THE *μ-PW* FRICTION TESTER AS AN ELEMENT OF ROAD SURFACE SKID RESISTANCE EVALUATION SYSTEM AT THE TRAFFIC ACCIDENT SCENE

Witold Luty

Warsaw University of Technology, Faculty of Transport
Koszykowa 75, 00-662 Warsaw, Poland
tel.: +48 22 2348564
e-mail: wluty@it.pw.edu.pl

Abstract

Conclusions regarding needs related with building of measurement device, used to road surface skid resistance evaluation in traffic accident scene, are presented in this paper. Review results of devices and testers used to road evaluation of road surface properties, which are responsible for tire-road grip coefficient, are presented. Methods of road surface skid resistance measurement have been evaluated, in the context of common use in the process of traffic accident scene description. In the case of portable devices there are generally indirect methods, using rubber specimen which is sliding on the road surface, under certain normal load. In such cases, the measurement results defined as friction coefficient can be correlated with a tire grip coefficient to the road surface. There has been shown that it is necessary to develop methods and technical means of road surface skid resistance evaluation, which ensure an increase a results reliability of road accidents reconstruction process. Assumption for building and design system of μ-PW tester, have been presented. Established device concept is based on the measurement of the rubber specimen friction coefficient to the road surface. During the measuring the specimen normal load is fixed and motion speed is controlled. Features of tester and possible modes of measure, have been shown. An important feature of the tester is the possibility of transfer measurement results to a computer in order to prepare of test report, as an annex to the Police report of the vehicle inspection, used by the police in the procedure of traffic accident scene describing.

Keywords: *road accident reconstruction, frictional resistance of road surface, traffic accident place documentation, friction tester*

1. Introduction

The traffic accident scene description is a base for accident reconstruction and as an effect it's a base for evaluation of accident participant involvement in guilt. An important element of the traffic accident scene description is the evaluation of road surface skid resistance. Currently, approximately 90% of court cases to determine participation in the guilt of causing a traffic accident, requires a reconstruction performing, using the value of tire-road grip coefficient. A source of information about the state of road surface in the traffic accident scene description are in practice data prepared by the Police officers at the scene but the value of tire-road grip coefficient values are taken by experts from literature [1]. Using literature values of tire-road grip coefficient in the analysis and reconstruction process of a real road accident brings a high risk of making mistake in the court process and as an result unjust guilt judging of innocent or acquittal of the real accident perpetrator. Frequent disputes about a value of tire-road grip coefficient taken in the accident reconstruction by expert, extend the time and increase costs of performed court investigation. Therefore, increase of the description of a road accident reliability, especially in the area of the tire - road grip coefficient, is an important both technical and social problem. It is possible to say that it is worth attempt to improve the current status quo.

Besides construction and technical tires condition, the typical causes of changes in the value of tire-road grip coefficient can be grouped as follows:

a) materials and technology

– properties of the carcass or filler materials and the differences in road surface technology affecting on its tribological properties, including surface roughness,

b) road exploitation and maintenance

– changes in road surface roughness as a result its wear due to road traffic (roughness reduction) breaches and fissures in the surface,

c) local road conditions

– fast temperature changes (e.g. effect of surface shading or sunlight),
– slow changes in temperature and humidity of road surface throughout the day,
– permanent changes in temperature and humidity of road surface throughout the year,
– an occurrence of a substance covering road surface e.g. water, glaze, icing, sand, dust, oil, etc.

As a result, in the same place of road accident, tire-road grip coefficient may take significantly different values, changing both in a long and in a short period of time. Therefore, only the result of the measurement may take into account the impact of most causes of changes in the tire-road grip coefficient values. It's possible to say that gathering relevant evidence to enable a reliable traffic accident reconstruction may allow a measuring instrument to evaluate the road surface skid resistance, which would be used as equipment by the Police patrols or experts- investigators. A current problem is the selection of appropriate method and measurement tool allowing the an evaluation of tire-road grip coefficient in place and immediately after road accident.

The aim of this work is to present the assumptions and results of their implementation in the construction of a measure instrument, which allows evaluating the skid resistance of the road surface in the process of road accident reconstruction. Due to the clearly defined goal and scope of use, it must ensure that the measuring device used to road surface skid resistance evaluation has the following features:

– the device should be lightweight and small enough to be able to carry it in the car, including police car,
– the device should be able to carry and handle by one trained person, without much physical effort and without special drive,
– the device should make possible a measurement of road surface skid resistance as well in a certain place (locally) as along a specific path like braking skid marks, along or across the traffic lane etc.,
– the device should be easy to use and resistant to human mistakes or to the possibility of intentional distortions of measurement results,
– low cost of purchase and operation,
– to ensure a high degree of confidence, the device should be under the metrology supervision (for example should be calibrated), and staff should be trained and supervised in the field of technical competence.

