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ABSTRACT

This paper presents findings and recommendations resulting from a study of the equipment and systems currently used to transport wheelchair-confined students. Objective of the study was to assist the California Department of Education in preparing specifications for loading and securement facilities used in transporting wheelchair-confined students. A total of 21 organizations, including school districts, school bus contractors and manufacturers, and a service agency, were visited to document and evaluate the types of loading and securement equipment now in use. Besides presenting findings and recommended specifications, the paper also raises several questions about the behavior of wheelchairs and associated hardware during an accident; the authors suggest conducting a dynamic testing program involving simulated accidents to provide answers to these questions. A number of photographs illustrate different types of wheelchair loading and securement equipment. (Author/JG)

STUDENT WHEELCHAIR TRANSPORTATION

- LOADING AND SECUREMENT -

California Department

of

Transportation

Carl F. Stewart

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October 1974

This paper was presented at the fifty-fourth annual meeting of the Transportation Research Board

ABSTRACT

California has no standard specifications or regulations which specifically address the construction and outfitting of special school buses required to transport wheelchair confined students. The standard requirements for regular school buses are not suited for buses carrying wheelchairs. Therefore, whenever a new wheelchair bus is proposed, the Department of Education (DOE) must issue an exemption from the regular school bus requirements. This practice has led to inconsistency in approved systems.

A state-of-the-art study was made to assist DOE in developing specifications for its "wheelchair" school buses, in particular, outfitting components such as loading and securement equipment were addressed. The study entailed visiting twenty-one entities, including school districts, transportation contractors and suppliers; documenting their systems; and evaluating their equipment.

This report presents not only the 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.

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INTRODUCTION

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 State Board of Education the authority to adopt regulations relative to the construction, operation, etc., of school buses. The Board has issued its specifications for school buses in the "California Administrative Code, Title 5, Education."

To transport wheelchair confined students, a regular school bus or another 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 and was provided therein so that alternative methods of meeting the intent of the 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." Since there are no specific specifications, laws or regulations governing wheelchair facilities, the CHP has a problem complying with Section 2807. Without specific guidelines, the CHP inspectors are faced with the problem of interpreting the intent of the law which regulates sizes of specific items on regular school buses when they are establishing requirements for similar items on wheelchair buses. For instance, they consider the size of bolts required to secure seats when they are evaluating the size of bolts for wheelchair hold-down devices.

Lacking exact specifications, most decisions regarding wheelchair buses are subjective ones, which result in undesirable inconsistency in acceptable systems.

A simple solution to the problem is to include within Title 5 specifications for "wheelchair" school buses. The CHP took the first step by drafting some basic specifications, which it submitted to 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 DOE's ad hoc committee in preparing specifications for loading and securement facilities used in transporting wheelchair confined school students.

RESEARCH PROCEDURE

A total of 21 different organizations, including school districts, school bus contractors, school bus manufacturers and a service agency, were visited to determine the type of loading and in-transit securement equipment now being used to transport wheelchair confined students. A list of those visited is attached. The demographic areas that the operators serve varies 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 the threat of fire. Also evaluated was the degree to which the components would be a potential hazard to passengers during a vehicular accident.

Finally, the various physical problems associated with transporting wheelchair confined students were discussed with the bus operators.

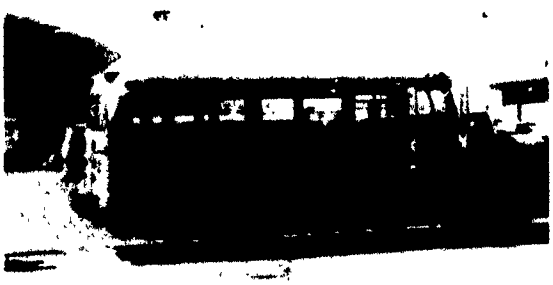
RESULTS AND COMMENTS

A brief description of the equipment found is included here. A more detailed description, with photographs, is included in a report[6] written for the California Department of Education.

