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AESTHETICS AND DESIGN: A HIGH TECH CONSTRUCTION SOLUTION IN SAN ANTONIO

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BACKGROUND

Highways and highway structures don't just pass through communities: they become part of them. In this era of increasing population, there is growing pressure that urban structures be multi-use facilities that aesthetically improve the community. San Antonio District faced not only these problems, but also a number of design challenges in the reconstruction of the San Antonio Downtown Y, so named because IH-10 and IH-35 join and separate in the shape of a "Y" in the heart of San Antonio (Fig. 1). The solution involved complex design and state-of-the-art concrete construction methods, as well as cooperation with City of San Antonio planners for future landscaping of areas under the bridge in the El Mercado (The Market) District of west San Antonio.

Portions of both interstates had been constructed in the 1950s. Commercial properties had grown up around the highways making it virtually impossible to acquire more right-of-way to expand the facilities horizontally. Also, by 1978 traffic counts were already double what they had been in 1960 and

FIG. 1a: San Antonio Downtown Y.

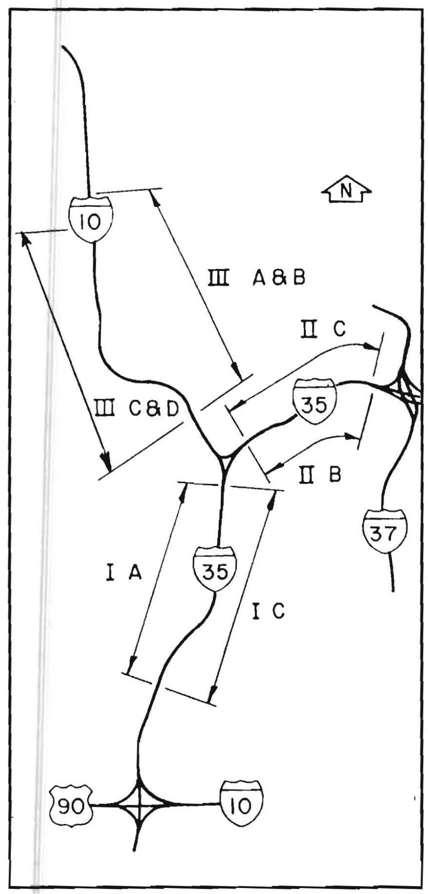

FIG. 1b: Plan view [Ref. 2, p6].

INSIDE...

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FIGURE 2: The winged segmental design chosen.

were predicted to double again before the year 2000 [Ref. 4]. New lanes were needed to increase capacity, but they had to be added without severely disrupting traffic flow during construction. In addition, San Antonio, a city which relies heavily on the tourist industry, needed the benefit of an outstanding, elegant structure.

DESIGN

The State Department of Highways and Public Transportation (SDHPT) established a plan of reconstruction that would: (1) require minimal purchase of new right-of-way; (2) have minimal impact on traffic during construction; and (3) be an aesthetically pleasing addition to the highway system in urban San Antonio. The plan combined at-grade traffic lanes with elevated lanes, generally within existing right-of-way. Several types of structures (prestressed concrete I girders with concrete deck, steel plate girders with concrete deck, steel box girders, concrete box girder, etc.) were considered for the elevated portion [Ref. 2] . A winged box girder built segmentally, span by span, seemed to solve the aesthetic and construction demands. The uncluttered, sweeping lines of the winged segmental spans appear light and graceful (Fig. 2). The span-by-span method of construction allows the new outermost inbound and outbound elevated lanes of the structure to be built almost entirely from above, using trusses and cranes, while the 100,000 average vehicles per day are carried on the existing main lanes. With careful construction sequencing and traffic control, this volume was maintained with surprisingly little delay (Fig. 3).

Two firms, T. Y. Lin International and Harland Bartholomew & Associates, were hired to do preliminary structure designs and prepare plans for the first three of six major construction contracts. Figg and Muller Engineers produced an alternate design. The first contract of each leg was let with the base and alternate designs. The successful low bid construction method was then to be used on the remaining parts of that leg. The alternate design won the contract on all three legs of the project. The alternate design consists of one-piece cross sections of match-cast precast elements and makes extensive use of concrete with 28-day strength of 6000 psi and of post-tensioned tendons in both the longitudinal and transverse directions [Ref. 4]. Considerable refinements to decrease weight, to reduce the number of precast units, and to simplify construction steps and post-tensioning operations have been made to the original designs. The last three contracts, designed by the SDHPT Bridge Division (D-5), carry these refinements even further. The cost of construction is approximately $36 a square foot of completed bridge deck.

The Downtown Y is one of the most complex segmental structures yet built. While the concept of segmented post-tensioned concrete is not new, the use of it throughout a structure incorporating curves, superelevations, ramps and gore points is (Fig. 4). To execute the design, some sophisticated construction methods and refinements of old methods were needed. Over the last ten to twelve years, various research projects at the Center for Transportation Research at the University of Texas and the Texas Transportation Institute at Texas A&M

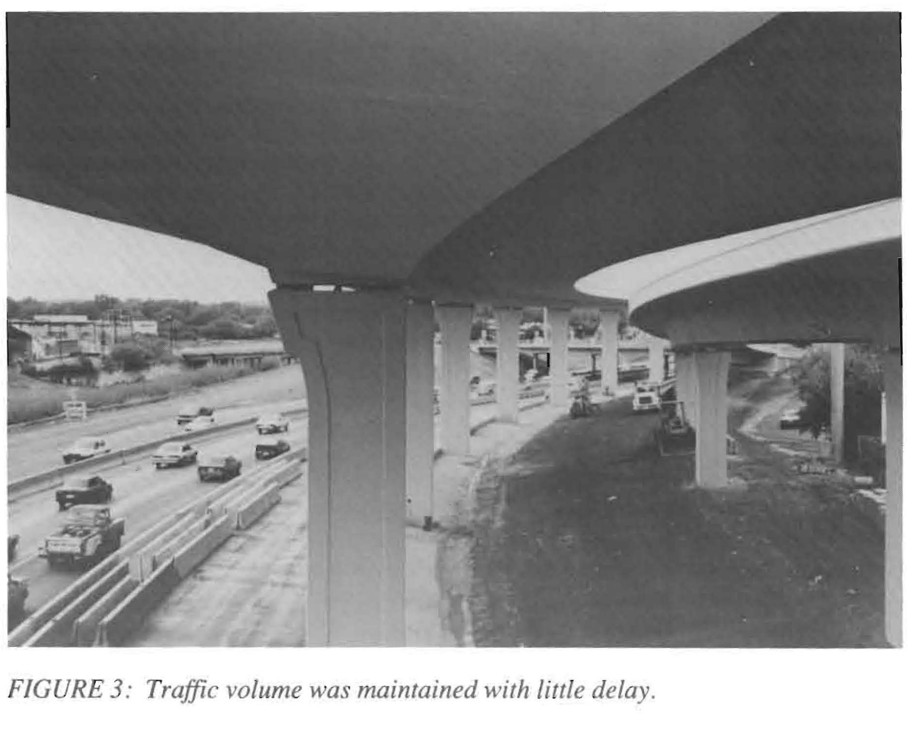

FIGURE 3: Traffic volume was maintained with little delay.

have contributed to technologies incorporated in the construction of this project. One technique that was refined is match casting of precast elements.

CONSTRUCTION

Casting

The match-cast technique requires considerable and very accurate control of the casting process to achieve proper horizontal and vertical alignment [Ref. 1]. Segments are cast in the various contractors' casting yards set up for the project five to ten miles away. Specialized adjustable steel forms (eight to ten per casting yard) are used to cast the segments. There are generally at least two sizes of box girder on each job, and each box size requires at least two casting cells: one for pier segments and one for span segments. Segments that are heavily congested with reinforcing steel and ducts for internal tendons (Fig. 5) use concrete mixtures containing high range water reducers to ensure good consolidation.

District 15 found it was necessary for district inspectors and contracting personnel to pay great attention to details such as tracking theoretical casting curves, then reading casting points to see how closely the actual points compared to the theoretical ones. Keeping exact logs of what truckload went into what column was another necessary quality control measure. With exact logs, if problems developed, the mix characteristics could be analyzed along with the placement conditions to quickly trace the root of the problem.

The learning curve for both district and contractor personnel was longer than anticipated, but the project has finally developed momentum. Start-up time has averaged about 10 months for contractors to establish original casting sequencing, design the necessary forms for the individual contract, obtain erection equipment, cast a supply of segments and train crews sufficiently before erection of spans can begin.

FIGURE 4: Ramps, gores, and superelevations make segmental design complex.

Span Erection

There are ten to seventeen segments per span. The average span length is 100 feet. Units between finger-type expansion joints consist of either two, four or six spans [Ref. 3].

A span can be erected in approximately forty to forty-five working hours, twice as long as originally hoped for. Segments are delivered to the site over completed spans of the structure, picked up by a crane, and set on the erection girder, where they are "dry-fitted" to ensure proper alignment, before epoxying. Epoxy is applied to both faces of the joint, and the joint is temporarily clamped while the epoxy cures. After the epoxy has cured, work on the closure joints and post tensioning begins.

All of the spans have at least one closure joint pour, either at the centerline of the pier or on either side of the pier segment. Currently, the centerline joint is the most common. First, the bottom slab closure joint is placed. The bottom slab internal tendons are installed and stressed, after which the remainder of the closure joint is made. Next, the external tendons are installed and stressed. Draped external tendons overlap at pier segments to provide continuity [Ref. 2]. The span is complete at this point, and the erection girders are advanced.

Various erection girders were used by different contractors. The most sophisticated, to date, is a steel box girder with an inverted cable-stayed system that allows for grading the girder. Adjustments in grading were made using built-in jacks. This type of girder can be advanced from span to span without any support from the ground (Fig 6).

The entire project will receive an overlay, upon completion, to give a uniform riding surface.

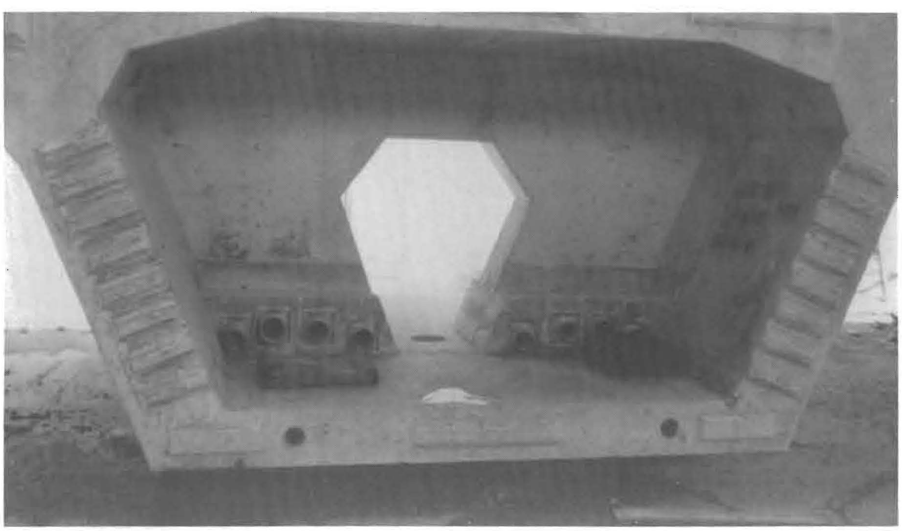

FIGURE 5: Detail of a match-cast segment.

