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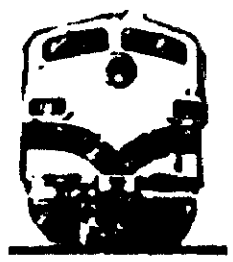
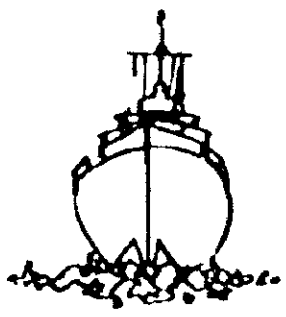
NATIONAL TRANSPORTATION SAFETY BOARD

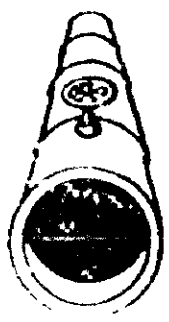


WASHINGTON, D.C. 20594



SPECIAL INVESTIGATION

METROPOLITAN COACH CORPORATION CHARTER BUS ACCIDENT BETHESDA, MARYLAND OCTOBER 11, 1975



REPORT NUMBER: NTSB-HAR-76-6

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB-HAR-76-6	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Special Investigation -- Metropolitan Coach Corporation, Charter Bus Accident, Bethesda, Maryland, October 11, 1975		5. Report Date June 9, 1976
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Surface Transportation Safety Washington, D. C. 20594		10. Work Unit No. 1815-A
		11. Contract or Grant No.
		13. Type of Report and Period Covered Special Investigation October 11, 1975
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

On October 11, 1975, about 9:05 a.m., a charter bus owned and operated by the Metropolitan Coach Corporation was eastbound, in heavy rain, on Interstate 495 in Bethesda, Maryland. As the bus negotiated a curve to the right at 50 mph, the rear wheels of the bus lost traction and the rear of the bus began to slide from side to side. In its final slide to the right, the bus rotated counterclockwise 160° and contacted the guardrail. The bus rolled over, rotated 270° about its longitudinal axis, and landed on its left side in a roadside ravine. Of the 29 bus occupants, 26 were injured.

The National Transportation Safety Board determines that the probable cause of this accident was the inadequate frictional coefficient between the tires and the pavement; the frictional coefficient could not resist the centrifugal force of the bus as it traversed the curve at the posted speed limit.

As a result of this special investigation, the National Transportation Safety Board made recommendations to the Federal Highway Administration, the National Highway Traffic Safety Administration, and the Maryland State Highway Administration.

PRICES SUBJECT TO CHANGE

17. Key Words Bus slide; lateral traction; frictional coefficient; superelevation; skid number; tire material; ASTM testing; road surface characteristics; single vehicle accident; intercity bus.		18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22151.	
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 18	22. Price $3.50

NTSB Form 1765.2 (Rev. 9/74)

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D. C. 20594

SPECIAL INVESTIGATION

Adopted: June 9, 1976

METROPOLITAN COACH CORPORATION, CHARTER BUS ACCIDENT BETHESDA, MARYLAND, OCTOBER 11, 1975

SYNOPSIS

On October 11, 1975, about 9:05 a.m., a charter bus owned and operated by the Metropolitan Coach Corporation was eastbound, in heavy rain, on Interstate 495 in Bethesda, Maryland. As the bus negotiated a curve to the right at 50 mph, the rear wheels of the bus lost traction and the rear of the bus began to slide from side to side. In its final slide to the right, the bus rotated counterclockwise 160° and contacted the guardrail. The bus rolled over, rotated 270° about its longitudinal axis, and landed on its left side in a roadside ravine. Of the 29 bus occupants, 26 were injured.

The National Transportation Safety Board determines that the probable cause of this accident was the inadequate frictional coefficient between the tires and the pavement; the frictional coefficient could not resist the centrifugal force of the bus as it traversed the curve at the posted speed limit.

FACTS

The Accident

On October 11, 1975, about 9:05 a.m., a charter bus owned and operated by the Metropolitan Coach Corporation was eastbound, in heavy rain, on Interstate 495 (I-495) in Bethesda, Maryland. The bus was transporting 29 persons between Chesterfield, Virginia, and Riverhead, New York.

