Development of Proposed Height Standards and Tolerances for Light-Post Traffic Barriers

JAMES E. BRYDEN

ABSTRACT

Current New York State height standards for light-post traffic barriers are based on crash tests, in-service accident experience, and analysis of vehicle geometric characteristics. However, those standards were set in 1969. Analysis of the geometric characteristics of current vehicles reveals that if mounting heights were lowered by 3 in., the railings would provide improved protection against vehicle underride and still provide satisfactory protection against vaulting. Crash-test data and extensive accident experience indicate that barriers mounted at this lower height will continue to perform well, even when a ±3-in. tolerance is permitted. Current New York State and AASHTO standards and the proposed new standards are presented, and it may be possible to increase the range of allowable heights after completion of research now planned or under way.

When New York State's light-post traffic barrier systems were adopted in the mid-1960s, top-of-rail heights were specified at 27 in., except for the W-beam median barrier, which was set at 29 in. Those heights were based on then-current standards for other barrier systems, analysis of vehicle and barrier geometry, and full-scale crash tests. In 1969 top-of-rail heights were increased to 30 in. for cable and box-beam and 33 in. for W-beam. That change occurred after vehicle vaulting occurred in a small number of barrier accidents, mostly involving W-beam. However, the change was also supported by an analysis of geometric characteristics of vehicles common at that time, which indicated that certain bumper and sheet-metal configurations contributed to the vaulting problem.

The heights implemented in 1969 are still in effect on current standard sheets. However, in the late 1970s barrier heights again became a concern when a large number of rehabilitation and preservation (R&P) projects were found with barrier heights substantially below current standards. Some had been installed at the original (lower) standard, whereas others were low from normal construction and maintenance variation, post settlement, or subsequent pavement overlays. Addition of overlays under the planned projects sometimes resulted in effective barrier heights much lower than current standards. The correction of all low barriers would be expensive and difficult to justify in terms of increased safety, especially where few accidents are expected. On the other hand, extremely low barriers cannot be expected to perform well, and a significant safety benefit may result by correcting rail heights on some projects. Until now barrier height corrections have been handled on a project-by-project basis. Further complicating the problem, an obvious shift in vehicle geometry has occurred over the past decade. It became apparent that hood heights on many newer cars were extremely low relative to traffic barriers mounted to current standards. Several recent barrier accidents involving underride of the rail were noted by New York research engineers, which added to this concern about impacts by low vehicles.

In January 1983 the Engineering Research and Development Bureau of the New York State Department of Transportation (NYSDOT) began planning a large-scale accident investigation to relate traffic barrier performance to rail height (1). However, because of the massive effort required to collect and analyze the large volume of accident data, development of new rail heights and tolerances would not be completed for some time. The Engineering Research and Development Bureau was therefore given the assignment of developing proposed interim heights and tolerances that could be used on R&P projects until new standards were developed based on results of the planned research. In this paper the development of the interim standards is described; these standards are based on four sources of information:

1. New York State and AASHTO height standards and tolerances,
2. Full-scale barrier tests,
3. New York State barrier accident experience, and
4. Vehicle geometric characteristics.

DEVELOPMENT OF CURRENT STANDARDS

New York State and AASHTO standards for light-post barrier heights are given in Table 1. AASHTO-suggested standards are provided in the 1977 barrier guide (2). The stated purpose of that publication is to "summarize the current state of knowledge and to present specific design guidelines for highway traf-

TABLE 1 Summary of Barrier Mounting Height Standards

Barrier Type (light post)	Height to Top of Rail Element (in.)			
	New York State		AASHTO	
	Original	1982[a]	Standard	Minimum[b]
Guiderail				
Cable	27	30	30	27
W-beam	27	33	30 (33)	27
Box-beam	27	30	27 (30)	24
Median barrier				
W-beam	29	33	33	27
Box-beam	27	30	30	27

[a]1982 standard sheets do not provide tolerances for mounting heights. All heights are specified as nominal dimensions.
[b]1977 AASHTO barrier guide (2, p. 69), provides the following recommendations on barrier height tolerances for guiderail: "In the absence of data supporting a contrary conclusion, height deviations greater than 3 in. from those recommended in Table III-B-1 would warrant height corrections. . . ." Recommended tolerances for median barrier are provided on page 110: ". . . the rail height of an operational system should be approximately equal to the original design height of the system. In any case, it is suggested that the barrier be approximately 27 in. above the ground or greater."

fic barriers. The guidelines establish ... how the barriers should be installed dimensionally or geometrically." It is important to note that this guide provides the state of the art in 1977; it is now outdated in some respects. Another important guideline is NCHRP Report 230 (3). It is recommended in this report that proposed barriers first be evaluated by full-scale crash tests to determine compliance with suggested criteria for barrier strength, occupant risk, and vehicle trajectory. However, it is also recommended that candidate barrier systems should be further evaluated through documented field installations. Both testing and field evaluation are necessary to determine satisfactory performance.

