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# Test Installation 3

### GENERAL

ighway safety features are evaluated for a particular test level through a series of vehicular crash tests under idealized impact conditions. Many important test parameters have been standardized

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to arrive at a practical stratifi cation of tests (test matrices) and to enhance the degree of test replica- tion. Care must be exercised in the interpretation of test results and in the projection of the results to in-service performance. Good performance under ideal test conditions does not ensure comparable performance under in-service conditions. As discussed in Chapter 1, the evaluation process should not stop with successful completion of tests recommended herein. Crash testing and in-service evaluation are both critical to evaluating the performance of a safety feature and in-service evaluation should be pursued as recommended in Chapter 7.

### TESTING SITE

A fl at surface, preferably paved, should be used when accelerating the test vehicle to the desired speed and to provide for unrestricted trajectory of the vehicle following impact. The surface should be free of curbs, swales, ditches, or other irregularities that could infl uence impact or post-impact be- havior of the vehicle except when test conditions require such features. If necessary, a flat compacted soil or sod surface should adjoin the paved approach area to replicate conditions for safety features normally surrounded by an unpaved surface, so that post-impact vehicular behavior can be properly assessed. Test documentation should include the type of pavement or soil surfaces used on the ap- proach to the test article, surrounding the test article, and on the post-impact trajectory of the vehicle.

It may not always be possible to have a totally fl at and smooth surface for the test vehicle to acceler- ate to the desired speed, and the vehicle may be bouncing somewhat down the track. However, it is critical that the vehicle be stabilized at impact. A compressed suspension at impact may cause the vehicle to nose dive and result in underriding of the test device. An extended suspension at impact may accentuate the upward movement of the vehicle and result in overriding and vaulting of the test device. In either case, the impact performance of the test device will likely be affected. Therefore, it is important that the test vehicle not be bouncing excessively just prior to impact and that the actual bumper height at impact be within 2 in. (50 mm) vertically of the nominal bumper height, i.e., when the vehicle is at rest.

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### SOIL

The impact performance of some soil-mounted features depends on dynamic soil structure interaction. Longitudinal barriers with soil embedded posts and soil-embedded support structures for signs and lumi- naires are such features. When feasible, these features should be tested with soil conditions that replicate typical in-service conditions. Soil conditions are known to vary with time, location, and environmental factors, even within relatively small geographical areas. Therefore, except for special test conditions, it is necessary to standardize soil conditions for testing. In the absence of a specifi c soil, it is recommended that all features whose impact performance is sensitive to soil-structure interaction be tested in a soil

that conforms to the performance specifi cation as described in Section 3.3.1. However, product develop- ers and user agencies should assess the potential sensitivity of a feature to foundation conditions. If the feature is likely to be installed in a soil that could be expected to degrade its performance, testing in one or more of the special soils described in Section 3.3.3 may be appropriate.

* + 1. STANDARD SOIL

It is recommended that the standard soil meet AASHTO standard specifi cations for “Materials for Aggregate and Soil Aggregate Subbase, Base, and Surface Courses,” designation M 147, grading A or B (see Appendix B, Section B1). It should be compacted in accordance with Sections 304.05 of AASHTO’s *Construction Manual for Highway Construction* (2) (see Appendix B, Section B3). The soil should be re-compacted, as necessary, before each test to meet density requirements of the

Construction Manual (2). The soil should be well drained at the time of the crash test. The test should not be performed if the ground is frozen or if the soil is saturated unless the test is specifi cally designed to evaluate these conditions.

* + 1. SOIL STRENGTH

Soil strength is critical to the performance of many soil-mounted systems and has historically been one of the biggest sources of variation within and among testing agencies. Experience has indicated that, even though agencies use the recommended soil specifi cations, there is still a signifi cant variation in the strength of the standard soil among testing agencies. Besides the soil itself, there are many other infl u- encing factors affecting system performance, such as the length, width, and depth of the fi ll material; degree of compaction and consolidation; and moisture content. Increasing the level of detail associated with specifi cations on the soil type and all the infl uencing factors would become cumbersome and is unlikely to reduce the soil strength variability. Therefore, it is recommended that a performance-based specifi cation be used in order to improve the uniformity and consistency of soil reaction within and among testing agencies.

