C–D road geometric design. Operational data obtained from Texas and Illinois were referenced in the development of the geometric design for I-270. The recommended C–D road design consists of 12-ft-wide lanes for two-lane and three-lane C–D roads; a 15-ft-wide lane was recommended for one-lane C–D roads. Minimum desirable shoulder widths were determined to be 4 ft left and 14 ft right, with an absolute minimum of 4 ft. The recommended separation between the mainline and C–D road was 18 ft. The recommended slipramp design consists of a 15-ft-wide lane with 4-ft-wide left and right shoulders and adequate acceleration and deceleration lane lengths. In order to prohibit improper wrong-way use of the slipramp, the separation between the mainline and C–D road was bowed out to 42 ft to accommodate overlapping traffic barriers.

Interstate Route 270 extends approximately 30 mi from the Capital Beltway (I-495) surrounding Washington, D.C., to I-70 in Frederick, Maryland (Figure 1). The I-270 corridor is nationally known as a high-technology growth corridor. In addition to the U.S. National Bureau of Standards headquarters and other federal, state, and county government offices, the I-270 corridor includes commercial developments oriented toward science and technology and intense residential developments. The existing six-lane freeway facility was originally constructed in the 1950s as a four-lane freeway (US-240) and is now severely constrained by peak-period traffic volumes that exceed roadway capacity. Projected significant increases in corridor employment (up 66 percent by the year 2000) and households (up 62 percent by the year 2000) resulted in the proposed reconstruction project. The reconstruction of I-270 is directed toward enhancing vehicular mobility along this important corridor.

Existing mainline I-270 traffic volumes within the limits of reconstruction range from 34,000 to 123,000 average daily traffic (ADT). Design-year 2010 traffic volumes range from 79,000 to 184,000 ADT. Design-hour traffic volumes (DHV) in the year 2010 are estimated to range from 5,870 to 8,400 vehicles per hour in the peak direction. I-270 mainline truck percentages are 5 percent of the ADT and 3 percent of the DHV. The existing I-270 vertical profile is essentially level.

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PROJECT PLANNING

Before initiation of formal project planning activities in July 1980, improvements to I-270 were the subject of extensive discussion and analysis by public and private groups at the state, federal, and local levels. In late 1977, the Montgomery County Chamber of Commerce conducted a seminar on the economic development of the I-270 corridor. One of the recommendations was the widening of I-270.

During the course of the project planning study, a wide range of improvement alternatives and options was evaluated including interchange reconstruction, high-occupancy-vehicle (HOV) lanes, ramp metering, widening to 8- and 10-lane sections, and collector-distributor (C–D) roads. These alternatives were presented at an all-day workshop, summarized in a brochure, distributed to a mailing list in excess of 2,500 people, and presented to various business and citizen groups. The "Combined Location and Design Public Hearing" was held on February 15, 1984, following circulation of an environmental assessment *(1)*. Nearly 300 persons attended the hearing; 28 persons offered comments.

On the basis of the public and agency comments received on the environmental assessment *(1)*, modifications to the project alternatives were made and a *Finding of No Significant Impact/4(f) (2)* statement was completed. Location and design approval was granted by the FHWA in late 1984.

The recommended project planning alternative consisted of the following design elements within the 16-mi reconstruction limits:

- Provide one additional mainline lane per direction (Figure 2);
- Provide a two-lane continuous C–D road in each direction from north of I-495 to the Maryland Route 124 interchange (Figure 2);
- Provide proper transitions to the C–D road beginning north of I-495 consisting of a six-lane section leading to the four-lane mainline and two-lane C–D road split;
- Shift the centerline alignment away from residential areas in three locations in amounts ranging from 24 to 45 ft;
- Provide retaining walls adjacent to residential areas to eliminate right-of-way acquisition (11 residences were to be displaced as a result of interchange improvements); and
- Provide noise barriers and visual screens to minimize adverse noise impacts in all residential subdivisions along I-270.

The total estimated cost for these improvements, including right-of-way, was in excess of $110 million in 1984 dollars.

