MASH Test 5-12 of the Schöck ComBAR Parapet

by

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Senior Research Fellow

and

Wanda L. Menges
Research Specialist

Contract No.: P2010353
Test No.: 401761-SBG1
Test Date: November 16, 2010

Sponsored by
Schöck Bauteile GmbH

TEXAS TRANSPORTATION INSTITUTE PROVING GROUND

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Wanda L. Menges, Research Specialist
Deputy Quality Manager

Richard A. Zimmer, Senior Research Specialist
Test Facility Manager
Quality Manager
Technical Manager
The purpose of the testing reported herein is to assess the performance of the Schöck ComBAR parapet according to the safety-performance evaluation guidelines included in MASH. The proposed crash test for this project was in accordance with Test Level 5 (TL-5) of MASH, which involves the 36000V tractor trailer (cab-behind-engine model) impacting the Schöck ComBAR parapet at a nominal impact speed and angle of 50 mi/h (80 km/h) and 15 degrees, respectively. This test is intended to evaluate the strength of the barrier in containing and redirecting heavy trucks.

The Schöck ComBAR parapet contained and redirected the 36000V vehicle. The vehicle did not penetrate, underride or override the parapet. No measureable deflection occurred. No detached elements, fragments, or other debris from the Schöck ComBAR parapet were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. No occupant compartment deformation occurred. The 36000V test vehicle remained upright during and after the collision event.

The Schöck ComBAR parapet performed acceptably according to the guidelines set forth for MASH test 5-12.
# SI* (MODERN METRIC) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

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### VOLUME

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NOTE: volumes greater than 1000 L shall be shown in m\(^{3}\).

### MASS

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### TEMPERATURE (exact degrees)

\[ ^\circ C = \frac{(^\circ F-32)}{1.8} \]

### ILLUMINATION

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### FORCE and PRESSURE or STRESS

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## APPROXIMATE CONVERSIONS FROM SI UNITS

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<td>1.133</td>
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### TEMPERATURE (exact degrees)

\[ ^\circ C = \frac{(^\circ F-32)}{1.8} \]

### ILLUMINATION

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### FORCE and PRESSURE or STRESS

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*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.*

(Revised March 2003)
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Table 6.1. Performance evaluation summary for MASH test 5-12 on the Schöck ComBAR parapet. ................................................................. 24
1. INTRODUCTION

1.1 PROBLEM

Roadside safety devices perform the important function of preventing serious injury to motorists during roadside encroachments. To maintain the desired level of safety for the motoring public, these safety appurtenances must be designed to accommodate a variety of site conditions, placement locations, and a changing vehicle fleet. As changes are made or in-service problems are encountered, there is a need to assess the compliance of the specific safety device with current vehicle testing criteria, and modify the device or develop a new device with enhanced performance and maintenance characteristics.

For many decades, concrete structures have been reinforced with steel bars. Steel reinforcing bars have served well. However, in some environments, steel has exhibited corrosion which results in loss of durability of structures. Several means of addressing this problem have been offered and implemented. One solution to the corrosion problem is to use fiber-reinforced polymer (FRP) reinforcing bars. One product currently available is ComBAR offered by Schöck Bauteile GmbH.

1.2 BACKGROUND

Since the 1940s, the United States has been committed to crash testing highway safety appurtenances. National guidelines for testing roadside appurtenances originated in 1962 with a one-page document – *Highway Research Circular 482* entitled “Proposed Full-Scale Testing Procedures for Guardrails” (1). In 1974, *NCHRP Report 153*, “Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances” was published (2). This 16-page document provided the first complete test matrix for evaluating safety features.

Published in 1978, Transportation Research Circular 191, “Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances” (3) provided limited interim changes to *NCHRP Report 153* to address minor changes requiring modified treatment of particular problem areas. An extensive revision and update to these procedures was made in 1981 with the publication of *NCHRP Report 230*, “Recommended Procedures for the Safety Performance Evaluation of Highway Features” (4). This 42-page document contained different service levels for evaluating longitudinal barriers whose test matrices included vehicles ranging from small passenger cars to intercity buses.