The basis for determining the recommended performance characteristics of the foundation soil was developed from the existing material specifi cations used in NCHRP Report 350 (119). In a round robin test of testing facilities, the dynamic performance of the current soil standard was evaluated. This standard dynamic test, as detailed in Appendix B, Section B5, showed that the existing material specifi cations are accurately represented by a minimum dynamic load (applied with a bogie vehicle or a pendulum) of 7,500 lb (3,400 kg) at defl ections between 5 in. (125 mm) and 20 in. (500 mm) of a standard steel post installation. Each test facility is free to defi ne the soils and installation procedures provided that this dynamic performance criterion is met. For example, the typical steel guardrail post

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driven into a stiff cohesive soil may well exhibit the required dynamic performance and would therefore be an acceptable installation process.

It is important to keep in mind that the parameters associated with the soils and installation procedures should be applied consistently to all installed systems to assure similar foundation performance. These parameters include, but are not limited to native soil, backfi ll soil, compaction, moisture content, and installation confi guration. Since the properties of the native soils may vary at a given test facility, the installation procedure required to meet the minimum dynamic performance may also vary. A recom- mended summary sheet, for inclusion in each test report involving soil-mounted installations, is shown in Figure 3-1.

Once a testing facility has developed an installation procedure that provides suffi cient dynamic capac- ity, it is important to make sure that the installation is not affected by conditions beyond the control of the testing facility. For example, a signifi cant rain may affect the performance of the installed system. To date, these environmental infl uences have been diffi cult, if not impossible, to quantify. Also, the cost of performing dynamic tests to quantify soil performance for each crash test installation is relatively high. Thus, a static test procedure is recommended as a surrogate. After the dynamic performance of a given soil and installation procedure is determined to be acceptable and certified, a static test utilizing the same steel post installation will be performed. The measured static load from this static test will form the basis for evaluation of future test installations. More detailed descriptions of this calibration process are presented in Appendix B, Section B6.

The recommended static test procedure is as follows. During the installation of each test system, two additional standard steel posts will be placed in a convenient location near the test installation where they will be subjected to the same environmental conditions as the installed system. The placement of these posts, as well as all system hardware, should accurately reflect the standard installation method certifi ed by the testing facility.

On the day of crash testing, a static test will be performed on one of these two test posts to determine if outside factors have affected soil strength. The installation is determined to be acceptable if the static resistance of the soil at 5, 10, and 15 in. (125, 250, and 375 mm) of defl ection, as defined in Appendix

B, Section B6, is at least 90 percent of the value determined during certifi cation testing. If the measured soil strength is lower than the required limits, the crash test will have to be postponed until the soil conditions are such that the soil strength is acceptable. The second test post is intended for this situation in which the test has to be postponed and the soil strength re-measured. It is important that each testing agency establishes the relationships between soil strength and various infl uencing factors for the local standard soil in order to know when the soil strength is within the specifi cations.

The recommended reporting of this static test, as well as in-situ and fi ll description based on ASTM D 2487, is shown in Figure 3-2. In addition to reporting acceptable soil strength as indicated by the

static test, detailed descriptions of the test installation, including classifi cation of native and fi ll materi- als, and installation procedures, should be documented. Any deviation or change to the procedures used in the dynamic certifi cation test should be reported. It is recommended that each test report of a full- scale crash test include the documentation shown in Figures 3-1 and 3-2.

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Percent Finer vs. Grain Size of Fill Soil for Dynamic and Static Load Tests



100

90

80

70

60

50

40

30

20

10

0

100 10 1 0.1 0.01

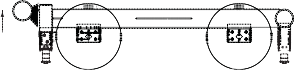
Grain Size, D (mm)

Dynamic Test Fill Soil

Static Load Fill Soil

W6 X 16

Comparison of Load vs. Displacement



14000

12000

10000

8000

6000

4000

2000

0

0 5 10 15 20 25 30 35 40

Displacement (in.)

Load vs. Displacement from Acceleration Data

Load vs. Displacement from Load Cell

Required Load

vs. Displacement

Load vs. Displacement from Static Load Test

**Date .............................................................................................** 4/4/2005

|  |  |  |  |
| --- | --- | --- | --- |
| Dynamic Setup | Post-Test Photo of Post | Static Load Test | Post-Test Photo of Post |
| Percent Finer | | Dia 2 ft  65 in.  103 in.  32 in.  247/8 in.  72 in.  43 in. 40 in.  Dynamic Test/Installation Details | |
| Load (lb) | | Winch or  Hydraulic 32 in. (813 mm)  Cylinder 25 in. (635 mm)  72 in. (1829 mm) 24-in. Diameter  Granular Fill  40 in. (1016 mm) 43 in. (1092 mm)  Static Load Test/Installation Details | |

