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TESTING A MODIFIED WEIGH-IN-MOTION SENSOR CROSSED BY DIFFERENT VEHICLES

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Abstract: *The paper presents in situ testing of a weigh-in-motion (WIM) overground sensor for urban traffic. These tests follow the static calibration of the sensor in the laboratory. The tests were performed with two sensors mounted in a closed parking lot. For this reason, vehicle speeds were limited to about 5km / h. Three vehicles were used for these tests: a car, an SUV, and a truck. Prior to testing, the vehicles were weighed on each wheel on an authorized scale. The outputs of the strain gauges glued to the elastic element of the sensor were measured and recorded. Several tests were performed for each wheel of the vehicle. WIM sensors are also used in automatic intelligent transportation networks.*

Key words: *Weigh-in motion sensor, urban traffic monitoring, above ground sensor, speed bumper, in situ measurements*

1. INTRODUCTION

Weigh-in-motion (WIM) sensors are buried in the highway, they cross the street and are used for weighing each wheel and axle, establishing the total mass of the vehicles, without disturbing the traffic. In addition, they are used for traffic monitoring and for collecting the data necessary for the design and monitoring of roads [1-4]. Few cities use WIM sensors integrated into intelligent transport systems (ITS), but this is a growing trend [5]. Commercially available sensors are expensive [1], difficult to install and uninstall and in fact are designed for highways and intercity roads, not for urban traffic, like the present sensor. WIM sensors are calibrated both statically (in the laboratory) and dynamically (mounted on the road). Calibration of WIM sensors mounted on the road is done by crossing the line of sensors with vehicles of different types, which have different masses, configurations, and speeds. For these tests, a portion of the road must be closed for a significant period of time. As the authorization to calibrate the WIM sensors on the road is very difficult to obtain, only tests in a closed parking lot were performed. For this reason, the speed of vehicles passing over the sensor has been limited to about 5km/h, although the sensor can operate at significantly higher speeds, but passing over the sensor at speeds higher than 30km/h becomes uncomfortable for passengers.

The WIM sensor presented in this paper is of the above-ground type, and it is designed to monitor urban traffic. An above-ground WIM sensor is known that mimics a bump speed on the outside and is mounted on the road in the same way. [1,6,7].

The sensor studied in this paper is modified from a WIM sensor above, in order to increase the sensitivity in their lateral ends, where it comes in contact with other similar sensors [8].

For this purpose, the elastic element has not been welded on its entire contour, leaving free portions above the side caps.

The air gaps between the elastic element and the side caps are sealed with rubber gaskets. Inside the elastic element are glued three T-type rosettes, whose grids are mounted in a half-bridge.

Half-bridge mounting ensures compensation for errors introduced by temperature variations and increases sensitivity. Prior to testing the road-mounted sensors, they were calibrated in the laboratory with static loads, using an Instron 8801 testing machine [9], resulting in the equation

$$F = k \cdot \varepsilon \quad (1)$$

where $k = 18.4\,[N/\mu\varepsilon]$.

The paper presents one of the first steps in the methodology, and in further work the sensor will be developed.

2. DESCRIPTION OF SENSOR

The WIM sensor intended for urban traffic monitoring (in terms of volume and structure) has the shape and dimensions of a speed bumps (figure 1).

To the inside of the upper part of the sensor (which is a cylindrical shell) three strain gauges T-type rosettes were glued, equally spaced between them and from the edges of the sensor (figure 2).

WIM sensors of this type are mounted in the same way as speed bumpers: a line of sensors crosses the road. Output signals are acquired with devices located in a cabinet mounted on the sidewalk.

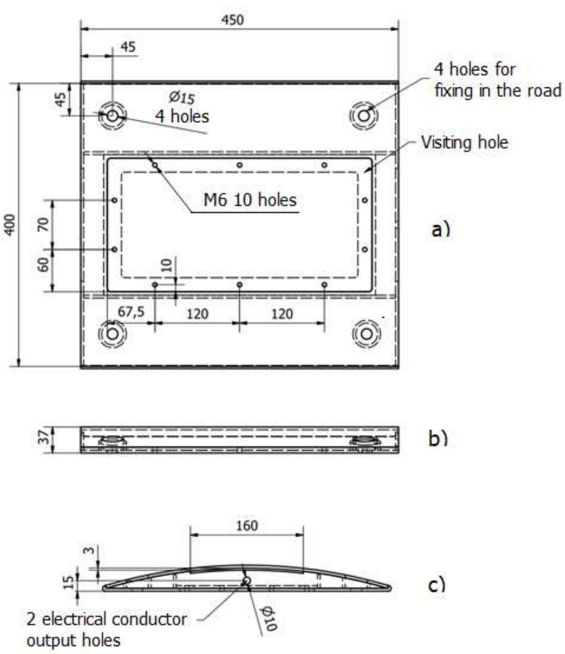


Fig. 1. WIM sensor above ground: view from the side in contact with the road, with the lid removed (a); side view (b); view towards an end cap (c)