Vehicles

Two basic types of vehicles are used by the properties visited for transporting wheelchair confined students. They are: The specially designed school bus (Class I) and the commercial-type van (Class II), (see Figure 1). The van is by far the most popular. The number of Class II vehicles ranged from 1 to 75 per property, whereas Class I ranged from 2 to 25.

One property has a van, which has been modified with strengthened walls, raised and reinforced door and raised door clearance, (Figure 2). This van is certified by the manufacturer to withstand the static load test of the School Bus Body Manufacturers Association.



Class I

Class II

School Bus Classifications
Figure 1

The average capacity of a Class II vehicle is 4 wheelchairs, the maximum number is 6. Class I vehicles are capable of transporting larger numbers of wheelchairs, up to 21, but the average varies from 5 to 10. Both types of vehicles carry seated passengers in addition to wheelchairs.

Wheelchair passengers face forward in all but 3 of the Class II vehicles. Sideway facing is the exception. Sideway facing is the norm, with limited forward facing, in the Class I vehicles.

Modified Van

Figure 2

Most of the handicapped transported with the equipment studied are between the ages of 3 and 21. A few persons over 21 are also 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 his chair.

Most vehicle drivers are women. Male drivers are more prevalent if ramps are used for loading.

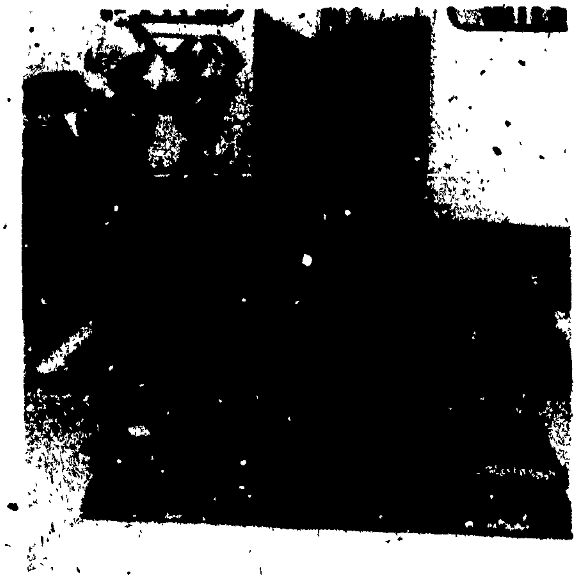
Loading

Slightly more than half of the properties 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 about handling either heavy wheelchairs or heavy passengers, especially by women drivers. Both Class I and II vehicles have been equipped with lifts operated by electric-powered hydraulic pumps or electric motors. Most lifts were mounted in the rear of the vehicle in the interest of safety.

One property mentioned the need to install an interlock to prevent accidental tilting of automatic, folding lifts while loading.

The heavy-duty lifts are capable of handling loads much heavier than a wheelchair. This, in itself, is not a disadvantage. However, the excess capacity adds weight to the lift, which distracts from vehicle performance and increases the effort for manual platform folding.

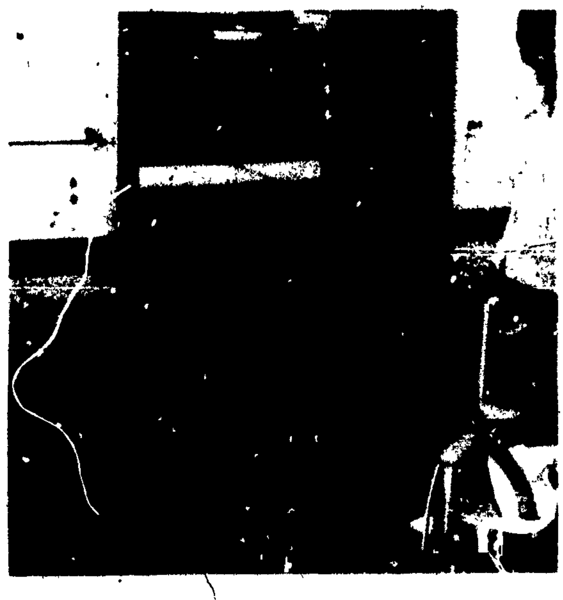


Heavy Duty

Swing In

Lifts

Ramp



Elevator

Loading Equipment

Figure 3

Lifts which block doors can be a problem in the event of an emergency, especially if the vehicle loses power. In some cases, lifts with automatic tilts could be released by manually bleeding the hydraulic lines.