**Test Facility & Site Location .....................................................** Midwest Roadside Safety Facility (see attached site map)

**In situ soil description (ASTM D 2487) ....................................** Sandy Gravel with silty fi nes

**Fill material description (ASTM D 2487) & sieve**

**analysis ......................................................................................** AASHTO Grade B Soil-Aggregate (see sieve analyses above) **Description of fi ll placement procedure ..................................** 6-in. (152-mm) lifts tamped with a pneumatic compactor **Bogie Weight ..............................................................................** 2108.8 lb (954 kg)

**Impact Velocity ...........................................................................** 19.83 mph (31.9 km/h)

Figure 3-1. Recommended Summary Sheet for Strong Soil Test Results

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Comparison of Static Load Test Results and Required Minimum Load vs. Displacement 

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 6000 |  | | | | | | | |
| 5000 |  |  |  |  |  |  |  |  |
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| 2000 |  |  |  |  |  |  |  |  |
| 1000 |  |  |  |  |  |  |  |  |
| 0 |  |  |  |  |  |  |  |  |
| 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |

D ispla cem e nt (in.)

Load v s . D is plac em ent from Static Load Test

M inim u m Static Load

100

P e rc e n t F in e r v s . G ra in S iz e o f F ill S o il fro m S ta tic Load Test 

G rain S ize, D iam eter (m m )

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| 80 |  |  |  |  |
| 70 |  |  |  |  |
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| 0 |  |  |  |  |
| 100 | 10 | 1.0 | 0.1 | 0.01 |

**Date .............................................................................................** 5/23/2005

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| --- | --- |
| Load (lb) | Static Load Setup |
| Percent Finer | Post-Test Photo of Post |

**Test Facility & Site Location .....................................................** Midwest Roadside Safety Facility (see attached site map)

**In situ soil description (ASTM D 2487) ....................................** Sandy Gravel with silty fi nes

**Fill material description (ASTM D 2487) & sieve**

**analysis ......................................................................................** AASHTO Grade B Soil-Aggregate (see sieve analyses above)

**Description of fi ll placement procedure ..................................** 6-in. (152-mm) lifts tamped with a pneumatic compactor

Figure 3-2. Example of Test Day Static Soil Strength Documentation

Note that the specified soil strength is intended as a minimum value and that higher values are ac- ceptable. However, it should be emphasized that the testing agency should use the same installation procedure used in the standard certifi cation test for all test installations. It is unacceptable to have different installation procedures for different safety hardware evaluation programs. In situations where the native soil varies signifi cantly at a given test facility, the installation methods established for each native soil should have similar dynamic performance. It should be noted that the measured soil resistance is associated with a specifi c combination of in-situ soil, standard soil, compaction condition, and depth and lateral extent of the fi ll material. Variation of any of these factors would be expected to change the soil strength and therefore necessitate a recalibration effort.

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If there is any signifi cant change to the native or fi ll soils, such as a major excavation in an area or a new supplier or source of material, a new dynamic certifi cation test should be conducted. Even with- out any signifi cant changes, it is recommended that the dynamic certifi cation test be performed at least every two years since relatively minor changes in soil constituents can signifi cantly affect soil strength and performance.

* + 1. SPECIAL SOILS

As mentioned above, there are situations in which the feature is likely to be installed in a soil that could be expected to degrade its performance. In such situations, testing in one or more of the following special soils may be appropriate. The following guidelines may be used to evaluate a feature in a weak, saturated, or frozen soil.

***Weak Soil***. It is recommended that the weak soil meet AASHTO standard specifi cation for “Fine Aggregate for Hydraulic Cement Concrete,” AASHTO designation M 6. The soil should be compacted in accordance with Section 304.05 of AASHTO’s *Construction Manual for Highway Construction* (2). The soil should be re-compacted, as necessary, before each test to meet density requirements of the Construction Manual (2). The soil should be well drained at the time of the crash test.

***Saturated Soil***. The “standard soil” and “weak soil” previously described may be used to evaluate the impact performance of a feature under saturated soil conditions. Moisture content of the soil should replicate expected in-service conditions.

***Frozen Soil***. The “standard soil” and “weak soil” described may be used to evaluate impact performance of a feature under frozen soil conditions. The degree to which the soil is frozen, measured in terms of depth and temperature, and its moisture content should replicate expected in-service conditions.