New York's light-post barriers are listed in the AASHTO guide, based on successful crash tests and field performance. In 1969 rail heights of these barriers were raised, as noted in Table 1. This change was based primarily on three considerations, documented in Research Report 51 (4):

1. A small number of accidents occurred where vehicles vaulted barriers installed to the original standards;
2. A large-scale field performance evaluation covering the period from 1967 to 1971 indicated that barrier penetration was frequent enough to be of concern, and these accidents resulted in higher injury rates than when the vehicle was contained; and
3. Measurements of then-current vehicles revealed that contoured bumpers on several popular models could slide over the top of the rail element, thus increasing the likelihood of vaulting.

Nine accidents involving barrier penetration were investigated at that time. One penetration of cable resulted from failure of the splices and was not related to mounting height. Penetration of one box-beam guiderail that had a mounting height of only 23 in. was investigated. The vehicle impacted at a high-roll attitude, which placed the bumper above the rail. Seven cases of W-beam vaulting were investigated; in each case the mounting height was near the 27-in. standard, but high-roll attitudes permitted the bumpers to mount and vault the barrier.

Subsequent analysis of statewide accident data (Table 2), including the Taconic Parkway and New York State Thruway, revealed that barrier penetration was not an isolated problem, but resulted in roughly 20 percent of the statewide and Thruway accidents. However, penetration included several different vehicle-barrier reactions, including vaulting, underriding, structural separation of the barrier, and contact with objects behind the barrier as a result of dynamic deflection. The incidences of vaulting and underriding could not be isolated. W-beam resulted in the highest penetration rate, and penetration of box-beam was extremely rare. Even with the higher penetration rate experienced by W-beam, the rate for light-post barriers was significantly better than the older barrier types they replaced. A follow-up accident survey was conducted after rail heights were raised. Those results, presented in Research Report 57 (5), appeared to confirm that barrier penetration was reduced, although the method of data collection made it impossible to determine the exact improvement and the actual occurrences of vaulting and underriding.

TABLE 2 Summary of Guiderail Accident Experience

Barrier Type	Total Impacts[a]	Percent Penetration[a]	Percent Injury Penetration[b]	Percent Injury Contained[b]
Research Report 51 *(4)*				
Cable GR	271	17.0	13.8	2.7
W-beam GR	106	27.4	15.4	11.6
Box-beam GR	32	9.4	28.6	9.6
Box-beam MB	33	3.0	0.0	22.0
All light post	388	18.0	15.5	7.4
All heavy post	1,561	28.8	19.0	9.3
W-beam GR and MB (Thruway)	183	20.8		
Box-beam MB (Taconic)	234	0.5	0.0	9.4
Research Report 57 *(5)*				
All light post	363	4.1[c]	–[d]	–[d]

Note: GR = guiderail and MB = median barrier. The data-collection periods are as follows: for Research Report 51, statewide, 1967-1969; Thruway, 1967-1969; and Taconic, 1968-1971; for Research Report 57, it was 1972-1975.

[a]Midsection accidents only.

[b]Midsection and end-section accidents.

[c]A large portion of accidents did not report penetration or containment. Some of these may have been penetrations.

[d]2.0 percent severe.

The data in Table 3 give geometric characteristics for a sample of vehicles from that period, with two specific measurements provided: first, the height to a point on the bumper that can lead to vaulting if that point reaches the top of a barrier, and second, the height to a point on the hood that can result in underriding if this point gets below the bottom of the rail. Examples of 1969 and 1981 vehicles with these points marked are shown in Figure 1.

TABLE 3 Geometric Properties of Typical Vehicles, 1960-1970

Year	Make	Model	Height (in.) Override	Height (in.) Underride
1969	Dodge	Charger	27	32
1969	Chrysler	300	26	32
1969	Pontiac	Lemans	25	31
1969	Chevrolet	Caprice	24	32
1969	Plymouth	Fury	22	36
1968	Ford	Thunderbird	22	29
1970	Plymouth	Barracuda	21	29
1970	Oldsmobile	88	21	32
1966	Chevrolet	Chevelle	21	33
1966	Chevrolet	Nova	20	33
1967	Ford	Mustang	20	31
1963	Chevrolet	Impala	19	34
1969	Chevrolet	Chevelle	19	31
1960	Chevrolet	Corvair	16	28
1962	Plymouth	Fury	15	32
1966	Volkswagen	Beetle	15	28
1960	Volkswagen	Beetle	14	28

The data in Table 3 indicate that bumper heights varied widely, and some popular vehicles had high bumpers that could lead to vaulting problems. However, the likelihood of barrier underride appears remote, even for small cars. The greatest vaulting concern was with the W-beam. Although the height to the top of the barrier was originally 27 in., the center of the upper corrugation was nearer to 24 in. When a vehicle bumper struck above this point, the low torsional resistance of the W-beam permitted it to twist, thus forming a ramp. In high-angle, high-speed impacts, bumpers that sloped down and back could slide over this ramp, thus resulting in vaulting. Examining the data in Table 3, it is apparent that several vehicles popular around 1970 could impact the W-beam in such a manner that the bumper would slide over the rail, especially if the vehicle was in a high-roll attitude at impact. Examples of such matches are seen in Figure 2, with 1969 and 1981 vehicles adjacent to a W-beam mounted 27 in.

