LOADING AND SECURING WHEELCHAIRS IN TRANSPORTING STUDENTS

Carl F. Stewart and Herbert G. Reinl, California Department of Transportation

California has no standard specifications or regulations that specifically address the construction and outfitting of special school buses that transport students confined to wheelchairs. The standard requirements for regular school buses are not suited for buses that carry wheelchairs. Therefore, whenever a new wheelchair bus is proposed, the California Department of Education must issue an exemption from the regular school bus requirements. This practice has led to inconsistency in approved systems. A study was made to assist the department in developing specifications for its wheelchair school buses. In particular, outfitting components, such as loading and securing equipment, were addressed. The study involved visiting 21 organizations including school districts, transportation contractors, and suppliers; documenting systems; and evaluating equipment. This report presents not only findings and specification recommendations but also several questions raised during the study on the behavior of wheelchairs and associated hardware during a vehicular accident. Some of these questions can be answered only by dynamic testing of the equipment.

•SECTION 6807 of the California Education Code states that "the governing board of a school district... shall provide transportation for those pupils whose physical handicaps prevent their walking to school." Section 16852 of the same code gives the California Board of Education the authority to adopt regulations relative to the construction and operation of school buses. The board has issued its specifications for school buses under Title 5, Education, in the California Administrative Code. To transport wheelchair-confined students, a regular school bus or other type of vehicle must be modified by installing specialized equipment. However, Title 5 does not include detailed specifications for such changes, and each school district desiring to transport wheelchair-confined students must first obtain an exemption to the standard school bus specifications outlined in Title 5. This exemption is authorized under section 14321 of Title 5 so that alternative methods of meeting the intent of the California Education Code could be introduced.

Section 2807 of the California Vehicle Code states that "the California Highway Patrol shall inspect every school bus at least once each school year to ascertain whether its construction, design, equipment and color comply with all provisions of law." Because there are no specific standards, laws, or regulations governing wheelchair facilities, the California Highway Patrol has a problem complying with section 2807. Without specific guidelines, highway patrol inspectors are faced with the problem of interpreting the intent of the law that regulates sizes of specific items on regular school buses when they are establishing requirements for similar items on wheelchair buses. For example, they consider the size of bolts required to secure seats when they are evaluating the size of bolts for wheelchair hold-down devices. Because exact specifications are not available, most decisions regarding wheelchair buses are subjective ones. This results in undesirable inconsistency in acceptable systems. A simple solution to the problem is to include within Title 5 specifications for wheelchair school buses. The highway patrol took the first step by drafting some basic specifications, which it submitted to the Department of Education (DOE) with the suggestion that they be expanded. DOE then formed an ad hoc committee and charged it with the responsibility of producing specifications for wheelchair buses.

OBJECTIVE

The objective of this study was to assist the DOE ad hoc committee in preparing specifications for loading and securement facilities used in transporting wheelchair-confined students.

RESEARCH PROCEDURE

Twenty-one different organizations, including school districts, school bus contractors, school bus manufacturers, and a service agency, were visited to determine the types of loading and in-transit securement equipment now being used to transport wheelchair-confined students. The demographic areas that the operators serve vary from city to rural. During each visit, the loading equipment, the hardware components for securing wheelchairs during transit, and the type of passenger securement were closely observed and photographed. In addition, a subjective evaluation was made of the ease of operation of the various components, particularly during adverse conditions such as fire or threat of fire. Also evaluated was the degree to which the components would be a potential hazard to passengers during a vehicular accident. The various physical problems associated with transporting wheelchair-confined students also were discussed with the bus operators.

RESULTS AND COMMENTS

A brief description of the equipment found is included here. A more detailed description, with photographs, is available elsewhere (1).

