Highway Safety Devices

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Texas Transportation Institute/SDHPT, D-10 Research	
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Abstract

This report is intended to provide information on selected safety devices that are available for use on Texas highways. These devices are not all of the roadway safety devices and as seen in the appendix are not the only devices that can be used to protect the motorist that might otherwise be involved in a serious incident.

The actual costs of installing a device depend on the location and the circumstances involved at the time it is installed. Also, for many of these safety systems there may be considerable variations, as in the case of signs. These circumstances make it impossible to state precisely thhe costs of a particular system. The data in the report are indicative of the typical costs in Texas -- but at a particular location the costs may vary substantially. The benefits of a device are even more dependent on the location. Thus reported benefit cost ratios are typical and should not be used as a prediction of benefits at specific locations in Texas.

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A Report

on

Highway Safety Devices

State Department of Highways and Public Transportation

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Introduction

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The actual costs of installing a device depend on the location and the circumstances involved at the time it is installed. Also, for many of these safety systems there may be considerable variations, as in the case of signs. These circumstances make it impossible to state precisely the costs of a particular system. The data in the report are indicative of the typical costs in Texas — but at a particular location the costs may vary substantially. The benefits of a device are even more dependent on the location. Thus reported benefit cost ratios are typical and should not be used as a prediction of benefits at specific locations in Texas.

As used here, the term **benefit** means the dollar value of improvements created by a highway safety device. These benefits accrue to highway users. The term **costs** refers to the dollar estimate of expenditures for acquiring, installing, operating, and maintaining a highway safety device. The term **benefit-cost ratio** is the quantity obtained when these dollar values of improvements (benefits) are arithmetically compared to the costs. Generally a benefit-cost ratio of 1:1 is considered a minimum before an expenditure is justified.

Safety shaped barrier that is used to separate a transit lane from general use freeway lanes.

Description And Function

Concrete barriers were designed to separate two opposing streams of traffic. The distinctive side slope of these barriers is designed to contain a vehicle and redirect it back to the same traffic lane. Originally concrete barriers were designed to be used as center median barriers to prevent head on collisions. During the past several years, however, the same concept has been used in bridge rails and for temporary barriers to protect crews that are reconstructing or maintaining the highway.

Use In Texas

Concrete barriers are used extensively on Texas urban freeways as median barriers, for bridge rails and for separation of reconstruction and maintenance activities from traffic. One of the bridge rails used in Texas is a modification of the concrete barrier. Texas is the leader in using 30-foot sections of these barriers to protect crews reconstructing freeways and later using the same barriers as permanent median barriers on the completed freeway.

Expected Safety Improvement

Concrete barriers are designed to contain any vehicle that strays from the travel lanes and encounters the barrier. Careful study has shown that accidents are much less severe if the vehicle is contained and redirected back into the original travel lane. Considering wide variety of conditions where concrete barriers are used, the overall reductions in accident costs might be somewhat greater than 50%. But, in high traffic areas, overall savings of up to 80% are not uncommon.

Benefits And Costs

The installed cost of concrete barriers range from $25 to $50 per foot with permanent barriers being toward the low side and temporary barriers being more expensive. Temporary barriers are more expensive because of the additional hardware required to connect barrier segments which can run from $4 to $87 per connection. Safety shaped bridge rail costs from $35 to over $125 per foot for a rail specifically designed to better contain large trucks. The useful life of concrete barriers is expected to be about 30 years. However, barriers can be damaged if hit by high speed vehicles, high angle impacts or very heavy vehicles. Such damaged sections must be replaced. These types of collisions do not materially reduce the life of a long section of barriers on a freeway. Temporary barriers used in reconstruction zones may have a significantly lower life span, perhaps as little as 3 to 10 years. Typically, benefit-cost ratios for concrete barriers range upwards to 5:1.

A turned down guardrail from the backside to show detail.

Description And Function

The turndown end treatment for guardrail is a safety treatment for guardrail ends, whereby the railing of the guardrail is twisted and turned down so that its blunt end is buried below the surface of the ground.

Use In Texas

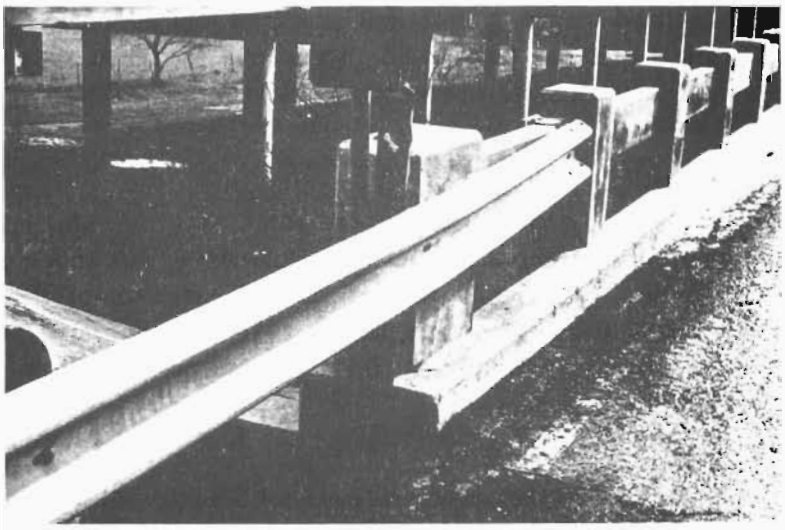
This treatment is now the standard for newly installed guardrail and added to older systems as a part of reconstruction projects. It has been used extensively in Texas since 1968 and has demonstrated effective performance through numerous impacts where no injury or accident has been reported.

Expected Safety Improvement

The turndown end treatment for guardrail greatly enhances motorist safety by preventing spearing of a vehicle on an otherwise exposed guardrail end. Also, this treatment provides a positive anchor to the guardrail. This anchor enables the full strength of the system to be available to redirect vehicles which impact at any location. Even terminals which have been damaged from a previous impact generally are able to maintain strength continuity for subsequent impacts elsewhere on the system.

Benefits And Costs

The cost of the turndown end treatment for guardrail is about $300 to $625 per treatment. The expected service life of the treatment is 10 years. The estimated reduction in accident losses from the turndown end treatment, relative to an untreated blunt guardrail end, is estimated to be $21,000 per accident. The benefits will exceed cost for a turndown end treatment on low volume highways and can be as much as 25:1 compared to an untreated, stand-up guardrail end.



This retrofit design improves driver safety.

Several methods can be used to attach the approach rail to the bridge.

Description And Function

The retrofit approach attachment is designed for improving the approach guardrail on existing bridges which were constructed in accordance with older standards. W-beam approach guardrail and concrete bridge rail are not connected together in some older bridges. A continuous system of guardrail, transition, and bridge rail is needed on such bridges to safely redirect errant vehicles. The retrofit treatment consists of modifying existing guardrail installations, wherein the approach guardrail is extended to lap over the concrete bridge rail or the safety curb. The approach guardrail is then bolted to the concrete bridge, providing a continuous railing system.

Use In Texas

The retrofit approach attachment is being applied to older bridges without continuous approach guardrail. It is expected that all of these structures statewide will eventually be retrofitted with this or an equivalent treatment.

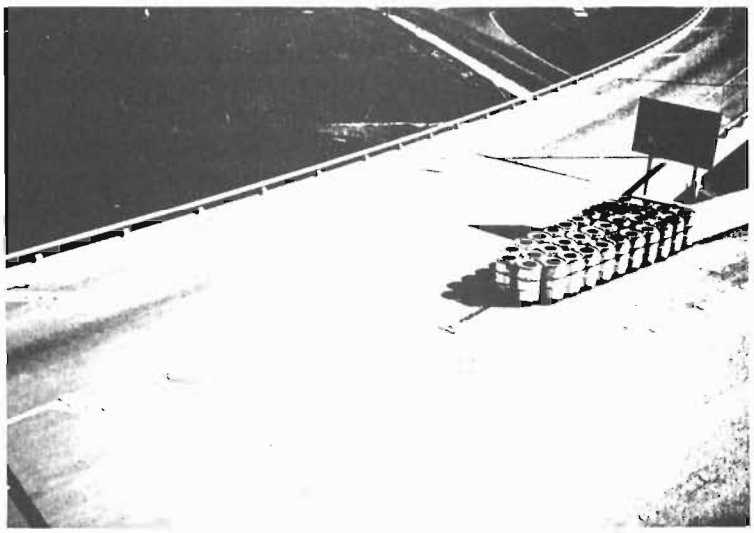
Expected Safety Improvement

In a small number of cases a vehicle may strike at exactly the point where the approach rail meets the bridge rail. The impact forces applied to the end of the guardrail can cause sufficient deflection to allow the vehicle to strike the end of the concrete bridge rail. The retrofit approach attachment provides a continuous rail system on a bridge. The full guardrail strength is thus made available in preventing an errant vehicle from impacting the bridge end and safely redirecting the vehicle onto the travel lane.