The use of ramps was restricted to vans due to 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 properties assign male drivers to vehicles equipped with ramps. Even then, two 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.

Many operators expressed a dislike for rear mounted loading equipment because of the increased hazard of placing the wheelchair passenger in the street during the loading and unloading.

Side mounted ramps and lifts that store 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

Inside Storage of Ramp -- With Padding

Figure 4

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 of the Class I type. 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, with remote or primary controls mounted on the lift.

Passenger Securement

A standard automobile seat belt was used by all properties visited to secure passengers in transit. Twenty-five percent secured the passenger to the chair only; 50 percent secured them to the vehicle only; and 25 percent secured them to both the chair and 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 to be heavy enough to secure a passenger during a vehicular accident. This view is supported by a major wheelchair manufacturer. 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.

The passenger should be secured to his wheelchair during loading and unloading to prevent him from falling out, particularly in the case of young children and those who cannot support themselves when their chairs are subjected to unusual movement. Passengers have been known to slide out from under belts restraining both the chair and the occupant. So, some passengers need to be secured directly to their wheelchair 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.

Several cases were observed where adjustable tracks or other belt anchorages were fastened to the vehicle by means of sheet metal screws and other fasteners of questionable strength. One case was noted where the belt webbing was pierced by a sheet metal screw and was subject to tearing.

Chair Securement

Half of the properties visited secure the wheelchair by attachments to the rims of the large wheels, the others by attachments to the frame.

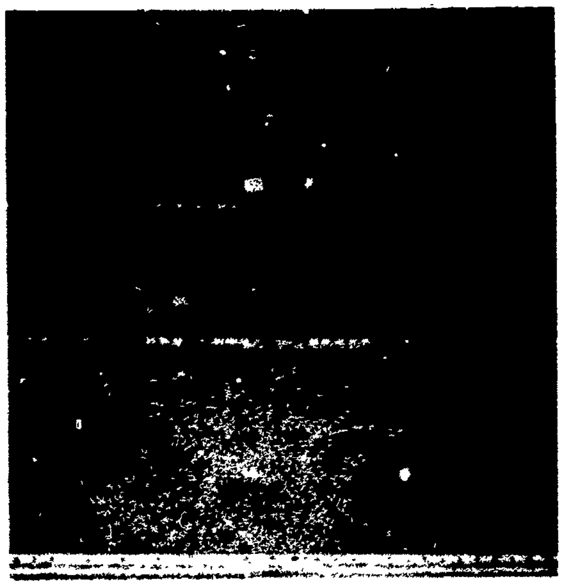
In some cases, chairs positioned sideways could rotate backwards, threatening to strike the passenger's head against the vehicle wall. In other cases, docking rails were used to support the backrest frame of the chair and prevent this kind of rotation.

Systems using chains, pins, or locking cams through the wheel rims all provided a loose securement and would allow some movement of the chair. In addition, these devices cause damage to wheel spokes.

As in the case of 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 of material such as in these cases may cause undesirable loss of strength unless proper precautions are taken. Since manufactured fasteners of known quality are readily available, such "jerry rigged" modifications seem unnecessary.

The rim clamp shown in Figure 5 provides a fast, simple and positive securement of the wheel rim. However, two 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.