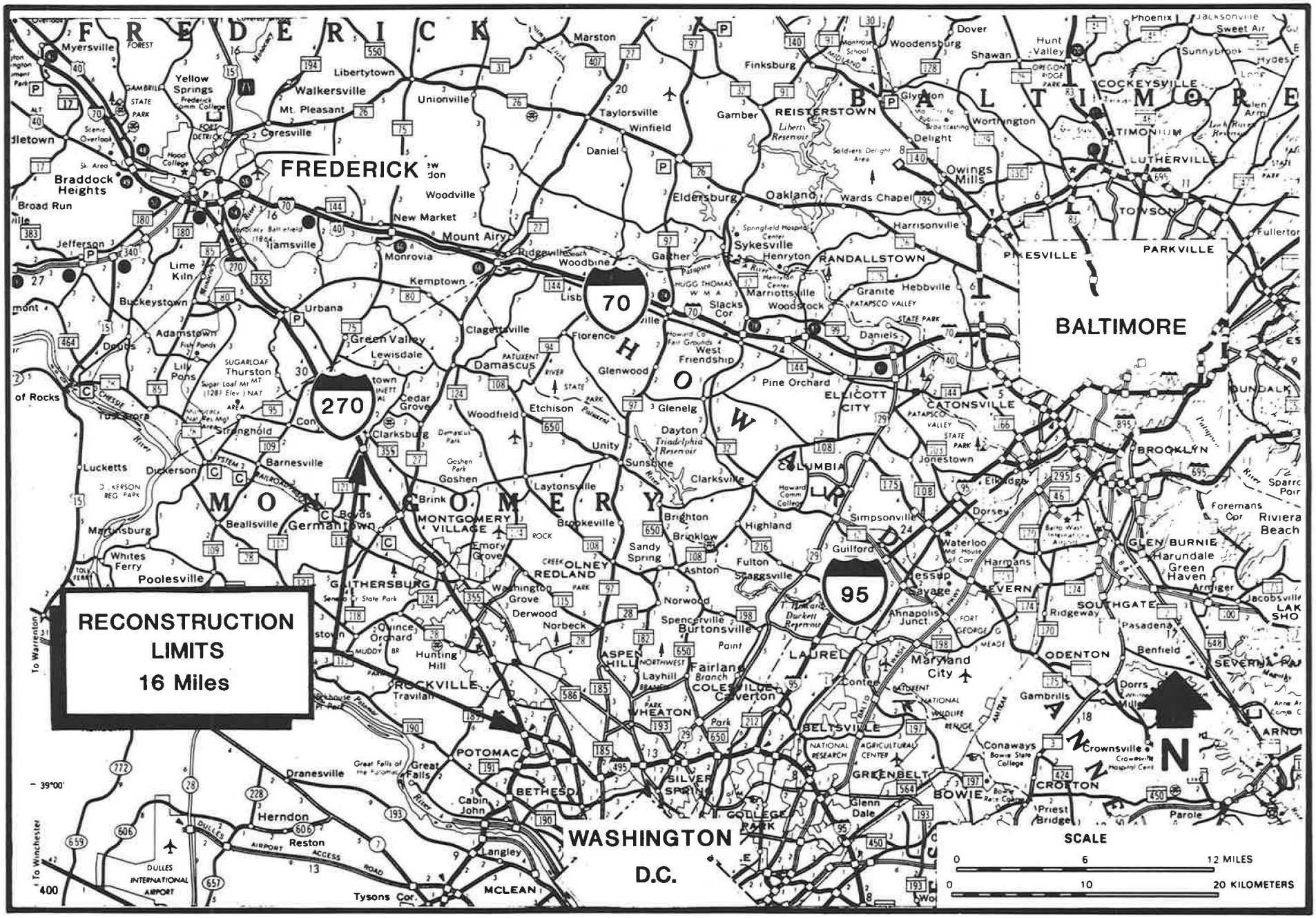
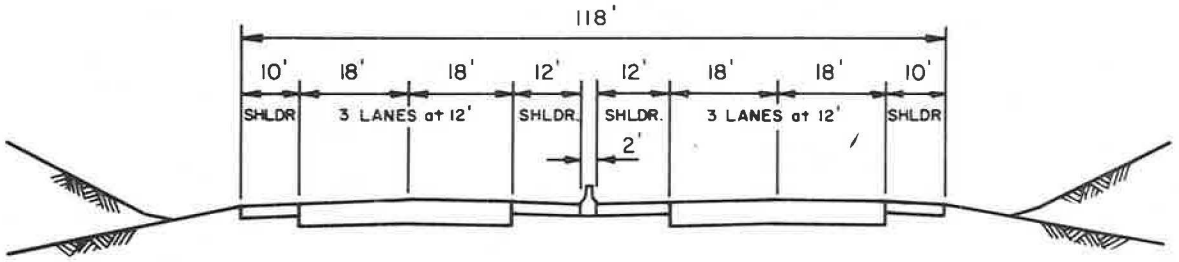
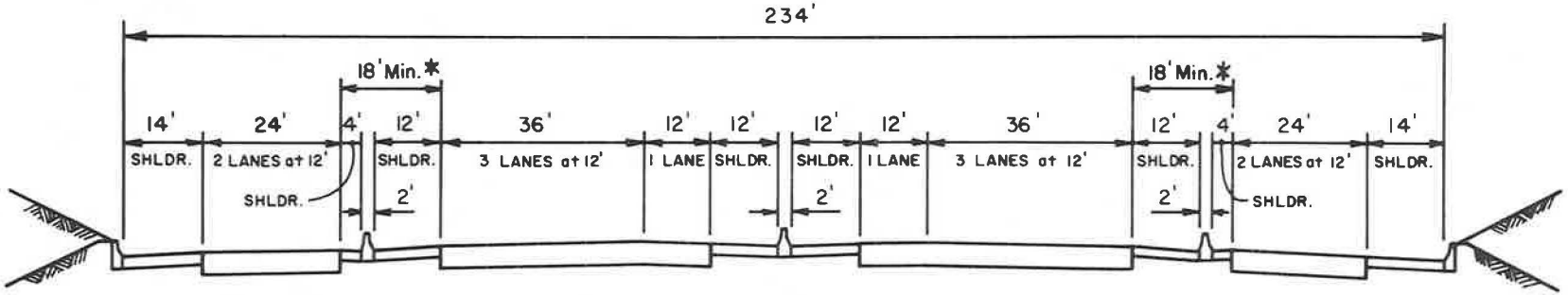