Benefits And Costs

The retrofit approach attachment costs about $2,800 per bridge, consisting of four guardrail modifications at $700 each. The service life is expected to be 15 years. The benefits will exceed cost for the retrofit approach attachment even if used on low volume roads. Compared to a discontinuous approach guardrail that would not safely redirect an errant vehicle away from the bridge end, the retrofit approach attachment can provide a benefit-cost ratio of up to 8:1.

A crew installing flashing lights and a background sign in order to make a barrel crash cushion more visible.



An overhead view of paint barrels used as a crash cushion.

Description And Function

The crash cushion was orginally developed in the early 1960's by the Texas State Department of Highways and Public Transportation in its research program. The orginal crash cushion was constructed of used 55-gallon paint drums connected together and secured to the ground by steel cables. Since the original design, several additional variations of the device have been developed by private industry. Other types of cushions use sand, water or plastic foam and containers consisting of plastic barrels, plastic tubes or old tires.

Use In Texas

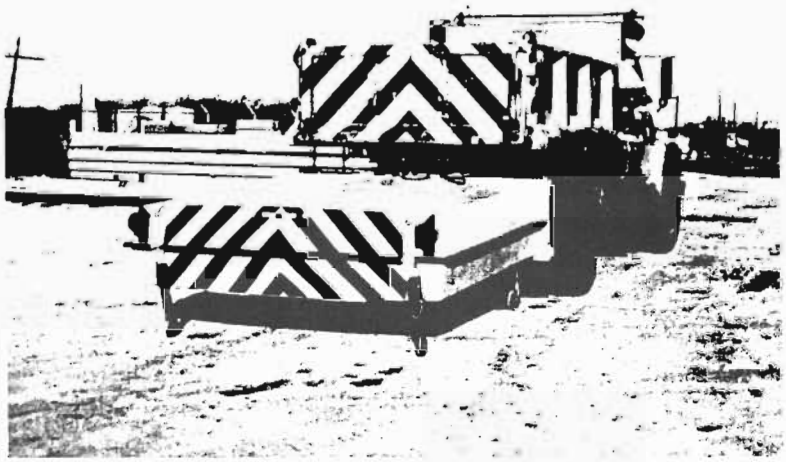
Crash cushions are in widespread use in Texas, particularly on high-speed, high-volume highways in or near urban areas. Crash cushions are used to shield rigid obstacles.

Expected Safety Improvement

Crash cushions are designed so that a vehicle striking the cushion will be decelerated to a stop or be redirected in such a way that injuries to the occupants are greatly reduced. They are effective in reducing the severity of collisions with rigid obstacles at diverging roadways and bridge piers. Crash cushions continue to demonstrate that fatalities, severe injuries and property damages are drastically reduced.

Benefits And Costs

Depending on their design and location, crash cushions range in installed cost from $3,000 to $15,000. The expected service life of a crash cushion system is three to five years. The extent of replacement or repair depends on the incident and the design of the device. The accident severity reduction benefits of crash cushions are great, relative to their cost. Lowering the severity of a typical fixed-object accident results in reducing the loss more than 90%. The benefits derived from using crash cushions vary widely depending on the traffic volume. Benefit-cost ratios occur in the range of 10:1 to 90:1.



A newly acquired truck attenuator ready to be installed.

Description And Function

Truck mounted attenuators are similar in design and function to crash cushions. They are mounted on slow moving maintenance vehicles and on parked vehicles being used to protect workers on the highway. The attenuator is designed to collapse on impact by a vehicle.

Use In Texas

Truck mounted attenuators normally are used in connection with small, relatively short term maintenance jobs such as herbicide spraying, paint striping, and other similar activities.

Expected Safety Improvement

There are two improvements to safety that are gained by using truck mounted attenuators. First, accidents are much less severe in vehicle collisions with attenuators as compared to collisions with the rear of a stationary vehicle. Secondly, the maintenance vehicle operators are much safer in case of a rear-end collision since much less force is transferred to the maintenance vehicle.

Benefits And Costs

The truck mounted attenuator costs about $5,000. The expected service life of a unit that is not hit is 20 years. The reduced injury and damage per accident of a vehicle hitting the attenuator instead of a stationary vehicle is estimated to be $23,000. The minimum benefit-cost ratio of this device is about 26:1. This is a low estimate, since the benefits of the device also depend on the number of maintenance personnel who would have sustained severe or fatal injuries.

Roadside signs have slip bases that breakaway if struck by a vehicle.

Even small signs use the slip base design.

Description And Function

Highway and traffic signs were originally mounted on steel supports that were rigidly attached to concrete foundations. Frequently, people were killed and/or seriously injured when their cars collided with these rigidly mounted signs. Engineers of the Texas State Department of Highways and Public Transportation recognized the hazard that existed and developed, through its research program, sign supports that would resist damage from high winds and allow the base connection to breakaway when struck by a vehicle.

Use In Texas

Thousands of these devices have been installed in Texas, nationally and internationally since the mid 1960's and are still in use. The design permits easy reinstallation of a sign support following a collision. It is estimated that these supports have an average service life of at least thirty years.

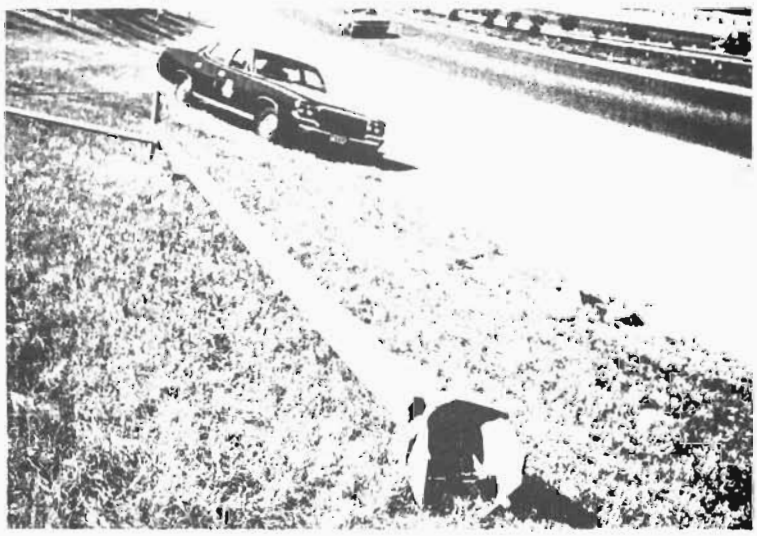
Expected Safety Improvement

Breakaway signs are struck frequently in Texas with minor damage to vehicles. Most of the colliding vehicles can be driven away. In the majority of cases, accidents are not reported; therefore, injuries are assumed to be minor or non-existent.

Benefits And Costs

Breakaway sign supports vary in size from small single post signs to large signs having as many as three supports. Thus costs of material and construction vary from less than $100 to more than $5,000 per installation. The extra cost of using breakaway supports is only about 10% of the initial cost. The efficacy of these devices in reducing forces on a colliding vehicle is so great that the benefit-cost ratio is about 300 to 1.

Luminaire supports have a breakaway design base.



Striking a luminaire support shatters the base but the vehicle and the pole are little damaged.

Description And Function

Highway lighting provides increased visibility at night and contributes to safety. However, to be effective lighting supports need to be placed close to the traveled way. Errant vehicles frequently collide with these supports. Early installations were constructed with steel bases bolted rigidly to concrete foundations.

Recognizing the hazard of such installations the State Department of Highways and Public Transportation through its research program developed designs to reduce the severity of impacts to vehicles colliding with these light poles. The most widely used design employs a cast aluminum base which breaks away when struck by the vehicle. A usual impact shatters the base. The lighting support is pushed in front, catapults over the vehicle, and falls harmlessly to the ground.

Use In Texas

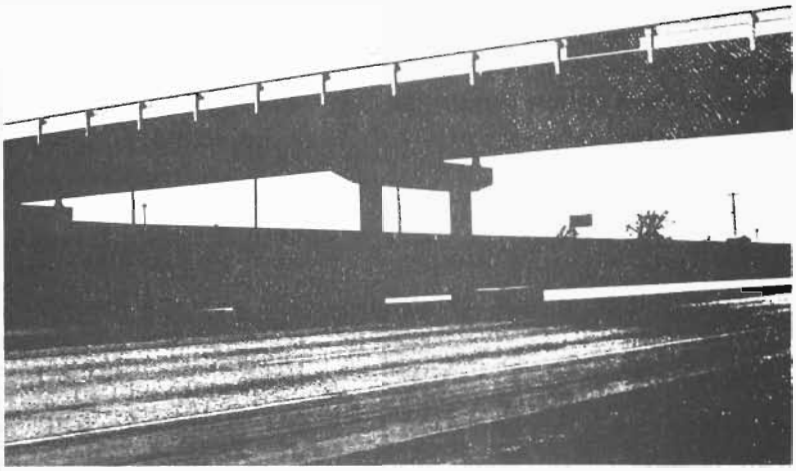
Thousands of these safety devices have been installed on Texas highways since 1970. The breakaway elements (cast aluminum bases) and the lights (luminaires) must be replaced following a collision. However, the poles can usually be re-installed. These breakaway devices have an average life of 10 to 25 years.

