MEASURING OF GRAVEL ROAD EVENNESS WITH ACCELERATION SENSOR TECHNOLOGY

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ABSTRACT

The Finnish public road network is 78 000 km of which 35% are gravel roads. They generally belong to the low volume road network, which provide standard level services.

The objective of the project was to develop a method to measure the evenness of gravel roads automatically. The method uses a vehicle equipped with a measuring instrument and data collection unit with data transfer connection. The measuring instrument affixed to the car includes a vertical acceleration sensor and a terminal unit with a data collection module.

The measuring method for gravel road evenness was developed by defining an interface between the software application and the measurement unit. The measurement of road evenness recorded by acceleration sensors was researched with the vertical accelerations made by two cars. The impact of tyre pressure was also studied with the car's vibration test equipment.

The research concluded that gravel road vertical evenness can be measured automatically. The disadvantage of the acceleration sensor method is that it only gives information from the driving line. The advantage is that a large amount of information can be collected in real-time. The method can also be applied to other purposes such as measuring the road surface roughness.

1 INTRODUCTION

In Finland, the public road network is 78 000 km of which 35% are gravel roads. Due to the great number of gravel roads, their condition and usability is of interest. Gravel roads generally belong to the low volume road network that serve sparsely populated areas as well as material transportation of basic production e.g. in forest and agricultural industry. In connection with the gravel roads the aim is to provide such a service level as meets the road users' basic needs. Gravel road classification sets requirements both for the road's structural condition and for its surface condition of which the latter is regarded as the more important criterion. The surface condition is determined by the road's evenness, consistency and dusting, and five condition classes have been defined for the roads. At present, the surface condition value is determined visually by reference images and text definitions.

1.1 Objective

The objective in the maintenance contracts is to make more use of electronic data management. Electronic data management helps to make the tendering process and quality management more effective, and render data collection, processing and distribution automatic.

The current system of visual inspections is problematic, because it is subjective and requires interpretation. Also the lack of unambiguous parameters makes it difficult to monitor the long-term condition of the gravel roads and the quality of the contractors. From a quality perspective, it is necessary that the road condition matches the road user expectations. In 2007 a research project was launched in order to create a new and more objective measuring method for gravel roads. The research focused on the road's surface condition (surface evenness) i.e. the most important criterion.

1.2 Earlier Research

Methods to measure the evenness of gravel roads and respective parameters were studied in the mid 1990's in Finland. Equipment based on an acceleration sensor was also used in the research. This earlier research compared the correspondence of the driving comfort values collected with a driving panel with the measured evenness results of some 100 gravel roads. The measured evenness results and evenness classification based on them were derived from the IRI values. As a conclusion of the project, it was suggested that the IRI value could also be applied to describe evenness and driver comfort, but not for monitoring the maintenance quality of gravel roads. [4]

2 DEVELOPING THE METHOD TO MEASURE GRAVEL ROAD EVENNESS

2.1 Condition Classification of Gravel Roads

The longitudinal evenness of gravel roads is assessed in accordance with the condition classification. The condition classification is based on a five-step image standard with which visual observations from the road are compared. The assessment also takes into account the road's consistency and cross-section. The final condition class, from 1 to 5, is determined by the worst property. However, road evenness is the most dominant property, because road users experience the lack of it as the most irritating feature. [7, 8]

In the contracts concluded prior to 2008, the contractor of a regional routine and periodic maintenance contract was responsible for monitoring gravel road quality using the condition classification. In practice, the assessment of gravel roads is carried out in 2-kilometre stretches divided into 100-metre sections. Each 100-metre section is classified according to the classes from 1 to 5 describing the road condition.

Figure 1. Example of the standard picture of gravel road condition class 2. [7]

2.2 Measuring Vibrations Caused by the Unevenness of the Road

Vibration is defined as the movement of an imaginable point around its position of equilibrium caused by a vibration source or stimulus. On a gravel road it means that depressions on the road act as a stimuli making the car and its passengers vibrate. The vibrations move up to the car's structures and its passengers. However, not all the energy from stimuli transfer to the vibration level, but part of the vibration energy is turned into heat for example. Vibrations on a gravel road consist of multi-frequency vibrations which are arbitrary. [2, 5, 6]

Vibration measurement usually measures the variation of displacement, velocity or acceleration as a function of time. When studying gravel roads, displacement of the bottom of the tyre is related to the road's depressions by the function h(t). The velocity in the vertical direction, v_z, and acceleration, a_z, are in turn derived from the displacement function h(t). This is presented in the formulae 1 and 2.

$$v_z = \frac{dh}{dt} \qquad (1)$$

$$a_z = \frac{dv_z}{dt} = \frac{d^2h}{dt^2} \qquad (2)$$

The effect of the vehicle's constant horizontal velocity, v_x, on the tyre's vertical acceleration, a_z, is presented in the formula 3.

$$a_z = \frac{h_x v_x^2}{l^2}, \qquad (3)$$

where h_x is the displacement magnitude over the travelled distance l [m]
l *is* the travelled horizontal distance

Acceleration sensor is well suited for measuring mechanical vibrations because its functioning is based on an electric signal generated by the movement of a body of known mass. [6, 9]

2.3 Measuring Equipment

The measuring equipment used in the research can be divided into two groups. The first one includes the measuring equipment affixed to the car measuring the vertical accelerations caused by the road's unevenness and transmitting the measured results. The second one includes the data management equipment (cell phone and server) taking care of refining, saving and presenting measured results to the user.