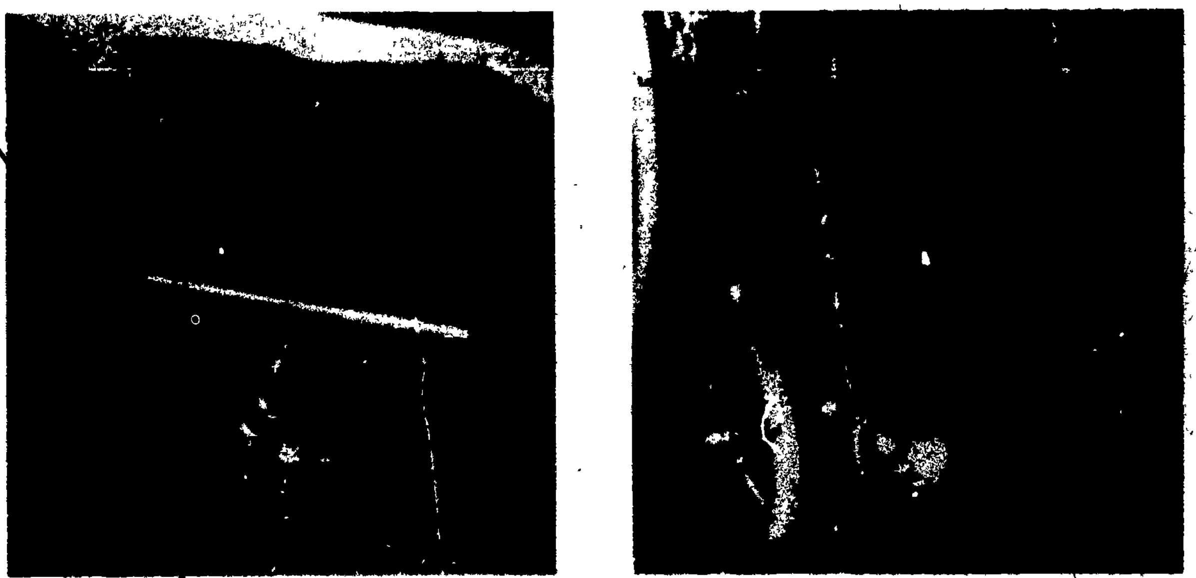


Rim Clamps on Adjustable Track

Figure 5

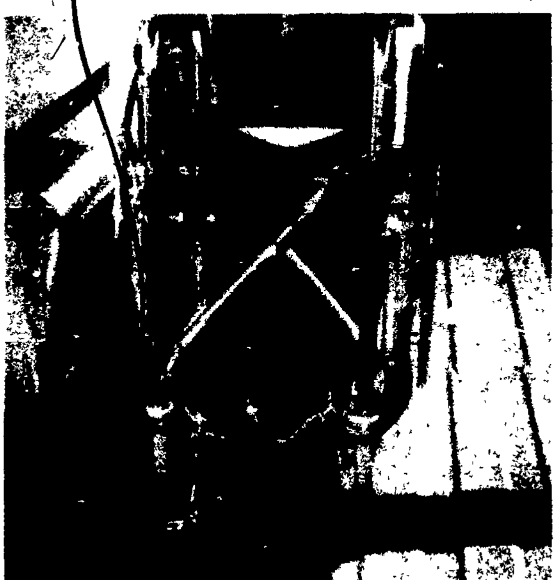
Devices mounted on floor stands or other permanent fixtures are obstructions that inhibit rapid removal of the wheelchair in case of an emergency.

Many of the frame anchor devices do not physically connect to the wheelchair frame. They depend on clamping force to secure the chair. An example is shown in Figure 6. Should 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 hooks system shown in Figure 7 pulls inward on the caster frame as the threaded rod is tightened. However, weight



"T" Bar Chair Securement

Figure 6



Chain and "S" Hook Chair Securement

Figure 7

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 upon the passenger.

