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# Road and Rail Infrastructure II

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# VERTICAL DYNAMIC LOAD IMPACT ON THE PAVEMENT OF AN URBAN FRONT ENGINE BUS

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## Abstract

The objective of this paper is to quantify the dynamic vertical load imposed to the pavement on a Brazilian urban front engine bus application. The analysed bus had a 4×2 configuration and, as it is allowed in accordance with Brazilian law, had 6 tons on the front axle and 10 tons on the rear axle, as static loads. In order to quantify this condition, the rear axle was instrumented with strain gauges to simulate as a load cell. Measurements were done on a real urban application (Curitiba city, Brazil). Results showed significant differences between the static load, data used for pavement specification, and the dynamic vertical load, which could have a direct impact on the pavement lifetime.

*Keywords: commercial vehicle, pavement specification, vertical load*

## 1 Introduction

South American cities public transportation, unlike European cities, is done mainly by urban buses. In Brazil, 80% of the urban buses have a front engine setup. This configuration can be described as one of the simplest configurations among all commercial vehicles – Figure 1. In accordance with the Brazilian's legal demand, a 4x2 commercial vehicle configuration is allowed to transfer 6 tons on the front axle and 10 tons on the rear axle for the pavement, as static loads. Nevertheless, due to lack of fiscalization, it is common to find overloaded vehicles during city rush periods.

On the other hand, the main flexible pavement dimensioning methods, used in Brazil [2], consider different static load on each axle of a commercial vehicle (truck or bus). It means that, for dimensioning purpose, it is considered that the load of a truck, or bus, does not vary along the road.

Considering a simplification of the suspension of a commercial vehicle – quarter model car (Figure 2), it is clear that the spring k1 and the shock absorber c1 have a dynamic behavior; its consequence is the variation of acceleration of mass M1 that represents the entire vehicle. Therefore, the acceleration of mass M1 generates a dynamic load that is transferred to the road surface.

**Figure 1** Typical front engine bus configuration [1]

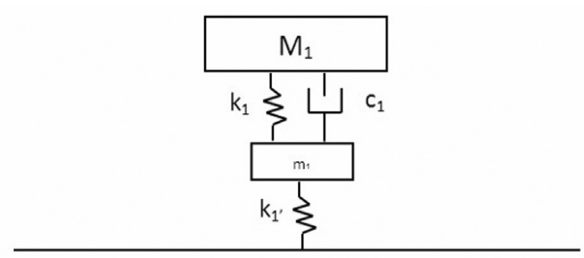


**Figure 2** Quarter model car [3]

## 2 Methodology

In order to verify the real vertical load applied on the pavement, a rear axle of a 4x2 commercial vehicle, with the maximum load distribution allowed in Brazil for this type of vehicle (6 tons on the front axle and 10 tons on the rear axle) was instrumented. Both sides of the rear axle beam were instrumented with one rosette, as shown on Figures 3 and 4.
The signal output was given in micro strains (μs), therefore it was necessary to calibrate the instrumentation setup, in order to have a correlation between the instrumentation output (μs) and the load transferred to the pavement (tons). Calibration of the rosette is presented on Figure 5.
A typical urban route in Curitiba city (Brazil) was defined for the measurements – Figure 6. The route has been divided in 6 different tracks:
· Tracks 1 and 2: reasonable pavement quality.
· Tracks 3 and 4: poor pavement quality.
· Tracks 5 and 6: good pavement quality.