Expected Safety Improvement

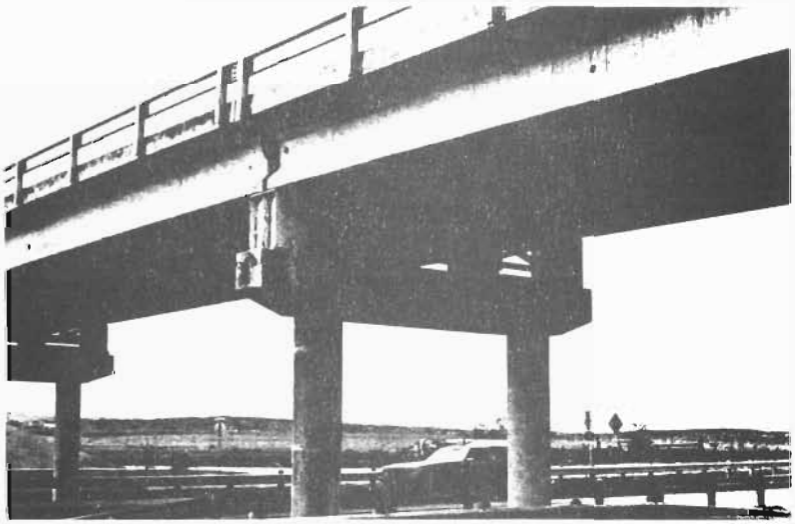
Some damage to the lighting support and to a vehicle is to be expected from an impact with the breakaway support. However, the reduction in fatal accidents involving non-breakaway designs is a major factor in improved roadway safety.

Benefits And Costs

The cost of installing the lighting support with a cast aluminum base ranges from $1,600 to $3,000, depending upon the height of the support and the number of luminaires mounted on the post. Of this cost, the breakaway base design costs only $200 to $400. The benefit-cost ratio is estimated to exceed 120:1.



Former low underpasses can be raised by jacking the structure.



Clearances can be increased without replacing the bridge structure.

Description And Function

Some overpass structures originally constructed years ago have minimum clearances for high loads. In some cases, it is possible to raise the structure to increase the clearance. This is accomplished by raising the entire span and inserting blocks at the support points. The approaches to the overpass for upper-level traffic are then brought to grade to complement the elevation of the raised structure.

Use In Texas

Several locations in Texas have been treated by raising overpass structures, and there are currently other projects under way. The treatment is costly and hence is cost-beneficial only at those locations where low clearance is a significant cause of accidents.

Expected Safety Improvement

Overheight load accidents, which can result in collapse of a structure, take place at a rate of about 175 per year in Texas, with approximately 90% of these occurring in urban areas. Raising overpass structures to provide greater clearance will significantly reduce high load accidents.

Benefits And Costs

Although this procedure is costly, it is less expensive than replacing the overpass with one that provides greater clearance. Raising an overpass structure costs $105,000 or more. The service life of this treatment is the same as that of the structure, about 25 years. The treatment is cost-beneficial primarily on high-volume facilities, principally in urban areas. The repair cost to a structure that is impacted can range from $5,000 for minor repairs to $250,000 for replacement of a severely damaged overpass. The incidence of high-load collisions with overpasses varies widely for individual structures, with some overpasses in heavily congested urban areas being hit as many as 25 times per year. This gives a range of benefit-cost ratios for raising overpass structures on a high-volume urban facilities of 2:1 to 50:1.

Multiple Mailbox Support

This design prevents mailboxes from being a hazard to motorists.

Description And Function

Vehicular collisions with mailboxes on the roadside can produce severe injuries or fatalities in accidents. A new mailbox support is being installed to reduce this hazard. The multiple mailbox support is a thin-wall steel tube formed in a loop. As many as five mailboxes can be supported by the system. Upon impact by an errant vehicle, the tapered shape of the support causes the frame with the mailboxes to be freed and projected upward and forward with only slight damage to the vehicle.

Use In Texas

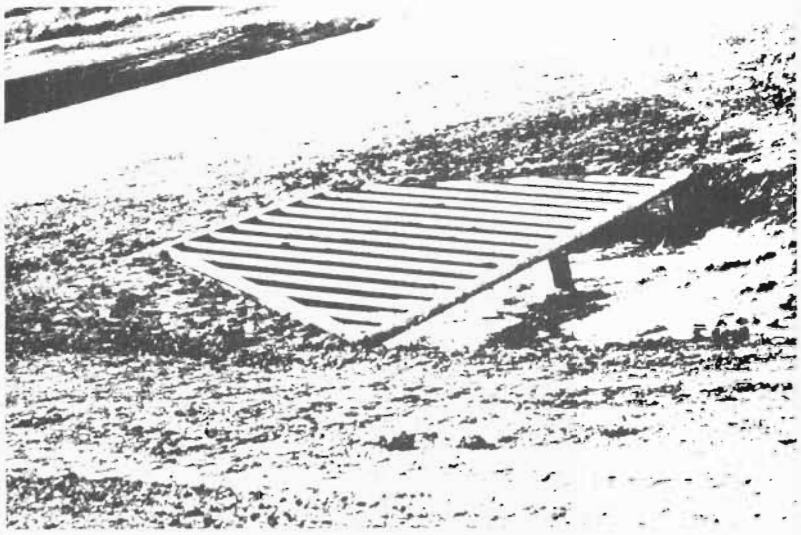
The multiple mailbox support is commonly used when a new mailbox support is installed. It also is being used to replace the standard wooden supports in many cases and is rapidly coming into widespread use along rural highways.

Expected Safety Improvement

The multiple mailbox support is designed to prevent rapid deceleration of an errant vehicle and to prevent the penetration of the mailbox support into the interior of the vehicle. The change in the velocity of the vehicle is slight, and the danger of any part of the mailbox support penetrating the windshield of the vehicle is essentially eliminated. The height of the old wooden supports, as well as their closeness to the roadway, is such that the horizontal beam supporting the mailboxes may be driven directly through the windshield of an impacting vehicle, causing serious injury to the vehicle's occupants. Use of the multiple mailbox support greatly reduces potential fatalities and injuries resulting from impacts with mailbox supports.

Benefits And Costs

This system has a very high benefit-cost ratio. Its installation cost of $60 is about the same as the standard wooden supports, but the hazard posed to motorists is significantly less than that of the wooden support. The expected service life of the system is five years. This system is cost-beneficial on all moderate- to high-speed facilities. The benefit-cost ratio of the system is higher for higher average daily traffic volumes. For example, the benefit-cost ratio will range upward from 60:1 on moderated volume highways.



A typical pipe grate used to protect the end of a culvert.

Sloped culvert end and embankment at 6:1.

Description And Function

A culvert safety end treatment is designed to reduce the severity of motor vehicle collisions with large culverts. The treatment consists of standard steel pipe grate positioned over an exposed culvert or a sloped culvert end and embankment at 6:1. An errant vehicle colliding with the culvert grate will pass over the culvert, rather than being stopped by it.

Use In Texas

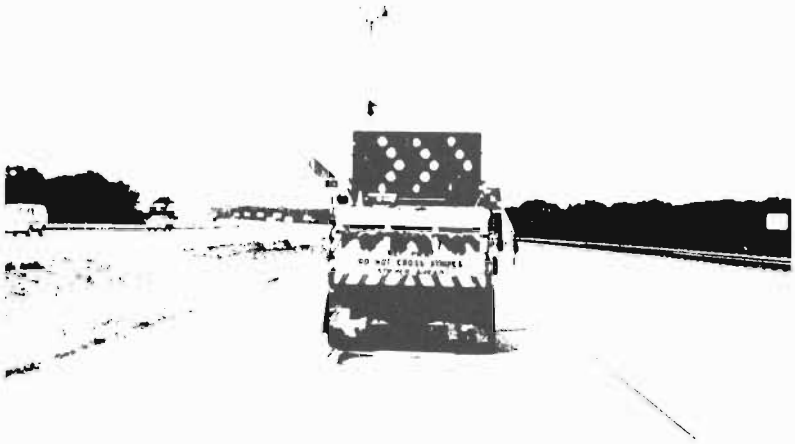
The safety benefits of treating culvert ends are well recognized. Culvert safety end treatments of various designs are included as part of new construction or reconstruction projects in Texas. Most culverts being installed presently utilize a sloped end section and earth embankment.

Expected Safety Improvement

A vehicle unexpectedly leaving the highway may have a severe collision if it strikes a culvert wall. Culvert safety end treatments are designed so that errant vehicles will pass over a treated culvert, thus avoiding serious damage.