The equipment affixed to the car is comprised of a capacitive acceleration sensor and a meter affixed onto the windscreen of the car. In this research it is the meter on the windscreen that transmits and refines the measured results. The measuring range of the acceleration sensor is 12g. The acceleration sensor is affixed to the suspension of the car's right rear wheel close to the tyre (figure 2). The idea is to minimize the influence of the vehicle's different properties on the measurement values. The measuring unit affixed to the windscreen uses wireless transmission to send the data to the cell phone application.

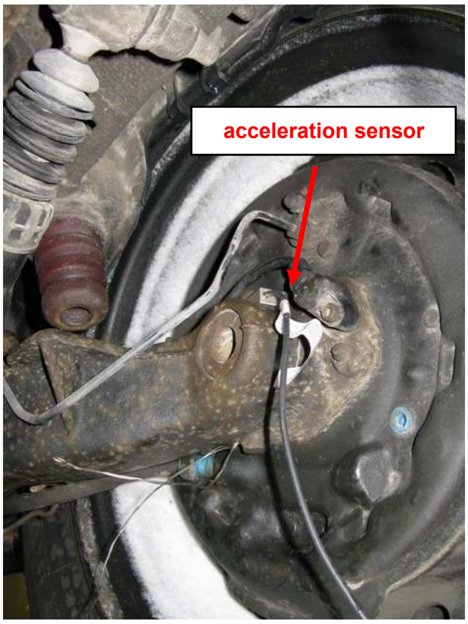

Figure 2. The location on the wheel suspension where the acceleration sensor is fixed

The objective in the development of the measuring device was to create an easy-to-use, yet reliable device and method. The prototype is constructed on a friction meter with an in-built Bluetooth connection. When assessing the results of the evenness measurements, it is essential to know the driving speed, which is provided by the cell phone application using GPS. Consequently, there is no need for a separate pulse sensor.

2.4 Reporting Measurement Results

The parameters of the 100-metre sections calculated from the measurement results are saved in the cell phone which is used as a data recorder during the measuring phase. The measuring location has already been identified and recorded in the system with the help of the road address from the road register, and each measuring phase also includes the metadata concerning the measurement. The ready refined location information makes reporting very much easier, and the measurement results can also be seen in real time on the display panel of the cell phone.

The measurement results are transmitted wirelessly to a web portal on an Internet server. The measurement results can be browsed in the portal, where they are clearly displayed on a dynamically manageable base map in colour codes (Figure 3).

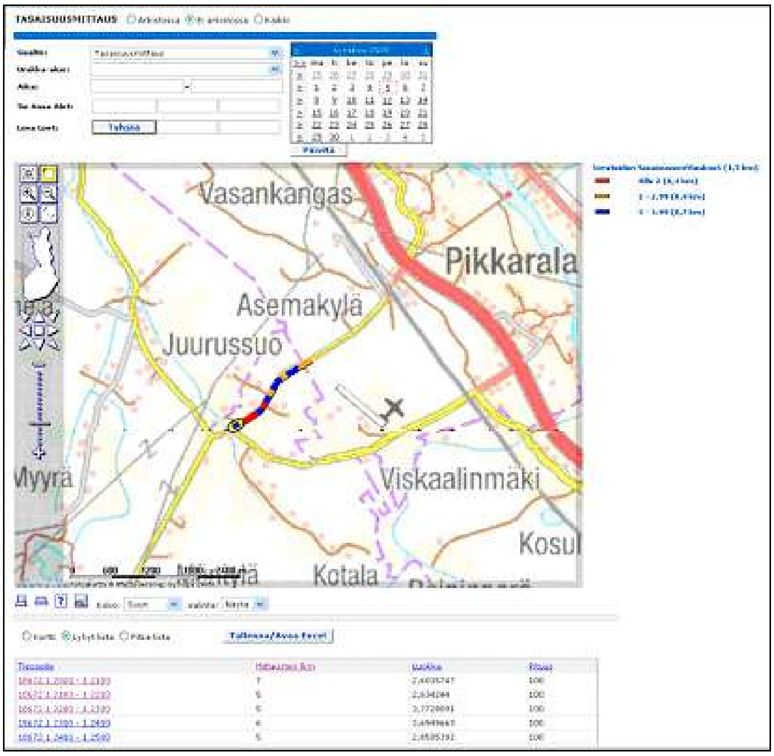

Figure 3. Measurement results are available in a web browser.