2. A review of facilities used to evaluation of road surface skid resistance

Literature and other sources give many examples of using measuring devices for the evaluation of pavement skid resistance, including road surface. The variety of measurement methods and design solutions is a result of their certain target applications.

Probably the best instrument to evaluate road surface skid resistance is a dynamometric trailer, equipped with real tired wheel. Trailers used in Poland and in many countries around the world in spite of different constructions give reliable measurements results of the tire-road grip coefficient (Fig. 1a). Sometimes mounted wheel is smaller than real car wheel (Fig. 1b) and the trailer can be also driven by human (Fig. 1c).

a) b) c)

Fig. 1. Examples of dynamometric trailers used to evaluation of road surface skid resistance [3,4]; a) polish trailer SRT, b) trailer Griptester pulled by car; c) trailer Griptester driven by operator

Such trailers are used mainly used to assess the technical state of road surfaces, and in generally for detection of their skid resistance descent in combination with a standard wheel. However, they do not meet assumed criteria because of their size, weight and cost of purchase. Because for tests a smaller or larger tired wheel is required, exploitation costs are also not acceptable.

However, there are devices with much smaller dimensions, which are also used to assess the road surface skid resistance. Examples of such devices are shown in Figure 2.

British Pendulum Tester VTI GRIP Tester

Fig. 2. Examples of portable measuring devices, used to assess the road surfaces skid resistance in the process of its supervision and technical maintenance [6,7]

The pendulum device (British Pendulum Tester) is now a standard. It is used in evaluation process of the road surface or road markings skid resistance in accordance with the norm [5]. During measuring the rubber specimen is used - reusable "slider" which cost is small. However, the measurement results obtained using this device relates only to each single point of the road.

Therefore, its application for inspect the road accident scene, taking into consideration previously adopted requirements, brings significant difficulties. More preferred solution is for example the VTI Grip Tester, which enables the assessment of road surface skid resistance even on a long distance and in any direction [7]. During testing a small tired wheel is used and the skid resistance force of the wheel at fixed value of the slip ratio is measured. The use of this device provides the ability of road surface skid resistance changes detection in process of road technical supervision and maintenance. However the measurement result does not represent the "pure" tire road grip coefficient.

In practice, to evaluate the road surface skid resistance, the simplest solutions are often used, e.g. in the form of devices commonly called as "drag sled". Examples of such devices in different variations are shown in Figure 3.

Drag sled flat type + dynamometer

Drag sled, section of the tire + dynamometer

Fig. 3. Examples "drag sleds" used to assess road surface skid resistance in place of road accident [8,13]

The use of devices such as “drag sled” can give satisfactory measurement results of road surface skid resistance and also results of traffic road reconstruction [9]. However, it is necessary to maintain a clearly defined procedure and measurement conditions.

The measurement result may be charged by effects of operating mistakes and intentional actions distortion. The literature mentions about problems with repeatability of the measurement results even made by different persons. As main reasons of this, it is considered different, uncontrolled movement velocity of the drag-sled during measuring and incorrect setting of the dynamometer to the direction of movement (as it is seen on the Fig. 3) [10]. These are significant disadvantages of “drag sled” devices. Another disadvantage of the “drag sled” devices is that tested section of tire as specimen gets wear more and more during tests. This cases changes in measurement results and makes necessary to replace entire drag sled after getting worn. That's why it can be concluded that the target device for the road surface skid resistance evaluation, while maintaining the simplicity of device design, should be based on removable rubber specimen and be resistant to procedural errors during measuring.

There are technical solutions that set the direction of development works. Examples of portable measuring devices are shown in Figure 4.

Tortus 3 - an universal electronic device to measure pavement skid resistance

DART - an electronic device to evaluate road surface skid resistance

Fig. 4. Examples of electronic testers used to evaluate the road surface skid resistance [11, 12]

Devices are operated by one person practically without effort. The person, performing measurement, has no influence on measured forces, because only gives motion of device body. Those portable devices have a measurement system which actually measures the coefficient of sliding friction of the rubber specimen to the road surface, but this is not a real tire-road grip coefficient. But such measurement result can be correlated with a tire-road grip coefficient. This requires the implementation of the experimental road tests.

Presented portable devices meets most criteria established before, but their use in place of a road accident can be difficult, especially when measuring on a long distance. We also know that it is necessary to meet the essential conditions of measurement, which include [2]:

- the need to control the speed of moving of the rubber specimen,
- ensure the appropriate value of the specimen unit normal load to the ground.