Benefits And Costs

For new construction, the installed cost of a typical culvert with the safety treatment is about $400 to $600 **more** than the installed cost of the culvert without the treatment. Treatments for cross drainage structures may cost from $4,000 to $5,000 each. The safety treatment can reduce the average cost per culvert-related accident by about $17,500. The expected service life of this treatment is 15 years. Culvert collision rates vary with traffic volume; however, this safety treatment can be cost-beneficial even on low volume roadways. On higher traffic volume highways, the benefit-cost ratio of treatment increases to more than 15:1.



A truck mounted arrowboard used to protect workers ahead.

A changeable message sign giving advanced information of a work zone.

Description And Function

Arrowboards and changeable message signs are lighted signs that provide a directional arrow or a word message to the driver about what should be done. They are used in advance of a maintenance or a construction area or to give directions during special events. These signs are used to provide a direct and understandable message to the driver that the road conditions are not normal and special care must be taken.

Use In Texas

The use of arrowboards for advance warning of and guidance through the work zones has become widespread in Texas. Changeable message signs are increasingly important in attempts to improve highway safety and operations, not only for the public but for persons in the work zone.

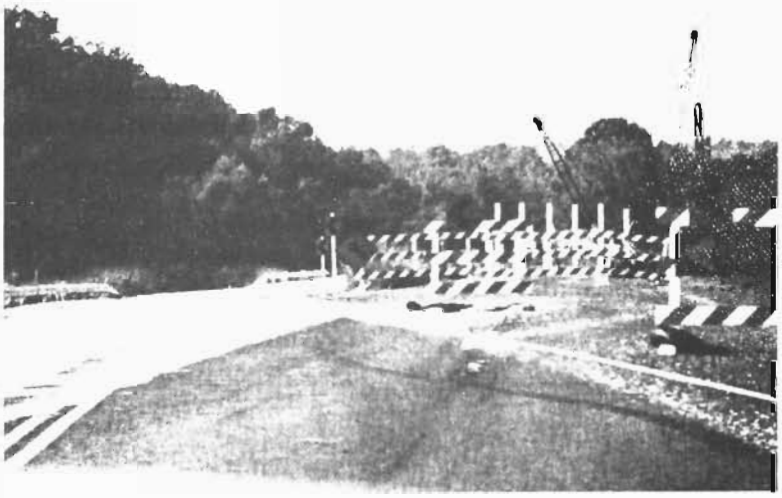
Expected Safety Improvement

The effectiveness of arrowboards in promoting driver and worker safety has been demonstrated by several studies. They significantly reduce speeds and queuing at work zones. When used for lane closures arrowboards contribute to 40% earlier merging of traffic than by using ordinary traffic control. Arrowboards have been shown to reduce the number of erratic maneuvers by 25%.

Changeable message signs are an effective method of reducing urban freeway congestion, which in turn improves safety by reducing traffic volumes and potential conflicts in the vicinity of special events or lane closures. Studies have shown increased and proper advance lane change activity, smoother lane changes, fewer late exits and reduced speeds at lane closure point. Up to 35% more drivers choose other routes during a freeway incident if a changeable message sign is used. These signs are efficient in re-routing traffic from freeways to alternate routes during special events. A study in Dallas showed that 60% of freeway drivers going to a special event selected an alternate route from a changeable message sign.

Benefits And Costs

Arrowboards cost approximately $4,000 each and have a service life of 7 to 10 years. Changeable message signs for work zones and urban freeway traffic management range in cost from about $50,000 to $80,000 each and have a service of 7 to 10 years. It is estimated that benefits to the motoring public, in terms of reduction in delays, of a changeable massage sign will in one year equal the initial cost of the sign.



Chevron signs being used to guide motorists through a construction zone.

Permanently mounted chevron signs used to mark a curve near a ramp intersection.

Description And Function

Chevron alignment signs are yellow signs with black chevrons pointing left or right. They are used to provide additional emphasis and guidance for motorists by calling attention to changes in alignment at highway curves and lane closures at highway construction sites. They are called chevrons because they look somewhat like the chevrons used by the military except that they are horizontal. The main advantage of the chevron signs over other delineation devices is that the arrow on the sign provides a positive indication of the direction the driver should move.

Use In Texas

Chevron signs are installed to provide additional delineation where motorists have more than average difficulty in negotiating curves. They are also installed to indicate the safe and proper path through construction zones.

Expected Safety Improvement

Many studies in and out of Texas have shown that changes in horizontal alignment are a factor in run-off-the-road accidents. Several studies have shown that significant numbers of accidents are reduced by the installation of chevron signs. Some studies have shown that chevron signs reduced these nighttime accidents by as much as 36%. In an opinion survey of officials in 38 states, the chevron sign was judged number one in effectiveness in reducing run-off-the-road accidents.

Benefits And Costs

Chevron alignment signs cost from $60 to $75 each. On a typical curve, the installation cost of the signs is about $300 for an average of five signs per curve. The expected service life of this type of sign is ten years. For a 36% reduction in nighttime accidents through use of the signs on a rural curve, with an average of one run-off-the-road accident per year at the location, the benefit-cost ratio is about 50:1.

Illuminated signs stand out from conflicting lights near a freeway.

Description And Function

Overhead signs and signs located a considerable distance from the edge of the roadway are commonly illuminated to attract motorists' attention and to increase the legibility of the message.

Use In Texas

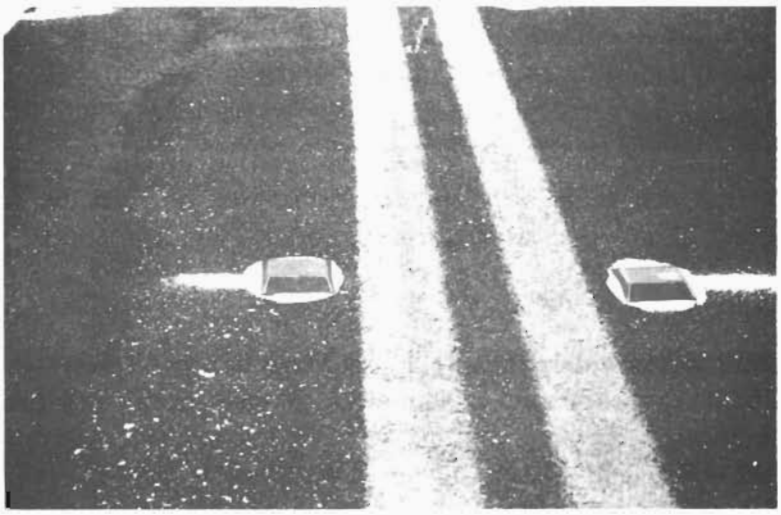
Texas has illuminated most overhead signs and some roadside signs on urban freeways. In addition, some signs are illuminated on principal urban arterial streets.

Expected Safety Improvement

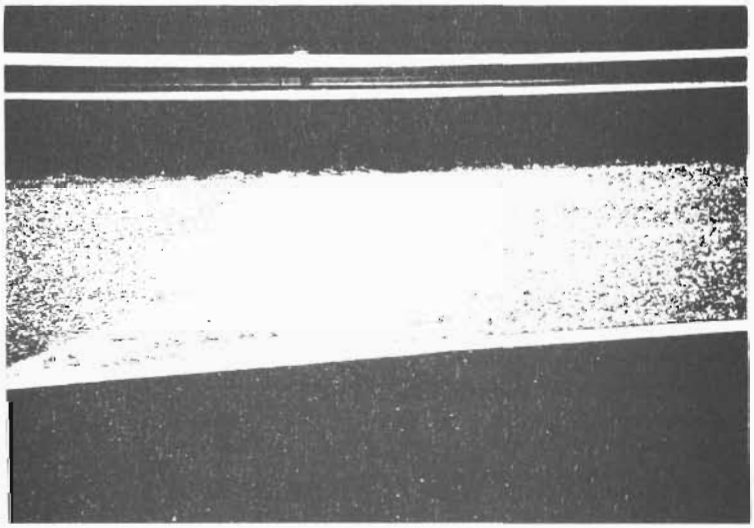
Failure of motorists to identify and read a sign can lead to erratic maneuvers. The higher visibility of an illuminated sign enables the motorist to prepare to read the message and avoid missing the information. Illuminated signs are expected to decrease accidents a maximum of 5%.

Benefits And Costs

The cost of sign lighting varies widely, but $1,500 per sign is a good average. The average life of sign lighting is about 25 years and is somewhat longer in the dry areas of the State. Improvements in operational efficiency and driver comfort, combined with the limited safety benefits, typically result in a benefit-cost ratio greater than 1.0. Development of high visibility sign sheeting has the potential to reduce the need for external illumination of signs. However, those materials are still experimental and some overhead and roadside signs will continue to need external illumination.



Detail of raised reflective markers glued adjacent to double yellow stripes.



Raised markers warn drivers of shoulder.