FIGURE 1 Project location map.



EXISTING I-270



PROPOSED RECONSTRUCTION

(Existing Right-Of-Way Width Varies 250' to 300')

* The Separation Between The Mainline And C-D Road Was Determined To Be 18' Minimum. At The Slip-Ramps, This Width Was Increased To 42' (See Figure 5).

FIGURE 2 Mainline typical sections.

FINAL DESIGN

In addition to regular maintenance and bridge redecking along I-270, three interchange improvements were identified early in the process and accelerated into the final design. Two of these projects consisted of new interchanges and one was a reconstruction.

At the present time, three separate and major mainline, C–D road, and interchange design projects are underway. Advertisement dates for individual construction contracts range from late 1986 to 1987.

I-270 FREEWAY RECONSTRUCTION ISSUES

The following list of reconstruction issues outlines the geometric, operational, and political aspects of the I-270 project, which in many ways affected the C–D road and slipramp designs discussed in this paper.

- Maintain three-through lanes per direction during all phases of construction.
- Avoid or minimize residential right-of-way acquisition through the extensive use of retaining walls.
- Maintain basic four lanes per direction for continuity along the mainline, including through-interchange areas.
- Provide state-of-the-art stormwater management controls, minimizing runoff of roadway pollutants into streams.
- Wherever feasible, provide second-story noise abatement.

AASHTO POLICY

In the 1984 AASHTO guide *A Policy on Geometric Design of Highways and Streets* (Green Book) *(3)*, and in the 1965 AASHTO guide *A Policy on Geometric Design of Rural Highways* (Blue Book) *(4)*, the use of C–D roads is recommended wherever high speeds, high volumes, or both, must be accommodated.

Use of C–D roads eliminates the interference to mainline through traffic by removing interchange weaving and interchange exits and entrances from the through lanes and placing them on separate, parallel, one-way roadways.

Although the use of C–D roads is operationally superior to conventional interchange arrangements, the cost of longer overhead structures, additional construction paving, and required right-of-way is greater.

