EFFECTS OF VEHICLE CHARACTERISTICS ON PAVEMENT RESPONSE AND PERFORMANCE

Paul J. Diethelm
Minnesota Department of Transportation
AASHTO/TRB Liaison Representative

Recently some optimism is emerging among the principal actors in the old battle of trucking concerns and those responsible for managing the life of road pavements. Many of us have been called to meetings where the situation was immediately adversarial. Pavement preservationists and load regulators of road agencies had a different purpose in their professional life than did those who move heavy loads on these pavements. Whenever legislators enact new laws governing load magnitude, those opposite sides perceive either great victory or agonizing defeat. The American Association of State Highway and Transportation Officials (AASHTO) and some of the individual states found the constant war to be extremely counterproductive. Little by little those old enemies are learning to interact with each other in a new quest to manage and fund the pavement life. The oil embarge of the 1970's forced us to find more fuel effective ways of moving goods. That meant higher loads on axles and sets, and also the gross load for trucks. Such liberalized allowances were made in the higher interest of the overall US concerns. Those new regulations do cause a decrease in pavement life. Supposedly commensurate new heavy truck fees were enacted to assure timely replacement or maintenance of road pavements which saw accelerated load stress damage.

The old choice between the boxing ring and the conference room as the place to settle differences is drifting toward the conference room. We still have our different ways of deciding the issues but we are talking with a mood of cooperation and negotiation.

It is the feeling of many of us in the pavements wing that with our present load spectrum, we've reached the load capacity of our road building materials and mixtures. Also our older-thinner mature pavements are coming due for repair more quickly. A number of choices emerge. First, allow diminished life of the pavement surface and increase user fees to repair them more frequently. That choice is perceived as unacceptable by the traveling public who conversely want longer periods between major pavement replacement or repair. Second, we could return to lower load allowances with the obvious reaction. Roads would again be load posted according to their capacity. In the US, extreme load carrying differences exist among and within the various parts of the highway network; the interstate highways; state roads versus the county, township, and city roads all of which act as collectors for each other. The differences in load capabilities are more a matter of the number of load repetitions than the country designation of a maximum load. Third, we can have serious interaction among the road actors and set reasonable truck gross load, generous axle set allowances for tandem, tridem and quad axles if, and only if, we simultaneously establish and enforce proven conditions for carrying those maximum loads.

The conditions that need to be specified include tire pressure, total tire width on individual axles of sets, load equalization within axle sets, spacing of axles within and between sets, outlawing suspension systems which contribute to large dynamic forces applied to the pavement (and to the truck).

The AASHO Road Test used the following axle/tire specifics for the evolved damage equivalency factors: 10 inch wide duals, load per inch of tire width of 450 pounds, typical tire pressure of 80 psi,load per tire up to 4500, nearly equal load per axle of tightly spaced multi axle sets, and bias ply tires. The US legal loads tended to be 18,000 pounds single, 32,000 pounds tandem and 73,280 pounds gross. We tended to sleep through many legislated changes in axle and gross load magnitude, tire sizes and types, axle configuration, singles (some wide) versus dual configuration, and unusual axle spacing. Tire, suspension, and truck/bus designers and builders now can conceive, build, and introduce load transmitting components which have never been characterized in terms of the road damage caused.

We are recognizing that the old load damage equivalencies do not represent many of the elements and conditions of modern trucks, and we're studying these changes. We're interacting with the many actors at formal Transportation Research Board functions, at AASHTO subcommittee meeting, at international affairs such as this symposium, etc.

For the remainder of this paper, the discussion will center on US efforts to produce modern damage factor for all those new variables. The stage of development for those answers varies from gleam-in-the-eye to final analysis and implementation of findings such as the Canadian RTAC study reported previously at this symposium.

AASHTO commits large sums of money to the National Cooperative Highway Research Program (NCHRP) projects relevant to this discussion. The intention of their 1-25 research project, which has the same title as this paper, is to develop information on the effects of various heavy vehicle (truck and bus) factors such as tire types (bias ply, radial, low profile radial, and "super single"), tire pressures, tire contact (area and load distribution), tire configuration (single, dual, and other), suspension systems (variable load, load sharing, and dynamic response), axle configurations (spacing, location, and steering axle), axle static loads, and operating conditions (speeds and acceleration/deceleration) on pavement response and performance. Research will be conducted in two phases. The specific objectives of Phase I are described below. During Phase II it is anticipated that analytical and experimental (possibly in coordination with the Strategic Highway Research Program) procedures will be used to investigate the effects of heavy vehicle characteristics on flexible and rigid pavements and to determine the impacts of such effects on long-term pavement performance. The specific objectives of the Phase II research will be determined after completion of Phase I.

In particular, the objectives of Phase I of the research are to (a) determine, collect, organize, assimilate, and evaluate all available data and information relative to the effects of heavy vehicle characteristics on pavement response to wheel loads; (b) identify and describe the necessary data base for accomplishment of the overall project objective; and (c) make recommendations concerning the research required for accomplishment of the overall objective.

