

# THE PAVEMENT QUALITY AND VIBRATIONS

SEBASTIAN TOPLAK<sup>1</sup>, SAMO LUBEJ<sup>1</sup>, ANDREJ IVANIČ<sup>1</sup> and MARJAN LEP<sup>1</sup>

<sup>1</sup>*Department of Transportation Eng., University of Maribor, Slovenia*

There is a lot of uncertainty regarding how to design roads in the city centre to find a compromise between driver comfort, safety and bearable impacts from vibrations to the neighboring buildings and human bodies. In the paper, three components of traffic planning and road design have been simultaneously taken into consideration: driver comfort, traffic safety and traffic-induced, ground-borne vibrations. In addition the paper provides the results of traffic speed and vibration measurements before and after pavement improvement on Koroska Street in Maribor, Slovenia. As expected, the improvement of pavement induced some additional traffic and dramatically increased the average speed. These caused worse traffic safety conditions, especially for pedestrians and cyclists, and also increased the noise and other airborne vibrations. On the other hand, ground-borne vibrations decreased and they are generally below the intensity which could cause damage to the buildings or would seriously disturb residents.

**Keywords:** Road traffic, Ground-borne vibration, Traffic safety, Inductive loop, Geophone.

## 1 INTRODUCTION

Traffic-induced ground and airborne vibrations are a serious problem for buildings and people. Vibrations caused by road traffic are generated if a vehicle strikes an irregularity in the road surface, such as construction irregularities, humps for traffic calming, dilatations, drainage covers or a very rough road surface. Vibration characteristics depend mostly on the vehicle's suspension system and the allowed speed and weight of vehicles.

Experts in the sustainable planning of roads are facing a problem of how to design new roads and how to restore existing ones to find a compromise between driver comfort (the driver wants to have smooth pavement and some level of service in terms of capacity), traffic safety (tending to reduce the speed, including speed humps) and bearable impacts from vibrations to the neighboring buildings and human bodies.

In this paper we have focused on and analyzed one very common phenomenon which occurs when poor pavement is replaced during road reconstruction: with increased comfort for drivers, a lot of additional traffic is induced and the livability of the neighborhood worsens. We observed two different situations in the old city centre of Maribor, Slovenia (Figure 1):

- Old, damaged pavement.
- New pavement.

The following measurements were performed: a traffic count with classification and speed measurements by inductive loop; vibrations were measured with geophones on different

locations in the neighbouring building to assess the damage to the building; and a vibrometer was used to assess impacts on the human body.



Figure 1. Old, damaged pavement (left) and new pavement (right).

## **2 OVERVIEW OF PREVIOUS RESEARCH**

Ground-borne vibrations caused by traffic are a common concern of society, because they very often cause problems to individuals and structures (Crispino 2001). Vibrations caused by traffic represent an external source and result from heavy traffic caused by buses and trucks. Cars and light trucks rarely cause vibrations that are discernible in buildings (Watts 1988). Road transport usually causes vibration frequency in the range between 5 and 25 Hz and a speed variation of soil from 0.05 to 25 mm/s (Hunaidi 2000). Vibrations caused by road traffic are generated if a vehicle strikes an irregularity in the road surface, such as:

- Construction irregularities.
- Humps for traffic calming.
- Dilatations.
- Drainage covers.
- A very rough road surface.

All these are intentionally constructed to improve traffic safety and the functionality of road infrastructure. Vibrations are also caused by damaged road surfaces (Lubej 2014). Vibration characteristics depend mostly on:

- Vehicles' suspension systems.
- The allowed speed and weight of vehicles.

The impact of physical characteristics of pavement (smoothness, friction) on ground borne vibrations has not been discussed very often in the past.

## **3 MEASUREMENT PROCEDURE**

The following measurements were performed:

- Traffic count and speed measurements with classification by inductive loop.
- Vibrations were measured with geophones at different locations in the neighboring old building, which is historically protected.

### 3.1 Speed measurements

Speed measurements of vehicles in free flow traffic were carried out simultaneously with the inductive loop Mikrobot QLTC 10.