Research to update *NCHRP Report 350* and take the next step in the continued advancement and evolution of roadside safety testing and evaluation was recently completed under NCHRP Project 22-14(02). The results of this research effort resulted in a new document published by the American Association of State Highway and Transportation Officials (AASHTO), entitled Manual for Assessing Safety Hardware (*MASH*), and supersedes *NCHRP Report 350* (6). Changes incorporated into the new guidelines include new design test vehicles, revised test matrices, and revised impact conditions.

1.3 OBJECTIVES/SCOPE OF RESEARCH

The purpose of the testing reported herein is to assess the performance of the Schöck ComBAR parapet according to the safety-performance evaluation guidelines included in *MASH*. The proposed crash test for this project was in accordance with Test Level 5 (TL-5) of *MASH*, which involves the 36000V tractor trailer (cab-behind-engine model) impacting the Schöck ComBAR parapet at a nominal impact speed and angle of 50 mi/h (80 km/h) and 15 degrees, respectively. This test is intended to evaluate the strength of the barrier in containing and redirecting heavy trucks.
2. SYSTEM DETAILS

2.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The Schöck ComBAR parapet is a reinforced concrete bridge rail that is 41.3 inches (1050 mm) tall and has a traffic face geometry matching the New Jersey traffic barrier. A cross section of the parapet is shown in figure 2.1, and reinforcement details are shown in figure 2.2. For the test installation, the parapet was installed on a concrete deck overhang that was reinforced with conventional steel bars and supported on an existing concrete foundation. All parapet reinforcement was ComBAR of the sizes and lengths shown in figure 2.2. Additional details are provided in appendix A.

2.2 MATERIAL SPECIFICATIONS

Concrete compressive strength for the parapet was specified to be 3625 psi (25 MPa) minimum and 4641 psi (32 MPa) maximum. Concrete cylinders tested on the day of the crash test (5 days of age) had a measured compressive strength of 3457 psi (24 MPa). Compressive strength of the deck at 8 days of age was 4708 psi (32 MPa). Appendix B presents the measurements of all concrete breaks.

The Schöck ComBAR is a glass fiber-reinforced polymer made from E-CR glass fibers and vinyl-ester resin. It is manufactured by Schöck Bauteile GmbH, Baden-Baden, Germany. Stated physical properties are:

- Ultimate Tensile Strength: 172 ksi (1188 MPa)
- Tensile Strength for 100-yr Service Life: 84 ksi (580 MPa)
- Ultimate Elongation: 26.1%
- Elastic Modulus: 9280 ksi (64 GPa)

2.3 SOIL CONDITIONS

The Schöck ComBAR parapet was installed on a reinforced concrete bridge deck. Therefore, no soil conditions were obtained.
Figure 2.1. Details of the Schöck ComBAR parapet.
Figure 2.2. Details of the reinforcement for the Schöck ComBAR parapet.

4a. Existing rebar, Bars 100 and 101, and $\varnothing 19 \times 560$ weld to A36 steel strap (5 x 100).

4b. Bars 100, 101, and longitudinal bars in deck are grade 60.

4c. Lap lengths - 550 mm for $\varnothing 16$ ComBAR bars in parapet, 510 mm for $\varnothing 16$ bars in deck, and 1020 mm for $\varnothing 25$ bars in deck.

4d. Longitudinal bar laps not permissible through control joints.

4e. Bar spacing in deck is typical for full length.

4f. Rebar $\varnothing 19 \times 560$ long, anchored with Hilti RE 500 epoxy 200 deep in existing concrete. Spaced @ 242 midway between existing rebar, 1300 upstream to 4500 downstream of impact.
Figure 2.3. Schöck ComBAR parapet prior to testing.
3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

According to *MASH*, three tests are recommended to evaluate longitudinal barriers to test level five (TL-5).