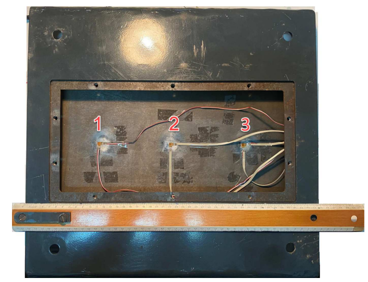


Fig. 2. WIM sensor (view from the side in contact with the road, with the lid removed): the three T-shaped rosettes (SGR1, SGR2 and SGR3) glued to the inside of the cylindrical shell can be seen

3. TESTING THE SENSORS

3.1 Measurement preparation

Three vehicles were used for tests, which were initially weighed on all four wheels, twice, at an authorized scale near the test site. The scale used holds the accreditations in accordance with the European Directive 2009/23 / EC (transposed in H.G. 617/2003 and H.G. 1302/2009). Figure 3a shows the FIAT Panda car positioned for weighing rear wheels and in figure 3b the weighing of the DAF LF truck. The weighing was repeated and the results were averaged. Only the driver was in both vehicles when weighed.

The results obtained after weighing the vehicles are:

- FIAT Panda car: average mass on the front wheel - 290 kg, average mass on the rear wheel - 180 kg, total mass - 940 kg;
- Volkswagen Touareg SUV: average mass on the front wheel - 640 kg, average mass on the rear wheel - 590 kg, total mass-2460 kg;
- DAF LF truck: average mass on the front wheel - 1810 kg, average mass on the rear wheel - 1580 kg, total mass - 6780 kg.

Immediately after weighing, the vehicles moved to the area where the sensors were mounted, thus avoiding significant variations in their mass. Tests were performed using two road-mounted sensors so that the wheels on the same axle step on the sensors simultaneously to avoid tilting the vehicles. Of the two sensors, only one was monitored with electrical strain gauges. The output signal from the strain rosettes was recorded with the Vishay P3 bridge and a laptop.

a)

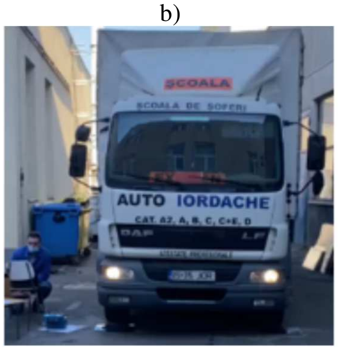
b)

Fig. 3. Weighing FIAT Panda (a) and DAF LF truck (b)

3.2 Performing tests

a)

b)



c)

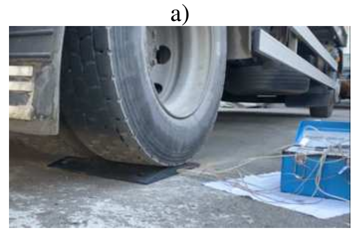
Fig. 4. Crossing the sensors with the FIAT Panda car (a), VW Touareg (b) and the DAF LF truck (b) respectively

The test procedure was as follows: three complete crossings were made over the sensors with all vehicles, with a speed of about 5 km/h, see figure 4. The output signals of the strain gauges were recorded.

