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THE USE OF GUARD RAIL IN THE SAFER OPERATION OF HIGHWAYS

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## S U M M A R Y

This paper deals with the use of guard rails in creating a safer highway for the travelling public. In the past much guard rail has been placed improperly and used in a manner which prevented it from providing an effective safety device. Guard rail itself is a hazard of some magnitude and should be used only when absolutely necessary and then should be designed and located according to modern standards which result in a barrier which will safely contain an out-of-control vehicle.

# THE USE OF GUARD RAIL IN THE SAFER OPERATION OF HIGHWAYS

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Paul R. Tutt\*

## Synopsis

Guard rail has been used in connection with highways for a long time. Many types of rail have been used and many installations have not been very effective in safeguarding the travelling public from obstacles along the roadway. Much rail has been improperly placed and many installations are not strong enough to accomplish their intended purpose. In recent years this subject has been viewed in a much more realistic manner and current installations are much improved. Research has indicated that it is possible to design and place a guard rail in such a manner that it will prevent a vehicle from leaving the travelled way and do so in such a manner that the occupants of the vehicle will not be injured.

The nature of guard rail is such that it has primarily tensile strength. This being the case it is necessary that both ends of the rail be securely anchored in order that the tensile strength of the rail can be used effectively. This can be accomplished by twisting the rail and fastening it to a heavy anchor post at the end in such a manner that the anchor connection develops the full strength of the rail. Undoubtedly further improvements will be accomplished in the area of protective rail design, but it is possible to do a reasonably good job using conventional rail elements properly placed and properly anchored.

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Guard rail has been in use for a long time as a part of almost every highway. Many different types of rail have been used, and considerable variation is still evident. Most recent construction, however, has been limited to what is known as deep beam rail shown in Figure 1. Although the rail element itself has been fairly well standardized, the manner in which it has been installed and the locations at which it has been placed still

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vary widely. In many cases not very much thought has been given to the manner in which the rail would behave in case of a collision. Several examples are shown in Figures 2, 3, 4, and 5. These show some of the varying purposes for which guard rail has been installed. Judging from what we see in these photographs, we might conclude that any time a roadside problem developed, the solution was to put up a guard rail, but to use as short a section of rail as possible, with little thought given to how this rail would function.

In the last few years it has become apparent to many highway design engineers and safety-conscious highway officials that much of the guard rail now in use was not serving in a practical manner. This situation is further emphasized by the more serious accident situation which now exists. Since the beginning of highway accident records, the accident rate per 100 million vehicle miles, which has served as an index of highway safety, has been decreasing. This was true in spite of the fact that the vehicle miles of operation of motor vehicles has increased steadily during this time as shown in Figure 6. The situation began to change, however, with the year 1961 apparently being the focal point.

Figure 7 shows the death rate per hundred million vehicle miles for the State of Texas and from this plot, it is evident that the death rate reached a low point in 1961, and since that time, has begun to move back up. This has occurred in spite of the fact that many freeway routes have now been opened, and the accident rate on these freeways is generally considerably lower than that on the average highway route. This causes the upward trend in the death rate to be even more disturbing.

A further look at the accident records indicates that many of the

accidents causing fatalities are one-car accidents in which some feature of the highway roadside is involved, and we will deal primarily with these accidents in this discussion. These may be as high as sixty per cent of the total and normally run above forty per cent, depending on the quality of the particular road in question. On controlled access highways, the possibility of having a two-car collision is reduced considerably since in most cases, only sideswipe and rear-end accidents are likely to occur. On these facilities roadside one-car accidents become predominant.

Looking still further into this situation, several interesting points come to light. Research indicates that many roadside obstacles can be either eliminated or rendered reasonably safe by means other than the use of guard rail. Several examples would be sign posts which break on impact, light poles which do likewise, slopes which are flat enough to be negotiated by an out-of-control vehicle without causing it to be overturned, and the elimination of such items as head walls and blunt drainage structures of all types. Moving obstructions farther from the road also improves the situation as shown in Figure 8.

Since many of these objectionable features have already been built into our existing highway system, it is probable that the use of guard rail will be necessary at these existing obstacles for some time. On new construction the use of guard rail and rail in general can be reduced considerably and possibly confined to use in the vicinity of structure approaches, both where the roadway passes under a structure and where it passes over a structure.

It should be kept in mind that while guard rail is normally considered to be a safety device, it is also a hazard. Much of the rail which has been erected in the past has been designed and located in a manner that it

may be more of a hazard than a safety device.

At this point, it became necessary to examine guard rail and other protective rails to determine if they can be used in an effective manner, and what should be done to improve the functional characteristics of protective rails. Considerable research has been conducted in this area in the past several years. The California Division of Highways has conducted crash tests as has the General Motors Proving Ground. Several other agencies have also conducted worthwhile research in the area of crash barrier testing. In Texas, actual controlled crash tests have not been conducted. The work which others have done has been investigated very thoroughly and the results of this work have been applied.

These studies indicated that the rail, as we know it, has primarily tensile strength. Although the rail element does have a section, this is usually lost on impact, and the rail element is flattened into a ribbon of steel. The tests do indicate, however, that if this ribbon of steel is properly located and securely anchored, it has the ability to withstand impacts of considerable force.

In looking at earlier installations, it was also determined that it would be desirable to eliminate the blunt end shown in Figure 9.