2.5 Possible Sources of Error

Errors occurring during the measuring phase can be divided into three categories: gross errors, systematic errors and random errors.

Gross errors are defined as significant errors, which may be caused by the measurer, momentary changes in the surroundings, or a momentary malfunction of the measuring instrument. [3]

Systematic errors are defined as errors of the measuring device, or errors from the effects of exterior factors and different measurers on the measurement result. All measuring instruments have a certain dimensional accuracy that they use to measure the magnitude in question. Effects from extrinsic factors lead to mistakes connected with the measuring conditions. Systematic errors can be caused by the position of the acceleration sensor on the car's wheel suspension. The optimal case would be to set the sensor in a totally horizontal position. In practice however, the affixed sensor remains always in a slightly slanted position, because it is difficult to find a horizontal surface on the wheel suspension, and moreover it would be difficult to verify that it would be in an absolute horizontal position within the cramped space available. The deviation in the sensor position may mean that other than strictly vertical accelerations affecting the vehicle also influence the measurement results. The road surface gradient also leads to a small error, but its influence is only in the order of some 0.5 %. [3]

A random or statistical error always causes some inaccuracy of measurements. A statistical error can be revealed by an adequately accurate measuring instrument, and the effect of statistical error can be diminished by making several measurements of the targeted object. [3]

2.6 Issues Taken into Account in the Use of the Method

The possible sources of error need to be taken into account when using this measurement method in order to get reliable results. The acceleration sensor has to be fixed onto the suspension of the car's right wheel as securely as possible. The sensor has to be fixed in such a way that its position is as horizontal as possible. Calibration has to be carried out when the measuring instrument is fitted onto another vehicle, or when it is refitted after having been removed.

The actual measuring is to be carried out following the normal driving line without avoiding potholes in order to receive a comprehensive description. In addition to being responsible for the correct use of the measuring method, the measurer also has to take into account depressions and potholes outside the driving line. In addition, tyre pressure has to correspond with the recommendations of the manufacturer.

3 MEASUREMENT

3.1 Measuring Method

During the development phase of the meter, the signal transmitted by the acceleration sensor was saved in a laptop using an oscilloscope. It was possible to convert the electric acceleration signal from the acceleration sensor into a true acceleration value as the sensitivity level of the sensor was known. The voltage from the sensor equalled the acceleration of 9.81 m/s2. The absolute average and RMS (RMS = Sqrt(RMS_read / Coefficient2) *9.81) value was calculated based on the acceleration signal. The values were calculated in segments of 1.2 seconds, which were also used to calculate the total averages for a 100-metre section. The acceleration value was interpreted and classified using the absolute average and RMS values, because they provided a relatively accurate picture of the extent of the road's unevenness. [1]

Driving speed has a significant effect on the acceleration forces on the vehicle. All vertical accelerations measured with the acceleration sensor were converted to equal the comparative velocity v_{norm} (60 km/h) to make the measurement results comparative. Calculating the change coefficient k is presented in formula 4

$$k = \frac{v_{norm}}{v_m}, \qquad (4)$$

where v_m is the speed of the vehicle at the moment of measuring

The classification of roads is done in 100-metre sections. The absolute average value of a 100-metre section was compared with the preliminary limit values of the classification. A preliminary classification scale was as in the following Table 1.

Table 1. Preliminary limit values applicable to gravel roads.

Evenness Class	**Acceleration Average for 100 metres (car1)** $[m/s^2]$
5	0–5,2
4	5,3–9
3	9,1–22,4
2	22,5–30
1	>30

The minimum measuring speed was set at 30 km/h. If measuring was carried out using a lower speed, it was mentioned in the measurement results presented on the web pages as a fault in the speed. Lower speed may be due to a road section being in a very poor condition, or avoidance of potholes for example. The number of measurement data, 10 biggest absolute average values and RMS values as well as 20 biggest acceleration values converted into the comparative speed were collected for the section. In addition, other basic data about the measurer, time and section of road as well as average measuring speed were collected. In addition to the evenness values, a reservation for the transverse and longitudinal gradient, consistency and dustiness of the road was built into the program.

Measurements in connection with the development of the method were mainly carried out in the spring and summer of 2008. Additional control measurements were carried out during the autumn of 2008. Two passenger cars were used for the measurements. The tyre sizes of the measuring cars were: car 1 225/50 R17, and car 2 185/65 R15.

Measurements were carried out on two road sections, which both had segments of even and dense surface as well as segments of more uneven surface. The idea in measuring various degrees of unevenness was to find out the kinds of acceleration levels they cause and use the information to help the classification of gravel roads. The driving line used in the measuring work was selected in such a way that it included as many potholes as possible. There were several small potholes at the beginning of road section 3400–3500. The end of the road section was even and the road surface was dense.