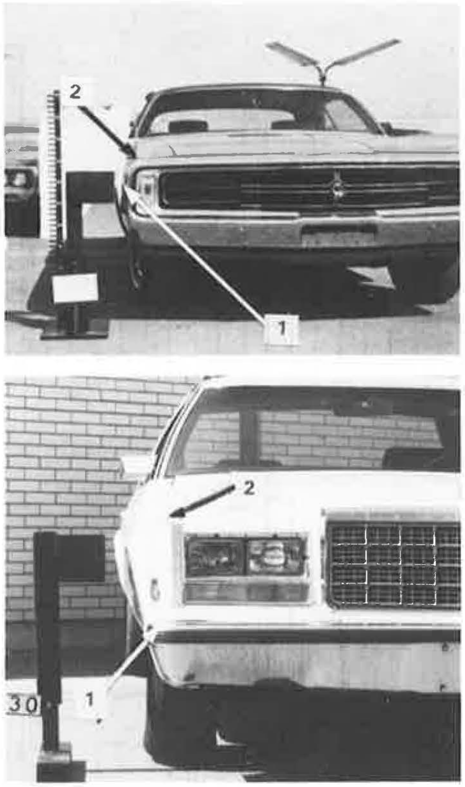

FIGURE 1 Guiderail override (1) and underride (2) points on 1969 (top) and 1981 (bottom) Chrysler sedans.

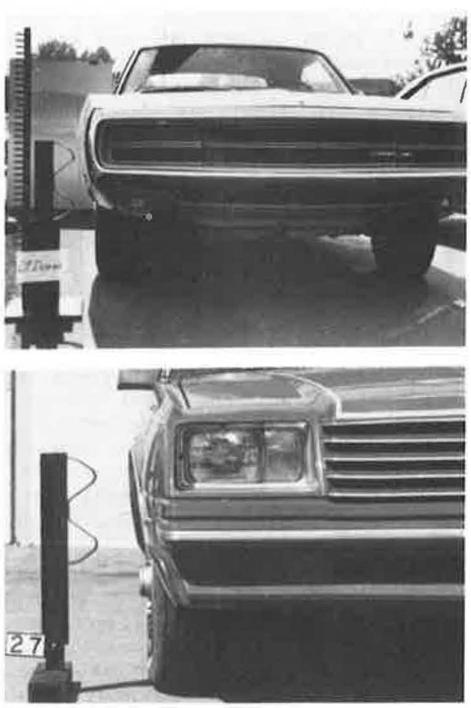

FIGURE 2 W-beam guiderail at 27-in. mounting height with 1969 (top) and 1981 (bottom) Dodge sedans.

FIGURE 3 Box-beam override (1) and underride (2) points on 1970 (top) and 1980 (bottom) popular small sedans.

high. Figure 3 shows examples of 1970 and 1980 small vehicles adjacent to a box-beam mounted at 30 in., which presents a risk of underriding.

PROPOSED HEIGHT STANDARDS AND TOLERANCES

Characteristics of Current Vehicle Fleet

Although the rationale used to set rail heights in 1969 appears soundly based, vehicle geometrics obviously have changed drastically since then. Cars are smaller and lighter, bumper heights are lower and more uniform to comply with Federal Motor Vehicle Safety Standard 215, and the front edges of hoods have been lowered to reduce air drag. Thus a reexamination of barrier heights was needed. As a starting point, vehicle geometric characteristics were measured for virtually all 1983 model passenger vehicles, light trucks, vans, and utility vehicles. Only measurements of duplicate vehicles sold by two or more divisions of the same manufacturer were omitted, such as the Plymouth Horizon and Dodge Omni. Two characteristics are of primary concern to ensure proper contact with traffic barriers--the bumper override point and hood underride point previously described.

This sample was selected because it permitted easy measurement of a wide range of vehicles under identical conditions by visiting area automobile dealers. Although the sample contained only 1983 vehicles, it was thought to be quite representative of the passenger fleet, especially in terms of bumper heights. Current federal bumper standards have been in effect for about a decade, so most passenger cars now have similar bumper heights. In addition, vehicle sheet metal now often remains nearly identical over several model years, and several popular 1983 models have not experienced significant design changes since the late 1970s. No effort was made to weight the resulting sample to account for sales volume. However, the resulting distribution does provide information on the extreme cases, and it is these limits that are of most concern. For the purposes of this effort, the data collected provide a satisfactory indication of maximum bumper height and lowest hood height, and these are the parameters needed to establish rail heights.

These characteristics are summarized in Table 4 and Figure 4 for a total of 86 vehicles. Heights were measured with the vehicle sitting on a flat surface and a 200-lb driver in the vehicle. However, they vary with vehicle loading, tire pressure, and especially with vehicle attitude and suspension position at impact. To accommodate a wider range of impact conditions, some adjustment should be made to these heights to arrive at design values. Because typical suspensions can easily accommodate ±3 in. of travel, that figure was chosen for this analysis. Certainly, greater disparities from the dimensions given in Table 4 can result under extreme conditions, but it is not realistic or even possible to accommodate the widest extremes in the design of the barriers.

Development of Proposed Standards

The highest and lowest contact points on all three types of railings are about 3 in. from the center of the rail. The box-beam has a 6-in. vertical face and the three cables span a total vertical distance of 6 in. The W-section rail, while measuring 12 in. overall vertically, has two major protrusions (corrugations) on the traffic face. The peaks of these protrusions are about 6 in. apart, 3 in. above and below rail center.