* + 1. EMBEDMENT OF TEST ARTICLE

Within the range of expected in-service conditions, the depth and method of embedment should be those likely to reveal the poorest performance of the test article. This may not be predictable, in which case testing should be done under embedment conditions designed to reveal the worst performance. The method used in embedding the test article should replicate, to the extent possible, the method by which the feature will be embedded in service.

The lateral extent of the fi ll material (if utilized) should be at least that of the minimum lateral extent established during the dynamic certifi cation test. However, it is generally acceptable to utilize a greater lateral extent for the fi ll material if the stiffness of the fi ll material is greater than the native soil. Again, variation in embedment for the purpose of tuning soil performance for a particular full-scale test is

not acceptable. The depth of the structural fi ll (if utilized) should always extend below the installed appurtenance.

A sign support is typically embedded by driving the post or stub directly into the soil, by inserting the support in a drilled hole and then backfi lling the soil, or by placing the support or stub in a concrete footing. Similar methods are used for embedment of a longitudinal barrier post. Most luminaire support

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poles are supported by a concrete footing, and most utility poles are placed in a drilled hole. The soil is then backfi lled.

Some testing agencies have developed universal foundations for testing breakaway devices consist- ing of multiple-use base plates supported on a very rigid concrete footing. While these foundations reduce testing costs, they effectively eliminate soil foundation interactions. They also raise ques- tions about feature-to-foundation interface friction and anchor bolt rigidity. If it cannot be shown that these effects are insignifi cant, the test report should, at a minimum, alert the user agency of potential problems and provide recommendations for foundation systems that will ensure proper breakaway performance of the support.

* + 1. SPECIAL STRUCTURES

Ends of roadside and median barriers must generally be anchored by terminal sections, bridge rails must be connected to a deck, and transitions are often attached to a rigid bridge end or wing wall on the downstream end of the transition. It is preferable that in-service designs of these auxiliary structures be used in the crash test when practical. For example, when testing a roadside barrier, it is preferable that the ends be terminated as they would in service. When this is not practical, special

structures must be constructed. A key requirement of a special end anchorage device for a longitudi- nal barrier is that it must have the capability to resist full tensile loads developed in the rail.

Testing of a bridge rail will, in general, require a special support structure, i.e., a simulated bridge deck. For a non-rigid bridge rail where lateral defl ection is of concern, the structure to which the railing is attached should simulate edge conditions so that the effect of vehicular penetration beyond the edge of the deck can be properly evaluated. Regardless of the rail’s strength, it may be desirable to evaluate structural adequacy of the deck itself for the impact conditions, in which case the deck structure should have the same strength and properties as the in-service structure.

If a universal or generic deck is used in a bridge rail test, it is desirable that impact loads imposed on the deck be measured or computed from measured vehicular response and reported. By so doing, a user agency will have some guidance on how to design a deck that differs from the one used in the test. Procedures that may be used to estimate impact loads from measured vehicular accelerations are presented in Reference 102. For tests of a fl exible-to-a-rigid longitudinal barrier transition, a prototype bridge end structure or wing wall structure must be constructed. Length, strength, and geometry of the

prototype should be suffi cient to approximate the impact response expected of the in-service bridge end or wing wall. Section 3.4.2.1 contains further recommendation on the prototype bridge end.

### TEST ARTICLE

* + 1. GENERAL

The material characteristics of all key elements in the test article that contribute to its structural integrity or impact behavior should be documented in the test report. Physical and chemical material properties can generally be obtained from the supplier providing the test article(s). When mill certi- fi cation test results or other documentation are not available, materials from key elements should be

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sampled, tested, and reported. To ensure that all critical elements are considered, a careful after-test ex- amination of the test article is essential. Materials should be tested independently when a failure occurs.

Material specifi cations such as AASHTO, ASTM, and so forth, should be reported for all key elements. Results of random sample tests should confi rm that stated specifi cations have been met and that key elements in the test article were representative of normal production quality. The testing agency should offer a judgment on the potential effects of marginal materials or materials that signifi cantly exceed minimum specifi cations on the performance of the test article. In addition, specifi ed but unverifi ed prop- erties of all other materials used in the test article should be reported.

The test article should be constructed and erected in a manner representative of in-service installations and should conform to specifi cations and drawings of the manufacturer or designer. To assure uniformi- ty and integrity of structural connections, current American Welding Society specifi cations for highway bridges (6), Aluminum Association specifi cations for aluminum bridges and other highway structures (1), American Institute of Steel Construction bolting procedures (10), and other relevant documents should be used as appropriate. Deviations from fabrication, specifi cation, or erection details should be delineated in the test report.