The beginning of road section 2250–2450 had an even and dense surface, but towards the end of the road section there were fairly big potholes. The potholes were in a row and therefore the driving line was selected in such a way that as many potholes as possible were included in the measurements.

3.2 Effect of Different Factors on the Measurements

In the autumn 2008 measurements were also carried out with a 150 g sensor covering a larger measuring range, because it became evident in the summer that the measuring range of the 12 g sensor is possibly not sufficiently effective for the accelerations caused by big depressions. Measurement was carried out on gravel road 18613, section 1. The measured depressions were approximately 3-4 cm deep. The objective was to study the applicability of the bigger acceleration sensor for gravel road measurements and to find out the size of maximum accelerations caused by depressions.

Measurements were carried out by measuring the selected approximately 200-meter road section twice with both sensors. The sensors were attached to each other and then fixed onto the suspension of the car's right rear wheel.

The uniformity of the vertical accelerations was studied in two separate cars on three different road sections. The measured road sections were sections 2250–2450 and 3400–3500 on road 18672, and, road section 1 between sections 835–985 on road 18632. One successful measurement was carried out by both vehicles on each of the two sections under study on road 18672. The measurement was considered successful when most of the depressions on the road were covered by the driving line. This also provided reference data on the effect of clear depressions on both vehicles. On the other hand, on road 18632 both vehicles carried out several measurements at driving speeds of 40 and 50 km/h. In addition, both speeds were used to carry out measurements using three different driving lines. The driving lines in the measuring direction were selected in such a way that the first one was furthest to the right and the following ones always at about a one-metre distance closer to the centre of the road. Consequently, the driving line of the last measurement was approximately at the centre of the road.

The effect of tyre pressure on the vertical acceleration was measured on February 15th, 2008. The wheel suspension testing unit was used in the acceleration testing (Figure 4). Vibration created by the testing unit is similar to that caused by a real road. Tyre pressures varied between 2.0–3.0 bar (measurement interval was 0.2 bar). The tyres used in the study were summer and studded winter tyres of the size 185/65 R15.

The wheel suspension was tested by a unit comprising two vibration plates. Each plate generates around a seven-second vibration sequence to the vehicle. As a result, the unit provides the suspension's damping efficiency as a percentage value for the measured tyres. The damping efficiency is based on how well the tyres follow the vibration plate at the resonance frequency during the testing period.

Figure 4. Equipment with vibration plates was used to study the effect of tyre pressure.

The wheel suspension testing unit was also used for making measurements with the same two cars (car 1 and car 2) in autumn 2008. The measurements were carried out with the acceleration sensor fixed onto the suspension of the rear right wheel measuring the acceleration caused by the vibration plates. Five measurements were carried out by each car. The acceleration signal from the vibration plates was saved in a laptop with Vibrocode (data from the measuring unit).

3.3 Calibration of the Measuring Method

The measuring method has to be calibrated for different vehicles, or when the measurement device is refitted. Calibration is done using the acceleration values from the vibration of the wheel suspension testing unit. The car specific data is fed into the equipment using the software. The formula calculating a car specific correction coefficient is presented in formula 5.

$$a_k = \frac{17{,}70}{v_5 \cdot \frac{9{,}81}{1280}} = \frac{22656}{v_5 \cdot 9{,}81}, \qquad (5)$$

where a_k is the car specific correction coefficient fed into the software
v_5 is the average of the sum of the five biggest absolute values.

3.4 Development of the Measuring Method

The purpose of the measurement method is to function continuously and rapidly taking samples from the acceleration sensor and calculating numeric values based on the made observations and transmit them to the data collection unit. The measuring device is designed to calculate, based on the observations made during 1.2 seconds, the sum of the absolute values of acceleration, the square of accelerations and collect the biggest acceleration values at an interval of 1.2 seconds. The device transmitted this data wirelessly through a Bluetooth connection to the data collection unit. The final measuring results were calculated based on these measuring values. The future needs of measuring road gradiant and driving comfort were taken into account in the data transmission interface.

The calculations made in the data collection unit provided parameters for each hundred-metre section of the road line, which could be used for quality assessment. The data collection unit converted the measuring values of each 1.2 second interval to correspond with the so called standard speed value. The limit values specified for the standard speed made it possible to count the number of potholes. The results from different cars varied. The results could be made comparable using the calibration coefficient. The gathered data was transmitted wirelessly to an Internet server. The measured results were studied and classified based on the limit values in the server. The final result was presented in colours on a map on the web pages. Pictures and other registered data could be attached to the results.

4 RESULTS

4.1 Measuring Different Magnitudes of Unevennes

The measurements produced the results presented in the Table 2. Table 2 presents the calculated acceleration average of the absolute accelerations and the RMS value. The values were always calculated at the interval of 1.2 seconds, which corresponds with the data transmission time of the final meter. In addition, the table also shows the total average values for the hundred-metre sections studied. The results show rougher road section is three times the length of the even one.