*MASH Test 5-10* involves an 1100C small passenger vehicle weighting 2420 lb (1100 kg) impacting the critical impact point (CIP) of the length-of-need (LON) of the barrier at an impact speed and angle of 62 mi/h (100 km/h) and 25 degrees, respectively. The purpose of this test is to evaluate the overall performance of the LON section, in general, and occupant risk, in particular.

*MASH Test 5-11* involves a 2270P pickup truck weighing 5000 lb (2270 kg) impacting the CIP of the LON at an impact speed and angle of 62 mi/h (100 km/h) and 25 degrees, respectively. The test is intended to evaluate strength of the section in containing and redirecting the 2270P vehicle.

*MASH Test 5-12* involves a 36000V tractor (cab-behind-engine model) and van-trailer weighing 79,300 lb (36,000 kg) impacting the CIP of the LON at an impact speed and angle of 50 mi/h (80 km/h) and 15 degrees. This test is intended to evaluate the strength of the barrier in containing and redirecting heavy vehicles.

The test performed and reported herein corresponds to *MASH* test 5-12. Procedures suggested in *MASH* were used to determine the target impact location, CIP of the LON. The target impact location was determined to be 10.8 m (35.5 ft) from the downstream end.

The crash test and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 4 presents brief descriptions of these procedures.

3.2 EVALUATION CRITERIA

The crash test was evaluated in accordance with the criteria presented in *MASH*. The performance of the Schöck ComBAR parapet is judged on the basis of three factors: structural adequacy, occupant risk, and post impact vehicle trajectory. Structural adequacy is judged upon the ability of the Schöck ComBAR parapet to contain and redirect the vehicle, or bring the vehicle to a controlled stop in a predictable manner. Occasional risk criteria evaluates the potential risk of hazard to occupants in the impacting vehicle, and to some extent other traffic, pedestrians, or workers in construction zones, if applicable. Post impact vehicle trajectory is assessed to determine potential for secondary impact with other vehicles or fixed objects, creating further risk of injury to occupants of the impacting vehicle and/or risk of injury to occupants in other vehicles. The appropriate safety evaluation criteria from table 5.1 of *MASH* were used to evaluate the crash test reported herein, and are listed in further detail under the assessment of the crash test.
4. TEST CONDITIONS

4.1 TEST FACILITY

The full-scale crash test reported herein was performed at Texas Transportation Institute (TTI) Proving Ground. TTI Proving Ground is an International Standards Organization (ISO) accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing certificate 2821.01. The full-scale crash test was performed according to TTI Proving Ground quality procedures and according to the MASH guidelines and standards.

The test facilities at the TTI Proving Ground consist of a 2000 acre (809-hectare) complex of research and training facilities situated 10 miles (16 km) northwest of the main campus of Texas A&M University. The site, formerly an Air Force Base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and safety evaluation of roadside safety hardware. The site selected for the installation of the Schöck ComBAR parapet is off the end of a wide out-of-service runway. The runway consists of an unreinforced jointed concrete pavement in 12.5 ft × 15 ft (3.8 m × 4.6 m) blocks nominally 8-12 inches (203-305 mm) deep. The runways are over 50 years old and the joints have some displacement, but are otherwise flat and level.

4.2 VEHICLE GUIDANCE SYSTEM

The test vehicle was guided into the test installation using a remote control steering system. The vehicle was operated under its own power with a push vehicle aiding in initial acceleration. Steering and other necessary control functions were accomplished through onboard equipment remotely controlled from a chase vehicle. A painted stripe was used to aid the driver in achieving the intended impact condition. A speed controller on the test vehicle engine was pre-set at the intended impact speed.