Description And Function

Raised pavement markers can be either reflectorized or non-reflectorized. They are generally made of plastic or ceramic materials that are glued to the pavement. They are used alongside traditional pavement strips to enhance the visibility of travel lanes. Jiggle bars and rumble strips are also raised markers used to alert motorists that they are outside of normal travel lanes.

Use In Texas

Texas uses a yellow stripe centerline to separate opposing traffic lanes. A white stripe is used to separate lanes of vehicles traveling in the same direction. Raised pavement markers of like color are used to increase the visibility of the lane demarcation system. Raised markers are used to increase the nighttime and wet weather visibility. Jiggle bars and rumble strips are used on freeway shoulders and at approaches to freeway exits and separations.

Expected Safety Improvement

Raised pavement markers reduce wet weather accidents by as much as 5%. Overall accidents will be lowered by as much as 12%. Raised pavement markers have been shown to reduce the frequency of accidents in a substantial majority of all sites. The safety effectiveness of jiggle bars has not been documented in experimentally controlled conditions. But studies of jiggle bars on intersection approaches and shoulders indicate a dramatic reduction in accidents. The public reaction to raised pavement markers is very positive.

Benefits And Costs

Raised pavement markers cost about $2 each for non-reflective markers and $4 each for reflective markers. These costs reflect a cost of $1,500 per mile. Shoulder width jiggle bars of the ceramic type typically used in Texas cost $64 each. The safety benefits of the two-lane double stripe roadway and jiggle bars have not been documented in controlled studies. But, both have the potential to have benefit-cost ratios over 1.0.

The positive public evaluation of raised pavement markers combined with wet weather visibility benefits probably yield a benefit-cost ratio greater than 1.0 in the areas of the State not subject to snow plowing.

A railroad crossing protected by gates and flashing lights.

Description And Function

For railroad-highway grade crossings, traffic control devices (passive and active) warn motorists of the presence of a railroad crossing at grade. Active devices (flashing lights, with or without gates) also warn drivers of the approach or presence of a train at the crossing.

Use In Texas

Virtually all public railroad-highway grade crossings in Texas are marked by a crossbuck sign mounted at the right side of the highway. In some cases, standard stop signs are added to increase protection. Where warning of an approaching train is needed, bells and flashing red lights are used. These lights are usually mounted on the crossbuck post and/or over the highway. Additionally, gates which block approaching traffic can be added. These active devices include: simple post-mounted flashing lights activated by a single track circuit; as well as complex combinations of overhead flashing lights with gates, which are activated by train speed-sensing motion detectors connected into traffic control systems.

Expected Safety Improvement

Use of flashing lights alone at a railroad-highway grade crossing has been estimated to reduce numbers of accidents by 70% to 90% as compared with the crossbucks alone. Addition of gates to existing flashing lights may further reduce the remaining accidents by 30% to 60% or more. In addition, the gates reduce not only the numbers but also the severity of accidents.

Benefits And Costs

The costs of active grade crossing devices are hightly site-specific, and only averages are given here. Average cost for a single grade crossing installation with flashing lights at the side of the highway is $65,000. Addition of lights cantilevered over the highway raises total installation cost to an average of $85,000. Gates with flashing lights cost an average of $100,000, while addition of cantilevered flashing lights over the highway raises the cost by $50,000 per single crossing. Benefit-cost ratios for railroad crossing improvements range from 2:1 up to 10:1, depending upon traffic volumes, number of trains per day, and characteristics of the crossing.

Safety lighting used for additional visibility of an exit ramp.

Safety lighting of a curved section.

Description And Function

Safety lighting refers to the placement of lights (luminaires) at a particular point on a relatively short section of roadway for the specific purpose of improving nighttime visibility.

Use In Texas

Safety lighting is used to provide the motorist with better visibility of short sections of highway. Common applications are at intersections, pedestrian crosswalks, and freeway interchange areas — where ramps and freeways merge and/or diverge. Safety lighting is added to traffic signal installations.

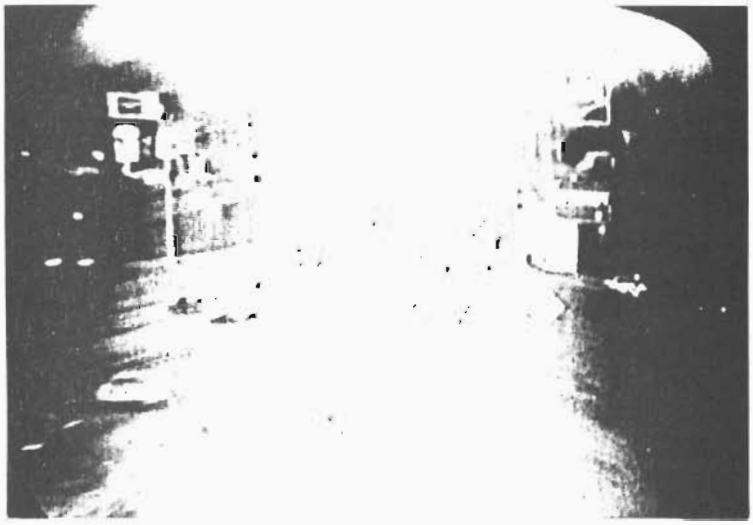
Expected Safety Improvement

With the addition of safety lighting, the nighttime accident rate reduction at intersection ranges from 28% to 62%. More complex channelized intersections have larger reductions than do relatively simple ones. At pedestrian crosswalks, accident reduction due to safety lighting is highly dependent upon the number of pedestrians using the crossing at night and ranges from 45% to 63%.

Benefits And Costs

The installed cost of a single 250 watt luminaire installed varies widely due to the mounting height, the type of pole used, the length of the mast arm, and the availability of power at the site. A reasonable average cost per luminaire is $1,500 to $2,000. Intersection and pedestrian crosswalk safety lighting normally requires two luminaires. Interchanges require a minimum of 8 and up to 12 luminaires for safety lighting jobs. The annual power cost per luminaire is approximately $90 per year. The luminaires are rated at 24,000 hours minimum life, about 6 years of service. The benefit-cost ratio for safety lighting is typically 3:1 and is always over 1.0 for urban situations. Rural safety lighting has a higher cost and a resulting lower benefit-cost ratio.

A traffic control center with television monitors.



Close-up of ramp control surveillance monitor.

Description And Function

Traffic control systems provide for the orderly, safe and efficient flow of persons and goods by motor vehicles over our surface streets and highways. The ordinary components of a modern traffic control system for an urban area include: (a) traffic control devices (signals, changeable message signs, etc.) (b) communications (for surveillance and command), (c) control and operating software (computer programs), (d) hardware (control center and maintenance facilities), and (e) technical staff. Traffic control can be as simple as a clock type timer at a four-way intersection or as complex as an interconnected system of signals operated by a central command center. Modern micro-processors allow for specialized timing of complex intersections, special timing for peak period traffic, and orderly traffic progression on major arterial streets.

Use In Texas

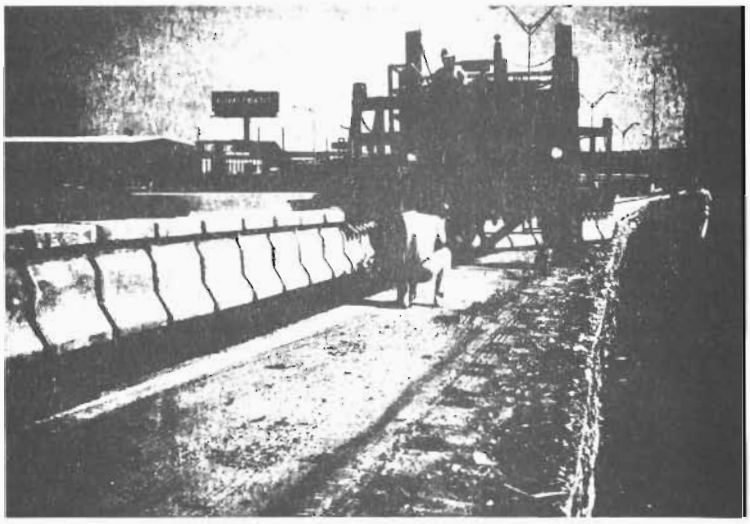
The placement of traffic control systems in Texas is guided by a system of technical criteria that are used to determine if a signal is to be installed, if it will be interconnected with other signals, and the control strategy that will be used for the system.