Construction Problems

As one might expect on an innovative project of large scale, most significant problems arose from inexperience.

Once contractor personnel and district inspectors learned what the complex design and new construction techniques demanded, span erection smoothed out. After a long and frustrating start, the project has had no more than the usual share of design flaws, personnel errors, material inconsistencies and equipment malfunctions.

The most frequently occurring problem was that of concrete consolidation. Even with superplasticizer, getting enough vibration to consolidate properly all areas of a segment was sometimes difficult, and honeycombing resulted in some segments. Acceptance criteria were established that determined whether a honeycombed segment could be patched or must be rejected.

The other recurrent problem was damage to alignment and to shear keys. This damage usually took place in the casting yard.

AESTHETIC FEATURES

The uncluttered graceful appearance of the Downtown Y is in part due to the mostly single column substructure. The columns flare to blend with the spine. Painted insets create the illusion of columns narrower than they actually are. Illumination is provided under the deck to the roadway and to the right-of-way .

Dedicated to the belief that the Department should be sensitive and responsive to the needs of the public, John Kight, District 15 Design Engineer, and his staff have worked closely with the City of San Antonio to plan an under-the-bridge plaza near the El Mercado that will be a model of urban development and multiple usage. Landscaping calls for benches, for fountains (the district is providing hookups and drainage during the construction of this leg of the Downtown Y) and for colored, textured pavers. The different colored pavers will coordinate with maps which will lead tourists to different are as of interest. There will be a bay provided for buses to load and unload passengers as well as an area for public parking.

The district put a great deal of effort into presenting the concepts appropriately to the public and showing the city council that aesthetic design does not have to be more expensive. The costs for extra details like the under-the-bridge plaza will be recovered in tangible ways like increased commerce and intangible ways like civic pride.

MAINTENANCE

The most beautiful structure in the world cannot be preserved without maintenance. With a structure as complex as the Downtown Y, short range constructibility had to be coupled with long-term maintenance in the original design concept [Ref. 1]. Access ports are cast in to certain segments so the external tendons and the interior of the boxes can be inspected. The District bridge maintenance team has been on a "guided tour" to familiarize them with the structure and its important features. A maintenance manual was developed specifically for the Downtown Y bridges. Two maintenance contracts have already been let to keep up with the routine maintenance that will keep this bridge looking and functioning beautifully for decades to come.

SUMMARY

The winged segmental Downtown Y project has fulfilled its three main goals: to provide an aesthetically pleasing structure for an urban area; to minimize the purchase of right-of-way; and to minimize impact on traffic flow during construction. It is the most complex segmental structure ever built. New construction techniques were used to execute the design. Inexperience hampered the start of the project, and most significant construction problems relate directly to personnel inexperience and the inherent complexity of the design. However, the overall experience with segmental construction was positive, and a tremendous amount has been learned about simplifying and speeding up this type of design.

Aesthetics, not only of the structure itself, but also of the landscaping beneath the structure were given close consideration. Planning for an open air plaza under the bridge near the El Mercado was done jointly by District 15 and the City of San Antonio.

The Bridge Division anticipates using span-by-span segmental construction on other urban structures where aesthetics, constricted right-of-way, and construction access are deciding factors.

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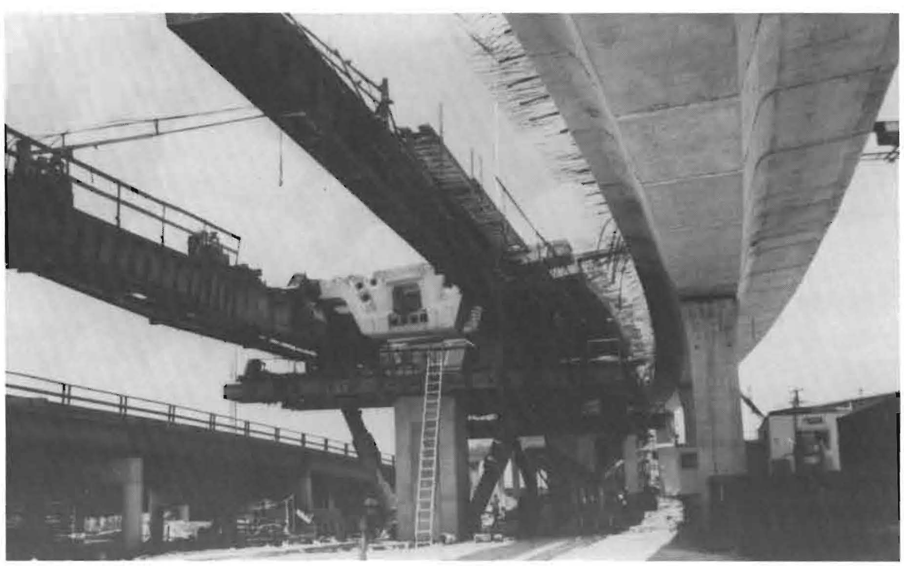

FIGURE 6: Dry-fitting a segment using a sophisticated erection girder.

HUMAN FACTORS IN DRIVING AND INFORMATION TECHNOLOGY

"Information technology is the tool of tomorrow. It will expand rapidly in the area of road traffic as it has in other areas of society. The main reason is that this technology constitutes a large rationalization potential which, contrary to other means, gets less expensive every day," said Professor Kare Rumar, Swedish Road and Traffic Research Institute (VTI), at the "Road Safety in Europe" conference, held in Göteborg, Sweden, in October 1988. Proceedings of the conference have now been published.

Information technology includes hardware (sensors, microcomputers, actuators), telecommunications (transmitters, receivers, etc), and software (signal analysis, expert systems, artificial intelligence, etc.).

Rumar says, "In some respects human performance is by far superior to technology as it is today represented by sensors, processors, artificial intelligence and actuators. Take for instance the simple human task of steering a car along the road — the most simple of all driving tasks. Even in daylight, that would be quite complicated to accomplish by purely technical means, and in adverse weather conditions would be close to impossible. Man has a wonderful quality to analyze and structure complicated visual stimuli in a fraction of a second. But man also has several limitations, and it is probably primarily here that support from advanced information technology is wanted."

One such limitation is physiological. "A driver may behave wrongly all his life and benefit from it, e.g., drive with short headways, overtake dangerously, over-estimate his visibility in night traffic, exceed speed limits, or not slow down for children at the curbside. Due to lack of continuous feedback (even negative feedback), road users improve very little just by participating in traffic. Inadequate expectations are created and established.

"Another psychological limitation is our limited capacity to process complicated and extensive information in a short or limited time. This problem is most pronounced in city center intersections with signs, signals, cars, cyclists and pedestrians. The way out is to concentrate on a few of these pieces of information. Sometimes this choice is wrong."

Sociological limitations involve personality changes. "Queueing in shops and sidewalks is very different from queueing on the roads. Nobody would dream of breaking or pushing himself into a post office queue. But that is almost normal behavior on streets. When walking, it is normal to allow the other person to enter a door first. When driving, similar behavior is exceptional. Sometimes we also make mistakes on foot. But that is very easy to solve by e.g., an apology. In driving, almost every little mistake is taken by the other driver as provocation. And the car has no signal for "Excuse me — that was not my intention."

"The closed-in situation of the driver creates an isolation, an anonymity, a feeling of 'everybody on his own' which releases behavior that is normally blocked by social norms, social contacts. Drivers tend not to be responsible. To be reckless, to break the traffic rules and laws are very low on the subjective criminology ranking of most people."

In assessing the future role of information technology, said Rumar, we must remember that the computerization of road traffic must be acceptable to the public and to drivers. Studies show that some important factors here are: no threat to personal integrity, no threat to driver control of the car, filling the needs of the driver, system reliability, user friendliness, and costs of investment and use. The new equipment must not introduce any new problems such as distraction (compare the mobile telephones of today).

Any measure introduced will be used by the driver to the best of his interest. That is to say, every measure introduced to improve safety will be used by the driver to improve safety only to the extent that he considers himself to have a safety problem.

If it becomes much more simple and effective to drive, each car will probably be used more, and longer distances driven. This would in itself impair safety, since we know that the correlation between exposure and accidents is high.

The lifetime of cars and drivers is steadily increasing. Consequently many vehicles will for a long time not be equipped with the new type of systems. How can safety be improved in traffic where only a proportion of vehicles are so equipped?

Half of the victims in road traffic are unprotected road users. If we really want to improve safety we have to include them into the system. But how can we equip pedestrians and bicyclists with advanced information technology?

From ***World Highways*** *40(July/August 1989):5.*

NO-STOP TOLL STATION OPEN IN NORWAY

An 8 kilometer underwater road tunnel linking the Norwegian town of Alesund with three islands off the nation's west coast was opened to traffic in October 1987. A vehicle monitoring system allows subscribing motorists to pass through the automatic toll booth at up to 60 kilometers per hour without having to slow down or stop, and to be charged less than drivers who pay cash. One approach lane is reserved for automatic toll registration, to be used by vehicles with an identity plate fastened to a side window. The plate contains all the information required by the system for identifying a vehicle, and reflects low-energy microwaves from a roadside antenna. A computer automatically charges the vehicle's account. Any payment form is feasible, such as prepayment for a certain number of trips or for a period of time, or payment may be charged directly to the vehicle owner's bank account, with no paperwork.

Unauthorized vehicles passing the electronic gate are videotaped and are fined later. If an authorized vehicle or its plate is stolen and the theft has been recorded in the system, an alarm sounds automatically if passage is attempted.

From ***World Highways*** *39(February 1989):8.*

ALTERNATIVE FUEL, PART II: THE CANDIDATES

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INTRODUCTION

This second article in the ***Alternative Fuels*** series discuses the advantages, disadvantages and availability of the most promising alternative fuels. The fuels covered are methanol, ethanol, natural gas (CNG and LNG), liquefied petroleum gases, hydrogen and electricity. Although methanol has been pushed nationally as the fuel of choice, natural gas is environmentally cleaner and maybe economically better for Texas.

METHANOL

Advantages

Methanol, which is produced from methyl alcohol, has been widely considered as the best alternative to gasoline. It can be burned "neat" (pure) or "near-neat" in a vehicle specially modified for this purpose Its liquid form would increase its public acceptance because it can be pumped like gasoline. Its cooler flame produces fewer nitric oxide emissions and reduces concentrations of target pollutants such as nitrogen oxides, nitric acid, and other oxidants. Ozone production would be reduced because of methanol's reduced photochemical activity. Net ozone formation from methanol emission is about 50% less than that from gasoline emissions [Ref.9].