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems, Inc. The accelerometers, that measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra small size, solid state units designs for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel.
at a rate of 10,000 values per second with a resolution of one part in 65,536. Once recorded, the data are backed up inside the unit by internal batteries should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as initiating the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The raw data are then processed by the Test Risk Assessment Program (TRAP) software to produce detailed reports of the test results. Each of the TDAS Pro units are returned to the factory annually for complete recalibration. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology. Acceleration data is measured with an expanded uncertainty of ±1.7 percent at a confidence fracture of 95 percent (k=2).

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60-Hz digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact. Rate of rotation data is measured with an expanded uncertainty of ±0.7 percent at a confidence factor of 95 percent (k=2).

Placement of the electronic instrumentation is shown in figure 4.1 and described below.

(A) The front accelerometers were placed on the truck frame rail 12 inches (305 mm) forward of the front axle, 19.5 inches (495 mm) left of the longitudinal centerline and at height of 34.5 inches (876 mm) above ground surface.

(B) The accelerometers and rate transducers at the rear of the tractor were placed 12.7 ft (3.9 m) rearward of the front axle, 16.25 inches (3.9 m) to the left of the longitudinal centerline, and at a height of 32.75 inches (832 mm) above ground surface.

(C) The rear accelerometers were placed on the trailer frame 52.25 ft (15.9 m) rearward of the front axle at longitudinal centerline and 37.0 inches (940 mm) above ground surface.

4.3.2 Photographic Instrumentation and Data Processing

Photographic coverage of the test included three high-speed cameras: one overhead with a field of view perpendicular to the ground and directly over the impact point; one placed behind the installation at an angle; and a third placed to have a field of view parallel to and aligned with the installation at the downstream end. A flashbulb activated by pressure-sensitive tape switches
was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked motion analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A mini-DV camera and still cameras recorded and documented conditions of the test vehicle and installation before and after the test.

Figure 4.1. Location of accelerometers and rate transducers.
5. CRASH TEST 401761-SBG1 (MASH TEST NO. 5-12)

5.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH test 5-12 involves a 36000V tractor van-trailer weighing 79,300 lb ±1100 lb (36 000 kg ±500 kg) and impacting the Schöck ComBAR parapet at an impact speed of 50 mi/h ±2.5 mi/h (80 km/h ±4 km/h) and an angle of 15 degrees ±1.5 degrees. The target impact point was 35.5 ft (10.8 m) from the downstream end, at the second control joint.

The 2000 Freightliner FL112 with 1993 Strick van-trailer used in the test weighed 79,220 lb (35 934 kg) and the actual impact speed and angle were 50.5 mi/h (81.3 km/h) and 15.6 degrees, respectively. The actual impact point was 620 mm upstream of the control joint, or 33.6 ft (10.2 m) downstream of the end. Impact severity was calculated to be 15,728 kip-ft, which was 9.25% above target.

5.2 TEST VEHICLE

A 2000 Freightliner FL112 tractor with 1993 Strick van-trailer, shown in figures 5.1 and 5.2, was used for the crash test. Curb weight of the 36000V vehicle (tractor and trailer) was 28,550 lb (12 950 kg). Ballast was installed in the trailer to bring total weight to 79,220 lb (35 934 kg). Ballast consisted of bags of sand weighing 100 lb each placed on a false floor to result in a height of center-of-gravity of the ballast of 71.75 inches above the ground. The ballast extended the full width and length of the trailer. See figure 5.2 and a drawing of the ballast configuration in appendix C, figure C1.

Test inertia weight of the vehicle was 79,220 lb (35 934 kg), and its gross static weight was 79,220 lb (35 934 kg). The height to the lower edge of the vehicle front bumper was 20.5 inches (521 mm), and the height to the upper edge of the front bumper was 31.5 inches (800 mm). Additional dimensions and information on the vehicle are given in appendix C, figures C2 and C3. The vehicle was directed into the installation using a remote control system and was free-wheeling and unrestrained just prior to impact.

