SUSPENSION DYNAMICS

The Vehicle and the Road*

J. Woodrooffe

Presented at

The Third International IRTENZ Seminar
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VEHICLE PAVEMENT INTERACTION is an area of common interest to both the trucking industry and highway agencies. The dynamic loads generated by moving vehicle axles affect vehicle ride as well as pavement performance. The problem is fairly complex and involves an understanding of both vehicle dynamics and pavement design. Recent studies have established that the dynamic loads generated by the axles of moving vehicles depend primarily on vehicle speed, level of pavement roughness, static axle load and suspension type. Suspension type, in particular, was shown to significantly affect the magnitude of the dynamic axle loads generated. In light of these findings, there is a growing interest in developing and installing suspension systems that will minimize the impact of dynamic axle loads of heavy vehicles. As a result, it appears that the time has come for developing a framework for the uniform evaluation of the dynamic properties of heavy vehicle suspensions. This would prepare the ground for developing legislation controlling suspension dynamic behaviour.

This paper offers an overview of the aspects that affect the dynamic axle loads generated by heavy vehicles and their impact on pavements. The focus of the discussion is on the dynamic behaviour of the various vehicle suspensions and their effect on pavement damage. Furthermore, the paper discusses the regulatory implications of these findings and proposes a framework for the uniform evaluation of heavy vehicle suspension systems.

VEHICLE DYNAMICS

Whittemore et al [1] presented one of the earlier studies dealing with the dynamic axle loads of heavy vehicles. Three different methods for measuring dynamic axle loads were evaluated, namely, a tire pressure transducer, a combination of strain gauges and accelerometers installed on the axles of a vehicle, and a wheel-force transducer mounted on the hub of tires. The latter was developed by General Motors for purposes of the study. It was concluded that the tire inflation pressure is not in-phase with the axle load and therefore the tire pressure transducer was considered unsuitable for dynamic load measurements. The other two measuring systems yielded comparable results in measuring dynamic loads. Efforts to model dynamic axle loads were limited to an analogue model of a quarter-car which allowed calculation of dynamic loads within 15% of the experimental values.

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More recent experimental and theoretical studies [2,3,4,5,6] have confirmed that heavy vehicle suspensions can impose high dynamic loads on road surfaces and that the magnitude of these loads varies considerably from one type of suspension to another. It has also been established [7,8,9,10] that the road structure responds to these dynamic loads and that the dynamic component can be related to fatigue life of the road structure.

Work by Sweatman [4] explored the effect of vehicle speed, pavement roughness and suspension type on the dynamic behaviour. The General Motors transducer was used for the dynamic load measurements. An important coefficient was defined to describe the dynamic behaviour of suspensions. Referred to as the Dynamic Load Coefficient (DLC), it takes the form of

$$\mathrm{DLC} = \frac{\mathrm{SD}}{\mathrm{Z}} \qquad (1)$$

where Z and SD are the mean, and the standard deviation of the dynamic wheel load, respectively. The DLC is in essence the coefficient of variation of the dynamic axle load. The study compared the dynamic properties of a number of suspension systems to arrive at a general equation relating DLC to the vehicle speed V (km/h) and the NAASRA pavement roughness R (counts/km) [11].

$$\mathrm{DLC} = a + bVR^{0.5} \qquad (2)$$

Woodrooffe et al [6,9,12] studied the dynamic and load sharing properties of a number of suspension types over a range of pavement roughnesses and vehicle speeds. Suspension variations included interaxle spread and axle load. Dynamic axle loads were continuously monitored for each axle of an instrumented vehicle, Figure 1, developed at the Vehicle Dynamics Laboratory of the National Research Council of Canada (NRC).