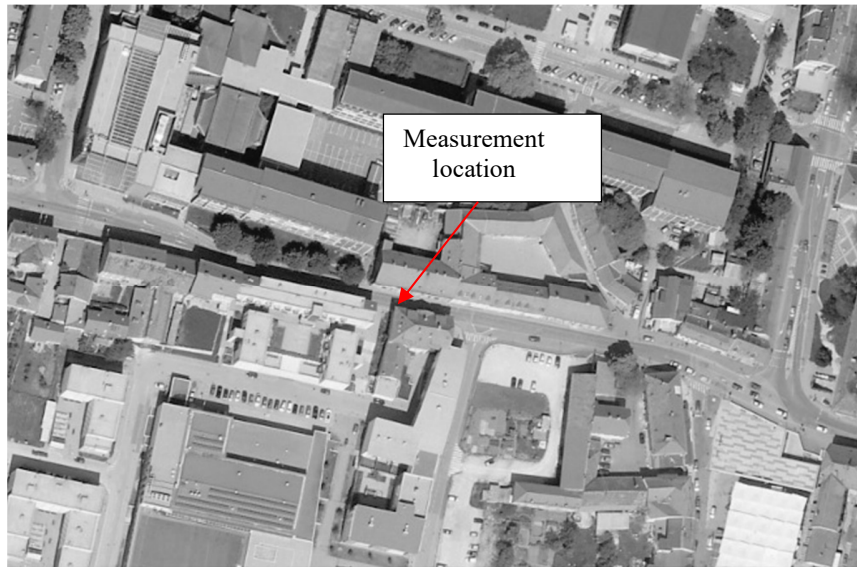


Figure 2. Speed measurement location.

With the described measurement equipment the free flow speed before and after the pavement reconstruction were measured.

Speed measurement results are shown in Table 1 and include data on the size of the covered sample (400 measurements for each direction before and after pavement reconstruction). Velocities V15, V50, V85 (these are speeds which 15 %, 50 %, or 85 % of drivers do not exceed), Vmin, Vmax and Sv (standard deviation) are shown.

Table 1. Results of measured free flow vehicle speeds on Koroska Street.

Traffic flow direction	S <sub>v</sub> standard deviation	V <sub>min</sub> / V <sub>max</sub> [km/h]	V <sub>15</sub> [km/h]	V <sub>50</sub> [km/h]	V <sub>85</sub> [km/h]
Old damaged pavement – before reconstruction					
Inwards	± 7.4	20 / 60	36.14	40.14	44.97
Outwards	± 4.8	20 / 72	36.05	40.14	45.10
New pavement – after reconstruction					
Inwards	± 7.3	38 / 83	47.00	54.00	62.78
Outwards	± 8.8	27 / 75	41.32	50.68	59.44

The values of the measured speeds before and after road reconstruction are very different. After the reconstruction the speed increases. V85 in the direction of the City Centre increased from 44.97 km/h to 62.78 km/h (Figure 3) and exiting the City Centre from 45.10 km/h to 59.44 km/h (Figure 4).



Figure 3. Cumulative speed distribution of free traffic flow into the City centre.