In a potential underride accident, it was assumed the vehicle suspension could be compressed 3 in., that is, the hood could be 3 in. closer to the ground than measured with the vehicle at rest. For analyzing possible override (vaulting) accidents, the opposite assumption was made, that is, the suspension could be extended 3 in., thus raising the bumper 3 in. higher than measured. To provide adequate engagement or bearing on the rail, not less than 3 vertical inches of sheet metal (or bumper) should contact the rail face.

TABLE 4 Geometric Characteristics of 1983 Vehicles

Vehicle Type	Override Height (in.) Lowest	Override Height (in.) Highest	Underride Height (in.) Lowest	Underride Height (in.) Highest
Subcompact				
Domestic	16	20	27.5	30.5
Foreign	15.5	20.5	27	30
Compact				
Domestic	17	21	28	31
Foreign	16	22	29	31.5
Intermediate				
Domestic	17.5	19	28.5	33
Foreign	17	18.5	29	32
Full size, domestic	17	19	30	34
Sports, specialty	13.5	20.5	13.5	31
Utility 4x4				
Full size	24	24	44	44
Compact	19	24	29.5	39.5
Pickup				
Full size	16.5	24.5	40	44
4x4	24	24	45	45
Compact	16.5	22	33	34.5
Van	18	18	44	44

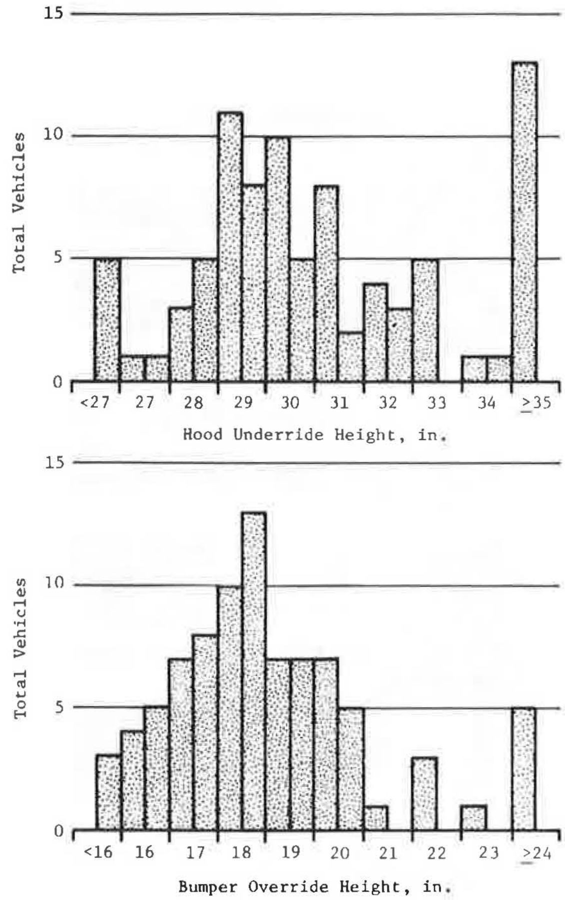

FIGURE 4 Distribution of barrier underride and override heights for 1983 model passenger vehicles, utility vehicles, and light trucks.

Working with these assumptions and the measured vehicle characteristics, proposed rail heights were calculated to prevent vehicle underride (submarining) or override (vaulting), as shown in Figure 5. To establish the desired maximum rail elevations, it was necessary to select a design vehicle hood height. Referring to Table 4 and Figure 4, it can be seen that only 5 of the 86 vehicles measured (all sport or specialty models) had hood heights less than 27 in. Thus 27 in. was selected as a starting point. Taking that value and subtracting 3 in. for suspension compression (positive pitch) brings the desired bottom-of-rail elevation down to 24 in. If the center of the rail rather than the bottom is at the top of the hood, the lower half (3-in. portion) of the rail will contact the front corner of the car, thus providing solid barrier-to-vehicle contact for all rails. The elevation of the center of all rails thus could be 24 in., and the maximum desirable heights to the top of the rail to prevent underride should be as follows: cable, 27 in.; box-beam, 27 in.; and W-beam, 30 in.

The opposite reaction--vaulting--may occur if the rail element is too low. To determine a minimum acceptable elevation, heights were measured to a substantial engagement point on the various vehicles. These override heights are shown in Table 4 and Figure 4. In this case only one passenger vehicle (a low-volume imported compact), some four-wheel drive utility vehicles (4x4), and 1-ton pickups (eight vehicles total) exceeded 21 in. Thus 21 in. was selected as a design starting point. Adding 3 in.

