FTA RESEARCH

REPORT SUMMARY

Crashworthiness Evaluation of Mass Transit Buses

Background

For better understanding of how injuries and damage result from bus crashes, the National Institute of Aviation Research (NIAR) used analysis based on computational and virtual reality methods to model crash effects on buses and their occupants. A detailed finite element model of a typical low-floor transit bus was generated, validated, and used to calculate the crash pulses for the passenger compartment in typical frontal, side, and rear crash scenarios. Detailed multibody and finite element models of typical transit bus interiors were also used to help analyze the injury mechanisms to bus passengers and drivers during collisions of transit buses with various vehicle types. These numerical simulation results were verified by a series of full-scale sled tests with a comprehensive set of anthropomorphic test devices (ATDs, informally known as “crash dummies”), representing a range of passengers from 12-month-old infants up through 95th percentile males. The sled tests, conducted at NIAR’s Crash Dynamics Laboratory, identified injury mechanisms to seated and standing passengers and aided in validating numerical models of bus interiors.

Objectives

The primary objectives of this research were to (1) characterize the structural response of buses, (2) characterize how passengers are injured when they interact with other passengers and bus fixtures, and (3) develop interior design concepts and crashworthiness design principles for safer mass transit buses.

Findings and Conclusions

The primary causes of passenger injury in bus crashes are impacts with other passengers and seat structures. New designs and guidelines have been developed to increase passenger safety.

The research found that primary mechanisms of injury to passengers are collision impacts with other passengers and seat structures. It also found that standard seatbacks in mass transit buses are too low to protect against neck injuries and indicated that high seatbacks and headrests would reduce rear impact injuries significantly. Responding to industry concerns that increased seat height would cause a reduction in passenger visibility, NIAR developed a seatback design that provides needed head and neck support while reducing operator-passenger visibility by only 20 percent. Introducing offset seat rows could improve the level of protection to passengers during severe side impacts.

The research suggested design guidelines that should reduce occupant injuries and damage to other vehicles in crashes. For example, the research led to a strong recommendation against side-facing seats for the protection of both the seated passengers in them and standing passengers they would strike in a crash. Similarly, removal of rear center-aisle seats is strongly recommended, eliminating the danger to passengers seated in them and to standing occupants. The current lack of child-specific injury protection could be remedied by adapting automotive child restraint systems for use in transit buses.

Finally, the research led to a strong recommendation for virtual testing and certification of transit buses using numerical modeling. When used in conjunction with experimental static and dynamic testing, numerical modeling allows for an efficient, iterative, cost-effective method to evaluate the crashworthiness behavior of mass transit buses.

Benefit

With judicious use of validated mathematical models, changing from an over-engineered bus design to a modernized design with lightweight materials and structural components could be achieved using a small fraction of the resources required for traditional experimental techniques involving building and testing full-scale models.

Project Information

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