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Dynamic Interaction between Vehicles and Infrastructure Experiment (DIVINE)

Summary of Technical Report

The purpose of this Summary is to highlight the findings of the OECD - (Organization for Economic Co-operation and Development) regards the benefits of heavy vehicles with air suspension on roads. The knowledge gained and appreciated by the cooperating countries can be shared with countries that are rapidly expanding their transportation infrastructures. The end result is a faster payback and reduced costs of maintaining these infrastructures.

- This study was through the participation of European and North American countries, as well as public and private institutions
- Purpose of the study was to provide scientific evidence of the effects of heavy vehicles and their suspensions on road systems
- 50% of road maintenance costs are associated with effects from heavy vehicles
- The amount of dynamic load exerting on roads is directly associated with the type of vehicle suspension

- Air Suspensions increase pavement life by 15% to 60 %
- This corresponds to increased static load of 4% to 12 %
- A 15% increase in vehicle mass limit can save upwards of $500 million per annum.
- Increased pavement life means significant reduction in road maintenance cost which forms 90% of annual road budget in OECD countries
- "Road Friendly" suspensions have low spring stiffness and coulomb friction with optimum damping. Well designed air suspensions best meet these criteria.

The following is a broader summary of the DIVINE report and its findings.

Background:

The titled study was initiated by the directorate of Science, Technology and Industry of the OECD in 1993. Interim results from the study were presented in 1995 and the final report in 1997. This is a brief synopsis of the final Technical Report.

About the OECD:

The Organization for Economic Co-operation and Development, a body of 30 member countries, all developed nations with functioning market democracies, emerged from the erstwhile European Economic Community (EEC) in 1961. Its mission is to help governments of member countries achieve sustainable economic growth and employment and rising standards of living, while maintaining financial stability.

This particular study was commissioned as a part of the OECD's program of co-operation in the

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field of research on Road Transport. The mandate for this program is to enhance the efficiency of road transport and minimize its impact on the environment through research, information exchange, policy assessments and policy formulation.

Participation:

A total of 17 countries participated in this study including Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hungary, Iceland, Japan, Netherlands, Norway, New Zealand, Sweden, Switzerland, UK and USA. It involved road agencies, road and bridge research organizations and the private sector from participating countries. Major elements of the study were carried out in 9 countries.

Objectives of the Study:

The main purpose of the DIVINE project was to provide scientific evidence of the dynamic effects of heavy vehicles and their suspension systems on pavements and bridges. This would support transport policy decisions affecting infrastructure and road freight transport costs and to indicate the most productive avenues for improving the interaction of heavy vehicles with roads and bridges.

A key element in this study was recognition of the infrastructure i.e. roads and bridges and heavy vehicles that use it, as one "transport system". This system is critical to the economic development and growth of commerce for nations. It is also an enormous national asset representing from one half to three times the Gross National Product. Maintenance of this infrastructure is a significant cost ranging from $10 to $90 million per 1000 km of road length with the funds distributed between new construction, rehabilitation and other maintenance. Significant portions of these total costs are directly attributable to heavy vehicles – up to 50% of rehabilitation costs. The remaining costs are related to the provision of mobility to other vehicle classes as well as other factors - such as environmental conditions – which are not directly related to road use.

Derived from this purpose were the following objectives of the project

- Reducing adverse impact of heavy vehicles on road networks
- Improve freight productivity through reforms in vehicle size and weight
- Quantify benefits of "Road Friendly" vehicle suspensions
- Take greater account of effect of heavy vehicles in road and bridge design

Methodology

The study was carried out with participation by public and private institutions related to road transport in participating countries. This included study of available statistics and data from these agencies, as well as experiments and tests carried out at various facilities. The Canterbury Accelerated Pavement Testing Indoor Facility (CAPTIF) in New Zealand, Virtta test site in Finland, United States Federal Highway Administration (USFHA) test road in Virginia, The RN 10 Trappes test road in France and several test bridges in Switzerland and Australia were used for testing. Test vehicles were also sourced from different participating countries.