The driver and passengers stated that as the driver attempted to negotiate a right curve in the road at 50 mph, the rear of the bus began to slide toward the left, and the driver corrected the bus' movement. The bus slid to the right and then to the left. Immediately after the bus fishtailed, it rotated counterclockwise 160° until its right front contacted the median guardrail. The bus rolled over and rotated 270° clockwise about its longitudinal axis before it came to rest about 20 feet beyond the guardrail in a roadside ravine.

Of the 29 occupants, 26 were injured. The most serious injuries were one leg fracture, one back injury, and one facial laceration.

Accident Site

I-495 circles Washington, D.C.; the roadway at the accident site has a 5° 51' right curve with a 1,091-foot radius. There are three 12-foot-wide eastbound lanes.

The road surface is bituminous concrete. The Maryland State Roads Commission's "as-built drawing" indicates that the superelevation on the curve is 0.06 ft/ft. The Maryland Highway Administration conducted ball-bank tests after the accident; readings from these tests were 8° at 50 mph and 3° at 30 mph.

At the request of the National Transportation Safety Board, the Maryland State Highway Administration conducted skid tests on October 29, 1975. The results of these tests are as follows:

Test Speed	Frictional Coefficient at Accident Site
30	0.46
40	0.36
50	0.30

The Federal Highway Administration recommends that road surfaces have a minimum skid number 1/ (SN) of 37 (0.37 coefficient of friction) for a mean traffic speed of 50 mph and an SN of 31 (0.31) for a mean traffic speed of 30 mph.

The average annual precipitation at the accident site is 43.25 inches. The two airports near the accident -- Dulles International Airport and National Airport -- reported that during 1970, more than 0.01 inch of precipitation occurred during 107 days at Dulles and 111 days at National. 2/

On November 14, 1975, the Baltimore division administrator of the Federal Highway Administration reported to the regional administrator that the ADT (average daily traffic count) at the accident site was 21,200 in 1973 and 27,800 in 1974. (See Appendix.) He also reported that there were 70 accidents between 1970 and 1974 in the area of the accident. Fifty-four percent of these accidents occurred on wet pavement and 56 percent were attributed to speed. Thirty percent of the accidents in 1970 occurred on a wet surface. Wet-pavement accidents increased to 80 percent in 1973 and dropped to 75 percent in 1974.

1/ Highway Safety Program Standard Number 12, page iv-9.
2/ Climates of the States, Volume 1, Eastern States, Water Information Center.

The Vehicle

The vehicle was a 1964, GMC-PD4106, 2-axle, intercity bus which was owned and operated by the Metropolitan Coach Corporation of Richmond, Virginia. Its estimated weight at the time of the accident was 20,935 lbs (7,390 lbs front and 13,545 lbs rear). Its odometer indicated 1,255,059.4 miles. The slack adjuster push rod traveled 1 1/2 inches at all wheel brake positions.

Other than accident-induced damage, the bus appeared to be in good mechanical condition.

The depths of the tire treads when the accident occurred are shown below:

Position	Tread Depth (all values in 32nds of inch) 3/
Right Front	18
Left Front	18
Left Rear Out	5*
Left Rear In	4*
Right Rear Out	6
Right Rear In	6

*Regroove

ANALYSIS

Several factors could have caused the driver to lose control of the bus as he was negotiating the curve. These factors include vehicle defects, hydroplaning, a reduction in the bus' turn radius, a bump or depression in the road surface, a brake application by the driver, or an inadequate frictional coefficient between the bus tires and the pavement surface. The examination of the bus did not disclose any defects that would have caused the loss of control. Hydroplaning was discounted for two reasons: (1) The 0.06 ft/ft superelevation provided sufficient slope for water drainage and (2) the calculated hydroplaning speed for the bus was 89 mph. This speed is much greater than the speed capability of the bus.