Figure 5. Road surfaces of the measured sections. The section between 2250-2450 on the left and between 3400-3500 on the right.

Table 2. Measured results from road 18672.

Road 18672 distance 2250-2350			distance 2350-2450			distance 3400-3500		
Time [s]	**Absolute acceleration avg.** $[m/s^2]$	**RMS** $[m/s^2]$	**Time [s]**	**Absolute acceleration avg.** $[m/s^2]$	**RMS** $[m/s^2]$	**Time [s]**	**Absolute acceleration avg.** $[m/s^2]$	**RMS** $[m/s^2]$
0? ,20	5,02	6,23	6,01? ,20	17,26	24,53	0? ,20	31,73	43,20
1,21? ,40	7,74	9,73	7,21? ,40	44,10	59,02	1,21? ,40	14,29	19,30
2,41? ,60	16,67	23,59	8,41? ,60	52,55	69,18	2,41? ,60	10,63	14,07
3,61? ,80	6,67	11,16	9,61? 0,80	13,64	19,03	3,61? ,80	11,88	14,59
4,81? ,00	8,57	11,45	10,81? 2,00	23,72	37,18	4,81? ,00	9,53	12,25
avg.	**8,95**	**12,43**	**avg.**	**30,26**	**41,78**	**avg.**	**15,61**	**20,68**

The visual presentation of the acceleration signal showed that the road sections with most depressions differ clearly to the more even sections. The greatest accelerations rose up till the measuring limit of the acceleration sensor, i.e. 12 g (Figure 6).

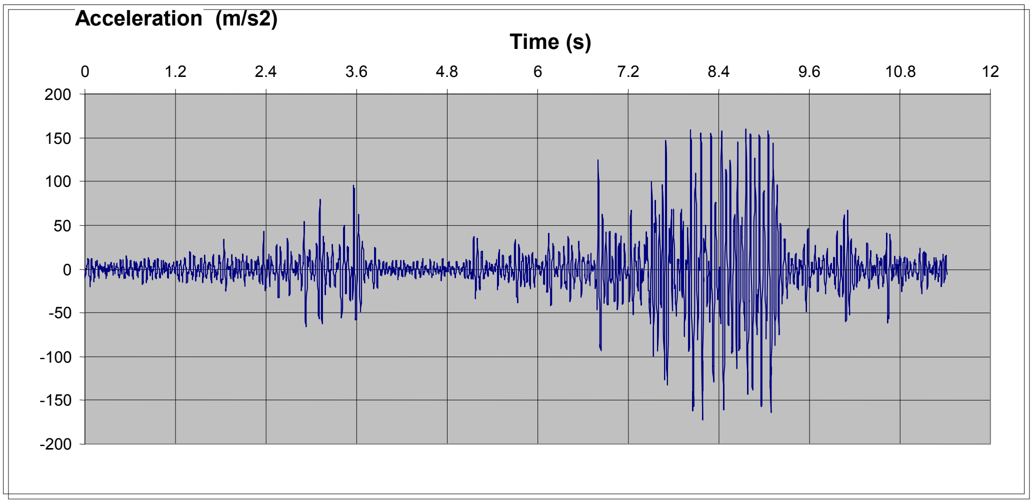

Figure 6. The acceleration graph from the road section between 2250–2450. The uneven stretch after the middle of the road section causes significant accelerations.

4.2 Applicability of the Measuring Method to Different Vehicles

It was decided to measure the values of road 18672 also using another vehicle (car 1). When the respective values in the Table 2 were compared with the values from the comparison vehicle, it was noticed that the previously measured values were 1.1–2.3 times greater than those from car 1. The greatest difference appeared on road section 2350–2450, which can be explained by the fact that the driving line of the car 1 ran in a slightly different location. Consequently, the number of depressions within the driving line causing greater accelerations had been smaller than in the previous measurement carried out by car 2.

Both cars were used for measurements on road 18632. Table 3 presents a summary of the measuring results of both cars. The measuring speed of each car was either 40 or 50 km/h. All the results presented in the table have been converted to correspond with a driving speed 60 km/h. When comparing the results of the cars carried out using the same driving speed and driving line, it can be noticed that the measuring values of car 1 are 0.67–0.82 greater than those of car 2. The difference is due to differences in the tyres, suspension and structures of the cars. The location and position of the acceleration sensor also influenced results. There were no great differences in the measuring values collected by the same car.