3. A conception of the device to evaluate the road surface skid resistance

Basing on predetermined criteria and on the review results, assumptions for target measurement device functional properties, metrology supervision, measurement concept and form of the measurement results presentation have been defined. Also the name of measurement device has been defined as

"μ-*PW*".

The conception of measure is based on a rubber specimen, pulled on the road surface. The surface of specimen contact area with road surface is 1 cm^2. The specimen in mounted together with its holder to the two-component force transducer, which measures simultaneously the specimen normal load and sliding friction force (Fig. 5). The ratio of the measured forces gives the specimen friction coefficient to the road surface, as follows:

$$\mu = \frac{F_x}{F_z}\,. \tag{1}$$

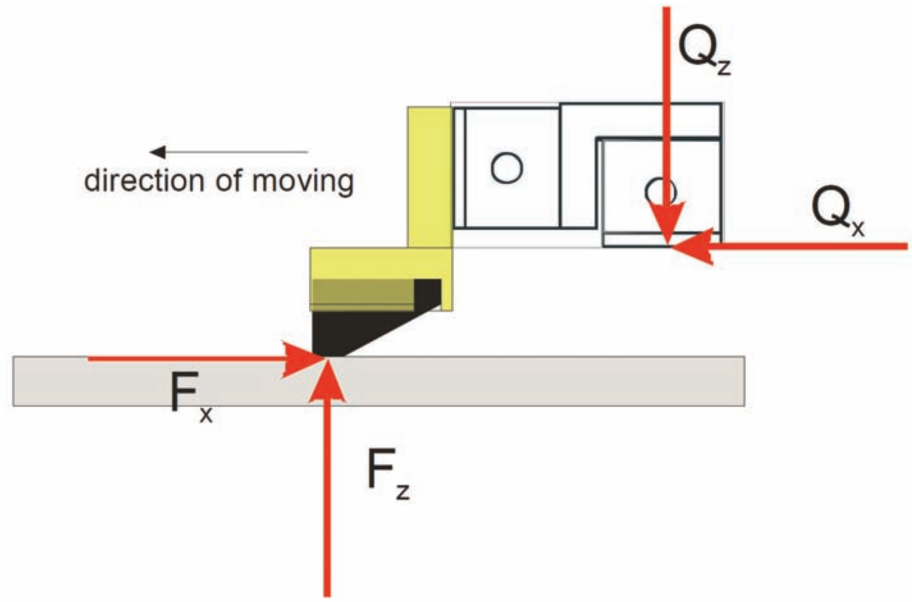


Fig. 5. The conception of measure - a diagram of forces transmitted through the rubber specimen from the ground on the two-component force sensor

A way of measure it relatively easy, but it is necessary to ensure suitable working conditions of the rubber specimen during measuring. In this case there have been assumed that:

- construction of the instrument should give an ability to set the rubber normal load from about 10 to 100N, relatively to air inflation pressure in vehicle tires,
- there should be maintained constant normal load value of the rubber specimen to the road surface during measuring regardless of the value of the longitudinal friction force,
- changes of road profile elevations or rubber specimen wear should not change the rubber specimen normal load,
- the angle of the of the rubber specimen set relative to the ground should be constant despite its wear during measuring,
- driving and steering of the device should not change a state of rubber specimen loads,
- the device construction should enable a measurement of traveled distance during measuring.

Schematic diagram of the device is shown in Figure 6. The rubber specimen with the force transducer 4 are fixed to the lower connector the movable frame, which consists of elements numbered as 11, 12 and 13. Linear bearings 3 and 9 are attached on the housing 1 side walls. They leads the movable frame column. Load of the rubber specimen in the normal direction is gravitational. So specimen normal load is such as a movable frame weight together with weights mounted to it in the upper connector 13. Described system enables maintaining a constant specimen normal load during measuring and also its constant angle set.

Trailing rear wheel 2 is coupled to the impulse rotation angle transducer (encoder). That sensor enables the measure and control of device travelled distance and moving speed during measuring. The front steer axle 10 enables driving and controlling the device travel direction by the operator.

Operator drives and controls the device through the drawbar 7, mounted on the front axle by joints. Driving the device during measuring causes an increase of front wheels normal load to the ground. This increases the device stability, but does not affect the values of the measured forces.

The drawbar is foldable. This allows reducing dimensions of the device during its handling and transporting (Fig. 7). On the drawbar handle a lever to control the movable frame elevation, during the device manoeuvring, is mounted.