If the driver had turned to the right more than was necessary to follow the curve, it would have increased the centrifugal force of the bus. Based on the driver's statement, there is no reason to suspect that he initially reduced his turn radius either to change lanes, to take evasive action, or to avoid other vehicles. However, after the bus lost lateral traction, the driver's attempts to control the vehicle's course by oversteering could have affected vehicle control adversely. The driver appears to have been unable to correct the bus' slide; this may account for the vehicle's observed fishtailing.

3/ Federal Motor Carrier Safety Regulation 393.75(c) requires a minimum tread depth of 2/32 inch.

If the bus hit a bump or depression, the momentary loss of load on a wheel could have contributed to the loss of traction; however, since investigators could not find any pavement surface irregularities, this possibility was discounted.

At some point after the bus lost its lateral traction, the driver probably braked. Even though the vehicle brakes were adjusted properly, the braking and centrifugal forces would have affected lateral stability adversely. Differences in the frictional characteristics of the bus tires could, and possibly did, create a lateral imbalance during braking, which could have contributed to the driver's inability to regain control. However, the effects of vehicle braking after traction was lost cannot be analyzed because it is not known when or how the brakes were used.

Based on the interrelationship of the curve radius, the superelevation, the pavement, and the tires, and based on the accident record at the site, the Safety Board concludes that the inadequate frictional coefficient between the pavement and the bus tires caused the busdriver to lose control. The rain made the pavement surface too slippery for the bus tires to withstand the centrifugal forces produced as the bus negotiated the curve at 50 mph and, as a result, the bus began to slide.

Curve Radius vs. Superelevation

The purpose of superelevation is to produce a banked curve which reduces lateral forces on a vehicle. These forces tend to cause outward skidding. The roadway's 0.06 ft/ft superelevation conforms with accepted highway design practice. 4/ Accepted design criteria suggest that the superelevation should not be more than 0.08 ft/ft in areas vulnerable to ice and snow because slow-moving vehicles may slide, laterally, down a banked curve if it is covered with ice.

However, calculations performed by the Safety Board show that the superelevation which would have produced no lateral load and no lateral sliding at 50 mph would have been 0.15 ft/ft, more than twice the actual superelevation.

The reason for banking curves at less than the slope optimum for posted speed is understandable. However, pavement surfaces which do not have enough superelevation through a curve must have a fictional coefficient high enough to prevent vehicles from sliding toward the outside of the curve at posted speeds.

4/ AASHTO, A Policy on Design of Urban Highways and Arterial Streets, 1973, pg. 324, 325.

When the 20,935-pound [illegible]s attempted to negotiate the curve, a calculated force of 3,199 [illegible]nds was pushing it laterally toward the outside of the curve. Thi[illegible]alculation is supported by the 8°, 50-mph, ballbank reading made dur[illegible] the October 29, 1975 tests. The calculated frictional value between [illegible] tires and the pavement would have had to be 0.153, or more, for the bu[illegible] not to lose traction in rounding this curve at 50 mph.

Frictional Coefficient

The frictional force which resists the centrifugal force that tends to cause vehicles to slide is represented in the formula F = uN, in which F equals the frictional or resisting force, u equals the coefficient of friction at the tire-to-road surface, and N equals the force which pushes down to the pavement. The resultant coefficient of friction is dependent upon the surface characteristics both of the tire and of the pavement.

Curve A (See Figure 1.) indicates the pavement's frictional coefficient as determined by the Maryland State Highway Administration's October 29, 1975, tests. Curve B indicates the calculated tire-to-pavement frictional coefficient at which the rear axle's tires would be expected to lose lateral traction. Curve C indicates the calculated tire-to-pavement frictional coefficient at which the bus would be expected to lose lateral traction. Curve D indicates the recommended minimum frictional values for mean traffic speeds as tested at 40 mph, in the Highway Safety Program Standard Number 12.

At all frictional values to the right of curve B, the bus should be stable and under lateral control. At 50 mph, the bus should be under control with any frictional coefficient above 0.237. Curve A indicates that the frictional coefficient under American Society for Testing Materials (ASTM) test E-274 was 0.30 at 50 mph.