Vehicles

Two basic types of vehicles are used for transporting wheelchair-confined students by the organizations visited. They are the specially designed school bus (class 1) and the commercial van (class 2). Examples are shown in Figure 1. The van is by far the most popular. The number of class 2 vehicles ranged from 1 to 75/organization; the number of class 1 vehicles ranged from 2 to 25/organization. The average capacity of a class 2 vehicle is 4 wheelchairs; the maximum capacity is 6 wheelchairs. Class 1 vehicles are capable of transporting larger numbers of wheelchairs (up to 21), but the average carried varies from 5 to 10 wheelchairs. Both types of vehicles carry seated passengers in addition to wheelchairs. Wheelchair passengers face forward in all but 3 of the class 2 vehicles. Sideway facing is the exception. Sideway facing with limited forward facing is the norm in the class 1 vehicles. Most of the handicapped transported with the equipment studied are between the ages of 3 and 21 years. A few persons over 21 years also are transported on special occasions. In some vans, the roof was not high enough to allow a high school student of above average height to sit upright in the chair. One organization, however, has a van that has been modified with strengthened walls, raised roof, reinforced door, and raised door clearance (Figure 2). This van has ample head room and is certified by the manufacturer to withstand the static load test of the School Bus Body Manufacturers Association. Most vehicle drivers are women. Male drivers are more prevalent if ramps are used for loading.

Loading

Slightly more than 50 percent of the organizations visited use lifts as wheelchair loading equipment, 30 percent use ramps, and slightly less than 20 percent use elevators (Figure 3). The popularity of lifts stems from a concern, especially on the part of women drivers, about handling either heavy wheelchairs or heavy passengers. Both class 1 and 2 vehicles have been equipped with lifts operated by electrically powered hydraulic pumps or electric motors. Most lifts were mounted in the rear of the vehicle in the interest of vehicular safety because the ramp platform provides added rear-end protection. On the other hand, many operators expressed a dislike for rear-mounted loading equipment because of the increased personal hazard of placing the wheelchair passenger in the street during loading and unloading. One organization mentioned the need to install an interlock to prevent accidental tilting of automatic, folding lifts while loading. Heavy-duty lifts are capable of handling loads much heavier than a wheelchair, which, in itself, is not a disadvantage. However, the excess capacity adds weight to the lift, and this detracts from vehicle performance and increases the effort for manual platform folding. Lifts that block doors can be a problem in an emergency, especially if the vehicle loses power. In some cases, lifts with automatic tilts can be released by manually bleeding the hydraulic lines.

The use of ramps was restricted to vans because of their relatively lower floors. The advantages of ramps include low installation cost, virtually no maintenance, and increased speed in unloading. The main disadvantage is difficulty in loading and unloading. For this reason, most organizations assign male drivers to vehicles equipped with ramps. Even then, 2 people are sometimes needed to load and unload heavy passengers or electric wheelchairs. Driver back injuries have been attributed to the use of ramps. Most ramps are side mounted and can take advantage of curb height to reduce the slope. Side-mounted ramps and lifts that are stored inside the vehicle are sharp, hard objects that could be a hazard in an accident. The padding shown in Figure 4 reduces this hazard. During loading and unloading, this pad is folded onto the roof of the vehicle so that it can protect the passenger's head from the sharp top edge of the door frame.

All the vehicles with elevators were class 1 vehicles. Extensive modification of the vehicle is required to recess the elevator into its side. The driver opens the side doors from the inside of the vehicle and rides the elevator up and down with the wheelchair.

Methods used to prevent the wheelchair from rolling off the platform of the lift or elevator included recesses in the floor and an eccentrically mounted flap on the outboard edge of the platform. The driver's ability to remain with the wheelchair on the lift is an important consideration in minimizing potential problems. Most of the lifts and elevators had this capability, and remote or primary controls were mounted on the lift.

Passenger Securement

A standard automobile seat belt to secure passengers in transit was used by all organizations visited. Twenty-five percent secured passengers to the chair only; 50 percent secured them to the vehicle only; and 25 percent secured them to both the chair and the vehicle. When the belt is either passed around or secured to the wheelchair back support frame and then around the passenger's waist, restraint is dependent on the strength of the wheelchair and its securement. Wheelchairs are designed to be as lightweight as possible, not heavy enough to secure a passenger during a vehicular accident. A belt securing the passenger directly to the vehicle is a more positive system. A direct securement of the passenger to the vehicle serves as secondary securement of the wheelchair. However, this securement should not be counted on too greatly. The chair must be independently secured to prevent its impact from causing injury to the passenger in an accident.

