B. Roadside Features Test Matrices

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Full-scale testing of roadside features with highway vehicles, or even with surrogate vehicles (bogies), is expensive. The expense can be viewed from two perspectives. First, we should consider how many times the feature will be replicated in the field. A rather large cash outlay for testing a feature that is to be built many times may in fact not be truly expensive. On the other hand, the same expenditure on testing a one-time-use feature would probably be exorbitant.

The other way to view the cost of full-scale vehicular testing is to ask how much more is likely to be revealed than could confidently be predicted through other, less expensive means. To run a test where the outcome is a near certainty is likely to be wasteful. And, a test to simply determine strength or structural integrity that could just as well be determined through inexpensive analysis or static testing would also be wasteful. Of course, these observations are based on the assumption that there is a rather sizeable body of experience upon which to draw in assessing the risk of missing some flaw in a feature that might only be revealed through full-scale vehicular testing.

Not thoroughly evaluating the test results also has the effect of increasing the cost of full-scale testing because the omission may lead to testing that would not have been needed if a fuller understanding of previous results had been obtained.

In essence, we should be sparing in our demands for full-scale vehicular testing of roadside features, giving consideration to how extensively the results might be applied, what we already know, and what alternative methods are available for evaluating the feature. Additionally, we should learn as much as we can from each test run, with the hope of applying the knowledge gained to other situations.

Ultimately, testing the interaction between vehicles and roadside features should lead to improved roadside safety, and desirably, to more cost effective roadside safety designs. To achieve both of these results, the testing that is undertaken must have relevance to service conditions, and the criteria used to evaluate the test results must take into account both human tolerances to impacts and what is technologically practicable.

In order to be relevant, testing must be conducted with vehicles and with approach speeds and angles that are representative of the upper severity limit of a large portion of accident conditions experienced in the field.

In my view, the current NCHRP Report 230 tests for longitudinal barriers miss the mark a little in this regard. The 4,500-pound automobile, 60-mph, 25-degree test may be a considerably more severe test than automobile traffic is likely to exert on field installations. First of all, that weight automobile is disappearing from our highways. Additionally, the speed-angle combination is unlikely. However, these factors alone do not mean the test is irrelevant. It might be a test that could be used to assess the likely performance of a barrier when struck by heavier vehicles, say pickups and vans, or even larger trucks or buses under less severe impact conditions. The problem here is that these other vehicles have larger front wheels, different and higher bumpers, and higher centers of gravity. Thus, the 4,500-pound automobile test is not likely to be a good predictor of a barrier's performance with these other vehicles.

I would also point out that the bus tests that are in NCHRP Report 230 are not representative of vehicles that account for a significant portion of the heavy vehicle barrier accidents, namely, truck semi-trailers. Nor are the intercity bus tests likely to give much insight on how a barrier and semi-trailers will interact. So, if your goal is to discover how likely a barrier is to contain semi-trailers, you probably need other tests.

In the designing of the test matrix (Figure 2) which is from the proposed AASHTO Guide Specifications for Bridge Railings, there was a very deliberate effort to match the tests to what were perceived as the barrier performance requirements for various highway conditions. Admittedly, there was some compromise and rationalization to avoid too radical a departure from past practices. Nevertheless, I believe it is a good fit with reality. The one place where the relevance of the matrix might be challenged is the 18,000-pound truck test. That truck does not represent a significant problem on our highways. It was selected for its front-end similarity to semi-trailers, its availability, its relatively low cost, and its relative ease of handling in crash tests. It is believed to be a stand-in for an empty semi-trailer.

In order to accurately compare the results between tests, we need tighter controls on how tests are run. Note that the guide specifications test matrix goes a little way in that direction. However, for feature acceptance testing we need much more detailed descriptions of the vehicles to be used for testing. Tire sizes, wheel designs, suspension systems, wheel set backs, wheel bases, and bumpers (in short, the basic geometry, weight and structure of the test vehicles) need to be rather tightly specified if we are to accurately determine the performance differences between various feature designs.