If the bus needed only a 0.237 frictional coefficient to resist the lateral forces which resulted from centrifugal force, and the test value was 0.30, the accident should not have occurred. Since the accident did occur, either the ASTM test values do not represent actual bus tire-to-road frictional coefficients or some other dynamic factor caused the bus to slide.

The Safety Board believes that the actual frictional coefficient at the bus tire-to-pavement interface was less than the 0.30 measured in the ASTM test.

In order to determine why the ASTM test value for the frictional coefficient differed from the actual coefficient, each variable important to determination of the frictional coefficient was reviewed. These variables were the pavement characteristics, the amount of water on the pavement, and the surface characteristics of the bus tire and the test tire. The pavement characteristics were eliminated as a variable because they were the same at the time of the accident and the time of the test.

LATERAL TRACTION ANALYSIS OF BUS ON 1,091-FT RADIUS CURVE;
0.06 FT/FT SUPERELEVATION, GVW-20,935 LBS., REAR AXLE 13,545 LBS.

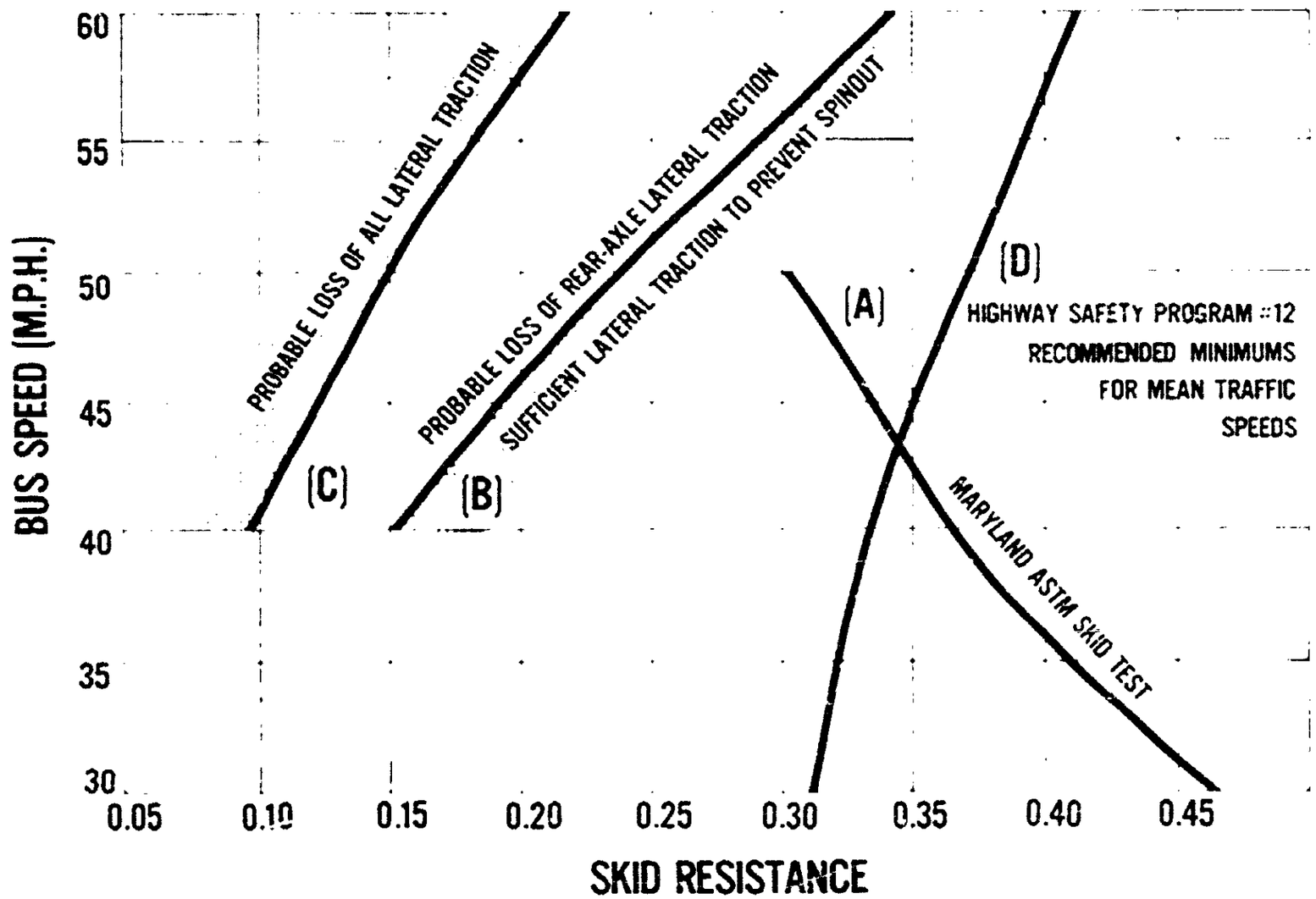

FIGURE 1

In the ASTM test, a test tire on a trailer is dragged over the surface which is being tested. The test tire is not permitted to rotate. Water is deposited on the pavement ahead of the tire. The 0.06 ft/ft superelevation at the accident site provided sufficient slope so that water would not accumulate on the surface but the pavement would be wet. The amount of water on the pavement should have been almost equal at the time of the accident and the time of the test.

The remaining variable is the surface characteristics of the test tire and the bus tire. Tire manufacturers can use rubber compounds to produce a tire which has good traction but wears quickly, or they can use a harder rubber compound to produce a tire which has relatively poor traction but wears well. The exact difference between the traction of the bus tire and that of the ASTM test tire is unknown. The lateral-traction analysis chart indicates that the difference must have been considerable. (See Figure 1.) The ASTM tire gave a coefficient of 0.30; however, the calculated coefficient with the bus tire at breakaway was 0.237.

In 1962, the Virginia Council of Highway Investigation and Research tested the stopping distances of various vehicles at Tappahannock, Virginia. 5/ Five passenger vehicles and a typical intercity bus, all equipped with tires manufactured with the ASTM-17 test tire rubber composition, were tested on five different frictional coefficient surfaces. At one test site, tests also were run with commercially available truck and bus tires. All the tests were run on wet surfaces.

