TRANSPORTATION RESEARCH DIGEST

May 2010

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TO: TRANSPORTATION PROFESSIONALS, MANAGERS, & POLICY MAKERS

FROM: ARIZONA TRANSPORTATION INSTITUTE

The volume of information on transportation issues, policies, technologies, and related topics is huge. Not even the most well-read professional can keep up with everything that might be useful to know. The *Transportation Research Digest* series is designed to expedite the transmission of information by condensing and summarizing significant documents. Busy professionals or managers may quickly obtain the gist of new developments and determine whether they need to see the full document.

The *Transportation Research Digest* is not meant to present definitive resolutions of scientific or policy controversies, but contributions to the pursuit of knowledge and the debate of issues. The intent is to be comprehensive rather than conclusive on the multitude of issues and topics of concern to those working in the field of transportation. Readers are encouraged to obtain the original document summarized in the *Transportation Research Digest* and subject the content to their own judgment.

Transportation professionals who would like to recommend documents to be summarized or submit summaries to be considered for inclusion in this publication are invited to do so. To recommend a document please send a copy (or information indicating how a copy can be obtained) of the research report to be summarized. To be considered, the report must meet the following requirements: (1) it is transportation related, (2) it is no more than two years old, (3) there is enough information in the report to warrant a two page summary. To write a summary, insure that the document being summarized meets the above requirements. The summary should be submitted in an electronic format. This summary should be in the 500 to 800 word range and may include tables and/or simple graphics—all of which must fit within the *Transportation Research Digest*'s two-page format. Submissions are subject to editing for clarity and length. We do not guarantee that all submissions will be published.

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Transportation Research Digests from December 1995 to November 2003 are available on request.

A "Topic" code in the Table of Contents will help readers more quickly identify items of interest. The topic codes are explained in the table below.

Code	Topic	Code	Topic
ADM	Administration	PLAN	Planning
AIRP	Airports	PRIV	Privatization
AVIA	Aviation	RAIL	Railroads
BIKE	Bicycles	RDSD	Roadside
CON	Construction	ROW	Right-of-Way
ECON	Economics	SAFE	Safety
ENV	Environment	STR	Structures
FIN	Finance	TECH	Technology
INOV	Innovations	TOLL	Toll Roads
MAIN	Maintenance	TRAN	Transit
MISC	Miscellaneous	TRF	Traffic
MVD	Motor Vehicle Dept	TRK	Trucking
PAVE	Pavement	VEH	Vehicles

Requests or inquiries may be made via e-mail (jsemmens@cox.net).

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Mechanical Properties of Tire Bales for Highway Applications by Brian Freilich and Jorge G. Zornberg, Center for Transportation Research, University of Texas at Austin, 3208 Red River, Suite 200, Austin, TX 78705-2650 (Texas Department of Transportation, Research and Technology Implementation Office, P.O. Box 5080, Austin, TX 78763-5080; http://www.utexas.edu/research/ctr/pdf_reports/0_5517_1.pdf) (Dec 2009)

Highlights

- The most notable cost savings associated with using bales is the reduction in cost of transporting and storing tire bales due to the instant volume reduction of the tires that can be accomplished at the site of the scrap tire dump.

Highway structures are typically created using materials that can readily be found at or near the construction site. If the nearby materials cannot maintain the required stability for the structure, engineers must find other cost effective alternatives. In projects where costs need to remain low and space must be conserved, innovative fill materials may be required in order to build the structure at a reasonable cost. Recently, the need for this suitable construction material has forced the Department of Transportation to use readily available scrap tires as the fill material, solving the need for a cheap material as well as a need to properly and safely dispose of the tires.

There have been numerous uses for scrap tires in highway projects, usually in the form of tire shreds or chips. Tire shreds have been commonly used as reinforcement elements mixed with soils, fill material for embankments, and as a fill material for asphalt pavements. Recent environmental and safety concerns regarding the combustion of large tire shred embankments have led to a significant reduction in their use in soil structures. Tire bales have recently emerged as an alternative scrap tire fill material for engineering applications because the bales use a significant amount of whole scrap tires, as well as the ease of constructing the tire bale structures as compared to tire shreds. Previous cost benefit analyses have indicated a taxpayer savings of $1.60 per tire when used as bales in highway applications rather than disposed of in landfills (Zornberg et al. 2004). Although there is interest in using tire bales as a fill material, the lack of material properties and cost data, and a fear of potential combustion within tire structures have hindered the use of tire bales as a viable alternative.

The overall objectives of this research program are to (1) define and measure the needed tire bale properties for design, (2) determine the feasibility of using tire bales in highway structures, including cost and stability considerations, and (3) develop specifications for the construction and use of tire bales in highway structures. The research program consisted of a series of laboratory and field testing programs to determine the mechanical and index properties of the tires bales. The laboratory testing was completed using innovative and large scale testing setups constructed specifically for this research program. Numerous design considerations, based upon the case history uses of tire bales, were modeled with the testing setups to determine the mechanical properties of the tire bales needed for future design. In addition, a literature review was conducted to determine the environmental impacts of the tire bales in soil structures, including groundwater contamination and the potential for exothermic reactions leading to combustion of the tire bale structure.

Results from the laboratory testing program were then used to study the stability of current scrap tire bale projects to ensure a satisfactory factor of safety. A cost benefit analysis was coupled with the analytical study to illustrate both the economical and mechanical advantages of reusing scrap tire bales in highway structures. A complete set of material characteristics of tire bales, specifications for the use of tire bales in highway structures, and cost benefit analyses will all be presented in the following document.

An in-depth cost benefit analysis and analytical study was presented for the use of tire bales in highway structures. The most notable cost savings associated with using bales is the reduction in cost of transporting and storing tire bales due to the instant volume reduction of the tires that can be accomplished at the site of the scrap tire dump. The cost of transporting tires in whole form is approximately $1.25, while transporting a whole tire in bale form only costs $0.42. Other cost benefits to using tire bales in highway structures includes the reduction in cost to make bales ($0.013) as compared to producing tire shreds ($0.64), and the ease of using tire bales in construction as compared to the methods required to place tire shreds.