For example, in a recent series of tests, three nearly identical tests were run on one barrier with similar, satisfactory results in each instance. A fourth test against a slightly different barrier gave significantly less desirable

PERFORMANCE LEVELS		TEST SPEEDS -- mph [1,2]			
		TEST VEHICLE DESCRIPTIONS AND IMPACT ANGLES			
		Small Automobile W = 1.8 Kips A = 5.4' ±0.1' B = 5.5' H_{cg} = 20" ±1" θ = 20 deg.	Pickup Truck W = 5.4 Kips A = 8.5' ±0.1' B = 6.5' H_{cg} = 27" ±1" θ = 20 deg.	Medium Single-Unit Truck W = 18.0 Kips A = 12.8' ±0.2' B = 7.5' H_{cg} = 49" ±1" θ = 15 deg.	Van-Type Tractor-Trailer [4] W = 50.0 Kips A = 12.5' ±0.5' B = 8.0' H_{cg} = See Note 4 R = 0.61 ±0.01 θ = 15 deg.
PL-1		50	45		
PL-2		60	60	50	
PL-3		60	60		50
CRASH TEST EVALUATION CRITERIA [3]	Required	a,b,c,d,g	a,b,c,d	a,b,c	a,b,c
	Desirable [5]	e,f,h	e,f,g,h	d,e,f,h	d,e,f,h

Notes:

1. Except as noted, all full-scale tests shall be conducted and reported in accordance with the requirements in NCHRP Report No. 230. In addition, the maximum loads that can be transmitted from the bridge railing to the bridge deck are to be determined from static force measurements or ultimate strength analysis and reported.

2. Permissible tolerances on the test speeds and angles are as follows:

   Speed -1.0 mph +2.5 mph
   Angle -1.0 deg. +2.5 deg.

   Tests that indicate acceptable railing performance but that exceed the allowable upper tolerances will be accepted.

3. Criteria for evaluating bridge railing crash test results are as follows:

   a. The test article shall contain the vehicle; neither the vehicle nor its cargo shall penetrate or go over the installation. Controlled lateral deflection of the test article is acceptable.

   b. Detached elements, fragments, or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.

   c. Integrity of the passenger compartment must be maintained with no intrusion and essentially no deformation.

   d. The vehicle shall remain upright during and after collision.

Table G2.7.1.3A Bridge Railing Performance Levels and Crash Test Criteria

Figure 2

Notes (cont.):

e. The test article shall smoothly redirect the vehicle. A redirection is deemed smooth if the rear of the vehicle or, in the case of a combination vehicle, the rear of the tractor or trailer does not yaw more than 5 degrees away from the railing from time of impact until the vehicle separates from the railing.

f. The smoothness of the vehicle-railing interaction is further assessed by the effective coefficient of friction μ:

μ	Assessment
0 - 0.25	Good
0.26 - 0.35	Fair
> 0.35	Marginal

where $\mu = (\cos\theta - V_p / V) / \sin\theta$

g. The impact velocity of a hypothetical front-seat passenger against the vehicle interior, calculated from vehicle accelerations and 2.0-ft. longitudinal and 1.0-ft. lateral displacements, shall be less than:

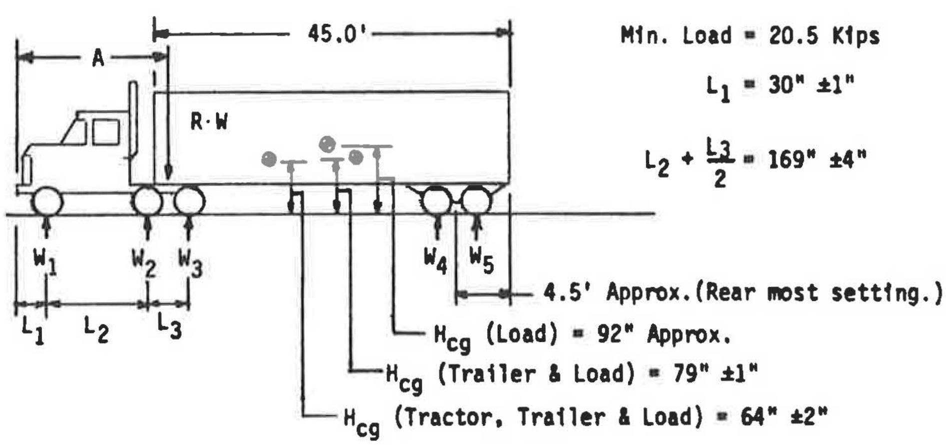
Occupant Impact Velocity - fps	
Longitudinal	Lateral
30	25

and the vehicle highest 10-ms average accelerations subsequent to the instant of hypothetical passenger impact should be less than:

Occupant Ridedown Accelerations - g's	
Longitudinal	Lateral
15	15

h. Vehicle exit angle from the barrier shall not be more than 12 degrees. Within 100 ft. plus the length of the test vehicle from the point of initial impact with the railing, the railing side of the vehicle shall move no more than 20-ft. from the line of the traffic face of the railing. The brakes shall not be applied until the vehicle has traveled at least 100-ft. plus the length of the test vehicle from the point of initial impact.

4. Values A and R are estimated values describing the test vehicle and its loading. Values of A and R are described in the figure below and calculated as follows:



Min. Load = 20.5 Kips

L_1 = 30" ±1"

$L_2 + \frac{L_3}{2}$ = 169" ±4"

$$A = L_1 + \frac{W_2 L_2 + W_3 (L_2 + L_3)}{W_1 + W_2 + W_3}$$

$$R = \frac{W_1 + W_2 + W_3}{W}$$

$$W = W_1 + W_2 + W_3 + W_4 + W_5$$

= total vehicle weight.

5. Test articles that do not meet the desirable evaluation criteria shall have their performance evaluated by a designated authority that will decide whether the test article is likely to meet its intended use requirements.

Table G2.7.1.3A (cont.) Bridge Railing Performance Levels and Crash Test Criteria

Figure 2 (continued)

results. But the truck used in the fourth test was not the same make as those used in the first three tests. Thus, we are left with the question of whether the change in test vehicle or the change in the barrier caused the change in results.

In regard to occupant risk, a free falling object, starting from rest, will reach a speed of 40 fps after falling 24.9 feet. NCHRP Report 230 describes a 40-fps occupant impact as not life threatening. I do not believe this. The maximum design delta V of 30 fps recommended in NCHRP 230 correlates to a fall of 15 feet--probably survivable. One would undoubtedly voluntarily accept such a fall if the alternative were death, but there is no guarantee that the fall would not result in serious injury, or even death.

The purpose of NCHRP Report 230 was not to serve as guidance for the acceptance of roadside features. However, it has become the basic document on the subject. In the next writing of NCHRP Report 230 we had better recognize this fact and give much more thought to the recommended design (acceptance) delta V's and do more to explain what they mean. Many people do not seem to recognize that relatively low speed impacts have the potential of being injury producing and have said, "If we can design crash cushions for 30 fps, why not sign and luminaire supports?" The answer is that there are vast technological and cost differences in achieving higher levels of performance from the differing types of features.

As a final thought on NCHRP Report 230, I would like to say that I believe it was an excellent work when it was produced. However, I have come to view it as a backward looking document. I would hope the next version of NCHRP Report 230 would look to the future, provide more guidance for designing test procedures for features or conditions we have not yet encountered. There should be a built-in test design philosophy. And I will reject that philosophy, out of hand, if it contains the word linkage. Linkage is a term sometimes used in arguing to maintain a given test over a superior alternative test. The advocates of linkage believe that the link with historic testing justifies its use.