5.3 WEATHER CONDITIONS

The crash test was performed the afternoon of November 16, 2010. Weather conditions at the time of testing were: Wind speed: 3 mi/h (5 km/h); wind direction: 257 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 65°F (18°C); relative humidity: 42 percent.
Figure 5.1. Vehicle/installation geometrics for test 401761-SBG1.
Figure 5.2. Vehicle before test 401761-SBG1.
5.4 TEST DESCRIPTION

The 360000V vehicle, while traveling at an impact speed of 50.5 mi/h (81.3 km/h), impacted the Schöck ComBAR parapet 620 mm (24.4 inches) upstream of the control joint (33.6 ft (10.2 m) from the upstream end) at an impact angle of 15.6 degrees. At 0.100 s, the cab of the test vehicle began to redirect, and at 0.203 s, the lower right front corner of the van-trailer contacted near the top of the parapet. At 0.403 s, the cab of the test vehicle was traveling parallel with the parapet at a speed of 49.5 mi/h (79.7 km/h). The van-trailer began traveling parallel with the parapet at 0.667 s, and was traveling at a speed of 47.4 mi/h (76.3 km/h). At 0.695 s, the lower right rear corner of the van-trailer contacted near the top of the parapet, and at 0.748 s, the right rear edge of the van-trailer ruptured. As the test vehicle continued along the parapet, it rode off the end of the parapet. The brakes on the test vehicle were not applied, and the test vehicle subsequently came to rest 117 ft (35.7 ft) downstream of the end of the parapet and 9 ft (2.7 m) toward the field side. Sequential photographs of the test are shown in appendix C, figure C3.

5.5 TEST ARTICLE AND COMPONENT DAMAGE

The Schöck ComBAR parapet sustained cosmetic damage only in the form of tire marks and gouges into the concrete traffic face of the barrier. Figures 5.3 and 5.4 show damage to the Schöck ComBAR parapet.

5.6 TEST VEHICLE DAMAGE

Damage to the test vehicle is shown in figures 5.5 and 5.6. The front axle of the tractor was deformed on the right side. Also damaged on the tractor were the front bumper, hood, right front spring and spring mount, right front wheel rim (no loss of air in tire), right fuel tank, right door, right outer tire and wheel rim of the front tandem axle, right inner front tire of the front tandem axle, and right outer tire and wheel rim of the rear tandem axle. On the right side of the van-trailer, the floor, roof, and back door were damaged. Estimated maximum crush to the tractor was 12 inches (305 mm) at the right front corner of the tractor at bumper height.

5.7 OCCUPANT RISK VALUES

Occupant risk values are not applicable for MASH test 5-12. However, data from the accelerometers, located at the vehicle mid-position, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity was 4.6 ft/s (1.4 m/s) at 0.221 s, the highest 0.010-s occupant ridedown acceleration was 6.5 Gs from 0.230 to 0.240 s, and the maximum 0.050-s average acceleration was -2.4 Gs between 0.232 and 0.282 s. In the lateral direction, the occupant impact velocity was 18.0 ft/s (5.5 m/s) at 0.221 s, the highest 0.010-s occupant ridedown acceleration was 37.2 Gs from 0.241 to 0.251 s, and the maximum 0.050-s average was -18.6 Gs between 0.232 and 0.282 s. Theoretical Head Impact Velocity (THIV) was 20.5 km/h or 5.7 m/s at 0.221 s; Post-Impact Head Decelerations (PHD) was 37.2 Gs between 0.241 and 0.251 s; and Acceleration Severity Index (ASI) was 2.08 between 0.234 and 0.284 s. These data and other pertinent information from the test are summarized in figure 5.7. Vehicle angular displacements and accelerations versus time traces are presented in appendix C, figures C4 through C13.
Figure 5.3. Vehicle/installation position after test 401761-SBG1.
Figure 5.4. Installation after test 401761-SBG1.
Figure 5.5. Vehicle after test 401761-SBG1.
Figure 5.6. Interior of vehicle for test 401761-SBG1.
## General Information