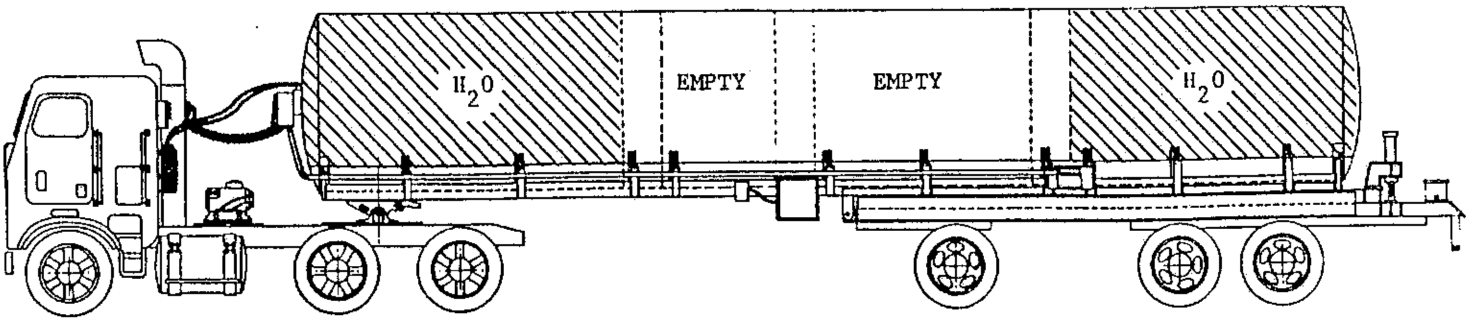

Figure 1 NRC Test Vehicle

What has emerged from these studies is first order understanding of the vehicle system and its constituent elements in relation to the magnitude of dynamic loading. Here are some important points.

i. Dynamic wheel loading of the type most harmful to the road system takes the form of a continuous oscillatory vertical motion of the whole vehicle mass as it travels over a road surface having some homogenous roughness. For a set speed, repeated runs over the same road section produced axle load responses which were practically identical in magnitude and location on the roadway [13,14].

ii. Sprung mass of the vehicle represents the whole vehicle body and contents supported by the suspension. The natural frequency of most loaded commercial vehicles ranges from 1.5 Hz to about 3.5 Hz. It is the response of this sprung mass which is the main contributor to dynamic wheel loads. The most practical means of reducing dynamic wheel loads is to lower the natural frequency while controlling the amplitude of the sprung mass. Typical values of sprung mass for a fully-loaded commercial vehicle lead to axle loads in the order of 7 to 9 tonnes.

iii. Unsprung mass refers to the wheels' axles and suspension parts which collectively move together having their own natural frequency in the range of 10 to 15 Hz. While this action may look aggressive to the casual observer, the magnitude of the wheel load attributed to this action is small principally due to the comparatively low mass of 0.7 to 0.9 tonnes per axle. On suspensions with aggressive unsprung mass action, such as air suspensions, hydraulic dampers are commonly incorporated into the design to keep this under control.

iv. Spring stiffness and damping are the two most important vehicle parameters affecting vertical repsonse. Ideally, the softer the spring rate, the less the dynamic load. Unfortunately, this degrades the handling characteristics such as roll stability of the vehicle. To compensate, additional roll stiffness can be built into the suspension either as part of the principle mechanism or as an add-on component such as a torsional roll bar.

The characteristics of the spring stiffness curve also appear to influence the vertical dynamics of the vehicle. It has been shown [15] that suspensions which are highly nonlinear in the working range may behave more aggressively than those with linear characteristics.

It is worth noting that the European trend in steel spring suspensions is towards soft linear springs with virtually no Coulomb friction. This is achieved by the use of polymer spacer blocks to keep the leaves of the springs separate and the elimination of slippers in favour of a bar link. Damping is provided by hydraulic dampers and roll stiffness is achieved with the use of a roll stabilizer bar. This trend represents a significant departure from the classic spring design which utilized tight spring packs producing high levels of sliding friction or coulomb damping within the spring pack and at the slipper.

Damping is essential in controlling the vertical movement of the vehicle and hence the dynamic loading to the roadway. Suspensions which have a high natural frequency will produce high dynamic loads with very small amplitudes. It is difficult to use hydraulic dampers in this situation as the working stroke will be small and the number cycles per unit time imposed on the dampers will affect its working life. To illustrate this, consider two separate vehicles systems: the first having a 1.5 Hz natural frequency, and the second a 3.0 Hz natural frquency. Let both systems be excited at their respective natural frequencies. If both systems are subjected to 0.5 g peak acceleration, then the vehicle system with a 3.0 Hz natural frequency will experience only one fourth the displacement experienced by the system with 1.5 Hz natural frequency. Not only will the dampers experience twice as many cycles, there will be very little stroke to work with.

v. Suspension type has an influence on dynamic wheel loading. This applies to axle group suspensions where load is shared among two or more axles. Commercial freight vehicle suspensions can be classified in the general category of either dependent or independent. A dependent suspension equalizes load between two axles, but the axles are coupled dynamically to each other. This coupling is achieved usually by a rigid beam as in the walking beam suspension. When the lead axle encounters a bump on the roadway, the impulse load experienced by the lead axle is reacted through to the second axle at the same instant in time. Similarly, an impulse loading of the second axle is reflected exactly in both magnitude and phase with the first axle. For a given road disturbance, the dependent suspension will experience twice the number of load impulses than that of an independent suspension.
The independent suspension equalizes static load between two or more axles but the axles are dynamically decoupled from each other. The four spring and independent air suspensions are two typical examples. Each axle of an independent axle group suspension has its own spring element. While the collective sum of the springs suspending the sprung mass equals a high stiffness level, the individual spring stiffnesses are low. This enables impulse displacements of the individual axles to be stored with less effect on the sprung mass than with dependent suspensions.