A total of 13-wheel crossings were made over the sensor:

- three crossings for the front wheel and three crossings for the rear wheel of the FIAT Panda, for the situation when the wheel is placed approximately in the middle of the sensor, respectively when it is moved to the left end of the sensor;
- six crossings for the front wheel and three crossings for the rear wheel of the VW Touareg, for the situation when the wheel is placed approximately in the middle of the sensor;
- two crossings for the front wheel and two crossings for the rear wheel of the DAF LF truck, for the situation when the wheel is located approximately in the middle of the sensor, as in figure 5, where the truck's front wheel and rear wheel crossings the sensors are shown. The rear wheels of the truck are double. These wheels have the width of the sensor. For this reason, the truck can only cross the sensors in the middle.

a)



b)

Fig. 5. Crossing the sensor with the front wheel of the truck (a) and the rear wheel respectively (b)

Each T-type rosette was connected in a half-bridge configuration (Vishay P3 bridge), their balancing being done before crossing the wheel over the sensor, for each channel separately. During the tests, the data was purchased on the laptop. Date acquisition time (sampling time for the rosette output signal was selected to one second); the outputs on channels Ch1, Ch2, and Ch3, which correspond to strain rosettes SGR 1, SGR2, and SGR3.

4. RESULTS OBTAINED

Tables 1-4 show some of the output signals of the three strain rosettes recorded when the vehicles crossed the WIM sensors. With these data, the diagrams of the variation of the output signals as a function of time were drawn. With their help, the weight of each axle and the total weight of the vehicle can be determined. In case of exceeding the maximum permitted weight, the registration number is identified with the help of video cameras and those who break the law will be fined.

Table 1

Output signals when FIAT Panda car is crossing the sensor approximately through the central part

Time	Ch 1 [με]	Ch2 [με]	Ch3 [με]
10:07:36	3	2	0
10:07:37	3	2	0
10:07:38	15	170	34
10:07:39	5	3	0
10:07:40	2	0	0
The output data is practically constant for zero load			
10:07:43	63	85	25
10:07:44	3	0	0

Table 2

Output signals when the front wheel of the DAF LF truck is crossing the sensor through the central part

Time	Ch 1 [με]	Ch2 [με]	Ch3 [με]
10:34:59	4	1	0
10:35:00	81	953	150
10:35:01	15	119	13
10:35:02	4	1	2
10:35:03	4	1	2

Figures 6-8 present the variation of the output signals as a function of time. Knowing the speed of the vehicle, the number of axles, and the distance between them, its category can be established.

Table 3

Output signals when the rear double wheel of the DAF LF truck is crossing the sensor through the central part

Time	Ch 1 [με]	Ch2 [με]	Ch3 [με]
10:36:33	1	0	0
10:36:34	2	2	2
10:36:35	266	831	231
10:36:36	18	25	0
10:36:37	17	5	0
10:36:38	17	5	1
10:36:39	17	5	1
10:36:40	7	5	1
10:36:41	6	5	1

Table 4

Output signals when the VW Touareg SUV is crossing the sensor through the central part, with stop at the top of the sensor

Time	Ch 1 [με]	Ch2 [με]	Ch3 [με]
10:44:59	5	-1	-3
10:45:00	48	129	36
10:45:01	45	41	142
The output data is practically constant during the constant load-holding period			
10:45:10	48	25	157
10:45:11	301	322	338
10:45:12	297	324	347
The output data is practically constant during the constant load-holding period			
10:45:20	301	329	347
10:45:21	68	88	20
10:45:22	6	-1	-4
The output data is practically constant for zero load			
10:45:27	9	26	6
10:45:28	45	81	144
10:45:29	219	255	306
10:45:30	218	251	301
The output data is practically constant during the stationary period of loading			
10:45:36	253	317	342
10:45:37	69	120	20
10:45:38	6	-1	-4

Vehicle speed is measured using other sensors (inductive loop or radar). Thus, the WIM sensors will be supplemented with other sensors, all of them being included in weigh-in-motion stations, which can provide real-time data on the volume and structure of traffic. These data are used by road designers but also by authorities to protect them.

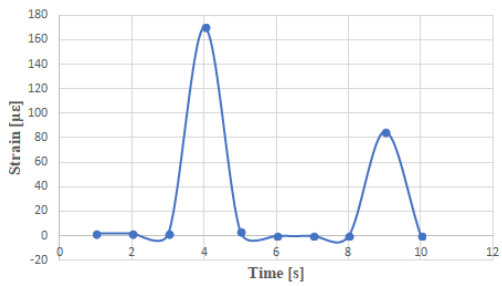
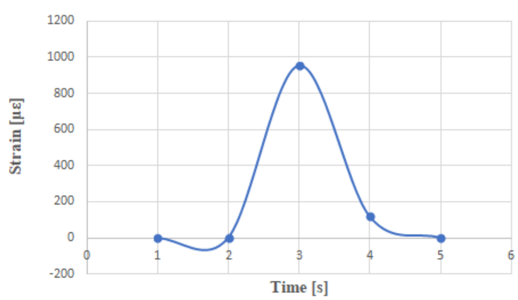
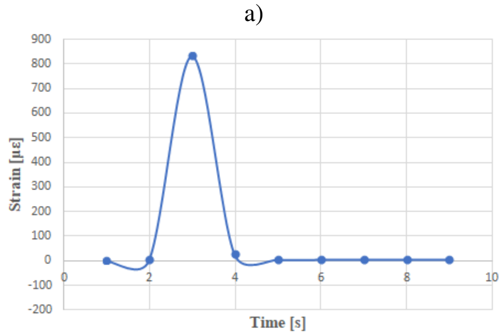