Static V/S Dynamic Loads

Trucks "wear" pavements at a rate which is dependent not only on the static load carried by the vehicle but also on the dynamic performance of the vehicle, on the longitudinal profile of the road and on the structural variability of the pavement. In fact, dynamic loads have a greater effect on pavement wear than tire characteristics. As a result, the effect of heavy vehicle suspensions on pavement condition and performance was determined as a major element of research and presented as one of three titled sections of the findings.

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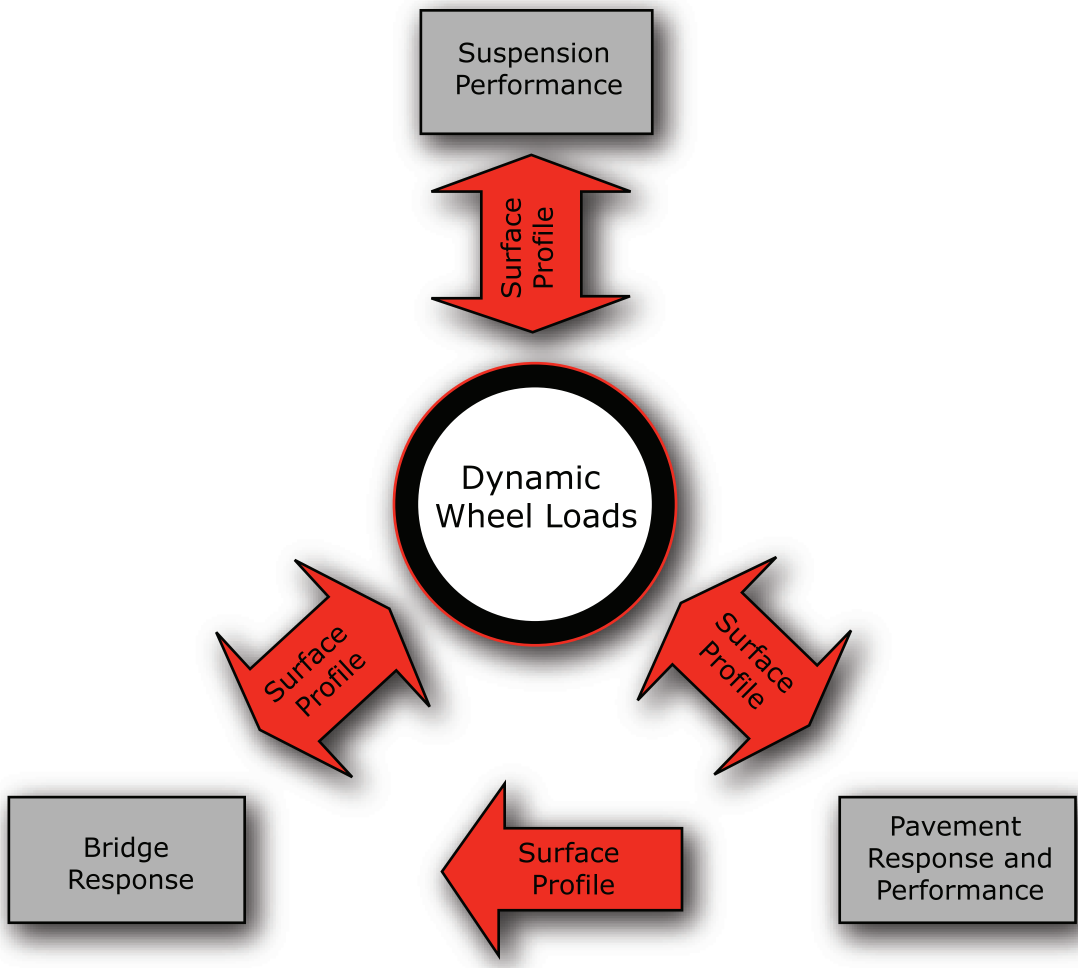
Figure 2.1: Interaction of Suspensions, Bridges and Pavements under Dynamic Loading



Findings relating to Heavy Vehicle Suspensions:

The findings with regard to heavy vehicle suspensions as referenced in different sections of the report are summarized here:

1. Use of air suspension increased pavement life by about 60% for thicker pavements and 15% for thinner pavements.

2. The above would equate to a static load increase of 4 to 12 percent. Such increase in axle weight would provide a significant improvement in road freight productivity and a reduction of indirect user costs.