The results showed that for sites 1, 2, 4, and 5, where all the vehicles were equipped with ASTM rubber-composition tires, the stopping distances for all vehicle types were similar at comparable speeds and on surfaces with comparable frictional coefficients (See Table 1.) However, at site 3, where the bus was equipped with commercially available tires, the stopping distance for the bus was twice that of the other vehicles. The report concluded:

> "#3. Size of passenger vehicle, from compact car to bus, does not widely influence the ability of the vehicle to stop during an emergency skid if all vehicles utilize the same general type of tire tread and a similar rubber composition. The ability of various size vehicles to stop when utilizing their normal type of tire was not established in the Tappahannock study and is a question needing further research."

Federal Motor Vehicle Safety Standard (FMVSS) 121 requires that antilock-equipped vehicles be capable of stopping in 35 feet at 20 mph, 72 feet at 30 mph, and 183 feet at 40 mph on a surface with a frictional coefficient of 0.75. In the 1962 Tappahannock tests, a bus which was equipped with

---

5/ ASTM Special Technical Publication No. 366, "Measuring Road Surface Slipperness."

TABLE 1. Stopping Distances (feet)

Vehicle	Site 1			Site 2			Site 3			Site 4			Site 5		
	20	30	40	20	30	40	20	30	40	20	30	40	20	30	40
		mph			mph			mph			mph			mph	
	.32	.28	.22	.44	.36	.30	.54	.48	.39	.78	.68	.51	.87	.80	.71
	frictional coefficient			frictional coefficient			frictional coefficient			frictional coefficient			frictional coefficient		
Standard Car	40	102	210	29	74	151	27	64	135	19	43	78	16	37	73
Large Car	--	---	---	32	89	171	--	--	---	--	--	--	--	--	--
Standard Car	43	119	---	28	82	158	26	65	129	17	43	79	15	43	76
Bus	51	126	266	30	83	181	49.9	142.4	302.4	10	31	66	13	30	54
Standard Car	43	104	255	31	79	166	25	66	140	18	44	85	18	33	71
Compact Car	44	115	236	35	93	179	29	76	152	22	52	95	18	42	78

ASTM test tires and with a conventional braking system stopped in less than half the distance required of a bus equipped with antilock brakes and with standard tires. This demonstrates that the traction capability (rubber composition and tread design) of a tire has a predominant effect on the stopping capabilities of motor vehicles.