Fig. 6. The output signal of the SGR2 strain rosette as a function of time when the WIM sensor is traversed by FIAT Panda car (symmetrical loading, with the wheel in the middle of the sensor)



a)



b)

Fig. 7. The output signal of the SGR2 strain rosette as a function of time when the WIM sensor is traversed by DAF LF truck: front wheel (a) and rear wheel (b)

More recently, WIM stations are included in intelligent traffic management systems. These systems are starting to be implemented in the big cities, contributing to the flow of traffic and reducing the number of accidents and pollution. Although they are currently expensive, intelligent transportation systems will experience a growing development due to their advantages. These major advantages cannot be achieved without the help of WIM sensors.

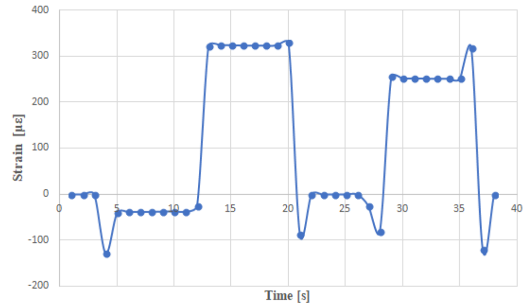


Fig. 8. The output signal of the SGR2 strain rosette as a function of time when the WIM sensor is traversed by VW SUV, with standing on the sensor

5. CONCLUSION

Commercial WIM sensors are calibrated both in the laboratory (static loading) and mounted on the road. The calibration of road-mounted sensors involves stopping traffic, is costly, time-consuming, and requires special approval from the authorities. Because the authors could not obtain such approvals, the WIM sensors were tested in a closed parking lot after the sensors were calibrated in the laboratory. Several series of crossings were made with a FIAT Panda car, VW Touareg, and a DAF LF truck.

The vehicles have weighed on each wheel before crossing with an authorized scale. After each crossing, the output signals returned to practically zero and this proves that the WIM sensor was loaded in the elastic range. But a perfect repetition of the load position on the sensor is not possible for several tests with the same vehicle. The results obtained are consistent with static calibration in the laboratory.

This article presents only one of the first steps necessary for the development of a new WIM sensor for urban traffic. Next comes the calibration of the sensor mounted on the road and then testing it in traffic.

But this depends on obtaining the necessary authorizations from the authorities. However, testing the sensors at low speeds (about 5 km/h) provided good results and demonstrated the validity of the proposed solutions. Even at this stage of development, these sensors could be placed at the entrance/exit of different parking lots or fenced spaces, etc. for monitoring vehicles traveling at low speeds.

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TESTAREA UNUI SENZOR DE EVALUARE A GREUTĂȚII ÎN MIȘCARE MODIFICAT, TRAVERSAT DE DIFERITE VEHICULE

Lucrarea prezintă testarea in-situ a unui senzor suprateran de cântărire în mişcare (WIM) pentru traficul urban. Aceste teste urmează calibrarea statică a senzorului în laborator. Testele au fost efectuate cu doi senzori montați într-o parcare închisă. Din acest motiv, vitezele vehiculelor au fost limitate la aproximativ 5 km/h. Pentru aceste teste au fost folosite trei vehicule: un autoturism, un SUV şi un camion. Înainte de testare, vehiculele au fost cântărite pe fiecare roată, pe un cântar autorizat. Au fost măsurate şi înregistrate ieşirile extensometrelor lipite de elementul elastic al senzorului. Au fost efectuate mai multe teste pentru fiecare roată a vehiculului. Senzorii WIM sunt utilizați şi în rețelele automate de transport inteligente.

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