The cost benefits of using tire bales in highway structures are illustrated using a series of case histories and construction alternatives commonly used for highway construction. In addition, each cost benefit analysis is coupled with an analytical study of the structure to illustrate the mechanical benefits of using tire bales. Both a limit equilibrium analysis and finite element code were used in the study. In general, the use of tire bales as drainage layers and reinforcement elements increased the stability of the structure. However, the low stiffness of the bales did increase the flexibility and deformations of the structures.

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Construction and Maintenance Practices for Permeable Friction Courses, *NCHRP Report 640* by L. Allen Cooley, *et al*. (Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; (202) 334-3213; http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_640.pdf) (2009)

Highlights
- The objective of this project was to recommend design, construction, maintenance, and rehabilitation guidelines that will maximize the advantages and minimize the disadvantages associated with the use of permeable friction courses (PFCs).

Information gathered from the literature review and survey of agencies was used to develop a state-of-practice on the use of PFCs. This state of practice is considered to be representative of practices used around the world, as a significant amount of literature was obtained and reviewed from other countries. The information gathered also was used to develop guidelines on the use of PFCs in order to accomplish the project objectives.

PFCs have been used since the 1970s. The initial use of PFCs was in Europe. Europeans took the U.S. version of open-graded friction courses developed in the 1930s through the 1970s and, through research, improved the performance of these mixes. Improvements primarily included the use of modified asphalt binders and fibers. The modified binders and fibers alleviated some of the problems that were encountered with open-graded friction courses in the United States.

Benefits realized from the use of PFCs are primarily associated with improved safety. PFCs have been shown to improve wet weather frictional properties, reduce the potential for hydroplaning, reduce the amount of splash and spray, and improve visibility. Other benefits identified in the literature included resistance to permanent deformation, smoother pavements (and, hence, improved fuel economy), reduced tire/pavement noise levels, and other environmental benefits.

Materials and mix design properties specified for PFCs were obtained from around the world. Materials used to comprise PFCs are coarse aggregates, fine aggregates, asphalt binders, and stabilizing additives. Stabilizing additives are used in PFCs to minimize the potential for draindown because draindown was identified as a major problem with open-graded friction courses during the 1970s and 1980s. Numerous methods of designing PFC mixes were identified; based on the information, the design of PFC mixes includes four primary steps: selection of appropriate materials, selection of a design aggregate gradation, selection of optimum asphalt binder content, and performance testing.

For the most part, PFCs are not given structural value within pavement structures. The literature did provide evidence, however, that PFCs do lead to cooler temperatures in underlying pavement layers. Cooler temperatures within the underlying layers provide a net increase in stiffness within these layers. This alone indicates that PFCs do add some structural value. The literature also suggested that there are two properties needed in order to establish a minimum lift thickness for PFCs: rain intensity and the permeability characteristics of the PFC layer. This information was used to develop a simple method for determining the minimum lift thickness for a PFC layer.

Construction of PFC layers is similar to most hot-mix asphalt (HMA) mixes with some slight differences. The primary difference in production of PFC is incorporation of stabilizing additives, namely fibers, because special equipment is needed for introduction of fibers. An important step in the construction process is transportation. Precautions should be taken to minimize the amount of cooling that occurs during transportation. Compaction of PFCs also is slightly different than for typical HMA; compaction is not conducted to meet some specified density, but rather, compaction is conducted to seat the aggregates. Only steel wheel rollers are used on PFCs, as vibratory rollers tend to fracture aggregates during compaction and pneumatic tire rollers tend to pick up the PFC.

The survey of agencies suggested that none of the agencies in the United States currently conduct operations to clean clogged PFC layers. Other general activities include preventative surface maintenance and corrective surface maintenance. Winter maintenance on PFCs is a perceived problem worldwide. Definitive methods for addressing PFC winter maintenance were not identified during this project. The literature suggested that experience was the only method for developing a winter maintenance program. However, the literature was explicit that PFC layers require a different winter maintenance program than typical dense-graded layers. PFCs reach freezing temperatures before dense-graded layers and stay at a freezing temperature longer. Therefore, more winter maintenance materials are required.

Rehabilitation of PFC layers is reasonably uniform around the world. In most instances, rehabilitation involves milling the existing PFC layer and replacing it with another PFC layer or another type of HMA. The literature did suggest that PFCs should not be overlaid unless they are sufficiently sealed.

The performance of PFC layers was divided into two separate categories: service life and performance life. Service life was defined as the length of time a PFC maintains its frictional properties and smoothness. Performance life was defined as the length of time the PFC maintains its beneficial properties. No specific literature was found that tracked the service or performance life of PFC layers. However, the literature and survey of agencies did suggest that most agencies expect 8 to 10 years of service life.

Limitations identified within the literature were essentially either related to winter events or clogging of PFC layers. Areas prone to heavy snowfalls are not recommended for placement of PFC layers. Areas that contain a lot of dirt or debris (e.g., near farms) also are not recommended for PFC placement. Other situations where PFCs are not recommended include projects that require long haul times, inlays, projects that require a lot of hand work, and critical pavement locations, including intersections or locations with heavy turning movements.

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America's Coming High-Speed Rail Financial Disaster by Ronald Utt (Heritage Foundation, 214 Massachusetts Ave. NE, Washington DC 20002-4999; ph 202.546.4400; http://www.heritage.org/Research/Reports/2010/03/America-s-Coming-High-Speed-Rail-Financial-Disaster; ph 202- 842-0200) (March 19, 2010)

Highlights
- High speed rail is extremely expensive per person served.
- Its impact on travel choices will be extraordinarily small.

In January 2010, the Federal Railroad Administration (FRA) of the U.S. Department of Transportation belatedly awarded $8 billion in the stimulus grants for high-speed rail (HSR) as authorized by the American Recovery and Reinvestment Act (ARRA). By pushing for these grants and promising to spend an additional $5 billion over the next five years, the Obama Administration has committed the United States to one of the most expensive forms of transportation that a nation could choose.