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<td>401761-SBG1</td>
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## Test Article

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<tr>
<td>Installation Length</td>
<td>130 ft (39.6 m)</td>
<td>Material or Key Elements</td>
<td>Glass Fiber-Reinforced Polymer</td>
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<td></td>
<td></td>
<td>Concrete New Jersey Shape Bridge Rail 41.3 inches (1050 mm) tall</td>
</tr>
</tbody>
</table>

## Soil Type and Condition

| Soil Type and Condition        | Concrete Bridge Deck, Dry |

## Test Vehicle

| Type/Designation               | 360kV        |
| Make and Model                 | 2000 Freightliner FL112 with 1993 Strick Van-Trailer |
| Curb                           | 28,500 lb (12 950 kg) |
| Test Inertial                  | 79,220 lb (35 934 kg) |
| Dummy                         | No dummy |
| Gross Static                  | 79,220 lb (35 934 kg) |

## Impact Conditions

| Speed                  | 50.5 mi/h (81.3 km/h) |
| Angle                  | 15.6 degrees |
| Location/Orientation   | 33.5 ft (10.2 m) |
| dwstrm of end          |                               |

## Impact Severity

| Impact Severity | 15728 kip-ft |

## Exit Conditions

| Speed                  | Not obtainable |
| Angle                  | Not obtainable |

## Occupant Risk Values

| Impact Velocity         | Longitudinal4.6 ft/s (1.4 m/s) |
| Lateral                | 18.0 ft/s (5.5 m/s) |
| Ridedown Accelerations | Longitudinal6.5 G |
|                       | Lateral37.2 G |
|                       | THIV20.5 km/h |
|                       | PHD37.2 G |
|                       | ASI2.08 |

## Vehicle Damage

| CDC                      | 02FRES3       |
| Max. Exterior Deformation| None measurable |

## Figure 5.7. Summary of results for MASH test 5-12 on the Schöck ComBAR parapet.
5.8 ASSESSMENT OF TEST RESULTS

An assessment of the test was made based on the following applicable MASH safety evaluation criteria.

5.8.1 Structural Adequacy

A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.

Results: The Schöck ComBAR parapet contained and redirected the 36000V vehicle. The vehicle did not penetrate, underride or override the parapet. No measureable deflection occurred. (PASS)

5.8.2 Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches (102 mm); windshield = ≤3.0 inches (76 mm); side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches (229 mm); forward of A-pillar ≤12.0 inches (305 mm); front side door area above seat ≤9.0 inches (229 mm); front side door below seat ≤12.0 inches (305 mm); floor pan/transmission tunnel area ≤12.0 inches (305 mm))

Results: No detached elements, fragments, or other debris from the Schöck ComBAR parapet were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. (PASS)
No occupant compartment deformation occurred. (PASS)

G. It is preferable, although not essential, that the vehicle remain upright during and after the collision.

Results: The 36000V test vehicle remained upright during and after the collision event. (PASS)
6. SUMMARY AND CONCLUSIONS

6.1 SUMMARY OF RESULTS

The Schöck ComBAR parapet contained and redirected the 36000V vehicle. The vehicle did not penetrate, underride or override the parapet. No measureable deflection occurred. No detached elements, fragments, or other debris from the Schöck ComBAR parapet were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. No occupant compartment deformation occurred. The 36000V test vehicle remained upright during and after the collision event.

6.2 CONCLUSIONS

The Schöck ComBAR parapet performed acceptably according to the guidelines set forth for MASH test 5-12, as shown in table 6.1.
Table 6.1. Performance evaluation summary for *MASH* test 5-12 on the Schöck ComBAR parapet.