Accident Record

The accident record at the site since 1970 suggests that the frictional characteristics of the pavement surface, when wet, deteriorated steadily. The increase in wet-pavement accidents is significant, considering the fact that the pavement was wet less than 30 percent of the time. Also, the high rate of wet-surface accidents at the site, when compared to the statewide wet-surface accident rate of 20 to 30 percent, 6/ and the inadequate test value of 0.30 to 50 mph suggest that not only is the accident site more slippery than others, but that the pavement surface should be corrected.

The 0.30 tested value at 50 mph is less than the 0.37 recommended by Highway Safety Program Standard No. 12.

The State of Maryland had available the accident data for this location and the location's high rate of wet-pavement accidents was recognized. Police, salvage operators, and rescue crews who responded to the accident commented on the frequency of accidents at the site. However, it appears that the State of Maryland had not recognized the significance of the accident data or had not acted upon it.

Highway Safety Program Standard No. 9, "Identification and Surveillance of Accident Locations," requires each state government to have a program (1) to identify accidents; (2) to produce an inventory of high-accident locations, of locations where accidents are increasing, and of design and operations features which are associated with severe accidents and high frequencies of accidents; (3) to take appropriate measures to reduce accidents; and (4) to evaluate the effectiveness of safety improvements. The provisions of this standard, when related to the available accident record, suggest that corrective measures would have resulted several years before the accident occurred had Program Standard No. 9 been followed.

The installation of a "Slippery When Wet" warning sign since the accident occurred attests to the Maryland State Highway Administration's concern regarding the accident site. However, Safety Board investigators evaluated the effectiveness of the sign and concluded that it lacked the prominence necessary to be noticed by motorists. Additionally, they concluded that the speed limit on the approach to and at the accident site is too high, given the reduced frictional coefficient.

6/ Memorandum from Baltimore Division Administrator, Federal Highway Administration, to Regional Federal Highway Administrator.

CONCLUSIONS

1. There were no apparent vehicle defects that contributed to the accident.

2. The curve was sharp and the road surface through the curve was slippery when wet.

3. Based on witness statements, the bus did not exceed the 50-mph posted speed limit. However, the speed limit was too high for the low coefficient of friction between the roadway surface and the vehicle tires.

4. The low frictional coefficient caused the bus to lose traction and slide outward on the banked curve.

5. The 0.06-ft/ft superelevation of the curve was theoretically less than half the superelevation needed to eliminate lateral vehicle loads at 50 mph.

6. The tested frictional coefficient of 0.30 at 50 mph on the accident site's wet roadway is less than that recommended in Highway Safety Program Standard No. 12.

7. The ASTM skid test yielded a frictional coefficient of 0.30 for the accident site, but the actual frictional coefficient of the bus tire and roadway surface was 0.237; the difference in results was caused by the difference in traction capability of the test tire and the bus tire.

8. The State of Maryland accident records indicated that the frictional coefficient of the roadway had deteriorated steadily since 1970.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of this accident was the inadequate frictional coefficient between the tires and the pavement; the frictional coefficient could not resist the centrifugal force of the bus as it traversed the curve at the posted speed limit.

RECOMMENDATIONS

As a result of this accident, the National Transportation Safety Board recommended that the State of Maryland:

"Install flashing lights, which are activated by wet pavement conditions, to complement the recently installed 'Slippery When

Wet' sign, and reduce the speed limit until construction and resurfacing can be accomplished. (H-76-20) (Class I, Urgent Followup)

"Increase the superelevation of the curve at the accident site and resurface it to increase the frictional coefficient of the pavement. (H-76-27) (Class III, Longer Term Followup)"

The Safety Board recommended that the National Highway Traffic Safety Administration:

"Compare frictional coefficients obtained with a commercial vehicle tire to that obtained with an ASTM E-274 skid-test tire and publish the findings. Also, determine whether there is a greater tendency for commercial truck and bus tires than passenger-car tires to lose traction on wet pavements. (H-76-25) (Class III, Longer Term Followup)

"Develop a Federal Motor Vehicle Safety Standard to require a minimum frictional coefficient for all commercial motor vehicle tires. (H-76-26) (Class III, Longer Term Followup)"

The Safety Board recommended that the Federal Highway Administration:

"Determine if the State of Maryland is in compliance with the requirement of Highway Safety Program Standard No. 9, 'Identification and Surveillance of Accident Locations' and advise the Board accordingly. (H-76-23) (Class III, Longer Term Followup)

"Establish minimum skid resistance values both for newly constructed and for existing pavement surfaces. Such minimum values must provide an acceptable margin of safety to accommodate all vehicle types under normal as well as predictable emergency maneuvering, and should consider the known varieties of commercial tire rubber compounds and the relationship of design speed and highway geometrics. After the minimum skid resistance values are determined, revise applicable highway design and pavement maintenance manuals accordingly. (H-76-24) (Class III, Longer Term Followup)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ WEBSTER B. TODD, JR.
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A. HOGUE
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. BALEY
Member

June 9, 1976

APPENDIX

* Form FHWA 121 (Rev. 5-73)

UNITED STATES GOVERNMENT

Memorandum

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

DATE: November 14, 1975

In reply refer to: 03-24.2.20

SUBJECT: Charter Bus Accident on I-495
October 11, 1975

FROM: Richard Ackroyd
Division Administrator
Baltimore, Maryland

TO: Mr. W. H. White
1-00.4.2 Regional Federal Highway Administrator
Baltimore, Maryland

We are forwarding herewith a copy of the State's letter dated November 13, 1975 and attachments. We furnished you an advance copy of the skid test results by memorandum dated November 5, 1975.

An analysis of the Accident Summary sheets was made:

Year	Number of Accidents	Number of Accidents Surface Dry	Wet		% Wet	Number of Accidents Attributed to Speed
1970	27	16	9	=	33%	13
1971	10	45	5	=	50%	5
1972	11	4	7	=	64%	7
1973	10	2	8	=	80%	7
1974	12	3	9	=	75%	7
Total	70	29	38	=	54%	39 = 56%

The State advised that studies have shown the wet weather accidents (excluding snow/ice conditions) accounted for:

Year	Interstate Only	All Systems
1973	28%	27%
1974	21%	24%

The post mileage is 0.63 and the one-way ADT for the section was 21,200 in 1973 and 27,800 in 1974. Note the post mileage for 1970 was 0.82 which may or may not have influenced the large number of accidents that year. We have been unable to determine why the statistical section was changed.

The skid numbers, and past experience with slag mixes such as the one placed on this section of road in 1968, indicate the surface has lost its initial high coefficient of friction. This is also indicated by the increase in the percentage of wet weather accidents.

2.

The curve is 5°15' and, while we have not measured the amount of super elevation in place, past design practice in Maryland has limited the rate of super elevation to 0.06 and generally no spiral transitions were used. Assuming those conditions, the curve design should be safe for 50 m.p.h. This was apparently verified by the ball bank reading in the test vehicle of 8° at 50 m.p.h.

The conclusion is that this is a fairly sharp curve that is slippery when wet; it is used by a high volume of traffic, and a large number of the accidents are caused by driving too fast for conditions.

Immediate remedial actions suggested are:

1. Placement of "Slippery When Wet" signs.

2. Install flashing lights activated by wet pavement conditions.

3. Reduce speed limit to 50 m.p.h.

4. Resurface with an open graded anti-skid mix.

5. Field conditions may warrant increasing the super elevation before resurfacing.

We believe the conditions revealed by this study warrant safety improvements financed by Interstate funds.

Since the Region 3 office, the Washington Office and the NTSB are interested in this section of road, we will wait on confirmation of our analysis or corrections thereto before making a formal recommendation to the State.

Roy D. Gingrich

Attachments

Roy D. Gingrich
District Engineer