Methanol provides smoke-free combustion, and its less evaporative nature reduces smog formation caused by escaping gas during refueling and by hot engines. There is no problem of particulate emission with methanol fuels. Southern California's particulate smog problem could be reduced by 20% if all light duty vehicles were converted to methanol [Ref.6].

In the form of methyl tertiary butyl ether or MTBE, methanol is an excellent octane additive. A properly designed engine will burn methanol with greater thermodynamic efficiency. An optimized methanol-powered engine is likely to use only 1.5 times the volume of fuel needed by a gasoline engine [Ref. 3]. High compression engines can be used for methanol because of its excellent combustion properties. Less heat is lost during combustion for two reasons: [Ref. 11]

(a) Requiring more heat to vaporize, the peak temperature of the combustion gases are reduced and less heat transfer occurs.

(b) Having no carbon-carbon bonds, methanol produces no heat-radiating carbon particles (soot).

A methanol vehicle will weigh much less than a normal gasoline-powered car because a methanol engine would inject fuel directly into the combustion chamber. A carburetor and air-intake manifold will not be required. The cooling system could also be modified because the heat produced is less. A much lighter vehicle would translate into more efficiency. In fact, with the introduction of thermal barriers and hot lubrication liquids, the radiator and cooling system could be eliminated, but this is not presently advisable. Further benefits can be derived by converting methanol to vapor using engine waste heat or by dissociating methanol prior to combustion. The catalytic dissociation of methanol at relatively low temperatures by using exhaust heat results in carbon monoxide and hydrogen and provides 20 percent more energy than methanol itself [Ref. 11].

Most of the present gasoline system can be used for methanol. This leads us to the concept of flexible fuel vehicles (FFV) which could run on both gasoline and methanol [Ref. 16]. In a FFV, the air-fuel ratio would be continuously adjusted using a sensor which measures the proportion of methanol and gasoline in the mixture. If more methanol is used, the air-fuel ratio is lowered and the spark is advanced to ignite the fuel sooner. To combat the corrosiveness of methanol, the FFV's will be fitted with stainless-steel tanks and stainless-steel mesh rubber hoses, which increases the price of the car by approximately $300 [Ref. 16]. GM and Ford are planning to test about 2,000 of these vehicles in California by 1992 [Ref. 16].

Disadvantages and Possible Solutions

Methanol has some disadvantages, too. It is more toxic than gasoline and is believed to be carcinogenic. Being corrosive, it can eat through aluminium used in gasoline tank linings and dissolve the rubber in fuel hoses. Vehicles using pure methanol (M100) require more frequent oil changes and cannot start at temperatures below 40 degrees Fahrenheit [Ref. 16]. The danger of being burned by methanol is higher because of its invisible flame. Methanol combustion produces two or three times the formaldehyde emission of gasoline [Ref. 6]. Formaldehyde forms twice as much smog as unburned gasoline [Ref. 11]. A catalytic converter could be used to convert the formaldehyde to carbon dioxide and water. Also, methanol possesses half the heating value of gasoline on a volumetric basis and contains 60 percent of the energy of a gallon of gasoline [Ref. 16]. The vehicle performance of 1 gallon of gasoline would require 2.1 gallons of methanol [Ref. 3].

Gasoline engines will not start on pure methanol when the temperature drops below 50 degrees [Ref. 5]. For this reason, methanol is blended with gasoline in certain proportions. The most popular combination is known as M85, which contains 85 percent methanol. M85, which burns with a bright yellow flame, can quick start at temperatures as low as twenty below zero [Ref. 16]. EPA laboratory tests indicate that the amount of hydrocarbon emissions from cars designed to run on M100 are 20 percent of those from comparable gasoline cars [Ref. 8]. For M85, this value rises to 70 percent [Ref. 5].

Methanol-blended fuels have been criticized for not providing any real benefits except for hydrocarbon emissions as far as pollution is concerned. M85 only reduces smog by 50 percent as compared with 90 percent for pure methanol [Ref. 16]. We need to realize that the ultimate potential of methanol as an alternative fuel lies in its application as a neat fuel. At present gasoline prices, it would be profitable for oil-exporting countries to produce and sell methanol as a neat-fuel substitute for gasoline, not mentioning the environmental benefits. Methanol manufacturers would certainly benefit by the increased use methanol as a automotive fuel because in 1986, world methanol producers faced the problem of disposing of about 1.65 billion gallons of excess methanol [Ref. 1].

Availability

Methanol can be produced from natural gas, biomass or coal. Methanol can be produced more cheaply from natural gas than can gasoline [Ref. 1]. Recent high prices for natural gas have stimulated exploration and drilling of natural gas, whereas in the past, natural gas was a secondary product associated with petroleum drilling. The depressed coal-producing regions in the Northeast would welcome the new economic lift provided by the production of methanol from coal derivatives. There are a number of coal gasification processes, which are commercially feasible, that can be used to produce synthesis gas from which methanol can be derived. However, the use of coal to produce methanol and other alternative fuels poses considerable environmental problems. The release of methane from coal mining and the production of nitrous oxide from coal combustion would contribute significantly to the greenhouse effect.

ETHANOL

Source

Ethanol is the primary product of biomass-based alcohol fuels in the United States. Most of the ethanol in the United States is extracted from sugar and starch feedstocks, especially corn. Ethanol is usually blended with gasoline at a 10 percent alcohol content known as "gasohol" [Ref. 12]. Most of the approximately one billion gallons of ethanol produced annually in the United States is used for gasohol [Ref. 11]. Most of the ethanol is produced in the Midwest region which is the grain belt of America [Ref. 11]. The Midwest region is also the largest consumer. The consumption of ethanol has also been rising in the Southern states, partly due to effective promotion of ethanol and a good retailing system [Ref. 11]. The yearly ethanol consumption is estimated to be 817 million gallons [Ref. 11].

Pros and Cons

Ethanol is less corrosive and possesses 33 percent more energy than methanol [Ref. 16]. However, it costs twice as much as gasoline [Ref. 16]. There is also the problem of carbon dioxide production during the fermentation process which produces ethanol.

There are four possible end products of ethanol as a fuel: anhydrous ethanol, hydrous ethanol, anhydrous ethanol-gasoline blends and ETBE or ethyl tert butyl ether [Ref. 11]. Current 10 percent ethanol gasoline blends use anhydrous ethanol [Ref. 11]. One-and-a-quarter liters of hydrous ethanol is equivalent to 1.0 liter of gasoline in terms of distance because of its superior thermodynamic efficiency [Ref. 11]. ETBE is a comparable to MTBE as an octane additive. Isobutylene is required to produce ETBE. It is more easily transportable than ethanol-gasoline blends, and it is easier to use than ethanol.

Availability

Ethanol would not be a feasible fuel without federal gasohol subsidies prompted by the powerful farm lobby in Congress. Farmers are trying to get rid of the large crop surpluses through the use of gasohol. In fact, prospects for large scale production of ETBE has brightened considerably due to the proposed IRS tax credits of 60 cents per gallon for blending ETBE with gasoline [Ref. 11]. Without the federal subsidies, the limited supply of ethanol would eliminate it as a U.S. fuel prospect.

Gasohol is currently being used widely in Brazil where it is also backed heavily by government subsidies [Ref. 11]. The production of gasohol is also increasing in certain land-locked African countries which are agriculturally oriented and where fuel imports are costly. For instance, molasses is being converted into gasohol in Malawi [Ref.11].

NATURAL GAS

About 80 percent of natural gas comes from underground reservoirs, and the rest is found with oil [Ref. 20]. It was once considered a nuisance for oil drillers exploring for petroleum. Approximately 6 trillion cubic feet of natural gas are flared annually as a by-product of oil production [Ref. 3].

The major constituent of natural gas is methane, which is a good, high octane fuel. As an alternative fuel, natural gas can be used in two forms, liquefied natural gas (LNG) and compressed natural gas (CNG). The major difference between both forms is that CNG is stored as a gas under high pressures, whereas LNG is piped as a liquid directly from the oil fields. The reason for compressing natural gas is that natural gas occupies 1,000 times the volume of an equivalent amount of gasoline [Ref. 20]. Cylindrical tanks are used to store CNG at a pressure of 2,400 psi [Ref. 4]. CNG contains only one-sixth the energy of gasoline per unit volume, thereby creating a possibility of fuel shortage if it is relied on as the only transportation fuel [Ref. 4]. Liquefied natural gas (LNG) possesses two-thirds the energy density of gasoline [Ref. 4]. Cryogenic, insulated storage is required to prevent LNG from achieving its boiling point of 259°F [Ref. 4]. Natural gas cannot be liquefied at room temperature.

Advantages

Natural gas is the cleanest of the immediately available alternative fuels. Natural gas vehicles (NGV) would emit 8 percent less carbon monoxide than gasoline cars [Ref. 12]. NGV's would also reduce nitrogen oxide by 25 percent, carbon dioxide by 23 percent and hydrocarbons by 13 percent [Ref. 12]. The use of compressed natural gas (CNG) in vehicles would totally eliminate particulates and evaporative hydrocarbons.

CNG vehicles possess 12 percent better fuel economy than gasoline, costing 30 to 50 percent less to burn per mile [Refs. 12 & 17]. Natural gas offers good distribution in the engine intake system and improves cold starting. The CNG vehicle was found to be competitive in fleet applications in which annual vehicle consumption exceeds 1,000 gallons and the price differential between gasoline and natural gas was over 50 cents per gallon on a gasoline equivalent basis [Ref. 3]. Twenty to thirty thousand CNG vehicles are estimated to be in operation in the United States [Ref. 3].

NGV's are safer than gasoline vehicles. CNG fuel tanks are one-half to one-quarter inch thick aluminum or steel cylindrical tanks that can withstand severe crush tests and burning, even dynamite explosions [Ref. 12]. Safety is also helped by the fact that

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SPECIALLY STRESSED PAVEMENTS NEED SPECIAL ATTENTION, PART I

by Joe W. Button
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INTRODUCTION

Standard pavement structural design methods and asphalt mixture design procedures were developed for pavements with moving traffic without regard for high, repetitive shear stresses, such as those generated by decelerating and accelerating heavy vehicles at certain pavement locations such as intersections (Fig. 1). Traffic loading, often expressed as passages of an 18 kip equivalent single axle load (ESAL), as determined from the AASHO Road Test, are used in the calculation of damage factors to estimate design life of a pavement. By definition, the ESAL's are applied by freely rolling tires which principally apply a vertical load to the pavement with the only horizontal load in the pavement being the force component generated by the vertical load.

Asphalt concrete pavements are typically designed and built as if the complete paving project was a tangent section. For this reason, nontangent segments of a pavement such as intersections, curves, approaches to railroad crossings, bus terminals and steep grades very often experience extreme forms of distress long before the tangent segments of the pavement and long before the design life of the pavement is attained. As a result, maintenance and/or rehabilitation of the specially stressed segments is required early in the pavement's service life which is costly both from the materials and labor standpoint as well as the user cost standpoint.

Intersection approaches, particularly on high traffic volume roads, should be designed and built to withstand damaging stresses in order to provide service lives approximately equivalent to those of adjacent tangent sections. This can be accomplished in a cost-effective manner using current technology.

