National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

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Tentative Service Requirements for Bridge Rail Systems

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 12-8, "Bridge Rail Service Requirements as a Basis for Design Criteria," by R. M. Olson, E. R. Post, and W. F. McFarland, Texas Transportation Institute, Texas A&M University

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THE PROBLEM AND ITS SOLUTION

Highway bridge railing systems have evolved through need and experience using design information not fully substantiated by research. The railings on early bridges had only to restrain pedestrians and slow-moving vehicles not capable of producing large impact forces. Aesthetics of the railing systems were of small import. The construction and maintenance of bridge railing systems were not major items of expense as is often the case today.

In more recent times, however, the advent of high-speed highways necessary to accommodate the large volume of heavier and faster vehicles has brought bridge railing systems into major importance. For example, some highway bridge railings in recent years have proved to be decorative but not structually adequate when subjected to the magnitude of impact forces produced by modern vehicles. Vehicle penetration of such railings has often occurred as a result of incomplete design criteria and inadequate service requirement definition.

During the last two decades, progress toward more reliable bridge rail systems has resulted from the efforts of engineers involved in designing new systems and conducting full-scale dynamic tests, but there still remains a need for a more comprehensive definition of service requirements. This one-year study for $30,000 was directed to this need, with due consideration being given to such factors as vehicle parameters, roadway characteristics, railing performance characteristics, comparative costs, and other pertinent information.

Although little more than a pilot study was conceivable with the limited funding, the research did succeed in developing a tentative list of service requirements for bridge railings, a rational technique for estimating the magnitude of collision forces based on vehicle damage, information for establishing tolerable limits of vehicle deceleration, and an analytical technique for predicting dynamic loads on bridge rails--all of which can be employed by engineers to evaluate current and future designs.

Because these findings are primarily the result of a literature search and a nine-state survey of highway engineers, it is believed that they are reliable and can be used directly. Negotiations are under way to arrange for further work in this topic area, which hopefully will produce rigorous design criteria and perhaps some recommended bridge railing system designs.

FINDINGS

General

Because trucks are involved in a small percentage of the fatal accidents--and bridge rails to restrain trucks are stronger and more costly--it would seem reasonable to eliminate trucks from design consideration except in unusual circumstances.

A bridge rail design based on a vehicle impact speed of 70 mph would have included approximately 75% of the standard and smaller-sized passenger vehicles in a group of 640 single-vehicle fixed-object fatal accidents as compiled by the California Highway Traffic Department. It is recommended that full-scale dynamic tests of bridge rails be conducted at an increased speed of 65-70 mph rather than the current 60 mph.

Evidence is available which indicates that for more than 50% of the fatal accidents involving bridge railing systems the collision involves the end of the railing.

Accident information indicates that approximately 20% of the fatalities involving bridge rail accidents result from penetration of the railing. Penetration can be eliminated by proper design for strength.

Vaulting of a bridge railing can be eliminated by proper attention to railing height in addition to structural strength, and elimination of abrupt discontinuities such as curbs, safety walks, and sidewalks in front of the railing.

Highway safety programs appear to be moving in the direction of safer installations if reduction in fatal accidents is accepted as the criterion.

It is evident from accident records that many bridge railing systems in existence are not structurally adequate to restrain or smoothly redirect an out-of-control standard-size passenger vehicle.

It is evident from photographic observations of actual failures of bridge railing systems that the weak link in most designs is usually located at post connections.

At the present time, the specifications of AASHO (1965) or BPR (1962) are not sufficient to provide the design engineer assurance that localized failures will not occur at connections unless full-scale dynamic tests are conducted.

Proof tests will be required for the foreseeable future in order to evaluate selected systems. Adherence to the bridge rail service requirements presented in the report, in conjunction with the rational analytical approach, can serve as a method of eliminating unpromising design concepts and in selecting testing conditions consistent with roadway characteristics.

In order to further limit vehicle decelerations it will be necessary to develop an impact attenuation device to provide lateral displacement of the bridge railing system. Indications are that a lateral displacement of 2 ft will result in a much lower deceleration level--other conditions remaining unchanged.

It is clear that guardrails and bridge rails must be designed as an integrated system to insure that transition zones between them will perform satisfactorily.

Bridge Rail Service Requirements

1. A bridge rail system must laterally restrain a selected vehicle.
2. A bridge rail system must limit vehicle decelerations to some tolerable level.
3. A bridge rail system must smoothly redirect a colliding vehicle.
4. A bridge rail system must remain intact following a collision.
5. A bridge rail system which serves vehicles and pedestrians must provide protection for both vehicle occupants and pedestrians.
6. A bridge rail system must have a compatible approach rail or other device to prevent collision with the end of the rail.
7. A bridge rail system must define, yet permit adequate visibility.
8. A bridge rail must project inside the face of any curb.
9. A bridge rail system must be susceptible of quick repair.
10. The foregoing nine requirements must be met by giving emphasis first to safety, second to economics, and third to aesthetics.

APPLICATIONS

The findings from this study are of value to engineers involved in the design of bridge railing systems, other researchers, and, perhaps most of all, the members of the AASHO Committee on Bridges and Structures because suggested revisions to the AASHO Specifications for Highway Bridges are included and warrant consideration. Further, the findings can be applied directly to practice, for they stand alone and they are stated explicitly in language familiar to the practicing engineer. Because the research was limited to one year and was intended to be principally a pilot study, there was no experimental work that would enable some determination of probable success if the findings were implemented in practice. Part of the value of the research is in confirming the common sense rules long adhered to by engineers designing bridge rail systems. Other value lies in the rational design approach for predicting impact forces on bridge railing systems, in comparing crash test data with accident information so as to provide insight into establishing estimates of severity of accidents, based on vehicle damage, providing insight into the additional research necessary to further advance bridge rail technology to the level commensurate with the capabilities of our times, and for highlighting the major policy question that must be resolved by the administrator--that is, how many fatalities as a result of vehicle-bridge rail collisions are too many? Until that question is answered, the design engineer is constrained in his approach, regardless of the tools at his disposal.