Table 3. The measured accelerations from the two cars on road 18632. Driving line:1 furthest to the right, 2 in the middle of the right lane and 3 on the centre line of the road

Vehicle	Driving line	Speed [km/h]	Absolute acceleration avg. 100 m $\left[m/s^2\right]$	Absolute acceleration avg. 150 m $\left[m/s^2\right]$	RMS avg. 100 m $\left[m/s^2\right]$	RMS avg. 150 m $\left[m/s^2\right]$
car 2	1	40	18,90	17,96	25,63	23,53
car 1	1	40	13,10	12,13	17,28	15,91
car 2	2	40	16,44	14,27	21,25	18,33
car 1	2	40	12,30	10,17	15,48	12,91
car 2	3	40	14,41	12,83	17,99	16,14
car 1	3	40	11,31	10,03	14,20	12,61
car 2	1	50	17,88	16,98	24,37	22,97
car 1	1	50	12,80	12,29	16,40	15,70
car 2	2	50	17,14	15,00	21,66	19,03
car 1	2	50	11,66	10,45	14,64	13,19
car 2	3	50	15,46	13,81	19,41	17,34
car 1	3	50	12,42	11,33	15,72	14,51

4.3 Effect of Tyre Pressure on the Measurement Value

The studied air pressure was between 2.0–3.0 bar and it was shown that tyre accelerations rose almost steadily with the increase of air pressure. This can be explained by the fact that tyre pressure had an effect on the suspension constant: increase in the air pressure by 0.2 bar increased the maximum acceleration in average by 3.02 m/s2 in summer tyres and 3.66 m/s2 in winter tyres. The effect on acceleration average was significantly smaller, because the values were respectively 0.52 m/s2 in summer tyres and 0.82 m/s2 in winter tyres. Figures 7 and 8 present the effect of tyre pressure on the measured maximum and average values of acceleration. The acceleration average has been calculated based on the duration of vibration applied to the tyre, i.e. approximately seven seconds.

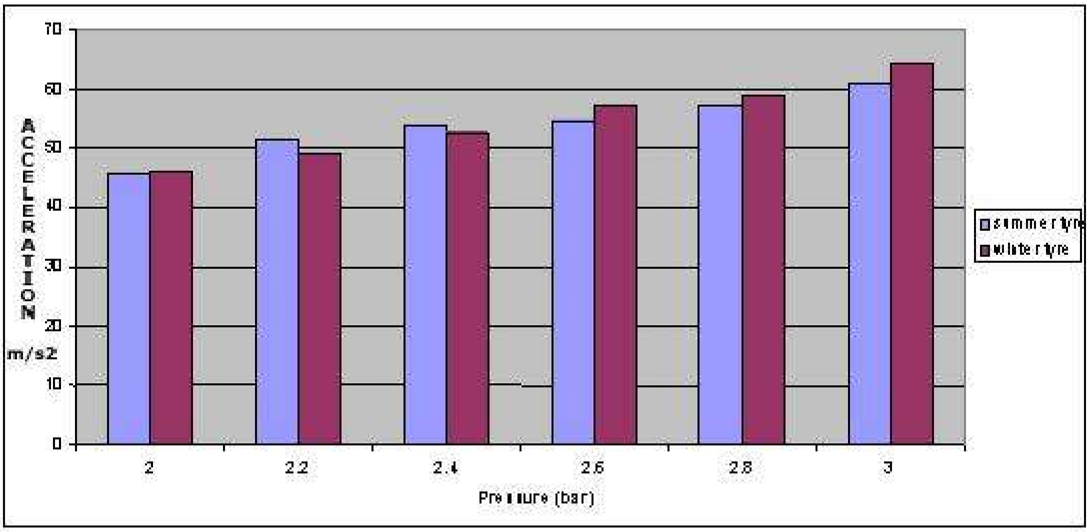

Figure 7. Effect of tyre pressure on the maximum acceleration value.

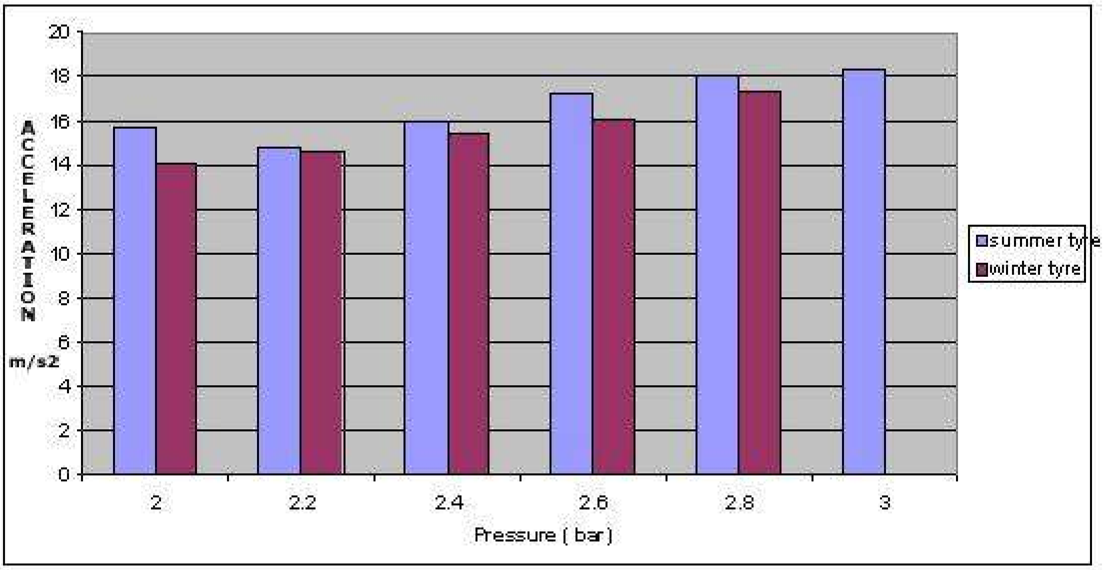

Figure 8. Effect of tyre pressure on the absolute acceleration average.