Expected Safety Improvement

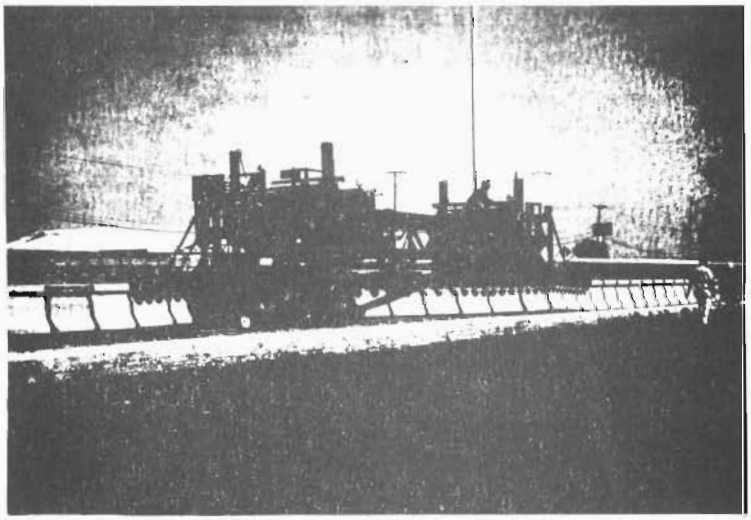
The major improvement expected from traffic control is in a more orderly movement of vehicles, although safety is a definite by-product of the traffic control system.

Benefits And Costs

Maintainability and reliability must be kept at high levels to provide safe control. Failing lights, detectors, and communication devices together with inefficient traffic control programs lead to poor traffic flow. The average life of a control system is about 20 years. Major upgrading is required after 10 years. Major retiming should be conducted every five years. Retiming should be done more frequently if traffic patterns are changing radically or growing rapidly. Retimings cost about $500 per signalized intersection with a benefit-cost ratio of at least 30:1. Upgrading costs of traffic control software and computers at 10-year intervals typically are $10,000 per intersection with a benefit-cost ratio of 5:1. Acquisition of a completely new system costs $50,000 per intersection and yields a benefit-cost ratio of 2:1.



Front view of Transfer/Transport Vehicle (TTV).



View of TTV moving the concrete barriers 8 ft. from shoulder.

Description And Function

A movable concrete barrier (MCB) is a segmented concrete barrier that can be manufactured to any of the "New Jersey" barrier shapes. The segments are 1 meter (3.28 feet) in length and are joined together by a pin and link joint. Continuous lengths of the barrier are lifted from the road, conveyed through an elongated "S" configuration across the road or away from the road, and set down to form a new lane or to be out of the way by the transfer and transport vehicle.

The MCB's primary function is work zone safety. The barrier can be moved and repositioned as a project progresses and can also be moved off of the roadway when not in use.

Use In Texas

Currently, Fort Worth is the only area in Texas utilizing the MCB. If results are favorable, the MCB may be used extensively on similar projects throughout the state.

Expected Safety Improvement

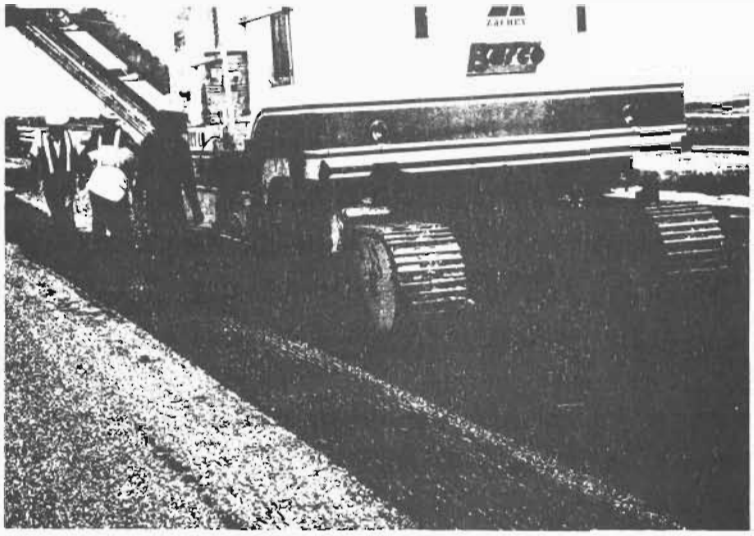
As are other concrete barriers, MCB's are designed to contain any vehicle that strays from travel lanes and encounters the barrier. Because the primary function is work zone protection, safety in this area is greatly increased. As can be seen, a concrete barrier is much more able to redirect a stray vehicle than are cones or wooden barriers.

Benefits And Costs

The concrete barrier itself costs $100+ per foot. This cost is higher than that of other types of concrete barriers because each meter section must be equipped with additional hardware for linking the pieces with each other.

The transfer/transport vehicle (TTV) cost is $185,000+ . The high cost is due to the complexity and specific purpose of the machine.

As with other concrete barriers, the life span of an MCB will be dependent on the severity of the crashes it experiences. Thus, the typical benefit/cost ratio will be in the area of 5:1.



Rotomill for texturing pavement.

Textured jointed concrete pavement.

Description And Function

Pavement texturing is used to reduce hydroplaning and increase skid resistance on concrete pavements, bridge decks, and other surfaces. The goal is to achieve a texture that is sufficiently deep initially and has a low enough decay rate to result in safe, high-friction surfaces that will endure for the life of the pavement. The basic texturing schemes are tining, sawcutting, carpet drag or artificial turf drag, brooming, roller grooving, and sprinkle treatments (though it is an addition to the pavement structure rather than a taking away, i.e., sprinkle treatment involves placing a high friction aggregate on the surface whereas the others involve cuts or grooves in the surface).

Use In Texas

Pavement texturing is used in Texas in areas where skid resistance has become poor or drainage has become inadequate. It is also used to increase safety factors in curves and steep gradients.

Expected Safety Improvement

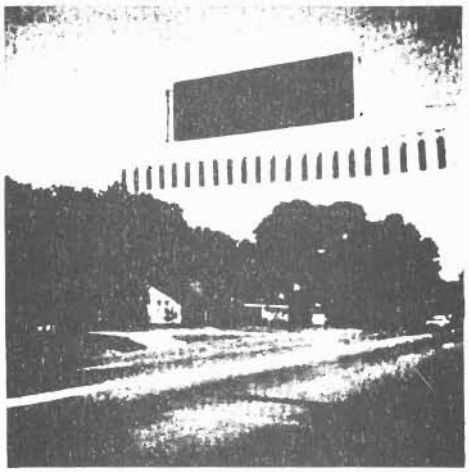
It is the hope of engineering practitioners that pavement texturing will decrease accidents caused by inadequate skid resistance and insufficient drainage. Macrotexture (or texturing) provides escape channels for water trapped between the pavement and a tire, allowing the tire to maintain its grip on the roadway.

Benefits And Costs

The benefits of pavement texturing include better drainage and better skid resistance of pavements which leads to reduced accident potential. The total benefit received will depend on the service life which in turn is dependent on the depth of the grooves, the type of surface, traffic volume, traffic characteristics (heavy trucks, etc.) types of tires (studded, snow chained, etc.) and others.

The cost of a texturing project is also variable. Cost is dependent upon the method of texturing used, the surface to be textured, the contractor's familiarity with the equipment and techniques, etc.

Overheight vehicle radar detector.



Hanging "ballast" warning device.

Description And Function

Advance warning systems are used to protect overpass structures against damage from collisions by overheight vehicles. These systems warn drivers of clearance requirements and some advise of alternate routes. A system may consist of electronically activated warning devices using radar beams, infra-red beams, etc., or simple cylindrical "ballasts" hung from wires representing the height of the approaching bridge.

Use In Texas

Texas has used the radar beam design (ex. Austin) and the cylindrical, hung "ballast" design (ex. Columbus) as advance warning devices.

Expected Safety Improvement

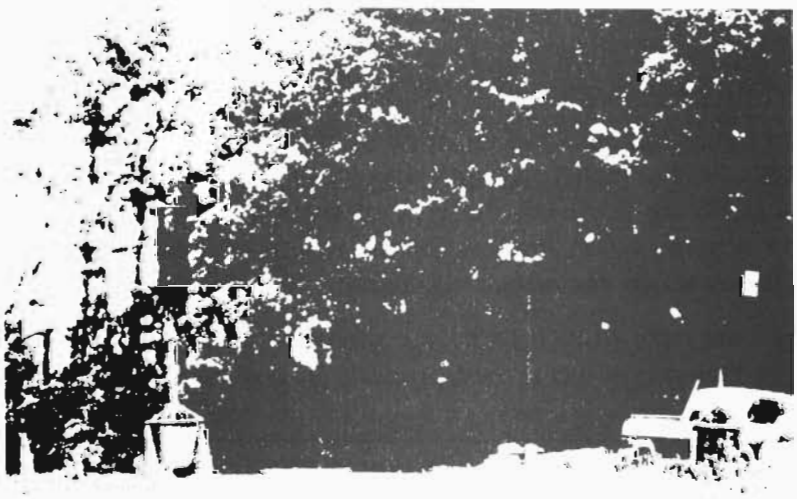
Advance warning devices, when properly aligned and in good working order, virtually eliminate overheight load/bridge clearance accidents. Proper clearance requirements result in a smooth flow of traffic and a reduced chance of congestion related accidents.

Benefits And Costs

The costs and benefits of an advance warning system for overheight vehicles is highly variable (benefits more so than costs). The cost of the system will be dependent upon the type used. It is feasible for a system which is electronically controlled to cost $50,000+.