**Figure 3** General view of the instrumented rear axle beam

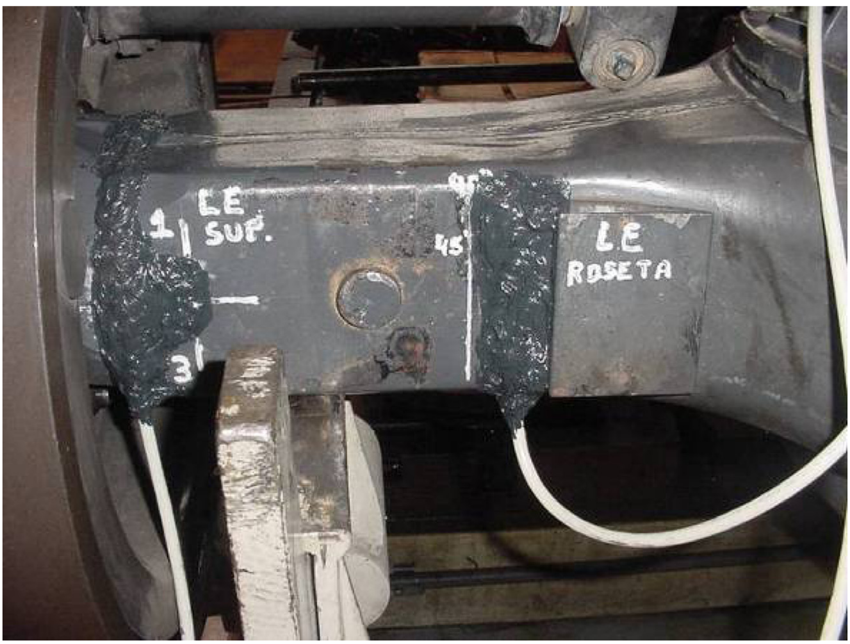


**Figure 4** Detail of the instrumentation of the left hand side of the rear axle beam – same instrumentation was made on the right hand side of the component

