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Research Results

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Development of Crush Zones for Passenger Railcars

SUMMARY

Crash Energy Management (CEM) has been developed as a means to protect occupants in train-to-train collisions. As part of CEM, sacrificial crush zones are designed into unoccupied locations in cars. These crush zones are designed to deform with a lower initial force and increased average force. With such crush zones, energy absorption is shared by multiple cars during the collision, consequently preserving the integrity of the occupied areas. Figure 1 shows the final cab end crush zone design that was developed as part of the research. A similar design has been developed for non-cab end crush zones. The non-cab end design does not include the deformable load distributor or the operator's compartment.

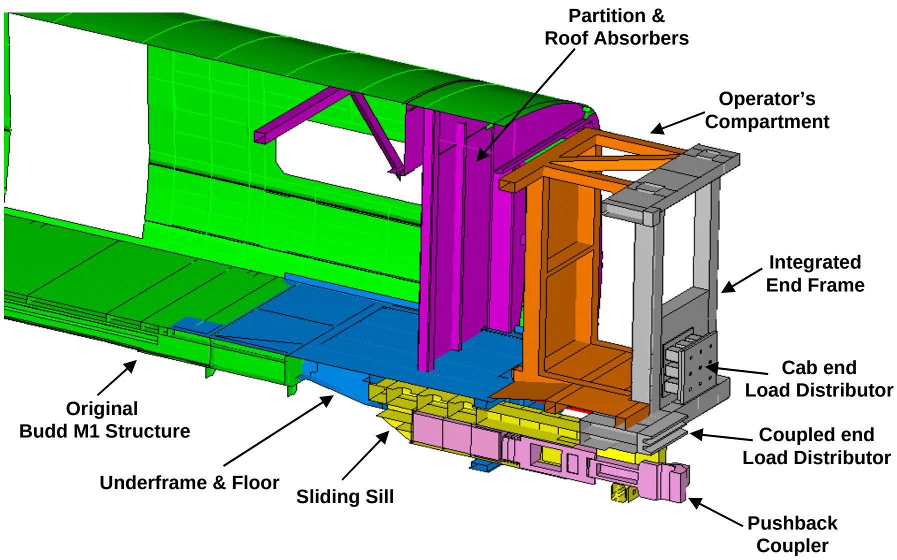

Figure 1. Cab Car Crush Zone Design–Quarter Model

The key elements of the design include features to control the colliding interface interaction, a fixed/sliding sill interface that allows push back of the entire front end structure of the cab car into the service closet space, and a set of primary and roof energy absorbers. The elements that help manage the interaction with colliding equipment are the push-back coupler and the cab end load distributor. The cab end load distributor is deformable and acts to resolve off-axis loads from the impact into loads that can be supported by the collision and corner posts. The elements that help manage the interactions of coupled cars are the push-back coupler and the coupled end load distributor. The coupled end load distributor acts to transmit the longitudinal collisions load between cars. For cab and coupled ends, the push-back coupler is designed to translate longitudinally and allow the ends to the equipment to come together, without developing sufficient lateral load to derail the equipment.

Introduction

The research on passenger equipment crush zones has included design development, fabrication of test articles, and full-scale impact testing. This research has resulted in the information needed to develop equipment specifications, industry standards, and Federal regulations.

Design

This note presents the approach taken to develop a passenger coach car and cab car CEM crush zone designs. Design requirements were developed based upon results from the conventional testing and an accident history review. Several preliminary designs were developed. Full-scale subcomponent testing was conducted in conjunction with the development of the final design. The designs were then retrofitted onto existing passenger cars and tested [1, 2].

The principal goal for both the cab car and coach car crush zone design is to protect the passenger volume. To achieve this goal, the coach car crush zone is required to absorb 2.5 million ft-lbs of energy per car end and to deform gradually when it crushes, minimizing vertical and lateral car motions. The cab car crush zone is required to absorb 3.0 million ft-lbs per cab end. In addition, it is required to crush gradually and manage the impact with colliding equipment to prevent override.

Figure 2 shows three of the preliminary design concepts. These concepts vary in how the energy is absorbed and in how the deformation is controlled.

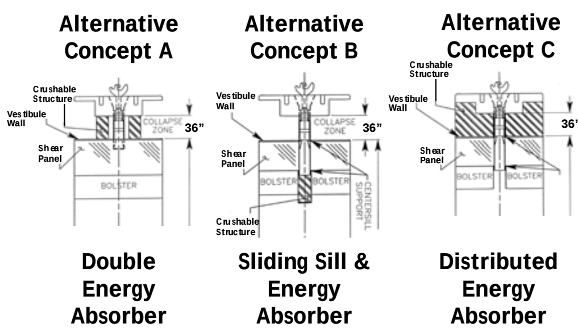

Figure 2. Crush Zone Preliminary Design Concepts

Figure 3 shows the final design concept, which incorporates the energy absorption strategy of Alternative Concept A and the sliding sill feature of Alternatives B and C for controlling deformation.

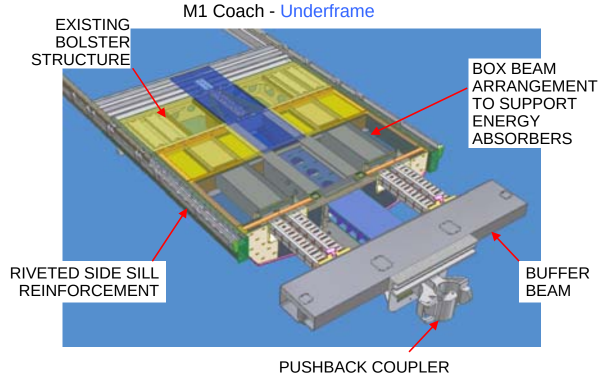

Figure 3. Crush Zone Final Design

Build

The crush zone designs were developed for retrofit onto existing Budd Pioneer and M1 passenger cars. The crush zones components were fabricated and shipped to the Transportation Technology Center in Pueblo, CO, for installation. Figure 4 shows selected components.