RESEARCH FINDINGS

While the concept of C–D roads is not new, little research information pertaining to desirable design geometrics or operational and safety characteristics exists.

The publication "Application of C–D Roads in Freeway Rehabilitation" *(5)*, which deals with C–D roads and their importance in the upgrading of existing congested freeways, was used as a guide in the development of the I-270 C–D road system. In describing the lack of C–D road research information, the article stated: ". . . each new facility usually rectifies the operational problems of the previous [one] . . .," implying that today's design practice serves as the ongoing research of which refinements are incorporated in future designs.

DESIGN ISSUES

In developing the recommended design for the C–D roads, the following design issues were addressed:

- Lane width,
- Right shoulder width,
- Left shoulder width,
- Lane balance,
- Lane continuity,
- Spacing distance between gore areas of slipramps, and
- Basic number of lanes versus capacity requirements.

DESIGN STUDIES AND RECOMMENDED DESIGN

To develop the proper ultimate design of C–D roads, key design issues were evaluated by weighing benefits of a design type versus practicality of the design. Construction costs and constrained right-of-way limitations in the I-270 corridor were important considerations.

Lane widths on the C–D road were generally 12 ft wide for a two- or three-lane typical section (Figure 3). In areas of tight right-of-way, an 11-ft lane width was considered in order to reduce the amount of new right-of-way acquisition at a cost of $\$16/ft^2$. Because the use of narrower travel lanes lowers capacity under uninterrupted flow conditions compared with 12-ft lanes according to the following table *(6)*, the operational benefits of a 12-ft lane were determined to exceed the cost savings; therefore, the 12-ft lane width was recommended.

	Percent of 12-ft Lane Capacity	
Lane Width (ft)	*Two-Lane Highways*	*Multilane Highways*
12	100	100
11	88	97
10	81	91
9	76	81

Lane balance and lane continuity were strictly maintained to maximize safety and efficient operations along the entire length of the I-270 mainline and C–D road (Figure 4).

SLIPRAMP DESIGN PRACTICES

AASHTO Policy

Although AASHTO policy recommends the use of C–D roads where high speeds or high volumes must be accommodated, it does not address desirable geometrics or safety and operational design issues for slipramps between the mainline and C–D road.

Research Findings

As discussed in the C–D road research findings, only limited research information is available.