* + 1. INSTALLATION DETAILS

###### Longitudinal Barriers

For tests examining performance of the length-of-need section, rails or barrier elements should be installed straight and level and then anchored. Horizontally-curved installations, sloped shoulders, superelevation, embankments, ditches, dikes, and curbs should be avoided for general performance tests. Barriers intentionally being tested for ditches, curbs, and roadside slopes should be tested under the relative conditions. The use of any nonstandard features should be documented and reported. As a general rule, length of the test section, including terminals or end anchorage devices, should be at least three times the length in which deformation is predicted, but not less than 75 ft (23 m) for a rigid barrier (i.e., one for which little, if any, lateral displacement is anticipated), 100 ft (30 m) for a semi-rigid barrier (e.g., a metal beam-and-post roadside barrier), and 600 ft (183 m) for a flexible barrier (e.g., cable barrier). For semi-rigid barriers, testing laboratories should use discretion if utilizing system lengths shorter than 175 ft and be able to provide adequate analysis to support the use of the shorter system length. It is recommended that semi-rigid barrier lengths only be tested at lengths less than 175 ft if the laboratory can ensure that there will be minimal contact length and deformed barrier length during the impact, that similar rail and post parts are used in both the body of the barrier system and the attached terminals, and that the main section of the barrier and the terminal sections have equivalent stiffness and dynamic deflection characteristics. Length of the test section should be such that: (1) terminals or end anchorage devices do not significantly influence the dynamic behavior of the barrier; and (2) the ability of the barrier to contain and redirect the test vehicle in the recommended manner can be clearly ascertained. Exceptions to recommended lengths can be made if it can be demonstrated that the installation satisfies these two requirements. Demonstration of an exception to the recommended barrier length requirements should include an analysis of anchor loading, cable or rail extension, and membrane action effects that might reduce lateral deflections. Note that it is desirable to measure anchor loads during testing of flexible (e.g., cable barrier) and semi-rigid barriers to enhance understanding of the transmission of rail tension along these barriers.

When a flexible barrier (e.g., cable barrier) is tested in combination with a roadside slope or median ditch, the length of the sloped terrain (e.g., slope or ditch) should exceed the predicted vehicle contact distance or length of deformed barrier to permit evaluation of vehicle containment, redirection, and stability prior to the vehicle encountering any transition to level terrain. The testing laboratory shall locate the sloped terrain segment within the minimum required 600-ft (183-m) length of barrier. Based on historical cable barrier testing in ditches, a 360 ft (110 m) to 400 ft (122 m) long segment of sloped terrain should provide adequate length to evaluate barrier performance and vehicle behavior. However, the testing laboratory is responsible for determining the length and position of the sloped terrain region within the overall length of barrier system. At the upstream and downstream ends of slope or ditch section, grade transitions may be used to transition the barrier system to level terrain before terminating the barrier ends with an appropriate cable end terminal or end anchorage system.

When evaluating cable barriers installed on slopes or within median ditches, crash test vehicles may become airborne before and/or after impacting the barrier system. When the airborne vehicle returns to the ground, the vehicle-ground contact may involve one or more wheels and possibly other parts of the vehicle. The soil properties and level of compaction in the region of vehicle-ground contact can influence vehicle behavior and vehicle-barrier interaction. To achieve a higher degree of consistency and uniformity in testing, it is recommended that an adequately-sized region of well-compacted, base material (e.g., AASHTO M147 Grade B material (1990)) measuring approximately 6 inches (150 mm) to 12 inches (300 mm) thick, be placed as a lining in the ditch in the predicted location of initial vehicle contact with the sloped terrain through the location of maximum lateral barrier deflection.

Roadside slopes and median ditches will have slope break points defined by the intersection of two different grades at one or more specific locations. For example, the front slope break point is formed by the intersection of level approach terrain with the fill slope. In the real-world, these discrete grade intersection locations (slope break points) will be rounded to some degree rather than be defined by a sharp angle. To account for this field rounding, the front and back slope break points of median ditches and roadside slopes used for testing and evaluation of cable barrier systems may be constructed with radii of 3 ft (0.9 m) to 5 ft (1.5 m).