The first design in which it was attempted to incorporate these features is shown in Figure 10. By twisting the rail and bringing it down to the ground, it is possible to provide a secure anchor without encountering a moment arm in the anchor post and this also eliminates the blunt end. The anchor post itself shown in Figure 11 is the strongest element in the system, and provides for an eight-bolt connection to the rail. The post shown here was installed too high. The connection at this post develops

the full strength of the rail at the anchor post as opposed to the one-bolt connection used to attach the rail to the posts in earlier installations. This first design included two special fabrication items. The anchor post had to be specially fabricated, and the intermediate post shown in Figure 12 was also a special fabrication item, which of course added to the cost of the total installation.

This design was discussed with several of the Districts and a number of installations were constructed similar to the ones shown in Figure 13. This provided an excellent field laboratory in which to determine how this design would work in practice. This field experience was very encouraging. Most of the work was conducted in District 9 on Interstate Highway 35 between Temple and Waco. The rail was installed in connection with a signing job. Since this was a relatively high-volume highway, practical field experience was gained very rapidly.

One of the first accidents which occurred involved a car which straddled the approach end of the guard rail. Some concern had been expressed about how the rail might behave under these circumstances, but experience showed that this really was not a serious problem. A first observation of this design might suggest the possibility that a car would be vaulted into the air by the inclined approach to the rail. This is not the case, however. A vehicle straddling the rail pushed the rail to the ground and breaks it loose from the posts one by one. The vehicle then knocks the posts down one by one and this acts as a decelerating force bringing the vehicle to a stop after the energy of the vehicle has been expended. Considerable damage to the underside of the car will result, but the passenger compartment remains undamaged, and, as of now, the passengers have been

able to survive this type of accident without any injury. In one case, a car was vaulted into the air, and the driver killed. But at this location, the approach end of the rail had been installed too high and the solid anchor contacted the solid undercarriage of the automobile. This was a case where the installation did not follow the plans, and the plans have since been further revised to make this situation almost impossible.

In most cases where the rail has been straddled, it will look something like the illustration shown in Figures 14, 15, and 16. In this case the car straddled the rail and demolished a portion of it. The car stopped on the rail. The driver was not injured, the car was damaged on the underside to a considerable extent, but the passenger compartment showed little damage. In situations such as this, both the rail and the automobile must be considered expendable in order to save the lives of occupants of the vehicle.

It is possible for the vehicle travelling at a high rate of speed and at a rather severe angle to penetrate an anchored rail such as shown in Figure 17. If the installation is placed parallel to the roadway and properly anchored, however, the possibility of penetration is rather remote. In most cases a side impact against a rail will result in some damage to the vehicle, but in many cases the accident will not be reported, and the damage to the rail will look something like that shown in Figures 18 and 19. Damage of this kind is frequently not repaired. It is visible, but not particularly noticeable to the travelling public, and does not seriously hamper the effectiveness of the rail. Had the rail not been anchored it might have been wadded into the condition shown in Figure 20.

Although the first installations of this rail were quite successful, it was found that it was possible to improve this situation through several



minor modifications. The use of an end flange on the approach end frequently resulted in this being placed higher than desirable, and in the one case discussed earlier, a fatal accident resulted from the installation being too high. In order to eliminate this possibility, the anchor post was modified as shown in Figure 21, and the end shoe eliminated. The rail was also raised to twenty-seven inches above the height of the shoulder. This produced an installation as shown in Figure 22. This design also eliminates the intermediate post which was one of the special fabrication items. This resulted in a saving in cost, and the more abrupt transitions from the anchor to the first full-height post results in a more positive destruction of the rail-post connection when the rail is straddled.

This end anchor is a long step toward the effective use of guard rail in creating safer highways. It is not the entire answer, however. Experience indicates that a spacing of 6 feet-3 inches for the post is also important and considerably safer than the 12 feet-6 inch spacing used previously.

The location of the rail with respect to the hazard involved is also extremely important. You will recall that Figures 2, 3, 4, and 5 showed rail installations which seemed to have little bearing on the location of the hazard involved. A general rule on the location of the rail would be to consider the path of a vehicle leaving the roadway at a speed of roughly 70 miles per hour and at an angle of approximately five to ten degrees. This of course is a hypothetical situation, but experience indicates that angles of this magnitude are reasonable. If the rail is located with this point of view in mind, it will in most cases serve the intended purpose. Another very important point is that the rail must be straight. Any curvature of the rail as shown in Figure 23 will permit lateral movement of

some magnitude, even if the end were anchored, before the end anchor becomes effective, and will thus require some portion of the rail to act independently. To be effective, the entire rail must act as a unit, and the anchor must be effective immediately upon impact. Figure 24 is a good example of a rail located properly with respect to a bridge rail, while Figure 25 shows a rail located properly with respect to a bridge pier. In this case the pier should have been farther away from the travelled way, however.

### Conclusions

There is no doubt that further improvements in the use of protective rail along our highways will be forthcoming, but there is also no doubt that very significant advances have been made in the last few years, and that our highways are safer as a result of this work. Guard rail at best is still something of a hazard and should not be used if the need for a protective rail can be eliminated in some other manner. The primary objective of the design engineer should be to provide a roadside which is as safe and free of obstructions as possible. Only when this is absolutely impossible should protective rail be used.