Research report 1172-IF, ***Avoiding Early Failure of Intersecting Pavements,*** addressed the initial phases of the problem as described above. The analysis was limited to asphalt concrete surfaced intersections. The overall purpose of this study was to develop techniques that can be employed in a cost-effective manner to design and build specially stressed portions of pavements that will exhibit performance equivalent to the tangent sections.

FIELD INVESTIGATION

A questionnaire was distributed among all the Texas highway districts in order to locate unsuccessful asphalt concrete intersections. Unsuccessful intersections were defined as those exhibiting significant premature pavement-distress related problems, such as rutting and/or corrugations (Fig. 2). Visual inspections were performed on about 20 unsuccessful intersections and eight were selected for further study. Some consisted of a series of thin overlays which would have been difficult to analyze from a materials standpoint.

Successful intersections were defined as those exposed to reasonably heavy traffic and exhibiting less than 0.25 inches of rutting and insignificant corrugations and/or flushing after 4 or more years of service. Visual inspections were performed on approximately 30 successful intersections and only 7 were considered for further study. Most of the intersections that were reported to be successful actually exhibited significant distress or they experienced very low traffic levels and were eliminated from the study. A sufficient number of "good" intersection approaches which had been last overlaid more than 4 years were not found. Therefore, some of the good intersections selected for study had received an overlay less than four years prior to this evaluation.

It was found that many districts have implemented an intersection maintenance program in which basically all intersections in the district exposed to significant traffic are upgraded every other year, as a minimum. Although the program is doing an excellent job

FIGURE 1: Intersection showing typical distress.

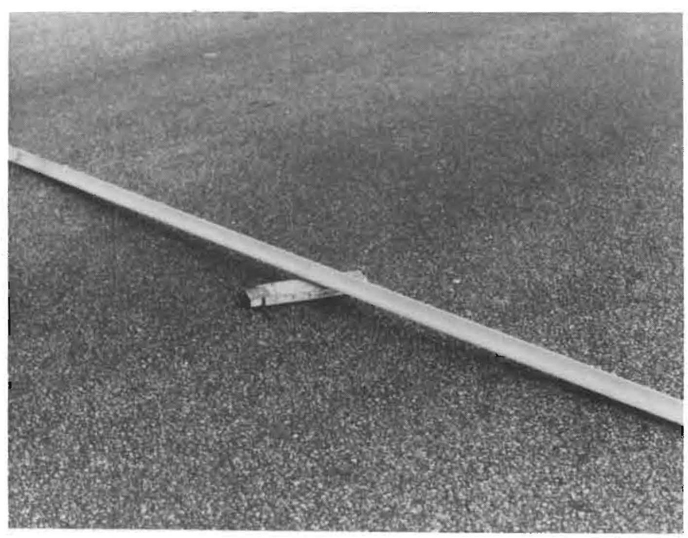

FIGURE 2: Detail of rutting.

in maintaining intersection quality, it did cause some difficulty in locating candidate intersections for this research study.

After performing a visual inspection on all the proposed sites, specific intersections were selected for further analysis. Some intersections were sampled and tested while others were given a more cursory study. Where possible, mixture design data, materials descriptions, typical sections and a sampling of daily construction reports were obtained. A summary of the intersections selected for study is given in Table 1.

TABLE 1: Summary of Selected Intersections

Location	Identification	Traffic, ADT,	Age of Last Overlay	Rut Depth, in.	Other Distress
District 8 Abilene	SH 36 @ Judge Ely*	4,600	6 1/2 yr	<0.25	None
District 10 Tyler	Loop 323 @ FM 756	38,000	5 mo	0.75-0.9	Flushing
	Loop 323 @ Mackim		5 mo	0.5-0.9	Flushing
	Loop 323 @ SH 110		5 mo	<0.25	None
District 13 Yoakum	SH 60 @ SH 36*	2,000	3 yr	0	None
District 15	Toepperwein @ IH 35*	12,000	2 yr	0	None
	Judson @ IH 35*	12,000	5 yr	<0.10	Slight Flushing
	Collesieum @ IH 35*	10,000	5 yr	0.05	None
District 18	FM 2170 @ SH 5	18,800	4 yr	0.25-1.0	Shoving
	SH 66 @ Rowlett*	14,000	3 yr	<0.2	None
District 19	US 259 @ SH 11	8,000	8 yr	0.13-1.0	None
	US 67 @ FM 989	6,700	9 yr	0.3-0.9	Shoving
	US 59 @ FM 989*	19,000	8 yr	0	None
District 20	US 96 @ FM 1013	10,000	6 yr	0.25-2.5	Shoving
	US 190 @ US 96	10,100	2 yr	0.13-1.0	Shoving

* Indicates good intersections

APPLICATION OF FINDINGS TO INTERSECTION ENGINEERING

Hot Mix Asphalt Concrete Specifications

Texas SDHPT specifications for Item 340, hot mix asphaltic concrete pavement, allow and possibly encourage the use of gap-graded mixes. These mixtures are characterized by the "hump" in the gradation curve near the number 40 sieve and a relatively flat slope between the number 40 and the number 10 sieve. This indicates a deficiency of material in the number 40 to number 8 sieve size range and an excess of material passing the number 40 sieve. Mixtures of this type, particularly when the fines are composed primarily of natural sand, are termed "critical" in that they lack resistance to plastic deformation, tend to rapidly loose stability if the asphalt content exceeds optimum, and become tender and shove during periods of hot weather. One method of improving the aggregate grading specification to yield tough intersection mixes would be to lower the upper limit of the total percentage of material allowed to pass the number 40 and 80 sieves.

Method of Testing

Design of hot bituminous mixtures in Texas requires the use of test methods Tex-205-F and Tex-206-F for specimen preparation. These test methods specify a mixing temperature of 275°F and a compacting temperature of 250°F, respectively, regardless of the grade or viscosity-temperature relationship of the asphalt cement. Examination of 1988 data for AC-20 asphalts used in Texas revealed that the viscosity may range from 6 to 14 stokes at 250°F and from 2.8 to 6.8 stokes at 275°F. Based on the experience of the authors, this range of viscosities will significantly affect density of the compacted specimens. Higher viscosity will, of course, result in higher air voids. since optimum asphalt content is selected at 97 percent density (or 3 percent air voids), it follows that the harder asphalts will require higher asphalt contents at a given compaction effort. Now since the materials under discussion are all AC-20's, the viscosity range at high pavement service temperatures (say 140°F) is comparatively small (1610 to 2280 stokes, based on 1988 Texas asphalt data). Therefore, in service, the higher asphalt content required by the design procedure may be detrimental to resistance to plastic deformation of the mix. Furthermore, when modified asphalts are used which have significantly higher viscosities at the compaction temperature, the standard design procedure may require binder contents in excess of that desirable for good performance.

Guidelines for the Marshall design procedure recommend a mixing temperature that provides 170 centistokes and a compaction temperature that provides 280 centistokes. Asphalt viscosity at compaction temperatures using the Texas gyratory compactor may not be as critical as viscosity when using the Marshall hammer but this supposition should be verified.

Economic Considerations

The potential significant economic benefits appears promising when intersection approaches are designed and constructed specifically to accommodate the special stresses to which they are subjected. The alternative has often been to maintain intersection approaches with overlays or level-up courses every two years. Cost comparisons of these alternatives on both a first-cost and life-cycle basis are of interest to the engineer and should be considered when selecting the optimum rehabilitation alternative for a particular intersection approach.

When pavement user cost is considered at an intersection, this cost may double since traffic flow on at least two different thoroughfares is interrupted.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The most common form of distress associated with failure of asphalt concrete intersection approach pavements was plastic deformation manifested in the form of rutting with shoving and flushing in some cases. In all cases investigated, rut depths more than 250 feet from the intersection were practically negligible. Ruts always become progressively deeper nearer the intersection. Shoving (usually manifested by transverse corrugations) was only a secondary problem at some locations. This combination of findings indicates that, the slower the traffic moves and the greater the frequency of horizontal forces (deceleration and acceration), the greater the damage is to asphalt concrete pavements.

2. The leading materials-related cause of intersection pavement failure was binder content in the asphalt concrete in excess of that required by the optimum mixture design. Some variation in asphalt content in a mix plant appears inevitable. It also appears that on occasion asphalt content is arbitrarily increased to facilitate compaction.

3. Most of the mixtures studied contained relatively high percentages of natural (uncrushed) sand. The smooth, rounded, nonporous, glassy character of these fine aggregates cause the mixture to be sensitive to asphalt content and weak in shear strength which increases the likelihood of permanent deformation. Approximately 30 percent minus number 40 sieve size material, which was largely field sand, was found in all the problem intersections. (State specifications for Item 340, Type D allow up to 40 percent passing the number 40 sieve.) Gap-graded mixtures containing rounded particles at the no. 40 sieve tend to be tender.

4. Aggregate gradations appeared to be very dense for some intersection pavements that experienced early failure. Dense aggregate gradations leave little room for asphalt binder, and the mixture may become unstable with a slight excess of asphalt. This is particularly true for fine-grained asphalt mixtures.

5. Air void contents obtained from almost all the rutted intersection pavements were comparatively low (less than 3 percent), particularly in the wheelpaths. This indicates that either the mixture designs were too dense or that they were overcompacted during construction such that additional densification by traffic caused the mixtures to become unstable soon after construction and exhibit plastic flow (rutting and/or shoving).

6. The filler (minus #200) content of the paving mixtures was generally low (<4%). This condition also enhances sensitivity to binder content. An increase in the amount of filler will stiffen the binder and thus increase the bulk viscosity of the mixture, which may help in diminishing permanent deformation potential. Increasing filler content should be done with caution as mixture flexibility (resistance to cracking) may be diminished. Filler to asphalt ratio should range between 0.6 and 1.2.

7. Several districts had established a routine two-year maintenance program, wherein most intersection approaches in the district with significant traffic received treatment every other year. This is an indicator of the severity of the problem with intersection pavement service life.

8. The potential for significant economic benefits appears promising when intersection approaches are designed and constructed specifically to accommodate the special stresses to which they are subjected. If a segment of pavement to be built or rehabilitated contains a large number of intersections such that it is not economically feasible to apply special pavements at the intersections, then the complete project should be designed and built to withstand the most damaging loads.

Recommendations

1. Reduce the quantity of sand size (minus #10, plus #200) particles allowed in Item 340 mixtures to be used on intersection approach pavements.

2. Limit the natural (uncrushed) sand content of mixes to be used on intersection pavements to about 13 percent. Special provisions should be allowed for "sharp" sands that have demonstrated good performance wherein they may exceed the specified value.

3. Convert aggregate gradation specifications from passing-retained to total percent passing. This should provide for a better general understanding of the specification and enhance mixture design and construction controls.

4. Institute a specification for voids in the mineral aggregate (VMA) considering the fact that the gyratory compactor generates a specimen that simulates final density after significant traffic. Optimum VMA values for gyratory compacted specimens may be slightly lower than those proposed by FHWA and the Asphalt Institute. All pertinent factors should be carefully examined before a VMA specification is prepared.