The benefits of these systems are highly variable due to their dependence on the amount of truck traffic, the type of structure involved, the type of truck and/or equipment involved, etc. Also, it is difficult to do a benefit/cost analysis for the systems because of the wide range in severity of probable collisions which can be/are prevented.

The advance warning systems have proven to be a cost-effective means of protecting overpass structures and can pay for themselves when used properly in needed areas.



Construction site portable traffic signal setup.

Description And Function

Portable (or temporary) traffic signals are on some construction sites to regulate traffic movements in place of flaggers. A typical configuration uses 12 inch lenses with 150 watt output per lens. The device is generator-powered, with dual display so drivers will not disbelieve when they see an electric traffic signal where there was none before. Modern models are approximately 11 feet high at the bottom of the light hood and generally conform to MUTCD standards.

Use In Texas

Though not yet used extensively in Texas, the portable traffic signal has good potential for construction site traffic regulation.

Expected Safety Improvement

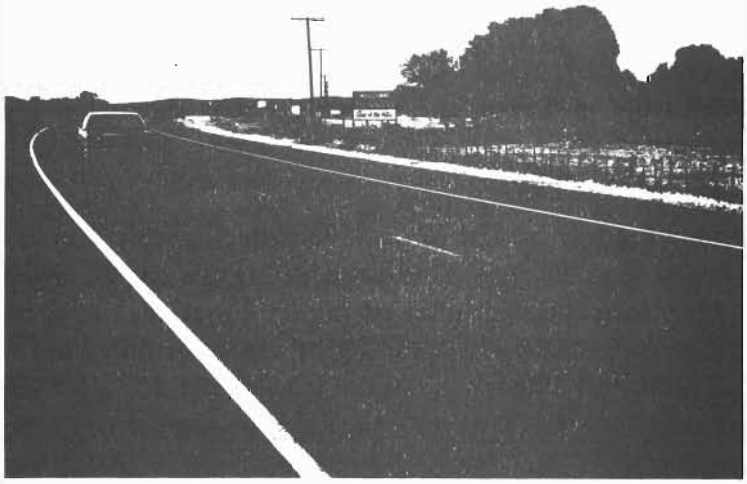
There is an increased factor of safety on the job site because superbly visible red-amber-green signals are much easier to see than flaggers. The portable signals can thus replace all but one flagger, the lone flagger becoming the controller of the light system. Other advantages of the portable traffic signals include: (1) elimination of flagger errors in judgment due to fatigue in poor working conditions, (2) lower liability rates for the contractor, and (3) minimizing of construction site "fender benders" with their petty property damage annoyances.

Benefits And Costs

The two units needed (two units are necessary) for use on a construction site could cost $20,000 to $25,000+ including generators and radio controls. Additional options which will increase cost may include a controller which sequences the lights on indication from the transmitter held by the flagger.

Assuming total hourly cost for a flagger is $10 to $20/hour plus an equal amount in fringes and taxes, a combination portable traffic signal could be paid off after 1,000 hours. The more flaggers it replaces, the faster the pay back period.

A benefit-cost ratio for this system is difficult to determine because of the possible benefit of saving lives.



Roadway edge striping.

Gore striping.

Description And Function

Pavement markings can be painted or stuck on, continuous stripes or dashed lines, yellow or white, straight or slanted but they have definite and important functions to perform in a proper scheme of traffic control. In some cases, they are used to supplement the regulations or warnings of other devices such as traffic signs or signals. In other instances, they are used alone and produce results that cannot be obtained by the use of any other device. In such cases they serve as a very effective means of conveying certain regulations and warnings that could not otherwise be made clearly understandable.

Use In Texas

Pavement markings are used continuously in Texas to separate lanes of traffic, to mark the edge of a lane or pavement, and in many other ways. The delineation follows the requirements set in the Manual on Uniform Traffic Control Devices (MUTCD) and is used in all needed or specified situations.

Expected Safety Improvement

It has been observed that basic delineation will provide major safety benefits where there was no previous delineation. It has also been observed that major improvements in delineation treatments on roadways that have some form of delineation can produce measurable changes in traffic performance. For example, delineation of the center line and outside edges of the traveled lanes is highly desirable on two-lane rural roads having paved surfaces at least 20 feet in width. It has been shown conclusively that such delineation results in significantly less lateral deviation, reduces driver stress, and in some cases, reduces accident potential. Drivers understand these markings and regard them as important to the driving task.

Benefits And Costs

The benefits of delineation include a smooth traffic pattern, improved traffic performance, a more aesthetically pleasing roadway, and possibly, life savings. The costs are usually minimum but, as stated, there is substantial evidence that delineation markings provide important guidance to the motorist, especially as visibility range decreases due either to adverse weather conditions and/or nighttime conditions. For these reasons, least-cost systems are generally preferred for the general roadway situations. The current state-of-the-art is now well enough established to provide minimum standard treatments for general situations in terms of line width, paint color, stripe-to-gap configuration and contrast.

Supplemental Safety Systems

Many other safety systems are being examined by the Department through research and field evaluations. Subsequent use of any system is based upon its overall and comparative effectiveness and economy. The following is a partial listing of these systems.

Bridge Barrier C202

A concrete barrier has been designed and tested that has the capacity to redirect school buses, 80,000 pound semi-trucks, and passenger vehicles. The barrier has a vertical face and concrete supports spaced every five feet. But, extensive national acceptance of an alternative design (the New Jersey barrier with it sloping face and ability to reduce property damage) has deterred utilization of the C202 barrier.

Monster Rail

A bridge rail, which is able to redirect an 80,000 pound, high-center-of-gravity tanker transport truck, has been tested. The barrier is 90 inches high and is scheduled for use by the Department at one selected high potential hazard location for testing. The added load and reinforcing requirement will enable only specially designed bridges to utilize this heavy duty rail.

Triple Corrugated Beam Bridge Rail

Bridges which were constructed many years ago occasionally used a through-truss steel design. These structures frequently had narrow roadways and are not readily widened. The primary objection to the use of triple corrugated rail is that the recommended design utilizes 8″ blockouts behind the rail element. This depth further reduces lane width available to the motorist. This concept has not yet been used; however, it may be useful at selected locations.

Breakaway Cable Terminal (BCT)

The use of a breakaway cable terminal (BCT) is an effort to provide an effective anchorage at the end of a guardrail, while eliminating the hazards of "spearing" or "ramping" of vehicles striking at that point. The BCT functions by breaking away and crumpling when impacted head-on and by redirecting the vehicle when impacted on the side. It works well for full-sized vehicles but is progressively less safe as automobile size decreases. At this time, it does not appear to meet national recommendations for guardrail end treatment performance. Installations of the BCT are undergoing field tests in Texas and other states.

Bridge Approach Guard Rail Transition

Where roadways narrow to cross a bridge, vehicles that strike the juncture of the approach rail and the concrete parapet suffer heavy damage. Fortunately, the frequency of this type of incident is extremely low. Present investigations are underway to address this problem, and an experimental treatment is scheduled to be installed by the Department for field observation.

Cable Barriers

Steel cables stretched between posts and tightened are an inexpensive and effective barrier system for use on low volume roadways. However, the total disruption of the barrier from a single impact usually exposes subsequent motorists to the obstacle for which the barrier was initially installed. Present investigaton of this concept is underway by the Federal Highway Administration to establish hardware and criteria for use.

Steel Bin Sand Barrier

The prevention of accidental median crossings and fatal injuries to motorists is an important consideration in the selection of a median barrier. A steel bin sand filled barrier has been designed and tested. It displays excellent vehicle containment and redirection performance. However, the needed maintenance of this design after an impact is a primary concern. The added hazard of loose sand on the roadway and the presence of bulky specialized equipment needed to restore the system to prompt service is of vital importance. Further, the excellent performance and low maintenance of the concrete safety shape barrier and its comparable costs to the sand bin barrier has discouraged active consideration of the steel bin sand system in Texas.

Sentre Gardrail Terminal

The Sentre guardrail terminal is a proposed safety treatment for guardrail ends. It is constructed from five breakaway steel guardrail posts, thrie-beam fender panels, and plastic containers filled with sand. When the terminal is struck on the end, the guardrail posts break away, and the vehicle is slowed to a stop. At present, there are in excess of 12 experimental installations of this Sentre guardrail terminal in Texas.

Tubular W-Beam Bridge Rail

The tubular W-beam bridge rail is designed for mounting on short bridges and culverts. It is a bridge rail made from standard steel guardrail components. It is made from standard W-beam barrier rail members welded back to back. The tubular rail element is relatively strong and is mounted on breakaway posts in order to cushion impacts. The system is designed to perform as a continuation of the guardrail. The tubular W-beam rail is designed to be a low cost, effective rail for short bridges.