In addition to the billions of dollars in capital costs that the federal and state governments will incur, domestic and international experience indicates that the President has committed the nation to providing a perpetual stream of substantial subsidies to offset the difference between fare revenues and operating costs of HSR and passenger rail in general. As a result, the HSR program could come to rival the nature of some entitlement programs in how much it will contribute to out-of-control annual federal deficits.

The world's passenger rail systems consist mostly of "ordinary" passenger rail, which operates at average speeds between 50 mph and 85 mph. Some systems include a few genuine HSR lines. In the United States, passenger rail (Amtrak) is the most heavily subsidized of all passenger travel modes, requiring a federal subsidy of $237.53 per 1,000 passenger miles, compared to $4.23 for commercial aviation and $1.50 for intercity busses. Rail subsidies in Europe are just as high, if not higher.

Other countries' experiences with HSR and passenger rail in all of its costly forms are instructive in judging how fiscally damaging the Administration's enthusiastic commitment to HSR may prove to be.

Europe in General. In 2008, Amtrak's inspector general published an analysis of government subsidies to passenger rail in Europe and compared them to Amtrak's subsidies. One purpose of the review was to address the contention that passenger rail in other countries, especially HSR, operates at a profit (i.e., without subsidies). For 1995-2006, the study found that the governments of Germany, France, the United Kingdom, Spain, Denmark, and Austria spent "a combined total of $42 billion annually on their national passenger railroads." The $42 billion that these six countries, which have a combined population of 269 million, spent on just passenger rail in 2006 is roughly proportionate to the $54.8 billion (most of which was funded by user fees) that the government of the United States (population of 309 million) spent on all forms of transportation, including highways, rail, aviation, water transport, and mass transit.

To put the European commitment to passenger rail in perspective, rail ridership (high speed, conventional intercity, and metropolitan commuter rail) in these six countries accounted for just 7.9% of all surface transportation modes on a per passenger, per billion kilometer basis. This suggests that these countries received a poor return on their money given that more than 90% of passengers in these countries chose other travel modes--mostly auto--despite the subsidies.

Japan. Japan's passenger rail--both high speed and not-so-high speed--has been extremely costly and has been a contributing factor in the genteel process of decline now enveloping this onetime economic superpower. Japan began operating an HSR system in 1964 at speeds of about 130 mph. By the 1990s, speeds in excess of 180 mph were common.

As a result of this commitment to HSR and the costs associated with the rest of the passenger rail system, the Japanese National Railway (JNR) was losing $20 billion per year and was issuing debt to cover all but the $5 billion covered by direct government subsidies. By the mid-1980s, the JNR's accumulated debt exceeded $300 billion. Recognizing that the JNR was not financially sustainable as a government program, the government began privatizing the passenger rail system in 1987, converting the JNR into seven separate joint stock companies and selling them off to the public over the next several years.

In Japan, unlike the United States, where Amtrak's losses can be attributed to half-filled trains, a trivial market share, and powerful unions, about 28.7% of passengers traveled by rail in 2007--the highest rate of rail use in the developed world. Today, several of the restructured, privatized Japanese passenger rail lines run at a profit, but only because they were acquired at a fraction of their capital costs and the government absorbed much of the system's debt.

As the preceding analysis reveals, the potential for serious financial problems with an HSR program include:

- Perpetual massive government subsidies and larger budget deficits;
- Wasted money because few passengers will use the system even with the high per-passenger subsidies for operating and capital costs;
- Service provided to only a small fraction of the traveling public in a handful of communities;
- Additional burdens imposed on hard-pressed state governments, which will be required to match the perpetual federal subsidies to build the system;
- Little or no difference in passenger mobility or environmental quality; and
- The creation of high-paying, low-productivity union jobs for political supporters.
- While these deficiencies make the HSR program a winner for some of the President's supporters and some Members of Congress, it will be a major loser for the taxpayers who will be forced to fund this new system.

Most taxpayers will continue to travel by more cost-effective and largely self-financed modes, such as cars and airplanes. They will also find that government will continue to shortchange their preferred transportation choices, notably autos and airlines, to pander to key constituencies: environmentalists, rail hobbyists, and labor unions. Given that more than 20% of federal transportation funding already goes to transit, which serves less than 2% of passengers nationwide, the federal government is quite capable of squandering even more money on additional low-value and underutilized transportation projects such as HSR.

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Relationships between Lighting and Animal-Vehicle Collisions by John M. Sullivan (University of Michigan, Transportation Research Institute, 2901 Baxter Road, Ann Arbor, Michigan 48109-2150; http://deepblue.lib.umich.edu/bitstream/2027.42/64281/1/102396.pdf) (Oct 2009)

Highlights
- The higher risk of collisions in darkness versus daylight appears to be associated with posted speed limit.
- Methods that extend the forward preview would likely help reduce the risk of such crashes.
- These methods might include dynamic modification of the forward beam pattern to extend the driver's view of the road, perhaps using advanced front lighting system technologies.

Recent fatal crash statistics indicate that approximately 200 persons are killed annually on roadways as a consequence of animal-vehicle collisions (AVCs). The Centers for Disease Control and Prevention estimated that 26,647 motor vehicle occupants were involved in crashes with animals in 2001-2002 that required treatment for nonfatal injuries. The Insurance Institute for Highway Safety estimates that there are 1.5 million deer-vehicle crashes in the United States each year, with a cost of $1.1 billion in vehicle damages alone. AVCs are clearly a significant roadway hazard, and great effort has been expended investigating measures to mitigate the extensive damage.

Two broad classes of mitigation approaches have been taken. One attempts to reduce the exposure of animals (primarily deer) to roadway traffic either by constructing physical barriers or by using animal behavioral inducements. Physical barriers include use of fencing along strategic sections of roadway to restrict roadway access, construction of underpasses or overpasses to provide protected road-crossing paths, and reduction in the size of the herd in the roadway environs. Animal behavioral measures include use of roadside reflectors, deer whistles, and the scent of predators around roadways to induce animals to stay away. Although less expensive, these latter methods appear to be of limited effectiveness.