3. Air suspensions increased pavement life by 45 to 65 percent for specific rutting criteria and 30 percent for a particular cracking criterion.

4. Pavement profile deteriorates more rapidly under a steel suspension than under an air suspension carrying the same load.

5. Use of air suspension on heavy vehicles could reduce dynamic loads by about 10 to 12 percent and therefore lead to significantly reduced pavement damage.

6. The concentration of dynamic loads for air suspension has only about half the magnitude of

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that for steel suspensions.

7. The progression of pavement unevenness is likely to be several times as rapid under loading from steel suspension than it would be under air suspension

8. Road friendly air suspensions reduce the maximum impact factors for the rear tandem and tridem axles of articulated semi-trailer trucks.

9. Low spring stiffness, very low Coulomb friction and appropriate level of viscous damping are properties of a road friendly suspension. These are to be found in well-designed and well-maintained air suspensions. It is unlikely that steel suspensions could achieve the desired level of performance.

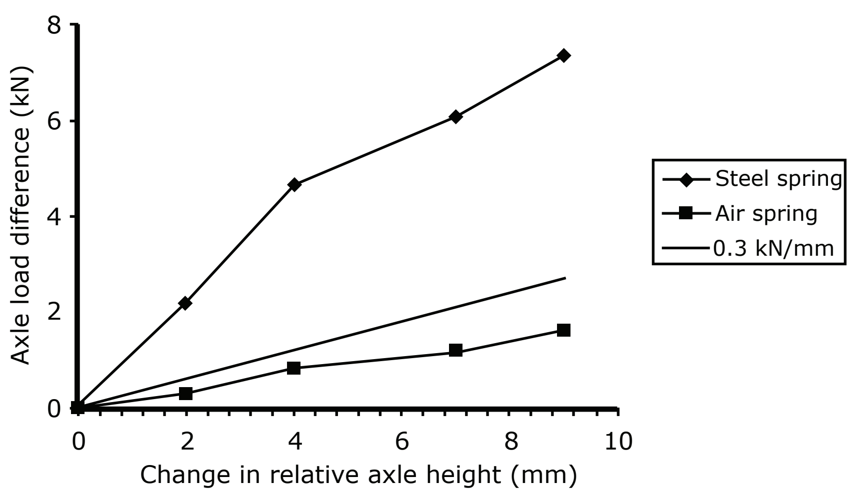
10. A suspension having low spring stiffness combined with an appropriate level of viscous damping (typically air suspension) will result in low dynamic loads at the sprung mass frequency.

11. Suspension load equalization across axles is an important performance attribute. Systems that equalize axle loads well – i.e. air suspensions- imply consistently better road loading.

12. The European Union allows a higher axle load (115kN instead of 100kN) in some cases if an air suspension or some other form of "road friendly" suspensions is used.

13. There are many reasons for use of air suspensions on heavy vehicles. In addition to better ride quality for both drivers and freight, air suspensions have the potential to improve almost every aspect of heavy vehicle dynamic performance, including safety related aspects of stability. They also distribute loads more evenly between axles and reduce heavy vehicle environmental impacts related to noise and vibration.

Figure IV.42. Axle load equalisation (stationary conditions) by suspension type (tandem axle trailing arm air suspension and tandem axle steel spring suspension)



Source: *NRC*

Findings from the DIVINE study are conclusive with regard to suspensions and their role in the overall "transport system". Type of suspension is a critical factor in the impact of Heavy Vehicles on pavements. Air suspensions are by far more "road friendly" than steel suspensions. Leading to increased pavement life, greater load carrying ability, reduced road maintenance and rehabilitation cost and higher road freight productivity.

Copy of the detailed Technical Report is available on-line at http://www.oecd.org/

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Additional Information
Other material related to air suspension includes:

"Effects of Heavy Vehicle Suspension Design on Dynamic Pavement Loading", Western Highway Institute, June 1989

"Manual for Incorporating Pneumatic Springs in Vehicle Suspension Designs", Society of Automotive Engineers, SAE HS-1576, January 1994

Jack Gieck, Riding on Air: A History of Air Suspension, SAE International, October 1999

"Spring Design Manual", Society of Automotive Engineers, SAE AE-21, February 1996

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