Articulating Portable Traffic Barriers

Fast moving or temporary maintenance locations on the highway system always create hazards for the workmen as well as motorists. The articulated portable traffic barrier is made up of five salvaged station wagons, connected by specially designed towing bars, and shielded on the sides by metal beam rail sections. The lead car provides the power for mobility and braking. Crash tests indicated the unit could effectively redirect low angle passenger vehicle impacts. However, its actual freeway use has some major deficiencies: due to its limited length, it is not practical to shield most operations; the lead car lacks adequate power and braking capability to safely enter and exit the freeway system; and the unit is about 8 ft wide, which blocks one additional lane, creating an increased hazard to the public through longer traffic queue lengths.

Deep Steel Beam Guard Rail

Guardrail constructed from steel triple corrugation rail elements is commercially available. The increased vertical surface of the rail element offers some impact performance advantages over conventional "W" beam sections. Barriers made from this material show some potential for containing and redirecting vehicles with low and high centers of gravity. Several factors have deterred its use in Texas. The beam is stiffer and has the potential of generating more severe occupant injuries than the more flexible " W" beam. The greater weight will result in more difficult installation and maintenance. Also the beams are much more expensive than the standard rail. The New Jersey concrete safety shaped barrier offers more positive vehicle containment as well as reduced maintenance when used as a median barrier.

Energy Absorbing Bridge Rail

Bridge rails designed to contain both passenger and heavier vehicles place a severe stress on the decks due to usual rigid post/deck connections. An energy absorbing rail that utilizes a conventional metal box beam barrier element is being investigated. The rail is mounted on a heavy resilient backing similar to that used in ship fendering systems. The ability for this system to distribute the impact energy coupled with its restorative properties should prove to be very forgiving to the motorist and cost effective to the Department.

Rectangular Wood Guardrail Posts

Currently round wooden posts are being utilized on guardrail installations in Texas. Field performance and crash testing involving these members have indicated that they function adequately and produce a minimum of wheel snagging on vehicle impact. In some other states. a 4″ × 8″ rectangular sawed post is utilized for guardrail. This rectangular design has apparent adequate structural strength and creates monetary savings on post purchases. However, the blocks and longer bolts which are needed to reduce wheel snagging at each post add substantially to the installation cost of this system. National research of rectangular post systems is ongoing, and the results will be appraised by the Department when concluded.

Biological Impact Attenuator

Vegetative materials such as yaupon, wild plum, oleanders, and sumac have the potential for use as vehicle impact attenuators at selective sites where conventional systems are not practical. Presently, the cost, complexity, and maintenance of vegetation have generally deterred its active consideration.

Attenuation Devices Composed of Sand-Filled Automobile Tires

Several attenuation devices made from old auto tires were designed, tested and installed on the highway system to reduce the severity of accidents involving roadside obstacles. Performance of these devices was excellent, and auto damage and occupant injuries were greatly reduced. This attenuation system is no longer in active use because it has been replaced by other devices that are easier to maintain, look better, and do not create the debris problem (scattered sand and tires) after an impact.

VanZelm Dragnet

Protection of the motorist from the opening between twin bridge structures has always been a perplexing problem. A steel chain link fence installed across the median at these twin structures provides a means to capture the out of control vehicle. The ends of the fence are connected to anchor posts with energy absorbing coiled steel tapes. On impact, 50 to 100 feet of the steel tapes are stripped from their containers at a controlled rate. This product is currently used at only two locations in the State and is no longer commercially available.

Gravel Arresting Beds

Run-away trucks on down grades in mountainous areas create a special problem in designing a system that will safely slow down and stop these vehicles. Excavated beds filled with gravel provide effective restraint of such vehicles with no injury to their drivers. The use of generally high geometric roadway standards in mountainous areas has limited the need for gravel arresting beds in Texas.

Programmable Traffic Control Signal Heads

Programmable traffic control signal heads are used in special locations to avoid confusion to the motorist. The heads are programmed to be seen only in certain areas of the roadway. For example, a protected left turn lanes requires that motorists in adjacent lane desiring to continue straight through the intersection not be confused by the signal in the left turn lane. These signal heads are not widely used because of their higher initial cost, expensive maintenance, and limited need.

"Z" Highmast Illumination for Urban Freeways

"Z" highmast illumination for urban freeways has been developed and is currently being tested in the Houston area. The "Z" illumination forms a lighting pattern that allows the illumination poles to be spaced further apart and near the right-of-way lines. The reduced potential for pole impact at these locations and the more uniform lighting patterns are being examined for their improvements to roadway safety.

Mechanically Activated Devices to Warn of Water Over the Roadway

Low water crossings in the Hill Country west of Austin and San Antonio have experienced flooding conditions more frequently since land development in these areas has increased. Motorists have trouble judging the depth of the water at these crossings. A warning device accented by flashing amber lights is available that shows water depth. It is battery powered and activated by the rising water. Tests of these units are being conducted by the Department in Travis County to determine their feasibility.

Sprinkle Treatment

The dwindling supply of high friction aggregate for use in pavements has caused an increase in material costs and concern for their future supply. A process has been developed to use high friction aggregate only on the surface of newly placed asphaltic and Portland cement concrete pavements. Immediately after pavement placement, a special spreader is used to sprinkle high friction aggregate on its surface. Subsequent rolling or tamping of the sprinkled aggregate imbeds this material in the road surface. Currently this process is infrequently utilized due to the economics of the operation, the still abundant supply of quality aggregate, and the greater disruption of the operation of traffic in adjacent lanes.

Appendix I

Headlight Glare Screens

The glare produced from the headlights of opposing vehicles prompted the erection of headlight glare screens on median barriers. A secondary benefit of the screen was that it discouraged unauthorized pedestrian movement across the main lanes. Due to improved access control and the reduction in unauthorized pedestrian crossing caused by heavy freeway volumes, a reappraisal of the necessity for glare screens was warranted. The effect of ambient light, the characteristic use of low beam headlights in urban areas, and the presence of a 32″ high concrete barrier have indicated that the glare screen could be safely eliminated.

High Specific Intensity Sheeting

Sign materials utilizing reflective sheeting have long been utilized by the Department to enhance sign recognition by motorists. A new sheeting with a higher intensity has been developed and guidelines for its use have been prepared by the Department. But, the extreme intensity of this material can cause sign message legibility to be adversely affected. Therefore, selective use of this material is necessary to achieve overall safety optimization.

Powder Coated Guardrail

Effective use of guardrail serves both as a physical shield for a roadside hazard and a visual warning to motorists of the presence of that hazard. Dirt, grime and other road film, which quickly adhere to all highway fixtures, greatly reduce the visibility of guardrail. The use of a paint applied as a powder enables periodic reapplication of a highly visible surface to guardrail installations. Also, the special paint may tend to resist the accumulation of road film for a longer period of time than does the conventional galvanized surface. A field evaluation of the benefits of this concept is presently under investigation within the Department.

Fabric Signs

To perform roadway maintenance on high-speed facilities large warning signs must be systematically displayed to prevent serious accidents. No work activity on the travelway is exempt from this requirement regardless of its short duration. Using conventional wooden signs for temporary setups is troublesome. A large trailer must be used; also these signs have stability problems from wind buffeting of large vehicles as well as reduced service life from handling. A substitute fabric sign is available which can be rolled up for storage, and a full complement of signs can be carried in a small compartment on a vehicle. The ready access to any needed sign (even when performing unscheduled maintenance) and the additional versatility of a variety of stick-on messages are extremely important in maximizing motorist safety. A limited quantity of reflective fabric signs is being acquired and will be field evaluated at selected locations in the State.

Appendix I

Technology Transfer

The Technology Transfer group was established in 1983 to serve as a link between creators of ideas and techniques and potential users. The T^2 group has developed a variety of methods for passing along information that will help improve the Texas highway system. Among the methods are:

1. A staffed lending library containing more than 12,000 research reports, journals, and periodicals. Through this library, you can access all of the highway research done in Texas, as well as informaton published by the Transportation Research Board, the FHWA, other states, and some foreign countries. A video collection, including construction, maintenance, and safety topics, is also housed in the library.
2. Computerized literature searching that can do comprehensive title searches or subject searches. Subject searches are conducted through DIALOG, a computerized information system linking over 200 databases including the Transportation Research Information Service (TRIS).
3. A variety of publications serving different needs:
   a. *Research Digest*, an annotated bibliography to keep personnel apprised of new information that is available from the library.
   b. *Technical Quarterly*, a magazine created for the exchange of technical ideas. It features articles on any subject that makes jobs easier, less costly, safer, more productive, or helps the Department's work be more in line with what the public needs.
   c. *Innovations*, a single-page flier that features problem-solving "tips from the field."
   d. *Departmental Information Exchange BULLETIN*, the newest T^2 publication, features news on the research program, product evaluation, and experimental projects.
4. The Technology Transfer System (TTS) an automated storage and retrieval system, is currently being developed. With TTS and a PC or CRT, you can key-word search materials contained in the T^2 library, as well as field and laboratory evaluations of products and equipment, field research, and all T^2 audio/visual materials. The system has a planned implementation date of February 1989.