Road roughness and vehicle speed represent the two input variables which drive dynamic wheel loading of commercial trucks. All of the experimental studies referred to above agree with the following observations and conclusions.*

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*The discussion which follows is supported with numerical examples presented by Woodrooffe et al. [6].

i. As the road roughness diminishes to that representative of an excellent road surface, all suspensions whether dynamically good or poor will converge to roughly the same low levels of dynamic wheel loading. This value will depend on vehicle speed. Typical values measured during the experimental program on excellent road surfaces expressed in terms of DLC range from 0.04 at 40 km/hr to 0.08 at 80 km/hr.

ii. As road roughness increased to levels representative of paved roads in fair condition, there was a marked divergence in the behaviour of good and poor suspensions. The best suspension tested at a vehicle speed of 80 km/hr recorded a DLC of 0.15 while the worst was measured at 0.39. This represents an increase by a factor of 2.6 in the dynamic wheel load of two commercially available suspensions in common use today.

iii. Characterization of road roughness is important when considering dynamic wheel loading of heavy trucks. Since it is the excitation of the sprung mass which has a first order effect on dynamic wheel loading, road profiles having a high content of wave lengths which match the natural frequency of the vehicle at highway designed speed are undesirable. For example, considering the range of natural frequencies of heavy trucks to be between 1.5 and 3.5 Hz, roadways designed for vehicle speeds of 100 km/hr should attempt to diminish road wave lengths between 8 and 19 meters. By improving the roughness quality of new roads, particularly in specific wave lengths, the magnitude of dynamic wheel loading of all vehicles can be reduced. In time, however, the roughness of all roadways increases, which excites the vertical response of the vehicle resulting in high dynamic loads controllable only through well-engineered suspension systems.

iv. Vehicle speed has a similar relationship to dynamic axle loading as does road roughness. At speeds below 40 km/hr there is little difference between good and poor suspensions for a given roughness common to the highway system. At speeds above 60 km/hr and to at least 80 km/hr, there is a very sharp increase in the dynamic wheel loading between good and poor suspensions. For example, on a roadway of fair roughness at 40, 60 and 80 km/hr, the best suspension averaged DLC values of 0.08, 0.11, and 0.15 respectively, while the worst suspension averaged DLC values of 0.10, 0.15 and 0.39 respectively. The DLC of the worst suspension increased by a factor of 2.6 from 60 to 80 km/hr while the best suspension increased by a factor of 1.4.

From the numerous studies that have been conducted, it is clear that first order reductions in dynamic wheel loading are achieveable through vehicle design. The science, however, has not matured to the point where standard test procedures and measurement techniques have been established in support of suspension performance criteria.

The following section will discuss what is currently understood about the effects of dynamic wheel loading on the road structure and will be followed by a discussion of a concept for the testing and measurement of suspension systems.

IMPACT OF VEHICLE DYNAMICS ON PAVEMENTS

Early efforts to evaluate the impact of dynamic axle loads on pavements date back to the late 1950's with the AASHO Road Test [16,17]. A number of special studies during the test involved measurement of the dynamic axle loads generated by various suspension types over a variety of levels of pavement roughness and vehicle speed. These studies used a pneumatic tire pressure transducer which was calibrated using a weigh-in-motion scale. A number of suspension types were tested including leaf-spring, walking-beam, rubber and air. It was found that their dynamic behaviour can be substantially different over the same levels of pavement roughness and vehicle speed. There were no efforts, however, to evaluate the impact of the various suspension types on pavement damage. Pavement damage was found proportional to the fourth power of the axle load, hence the so-called "fourth power law".

Subsequent studies of the impact of dynamic load on pavement damage were enhancements of the fourth power law. Eisenmann [18] derived a theoretical relationship for the pavement damage caused by a dynamic axle load normally distributed. Sweatman [4] expanded this relationship to account for the kurtosis and the skewness in the actual probability distribution of the dynamic load. The derived coefficient designated as the "dynamic load stress factor" was used in conjunction with experimental data to rank various suspension types. On the basis of the calculated dynamic load stress factor, the range of pavement damage caused in addition to the damage caused by the static load was between 10% to 40% depending on suspension type.

The approach taken by more recent studies is to relate the magnitude of dynamic axle loads to pavement response parameters measured by sensors embedded into the pavement structure. Gorge [19] described a number of different methods for measuring dynamic loads ranging from an accelerometer arrangement to wheel-force transducer. Addis et al [13] used an optical tire deflection device calibrated to give tire load from tire deflection. One of the main findings of this study was that replicate dynamic axle load waveforms are repetitive in-space. These efforts established a good relationship between dynamic axle load and dynamic pavement response parameters. They stopped short, however, from directly relating dynamic axle load to pavement performance.