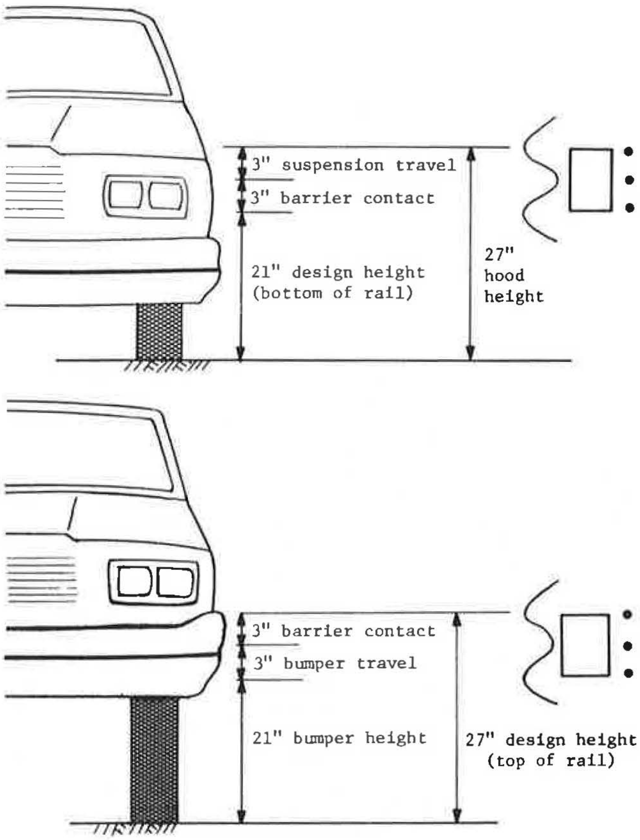

FIGURE 5 Desirable rail heights to protect against underride (top) and override (bottom).

for vehicle rise (because of roll away from the barrier) and limiting this point on the vehicle to the midpoint on the rail again establishes centers of all rails at an elevation of 24 in. This translates into desirable heights to top of rail to prevent override as follows: cable, 27 in.; box-beam, 27 in.; and W-beam, 30 in.

Thus setting these rail heights accommodates nearly all passenger vehicles and most light trucks, vans, and utility vehicles in terms of both submarining and vaulting. These heights were chosen considering reasonable margins to accommodate suspension travel, sheet-metal deformation, and other variables.

Other Studies Supporting These Proposed Standards

Although these height standards appear rational based on current fleet characteristics, it is desirable to examine additional data to determine how vehicles can be expected to react to these heights. Thus both full-scale crash tests and in-service performance data were examined to determine how barriers at the proposed heights may perform. NYSDOT conducted numerous crash tests in the 1960s on its current barrier systems and on geometrically similar prototypes (6,7). The data in Table 5 summarize 29 midsection tests, including a wide range of vehicles, impact conditions, and mounting heights. The single most important point gained from reexamining these tests is that none resulted in a vehicle vaulting over a barrier, even though nearly all these barriers were at or below the heights proposed here. However, 5 of the 29 tests resulted in the hood of the vehicle getting under the rail or partial snags and spin-outs. These tests indicate that mounting heights of 27 in. for the cable and box-

TABLE 5 Summary of Full-Scale Crash Tests

					Impact	
Test[a]	Barrier Type	Height (in.)	Vehicle Type	Weight (lb)	Speed (mph)	Angle (degree)
18	Cable GR	30	1960 Plymouth	3,900	62	32
20[b]	Cable GR	30	1961 Plymouth	3,300	58	25
21	Cable GR	27	1956 Anglia	1,623	57	25
33	Cable GR	30	1961 Plymouth	3,300	56	25
36[b]	Cable GR	27	1961 Plymouth	3,300	35	43
37[b]	Cable GR	30	1961 Plymouth	3,300	53	5
46	Cable GR	27	1961 Plymouth	3,300	53	25
47	W-beam GR	27	1962 Plymouth	3,000	48	25
48	W-beam GR	24	1962 Plymouth	3,000	45	25
49	W-beam GR	30	1961 Plymouth	3,300	58	25
50[b]	W-beam GR	33	1955 Porsche	2,000	61	25
51	W-beam GR	33	1966 Plymouth	3,945	50	25
20[b]	W-beam MB	29	1957 DKW	1,975	70	25
40	W-beam MB	30	1964 Ford	3,680	46	35
5	Box-beam GR	27	1965 Plymouth	3,385	58	25
8	Box-beam GR	27	1966 Plymouth	3,385	55	25
19	Box-beam GR	27	1957 Anglia	1,623	60	25
25	Box-beam GR	27	1961 Plymouth	3,300	50	25
34	Box-beam GR	27	1961 Plymouth	3,300	49	35
4	Box-beam MB	26	1957 Ford	3,600	58	18
5	Box-beam MB	26	1957 Ford	3,600	52	24
6	Box-beam MB	27	1964 Ford	3,680	57	25
18	Box-beam MB	27	1957 Hillman	2,135	61	25
24	Box-beam MB	27	1961 Plymouth	3,500	56	25
26	Box-beam MB	27	1961 Plymouth	3,500	43	35
42	Box-beam MB	27	1964 Ford	3,680	62	25
43	Box-beam MB	27	1964 Ford	3,680	55	25
43	Box-beam MB	27	1961 Plymouth	3,500	50	25
44[c]	Box-beam MB	27	1961 Plymouth	3,000	44	25

Note: GR = guiderail and MB = median barrier.
[a]Some test numbers are duplicated because two series were conducted on two different projects.
[b]Test resulted in partial snag or spin-out.
[c]Barrier installed behind depressed median. Hood of car underran barrier and snagged.