Passengers, particularly young children and those who cannot support themselves when their chairs are subjected to unusual movement, should be secured to their wheel-

Figure 1. (a) Class 1 and (b) class 2 school buses.

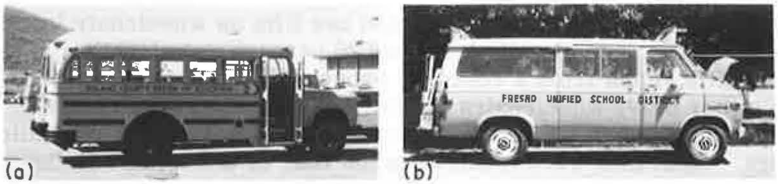
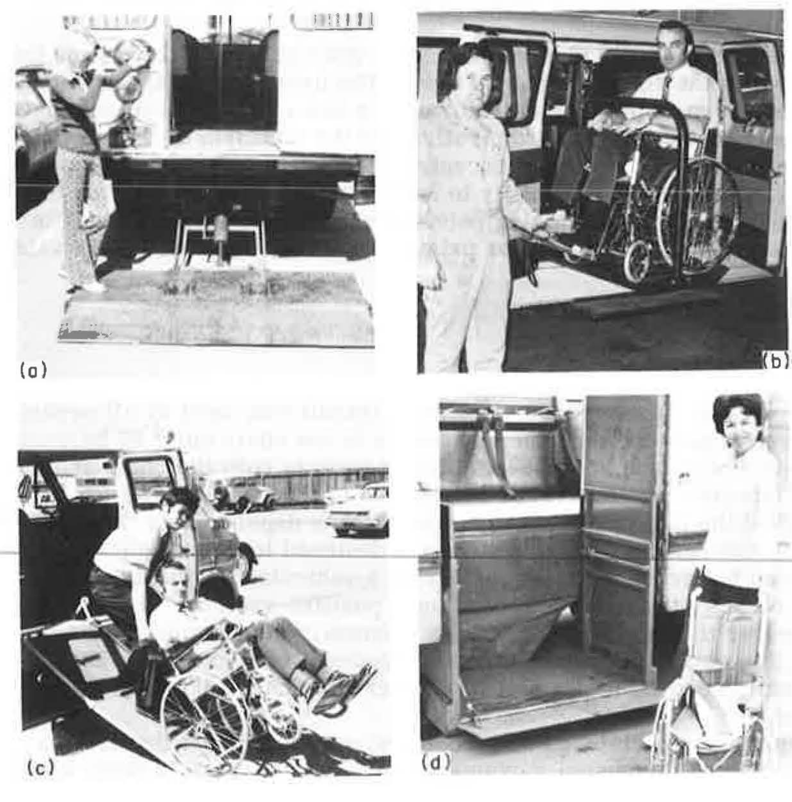


Figure 2. Modified van.

Figure 3. (a) Heavy-duty and (b) swing-in lifts and (c) ramp and (d) elevator loading equipment.



chairs during loading and unloading to prevent them from falling out. Passengers have been known to slide out from under belts restraining both the chair and the occupant. Therefore, some passengers need to be secured directly to their wheelchairs during transit. Belts with quick-release buckles speed securement and release. In some cases, precautions are needed to prevent unsupervised passengers from releasing their belts during transport. In several cases, adjustable tracks or other belt anchorages were fastened to the vehicle by means of sheet metal screws and other fasteners of questionable strength. In one case, the belt webbing was pierced by a sheet metal screw and torn.

Chair Securement

Half of the properties visited secure wheelchairs by attachments to the rims of the large wheels; the others secure them by attachments to the frame. In some cases, chairs positioned sideways could rotate backwards, which could cause the passengers to strike their heads against the vehicle wall. In other cases, docking rails were used to support the backrest frame of the chair and prevent this kind of rotation. Systems that use chains, pins, or locking cams through the wheel rims provide a loose securement and allow some movement of the chair. These devices also cause damage to wheel spokes.