The possibility of chair rotation about its axis of securement was found in devices such 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 are capable, if not encouraged, to slide off of the sloping chair frame where it is attached (see Figure 6). Especially with heavy wheelchairs, the T bar and hooked clamp devices do not restrain longitudinal movement. It is therefore possible that a sudden stop or an accident could cause a passenger secured to the vehicle to sustain chair impact.

A four-belt system--belts attached to the four "corners" of the chair--easily adjusts to different size chairs and positively secures the chair even if the wheels collapse. However, this system may require slightly more time than others to secure to the chair or release during an emergency.

The most versatile wheelchair or passenger securement system utilizes cargo hold-down equipment. Since 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. The fact that the tracks work equally well in the floor and on the wall increases the versatility.

GENERAL DISCUSSION

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 enviable low school bus accident record in California. They are all to be commended.

For a better appreciation of this record, note that:

> During the 171,246,061 school bus miles driven in the 1972-73 school year, there was not a single bus occupant fatality. In fact, there has been only one pupil passenger fatality in the last five years.
>
> The injury rate record is equally impressive. There were only 167 pupil passengers injured in 1972-73, which is an injury rate of just 0.95 per million miles traveled.

This outstanding record reflects a deep concern for safety by those responsible for transporting school students, a concern which was continually manifested during this study. The persons interviewed repeatedly expressed a desire to transport wheelchair students as safely as regular students. And there does appear to be a difference. Regular students are normally transported in a Class I vehicle, one equipped with many more safety features than the standard commercial van, which is usually used to transport wheelchair confined students. The van, a Class II 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 since it lacks all the safety features added to Class I buses, it cannot possibly be as safe. If, therefore, 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, great concern was unanimously expressed for the need to evacuate the wheelchair students rapidly in case of an emergency. Yet no extra preventive measures were found which had been made to minimize perhaps the most potentially damaging emergency of all, fire.

So catastrophic are the effects of fire that rapid evacuation is less important in a hazardous situation than fire prevention. If fire does occur after an accident, the loading mechanism, ramp or hydraulic lift, could jam, the driver could be seriously injured, the bus could be overturned, the wheels of a wheelchair could be severely damaged, or a host of many things could occur which would either drastically slow or completely preclude wheelchair evacuation.

Fuel spillage is a prerequisite for a serious post-accident fuel-fed fire. Thus, the number of fires can be lessened by reducing the number of times fuel is spilled. At least two changes can be made in the van-type vehicle which would reduce the likelihood of fuel spillage during an accident, relocating the fuel tank or providing a rupture-proof tank.

It is beyond the scope of this study to investigate the problem of the post-accident fuel-fed fires on vehicles transporting wheelchair confined students. The problem is a very serious one, however, and deserves special study.

The practice of modifying a commercial type van for use in transporting wheelchair students as opposed to a Class I bus or a special-built van was discussed during the interviews. Apparently, the frequent use of the van for transporting wheelchair students is motivated by two 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 I bus.

It is reasonable to assume that the commercial, off-the-shelf, van costs less than a specially-built van-type vehicle. The big question is, how much less? Most of those interviewed thought that when the modification of a commercial van, particularly when the roof is raised, is included in the total cost, the cost differential between the two 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 II vehicle, the off-the-shelf van will continue to be the most popular.

The advantages of a vehicle designed and built for the express purpose of transporting wheelchair confined students are so numerous that a cost/benefit comparison study should be made between such a unit and the off-the-shelf van.

Another subject frequently brought up was the possible behavior of the student's wheelchair during an accident.

The most often 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 which attach to the wheels. However, insofar 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 which precludes excessive movement of the chair during a vehicular accident.

Some of the equipment found might be presenting a false sense of securement: Although certain types of equipment have been performing adequately during normal usage, how they would perform during a vehicular 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.

It is obvious from the difference of opinion on the behavior of the wheelchair and its associated hold-down hardware in a vehicular accident that dynamic testing of full scale equipment is needed.