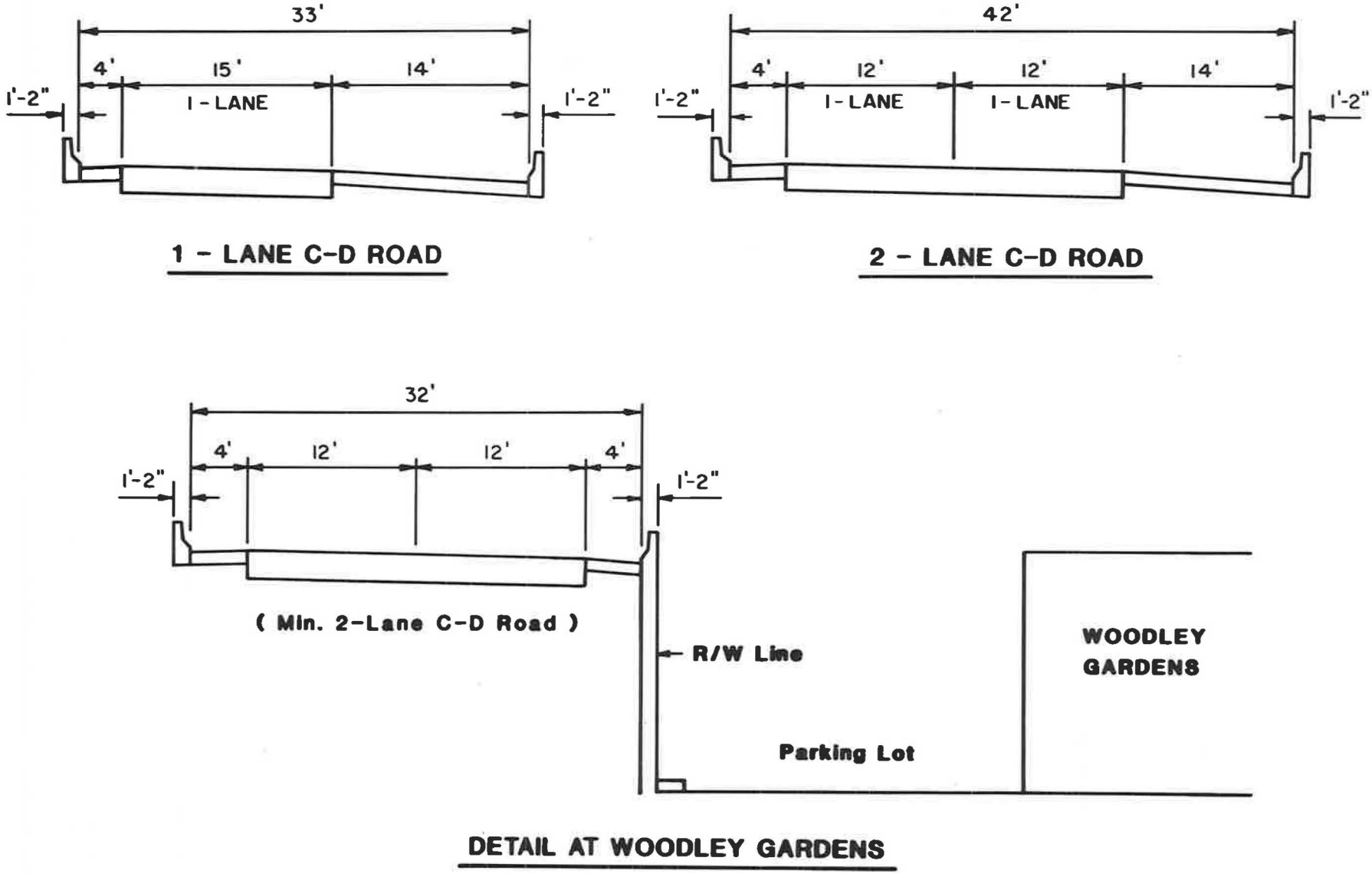


FIGURE 3 C–D road typical sections.