The other approach is intended to influence driver behavior by providing some form of warning or advisory information to better prepare drivers to avoid a collision with an animal in the road. Methods include placement of static road signs at locations where animals frequently cross, use of active signs that detect and signal the presence of animals, seasonal educational campaigns to advise drivers about periods of elevated risk, clearing densely wooded areas along roadsides to provide greater preview area to detect animals, use of restricted speed limits in problem areas, installation of roadway lighting, and use of in-vehicle night vision systems to assist detection at night. Most of these countermeasures depend on the assumption that driver behavior can directly influence crash risk. That is, an AVC may be avoided with adequate prior warning. Indeed, it is probable that reduced speed could mitigate the severity of damage resulting from an AVC. Thus, fatal AVCs may be avoided by the simple reduction of impact forces. However, it is also clear that many measures seek to identify the animal's location for the driver so that a collision might be avoided entirely. If AVCs result from situations in which the animal darts into the roadway, it may well be the case that such collisions cannot be avoided because drivers do not have sufficient time to detect the animal and make an effective avoidance maneuver. Indeed, the evidence about the usefulness of a preview is either scant or indicates no effect. For example, in one of the few studies of the use of roadway lighting to mitigate deer-vehicle collisions, there was no observed reduction in deer-vehicle accidents when lighting was present. Few other studies have attempted to address this question directly.

This report examines some of the characteristics of AVCs. First, crash trends in the United States from 1990 to 2007 are examined to determine how the animal collision picture is developing. Next, diurnal and seasonal trends are examined to obtain a general view of how AVC risk varies over time. This is followed by a geographic breakdown of AVCs by state to describe how risk varies within the United States. Finally, the interaction of vehicle speed and ambient light is examined to determine whether they interact in a way that suggests vehicle lighting and driver vision can influence crash avoidance.

In 2007, there were 223 fatalities in the United States in crashes for which a collision with an animal was the first harmful event. Compared to the 106 fatalities of that type in 1990, this change represents a 110% increase. Aanalysis suggest that this increase cannot be fully explained by increases in vehicle miles traveled, nor by changes in the general fatal and nonfatal crash rates. Animal-vehicle collisions (AVCs) represent an increasing share of the overall crash picture.

In the United States, about 77% of AVCs involve collisions with deer. One consequence of the prominence of deer involvement is that temporal patterns of crash occurrence broadly mirror the activity patterns of deer. Peak daily deer activity coincides with dawn and dusk. Similarly, peak crash levels follow this pattern, perhaps with some adjustment related to ambient light level: highest collision risk occurs about an hour after sunset when ambient light level has declined. Peak seasonal deer activity occurs during mating season in October and November, it declines in winter, and rises again in the spring. A similar pattern is found in both the fatal crash record and the fatal/nonfatal AVC profile for Michigan.

Perhaps the most significant result for vehicle lighting is that the relative risk of AVCs in darkness versus daylight appears to be associated with posted speed limit. Higher posted speeds result in proportionally greater crash risks in darkness. The effect is observed for fatal collisions compiled from the Fatal Accident Reporting System (FARS), and for injury and property-damage-only (PDO) crashes compiled from Michigan crash datasets. One implication of this association is that limited forward preview time results in elevated AVC risk, and that methods that extend the forward preview would likely help reduce the risk of such crashes. These methods might include dynamic modification of the forward beam pattern to extend the driver’s view of the road, perhaps using advanced front lighting system technologies. Extension of the forward view could also be accomplished with night vision enhancement and other advanced detection systems that help drivers identify the position of animals in the roadway.

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Safety Benefits of Paved Shoulders by Shauna L. Hallmark, Thomas J. McDonald, Ye Tian, David J. Andersen, Center for Transportation Research and Education, Iowa State University, 2711 South Loop Drive, Suite 4700, Ames, IA 50010-8664 (Iowa Department of Transportation, 800 Lincoln Way, Ames, IA 50010; http://www.intrans.iastate.edu/reports/Hallmark_paved_shoulders.pdf) (Nov 2009)

Highlights

- Paved shoulders may reduce run-off-road crashes by about 3%.

Single vehicle run-off-road (ROR) crashes are the most common type of fatal passenger vehicle crash in the United States. In Iowa, ROR crashes accounted for 36% of all rural crashes, more than 61.8% of rural fatal crashes, 9% of total crashes, and 32.6% of total fatal crashes in 2006.

Paved shoulders are a potential countermeasure for ROR crashes. Several studies are available that have generally indicated that paved shoulders are effective in reducing crashes. However, the number of studies that quantify the benefits is limited.

In 2004, Iowa adopted a paved shoulder policy for higher volume roads, but a wide range of paved shoulder types has been utilized for many years in the state. Because the benefits of paved shoulders have not been quantified, the Iowa Department of Transportation (Iowa DOT) requested a study to analyze the safety performance of various paved shoulder designs on a wide spectrum of traffic and roadway types.

The research described in this report was designed to evaluate the effectiveness of paved shoulders. As part of the research, two surveys were conducted that assessed the opinions of field maintenance personnel and law enforcement personnel regarding the effectiveness of paved shoulders. Most maintenance personnel felt that paved shoulders lead to reduced maintenance costs, and most law enforcement personnel felt that paved shoulders reduce ROR crashes and improve safety for officers who have to pull over for traffic stops.

This research also included a crash analysis for non-Interstate roadways where paved shoulders have been installed in Iowa. The team made site visits and collected roadway data for 256 roadway sections in Iowa. The majority included locations where paved shoulders had been installed, but a number of control sections were collected as well. Each test segment was reviewed, and the construction year in which paved shoulders were implemented was determined. In some cases, the roadway segment could not be located in a geographic information management systems (GIMS) database, and in other cases the construction year could not be determined. These cases were removed from further analysis. This resulted in a total of 220 sites analyzed, including 77 control sections and 143 test sections. Sections included both two- and four-lane roadways. Four-lane roadways were both divided and undivided.