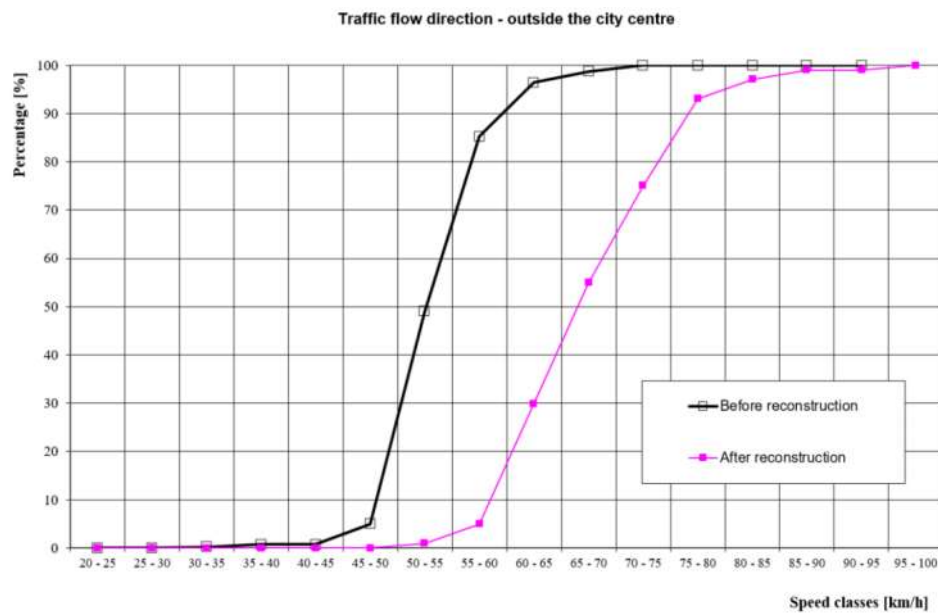


Figure 4. Cumulative speed distribution of free traffic flow out of the City centre.

### 3.2 Vibration measurement

For the measurement of vibrations caused by traffic, we set three measurement points in the old building which is historically protected (Figure 5). The first one was placed inside the building on the wall at 0.5 m from the ground (M-1), the second one was also placed inside

the building on the wall at 2.0 m from the ground (M-2) and the third one was placed on the building wall outside at 6.4 m from the ground (M-3). The results of the measurement point M-1 are analyzed in Table 2.



Figure 5. The measurement points at the old building close to Koroska Street.

Table 2. Vibration measurements results.

No.measurement	PVV [mm/s]	f [Hz]	PVV [mm/s]	f [Hz]
	Before pavement renewal		After pavement renewal	
1.	4.40	24	1.52	22
2.	3.63	28	1.14	23
3.	4.80	24	1.01	51
4.	3.40	30	0.63	17
5.	6.40	27	1.14	30
6.	3.60	32	1.02	16
7.	4.60	31	1.65	30
8.	3.04	30	1.39	18
9.	5.33	47	2.03	24
10.	12.40	16	1.78	18
11.	2.30	37	2.16	34
12.	1.82	43	1.65	24

Results of vibration measurements before pavement renewal show (Figure 6) that the vibrations induced by urban buses and medium-duty vehicles are predominantly in the range from 16 to 47 Hz (oscillations per second) and have a peak vibration velocity (PVV) from

1.82 to 12.4 mm/s. Measurements of vibrations after pavement renewal (Figure 6) show that the vibrations decrease. The frequencies range from 17 to 51 Hz and the vibrations PPV from 0.63 and 2.16 mm/s.

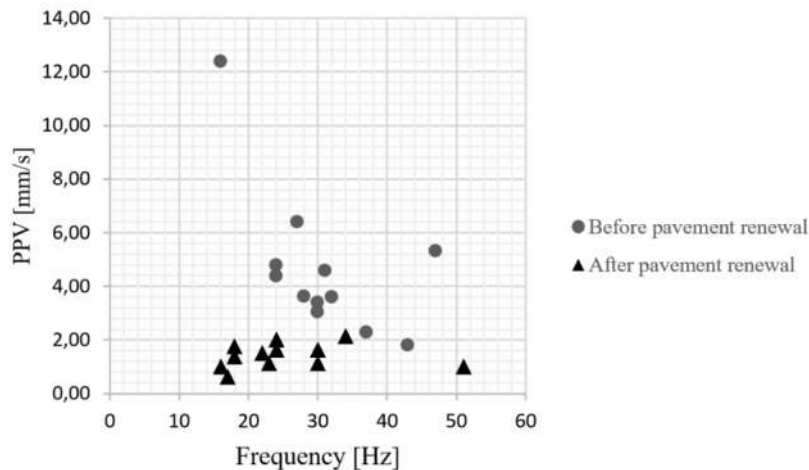


Figure 6. The measurement points at the old building close to Koroska Street.

Concerning German standards for vibration in buildings, the measured values of vibrations before the pavement renewal are above the acceptable level of 3 mm/s for historic buildings (DIN 4150-3 1999). After pavement renewal, the vibration level is reduced and is below the threshold.

#### 4 CONCLUSIONS

As expected, the improvement of pavement induced some additional traffic and dramatically increased the average speed. These also caused an increase in noise and other airborne vibrations. On the other hand, ground-borne vibrations in the neighborhood decreased and they are generally below the intensity which could cause damage to the buildings.

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