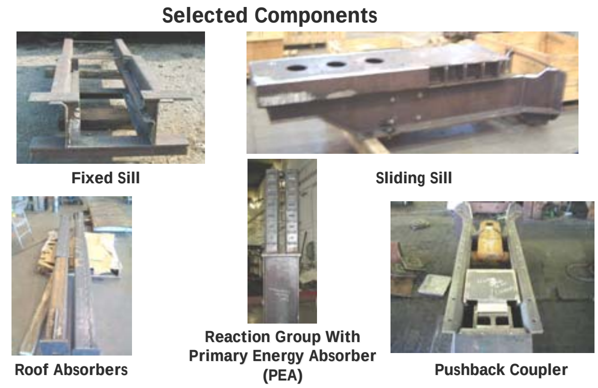

Figure 4. Selected Crush Zone Components Before Installation

The cars were prepared for installation, while the crush zones components were being fabricated. A cut-out sequence was developed for use by the assembly team. The ends of the cars have been removed and the edges on the cut-out planes ground smooth in preparation for retrofit components. Once the existing car structure has been prepared, a set of components is used to build up the existing body bolster, side sills, and floor structure to serve as the fixed components into which the sliding components will push back. Next, the sliding sill assembly, including some push-back coupler components, will be attached to the fixed components. The integrated end frame is then welded to the sliding sill, followed by placement of the primary and roof energy absorbers. Figure 5 shows a completed car end with the crush zone components installed.

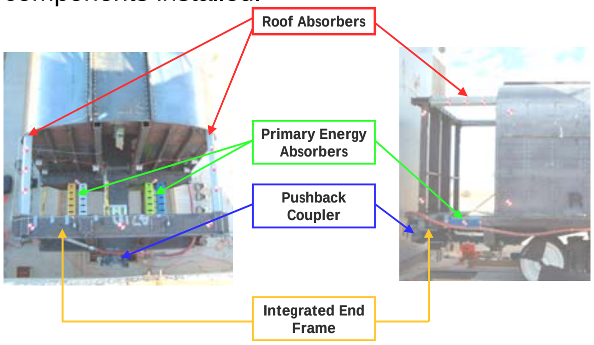

Figure 5. Installed Crush Zone

Full-Scale Tests

The results from the full-scale impact tests show that the CEM design has superior crashworthiness performance over conventional equipment. In the single car test of conventional equipment, the car crushed by approximately 6 feet, intruding into the occupied area, and lifted by about 9 inches, raising the wheels of the lead truck off the rails [3]. Under the same single-car test conditions, the CEM trailer car crushed approximately 3 feet, preserving the occupied area, and its wheels remained on the rails [4].

Figure 6. Conventional and CEM Single Car Test Results

In the two-car test of conventional equipment, the conventional car again crushed by approximately 6 feet and lifted approximately 9 inches as it crushed; in addition, the coupled cars saw-tooth-buckled, and the trucks immediately adjacent to the coupled connection derailed [5]. In the two-car test of CEM equipment, the cars preserved the occupant areas and remained in-line, with all of the wheels on the rails [6].

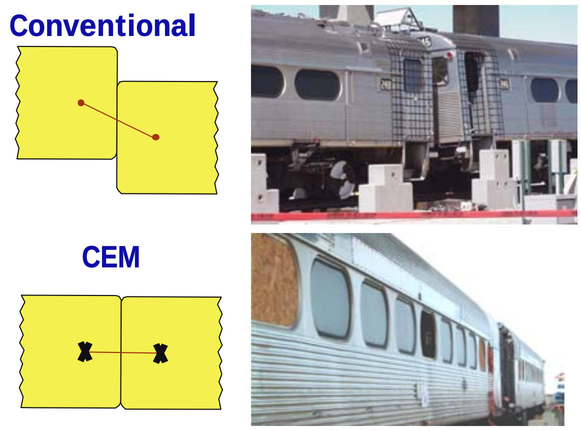

Figure 7. Conventional and CEM Two Car Test Results

In the train-to-train test of conventional equipment, the colliding cab car crushed by approximately 22 feet and overrode the locomotive [7]. The space for the operator's seat and for approximately 47 passenger seats was lost. Computer simulations of the train-to-train test of CEM equipment indicate that the front of the cab car will crush by approximately 3 feet and that override will be prevented [8]. Structural crush will be pushed back to all of the trailer car crush zones, and all of the crew and passenger space will be preserved. The train-to-train test of CEM equipment, which is planned for March 2006, is expected to confirm these predictions.

Figures 6, 7, and 8 show some of the results of single, two-car, and train-to-train impact tests and predictions, respectively.

Figure 8. Conventional Train-to-Train Test Result and CEM Train-to-Train Test Prediction

Conclusions

The modeling performed as part of the research shows the potential benefits of alternative crashworthiness strategies. The full-scale testing is used to confirm the effectiveness of the most promising strategies. Development of designs implementing these strategies results in detailed requirements. Fabrication of the test articles shows that such designs can be practically built. Information on costs to design and build is consequently developed while designing and building the test articles. This cost information is currently being used with information from the Federal Railroad Administration's (FRA) field study and extrapolations from the full-scale testing to evaluate the economics of applying CEM.

Acknowledgements

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References

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