As in passenger securement, wheelchair securement devices were sometimes attached to the vehicle with screws and other fasteners of questionable strength. For example, one device was found anchored by U-bolts made by bending threaded rod stock to shape. Another had a link of its chain welded to an adjustable track fastener in such a way that bending stresses would be induced in the weld metal. Welding and reworking material as were done in these cases may cause undesirable loss of strength unless proper precautions are taken. Because manufactured fasteners of known quality are readily available, such jerry-built modifications seem unnecessary.

The rim clamp shown in Figure 5 provides a fast, simple, and positive securement of the wheel rim. However, 2 clamps alone are not sufficient to prevent rotation of the chair about the rear axle. A third securement point (usually a strap) is used to prevent rotation. Mounting the rim clamp on the side wall reduces its suitability for chairs with varying wheel diameters. Some securement devices were mounted across doorways, thereby obstructing the doors. Devices mounted on floor stands or other permanent fixtures are obstructions that inhibit rapid removal of the wheelchair in case of an emergency.

Many of the frame anchor devices do not connect to the wheelchair frame. They depend on clamping force to secure the chair. An example is shown in Figure 6. If the chair wheels collapse, such devices can lose contact with the frame and no longer provide restraint. The extra loading exerted on them by the clamping force also increases the possibility of wheel failure, particularly if they are overtightened. The chain and S-hook system shown in Figure 7 pulls inward on the caster frame as the threaded rod is tightened. However, weight of the passenger on the chair during normal transit usually is sufficient to overcome this effect. On the other hand, should the bus overturn, such a device would tend to force the chair to close on the passenger.

The possibility of chair rotation about its axis of securement was found in such devices as the T-bar and others with single attachment to the vehicle. Wheel friction on the vehicle floor and passenger securement to the vehicle are the only forces preventing this rotation. In addition, depending on the configuration of the chair frame, some T-bar devices can slide off the sloping chair frame where they are attached (Figure 6). Especially with heavy wheelchairs, the T-bar and hooked-clamp devices do not restrain longitudinal movement. Therefore, a sudden stop or an accident could cause a passenger secured to the vehicle to sustain chair impact from inadequate chair securement.

A 4-belt system (belts attached to the 4 corners of the chair) easily adjusts to chairs of different sizes and positively secures the chair even if the wheels collapse. However,

Figure 4. Inside storage of ramp with padding.

Figure 5. Rim clamps on adjustable track.

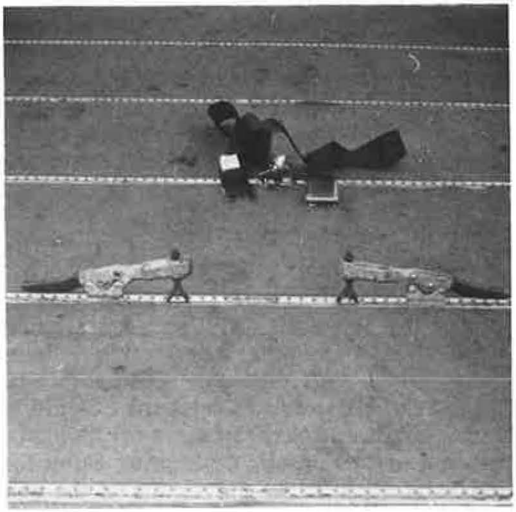


Figure 6. T-bar chair securement.