A generalized linear model (GLM) using a Poisson distribution with a log link function was used to investigate the relationship between crash reduction and paved shoulder implementation. The response variable was monthly crash frequency. Traffic volume and segment length were modeled as offsets. An attempt was made to model only ROR and cross-centerline crashes, but because we were using individual months as the observation period, this attempt resulted in a large number of observations with no crashes, which made it difficult to fit an adequate model.

Model results indicated that the covariate for speed limit was not significant at the 0.05 confidence level and was removed from the model. All other variables that resulted in the final model were significant at the 0.05 confidence level. The final model indicated that the season of the year was significant for predicting the expected number of total monthly crashes, with a higher number of crashes occurring in the winter and fall than in the spring and summer. The model also indicated that the presence of rumble strips, paved shoulder width, unpaved shoulder width, and the presence of a divided median correlated with a decrease in crashes. The model also indicated that roadway sections with paved shoulders had fewer crashes in the after period than in both the before period and control sections.

The actual impact of paved shoulders depends on several other covariates, as indicated in the final model, such as installation year and width of paved shoulders. However, comparing the expected number of total crashes before and after paved shoulder installation for one scenario indicated around a 3% crash reduction in the after period, after accounting for differences in control sections.

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Truck Mechanical Condition and Crashes in the Large Truck Crash Causation Study by Daniel Blower and Paul E. Green, University of Michigan, Transportation Research Institute, 2901 Baxter Road, Ann Arbor, Michigan 48109-2150 (U.S. Department of Transportation, Federal Motor Carrier Safety Administration, 1200 New Jersey Avenue SE, Washington, D.C. 20590; http://deepblue.lib.umich.edu/bitstream/2027.42/64999/1/102509.pdf) (Mar 2009)

Highlights
- Post crash inspections showed that almost 55% of vehicles had one or more mechanical violations.
- Almost 30% had at least one out of service condition.
- Among mechanical systems, violations in the brake (36% of all) and lighting system (19%) were the most frequent.

The number of trucks involved in fatal accidents has remained relatively stable in recent years. The Trucks Involved in *Fatal Accidents Factbook*, *2006* shows that about 5,200 trucks were involved in a fatal crash annually, between 2002 and 2006, with the annual totals ranging from 4,950 in 2002 to 5,343 in 2005. Similarly, crash rates for trucks have remained stable in the past five years. The National Highway Traffic Safety Administration's (NHTSA) *Traffic Safety Facts, 2007* shows that fatal crash involvements for heavy trucks per 100 million miles varied only between 2.02 in 2007 and 2.22 in 2004 and 2005. Rates of injury and property damage only crash involvements slightly declined over the period, from 44 to 33 and from 156 to 147 per hundred million miles respectively.

It is the mission of the FMCSA to reduce the toll of deaths and injuries in truck and bus crashes. The Motor Carrier Safety Improvement Act of 1999 (Public Law 106-159), which established the Federal Motor Carrier Safety Administration (FMCSA), required the Agency to "conduct a comprehensive study to determine the causes of, and contributing factors to, crashes that involve commercial motor vehicles." To meet that requirement, FMCSA joined with NHTSA to design and operate the *Large Truck Crash Causation Study* (LTCCS).

The LTCCS is largest and most ambitious study of truck crashes to date. The Federal Motor Carrier Safety Administration has identified four key safety areas in achieving the goal of crash reduction: commercial and passenger vehicle drivers; commercial vehicles; the roadway and environment; and motor carrier safety management practices. The LTCCS included detailed information in each of the four key safety areas. The LTCCS was designed to include all elements in a traffic crash—vehicle, driver, and environment. In addition, extensive information is collected about the operator of each truck involved, including details about driver compensation, vehicle maintenance, and carrier operations.

Clearly, driver and other factors are important in truck crashes. This study was not designed to provide a full accounting of the factors that contribute to truck crashes, but instead to exploit the rich detail available in the inspection data on the condition of the vehicle and the compliance of the driver with FMCSA requirements. In all of the analyses, the salience of driver factors was clear. Even without looking at specific driver actions in the crashes, it is clear that driver condition is clearly associated with crash risk.

Yet the condition of the truck also plays a large role. If driver condition, training, and experience shape and limits the driver's contribution to crashes and the actions that cause crashes, the condition of the vehicle certainly shape and limit the driver's ability to respond effectively in avoiding crashes. Thus, FMCSA's role in supporting roadside inspections and enforcing the regulations governing vehicle condition is critical. Research such as the present study could be used to identify the systems on trucks most important to crash reduction and to drive improvements in those systems from the present level.

Finally, it is noteworthy that two recent surveys of safety practices among motor carriers both highlighted vehicle condition in reducing crashes. In a survey of safety managers of the "safest" motor carriers, 90% "agree[d] that deploying a defect-free fleet is the most important thing they do to ensure highway safety." In another survey of effective safety management techniques, safety managers at motor carriers ranked at-risk driver behaviors (e.g. speeding or tailgating) as the top problem area. High risk drivers is number two. But in identifying solutions to safety issues, safety managers ranked regularly scheduled vehicle inspection programs as the number one solution, with hiring of safe drivers based on criteria relating to driver crash, violation, or incident history as number two.

The LTCCS is the most richly detailed source of crash data currently available. The contrast just in terms of the inspection data alone in the LTCCS and what is available from conventional sources such as FARS, TIFA, and GES, clearly illustrates the value of the LTCCS project. The depth of analysis possible, down to the level of brake adjustment, is well beyond what has been hitherto possible. This is not to say that the LTCCS is without flaw. The way some of the data were collected, e.g., violations in the light system, limited the scope of analysis here, because the location of the lights in violation could not be determined for a large number of trucks. A more serious limitation is in the number of cases. Some suggestive associations could not be pursued because there were too few cases in the data set. But overall, the value of the comprehensive approach to crash data collection has been abundantly demonstrated. Follow-on projects, applying the lessons learned from the LTCCS, could provide great guidance to realizing FMCSA's mission to significantly reduce truck crashes in the US.

