Full-Scale Appraisals of Guardrail Installations By Car Impact Tests

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• THE GENERAL MOTORS Proving Ground at Milford, Mich., has approximately 65 mi of road, along which there are 18 mi of guardrail. Most of this rail is of the convex steel-beam type mounted on wooden posts, most of which are many years old. Preliminary tests showed that these installations provided practically no protection for cars striking them at speeds as low as 35 mph. The posts have deteriorated with age and the rail provides relatively little beaming strength. These installations did not provide adequate safety on the test roads; therefore, Proving Ground management decided to institute a fullscale testing program to find out whether there was any practical way to remount the existing rail to provide satisfactory protection. Because the results were not very satisfactory, it was decided to make an appraisal of the new standard beam-type and cable-type guardrails mounted in various manners, inasmuch as no full-scale tests on guardrails of these types were available. Inasmuch as the tests on the cable-type guardrail are not complete, this paper deals mainly with the standardized beam-type rail. All information derived from these tests has been made available to the Highway Research Board Committee on Guardrails and Guideposts.

To be satisfactory, the guardrail must keep the car from passing through it and into a roadside hazard; it must redirect the car with a deceleration which is tolerable to the occupants; it should not direct the car back into the road, thereby causing a hazard to other traffic; and it should inflict a minimum amount of damage to the car.

The test technique involves driving a car into the rail at a definite angle and speed by remote control. Much work has been done at 35 mph, because there is little use in testing at higher speeds until an installation has proved satisfactory at the lower speed. Tests have been conducted at speeds varying from 30 to 65 mph at angles from 20 to 30 degrees.

Tests conducted at the Proving Ground indicate that if a car is traveling in a passing lane on a four-lane, dual, divided highway at 65 mph, and the steering wheel is cut to the right as rapidly as possible, the car can develop a 20-degree angle with a guardrail located 10 ft to the right of the edge of the pavement. Highway statistics also show that in the majority of guardrail accidents the car impact angle is 20 degrees or less. Cars traveling at higher speeds will tend to strike a rail at a smaller angle. Therefore, most Proving Ground tests were run at 20 degrees because it is a severe but reasonable angle.

Data taken on these tests include standard-speed and high-speed motion pictures from various angles, and oscillographic recordings of impact speed and longitudinal and lateral decelerations. A complete still-picture record is also obtained of the guardrail before and after impact and of the damage done to the car.

Approximately 40 tests were run during 1958. From an analysis of the most significant tests, the following observations have been made:

1. Good beaming strength is essential. If a guardrail pockets a car, high vehicle decelerations are produced. Low beaming strength accounts for the relatively poor performance of the convex-type rail regardless of the post mounting; high

beaming strength accounts for the relatively good performance of the new standard-beam-type rail.

2. Posts should be designed so that they do not drag the rail down as they yield under impact. This is of primary importance because a rail which has been dragged down will contact the car below the center of gravity and encourage the car to pass over or to overturn. However, it is also important that posts deflect under impact because this provides flexibility to the rail and prevents the car from being turned in its path too abruptly, thereby generating intolerably high decelerations.

3. The rail ends must be anchored solidly enough so that the full tensile strength of the rail can be developed in the end sections or in short installations. If the end is not solidly anchored and the rail is impacted near the end, the end attachment will fail and the rail will pocket the vehicle, losing most of its effectiveness.

4. Mounting the rail on spring brackets appears to help minimize damage in lowspeed accidents. It is not desirable to have the rail either rigid, as a concrete wall would be, or too loose. Probably a different amount of lateral flexibility is desirable for each impact situation. However, the Proving Ground tests to date indicate that the slight lateral flexibility provided by spring-type mounts greatly reduces the car damage and lowers lateral decelerations on 35-mph accidents. In higher-speed accidents, this flexibility is not essential, but it seems to do no harm.

5. Reducing the spacing between posts improves the effectiveness of the rail. A standard 12-gauge, beam-type guardrail, mounted on posts spaced 12 ft apart, provides only marginal protection for a car striking it at 65 mph at a 20-degree angle. The same rail mounted on the same posts spaced 6 ft apart provides good protection for a car striking it under these conditions.

6. Although a complete investigation of the various types of posts has not been attempted it is apparent that 6- by 8-in. treated wood posts are very good when new. Steel I-beam posts of 6- by 8-in., $8\frac{1}{2}$-lb per ft section, appear to be weak in bending and have too small an area bearing on the soil. Reinforced precast 6- by 8-in. concrete posts seem to give good results. (The posts tested, however, are not of optimum design.) The tendency of concrete posts to shatter and disintegrate when hit is not considered undesirable, as this helps the post avoid pulling the rail down as it fails, and considerable kinetic energy is absorbed by the mass of the post. A typical impact will destroy from four to eight concrete posts. Spring mounting a rail on the concrete posts helps to prevent damage to both car and posts on light impacts.

7. The rail should be mounted high enough so that it will remain above or at the car center of gravity throughout the crash. Most cars of American manufacture have a center of gravity height of from 21 to 24 in. If the rail were mounted too high, the car would tend to go under the rail, and extensive damage from the posts would occur. Proving Ground tests were made with the rail at standard mounting height of 18 in. from the ground to the center of the rail. This appears to be a satisfactory height for the speeds and angles of impact used at the Proving Ground.

8. Limited tests conducted with cable-type guardrail indicate that it inflicts considerable damage on the vehicle because the cables tend to cut through the vehicle, tearing off large sections of fender, and perhaps wheels. The supporting posts also severely damage the vehicle.

9. Improved end plates are a definite need. Vehicles striking the end of conventional installations are damaged severely and occupants would be injured.

10. Tests show that the new beam-type rail mounted on 6-ft centers, which is most satisfactory to date for passenger cars, does provide appreciable protection for large buses. Complete protection for high-speed trucks and buses will require heavier construction.

11. Impacts with guardrails are accidents resulting in vehicle damage and possible injury to the occupants. There-

fore, guardrail should be used only if it is completely impractical to provide safe roadsides. Where this is impossible, an adequate rail installation, the design of which is based on the results of actual tests, should be used.

In conclusion, the purpose of a guardrail is to prevent a vehicle from entering an area in which it cannot safely travel. The guardrail should do its job with a minimum of injury to the passengers, damage to the vehicle, and to the rail itself. This means that the ideal guardrail should turn the vehicle from its original path to a path parallel to the guardrail with tolerable decelerations on the vehicle. It should not deflect the vehicle back into the road, endangering other traffic. In performing the turning action, it is necessary that the rail deflect because it is impossible to turn a vehicle instantaneously. The amount of deflection determines largely the lateral acceleration peak produced on the vehicle. A rail which will do all of these things has not yet been designed and would probably be prohibitively expensive. Therefore, guardrails should be used only as the last resort when all other means of eliminating the roadside hazard are completely impractical.

Although the tests described here are thought to be the most comprehensive series ever conducted, additional research is required to evaluate beaming strength *versus* post spacing, post design for optimum strength and bearing, end designs for full strength, and designs to ease end impacts.