WHAT'S WRONG WITH ROADSIDE DESIGN?

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INTRODUCTION

The Center for Auto Safety is an independent, nonprofit, public interest organization located in Washington, D.C. We work to promote highway, vehicle, and mobile home safety through research and publications and through stimulating debate on issues affecting the safety of the traveling public. The Highway Safety Project at the center has focused its attention on the roadside design, construction, and maintenance practices of the highway program. The failure by highway agencies to incorporate safe design into our nation's newest highways is well documented in the project's study: "The Yellow Book Road: The Failure of America's Roadside Safety Program."  

Our researchers have inspected and photographed streets and highways in some 22 states; and the problem of roadside obstacles, unsafe highway design, and dangerous construction practices appears to a greater or lesser degree in every one of them. It is not our intention today to focus on individual states but rather to illustrate a nationwide problem: the recurring failure to implement safety practices which are well-known and have been agreed upon and recommended as policy.

In many states and localities, new construction or major no-safety related reconstruction continues to be favored to the detriment of safety improvement work. Neither the Federal Highway Administration nor most state highway departments have undertaken the fundamental administrative reforms necessary to ensure that new roads are designed and constructed to safe design standards.  

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1 In 1973, under a grant from the State Farm Companies Foundation, the Highway Safety Project began an 18-month study of the Federal-aid Highway Program. The report from that study, The Yellow Book Road: The Failure of America's Roadside Safety Program, is available for $12.50 from the center.

2 The author wishes to acknowledge similar work done in this same area by other staff members at the Center for Auto Safety. For example, see Art Delibert's speech "What's Wrong with Highway Design?" presented before the November 1976 meeting of the AASHTO Design Committee.
It is not our purpose to provide a compact course in proper roadside design. The techniques and devices described today have all appeared in the literature and ought to be familiar to an audience versed in highway design. Instead, I would like to demonstrate through a series of illustrations some of the unsafe practices found on new and old highways, both local and interstate, in the hope that you, the professionals who design, construct, and maintain our highways, will do something to correct these dangerous problems.

FORGIVING ROADSIDES

First we have a couple of examples of highway design demonstrating a coordinated effort to provide a forgiving roadside. Figure 1 shows a highway with a clear recovery area, free of physical obstructions. Note:

—pavement markings are well maintained;
—the sign support is of a breakaway design and located well off the roadway;
—there is a full width shoulder with a contrasting color and texture;
—slopes in both the median and roadside are flattened;

Figure 1.

trees and landscaping are located at least 30 feet off the road;
and drainage facilities have been made flush with the ground.

Deep cuts and high fills in this mountainous region make a continuous recovery area impossible (Figure 2). The only feasible solution was to provide a positive protective barrier system. Because the area is often foggy or covered by low clouds, proper delineation of the roadway is of paramount importance. Note:

—continuous delineation is provided along both sides of the highway. The square markers are kept clean to retain their visibility.
—light sensors have been embedded in the pavement to provide lane delineation under inclement weather and at night. Again, wide shoulders of a contrasting color and texture have been provided.

Unfortunately, we have encountered very few miles of the safe design just illustrated. In the thousands of miles of highway that we have inspected, fixed object hazards, dangerous work zones, improperly installed guardrail, and confusing signing have been the rule rather than the exception.

FIXED OBJECTS ON ROADSIDES

Exactly what are fixed objects that make our streets and highways so dangerous? Drainage structures, such as this culvert (Figure 3), located adjacent to the road can be extremely hazardous. We found this one and hundreds of other culverts of various shapes and sizes on an interstate that has been open to traffic for less than three years. These hazardous structures could have been avoided by using channels and inlets that offer little or no obstructions.

As demonstrated by Figure 4, a flush inlet design was used. Unfortunately, the highway department created another obstruction by placing this short section of safety shape directly in front of the inlet.

Figure 2.
Evidently it is being used to prevent backsplash, however, a much safer solution could have been found.

To minimize the hazards presented by luminaire supports and utility poles, they should be placed well behind existing guardrail. If the support is exposed to traffic, breakaway or frangible supports should be used. As you can see from this photo (Figure 5), the light support could have easily been located behind the existing guardrail.

This next example (Figure 6), shows an enormous sign located just in advance of an overpass. The concrete foundation and the massive support system present an unnecessary hazard. Some money could have been saved and the hazard eliminated by mounting the sign on the overpass, as recommended by the "Yellow Book".