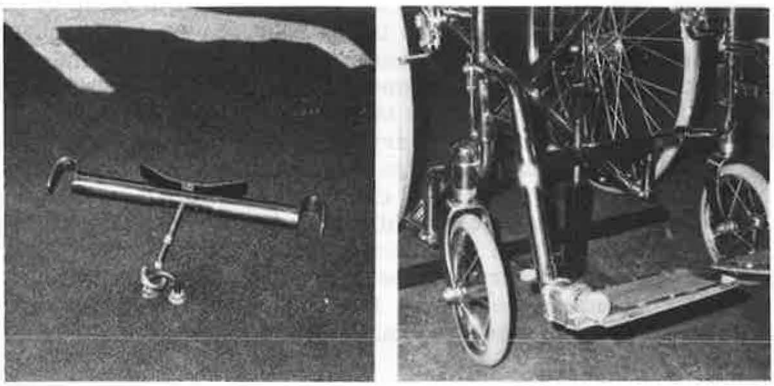
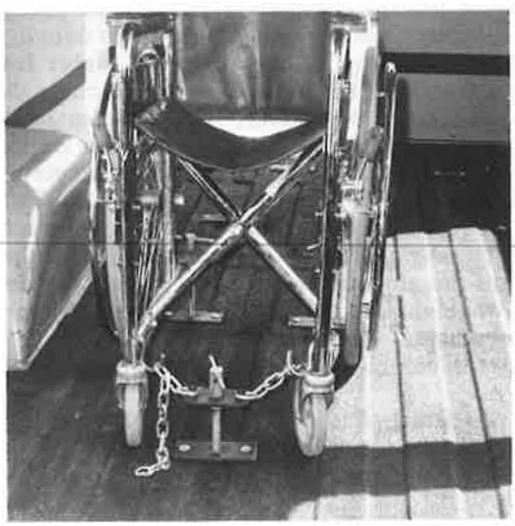


Figure 7. Chain and S-hook chair securement.



this system may require slightly more time than other systems do to secure to the chair or to release during an emergency.

The most versatile wheelchair or passenger securement system uses cargo hold-down equipment. Because this system features a continuous track, numerous locations are available for the snap-on anchors of the system. The greater the number of tracks, the greater the versatility of the system. That the tracks work equally well in the floor and on the wall increases the versatility.

ACCIDENTS AND HAZARDS

The combined efforts of the California Department of Education, the California Highway Patrol, the school districts, the school bus contractors, and the school bus manufacturers have resulted in an enviably low school bus accident record in California (2). They all are to be commended.

For a better appreciation of this record, one should note 2 things.

1. During the 171,246,061 school bus miles (273 993 697.6 school bus km) driven in the 1972-73 school year, there was not a single bus occupant fatality. In fact, there has been only 1 pupil passenger fatality in the last 5 years.
2. There were only 167 pupil passengers injured in 1972-73, which is an injury rate of only 0.95/million miles (0.59/million km) of travel.

This outstanding record reflects a deep concern for safety by those responsible for transporting school students, a concern that was continually manifested during this study. The persons interviewed repeatedly expressed a desire to transport wheelchair students as safely as they transported regular students. But there does appear to be a difference. Regular students are normally transported in a class 1 vehicle, which is equipped with many more safety features than the standard commercial van, which is usually used to transport wheelchair-confined students. The van, a class 2 vehicle, is also the most popular vehicle in use for other special education transportation. This is not to imply that the van is unsafe, but, because it lacks all the safety features added to class 1 buses, it cannot possibly be as safe. Therefore, if all students are to be transported with equal safety, similar specifications are needed for all types of school buses. One of the most striking examples of the need for similarity is gas tank specifications. During the study, everyone expressed great concern for the need to evacuate the wheelchair students rapidly in case of an emergency, yet no extra preventive measures were found to have been made to minimize perhaps the most potentially damaging emergency of all—fire. So catastrophic are the effects of fire that, in such a hazardous situation, rapid evacuation planning is less important then fire prevention because of the problems associated with wheelchair unloading. If fire does occur after an accident, the loading mechanism could jam, the driver could be seriously injured, the bus could overturn, the wheels of a wheelchair could be severely damaged, or a host of other things could occur that would either drastically slow or completely preclude wheelchair evacuation. Fuel spillage is necessary for a serious postaccident fuel-fed fire. Thus the number of fires can be lessened by reducing the number of times fuel is spilled. At least 2 changes can be made in vans that would reduce the likelihood of fuel spillage during an accident; (a) relocating the fuel tank or (b) providing a rupture-proof tank (3). Investigating the problem of postaccident fuel-fed fires on vehicles transporting wheelchair-confined students is beyond the scope of this study. The problem is a serious one, however, and deserves special study.