Another approach was taken by Papagiannakis et al [14], whereby the impact of dynamic axle loads on pavement performance was evaluated using analytical methods. Dynamic axle loads were experimentally determined over a range of pavement roughnesses and vehicle speeds using the NRCC's instrumented vehicle. Only two suspension types were tested, namely, an air suspension and a rubber suspension. These were shown to represent extremes in dynamic behaviour [6]. The findings of the study verified the repetitive in-space nature of replicate axle load applications observed by Addis et al [13]. It was, furthermore, pointed out that although this loading condition is not the case under normal traffic, it was typical of the loading experienced by AASHO Road Test sections. Another observation was that the dynamic loads generated by tandem axles have roughly the same amplitude and are in phase. This suggests that for the range of variables tested, dynamic load sharing between axles does not seem to be important in evaluating pavement damage. Nevertheless, non-equal load sharing between multiple axles seems to be a problem for a number of suspension types under static conditions and this should have an impact on pavement damage.

Regression equations were fitted to the dynamic load data generated by the two suspension types, Eq. 3 and 4.

$$SD = 0.087\ V^{0.398}\ R^{0.725} \tag{3}$$

$$SD = 0.005\ V^{1.265}\ R^{0.671} \tag{4}$$

where SD is the standard deviation of the dynamic axle load (kN), V is the vehicle speed (km/h) and R is the level of pavement roughness (in/mi on the International Roughness Index Scale [20]). The impact of suspension type on the magnitude of axle load variation was demonstrated by plotting the SD of the dynamic load versus vehicle speed for the highest level of pavement roughness tested, (i.e. 201 in/mi). It can be seen that the rubber suspension causes substantially larger load variation than the air suspension for vehicle speeds higher than approximately 40 km/h. Maximum DLC values as high as 0.10 were reported for the air suspension and 0.20 for the rubber suspension. Thus, the suspension type alone could have reduced the coefficient of variation of the dynamic load by a factor of 2.

The analytical part of the study by Papagiannakis et al [14] consisted of two parts. First, the performance of a number of AASHO Road Test sections was simulated by taking into account the repetitive in-space dynamic axle load experienced over their service lives. Second, the impact of suspension type on pavement damage was evaluated on the basis of the experimental dynamic load data. A modified version of the pavement performance model VESYS-III-A [21] was used in both parts of the analysis. The methodology followed for simulating the performance of the AASHO Road Test sections consisted of dividing the pavement length over which the dynamic axle load goes over a complete load cycle, (i.e. evaluated equal to 5.2 meters) into subsections and by assigning load segments from the passing vehicle axles to each subsection. The described methodology improved considerably the accuracy of pavement performance predictions in four of the six pavement sections analyzed, Figure 2, while a marginal improvement was realized for the other two sections. It was concluded that dynamic axle loads do have a significant impact on pavement performance and that they should be properly taken into account in pavement design. The second part of the analysis used the experimental dynamic load data as an input to the pavement performance prediction model assuming their random arrangement in-space. The impact of a suspension type on pavement performance was compared to the pavement performance under static load. It was found that over the life of pavement, the rubber suspension may cause up to 22% more damage than the static load while the air suspension may cause up to 8% additional damage, Figure 3.