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<th>Test No.: 401761-SBG1</th>
<th>Test Date: 2010-11-16</th>
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<td><strong>MASH Test 5-12 Evaluation Criteria</strong></td>
<td><strong>Test Results</strong></td>
<td><strong>Assessment</strong></td>
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<td>Structural Adequacy</td>
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<tr>
<td>A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable</td>
<td>The Schöck ComBAR parapet contained and redirected the 36000V vehicle. The vehicle did not penetrate, underride or override the parapet. No measureable deflection occurred.</td>
<td>Pass</td>
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<tr>
<td>Occupant Risk</td>
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<tr>
<td>D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.</td>
<td>No detached elements, fragments, or other debris from the Schöck ComBAR parapet were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area.</td>
<td>Pass</td>
</tr>
<tr>
<td>Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</td>
<td>No occupant compartment deformation or intrusion occurred.</td>
<td>Pass</td>
</tr>
<tr>
<td>G. It is preferable, although not essential, that the vehicle remain upright during and after collision.</td>
<td>The 36000V test vehicle remained upright during and after the collision event.</td>
<td>Pass</td>
</tr>
</tbody>
</table>
REFERENCES


2a. Chamfer top edges of Parapet and back edges of Deck - 19mm each way.
2b. Concrete strength of parapet shall be minimum 25 MPa (3625 psi), maximum 32 MPa (4640 psi).
2c. Paint all visible surfaces of parapet white min. 24 hours prior to test.
3a. Bars 100 and 101 at 300mm spacing. Place Bars 100 midway between Bars 101.
3b. Bar spacing in deck is typical for full length.

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4a. Existing rebar, Bars 100 and 101, and Ø 19 x 560 weld to A36 steel strap (5 x 100).
4b. Bars 100, 101, and longitudinal bars in deck are grade 60.
4c. Lap lengths - 550 mm for Ø 16 ComBAR bars in parapet, 510 mm for Ø 16 bars in deck, and 1020 mm for Ø 25 bars in deck.
4d. Longitudinal bar laps not permissible through control joints.
4e. Bar spacing in deck is typical for full length.
4f. Rebar Ø 19 x 560 long, anchored with Hilti RE 500 epoxy 200 deep in existing concrete. Spaced @ 242 midway between existing rebar, 1300 upstream to 4500 downstream of impact.

The Texas A&M University System
Texas Transportation Institute
College Station, Texas, 77843

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BAR 1
SCALE 1:5

BAR 100

BAR 101
APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

TEST NUMBER:  401761-SBG1

DATE:  2010-11-16

All reinforcing in the parapet was supplied by the Sponsor without documentation.
### Project No.: 401761-506

### Placeiment: PARAPET

### Casting Date: 2010-11-11

### Mix Design P.S.I.: 4000

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<th>Truck No.</th>
<th>Batch Ticket</th>
<th>Yards</th>
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### Break Date | Cylinder Age | Truck No. | Total Load (Pounds) | PSI Break | Average |
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<td>3378</td>
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<td></td>
<td>2</td>
<td>103,000</td>
<td>3643</td>
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### Quality Policy Form

**5.7.2 Concrete Break**

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**Subject:** Revised by: W. L. Menges
Approved by: C. E. Bath

**Revision:** 4
**Page:** 1 of 1

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**Project No.:** 40761-566

**Placement:** DECK

**Casting Date:** 2010-11-08

**Mix Design P.S.I.:** 5000

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**Break Date**

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<th>Cylinder Age</th>
<th>Truck No.</th>
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**Printed name of Technician taking sample:**

**Signature of Technician taking sample:**

**Printed name of Technician breaking sample:**

**Signature of Technician breaking sample:**

---

*35*
APPENDIX C. CRASH TEST NO. 401761-SBG1

C1. VEHICLE BALLASTING

Figure C1. Details of vehicle ballasting.
Figure C1. Details of vehicle ballasting (continued).
Figure C1. Details of vehicle ballasting (continued)
C2. VEHICLE PROPERTIES AND INFORMATION

DATE: 2010-11-16  TEST NO.: 401761-SBG1

TRACTOR
YEAR: 2000  MAKE: Freightliner  MODEL: FL112
VIN No.: 1FUYTWEB5YAF06200  ODOMETER: 