It seems that the effect of air pressure on accelerations is insignificant at low acceleration values, but on the other hand it seems to increase at great accelerations (Figure 9).

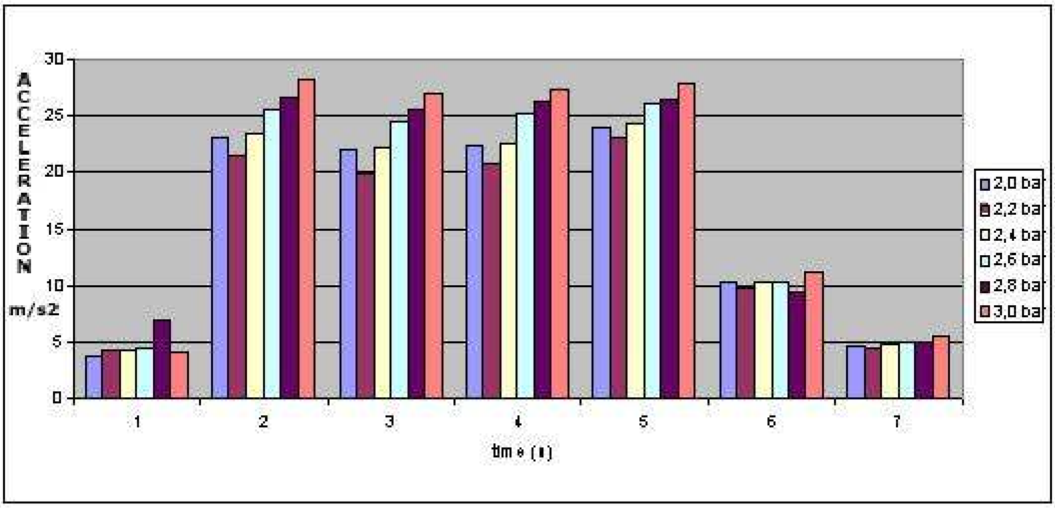

Figure 9. Measured accelerations grouped into one-second sequences.

4.4 Applicability of the Wheel Suspension Testing Unit for Calibrating the Measuring Method

The accelerations measured from the wheel suspensions were calculated for a six-second interval based on the absolute acceleration average. There was no great dispersion in the magnitude of acceleration sequences measured by the same vehicle. Of the two vehicles used in the study, car 1 showed lower acceleration at the six-second vibration sequence. The measuring results of car 1 were in average approximately 0.8 times higher in comparison with those of car 2. In summer 2008 measurements carried out on gravel roads the results of car 1 were 0.67–0.82 times those of Car 2 (on average approximately 0.75). Based on these results it was concluded that the wheel suspension testing unit is suitable for the calibration of the method.

4.5 Measurements Using the Acceleration Sensor with a Larger Measuring Range

It was decided to make measurements also using a larger acceleration sensor (150 g). Table 4 presents the measuring results from the same road section using sensors of different sizes.

Table 4. The measuring results of October 9, 2008, when the same road section was measured using sensors with two different measuring ranges.

Measuring Area of the Used Sensor (± g)	Maximum Acceleration at Measuring Speed 40 km/h (g)	Maximum Acceleration Converted to Correspond to the Comparison Speed v_{norm} = 60 km/h (g)
12	15,5	23,3
12	15,7	23,6
150	11,1	16,6
150	12,5	18,7

The depressions on road 18613, which were approximately 3-4 cm deep (Figure 10) caused approximately 12 g acceleration in the 150 g sensor. The same depressions caused over 15 g acceleration in the 12 g sensor. The 15 g acceleration of the smaller sensor can be explained by the fact that when the measuring range is exceeded, acceleration registered by the sensor is no longer so accurate.

Figure 10. There were big depressions in the driving line of road 18613.

Figure 11 presents the acceleration graphs of both sensors from road 18613. The graph shows how the differentiation ability of the sensor with bigger measuring range is much poorer at low acceleration levels. The graph based on the sensor data shows accelerations from the larger depressions in the road, but with differentiating accelerations of less than 10 g the graph is not even close to the differentiation ability of the smaller sensor. The smaller 12 g sensor reveals the most common accelerations caused by the road surface, but it is not so well suited for the classification of greater unevenness such as potholes because its measuring range is too small. However, the smaller 12 g sensor is better suited for the classification of evenness than the bigger 150 g sensor, because the 150 g sensor does not differentiate so accurately low acceleration levels. In addition, the measuring range of the 12 g sensor can be technically extended by using a lower driving speed.