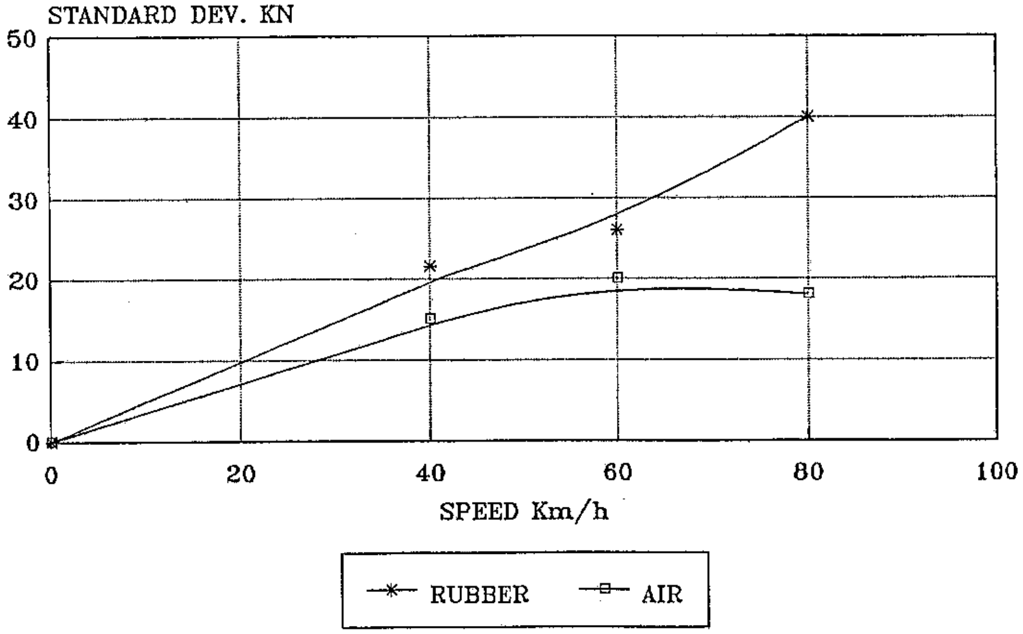

Figure 2. Impact of vehicle speed on axle load

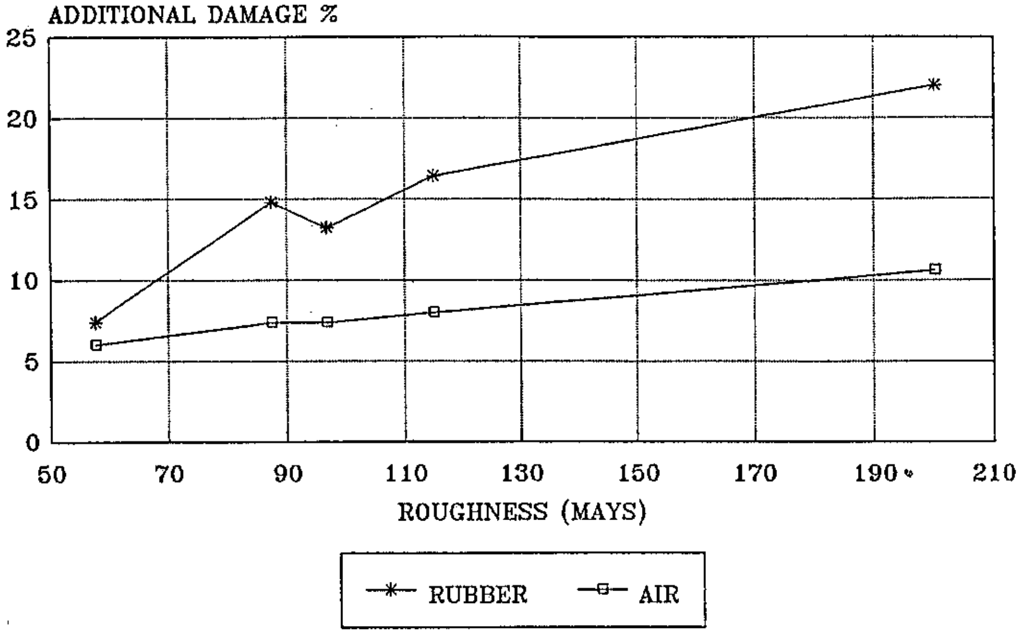

Figure 3. Impact of suspension type on pavement performance

An experiment was conducted as part of the Canadian Weights and Dimensions Study (7) to determine the first order effect of dynamic loads on pavement deformation. The dynamic loads were created by a 40 mm high by 90 mm wide wooden plank placed on the road surface. Dynamic loads from NRC's instrumented vehicle were recorded and syncronized to road deflection data. The deflection data was provided by three subsurface differential transformers (DC-DT's) located in the road structure. The structure of the roadway consisted of a 56 mm asphalt concrete surface with a 750 mm granular base overlying a clay subgrade. Figure 4 shows the primary influence of vertical dynamic loading on pavement deformation.

The deflection ratio has been defined as the magnitude of the deflection recorded under dynamic axle loads induced by perturbations on the road surface divided by the deflection measured under the same wheel, vehicle velocity and pavement temperature with no road surface perturbations in place. A regression analysis correlating the impact factors with the dfelction ratios yielded the expression:

$$\text{Deflection Ratio} = 0.27 + 0.659\ (\text{DIF}) \qquad (5)$$

$$N = 41 \quad r^2 = 0.73 \quad \text{Sey} = 0.148$$

Dynamic load/deflection trends for the tandem drive axles (2 and 3) exhibited greater scatter than shown in Figure 4 for the carrying axles. The majority of data scatter was associated with tests conducted at 37 km/h. At comparable impact factors, deflection ratios for the drive axles at this velocity were approximately 30 percent larger in magnitude than deflection ratios determined at other velocities and loading conditions. This may be attributed to the fact that the drive axles are coupled via the walking beam forming a separate mechanical system having a natural frequency of 15 hertz. At the 37 km/h the 1.52 m axle spacing coincides with the 15 hertz natural frequency peak, causing an amplification of dynamic force and corresponding increases in pavement deflections. Deleting the 37 k/h data, the best-fit correlation relating the deflection ratios to dynamic impact factors (DIF) for the tandem drive axles was:

$$\text{Deflection Ratio} = 0.66 + 0.437\,(\text{DIF}) \qquad (6)$$

$$N = 22 \quad r^2 = 0.68 \quad \text{Sey} = 0.174$$

From equations 1 and 2, a single road surface perturbation causing dynamic axle loadings equal to 1.5 times the static weight yield pavement surface deflections which are, on average, 1.3 times the magnitude of the deflection under the same axle on a relatively smooth pavement surface.

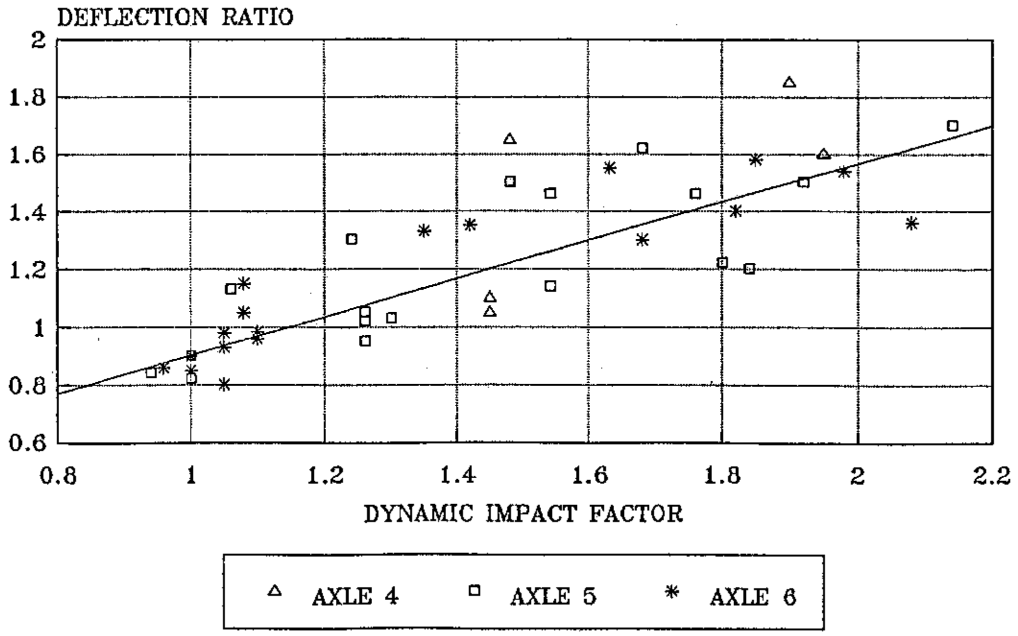

Figure 4 : Dynamic impact factor versus deflection ratio

Results of analyses carried out on deflections recorded under a wide range of tandem axle dual tire loads included in the Pavement Impacts Investigation and tested at the site are presented in Reference 22. The results indicate that under normal test conditions pavement surface deflection are proportional to static axle weight raised to the pwer of 0.747. Employing this relationship, 50 and 100 percent increases in static axle loads cause 35 and 68 percent increases, respectively, in pavement deflections. In comparison, using equation (5), percent changes in the magnitude of surface deflectons caused by 50 and 100 per cent variations in dynamic axle loadings are 35 and 70, respectively. These comparisons suggest that the effect of changes in dynamic and static wheel loads on the mangitude of pavement surface deflections are similar.

PROPOSED FRAMEWORK FOR VERTICAL DYNAMIC EVALUATION

The large spread in dynamic axle loads recorded between the best and worst performing suspensions supports the need to qualify suspension systems in terms of their vertical dynamic behaviour. To describe the vertical dynamics of a suspension in a complete manner can be an exhaustive exercise since dynamic activity of a suspension is highly sensitive to at least four parameters, namely, vehicle speed, road roughness, static axle load, and general configuration of the test vehicle. However, in a regulatory sense and to a certain extent for scientific classification, the primary interest is the upper level of the dynamic loads which are generated at highway speeds on moderately rough roads. Therefore, a first approach in rating suspension systems is to test suspensions for at least one accurately controlled set of test conditions which produce reasonably high levels of dynamic load.

What follows is an example of one concept that if developed could lead to a unified first order rating system for heavy truck suspensions.