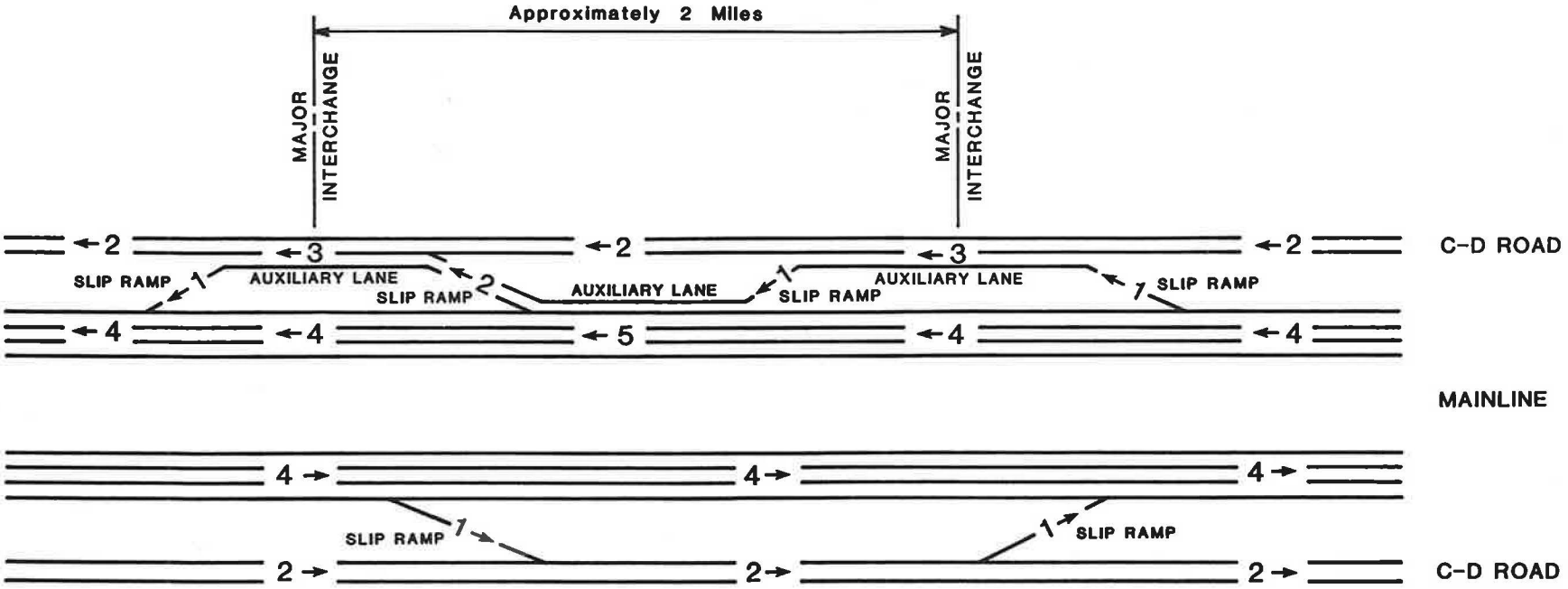


FIGURE 4 Mainline and C–D road lane arrangements.

Design Issues

In developing the recommended design for slipramps along the C–D road, key design issues addressed included

- Slipramp lane width,
- Left shoulder width,
- Right shoulder width,
- Acceleration and deceleration lane lengths, and
- Opening treatment at merge and diverge points.

Design Studies and Recommended Design

In developing slipramp lane width, advantages and disadvantages of using 12-ft-wide versus 15-ft-wide lanes were examined. Because 12-ft approach and departure widths were used for acceleration and deceleration lanes in the slipramp area, the advantage that would be served by an additional 3-ft width in the slipramp area with a nearly instantaneous passing of the slot in the median barriers where slipramp lengths were approximately 180 ft appeared questionable (Figure 5).

With special emphasis on safety and efficient traffic operations, a 15-ft-wide slipramp was recommended.

For the left shoulders, a 4-ft minimum offset to the barrier was recommended in the slipramp area. Because the passing of the slot in the slipramp area between traffic barriers is nearly instantaneous, it is unlikely that vehicular breakdowns would occur that would require a shoulder refuge area. In the event a breakdown occurred, the 27-ft total width would provide ample refuge for disabled vehicles.

In order to maintain a safe running speed for traffic transferring from the mainline to the C–D road and its return, AASHTO's desirable deceleration and acceleration lane lengths were provided to accommodate a 60-mph mainline design speed and a 50 mph C–D road design speed (Tables 1 and 2).

The most important feature in developing the slipramp, or transfer lane, between the C–D road and the mainline was the proper development of the gore details at the divergence from the mainline or C–D road and the immediately following associated merge. At this point, the driver has made the decision to enter the slipramp and should be provided with a smooth geometric design to ensure a safe operation during the transfer. Research developed by the Texas Highway Department indicates that a 4-degree diverging angle with 2-degree transition curves provides smooth transitions between major arterials and frontage roads.

For the I-270 project (a high-type design), the maximum degree of curvature (3 degrees) accommodated a 50-mph design speed. A 4-degree divergence angle was maintained as maximum.

The Texas Highway Department also found through practical experience that the exit and entrance gore area crash cushion should overlap to prohibit the independently minded driver from attempting to cross through the resulting gap in the slipramp barriers in conflict with the intended traffic flow in order to avoid downstream congestion. To obtain this overlap, the outer separation of typically 18 ft was bowed out to 42 ft to provide an overlap between the barriers and to maintain desirable shoulder widths.