ADVANTAGES OF SPECIALLY DESIGNED VANS

Modifying a commercial van for transporting wheelchair students instead of using a class 1 bus or a specially built van was discussed during the interviews. Apparently, frequent use of the vans for transporting wheelchair students is motivated by 2 primary factors: low occupancy demand and apparent economy. In most school districts, the density of wheelchair students is low; therefore, the demand for ridership is too small to warrant the use of a large-capacity class 1 bus.

To assume that the commercial, off-the-shelf van costs less than a specially built van is reasonable. But the question is how much less. Most of those interviewed thought that, when the modification of a commercial van, particularly for raising its roof, is included in the total cost, the cost difference between the 2 vehicles would be small. All agreed that, from a safety standpoint and from the standpoint of durability and maintenance requirements, a specially built vehicle would be far superior to an off-the-shelf commercial van. However, until more stringent requirements are placed on the class 2 vehicle, the off-the-shelf van will continue to be the most popular. The advantages of a vehicle designed and built expressly for transporting wheelchair-confined students are so numerous that a cost-benefit study should be made between such a unit and the off-the-shelf van.

BEHAVIOR OF WHEELCHAIRS IN ACCIDENTS

A subject frequently brought up was the possible behavior of the wheelchair during an accident. The most frequently expressed opinion was that the wheels are the weakest part and would probably collapse in an accident. For that reason, many were opposed to using hold-downs that attach to the wheels. However, as far as securement is concerned, a positive attachment to the wheels would prevent excessive movement of the chair even if the wheels did collapse. Therefore, the deciding criterion for acceptance should be any system that precludes excessive movement of the chair during a vehicular accident. Some of the equipment found might be presenting a false sense of security. Although certain types of equipment have been performing adequately during normal use, how they would perform during an accident is highly questionable. For instance, the hardware used to attach some of the equipment to the vehicle appeared to have ample static loading resistance but did not appear to have adequate impact resistance. One can conclude from the difference of opinion on the behavior of the wheelchair and its associated hold-down hardware in an accident that dynamic testing of full-scale equipment is needed.

CONCLUSIONS

Six conclusions can be drawn from the study.

1. Even though the school bus occupancy injury and fatality rate is very low in California, the Department of Education and the highway patrol have a justifiable concern for the need for statewide standard specifications for hardware components on buses used to transport wheelchair-confined students.
2. Use of manufactured securement equipment instead of "homemade" devices should be encouraged.
3. More emphasis needs to be placed on fire-prevention measures for vehicles used to transport physically handicapped students.
4. Static and dynamic testing of wheelchair and passenger securement is needed.
5. The standard commercial van is deficient in the following areas insofar as it is used as a school bus for wheelchair students: (a) headroom for most high-school-age students and (b) safety features comparable to the bus used for transporting other than special-education students.
6. A cost-benefit study, measured with respect to safety, is needed on buses built specifically for transporting wheelchair-confined students.

RECOMMENDATIONS

Three sets of recommendations are offered. The first, the interim set, covers the adoption of hardware component specifications according to engineering judgment. This set should be implemented as soon as possible. The second, the future set, covers action that should be taken to obtain physical test data on hardware components recommended for interim implementation. After these data are collected and evaluated, the specifications should be revised accordingly. The third, the special set, covers 2 areas that concern operators of special-education transportation vehicles even though the subject areas are outside the objectives of this study.

Interim Set

Recommendations on the interim set cover the vehicle floor, loading equipment, and wheelchair and passenger securement.

Vehicle Floor

The floor of the vehicle shall be level and free of projecting mountings or fastening devices for securement equipment when the equipment is not in use, and it shall have a nonskid surface or covering.

Loading Equipment

Six specifications are given for loading equipment.

1. Loading equipment shall have nonskid surfacing in the walkway portion including ramp steps.
2. Lift and elevator equipment shall have stops to minimize the possibility that a wheelchair will roll off the lift platform.
3. Loading equipment shall be provided with protective padding when it is inside the vehicle.
4. Loading equipment that blocks doorways shall be equipped with a manual, externally operated emergency release mechanism capable of clearing the doorway.
5. Controls for lifts and elevators shall be located close to the lifting platform.
6. Ramps carried in a vertical position inside the vehicle shall be secured at their top during transit.