TABLE 6 Summary of TTI Crash Tests

Test	Barrier Type	Vehicle Type	Impact Speed (mph)	Impact Angle (degree)	Bumper Impact Point	Result
1	W-beam	1974 Plymouth	63	25	Top of W	Vault
2	W-beam	1974 Plymouth	63	15	Center of top corrugation	Redirect
3	W-beam	1974 Plymouth	63	26	Center of top corrugation	Partial redirect
4	W-beam	1974 Vega	58	15	1 in. below top corrugation	Redirect
5	Cable	1974 Plymouth	60	25	Center cable	Redirect
6	Cable	1974 Vega	58	17	Bottom cable	Redirect

beam and 30 in. for the W-beam did not result in poorer performance compared with current height standards.

A series of six tests was conducted by the Texas Transportation Institute (TTI) in 1978 to study the performance of heavy-post W-beam and light-post cable barriers installed on the side slope outside the shoulder (8). Results are given in Table 6. The net effect of these installations was that the vehicle impacted high on the barriers, which might be expected to result in vaulting. In fact, however, only one test produced a vault--a 60 mph, 25-degree impact with the bumper striking the very top of the W-beam. In three other 60 mph tests the bumper struck at or just below the top corrugation, but no vaulting resulted. In two cable tests at 60 mph, bumper contact was at the center and bottom cables, several inches above the normal contact point, and both resulted in smooth redirection. Thus these tests indicated that heavy-post W-beam and light-post cable both provide considerable latitude in bumper impact height before vaulting becomes a problem.

Although full-scale crash tests provide a satisfactory indication of barrier performance, in-service performance data for barriers at the proposed heights would be an even better indication. Rail height data for light-post barriers in New York State from two different investigations are given in Table 7. Research Report 57 (5) included height data from barriers on 47 NYSDOT contracts and 200 centerline miles of the New York State Thruway, all installed between 1969 and 1971. Depending on barrier type, between 15 and 60 percent of that sample was at or below the proposed height. However, of 363 accidents recorded on that sample during a 3-year period, only 4.1 percent resulted in vehicle penetration, although underride and vaulting were not identified separately. Considering the long service lives of traffic barriers, most of this sample is probably still in service. However, some heights may now be lower because of recent pavement overlays.

TABLE 7 Summary of In-Place Barrier Heights for 1971 and 1983 Samples

Barrier Type	Proposed Height (in.)	Percentage of Total Length ≤ Height 1969-1971[a]	Percentage of Total Length ≤ Height 1983[b]	Percentage of Runs ≤ Height, 1983[c]
Cable GR	27	40	22	42
W-beam GR	30	25	40	78
Box-beam GR	27	15	21	30
W-beam MB	27	60	0	0
Box-beam MB	30	25	31	50

Note: GR = guiderail and MB = median barrier.
[a]1,755 measurements on 47 contracts plus 195 centerline miles on New York State Thruway, all installed 1969-1971.
[b]1,440 measurements on 48 projects of various ages, 30 measurements per project.
[c]Percentage of all runs with 1 or more of 30 measurements at or below recommended height.

Also summarized in Table 7 are heights of light-post barriers measured at 48 locations on state highways in 1983. This work was conducted under preproject planning for the traffic barrier study discussed in the beginning of this paper. These data also indicate that a sizable portion of existing barriers is at or below the proposed standards. To assess current barrier performance under that study, a 1-year sample of accident reports was obtained from the New York State Department of Motor Vehicles. This sample consists of 4,695 accidents in which collision with a traffic barrier was recorded as the first harmful event, and covers the period from July 1982 through June 1983. A full analysis of this information will be performed under the investigation now getting under way, including site investigations and examination of motorist and police accident reports. However, working with the computerized accident file, it was possible to make some judgments of barrier performance. Vaulting of barriers is of great concern, especially in cases where vaulting a median barrier results in collision with another vehicle. Although the computerized accident records do not identify vaulting or underride, they do list secondary impacts with other vehicles. For the 4,695 accidents in this sample, only 11 secondary impacts with other vehicles were listed, and only 6 were on the barrier systems under consideration. One involved a box-beam median barrier and five involved light-post guiderail, but none resulted in serious injuries. Thus these records provide strong evidence that vaulting of median barriers is not a significant problem on New York State highways, even though a substantial portion of the barriers in service is mounted at or below the proposed heights.

Finally, research currently under way or planned by the FHWA was reviewed to determine what other information may be available. Work started in 1983 is studying the effects of mounting heights on barrier performance, but results will not be available until mid-1984. Although some light-post rails will be included, that work concentrates primarily on heavy-post barriers.

Mounting Height Tolerances

Based on the foregoing discussion, mounting heights of 27 in. for the cable and box-beam and 30 in. for the W-beam would appear to provide the best match with current vehicles. Review of crash-test results and accident experience indicates that these heights will provide satisfactory redirection of errant vehicles. Now the question of height tolerances must be resolved. The AASHTO barrier guide recommends 3 in. for guiderail and a minimum of 27 in. for median barrier. In this analysis the effects of adopting the ±3-in. tolerance for all light-post barriers was examined.

The proposed heights include a 6-in. allowance for suspension travel, sheet-metal contact, and other variables, and provide protection against both underride and vaulting. Referring to Figures 4 and 5, most vehicle geometries are seen to provide additional allowances above or below the selected design values--27 in. for underride and 21 in. for override. Permitting a ±3-in. tolerance on mounting height reduces the total margin of safety somewhat, but most vehicles are still providing substantial allowances to protect against underride and vaulting. For example, two-thirds of the vehicles examined had override heights of 19 in. or less and underride heights greater than 29 in., thus providing at least an extra 2-in. margin of safety for most vehicles.