Unprotected bridge columns are common on new and old roads alike. These (Figure 7) are particularly dangerous since the overpass
is located on a curve, and there is no illumination or reflectorization delineating the obstruction. If elimination of the columns is impossible, the use of a concrete safety shape would help to reduce the hazard.

Curbs such as this one (Figure 8), should not be used on high speed facilities as they do not adequately prevent a vehicle from leaving the roadway and, when struck, curbs can cause the driver to lose control. We found this curb and several others like it on a brand new highway. At the low end, the curb is about 13 in. high.

Confusing designs such as this median crossover (Figure 9), could lead the driver off the travelled way. The pavement markings, especially if the yellow edge lines are still visible, could lead right into this nonreflectorized fixed object—the guardrail.

Apparently these crossovers were found to be unnecessary or dangerous and have been closed. The hazards, however, remain. In addition to the safety hazard created by the guardrail closure, there
is a drop-off of at least 24 in. One highway department went to a
tremendous expense to create these hazards—located at approximately
one mile intervals—on this new section of interstate. Complete re-
moval of the crossover would improve the safety and aesthetics of the
highway and eliminate the potential costs of guardrail and delineator
installation and maintenance expenses.

Gores are especially hazardous because of the numerous erratic
maneuvers made by drivers in these areas. Sign supports, blunt-end
guardrail, and other obstructions must be kept out of the gore. Since
a high percentage of the run-off-the-road accidents occur in this area,
it is essential that a clear traversable recovery area be provided. This
luminaire support placed in this exposed position creates an unneces-
sary hazard. A better design would have been to place the support
slightly further back behind the guardrail (Figure 10).

Unprotected rock cuts close to the travelled way always present
a formidable hazard. This one is especially dangerous since it is lo-
cated adjacent to the gore. When it is impossible to remove the rock
itself, the concrete safety shape used along the rock has had excellent
results (Figure 11).

Careful attention to the way traffic is handled through construction
and maintenance zones can pay tremendous dividends in increased
safety. Work zones today are so unnecessarily hazardous that drama-
tic benefits can be achieved if highway agencies and personnel increase
efforts to advance motorist and worker safety.4 Unobliterated pave-

Figure 10.

4 For additional information, see the Center for Auto Safety, Highway
Safety Project, “Comments on FHWA’s Advance Notice of Proposed Rule-
making on Construction Zone Safety,” FHWA Docket #76-14, November 22,
1976.
ment markings often lead the motorist directly into barricades. Adding to the confusion, the pavement used on the detour is often of a different color and texture than that of the main roadway.

TRAFFIC CONTROL DEVICES

Many times we have found that traffic control devices are being used to alert only one direction of traffic when in reality the devices are affecting both directions. These barrels (Figure 12), with panels are an example of just that. These are being used to close a lane to oncoming traffic. At night, these unreflectorized, unlit barrels pose a substantial hazard that cannot be easily seen by drivers coming in the opposite direction.

Unmarked shadow vehicles pose another potential hazard (Figure 13). The truck carrying the arrow board cannot be seen by a driver traveling in a small vehicle behind this slow moving or stopped maintenance truck.

GUARDRAIL PROBLEMS

The improper installation of guardrail is one of the most prevalent hazards found along our roads. Recall from FHWA’s Handbook of Highway Safety Design and Operating Practices, the so-called “Green Book,” the following:

*When a hazardous roadside feature or appurtenance cannot be removed, relocated, or redesignated to eliminate the hazard, guardrail should be used to redirect an errant vehicle away from the hazard. The use of guardrails should be considered early in the design process when the potential exists for altering the design to eliminate guardrail need.*

Guardrail itself is a hazard and should not be used unless absolutely necessary. For this reason, it has been established FHWA policy for 10 years (see IM 21-6-66, August 1, 1966) that complete elimination of a roadside obstacle is greatly preferred over mere protection of it by a guardrail. Since this (Figure 14) is relatively flat terrain, a gently sloped recovery area could have been provided for a minimal cost and for an increase in safety benefits. The fixed object hazard created by the sign can be eliminated by either removing the possibly unnecessary sign or by placing it off the road on breakaway supports.

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Frequently, the cost of earthwork is offset by savings in maintenance and in the elimination of the unnecessary guardrail. If for some reason the guardrail was found to be necessary, it should always be carried beyond the point of theoretical need to allow it to function properly. In this case, a car sliding along the guardrail would probably deform the rail and be directed toward the sign post. The installation of short intermittent lengths of guardrail pose the additional hazard of the exposed rail end.

