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Of Transportation

**Federal Railroad
Administration**

Research Results

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Alternative End Frame Design of Passenger Rail Cab Car

SUMMARY

At the request of the American Public Transportation Association (APTA), the Office of Research and Development of the Federal Railroad Administration (FRA) conducted a series of full-scale grade crossing tests. The purpose of the tests was to demonstrate the enhanced performance of cab car end frame designs promulgated in Federal requirements and the industry standard adopted by APTA in 1999. Two end frame designs were developed. The first design was representative of cars built before the promulgation of the requirements and standards and referred to as the 1990's design. The second design incorporated all the enhanced strength-based design requirements, as well as a requirement that the corner or collision post be able to experience "*severe deformations*" without experiencing failure at the connections. This design was referred to as the state-of-the-art (SOA) design.

The impact conditions to be tested were planned at several meetings of APTA's Passenger Railroad Equipment Safety Standards (PRESS) Construction and Structural (C&S) group. The final scenario agreed upon by the group was a grade crossing scenario where the corner post is loaded above the end beam. This scenario puts the operator at greatest risk due to the loss of survivable volume. This condition is similar to accidents occurred in Yardley, PA, and Portage, IN, where a steel coil penetrated the end of a cab car, resulting in the loss of several lives. The test speed was determined from initial large deformation crush and collision dynamic calculations such that the steel coil would penetrate the 1990's design by a distance greater than 1 foot and not penetrate the SOA design by the same distance.

The results from the grade crossing tests, shown in Figure 1, demonstrated the improved crashworthiness performance of the SOA design. The corner post was capable of preventing intrusion into the operator's survivable space. Under nominally the same conditions, the 1990's design allowed full penetration into the cab area and subsequent loss of survivable space for the operator.

Figure 1. Results from Grade Crossing Tests

INTRODUCTION

The aim of crashworthiness studies is to minimize the possibility of injuries or fatalities caused by the loss of occupant volume, and decelerations and force loads caused by secondary impacts. The results presented describe the improvement in preserving the cab car operator's survival volume during a grade crossing collision. The scenario envisioned is that of a cab car striking a heavy object in an offset manner where the primary structure involved is the cab car corner post. A typical design from pre-1999 Federal regulations (termed the 1990's design) and a modified design compliant with current Federal regulations and APTA's manual of recommended practices (SOA design) are presented. The objective of the test was to measure the effectiveness of the corner post design in preserving the occupant volume.

Figure 2 is a schematic of the 1990's grade-crossing test setup. The tests included a steel coil supported on a frangible table. The coil, weighing approximately 40,000 pounds, was centered on the corner post, and the bottom of the coil was just above the height of the cab car floor. The nominal speed determined through pre-test analyses was the cab car moving at 14 mph and striking the steel coil.

Figure 2. Schematic of the 1990's Grade Crossing Impact Test Setup

Designs Developed

Two Budd Pioneer cars were modified with the developed end frame designs, see Figure 3. Many of the key structural elements are similar for the 1990's and SOA designs. The principal differences are the size of the corner posts, the presence of a bulkhead sheet attached to the lateral member/shelf to the collision post to the corner post and to the end beam on the SOA design, and the length of the side sill on the SOA design, which extends past the operator compartment to the end beam removing the presence of the step well.

Figure 3. End Frame Designs

Analyses and Test Results

The test for the 1990's end frame was conducted on June 4, 2002. The SOA design was tested on June 7, 2002. Prior to both tests, two modeling techniques were used to help locate and range the instrumentation and design the impact speed. Detailed nonlinear large deformation finite element models predict the modes of deformation and failure, as well as determine the force crush characteristics. A collision dynamics model was used to determine the trajectories of the cab car and coil and evaluate the extent of crush as a function of impact speed. Figure 4 shows a comparison of the predicted and measured deformations from the SOA design. The modes of deformation and failure predicted were in close agreement with the observed performance.