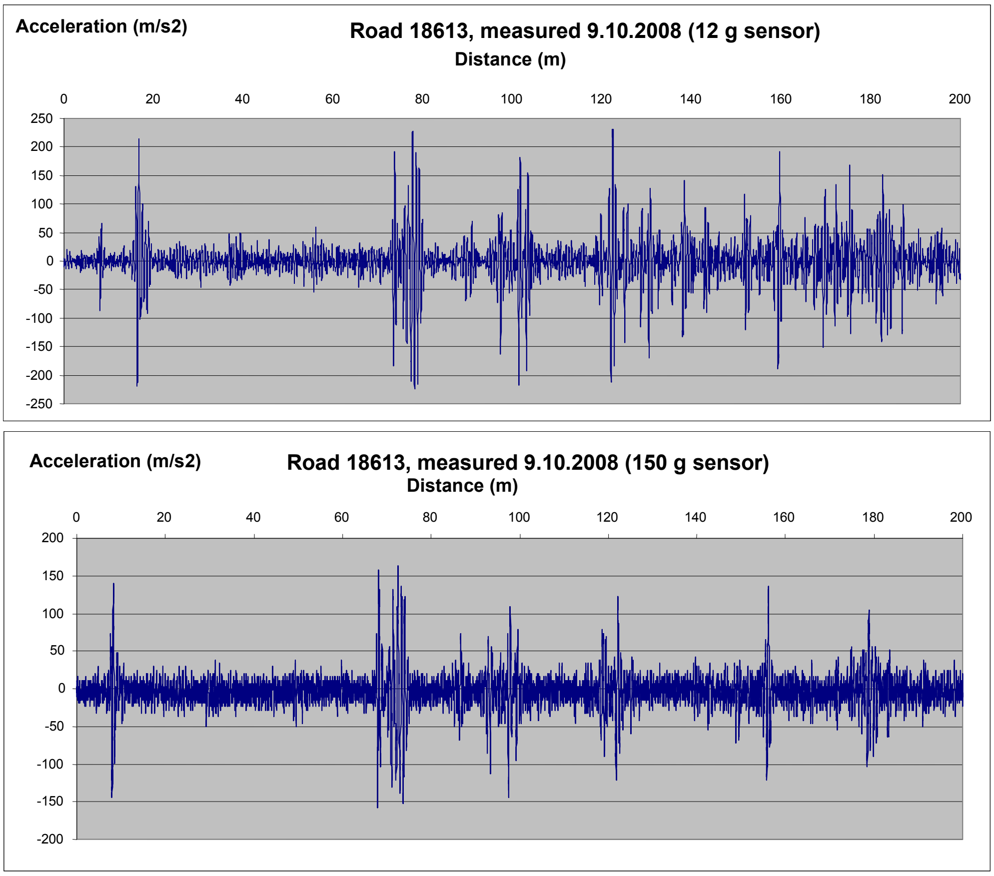

Figure 11. 12 g and 150 g sensor's acceleration figure from the gravel road 18613.

5 CONCLUSIONS

Measuring the evenness of gravel roads plays an important part in the routine and periodic maintenance of the lower classified road network. The assessment of evenness based on visual observations needs to be complemented by new measuring techniques. The developed automatic method for measuring the evenness of gravel roads seems to be well suited for measuring, monitoring and managing the evenness of gravel roads. The disadvantage of the results from the measurements by the acceleration sensor is the fact that it only generates data from the driving line of the car. In the future one line of research could be to study the possibility to measure and combine computer vision to the measuring data from the acceleration sensor. Computer vision would make it possible to observe depressions on the road in its entire scope, and also monitor the width of the road.

The developed method makes it possible to collect data on the evenness of gravel roads automatically. It makes it possible to collect large amounts of data and monitor the development of the evenness data. Consequently, it will be possible more efficiently than before to monitor the development of and react to the changes in the evenness of the gravel road network. In the future, the existence of historical data will also provide possibilities for making new kinds of analyses of the development of the condition of gravel roads, such as how the evenness of a new gravel road develops within a specific period of time, for example. Longer-term monitoring provides important information for decision makers on the development of the condition of the road network.

The measuring method developed in the project is especially well suited for assessing a road network, because it can be done in real time. The real-time aspect opens up several new possibilities to develop the management of the condition of the road network, monitor the quality of contractors and provide for safety risks more efficiently. The development of the measuring method is also prepared to include other measuring variables in the method. The measuring method will most likely be applicable also to measuring evenness in the winter. In the winter the measuring unit can also be used for measuring friction. In Finland the measuring method in the regional contracts concluded in 2009 and later has changed, but this method could be applied also to the newer contracts with a few modifications.

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