For a barrier system that is dependent on rail tension to perform properly, e.g., tensioned cable barrier, the barrier system should be tensioned to that specified for a temperature of 100.0ºF (37.8ºC) for testing. This minimizes the effect of varying ambient temperature on the test results of a tensioned barrier system. Furthermore, a cable barrier is encouraged to be tested with both the largest and smallest recommended post spacings. Testing with the largest post spacing allows for assessment of maximum barrier deflection as well as its greatest working width. Testing with the smallest post spacing allows for assessment of vehicle instability. Barrier deflection and working width associated with intermediate post spacings may be estimated from computer simulation or supplemental crash testing.

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A free-standing, unanchored barrier, such as a pre-cast, segmented concrete barrier whose impact performance depends in part on frictional resistance between it and the surface on which it is resting, should be tested on a surface that replicates the type on which it will be placed in service. If it will be placed on more than one surface in service, it should be tested with the surface that is likely to have the most adverse effect on performance, usually the one having the least frictional resistance. The type of surface as well as end anchorages or terminals used should be reported.

The barrier system used for a transition test should be oriented as it would be in service. As a general rule, transitions of most concern are those that serve to connect a less stiff barrier on the upstream side to a stiffer barrier on the downstream side, such as the transition from a flexible roadside or me- dian barrier to a rigid bridge rail. In such cases, length, strength, and geometry of the prototype bridge rail or wing wall should be suffi cient to approximate impact response expected of the in-service bridge rail or wing wall. It is recommended that the length of the prototype bridge rail or wing wall be at least 17 ft (5 m). A minimum of 50 ft (15 m) of the more fl exible barrier is recommended, exclusive of a properly anchored end.

In cases where the transition serves to connect longitudinal barriers with similar lateral stiffness, but with different geometry, a minimum of 50 ft (15 m) is recommended for each of the adjoining barri- ers, exclusive of a properly anchored end.

###### Terminals and Crash Cushions

Reference should be made to Section 2.2.2 for recommendations relative to the manner in which a terminal or crash cushion should be oriented with respect to the vehicular approach direction. When testing terminals, the test article should be erected on level grade. As a rule, a 100-ft (30-m) length-of- need for a semi-rigid barrier (e.g., a metal beam-and-post roadside barrier), and 300 ft (92 m) for a flexible barrier (e.g., cable barrier) should be attached to the terminal and anchored at the downstream end. If the terminal is designed for a specifi c longitudinal barrier, the length-of-need section used in the test should be composed of the specifi c barrier. Exceptions to the recommended length for the length-of-need section are permissible provided the ability of the terminal to stop, contain and redi- rect, or allow controlled penetration of the test vehicle in the recommended manner can be clearly ascertained. As noted in Section 3.4.2.1, cable end terminals and end anchorage systems should be constructed, tested, and evaluated on level terrain unless specifically intended for use on slopes steeper than 10H:1V.

A rigid, non-yielding backup structure should be used to simulate a highway feature (such as a bridge pier, elevated gore, or bridge end) when appropriate. The shape of the backup structure should be selected to represent the worst case condition for each of the recommended tests. For example, a re- directive crash cushion designed to be used in the median should be tested with a rectangular-shaped backup structure with the maximum allowable width for tests involving the vehicle approaching from the crash cushion side of the obstacle. In this way, the risk of a vehicle snagging on the end of the backup structure during Test 36 should be maximized. However, during reverse direction testing, Test 37, a narrower backup structure, such as a concrete safety-shaped barrier should be utilized to maxi- mize the risk of the test vehicle snagging on the end of a cushion’s fender panel system. The crash cushion should be anchored as required by specifi cations or drawings.

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* + - 1. ***Support Structures, Work-Zone Traffi c Control Devices, and Breakaway Utility Poles*** Reference should be made to Section 2.2.4 for recommendations relative to the manner in which a support structure, a work-zone traffi c control device, or a breakaway utility pole should be oriented with respect to the vehicular approach direction. Testing should verify breakaway or yielding features designed to function identically when impacted from specifi c directions, such as a breakaway base de- signed for front or rear impacts, or those features designed to function identically when impacted from any direction, e.g., a breakaway base designed for omni-directional impacts.

Supports should be fully equipped with full-height structures, including signs, mailboxes, call boxes, and mast arms for luminaires. For tests of a luminaire support, it is preferable that an actual luminaire be used rather than a substitute equivalent weight as has often been used in the past. Tests have shown the lumi- naire/ballast can break loose during impact and consequently may present a hazard to other motorists or to occupants of the impacting vehicle. A full-length utility pole should also be used together with associ- ated cross-arm(s), down guy wires, and conductors (lines). For road closure gates, the typical length of the gate arm anticipated to be used in the fi eld should be installed. Road closure gates are typically tested with the gate arm in the up position. Nevertheless, an assessment should be made as to whether the test is more critical with the gate arm in the up or down position, and test accordingly.