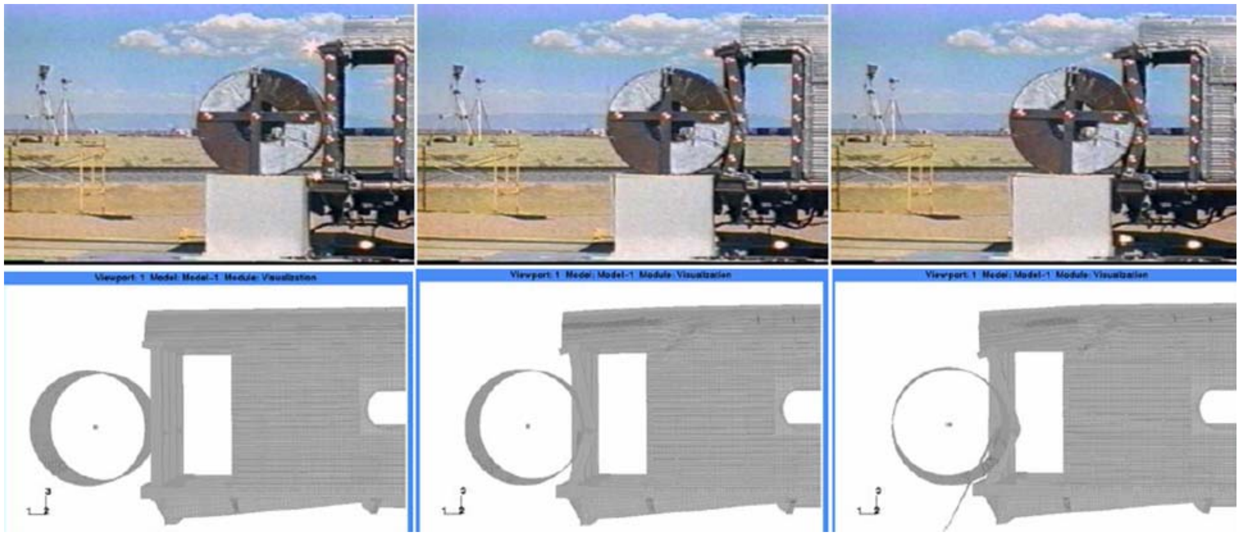

Figure 4. Comparison of Measured and Pre-Test Predicted Modes of Deformation for SOA Design

Using the force crush characteristics derived before the test, it was possible to predict the safe speed at which to run the test for crush greater than 1 foot for the 1990's design and less than 1 foot for the SOA design. The 1-foot crush distance was agreed upon as the maximum allowable inward penetration that would still leave sufficient survivable space for the operator to survive the collision. Figure 5 shows the estimated crush as a function of the closing speed.

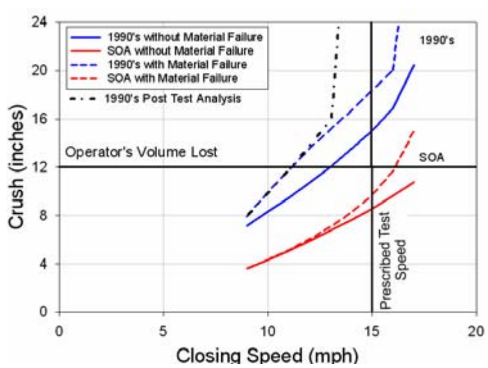

Figure 5. Maximum Safe Closing Speed versus Crush Distance

CONCLUSIONS

Two end frame designs were tested at the request of APTA to demonstrate the benefits of including enhanced strength and deformability requirements. The SOA end frame design shows significant increases in safe closing speed under the tested impact conditions when compared to the 1990's design. The key difference between the two designs was the need to incorporate the severe deformation requirement while developing the SOA end frame design.

ACKNOWLEDGEMENTS

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CONTACTS

Eloy Martinez
Federal Railroad Administration
Office of Research and Development
1120 Vermont Avenue NW - Mail Stop 20
Washington, DC 20590
Tel: (202) 493-6354
Fax: (202) 493-6333
Email: eloy.martinez@dot.gov