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A Novel Technique for Stiffening Steel Structures by Ayman M. Okeil, Yilmaz Bingol, and Rubiat Ferdous, Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA 70803 (Louisiana Department of Transportation and Development, P.O. Box 94245, Baton Rouge, LA 70804-9245; http://www.ltrc.lsu.edu/pdf/2009/fr_441.pdf) (Mar 2009)

Highlights
- Glass Fiber Reinforced Polymer may increase steel structure strength by 200%.

The use of Glass Fiber Reinforced Polymer (GFRP) pultruded sections for strengthening steel structures was investigated. The GFRP section was bonded to thin-walled steel plates in an orientation that contributes to the out-of-plane stiffness of the plate more than the in-plane strength as is the common practice in most fiber reinforced polymer (FRP) strengthening applications. The two parameters contributing to the out-of-plane stiffness were the geometric and material properties of the GFRP stiffener. Because of the GFRP stiffener orientation, it is possible to use low modulus FRP materials rather than the more expensive high-modulus materials.

Two types of specimens were tested to demonstrate the difference in behavior between both strengthening techniques (in-plane and out-of-plane). Axial tension specimens were tested with and without GFRP sections bonded to the steel surface. This in-plane contribution was found to increase the stiffness of the tension specimen by 13 percent, which is a modest gain that may be beneficial for stiffening flexible structures that suffer from excessive deformations such as moveable bridges. Beam specimens were tested to explore the proposed out-of-plane strengthening technique. The results showed that stiffening the beam delayed web shear buckling (designed mode of failure) and that the failure load was 56 percent higher than the buckling load for the unstiffened beam. The behavior of the stiffened beam was ductile yet to a lesser extent than the unstiffened beam, which is common with most FRP strengthening techniques.

No code provisions exist for estimating the shear capacity of steel beams with FRP stiffeners. The existing code was still used to estimate the increase in strength assuming that the GFRP stiffener behaved in an identical manner as steel stiffeners. According to these calculations, the code estimated a 219% increase in strength. This substantially higher estimate was due to the fact that the debonding of the GFRP stiffener was not taken into account. Thus, it can be stated that new formulas will need to be developed for estimating the strength of GFRP-stiffened steel webs. This will require a concerted research effort to cover the various parameters that may affect the performance of the proposed technique such as: (1) the ratio between out-of-plane geometric and material properties of the GFRP stiffener and the bare steel member, (2) the contact area between the GFRP stiffener and the steel member, (3) the orientation of the GFRP stiffener, (4) mechanical properties of the epoxy used to bond the GFRP stiffener, (5) the impact of cycling loading on the performance of the strengthening technique, and (6) the original mode of failure of the unstiffened beam (i.e., full plasticization, inelastic buckling, and elastic buckling).

Recommendations

Since this study was limited in scope, no specific implementation recommendation could be presented. Also, no code provisions exist for estimating the shear capacity of steel beams with FRP stiffeners. The existing code was still used to estimate the increase in strength assuming that the GFRP stiffener behaved in an identical manner as steel stiffeners. According to these calculations, the code estimated as 219% increase in strength. This substantially higher estimate was due to the fact that the debonding of the GFRP stiffener was not taken into account.

Thus, it can be stated that new formulas will need to be developed for estimating the strength of GFRP-stiffened steel webs. This will require a concerted research effort to cover the various parameters that may affect the performance of the proposed technique such as:

- the ratio between out-of-plane geometric and material properties of the GFRP stiffener and the bare steel member,
- the contact area between the GFRP stiffener and the steel member,
- the orientation of the GFRP stiffener,
- mechanical properties of the epoxy used to bond the GFRP stiffener,
- the impact of cycling loading on the performance of the strengthening technique, and
- the original mode of failure of the unstiffened beam (i.e., full plasticization, inelastic buckling, and elastic buckling).

Finally, the proposed stiffening technique may not limited to shear strengthening. The same approach can be used for any buckling prone member. For example, a compression flange may be stiffened in a similar manner by bonding a GFRP stiffener to its top or bottom surface. In other words, this study opens new venues for a wide range of new applications of FRP materials for structural strengthening.

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Arterial Intelligent Transportation Systems—Infrastructure Elements and Traveler Information Requirements by C. Michael Walton, Khali Persad, Zhong Wang, Kristen, Svicarovich, Alison Conway, Guohui Zhang, Center for Transportation Research, University of Texas at Austin, 3208 Red River, Suite 200, Austin, TX 78705-2650 (Texas Department of Transportation, Research and Technology Implementation Office, P.O. Box 5080, Austin, TX 78763-5080; http://www.utexas.edu/research/ctr/pdf_reports/0_5865_1.pdf) (Aug 2009)

Highlights
- Detection technologies are a key component to successful deployment of any arterial ITS technology system.
- Signal optimization is the most effective way to improve arterial traffic operations.
- If dynamic message sign systems are going to be deployed on the arterial network, they should be located in areas where realistic alternative routes exist.

Recent ITS technology developments have vastly improved the ability of TxDOT to monitor and manage its arterial systems. Research on arterial performance measures is of practical importance to develop optimal traffic management strategies and improve operational efficiency on urban arterial roadways. This research addresses two TxDOT goals: making the current transportation system more efficient through innovative arterial ITS deployments, and maximizing the benefits of existing ITS infrastructure and new arterial ITS deployments. Specifically, six research questions have been addressed:

1) What ITS strategies would be most beneficial to improve arterial management?
2) What are the desired ITS technologies & solutions to improve arterial management?
3) How to identify and prioritize arterials suitable for ITS deployments?
4) What are the practical performance measures?
5) What are the desirable traveler information and dissemination modes?
6) What are the technical and financial considerations for arterial ITS deployment?

There are three main emphasis areas that this research has addressed: 1) identify the elements of arterial management systems that would benefit most from ITS technologies and related real-time information; 2) identify the available ITS technologies that would have the most immediate impact on arterial management systems; and 3) identify performance measures and traveler information dissemination modes that most clearly provide arterial performance information to the traveling public. The first area of emphasis addressed the elements of arterial management systems in terms of the potential benefits derived from real-time arterial traffic information. The elements included arterial surveillance of operations and infrastructure, traffic control (providing for transit priority, emergency vehicle preemption, adaptive signal control, etc.), lane management (HOV facilities, reversible flow lanes, emergency evacuation, etc.), parking management elements, enforcement (speeding, red-light running, failure to stop/yield), integration with transit information systems, incident management, and traveler information.