The only adverse vehicle reactions in Tables 5 and 6 were associated with mounting heights outside the range proposed here. Finally, the distribution of barrier heights reported in Table 7 is shown in Figure 6. The range of heights is substantially wider than the proposed range, but accident data indicate satisfactory barrier performance and no evidence of serious consequences from vaulting the median barrier. Thus it appears that adoption of the AASHTO tolerance of ±3 in. is reasonable and prudent at this time.

DISCUSSION AND SUMMARY

Analysis of current vehicle geometries suggests that rail heights of 27 in. for cable and box-beam barriers and 30 in. for the W-beam provide satisfactory protection against both underride and vaulting. These heights provide margins of at least 6 in. to accommodate suspension travel, sheet-metal contact, and other variables for all except a few low-volume specialty cars and some 4x4 utility vehicles and heavy-duty pickups. Adopting the suggested AASHTO height tolerance of ±3 in. still provides a margin of several inches for most vehicles. Review of available crash-test and in-service accident data indicates that both the suggested heights and tolerances can be expected to provide satisfactory performance. In fact, many barriers now in service on state highways are within the proposed height range, and accident records indicate satisfactory performance.

Based on the results of this analysis, the following mounting heights for light-post barriers are recommended (note that GR = guiderail and MB = median barrier):

Barrier Type	New Construction or Adjusted for Height (in.)	Tolerance (in.) Max.	Min.
Cable GR	27	30	24
Box-beam GR and MB	27	30	24
W-beam GR and MB	30	33	27

Current models of small and large sedans and a pickup truck are shown adjacent to a W-beam and a box-beam at these recommended heights in Figure 7. These proposed new standards offer several distinct

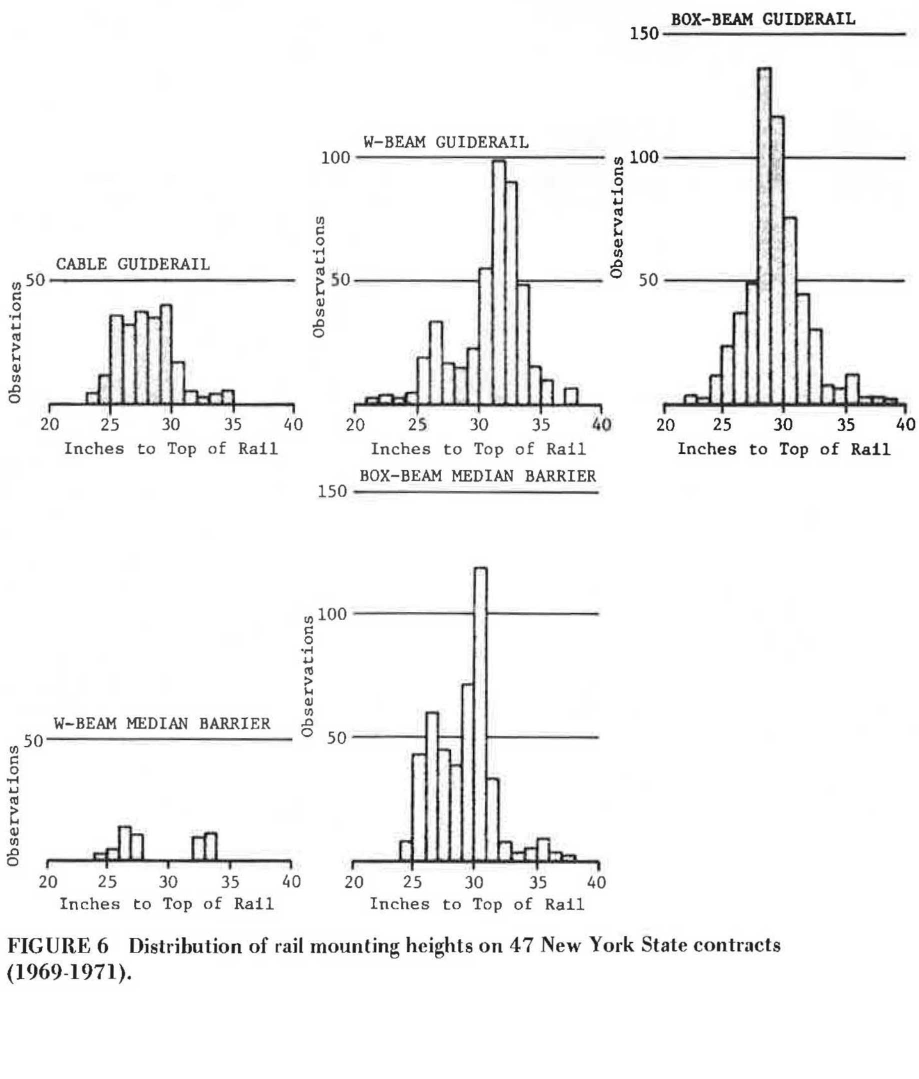

FIGURE 6 Distribution of rail mounting heights on 47 New York State contracts (1969-1971).