Accomplishment of the Phase I objectives is expected to involve the following tasks:

<u>Task 1 - Pavement Response Models</u>

<u>Task 2 - Vehicle Response Models</u>

<u>Task 3 - Database Requirements</u>

Task 4 - Fleet Characteristics

Task 5 - Recommendation

Many of us on the advisory (planning, monitoring) committee felt the success of that eventual project hinged on utilization of the huge body of existing knowledge. Other information not on hand such as the "in-use" profile of suspension types, tire types, pressure, sizes, and dual/single configuration; along with axle configuration. Independent works have been done in vehicle performance and in pavement performance, but the "real time" interaction between the two is not well understood. It appears that there must be pure pavement as well as pure vehicle portions of the study and then integrate the effects. A need exists to uncover the real causation of the sudden early rutting problem in asphalt pavements. What is the extent and nature of the rutting problem nationwide and worldwide? If no acceptable pavement response to dynamic load model exists, one will have to be developed in that 1-25 project. Our knowledgeable Australian friends will be asked for help on that one. There must be synchronous measurements of vehicle dynamic loading and simultaneous pavement response. Tire forces applied to the surface, and near surface, needs to be understood far better. An expected product from this in-progress research should be better asphalt wearing course design to resist today's higher tire pressure and better understanding of stress deeper in the pavement structure caused by the large load support of triple and quad axle sets. That's a very ambitious study, and regrettably only begun.

Other NCHRP projects which will bear on the overall subject includes the Turner Proposal which postulates higher gross load per truck but lower load for each axle configuration. Hopefully truck productivity might be enhanced while pavement stress would be reduced. Another in-progress project (1-26) addresses our need for Mechanistic-Empirical Pavement Design Methods. Two other associated NCHRP projects are looking at modernization of specifications for Hot-Mix Asphaltic Concrete (10-26A) and development of asphalt-aggregate mixtures analysis system.

Other efforts are underway by the US Federal Highway Administration wherein a fresh new look will be taken at the way we characterize road stress and resulting pavement performance. A project entitled "Impact of Truck

Characteristics on Pavements - Truck Load Equivalency Factors" is in the formative stages and its basic purpose will be verify or modify the RTAC Canadian road-stress results for potential use in the US. Through the use of similarly instrumented pavements, we expect to study the modern truck characteristics enumerated previously which need study. The time worn ESAL (Equivalent Standard Axle Load) could thus be replaced or modernized.

AASHTO has commissioned the Transportation Research Board (TRB) to study conceptually whether it might be possible to redesign some trucks to cause less damage even while carrying heavier loads. Chaired by Dr. C.M. Walton of the University of Texas, this group will assess costs and benefits from trucks having many more axles to spread their weight more evenly over the highway. They are also asked to analyze how trucks with extra axles would affect highway safety.

The Papagiannakis-Hass report of 1986 entitled "Wide Based Tires; Industry Trends and State of Knowledge on the Impact on Pavements" is worthy of your review. That report, published by the Department of Civil Engineering, University of Waterloo, Ontario, Canada, is a marvelous summarization. It acknowledged that substantial fuel savings were possible from the use of wide based tires but regrettably that comes at the expense of the pavement structure. In its' simplest forms, the wide based singles caused more pavement damage than the replaced conventional dual tires at comparable load. The study uncovered little work aimed at designing roadway surface materials for the higher tire pressure of today's tires. Rutting is becoming the next frightening factor for pavement types to understand and eliminate. Major experimental works were reviewed from the past 10 years. One relationship developed during the study showed that 100% increase in the tire pressure could increase rut depth by 900%. Surveys done recently on the array of tire pressure show an average near 100 psi with stray values up near 140 thus contrasting greatly with the road test equivalencies derived at 75-80 psi pressure.

We are very pleased to have Canada as our knowledgeable and cooperative neighbor. We have a sharing interaction with the individual provinces and their federal government. We do occasionally stress international relations from the fact that individual states and provinces have their own tire/axle/truckload allowances. Uniformity of such allowances cannot preceed the costly creation of more uniform pavements. Unless some new and large source of highway funds is enacted soon, we will continue to manage a system containing many weak and/or broken pavements. Our bridge system can be used to demonstrate the point. Some mainline bridges are up to 100 years old and they were designed to carry neither present truck weights nor the present frequency of such loads. Many of us know of regrettable cases where we gave in to great pressure to upgrade the loads allowed on an old thin pavement where previously loads had been appropriately restricted. We had one recently between my State of Minnesota and a Manitoba provincial road in Canada. Inside of 2 weeks, the new traffic generated, (heavily loaded fertilizer trucks,) destroyed the road and we had an immediate unprogrammed financing problem.

In an effort to intercept an accelerating asphalt pavement rutting problem, AASHTO established a Task Force to determine the role of high pressure tires. It soon became obvious to the Task Force that the tires are gradually being inflated to higher levels. The radial tire is designed to run that way. The load per tire was found to contribute to the new rutting rate since modern load allowances are far higher than even 10 years ago. A symposium was designed and held to uncover the facts and recommend short and long term solutions. We identified experts from the many aspects of the problem and invited them to an interactive workshop. Viewpoints were taken from the Task Force, the States, tire and truck designers and manufacturers, fleet and independent truck operators, airport specialists, and academia. Four workshop sessions were then held to elicit new compound solutions and a better understanding of the problem by the diverse actors. A serious dialogue was initiated between the trucking industry and the Highway Departments related to tire pressure. Since a "proceedings" was published, only summary bullets will be given here. [Requests for copies of the 'Proceedings of a Symposium/Workshop on High Pressure Truck Tires' should be addressed to AASHTO at 444 North Capitol Street, Suite 225, Washington, D.C. 20001.]