The second area of emphasis addressed the ITS technologies available for arterial management in terms of their ability to provide the information needed for one or more elements of an arterial management system. The third area of emphasis addressed best-practice arterial performance measures, methods for quantifying these measures, and modes of disseminating this information to TxDOT staff, other agencies, and travelers.

Recommendations

Detection technologies are a key component to successful deployment of any arterial ITS technology system. No negative traffic impacts result from deployment of detection systems. So it is recommend using various means of data collection technologies such as detectors, video detection, GPS detection, cell phone detection, toll tag detection, and so on to improve arterial data collection.

Coordinated signal control plays an important role in responding to recurrent or nonrecurrent congestion. Signal optimization is the most effective way to improve arterial traffic operations. The software and hardware are already mature and widely available. Therefore, it is recommended that TxDOT should consider coordinated signal control implementation to enhance arterial system performance as the first priority.

Information dissemination technologies are essential for arterial management enhancement. Desirable characteristics of arterial traveler information systems include (a) Provide route and decision guidance (b) Be timely, accurate, available, and cost effective, and (c) Be easy to access and safe to use. It is recommended that TxDOT staff should fully consider these characteristics to maximize the benefits when implementing the information dissemination technologies.

Comprehensive websites offering a variety of content on traffic flow, incidents, construction, and weather that can be personalized to localized information for a specific user are most useful. Websites must be easily navigable and provide information in understandable text and graphic formats. Integration of the information into a graphical display might provide some users, especially infrequent pass-through users, with a better understanding of existing traffic conditions. These findings are recommended for TxDOT future use.

The ideal message design should reduce driver's uncertainty regarding traffic conditions instead of overwhelming him or her with unneeded data. An auditory method is adequate and effective when drivers are familiar with the network. If dynamic message sign (DMS) systems are going to be deployed on the arterial network, particularly during peak hours, they should be located in areas where realistic alternative routes exist. Specifically, the DMS should be located so that traffic can be easily redirected to an alternative route that under normal operating conditions has some available capacity to accommodate additional traffic volumes. These findings should be carefully considered for future information dissemination applications.

Arterial management can be integrated with TxDOT's traffic management plan so that the freeway traffic operations can be enhanced through improving the interactions between arterial and freeways. Therefore, it is recommended that TxDOT should actively integrate arterial and freeway operations systematically.

The technologies for vehicle registration/identification, toll collection, and ATIS are similar, and it is recommended that the possibilities for integration should be pursued. This integration would benefit arterial data collection as well.

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Evaluation of Best Practices for Controlling Signal Systems During Oversaturated Conditions by N.A. Chaudhary, C. Chu, S.R. Sunkari, K.N. Balke, Texas Transportation Institute, The Texas A&M University System, College Station, Texas 77843-3135 (Texas Department of Transportation, Research and Technology Implementation Office, P.O. Box 5080, Austin, TX 78763-5080; ftp://ftp.dot.state.tx.us/pub/txdot-info/rti/psr/5998.pdf) (Feb 2010)

Highlights

- When blocking occurs, increasing cycle length decreases capacity.
- Lagging phases with heavy demand improves throughput.
- A 500-foot single-lane left-turn bay is sufficient when cycle length is set properly.

Signalized intersections are often the source of urban traffic congestion, which may remain localized or quickly spread to adjacent signals or freeway off-ramps. The latter scenario occurs on a daily basis in many cities, resulting in increased delays, fuel consumption, vehicular emissions, driver frustration, and crashes. Unfortunately, no standardized procedures, tools, or guidelines are available to practitioners to provide for proper characterization and effective mitigation of specific congestion problems in their systems. The objective of this project was to develop guidelines for effectively combating congestion in traffic signal systems.

The project had four key tasks. First, researchers conducted a thorough review of literature to identify all previous research dealing with congestion at traffic signals. This task included assessment of documented field studies. Topics studied during this process included characteristics of congestion at traffic signals, their root causes, and tools available to minimize the impacts of these causes. This information provided the basis to develop preliminary guidelines for mitigating congestion at traffic signals.

In the next task, researchers gathered related information from selected practitioners in Texas. These practitioners included personnel from Texas Department of Transportation (TxDOT) districts, other public agencies, and consultants. Researchers limited the focus of this inquiry to Texas. To collect information about practitioners' perceptions regarding congestion at traffi c signals and practical approaches for its mitigation, researchers developed a questionnaire and sent it to 27 selected participants. Researchers received the completed questionnaire from 17 people and synthesized this information.

Next, researchers used a microscopic simulation program to study the capacity of an approach lane feeding traffic to a through plus a left-turn lane at a signalized intersection. The simulation enabled exploration of the impacts of bay-length, signal phasing sequence, cycle length, and traffic distribution on the capacity.

In the fourth and final task, researchers conducted limited field studies to refine and apply guidelines developed previously. For these field studies, they collected data for a small three-intersection system in College Station, Texas, and three intersections in Austin, Texas.

Data collection at the first site consisted of in-field manual data collection and extraction of data from video recordings at the site. For the Austin sites, data came from videos recorded by the City of Austin at sites selected by the researchers after field visits. Researchers used computer simulation and engineering judgment to derive and recommend improved timings for two of these sites.

The literature review revealed a lack of tools and guidelines for congestion mitigation in signalized systems.

Furthermore, there is a lack of published case studies to convey lessons learned. Even though a precise

definition of congestion does not exist, there is agreement that congestion results in detrimental queuing.