To control vehicle parameters, a standardized towable test bed will form the suspension test apparatus. Shown in Figure 5, the concept would take the form of a rigid structural trailer containing a concentrated mass equivalent to some pre-determined standardized axle load. Considering current weight regulations, it would seem reasonable that the mass of the trailer should result in static wheel forces of 40 kN (8.16 tonnes). The mass would be varied depending on the number of axles of the suspension.

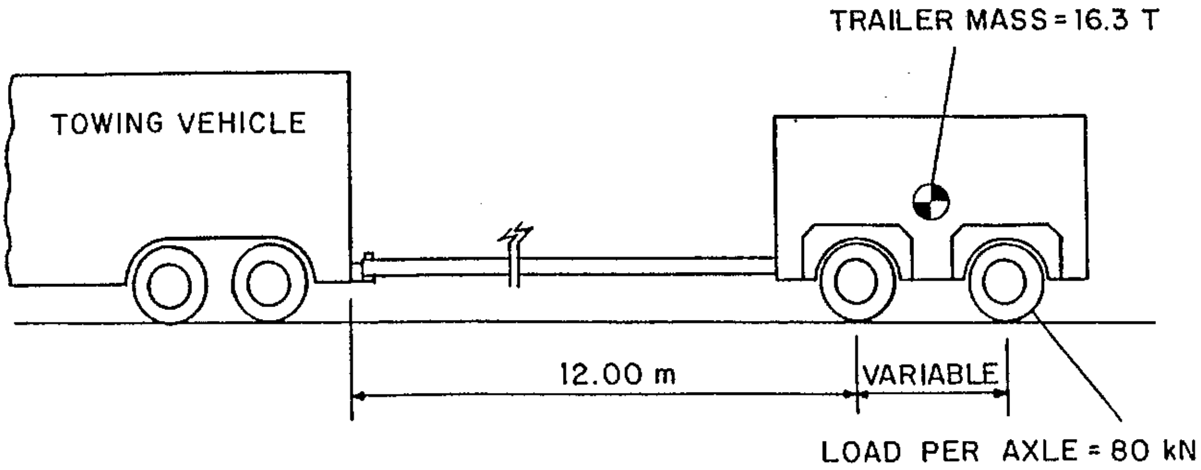

Figure 5. Standardized Towable Test Bed

The test trailer would have a long drawbar to minimize the effects of dynamic transfer from the towing vehicle to the test trailer. The trailer should have a low mass centre balanced between the axles of the suspension and the whole trailer unit should have minimum pitch inertia. The suspension being tested could be fabricated using a standard subframe, which would be mounted to the test trailer. It may be desirable to specify standard axles, wheels and tires for a standardized test program.

It will be critical to control vehicle speed to some predetermined value or set of values. Since there is little dynamic activity below 40 km/h, a desirable set of test speeds would be 40, 60, 80 and 100 km/h.

Instrumentation requirements could be limited to measurements of vehicle speed, the vertical acceleration of each axle and the sprung mass and some measure of road roughness. Since the mass of the trailer and mass of the unsprung components are known, dynamic axle forces can be resolved by summing the products of the various masses and accelerations. The dynamic axle load data would be processed in a statistical manner yielding Sweatman's DLC. To arrive at a single number to rate the first order dynamic performance of a given suspension will require agreement on a standard test procedure. The input variable road roughness is the one parameter that cannot be universally controlled. If, however, a certain road roughness could be taken as the standard reference roughness for rating suspensions, it would be possible to identify a set of roads with roughness values on either side of the standard value. The suspension performance at the reference roughness could then be evaluated by interpolation of the results. Another technique for roughness input would be with the use of a road simulator or vehicle shaker.

For some applications, describing the vertical dynamics of a suspension with a single numerical value may not be acceptable. The mechanical behaviour of a suspension system can be further described by determining the rate of change of dynamic load with respect to the predominant variables evaluated at a particular set of baseline test conditions. The experiments following the baseline test would involve test conditions where velocity, road roughness and axle load would be independently varied. The experimental results could be tabulated or displayed as shown in Fig. 6.

In addition to the assessment of dynamic wheel loading, it will be important to assess the load equalization performance of suspensions. Within the industry there are variations in the 5th wheel height of tractors and the coupling heights of trailers. Mismatching tractor and trailer coupling heights will result in variations in the pitch attitude of a trailer and its suspension. To gain an appreciation for the load equalization sensitivity to pitch attitude of the various suspensions, a static pitch test is suggested.