5. Require a minimum Hveem stability of 40 for mixes to be applied on high traffic volume intersection approaches. This is an indirect method of assuring good aggregate quality.

6. The FHWA recommends a filler to asphalt ratio of 0.6 to 1.2 for asphalt concrete mixtures. Filler to asphalt ratio should be examined routinely during mix design and construction.

7. Use of comparatively large maximum size aggregate and/or asphalt modifiers to increase viscosity at higher pavement service temperatures may offer cost-effective alternatives to prolong intersection pavement life. Options include dense-graded large stone mixes (Type C or B), stone-filled mixes and plant mix seals. The National Asphalt Pavement Association recommends a maximum aggregate size of 3 inches or up to two-thirds the pavement layer thickness, whichever is smaller for heavy duty mixes.

8. Establish a specification for

"washed" stone (crusher) screenings which would require near 100 percent passing the #4 sieve and limit the minus #200 material to a maximum of about 6 percent. The absence of this specification has causeed problems in procuring materials of adequate quality to replace natural (uncrushed) sand.

9. Train design and construction personnel on the use of the 0.45 power gradation chart. This could help recognize gradation problems early and indicate where adjustments are necessary.

10. Consider specifying constant asphalt viscosities during mixing and compaction rather than constant temperatures for standard test methods Tex-205-F and Tex-206-F. Use of the mixing temperature of 275°F and the compaction temperature of 250°F for hard or modified asphalts with the standard Texas mix design procedure may result in excess binder content which could lead to rutting or flushing.

11. Consider the use of portland cement concrete for intersection approaches where economic analyses of the alternatives indicate its appropriateness.

12. Employ a sequential construction technique where all intersection approaches within the project are built or overlaid prior to the remainder of the job with a special, tough mix to accommodate the special stresses.

M. Ameri-Gaznon, Joe W. Button, D. Perdomo, D. N. Little and D. G. Zollinger. ***Avoiding Early Failure of Intersection Pavements,*** *FHWA/Texas-90/1172-1F. College Station: Texas Transportation Institute, Texas A&M University, 1989.*

WHO?...ME?...POLLUTE?

by The Pollution Abatement Unit
Texas Water Commission

NONPOINT SOURCE WATER POLLUTION — it's a term you will hear much more in the coming months. This type of water pollution is not one of those good-guys vs. bad-guys issues, so what does it mean and what does it have to do with you?

Simply put, it describes all of the pollution that water picks up as it flows across the surface of the land. We all know how clean and fresh everything looks and smells after a rainfall. It's like Mother Nature has given our environment a shower and cleaned it up. But what happens to all that "stuff" that has washed off our lawns, streets, construction sites and agricultural and industrial areas? It runs off into drainage ditches and streams where it eventually finds its way to the rivers, lakes and aquifers from which all Texans draw their drinking water. All of that "stuff" becomes nonpoint source water pollution!

Have you ever said to yourself "Sure, I believe in cleaning up the environment, but I'm only one person: What can I do?" Reducing nonpoint source water pollution is one of the best ways that you, personally, can do something about protecting and preserving the environment that sustains our life. Your personal actions at home and at work can have a real impact on the quality of water with which you and your family cook, drink and wash. You can make a difference!

The key to much of the water pollution in Texas is how all chemicals are used by society — by you, your family, friends and neighbors. Think about the gasoline and oil you use in your car, boat and lawnmower, the herbicides, pesticides and fertilizers you use on your lawn, and the cleansers and solvents you use outside at home and work. The residues from these chemicals move down towards our water supply each time it rains. In addition, litter yard clippings, animal droppings and soil from construction sites, yards, streets and farms contribute to the problem. Your environmental housekeeping habits and those of your neighbor make a big difference in the traces of pollutants which end up in Texas waterways.

What can you do about preventing this type of pollution? All that it takes is for you to think about your personal activities and how you manage the property you own. Household cleansers, pesticides, poisons, paint, motor fuel and lubricants — just about anything which comes in a can or bottle is a potential water pollutant. Use these products carefully! Look for alternatives that keep our water clean, like taking used motor oil to a local service station for recycling, instead of pouring it down the storm drain. Talk to your neighbor about using your excess pesticides, paint and paint thinner, rather than throwing it in the trash or washing it down the drain. When possible, buy and use only those products that contain little or no toxic chemicals. Always read and follow the label directions, especially when using fertilizers, weed killer, insecticides or anything that is flammable. That old idea "if one pound is good, two pounds must be great" does not apply when using most chemical products. That extra "dose" often ends up as a nonpoint source of pollution and can be a potential "overdose" to our environment.

The Texas Water Commission is the state agency responsible for protecting and enhancing the water quality of the state while fostering economic development. This article is part of TWC's extensive professional and public education effort.

A FISH STORY?

Antifreeze mechanisms of flounder and other salt water fish (found in northern climates) are being studied by Professor Thomas Caceci of Virginia Tech under a research grant to determine if there is a viable alternative to road salt that is noncorrosive, biodegradable and cost-competitive. The flounder's protein chains prevent creation of ice crystals in fish cells down to at least 28 degrees F. Under the research project, Dr. Caceci hopes to create an artificial version of the flounder's antifreeze that will reduce the freezing temperature to 10 to 15 degrees F. Such an antifreeze might also have application as a deicer for airplane wings and may help keep citrus crops from freezing.

From ***The Wheel*** *4 (Fall 1989):4, Colorado Transportation Information Center, as seen in* ***The Virginia Eclectic*** *5 (January 1990):6.*

ALTERNATIVE FUELS

Continued from page 7

the lighter natural gas dissipates faster in case of leaks. NGV's also require less maintenance because natural gas burns more completely. Oil changes are not needed before 12,000 miles, and spark plugs could last as long as 75,000 miles [Ref. 12]. A recent study by the General Land Office in Texas showed that the less polluting CNG vehicles could reduce fuel costs by 60 percent [Ref. 13]. If half of the 5,700 state vehicles in Austin were converted to natural gas, an annual savings of at least $2 million could be obtained [Ref. 13].

Disadvantages

The major disadvantage is the inconvenience caused by the burdensome fuel tanks which need to be attached to a pickup truck bed, car trunk or under a bus. About 36 percent of a CNG vehicle's weight consists of a full fuel load and fuel tank, compared to 11 percent for a normal gasoline car [Ref. 14]. A 10 to 20 percent power loss can be expected due to the additional weight of the storage system and the lower energy output [Ref. 7]. The total range of a 6-liter truck is approximately 25 percent that of a comparable gasoline vehicle [Ref. 14].

Current regulations ban the use of CNG vehicles on certain tunnels and bridges for fear of explosion [Ref. 22].

A nationwide refueling system does not exist, despite the fact that natural gas in the form of methane has been used in homes for heating and cooking for a very long time. Dual fuel vehicles with gasoline as backup could be used, but more tanks would be required.

Availability and Costs

The cost of converting a single-fuel vehicle to one having a CNG dual-fuel system is approximately $1,000 to $1,500 [Ref. 4]. The two methods for refueling CNG vehicles are "fast fill' and "slow fill". Fast fill refueling is a five minute operation that uses a high-volume, high-pressure source to fill the vehicle. "Slow-fill" refueling consumes several hours and is used primarily for overnight parallel servicing of a number of vehicles.

We may be entering a natural gas era soon in view of the heightened environmental concerns of the 90's. The Department of Energy estimates United States has 187.2 trillion cubic feet of proven natural gas reserves or, in other words, three centuries worth of gas supply [Ref. 20]. Natural gas reserves have leapt by 93 percent since the oil price shock of 1973 [Ref. 10]. The six-year excess supply of natural gas in the market is drawing to a close this year [Ref. 15]. In fact, the price of natural gas is forecasted to increase by 10 percent every year [Ref. 15]. The American Gas Association projects a 1.2 percent share for CNG in the total gas demand for the year 2000 [Ref. 10].

Texas has a lot to gain from a natural gas "explosion" because Texas sits on 26 percent of the natural gas reserves in the United States [Ref. 18]. In 1988, Texas produced 6.2 trillion cubic feet of natural gas, and natural gas production taxes added $1.1 billion to the state coffers [Ref. 15]. For every 1 trillion cubic feet of natural gas sold, an additional 50,000 Texans will have a job, and $1 billion worth of revenue will be generated [Ref. 21]. The Texas legislature has recently passed bills to promote the use of natural gas in state-owned or operated fleets. Also, the price of the stamp (similar to gasoline tax) used to purchase CNG has been reduced from $216 to $90 [Ref. 15].

CNG has been a great hit in Italy where in 1984, more than 250,000 vehicles were operating on CNG and these vehicles were serviced by a network of 240 fueling stations [Ref. 3]. CNG vehicles are also very popular in British Columbia where 50 service stations offer natural gas pumps next to gasoline pumps with natural gas at half price [Ref. 17]. Part of the price reduction is due to a tax break given to users of CNG. CNG is also popular in Argentina and New Zealand [Ref. 17].

Australia Gas & Light is currently conducting trials in the use of LNG as an alternative fuel to solve Australia's potential fuel problems in the 1990's [Ref. 19]. Fifty motorists in New South Wales and South Australia have been involved in home refueling trials of LNG. The low price of LNG has created a positive impression on the motorists involved, despite the lower energy content compared with gasoline.

LIQUEFIED PETROLEUM GASES (PROPANE)

Advantages

Propane is the most widely used alternative fuel and is included in the California clean air program. Liquefied petroleum gases are based on propane, which is a relatively high-octane fuel that is gaseous at ambient temperatures. Propane is a nontoxic gas which is odorless and colorless. Propane has a 100-plus octane rating, which means pure fuel only without the presence of additive boosters. Propane is 270 times more compact as a liquid than natural gas thus enabling a greater concentration of energy in a small space (91,5000 BTU's of heat energy per gallon) [Ref. 8]. Propane provides improved efficiency, emissions, and cold starting, compared with gasoline. Propane emits less carbon monoxide and fewer reactive hydrocarbons than gasoline, and there is less aldehyde in propane emissions. The pressure reduction processes required to accomodate a gas results in a power loss of 5 to 20 percent [Ref. 4]. Liquid propane has approximately 70 percent of the energy per unit volume of gasoline, but is economically attractive on both a volumetric and an operational basis [Ref. 4].

Availability and Costs

A propane vehicle, which is designed for a dual-fuel operation usually with gasoline as the backup fuel, costs an extra $1,000 to $1,500 per vehicle [Ref. 4]. Propane motor fuel tanks range from 30-gallon capacity for cars to 116 gallons on pick-ups [Ref. 8]. Filled at 80 percent capacity and calculated at 16 miles per gallon, the range of an 84-gallon motor fuel tank is 1,092 miles [Ref. 8]. Travel from coast-to-coast on a LPG vehicle is possible because of the existence of a nationwide network of propane dealers. There are 25,000 LP Gas dealers in the United States [Ref. 8]. In Texas alone, there are more than 2000 refueling stations, of which 8 are automated [Ref. 8].