- Tire pressure ranges from 40 to 150 psi
- Local contact pressure is far higher than the inflation pressure

- Tire pressure under dynamic conditions differ greatly from static conditions.
- Biggest concern from higher tire pressure is on thin pavements and the uppermost layers of thicker asphalt pavements
- Keep big trucks on strong roads or limit loads and tire pressure
- Devise new stiffer mix designs for upper layers without increasing cold weather cracking problems. Removing and replacement of distressed layer may be preferable to overlay.
- Begin government testing and approval of truck suspension system components, including tires
- Radials, and their higher pressure, are more efficient, durable, and safe than bias ply tires
- Trip speeds are higher so dynamic stresses have increased on pavements
- Radials are rated one load range higher than the replaced bias ply tires and this is accompanied by a tire pressure increase of 15 psi
- If the European higher axle load would become worldwide, we could expect an additional 10-15 psi pressure.
- Rough roads are a major contributor to higher vehicle dynamic loads
- The old familiar 18 wheeler could become a 10 wheeler if trials to replace the dual tire configuration with wide singles are favorable
- The resultant force of a smaller contact area from a higher pressure tire will be nearer to critical edges, joints and corners of rigid pavements.
- A higher concern must be exercised under a higher tire pressure regime in the control of adequate density and voids control of asphalt pavements.
- Contact pressure and load per tire may well be more important than tire pressure per se.
- Until the many related factors are studied, the symposium recommendation to the Task Force is that tire pressure should not be legislated yet. However, an interim control at 105 psi could be considered.

- More and more weigh-in-motion equipment will inform us soon on the real "complexion" of the traffic loads and axle configurations.
- Truck freightlines and truck designer/manufacturers have volunteered cooperative effort where needed.
- The Accelerated Loading Facilities (ALF) can be used to get some quick answers on high pressure truck tire questions.
- Field verification of mechanistically estimated pavement stresses must be conducted.
- The Surface Transportation Assistance Act of 1982, which allowed increased load, de facto, resulted in higher tire pressure.
- The truck dynamics versus road stress must be studied as a system rather than as separate issues.
- The Strategic Highway Research Program project on future asphalt properties must consider some of the enumerated knowledge deficiencies.

Summary

We will soon have accumulated enough new knowledge to characterize pavement stress as a function of the multitude of vehicle variables. We are truly at a crossroads in that regard. Vehicle owners can take economic advantage of new vehicle components within a 5 to 10 year span. With the present level of funding, roadways are being replaced during a 50 to 100 year span. Pavement life ranges from 15 to 30 years. It is not a good marriage when loads, axle configurations, and load support conditions change very quickly whereas the highway industry cannot make commensurate changes to keep up with accelerating pavement wear out stresses. We must work closer together to solve each new wave of pavement and vehicle economics problems. The TRB and AASHTO type agencies around the world have done a good job sponsoring narrow subjected high technology activities. Now we must force serious and thoughtful interaction among the truck/road actors. An annual or biannual symposium such as this one would be most beneficial. An agency such as the World Bank with its global involvements and continuity could be asked to organize and orchestrate such meetings. This New Zealand symposium following the Canadian RTAC meeting by 1½ years seems about right. Now that this cooperative inertia is established it should be continued.

Minnesota Department of Transportation

Transportation Building, St. Paul, MN 55155

Phone 612-296-3066

August 5, 1987

Mr. Geoff Walsh
Organizing Committee
Institute of Road Transport Engineers
of New Zealand
P.O. Box 7151, TE NGAE
Rotorua, New Zealand

Re: IRTENZ Seminar Paper and Abstract

Dear Mr. Walsh:

Enclosed, in the form you requested, is a camera ready original of my paper and abstract for the Heavy Vehicle Seminar. Our arrangements for participation at the Seminar are nearly complete thanks to your efforts.

Sincerely,

Paul J. Diethelm

Paul J. Diethelm by LK
Physical Research Engineer

PJD:clc

ABSTRACT

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Active research aimed at modernizing and understanding the truckload damage equivalencies is reviewed. Equivalencies based upon load and vehicle conditions of the early 1960's are no longer applicable. Concerted efforts are being made to interact vehicle dynamics and resultant road stresses. Such efforts are enumerated and reviewed. A special emphasis of this paper addresses the role of higher tire pressure on early asphalt pavement life rutting and recently accelerated normal rutting. Serious consideration is being given to some interim pressure control of truck tires in the US. A country wide decision in 1982 to increase truck and axle load allowances had inadvertently increased tire pressure. An enhanced spirit of cooperation has evolved among the road-truck actors to mutually solve problems.