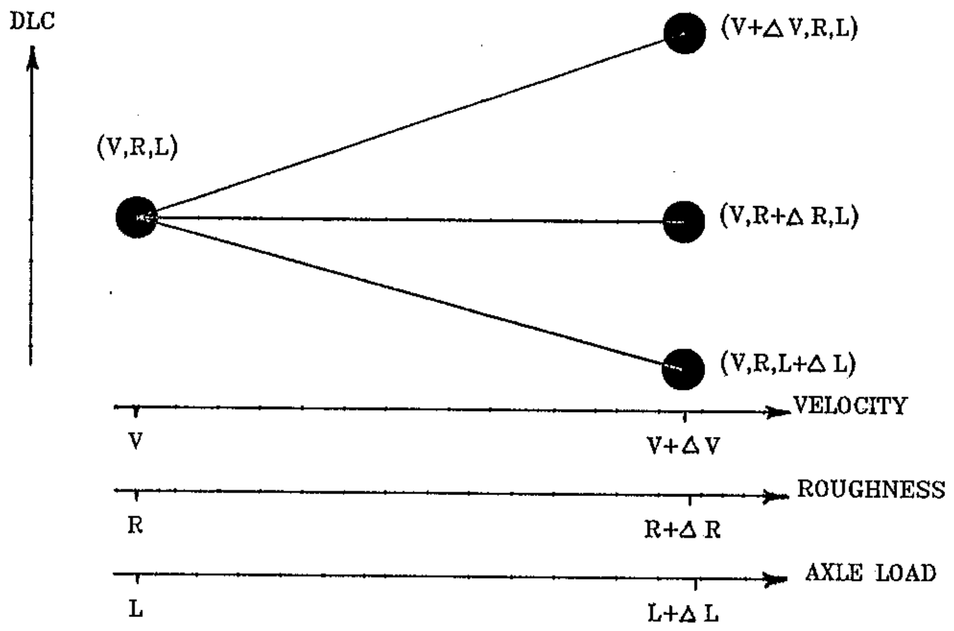

Figure 6. Rate of change of DLC

One criteria used to assess the pitch load equalization characteristics of the suspension is in the form of percentage load transfer (PLT) recorded for varying pitch. PLT for a tandem axle group is defined as follows:

$$\mathrm{PLT} = \frac{L_t - L_y}{L} \cdot \frac{100\%}{\theta} \qquad (7)$$

where L_t and L_y are the changes in the vertical load of the trail and lead axles measured as the trailer is tilted through pitch angle θ, and L is the total weight suported by the axle group. Agreement will be needed on the pitch angle limits and the acceptable variation of PLT within the bounds of these pitch angle limits.

REGULATORY IMPLICATIONS

Softer spring rates are associated with suspensions with good dynamic performance. Unfortunately, this results in the degradation of roll stiffness of the suspension. It will be imperative to ensure that sufficient roll stiffness is maintained as suspensions are optimized for improved vertical dynamic performance. This is to suggest that any suspension rating system must include roll stiffness. Parameters such as roll centre and roll steer also play a significant roll in vehicle stability and it may be appropriate that these factors should also be considered.

In addition to the assessment of dynamic wheel loading, it will be important to assess the load equalization performance of suspensions. Within the industry there are variations in the 5th wheel height of tractors and the coupling heights of trailers. Mismatching tractor and trailer coupling heights will result in variations in the pitch attitude of a trailer and its suspension. To gain an appreciation for the load equalization sensitivity to pitch attitude of the various suspensions, a static pitch test is suggested.

One critera used to assess the pitch load equalization characteristics of the suspension is in the form of percentage load transfer (PLT) recorded for varying pitch. PLT is defined as the longitudinal percentage load transfer from the lead to the rear axle of an axle group per degree of trailer pitch attitude [6,10]. Agreement will be needed on the pitch angle limits and the acceptable variation of PLT within the bounds of these pitch angle limits.

It is probable that in time, performance standards for heavy truck suspensions will be developed and implemented. The investment in road infrastructure and the high cost of maintenance, coupled with a continuing increase in the volume of commercial road transport, have created a climate conducive to corrective action. Future trends in highway transport suggest that simple economics and regulatory uniformity are generating a truck fleet that is more uniform in terms of wheel base and loading. Vehicle speeds are also becoming more uniform because of fuel economy. This suggests that the vertical dynamic performance of heavy trucks will become more uniform which could have a serious effect on the road structure as it has been shown that two identical vehicles will dynamically load a given roadway at exactly the same place if their speeds are equal. By reducing the dynamic loading of these vehicles through improved suspension design, the impact of the dynamics of fleet uniformity will be reduced.

The development of suspensions with lower dynamic characteristics may require regulation, as there are no incentives for manufacturers or users to specify such suspensions. It is likley that these regulations will be based on performance standards as outlined in the previous section.

In addition to product performance regulations, there may be more stringent suspension enforcement requirements at weigh scales. It is probable that road side weigh stations will be automated for single axle assessment which will present the opportunity to check and enforce static load equalization of truck suspensions.

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