This is yet another example (Figure 15) of intermittent guardrail installation. In this state, the guardrail was stopped at the beginning of each bridge deck and then restarted on the bridge proper, thereby creating the unnecessary hazard of exposed guardrail ends. We won't go into the danger created by the half-painted barrels.

There are numerous hazards present in this next illustration (Figure 16). The guardrail section is much too short to prevent an out-of-control vehicle from hitting the bridge columns nor does it give any protection to the "Emergency Stopping Only" sign. The blunt end of the guardrail itself presents a formidable hazard. Another fixed object is located in the gore—an "exit" sign on nonbreakaway supports. The only breakaway sign in this entire group is the 25 mph sign; it is the only element that is actually being protected by this guardrail.

There are many examples of guardrail set up in a construction site to protect the workers, bridge columns, and equipment. Unfortunately, much of the safety benefit is lost by the careless storage of equipment in front of the guardrail.

Nonreflectorized, timber barricades are filling in this break in the guardrail (Figure 17). Crash tests and experience have confirmed that timber barricades fail to prevent penetration of vehicles and do not adequately redirect vehicles when struck. Certainly these devices are no substitute for a positive barrier system. FHWA Notice N5160.27, issued February 2, 1977, forbids the use of timber barricades as a positive barrier system on roads with operating speeds of over 20 mph. Nevertheless, several states are continuing to use these dangerous devices where a positive barrier system is needed.

This is another example (Figure 18) of a make-shift device used where a positive barrier is needed. A few feet beyond this, there is a 50 ft drop-off to the roadway below. Take a closer look at some of the details that go into safe guardrail installation.

A diagram in the FHWA "Green Book" illustrates the three elements necessary to effect a proper transition from a metal-beam guardrail to a concrete parapet wall:
Figure 18.

1. The rail must be bolted to the wall to provide adequate tension;
2. The rail should be blocked out from the leading edge of the wall to prevent a vehicle from snagging on that edge;
3. The post spacing should be reduced on the last six to eight posts in advance of the wall to provide a transition from the very flexible guardrail to the inflexible concrete wall.

As can be demonstrated by this next group of illustrations, these three elements are often neglected. The guardrail and the bridge parapet have been treated here as completely independent elements. There is no connection between the two (Figure 19).

Figure 19.
In this case, the guardrail leading into the bridge has been installed behind the parapet. In effect, the rail would guide an out-of-control vehicle directly into the concrete wall (Figure 20). In this instance, there has been no reduction in the post spacing. This does not provide the transition necessary to prevent pocketing between the guardrail and the parapet (Figure 21).

Here (Figure 22) the guardrail has been completely omitted. On this particular construction site, we found the guardrail had been torn out on all bridge approaches, leaving the “elephant traps” and bridge parapets unprotected. This condition was allowed to remain in this dangerous state for several months.

Now let’s look at a couple of examples of guardrail at the run-off end of the bridge. Again, the guardrail should be bolted to the parapet wall to facilitate a smooth transition (Figure 23). In this example, the guardrail to bridge connection has been accomplished rather well; however, two posts were dropped over the drainage area creating a condition where possible pocketing can occur.

Unfortunately, many of our bridge to guardrail connections are inadequate. An out-of-control vehicle, if indeed restrained by this railing (Figure 24), would be guided into the concrete parapet at the end of the bridge and then possibly into the blunt end of the guardrail.
In this next photo (Figure 25), there are a couple of added hazards. A nonbreakaway luminaire support and a culvert are located between the bridge parapet and the blunt end of the guardrail.
Blocked-out W-beam guardrail on steel posts can deflect up to 4 ft in a severe crash. For this reason safety experts emphasize that there must be at least 4 ft between guardrail and the obstruction from which it is intended to protect the motorist; otherwise, a vehicle striking the guardrail may impact the hazard despite its presence.

In this example (Figure 26), the guardrail is abutting the bridge column and gives no room for any deflection. In a crash, the guardrail would probably not prevent an errant vehicle from striking the column. A better solution would have been to design the bridge without the columns, or, if that was impossible, to use a concrete safety shape.

In Figure 27, the post spacing was reduced before the bridge column on the right. This will strengthen the rail, lessen deflection, and help prevent possible pocketing. Unfortunately, this reduced spacing was not continued beyond the first column. Instead, only one post was used. A vehicle crashing at a point beyond the first column could easily be guided into this second column.