Therefore, a major thrust of research has been on the development of procedures for queue management. Most procedures assume knowledge of true demand and capacity, which is assumed to be fixed. In congested signal systems, these assumptions are not true. Conceptually, accurate demand estimation should be possible by monitoring queue-change over time. However, field studies in this project revealed that this is not always possible. This challenge can be overcome by using a repetitive process of demand assessment and timing adjustments. Simulation experiments revealed that signal capacity is a function of geometry, traffic conditions, and control parameters, and may be significantly less than expected. Key findings include:

- When blocking occurs, increasing cycle length decreases capacity.
- Lagging phases with heavy demand improves throughput.
- A 500-foot single-lane left-turn bay is sufficient when cycle length is set properly.

The two cases studied in this project showed how to mitigate traffic congestion under certain conditions. At the College Station site, field observation and available tools demonstrated the benefit of using shorter phase times. The second study demonstrated how congestion could be mitigated using simple field observation and expert judgment.

Mitigating traffic congestion in traffic signal systems is not an easy task because common assumptions about capacity are often violated and because demand is difficult to assess when queues have grown beyond certain bounds. Adverse impacts of congestion can often be reduced by proactive management. This strategy requires optimal controller settings, functioning traffic sensors, and properly trained and experienced staff.

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Analysis of the Potential Benefits of Larger Trucks for U.S. Businesses Operating Private Fleets by John Woodrooffe, Bruce M. Belzowski, James Reece and Peter Sweatman, Transportation Safety Analysis Division, Automotive Analysis Division, University of Michigan, Transportation Research Institute, 2901 Baxter Road Ann Arbor Michigan 48109-2150 http://deepblue.lib.umich.edu/bitstream/2027.42/65000/1/102510.pdf) (May 2009)

Highlights

- If a 14,000 lb additional cargo weight allowance (97,000 lb GVW) and Interstate usage of twin 53 ft trailer LCVs were permitted, diesel fuel reduction would be nearly 3 billion gallons and the amount of CO2 produced would be reduced by over 65.3 billion lbs.

This study examines the current operational and economic performance of a sample of companies that operate private fleets and establishes a present-day baseline of transport productivity and efficiency. It also estimates how transportation performance and environmental impact would likely change if the existing federal limitations were to be lifted, resulting in greater maximum gross vehicle weight (GVW) limits and the use of long combination vehicles (LCVs). The study benchmarked the current transportation efficiency of a sample of companies operating private fleets identified in concert with National Private Truck Council (NPTC). The parameters that were used to define efficiency focused on over-the-road operating costs, cargo transported (both by mass and volume), and miles travelled. It includes measures of fuel use, emission output and truck trips required for the companies' annual transport tasks.

Findings

Increases in weight and length would have a direct beneficial effect on the challenges facing American businesses. The main future challenges over the next five years that interviewees reported focus on fuel availability and cost, congestion, improved distribution efficiency, and driver availability. In general, these challenges would benefit from the opportunities they see should vehicle weight and length be increased. The analyses show that fuel costs are reduced significantly through the reductions of shipments due to increased vehicle weight and length. Companies' experiences with LCVs in some states suggest some of the congestion reduction and distribution efficiencies these provide. They also explain some of the challenges of moving freight outside of the major highways.

Large numbers of companies can benefit from increased tractor-trailer weight and length. The analysis of the potential benefits of increased trailer weight and length provided a number of ways of measuring the benefits. The survey of the NPTC membership found that that 56% of the companies' shipments weigh out and 34% cube out which present significant opportunities for benefit from either heavier or longer vehicles. Finally, the survey respondents were asked to estimate the percent reduction in shipments/truckloads for their company if the 80,000 pound weight regulation was changed to 97,000 pounds. These estimates were checked against the detailed data collected from the companies to ensure consistency. When discrepancies were found, the companies were contacted and the differences resolved. The estimate of reduction in truck loads was 10% if the allowable weight was increased and 6% if LCV's were permitted. If both strategies were implemented, then the estimated reduction in truck loads from the members surveyed would be 16%.

Companies report significant potential benefits from tractor-trailer weight and length increases. The interviews with a cross section of NPTC companies revealed that the gains from increases in tractor-trailer weight and length would be primarily from the cost of operations and vehicle miles traveled, though some companies will also gain from improved customer service, product mix, and reduced time to market. The quantitative analyses of each company's operations bear out these observations. The major potential operating cost benefit of increased tractor-trailer weight or length would be reduced diesel fuel consumption from needing fewer shipments, either because a trailer that now weighs out could carry more cargo, or a company whose trailers frequently cube out could add a second trailer. The reduction in miles per gallon due to heavier or longer trucks would be greatly offset by the significant improvement in transport efficiency (amount of fuel used per cargo unit transported) and the reduction in total miles driven from making fewer shipments.

Increasing the weight or length of vehicles also provides benefits for the environment and national fuel supply through reduced energy consumption. Three impacts of fewer shipments on the overall economy and the environment are less traffic congestion, less fuel consumption and fewer emissions, particularly carbon dioxide (CO_2), resulting from fewer truck trips, less congestion and fewer hours of idling. For the five companies that could benefit from additional cargo weight of 14,000 lbs., their total annual fuel reduction is estimated at 10.8 million gallons, which would result in a reduction of 240 million lbs. (120,000 tons) of CO_2. With an 8,000 lb. increase, the fuel reduction of 7.5 million gallons would result in a CO_2 reduction of 167 million lbs. (83,000 tons); and for the three companies that would benefit from LCVs and would consume 23.8 million fewer gallons, it would be 528 million lbs. (264,000 tons).

If a 14,000 lb additional cargo weight allowance (97,000 lb GVW) and Interstate usage of twin 53 ft trailer LCVs were permitted, and the fuel consumption and emissions reduction benefits estimated for this study's subset of vehicle fleets were representative of the national class 8 truck fleet (which is unknown), then the national annual diesel fuel reduction would be nearly 3 billion gallons and the amount of CO_2 produced would be reduced by over 65.3 billion lbs. (32.6 million tons). If only an 8,000 lb cargo increase were allowed (91,000 lb GVW) along with LCVs, then the national annual diesel fuel reduction would be 2.6 billion gallons and amount of CO_2 produced would be reduced by 58.6 billion lbs. (29.3 million tons).