CONCLUSIONS

1. Even though the school bus occupancy injury and fatality rate is very low in California, the DOE and CHP have a justifiable concern for the need for statewide standard specifications for hardware components on buses used to transport wheelchair students.

2. The use of manufactured securement equipment should be encouraged at the exclusion of "home-made" devices.

3. More emphasis needs to be placed on fire preventive measures for vehicles used to transport physically handicapped students.

4. Static and dynamic testing of wheelchair and student securement is needed.

5. The standard commerical van is deficient in the following areas insofar as its use as a school bus for wheelchair students:

a. Inadequate headroom for most high school age students;

b. Lack of 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 for the specific purpose of transporting wheelchair confined students.

RECOMMENDATIONS

Three sets of recommendations are offered. One set -- interim -- will cover the adoption of hardware component specifications which were selected by engineering judgment. This set should be implemented as soon as possible.

The second set -- future -- covers action which should be taken to obtain physical test data on the hardware components recommended for interim implementation. After these data are collected and evaluated, the specifications should be revised accordingly.

Even though the subject areas are outside the objectives of this study, the third set -- special -- will cover two areas which concern operators of special education transportation vehicles.

(Interim)

1. Vehicle Floor:

The floor of the vehicle shall:

a. Be level and free of projecting mountings or fastening devices for securement equipment when the equipment is not in use;

b. Have a nonskid surface or covering.

2. Loading Equipment:

a. Loading equipment shall have nonskid surfacing in the walkway portion, including ramp steps;

b. Lift and elevator equipment shall have stops to minimize the possibility of a wheelchair rolling off the lift platforms;

c. Loading equipment shall be provided with protective padding when it is exposed inside the vehicle;

d. Loading equipment that blocks doorways shall be equipped with a manual, externally operated emergency release mechanism capable of clearing the doorway;

e. Controls for lifts and elevators shall be located in close proximity to the lifting platform;

f. Ramps carried in a vertical position inside the vehicle shall be secured at their top during transit.

3. Wheelchair Securement:

Equipment for securing wheelchairs during transit shall:

a. 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 three thousand (3,000) pounds;

b. Consist of a minimum of two for each wheelchair, with each to be mounted separately to the vehicle and have separate points of attachment to either the frame or wheels of the wheelchair;

c. Be mounted so that the chair is prohibited from moving more than three inches in either a straight or circular direction and from tipping in the event the vehicle is overturned;

d. Be secured to the vehicle with not less than 3/8 inch bolts, lockwashers 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 one of those areas, a reinforcement plate or washer not less than 1/16 inch thick and 2 inches square or 2½ inches in diameter shall be provided between the bolt head and metal pierced;

e. Be capable of restraining the wheelchair in the event the wheelchair wheels collapse.

If adjustable tracks are used as part of the securement equipment, the tracks shall be secured to the vehicle at intervals not less than specified by the manufacturer.

Where webbing type equipment is used, release buckles shall be positioned so as to have direct in-line tension.

Electric wheelchair batteries shall be secured to the wheelchair during transit.

4. Passenger Securement:

a. Each passenger shall be secured to the vehicle by a standard webbing type 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 a single 9/16 or two 7/16 inch bolts;

b. Passengers who are not capable of preventing a fall from their wheelchair shall be secured to the wheelchair by a standard webbing type seatbelt.

(Future)

5. Perform static tests on that equipment which by engineering judgment appears to have less than desired strength.

6. Perform crash tests of prototype vehicles containing simulated wheelchair students, the students to be instrumented so as to obtain body reactions during the test. Interior movies should be taken so as to record counterreactions of students and equipment, with special attention paid to the behavior of the wheelchair and its securement equipment.

(Special)

7. Conduct a probability and preventive study on fuel spillage post-accident fires involving commercial van type vehicles.

8. Conduct a cost/benefit study, as measured with respect to safety, on a low volume vehicle designed and built for the specific purpose of transporting wheelchair confined students.

REFERENCES

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