The test may involve multiple supports such as multiple mailbox supports or multiple, closely spaced drums in a work zone. Orientation and spacing of these supports should be representative of in- service conditions.

Occasionally, a work-zone traffi c control device, such as a barricade or a plastic drum, will overturn or will intentionally be placed in an overturned position along the highway shoulder in a work zone.

Alternatively, a barricade may typically be placed so that its panels are parallel rather than perpendicu- lar to traffi c. Devices placed in these types of “out-of-service” orientations may pose a greater risk to an errant motorist than the upright or normal position. If there is a reasonable expectation that a device will be commonly found adjacent to traffi c in an “out-of-service” orientation and this orientation poses a greater risk to the motorist than in the normal position, it should be tested in the alternate position. If it cannot be determined which position is more critical, tests in both the normal and “out-of-service” orientations should be conducted.

For tests of a sign support system, the area of the sign panel should approximate the largest panel that would normally be used on the support system. Sign panel material should be the same as that normally used or to be used on the support system. If panels of different materials, such as plywood, sheet met- als, or fi ber reinforced plastics, are used with the support system, the test should be conducted with the material expected to pose the greater risk to occupants of the impacting vehicle. If it cannot be deter- mined which material is most critical, it is recommended that the test be conducted with the panel of greatest mass. The aspect ratio of the sign (height-to-width ratio) should be typical of the largest panel that would normally be used on the support system. Mounting height of the sign panel (distance from ground to bottom of panel) should be the minimum height the panel would normally be mounted in service unless it can be shown that a higher mounting height would pose a greater risk to occupants of the impacting vehicle.

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For tests of a mailbox support system with a single mailbox, the mailbox should be the largest that would normally be used on the support system. For tests of a mailbox support system with multiple mailboxes, the number and size of mailboxes should be the largest that would normally be used on the support system.

###### Truck-Mounted and Trailer-Mounted Attenuators (TMAs)

Truck-mounted and trailer-mounted attenuators are to be subjected to the same test matrix. For all of the recommended crash tests, the supporting truck should be placed on a clean, dry, paved surface. Asphalt or portland cement concrete surfaces are recommended. Conditions such as a polished sur- face or a bleeding asphalt surface that could lower available tire-pavement friction should be avoided. The supporting truck should be in second gear with the parking brake set. Front tires should be centered with no steering angle; that is, they should point straight ahead and not be turned to the left or to the right. When appropriate, an infi nitely heavy support truck can be simulated by blocking the support truck against forward and lateral motion.

* + 1. TEST INSTALLATION DOCUMENTATION

The following sections present a summary of the critical test installation parameters that should be measured and included in the test report. Note that the following recommendations should be considered a minimum level of reporting. Testing agencies are strongly encouraged to provide documentation of any parameter deemed important to the test results.

###### Longitudinal Barriers and Longitudinal Channelizers

Barrier geometrics that should be reported include: mounting heights; lengths of rail elements; length of test installation; lateral placement of barrier relative to embankment or ditch; length and longitudinal position of sloped terrain within the overall test installation; alignment and orientation of the barrier relative to vehicular approach; and targeted point of impact relative to the end of the barrier. Other parameters to be reported include: barrier tension for cable barriers; type and location of temperature compensators; cable connectors, splices, and fittings; and the layout and configuration of sections on the slope or within the ditch with compacted base material. The manner in which the barrier is terminated, anchored, or both should also be presented. All connection details should be described, including pre-cast concrete barrier joints; nuts, bolts, and washers used to anchor a bridge railing post to a bridge deck or abutment; and all hardware used to connect rail elements or attach them to a supporting post. Bolt torques or tightening procedures should also be identified. Detailed construction drawings sufficient for complete reconstruction of the as-tested system should also be reported.

Reported foundation details should include the manner in which the barrier was supported, includ- ing description of the structural details of the attachments between the barrier and its foundation or associated bridge deck or pavement. Details of any simulated wing wall and or bridge end should also be reported for tests involving approach guardrail transitions. Embedment procedures and depths for posts and other components should also be adequately described. The type of surface and the friction- al characteristics of pavements placed under free-standing temporary barriers should also be reported.