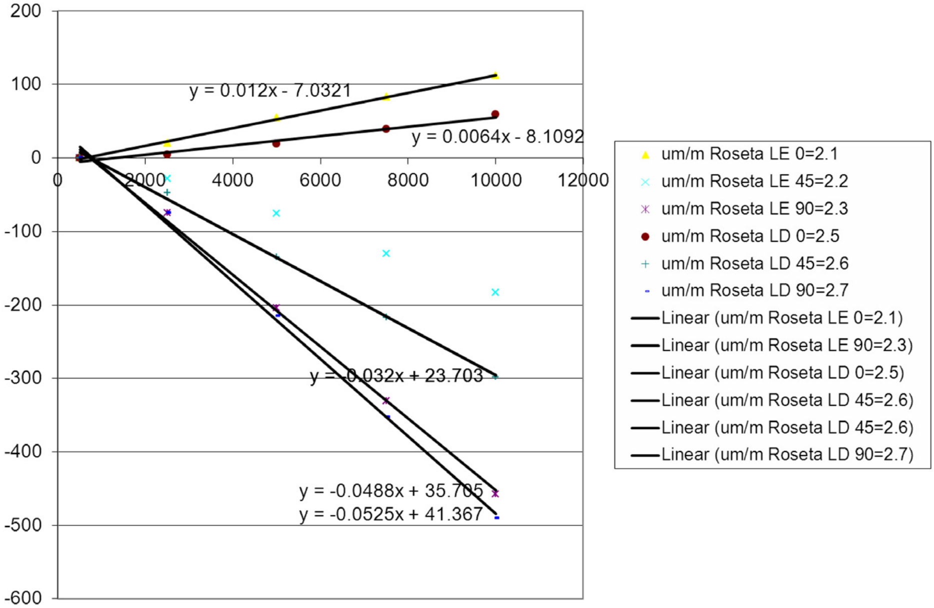


**Figure 5** Equation for rosette calibration: μs to kg

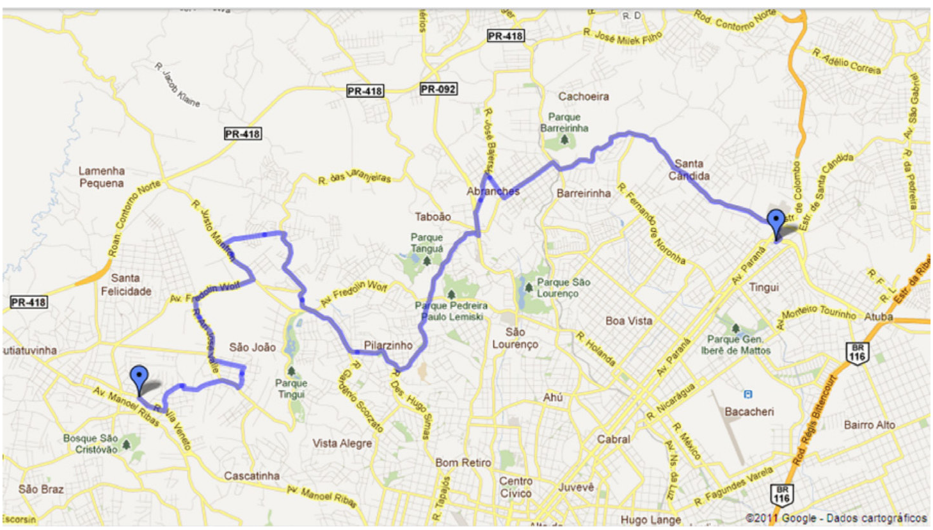


**Figure 6** Measured route – Curitiba city, Brazil – Source: Google Maps

## 3 Results analysis

The histograms for different parts (tracks) of the route were calculated – Tables 1 to 3. It is important to highlight that just the negative accelerations were taken into account, due to the fact that the positive accelerations do not affect the pavement lifetime. Likewise, the percentage sum of each histogram will not be equal to 100%.

**Table 1** A histogram regarding tracks with reasonable pavement quality

| | Track 1 | | | | | Track 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10-11 tons | 11-20 tons | 20-30 tons | 30-40 tons | > 40 tons | 10-11 tons | 11-20 tons | 20-30 tons | 30-40 tons | > 40 tons |
| Rear axle | 31.13% | 21.32% | 0.13% | 0.01% | < 0.01% | 44.56% | 11.15% | 0.34% | 0.03% | < 0.01% |

**Table 2** A histogram regarding tracks with poor pavement quality

| | Track 3 | | | | | Track 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10-11 tons | 11-20 tons | 20-30 tons | 30-40 tons | > 40 tons | 10-11 tons | 11-20 tons | 20-30 tons | 30-40 tons | > 40 tons |
| Rear axle | 23.23% | 25.32% | 3.12% | 0.56% | < 0.1% | 23.43% | 22.23% | 2.55% | 0.22% | 0.03% |

**Table 3** A histogram regarding tracks with good pavement quality

| | Track 5 | | | | | Track 6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10-11 tons | 11-20 tons | 20-30 tons | 30-40 tons | > 40 tons | 10-11 tons | 11-20 tons | 20-30 tons | 30-40 tons | > 40 tons |
| Rear axle | 71.87% | 8.98% | 0.02% | < 0.01% | < 0.01% | 65.78% | 10.51% | 0.15% | 0.10% | < 0.01% |

It is possible to verify that on tracks with good pavement quality the axle keeps loads close to its static value (10-11 tons), but even on reasonable pavement quality, due to the increment of vehicle speed and presence of depressions and holes, it is possible to find loads that vary from 11 to 20 tons.
This situation is even worse if we considered the poor pavement quality tracks, where loads from 20 to 30 tons can be found.

## 4 Conclusions and recommendations

After the results analysis, it can be concluded that the parameter used for the pavement dimensioning in Brazil (static load) is lower than the real vertical load applied on the road surface.
As mentioned before, due to the lack of fiscalization it is common to have commercial vehicles overloaded which can then generate bigger vertical dynamic loads to the pavement. In this way, it seems to be quite interesting to start a discussion about real loads applied on the road surface, in order to have a better pavement dimensioning and a more efficient maintenance program.
Also it is important to highlight that the authors of this paper are doing a research (Doctorate thesis) on this subject.

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[2] DNIT, Manual de pavimentação (Pavement dimensioning guideline), Departamento Nacional de Infraestrutura de Transportes (Brazilian Department of Infrastructure and Transportation), Diretoria de Planejamento e Pesquisa (Directory of Planning and Research), Coordenação Geral de Estudos e Pesquisa (General Coordenation of Studies and Research, Instituto de Pesquisas Rodoviárias (Institute of Road Research), 3rd ed, Rio de Janeiro, Brazil, 2006.

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