Wheelchair Securement

Eight specifications are given for equipment for securing wheelchairs during transit.

1. Equipment shall consist of woven webbing or metal fasteners. The webbing shall be of approved cargo or seatbelt type. Fastenings of webbing to mounting points shall be in accordance with manufacturer's specifications. All fasteners shall have a rated capacity of not less than 3,000 lbf (13 350 N).
2. A minimum of 2 fasteners for each wheelchair shall be required. Each shall be mounted separately in the vehicle and have separate points of attachment to either the frame or wheels of the wheelchair.
3. Fasteners shall be mounted so that the chair cannot move more than 3 in. (7.6 cm) in either a straight or circular direction and cannot tip if the vehicle overturns.
4. Fasteners shall be secured to the vehicle with not less than $^3/_8$-in. (0.95-cm) bolts, lock washers, and nuts or self-locking nuts of a strength designation not less

than Society of Automobile Engineers grade 5. The mounting bolts should pierce the vehicle frame, subframe, body post, or equivalent metal structure. If they fail to pierce any of those areas, a reinforcement plate or washer not less than $\frac{1}{16}$ in. (0.16 cm) thick and 2 in. (5.1 cm) square or 2.5 in. (6.35 cm) in diameter shall be provided between the bolt head and the metal pierced.

5. Fasteners shall be capable of restraining the wheelchair if its wheels collapse.
6. If adjustable tracks are used as part of the securement equipment, the tracks shall be secured to the vehicle at intervals not less than those specified by the manufacturer.
7. Where webbing equipment is used, release buckles shall be positioned to have direct in-line tension.
8. Electric wheelchair batteries shall be secured to the wheelchair during transit.

Passenger Securement

Each passenger shall be secured to the vehicle by a standard webbing seatbelt secured to the vehicle in the same manner as the chair securement equipment except that attachment of the seatbelt to the vehicle may be made by one $\frac{9}{16}$-in. (1.4-cm) or two $\frac{7}{16}$-in. (1.1-cm) bolts. Passengers who cannot prevent themselves from falling from their wheelchairs shall be secured to their wheelchairs by a standard webbing seatbelt.

Future Set

Static tests on that equipment that, by engineering judgment, appears to have less than desired strength shall be performed. Crash tests of prototype vehicles containing simulated wheelchair students shall be performed. The students shall be instrumented to obtain body reactions during the test. Interior movies should be taken to record counterreactions of students and equipment; special attention should be paid to the behavior of the wheelchair and its securement equipment.

Special Set

A probability and preventive study on fuel-spillage postaccident fires involving commercial van vehicles shall be conducted. A cost-benefit study, measured with respect to safety, on a low-volume vehicle designed and built specifically for transporting wheelchair-confined students also shall be conducted.

ACKNOWLEDGMENT

We wish to thank members of the advisory panel who helped direct this research: Stanley McDougall, Department of Education; Charles Allen, California Highway Patrol; and Max Barney, Los Angeles City Unified School District. We also wish to thank Jack Lieberman, chairman of Ad Hoc Transportation Committee, California Department of Education, and E. Kynaston of the California Highway Patrol for their excellent counseling. This project was under the general direction of Charles E. Zell, Office of Research and Development, Division of Mass Transportation. The contents of this report reflect our views; we are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the state of California.

REFERENCES

1. C. F. Stewart and H. G. Reinl. Student Wheelchair Transportation—Loading and Securement. Division of Mass Transportation, California Department of Transportation, DMT-1-74, Aug. 1974.
2. 1972-73 Annual School Bus Accident Report. California Highway Patrol, Sacramento.
3. P. Cooley. Fire in Motor Vehicle Accidents. Highway Safety Research Institute, special rept., April 1974.
4. Code of Federal Regulations, Title 49—Transportation, Chapter 5, No. 571.209.