As described in Chapter 6, specifi cations for the as-tested materials should be reported for all impor- tant components and for associated hardware (fasteners, nuts, washers, backup plates, etc.) used in the barrier. Actual sizes and physical and chemical properties should be reported. Often this information is available on mill certifi cation documents that can be obtained from the supplier.

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###### Terminals and Crash Cushions

Documentation of crash cushion geometrics should include mounting heights of rail elements; post spacing; length of test installation, including backup structure if used; position of energy-absorbing ele- ments; and targeted point of impact relative to the end of the article. The manner in which the ends of the device were anchored, including cable anchors and special backup structures, should also be report- ed. Detailed construction drawings suffi cient for complete reconstruction of the tested system should be included.

The report should also include the manner in which the device was supported, including embedment procedures for posts embedded in soil (driven, drilled and backfi lled, placed in driven inserts, concrete footing, etc.); description of the soil and soil properties as described in Section 3.3.1; and description of the surface on which a free-standing device was resting, including the type and condition of pavement, when relevant.

Specifi cations for the as-tested materials should be reported for all important components and for asso- ciated attachment hardware (fasteners, nuts, washers, backup plates, etc.) used in the test article. Actual sizes and physical and chemical properties should be reported. Often this information is available on mill certifi cation documents that can be obtained from the supplier.

* + - 1. ***Support Structures, Work-Zone Traffi c Control Devices, and Breakaway Utility Poles*** Geometric data to be documented for these devices includes: height and width of sign panel, mounting height of sign panel above grade, spacing of multiple-post sign supports, mass of all breakaway sup- port components and utility pole segments, targeted impact point and direction of vehicular approach relative to test article(s), orientation of breakaway mechanism relative to vehicular approach, position of fasteners used in mounting sign panel to wind beams (if used) and in connecting wind beams (or panel) to support posts, dimensions of traffi c control devices, mounting height and connection details of lights used on traffi c control devices, location of slip planes and hinge points relative to the ground for breakaway supports, height of luminaire pole and luminaire, dimension and orientation of cantilevered luminaire support arm, height of pole and cross-arm for utility pole, and size and location of all ele- ments mounted on call-box support or mailbox support. Bolt torques or tightening procedures should also be identifi ed. Detailed construction drawings suffi cient for complete reconstruction of the tested system should be included.

Foundation data to be reported include: embedment procedures for posts or poles embedded in soil (driven, drilled and backfi lled, placed in driven inserts, concrete footings, etc.); embedment depth of test article; description of soil and its properties if relevant; and description of the surface on which a free- standing device was resting, including the type and condition of pavement, when relevant.

Specifi cations for the as-tested materials should be reported for all important components and for as- sociated attachment hardware (fasteners, nuts, washers, back-up plates, etc.) used in the test article. Actual sizes and physical and chemical properties should be reported. Often this information is avail- able on mill certifi cation documents that can be obtained from the supplier. Dynamic impact properties of materials that are designed to fracture or tear, such as brittle sign supports and frangible bases, should also be reported.

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###### Truck-Mounted and Trailer-Mounted Attenuators (TMAs)

Truck-mounted and trailer-mounted attenuators are subjected to the same documentation procedures. Geometric data to be reported include length, width, and height of attenuator; height of attenuator with respect to the ground; length of supporting truck; mass of TMA and supporting hardware; detailed drawings of mounting hardware; and targeted impact point on TMA. Descriptions of the test surface, in- cluding type (asphalt or portland cement concrete), fi nish, and state of wear, should be reported as well.

Specifi cations for the as-tested attenuator, other structural elements, associated hardware (fasteners, nuts, washers, backup plates, etc.) used in the test article, and sizes of hardware elements should be reported.

The make, model, mass, and ballasting of the supporting truck should be reported. For Tests 50, 51, and 52, the maximum allowable weight of the support truck should be used in the testing while the minimum allowable weight should be used for Test 53. The support truck may be braced against for- ward and lateral motion if there is no upper limit on the weight of the support truck that can be used with the TMA. The manner in which the supporting truck is braked (i.e., parking brake set, engine in second gear, etc.) or blocked against forward motion should also be described in detail.

* + 1. TEST INSTALLATION DISPOSAL

Testing agencies should keep components of the test installation in storage until after the FHWA eligibility process has been completed in case questions are raised regarding the test installation. The components to be kept in storage should include components that are damaged and key structural components related to the impact performance of the test article, such as the anchor cable assembly of a barrier system fora redirection impact. The stored components should, to the extent possible, be kept from adverse environmental conditions that could significantly change their properties.