Figure 24.

Figure 25.
Let's take a closer look at that post. On inspection (Figure 28), we find that the post has not been connected to the rail—weakening this section even further.

Experience (Figure 29) with the blocked-out W-section beam guard-rail indicates a need for a back-up plate—a short piece of rail, about one foot in length—placed at the nonspliced post connections to reduce the possibility of shear failure of the rail element at the post. Most installations we've examined, however, omit this important back-up plate (Figure 30).

Another often omitted piece of hardware is the washer under the mounting bolt. The washer minimizes the possibility of the bolt head pulling through the rail element. In this case, not only was the washer omitted, but the bolt as well (Figure 31).
The omission of back-up plates, bolts, and washers are not the only ways to weaken guardrail. Guardrail that has been improperly drilled or used for the wrong purpose can be substantially weakened (Figure 32). In this case, this section of guardrail was factory drilled for use.

Figure 28.

Figure 29.
at a splice section, not for a connection to the parapet. As you can see, the guardrail has begun to split where the extra holes were drilled.

It appears from the rusting around the edges that this section of guardrail was drilled out on the site (Figure 33). It apparently was used in a situation similar to the one illustrated in the last figure but was removed and is being reused here at a splice. Some splitting has also occurred on this section.
Guardrail height varies considerably. The "Green Book" recommends a minimum of 27 in.; however, much of what is out there on the highway is substantially lower.

We observed several variations based on this theme (Figure 34). Located usually at a drainage structure, the post was set back and then blocked out until it met the rail. We haven't come across any test data or research that supports this detail. Our guess is that a vehicle
striking the rail close to this position of the guardrail would cause the post to pivot and cause possible pocketing.

Guardrail and railings that have been struck are ineffective or substantially weakened. In order to retain their effectiveness, any damage must be repaired immediately. In this example (Figure 35), the rail has been left in this condition for quite some time.

IMPACT ATTENUATORS

Maintenance and repair of other devices out on our highways of critical importance. This impact attenuator (Figure 36) performed its function well by providing protection for this bridge column. In the condition it's in now, though, it provides no protection. Repair or replacement of damaged devices should occur as expeditiously as possible.
Equally important as maintenance and repair is correct usage of a device. The use of impact attenuators to close this crossover is not only expensive but also creates additional roadside obstacles (Figure 37).

NONCONFORMING AND CONFUSING SIGNS

In our travels, we have come across a variety of nonconforming and confusing signs. I would like to share a few of them with you in the hope that the next time we visit your state, we won't see these or any other signs that are just as bad.

This sign is to the point—"Move Left" (Figure 38). However, there are standard signs outlined in the MUTCD that should be used instead. Double arrows—does this mean converge on the center line (Figure 39)? We never did find out exactly why that configuration was being used.

The so-called "Silent Sam" (Figure 40) does not take the place of a flagperson. It not only adds an unnecessary fixed object hazard to the work site, but also diverts the driver's attention away from the highway.

Figure 36.

Figure 37.
This last example (Figure 41) is from downtown Plains, Georgia. Even the traffic control devices used in the President's home town do not conform to the Manual on Uniform Traffic Control Devices.

CONCLUSION

As one of our researchers so cogently pointed out in a recent article:

... design researchers have been working for years creating and refining such roadside safety devices as sign and light poles that gently break away when struck, instead of rigidly resisting the crashing car; guardrail approach end designs which flare away from the road and are buried in side embankment, instead of bluntly spearing right through an oncoming car which has slipped a few inches off the road; crash cushions of assorted types that can be put in front of deadly objects to safely absorb the energy of an impacting vehicle; improved barrier and bridge parapet designs which can safely restrain both heavy trucks and lightweight cars without either slamming the vehicles to a sudden stop or bouncing them back across traffic.

But highway officials have been very slow to incorporate these and other improved design principles in their construction and maintenance programs. And they have utterly failed to undertake substantial roadside safety improvement programs on older roads, despite strong encouragement from the FHWA and the existence of several federally-funded and congressionally-mandated programs for this purpose.6

The difference between a harmless ran-off-the-road incident and a fatal or serious injury accident can be attributed to the design of the roadside. While roadside design may not initiate an accident, it can determine its outcome.

I hope that the problems illustrated today have struck a responsive chord and that as professionals you will do something about these hazards so that we can eliminate needless deaths and injuries on our nation's highways.

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