TABLE 1 MINIMUM ACCELERATION LENGTHS (ft) FOR ENTRANCE TERMINALS WITH FLAT GRADES OF 2 PERCENT OR LESS *(1)*

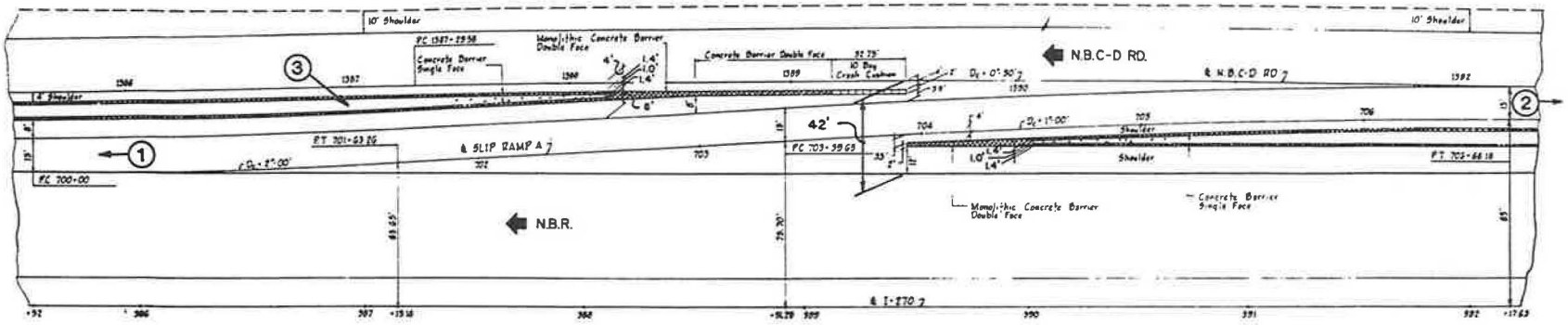
Highway Design Speed V (mph)	Speed Reached V_a (mph)	Initial Speed V_a (mph)[a]								
		0	14	18	22	26	30	36	40	44
30	23	190	–	–	–	–	–	–	–	–
40	31	380	320	250	220	140	–	–	–	–
50	39	760	700	630	580	500	380	160	–	–
60	47	1,170	1,120	1,070	1,000	910	800	590	400	170
70	53	1,590	1,540	1,500	1,410	1,330	1,230	1,010	830	580

[a]Corresponding entrance curve design speeds are 0, 15, 20, 25, 30, 35, 40, 45, and 50 mph.

TABLE 2 MINIMUM DECELERATION LENGTHS (ft) FOR EXIT TERMINALS WITH FLAT GRADES OF 2 PERCENT OR LESS *(1)*

Highway Design Speed V (mph)	Average Running Speed V_a (mph)	Average Running Speed on Exit Curve V_a' (mph)[a]								
		0	14	18	22	26	30	36	40	44
30	28	235	185	160	140	–	–	–	–	–
40	36	315	295	265	235	185	155	–	–	–
50	44	435	405	385	355	315	285	225	175	–
60	52	530	500	490	460	430	410	340	300	240
65	55	570	540	530	490	480	430	380	330	280
70	58	615	590	570	550	510	490	430	390	340

[a]Corresponding exit curve design speeds are 0, 15, 20, 25, 30, 35, 40, 45, and 50 mph.



SLIP RAMP DETAIL : C-D ROAD TO MAINLINE

Scale : 1"=50'

NOTES

1. **Length of acceleration lane based on AASHTO speed change criteria (50 MPH to 60 MPH, 170' minimum, see Table 2) and traffic merging requirements: typical length 600'+ 300' taper.**

2. **Deceleration lane on C-D Road is a taper-type exit with 4° maximum divergence. Deceleration lanes on the mainline (taper-type) are based on AASHTO speed change criteria (60 MPH to 50 MPH, 240' minimum, see Table 2) and traffic diverging requirements: typical length 240'.**

3. **Confirmation Signing**

4. **Transition between 18' Outer Separation & 42' Outer Separation for "Bowed-Out" Slip Ramps**

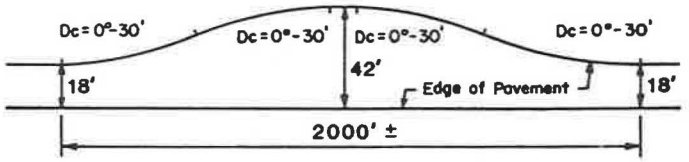


FIGURE 5 Slipramp detail.

SUGGESTED RESEARCH

- Operational effects of reduced shoulder widths on both mainline and C–D road traffic flow.
- Operational effects of a 12-ft versus a 15-ft lane on slipramps.
- Operational effects of reducing the C–D road to one lane in areas of light traffic volumes.
- Recommended spacing between slipramps based on distance and peak-hour volumes.

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