There are approximately 330,000 propane-fueled highway vehicles in operation in the United States and over 2.5 million worldwide [Ref. 7]. Eighty-five percent of the propane-fueled vehicles in U.S. operate on propane alone [Ref. 7]. Propane vehicles in this country consumed 450 million gallons of propane in 1987 [Ref. 7]. If future resources of propane are channeled to the transportation market, there could be 2.85 to 3.6 million propane vehicles on the road by the year 2004 [Ref. 7]. LPG vehicles have made significant advances in other countries, notably Canada, the Netherlands, Italy, Japan, South Korea and New Zealand. Propane fuels about 10 percent of the vehicles in the Netherlands [Ref. 8].

A major surplus in the propane market is expected in the next decade because of chronic oversupply. LPG vehicles cannot be expected to solve the surplus problem because it can only replace approximately 2 percent of petroleum use, propane being a by-product of petroleum refining [Ref. 4]. Propane vehicles may be a economic boon for Texas since one fourth of all proven U.S. natural gas reserves are in Texas [Ref. 9].

HYDROGEN

Feasibility

Among all the alternative fuel choices mentioned in this article, hydrogen has the bleakest immediate future in the alternative fuel market. The major reason for this fact is that the present conversion processes are extremely expensive. A feasibility study was conducted in Uppsala, Sweden, in 1988 for converting an urban mass transit system to hydrogen [Ref. 11]. The operation costs were discovered to be 21 percent higher than an equivalent diesel bus system. However, the golden age of hydrogen is expected to take off in about fifty years and possibly peak a hundred years from now [Ref. 11]. Several new conversion techniques are being researched and a breakthrough is possible by the end of the century. The argument for hydrogen is that being a non-carbon source of energy, it will be the best remedy for the serious greenhouse effect. In fact, hydrogen and electricity complement each other as a joint fuel approach — one's strength compensates the other's weaknesses. Significant movement from fossil fuels to hydrogen could begin as early as the year 2000 [Ref. 11].

Advantages and Disadvantages

Hydrogen is an attractive option as a fuel substitute because of its clean-burning characteristic. Apart from its abundance, it is also nontoxic and does not produce carbon, sulfur or lead components when it burns. Carbon dioxide emissions are zero. Hydrogen, unlike gasoline, can be manufactured using any energy source. It is also a sustainable energy source because hydrogen, which is produced by water separation, becomes water again when it is not used. Hydrogen is a strong combustion stimulant that can extend the "lean misfire" limit of other fuels when blended with them [Ref. 11]. Extending the lean misfire limit of a gasoline engine reduces the nitrogen oxide emissions and increases thermal efficiency. Hydrogen/CNG blends have been proposed as alternative fuels of the future. All ultra lean natural gas/hydrogen mixtures possess high thermal efficiency.

One drawback is that its high-flame temperature can emit more nitrogen oxides (NOx) than gasoline. It also possesses a low energy density as a pressurized gas. It is also plagued by the problems typically affecting any gas-powered vehicle — power loss and heavy fuel-storage systems. Hydrogen is not readily available as a fuel at this time.

ELECTRIC VEHICLES

Background

The difference between electric vehicles and other alternative fuels is that a different propulsion technology is used at the point of consumption. One fact that may not be common knowledge is that in 1910, nearly 40 percent of the automobiles in America were electric, and by 1912, at the peak of their popularity, nearly 34,000 electric cars were in use [Ref. 3]. By the mid-1920s, electric vehicles had declined so greatly in popularity in face of the rapidly advancing internal combustion engine (ICE) powered vehicles that they had become virtually extinct on the American road [Ref. 3]. The decline of the electric vehicle could be attributed to three major factors. Firstly, battery limitations provided a major constraint on the vehicles range, payload, and speed. Secondly, the presence of a comparatively high-performance, low-cost alternative in the form of the ICE vehicle was detrimental to the interests of the electric vehicle. Thirdly, there were abundant, low-cost supplies of fuel for the ICE automobile.

Advantages

Electric vehicles are very attractive options because their operation does not pose many environmental problems. Furthermore, the operation of a 100 million EVs would require an addition of less than 5 percent of present US electrical capacity [Ref. 3]. The typical EV will consume roughly 2,500 kWh annually, corresponding to an average power demand of 0.30 kw and roughly equal to the average load of a domestic water heater [Ref. 3].

Of course, the initial production of electricity must be clean for the electric vehicles to be completely nonpolluting. Electric vehicles are presently used in commercial fleets and have good potential for short-trip, light-duty deliveries, commuting, or business services, primarily in densely populated urbanized areas. The oil crisis of the 1970s revived interest in electric vehicles, and this renewed interest has also been growing in Europe and Japan in the past few years.

Economic Trade-Offs

The basic economic trade-off between an electric vehicle and an ICE vehicle of comparable performance is the higher purchase cost of the electric vehicle, which must be recovered through its lower operating costs. The higher initial cost is due to the EV's more expensive power train and the added structural and body weight needed to accommodate the battery weight. Operating savings stem from the low cost of electrical energy per mile traveled and from lower expected maintenance costs. One governing factor of this trade-off in relation to the EV is the vehicle range because greater range requires a larger battery which adds to battery and vehicle costs. The specific energy (Wh/kg) and mass of the battery are important considerations in EV design. For a given battery mass, the range increases in direct proportion to specific energy, whereas for a fixed specific energy, vehicle range does not match increases in battery mass because of the lower efficiency of the vehicle as battery mass increases. Less battery mass is required to achieve a unit increase in vehicle range at higher specific energies. Since range extension would be cheaper by increasing the specific energy instead of the mass, battery research and development has been devoted to this direction.

Feasibility

Despite the availability of various electrochemical systems as candidates for EV applications, only a comparatively small number are regarded as having potential. The established ones like lead/acid, nickel/ferum and nickel/cadmium combinations exhibit moderate specific energies within the range 35-55 Wh/kg but provide excellent reliability and ruggedness [Ref. 3].

State-of-the-art batteries exhibit 40 Wh/kg, but this value can be raised to 60 Wh/kg if flow-through or bipolar systems are developed [Ref. 3]. The batteries in developmental stage such as zinc/bromine, zinc/chlorine and nickel/zinc have potential for substantially improved electrical performance.

The aluminium/air battery is unique in its method of recharging which can be performed in five minutes by replacing its aluminium plates, thus offering the possibility of potentially unlimited range.

Among the most exciting battery systems in the exploratory stages are the fuel cells, powered by methanol, which would provide unlimited range capability. At a gasoline price of $2.00 per gallon, present battery technology can provide competitive commuter cars with a range between 50 to 90 miles [Ref. 3]. Advanced battery technologies could extend this range to 100-150 miles within the next decade [Ref. 3]. The development of electric vehicles with ranges exceeding 250 miles would require major technological breakthroughs because the most economically viable commuter car with such a range capability must have a battery cost below $70/ kWh at a specific energy value of 200 Wh/kg [Ref. 3].

The development of a successful en route recharging system would definitely brighten the future prospects of the electric vehicle, as would a breakthrough in solar power storage. One very promising development in the electric vehicle scene is the roadway-powered electric vehicle (RPEV) system which is a hybrid electric vehicle system that possesses a battery-electric power train and receives its energy supply at a relatively steady rate from a special electromagnetic inductive coupling system [Ref. 2]. Each vehicle is propelled by a separately excited DC motor that draws current from a lead-acid battery. The vehicle also contains a pickup inductor and a custom-designed onboard circuit to charge the battery from power derived by interaction with the magnetic field of a roadway inductor. The RPEV overcomes the power limitations plaguing the conventional electric vehicle by providing a semicontinuous charging current to the vehicle's moderately-sized battery, which provides the vehicle with an unlimited range. It can operate independently of the powered roadway for significant periods of time because of the battery. RPEV technology has advanced from its initial laboratory implementation to the prototype development and testing stage on a transit bus.

SUMMARY

We have explored six different alternative fuel options: methanol, ethanol, natural gas, propane, hydrogen and electricity. As was mentioned earlier, methanol has been touted nationally as the best alternative. Meanwhile, in Texas, intensive efforts are being made to promote the use of natural gas through legislation because wider utilization of natural gas would be a big boost to a sagging local economy. Ethanol is being propped up by massive government subsidies to help the farm belt states. Propane is already being used in approximately 330,000 vehicles in the U.S. Hydrogen is not feasible now, but may realize its full potential in the next century. Short-range, light duty electric vehicles are currently feasible. Long-range EV will require major technologicial breakthroughs.

It might be wise if we could adopt a multibased approach to fuel substitution, like flexible fuel vehicles rather than changing from a single-based fuel vehicle (gasoline) to another type of single-based fuel vehicle. Dependence on any one fuel option could mean being at the mercy of another cartel like OPEC. We could benefit from the positive factors of different fuel choices, and the weakness of one fuel option could be compensated by the strengths of another.

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DEVELOPING AND MAINTAINING CREATIVITY IN A TECHNICAL STAFF

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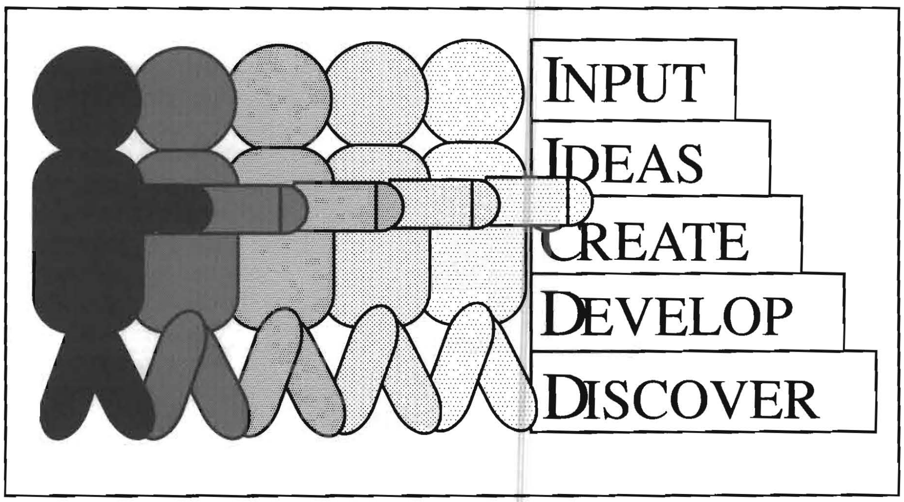

Every good manager needs to develop his human relations and management skills to effectively lead his staff. Managing today's technical staff requires paying special attention to continued technical growth. This is due in part to the speed of technological change and development of new products. Good technical personnel are a valuable resource and they need a creative environment to maximize their productivity and development.

Those of us who have chosen to practice in a technical field spent much of our early career developing problem-solving skills. Today's college graduates enter the job market with a wealth of information and their managers need to be careful to foster each person's growth and creativity. Lack of effective management can hurt performance of both the technical individual and the organization as a whole.