TRAILER
YEAR: 1999  MAKE: Strick  MODEL: 
VIN No.: 1S12E845690360899

GEOMETRY ( inches )

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<tr>
<th>A</th>
<th>96.50</th>
<th>D</th>
<th>52.00</th>
<th>J</th>
<th>66.25</th>
<th>M</th>
<th>31.50</th>
<th>P</th>
<th>80.00</th>
<th>S</th>
<th>14.00</th>
<th>V</th>
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<tbody>
<tr>
<td>B</td>
<td>45.00</td>
<td>E</td>
<td>343.00</td>
<td>K</td>
<td>76.00</td>
<td>N</td>
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<td>C</td>
<td>165.00</td>
<td>F</td>
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<td>L</td>
<td>46.50</td>
<td>O</td>
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<td>R</td>
<td>73.00</td>
<td>U</td>
<td>75.25</td>
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Allowable Range:  
- C = 200 inches max.  
- L = 52 ±2 inches  
- Overall Trailer Length = 600 inches max.  
- Overall Combination Length = 780 inches max.  
- Trailer Overhang = 87 inches max.  
- Ballast Center of Mass Ht = 73 ±2 inches above ground.

MASS ( lb )

<table>
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<tr>
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<th>CURB</th>
<th>TEST INERTIAL</th>
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<tbody>
<tr>
<td>M1</td>
<td>8890</td>
<td>9520</td>
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<td>M2</td>
<td>5220</td>
<td>17230</td>
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<td>M3</td>
<td>5440</td>
<td>14750</td>
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<td>M4</td>
<td>4100</td>
<td>17770</td>
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<td>M5</td>
<td>4900</td>
<td>Allowable Range 19950</td>
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<tr>
<td>M_Total</td>
<td>28550</td>
<td>29,000 ±3100 lb</td>
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Figure C2. Vehicle properties for test 401761-SBG1.
C3. SEQUENTIAL PHOTOGRAPHS

Figure C3. Sequential photographs for test 401761-SBG1 (overhead and frontal views).
Figure C3. Sequential photographs for test 401761-SBG1 (overhead and frontal views) (continued).
Figure C4. Vehicle angular displacements for test 401761-SBG1.

No data available.
(channel saturation)
Figure C5. Vehicle longitudinal accelerometer trace for test 401761-SBG1 (accelerometer located at rear of tractor).
Figure C6. Vehicle lateral accelerometer trace for test 401761-SBG1 (accelerometer located at rear of tractor).
**Z Acceleration at Rear of Tractor**

Test Article: Schöck ComBAR parapet  
Test Standard Test No.: MASH 5-12  
Test Vehicle: 2000 Freightliner FL112 with 1993 Strick Van-Trailer  
Test Inertial Weight: 79,220 lb (35934 kg)  
Impact Speed: 50.5 mi/h (81.3 km/h)  
Impact Angle: 15.6 degrees

---

**Figure C7.** Vehicle vertical accelerometer trace for test 401761-SBG1 (accelerometer located at rear of tractor).
Figure C8. Vehicle longitudinal accelerometer trace for test 401761-SBG1 (accelerometer located near the front of the tractor).
Figure C9. Vehicle lateral accelerometer trace for test 401761-SBG1 (accelerometer located near the front of the tractor).
Z Acceleration Near Front of Tractor

Figure C10. Vehicle vertical accelerometer trace for test 401761-SBG1 (accelerometer located in the front of the tractor).
Figure C11. Vehicle longitudinal accelerometer trace for test 401761-SBG1 (accelerometer located at the rear of trailer).
Figure C12. Vehicle lateral accelerometer trace for test 401761-SBG1 (accelerometer located at the rear of trailer).
Figure C13. Vehicle vertical accelerometer trace for test 401761-SBG1 (accelerometer located in rear of trailer).