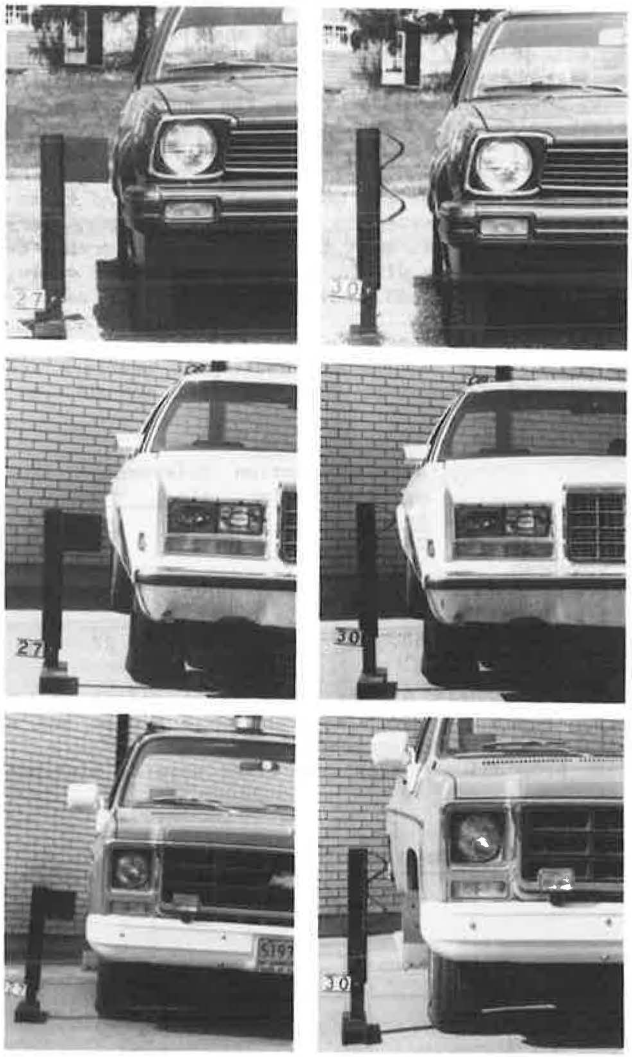

FIGURE 7 Late-model small sedans, large sedans, and light trucks with box-beams at 27 in. (left) and W-beams at 30 in. (right).

advantages compared to the current New York State standards listed in Table 1:

1. Height adjustment costs will be minimized;
2. Barriers already installed to current standards will be within the new range;
3. Existing barriers already installed to current standards can accommodate at least two overlays, and those installed to the proposed new standards can accommodate at least one overlay before height adjustment is necessary;
4. These proposed heights appear to provide satisfactory protection against both underride and vaulting for the current fleet and accommodate most vehicles currently in service, including vans and light trucks; and
5. This proposal appears reasonable and defensible in terms of considerable crash-test and in-service accident experience.

Because more definitive research results will not be available for some time, implementation of these standards at this time offers the potential of improving highway safety and reducing construction costs on R&P projects during the interim period. Further refinements to the proposed standards and tolerances can be made at the completion of the planned research, with little or no adverse effects caused by early implementation of this proposal.

ACKNOWLEDGMENT

Vehicle measurements reported here were performed by Robert P. Murray, James W. Reilly, and Alan W. Rowley. Historic crash-test data were compiled by Richard G. Phillips, and the computer analysis of vehicle characteristics was completed by William G. Roth. William C. Burnett, Director of Engineering Research and Development, provided several ideas for the analysis and this report, as well as a detailed technical review of the preliminary draft. Research reported in this paper was conducted in cooperation with FHWA, U.S. Department of Transportation.

REFERENCES

1. Traffic Barrier Performance Related to Vehicle Size. Study Proposal for Research Project 180-1. Engineering Research and Development Bureau, New York State Department of Transportation, Albany, June 1983.
2. Guide for Selecting, Locating, and Designing Traffic Barriers. AASHTO, Washington, D.C., 1977.
3. J.D. Michie. Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances. NCHRP Report 230. TRB, National Research Council, Washington, D.C., March 1981, 42 pp.
4. J. VanZweden and J.E. Bryden. In-Service Performance of Highway Barriers. Res. Report 51. Engineering Research and Development Bureau, New York State Department of Transportation, Albany, July 1977.
5. R.D. Carlson, J.R. Allison, and J.E. Bryden. Performance of Highway Safety Devices. Res. Report 57. Engineering Research and Development Bureau, New York State Department of Transportation, Albany, Dec. 1977.
6. M.D. Graham, W.C. Burnett, J.L. Gibson, and R.H. Freer. New Highway Barriers: The Practical Application of Theoretical Design. In Highway Research Record 174, HRB, National Research Council, Washington, D.C., 1967, pp. 88-183.
7. J.L. Whitmore et al. Testing of Highway Barriers and Other Safety Accessories. Res. Report 38. Engineering Research and Development Bureau, New York State Department of Transportation, Albany, Dec. 1976.
8. H.E. Ross, Jr., and D.G. Smith. Impact Behavior of Barriers on Non Level Terrain. ASCE, Journal of the Transportation Engineering Division, Vol. 107, No. 1, Jan. 1981, pp. 69-79.

Publication of this paper sponsored by Committee on Safety Appurtenances.