From my personal experience, I have used several techniques to assure that a technical individual continuously grows in his or her creative thinking process. The following specific management methods have yielded positive results for me:

• When assigning a project, do not provide too much information during the initial discussion on the "ways it has always been done." Present the project or problem and ask for conceptual solutions or designs within a short target date. Save "the way we've done it before" to a second stage discussion.

• Assemble a small group of technical staff for at least one brainstorming meeting early in the design process, no matter how small the project. Encourage each individual to actively say, "What if we did it this way?" These meetings develop team building and help foster new ideas. Never make fun of what appears at first to be "crazy" ideas. Crazy and creative often go hand in hand.

• Tell staff how their piece of a project fits into the big picture and why their part is important. It is my belief that most technical people want to feel they are in some way helping society through their work. Building for the sake of building or for monetary rewards are seldom the ultimate incentive for professionals.

• Make certain technical journals circulate freely to every staff member. Actively encourage technical people to stay on top of new products and construction methods. Reward the use of new products with praise. It does not make sense to build the "old way" as better products come on the market.

• Encourage staff to write articles for publication relative to their best projects. Volunteer to co-author if they are at first hesitant. There are endless varieties of journals and professional magazines that are always looking for items. It is just as important to tell others about your professional work as it is to do it.

• Establish an office policy that requires the use of tape recorders for dictation of routine field reports and correspondence. It is surprising the resistance to dictation I have encountered from technical staff. Dictation skills are easily learned and save a significant amount of time that can be more wisely used for professional tasks.

• Assign the most recent college graduates to work with your most creative people. Trying to use a new energetic person to "pull up" a noncreative employee will benefit neither person and may turn off the new person's thinking energy before it has a chance to really bloom.

• Encourage attendance at professional conferences, training courses, and trade shows in specific areas of expertise. A key to getting the most out of this overhead expense is to require the individual to verbally review during a staff meeting what he or she saw or learned at the conference. This brief "show and tell" presentation will likely transfer an idea or product into memory of another designer for use on a current of future project.

• Encourage use of what I consider the best engineering tool ever invented — the telephone. When working on a technical project, staff should not only freely talk among themselves but must always reach out to the outside world for information. Manufacturers, suppliers, government agencies, and other technical people form a critical network for effective problem solving. Encourage staff to call all potential resource persons.

• Implement an effective computer aided drafting (CAD) system. Computers can have a very positive effect on productivity. Standardization and the ability to quickly reproduce previous details and drawings takes much of the drudgery out of repeatedly designing similar projects. However, extreme caution should be exercised by every manager to prevent thoughtless reproducing. The accent should be on what is being produced and not just on how fast a design is generated. Be certain your staff uses the computer and the computer does not use them.

Effective management of all technical professions require an environment that encourages communication and creativity. We cannot afford to waste or unwittingly stifle the growth of technical people. They are our most important resource. Manage them wisely.

*Reprinted with permission from **Public Works** 120 (September 1989):124.*

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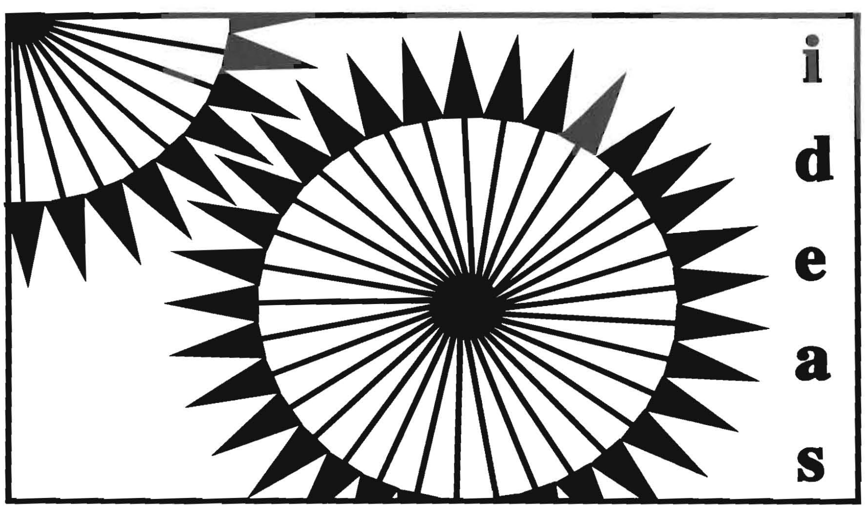
(512) 465-7644 TEX-AN 241-7644

The D-10R Technology Transfer Library does information searches for department personnel. Take advantage of this service when a field problem has you stumped or when you need to know the latest on a subject. The Library can also send you copies of articles and publications summarized in ***The Research Digest, Technical Quarterly,*** and ***The Annual Listing.*** Call the D-10R Technology Transfer Library with your requests.



BRAINSTORM ALERT!

The Structural Design (Area IV) Research Advisory Committee wants District input on subjects such as bridge maintenance, constructibility and rehabilitation for a pre-problem statement brainstorming session. This meeting will be held 20-21 August 1990 at College Station. Send your ideas to Vernon Harris, Bridge Division (D-5), La Costa Centre, 6300 La Calma Dr., Austin, TX.

DID YOU KNOW?

Are CAT scans for nondestructive testing of asphalt core samples feasible? At the University of Southern California, Los Angeles, researchers are applying the same technology used in medicine for computer-aided tomography (CAT) scans to produce images of the inside of asphalt core samples. Development of this method may provide a powerful new technique for diagnosing problems in asphalt pavements and for new nondestructive tests that can be used for routine quality control.

*From **The Wheel** 4(Fall 1989):4, Colorado Transportation Information Center, as seen in **The Virginia Eclectic** 5(January 1990):6.*

NATIONAL TRAFFIC DATA ACQUISITION CONFERENCE AND EXPO

The SDHPT will be hosting the National Traffic Data Acquisition Technologies Conference and Expo in Austin, Texas, on August 26-30, 1990, at the Stouffer Austin Hotel. Sponsors include the American Society for Testing and Materials, Texas A&M University, University of Texas at Austin and the Federal Highway Administration.

The conference will present the latest data collection and weigh-in-motion (WIM) equipment and site installation techniques to provide participants with possible technical solutions and techniques for meeting the growing demands of traffic data acquisition. Conference sessions will be enhanced by exhibits of numerous displays on data collection equipment and procedures.

Following is the tentative conference agenda:

PROPOSED SCHEDULE

Monday – August 27, 1990

GENERAL

"Overview of Traffic Data Acquisition Technologies and Applications" by Dr. Clyde Lee of University of Texas at Austin.

"Traffic Data Initiatives of the American Society for Testing and Materials" by Mr. Larry Hart of Rainhart Company, Austin, Texas. (Not confirmed)

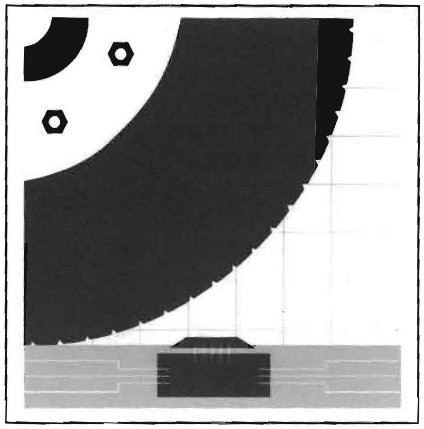
"FHWA Perspective on Traffic Data Acquisition Technologies and Applications" by Mr. Dean Carlson, Executive Director of the Federal Highway Administration, Washington D.C. (Not confirmed)

SESSION I – DEMANDS FOR TRAFFIC DATA COLLECTION

A. *Enforcement*

"The Need for Traffic Data Acquisition for Enforcement" by Captain Bill Mickler of Florida DOT, Tallahassee, Florida.

"The FHWA Perspective on Acquiring Traffic Data for Enforcement" by Mr. John MacGowan of FHWA, Washington, D.C. (Not confirmed)



B. *Data Collection*

"Traffic Data Needs for Design" by Mr. Harshad Desai of Florida DOT. (Not confirmed)

"Traffic Data Needs for FHWA Programs: The Traffic Monitoring Guide and the Highway Performance Monitoring System: by Mr. Dave McElhaney of FHWA, Washington, D.C.

"Traffic Data Needs for the Strategic Highway Research Program" by Mr. David Albright of New Mexico DOT.

"Overview of the Heavy Electronic Vehicle License Plate Program (HELP)" by Dr. C. Michael Walton of Center for Transportation Research, University of Texas at Austin.

"The Use of Piezo Electric Coaxial Cables for WIM Applications" by Dr. Gilles Bailleul of Philips Corporation, Electronic Instrumentation, Industrial Automation Division.

C. *Toll Facilities*

"Traffic Data Acquisition for Toll Facilities" by Mr. Stanley Ciszewski of Garden State Parkway. (Not confirmed)

"Prospects for the Automation of Toll Facilities" by Mr. Henri Cyna of Internation Bridge, Tunnel, and Turnpike Association, Paris, **France.**

"Overview of Trucking Industry Issues" by Mr. Dave Willis of ATA Foundation, Inc., Washington, D.C.

"Data Collection in the Toll Industry" by Mr. Richard Ridings of Oklahoma Turnpike Authority.

Tuesday – August 28, 1990

A. *Site Inspection*

PAT – RADIAN – AVIAR – STREETER – GOLDEN RIVER – SARASOTA

PIEZO CABLE AND FILM

ATR, AVC (STREETER, PAT, SARASOTA)

B. *Tour of Surrounding Area*

Wednesday – August 29, 1990

SESSION II – CURRENT TRAFFIC DATA TECHNOLOGIES AND APPLICATIONS

A. *Enforcement*

"Automated Enforcement Facilities in Oregon" by Mr. Ken Evert of Oregon DOT.

"Automated Enforcement Facilities in the United Kingdom" by Mr. Jack Winder, **United Kingdom.** (Not confirmed)

B. *Data Collection*

"Automated Traffic Data Acquisition in Arizona" by Mr. Ed Green of Arizona DOT.

"WIM in Pennsylvania" by Ms. Barbara Mason of Pennsylvania DOT.

"Automated Traffic Data Acquisition in Florida" by Mr. Rick Reel of Florida DOT.

"Automated Traffic Data Acquisition in California" by Mr. Koney Archuleta of CALTRANS.

"Automated Traffic Data Acquisition in Texas" by Mr. Dean Barrett of Texas SDHPT.

"Automated Traffic Data Acquisition in Idaho" by Mr. John Hamrick of Idaho DOT.

C. *Toll Facilities*

"Automated Operation and Auditing Technologies in Toll Facilities."

"Fastoll –The Virginia Project"

by Dr. Peter Davies of Castle Rock Consultants, Nottingham, United Kingdom.

"Automated Vehicle Identification in Toll Facilities" by Mr. Jim Schmidt of AMTECH.

"Toll Facility Operator Viewpoint" by Mr. Stanley Ciszewski of Garden State Parkway. (Not confirmed)

SESSION III – EMERGING TRAFFIC DATA TECHNOLOGIES

A. *Enforcement*

"Design of an Automated Enforcement Station" by Mr. Mark Young of Idaho DOT.

"Overweight Restriction on Ferry Boats" by Mr. Luis Ramirez of Texas SDHPT.

"Impacts of Emerging Technologies on the Trucking Industry" by Mr. Charlie Jaynes of Central Freight Lines.

"Intermodal Compatibility Through Emerging Technologies" by Mr. Jim Devine of Sealand Company. (Not confirmed)

B. *Data Collection*

"Emerging Technologies in Traffic Data Collection" by Mr. Perry Kent of FHWA.

"Piezometer Film Technology" by Mr. Said Majdi of Texas Transportation Institute.

"Arkansas' Experience with Emerging Technologies" by Mr. Thomas Black, Arkansas Highway and Transportation Department.

"Oregon's Experience with Emerging Technologies," by Ms. Barbara Koos of Oregon DOT.

"Ohio's Experience with Emerging Technologies" by Mr. Don Hall of Toledo Scale.

C. *Toll Facilities*

"A New Automated Toll Collection System" by Mr. Raul Scheller of Allen Bradley International Group.

"Innovative Automation" by Mr. Eugene Pentimonti of American President Lines.

"Oklahoma's No-Stop Turnpikes" by Mr. Jim Berry, OK Turnpike Authority.

Thursday – August 30, 1990

GENERAL SESSION

"Summary of Enforcement Sessions" by Mr. Bill Mickler of Florida DOT.

"Summary of Data Collection Sessions" by Mr. Perry Kent of FHWA.

"Summary of Toll Facility Sessions" by Mr. Ron Cunningham, Port Authority of New York and New Jersey.

"Future Directions in Traffic Data Acquisition Technology" by Dr. Wiley Cunagin of TTI.

"Closing Remarks" by Mr. Jon Underwood of Texas SDHPT.

The conference is targeted at traffic engineers, traffic analysts, transportation planners, design engineers, highway safety engineers, law enforcement personnel, trucking industry policy makers, data collection manufacturers and researchers in related fields.

For additional information on the conference or registration information, please contact Ms. Tanya Pavliska at 512-465-7936 or Tex-An 241-7936.

IMPROVING TRUCK SAFETY AT INTERCHANGES: FHWA-ID-89-024

PURPOSE

This report is written to help highway design engineers improve safety at interchange ramps. Engineers can apply countermeasures or corrective actions to six specific ramp design features that were found to contribute to truck accidents. The report is based on a study supported by the Federal Highway Administration (FHWA) and conducted by the University of Michigan Transportation Research Institute (UMTRI).

APPROACH

UMTRI researchers first selected 15 troublesome ramps at 11 interchanges in 5 States for study. They judged that truck accidents occurring at the study sites were all clearly related to geometry and vehicle dynamics. To determine specific problems and causes of accidents, researchers used a computer model developed by UMTRI that simulated truck performance on the actual ramps. The computer model confirmed suspicions that certain ramp design features contribute to accidents. The model operates in a path-following mode through the use of a driver steering model. The model "looks ahead" and steers the vehicle along the specified curve much like an actual driver does.

RECOMMENDATIONS

Truck accidents on ramps generally involve loss of control resulting in rollovers and jackknifes. Often these accidents are related to ramp design features. In general, tight radius curves on ramps and short acceleration and deceleration lanes cause problems with heavy trucks. Driver failure to heed posted advisory speeds is a contributing factor, but so are excessively high advisory speeds, too few signs, and poor placement of signs. Posted advisory speeds which are too high and lack of appropriate signs may lead drivers to ignore low safety margins present. In some cases, design criteria used fail to consider truck performance characteristics. Findings and recommendations relate to six specific problem areas illustrated in Figure 1:

1. Poor transition to superelevation at interchanges creates high levels of side friction demand that increases the threat of rollover. Developing appropriate superelevation levels along a curve can limit lateral forces that threaten driver control. One countermeasure is for engineers to incorporate

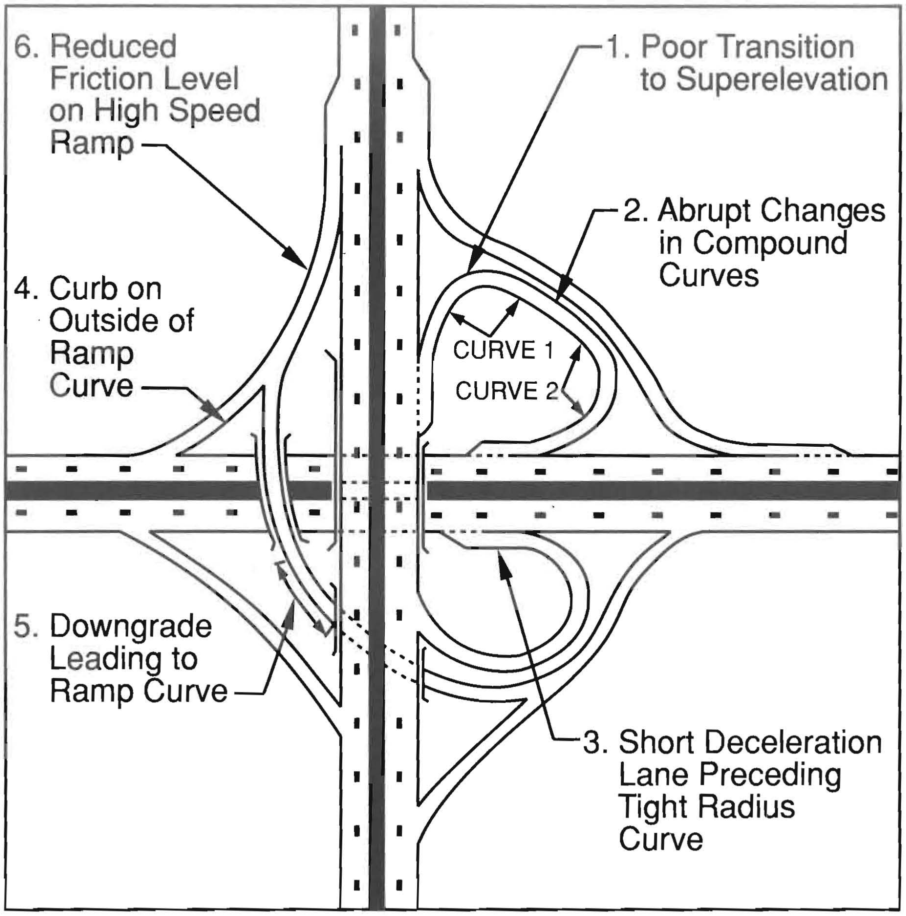


FIGURE 1: Composite illustration of ramp geometric features leading to truck accidents.

a greater safety margin into formulations for side friction factors. Reviewing the adequacy of posted speed limits and improving signs at interchanges are also realistic solutions.

2. Abrupt changes in compound curves, especially where successive portions bring sudden changes of radii, is another problem. This geometry places excessive demands on truck drivers while pushing the side friction factor to the point of rollover. Inadequate signs compound problems created by ramp geometry and limited truck capability. The most effective solution may be for engineers to add more adequate signs to alert drivers to changing curve conditions.

3. Short deceleration lanes preceding a tight-radius exit have also created problems. Short lanes make it less likely that trucks will decelerate enough to negotiate short-radius curves, thereby increasing the potential for rollovers. Excessive braking, on the other hand, increases the possibility of a jackknife occurring. Increasing deceleration lane length may accommodate truck drivers and reduce the hazard. Designing ramps with the taper beginning sooner is also encouraged.

4. Curbs placed on the outside of a ramp curve may be tripping mechanisms in rollover accidents. Curb contact results from trucks' tendency toward high-speed offtracking. Engineers can plot the path radii and eliminate the problem by overlaying the curb with a wedge of pavement. Outside curbs should be eliminated if implicated as tripping mechanisms in accidents.

5. Substantial downgrade leading to a tight ramp curve can cause trucks to rollover. Trucks can speed up substantially on downgrades simply by coasting. This increase in speed, involuntary and often sudden, leads to a corresponding increase in lateral acceleration that contributes to accidents. Engineers might simply reevaluate and recalculate parameters to aid in redesign at sites where accidents are common. The current policy of accepting ramp downgrades as high as 8 percent may be ill-advised at sites on which a relatively sharp curve remains to be negotiated toward the bottom of the grade. Placement of special signs at sites along these downgrades also may be recommended.

6. Friction levels on a high speed ramp may be dangerously lowered in certain conditions. Hydroplaning may occur in wet weather at sites with poor pavement texture conditions. Trucks may be particularly vulnerable on large radius curves. One proved countermeasure is to resurface ramps with high-friction overlays. Using an independent measure of pavement texture to estimate friction levels may also be advisable.

An understanding of these problems strongly suggests that appropriate design criteria can produce effective countermeasures. The highway engineering community can expect revised design practices to dramatically reduce truck hazards on interchange ramps.

SIGN VANDALS... IF YOU CAN'T BEAT THEM — TRY THIS

We've all seen them: signs that have been vandalized — ones full of holes, covered with spray paint, intentionally altered or run down or completely missing. What to do about the problem has plagued road departments for years and is a real source of frustration to local officials.

Every road department knows how expensive it is to repair or replace signs. Since penalties for the crimes are rarely enforced, there is no real deterrent. Unfortunately for those in charge of replacing the signs, many young people feel it's worth the gamble to have one of these signs displayed in their rooms or apartments.

A county in the state of Ohio has taken a different approach to the problem and so far it is succeeding in reducing vandalism to their road signs. Their approach combines education along with distribution of free replicas of road signs.

Officials in Franklin County, Ohio, introduced a public awareness program that included news releases, presentations to local groups, and displays. Schools also were targeted. Students were told of the seriousness of sign vandalism and the costs associated with repair and replacement. One of the facets that has been instrumental in the program's success is the free distribution of a series of eight miniature replicas of actual road signs. These replicas have been reproduced in color on heavy paper.

A Franklin County official estimates that the program has reduced vandalism and associated costs by as much as 40 percent. Maybe it's worth a try in Texas. If anyone decides to give it a try, let us know the outcome so we can pass the word along.

*From **The Link** 5 (Winter 1989):4, Kentucky Transportation Center. Reprinted, with revisions, from **Better Roads** (October 1988).*

The ***Technical Quarterly*** will be appearing on an irregular, rather than quarterly, basis for the foreseeable future.

ERRATA

In "Low-Maintenance Attenuator Performs Well," TQ5-3(February 1990):4, the design of the split-plate front anchor should be attributed to Energy Absorption Systems, Inc., rather than Texas Transportation Institute.

In "Strategic Highway Research Program: Texas Involvement in LTPP," TQ5-3(February 1990):9, the Table 2 column titles are reversed.

The editor apologizes for these errors.

The information contained herein is experimental in nature and is published for the development of new ideas and technology only. Any discrepancies with official views or policies of the TSDHPT should be discussed with the appropriate Austin Division prior to implementation of the procedures.

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