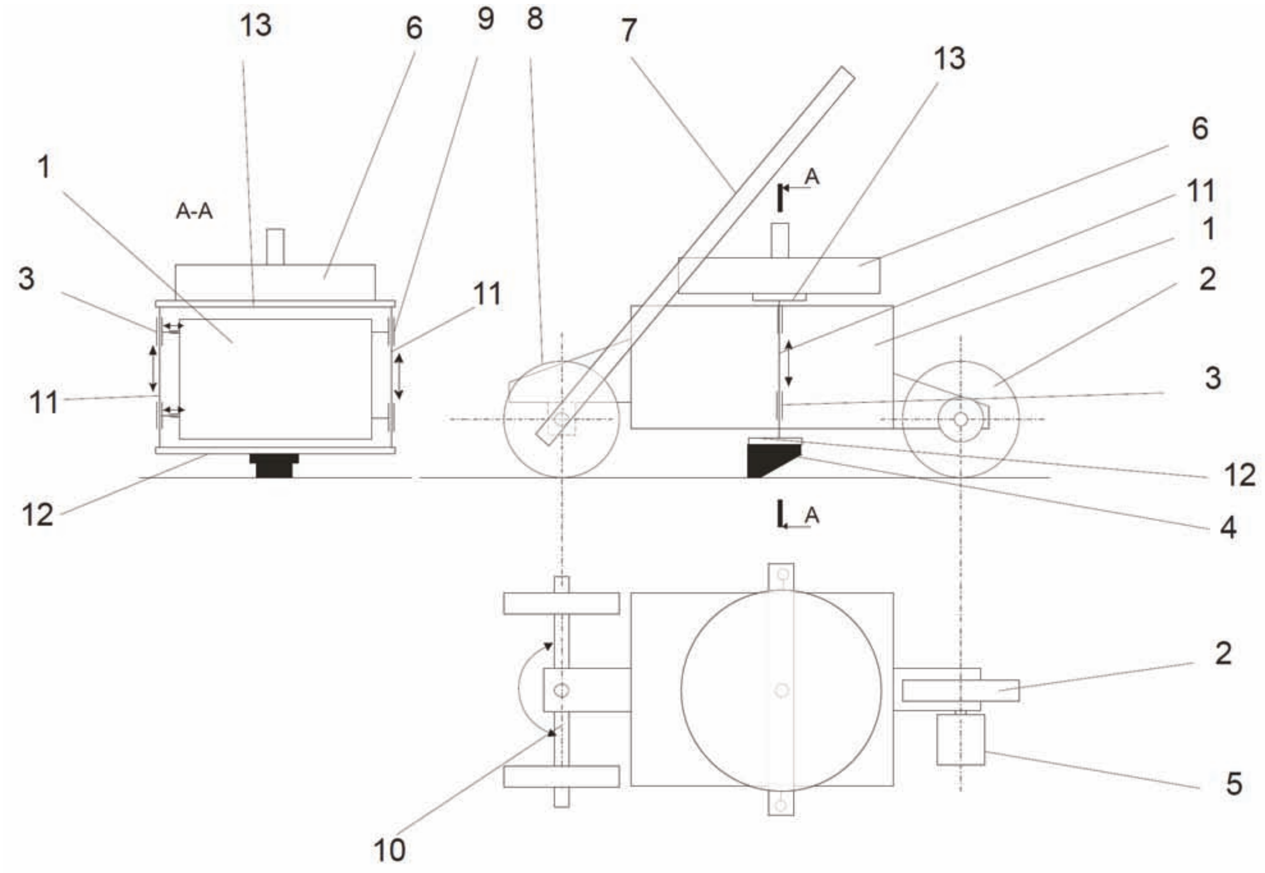
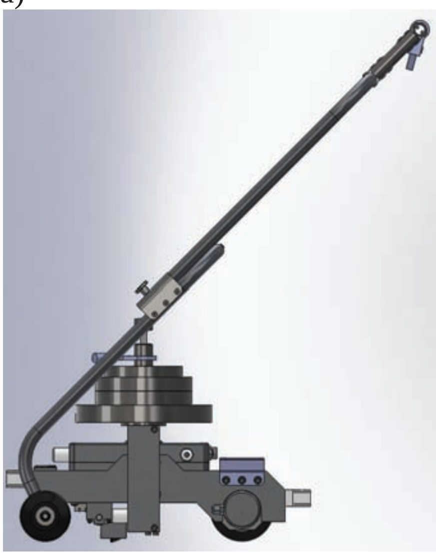


Fig. 6. Schematic diagram of the device μ-PW to measure the friction coefficient of the rubber specimen to the road surface; 1- device housing; 2- trailing rear wheel; 3,9 - linear bearings of movable frame; 4- rubber specimen with force transducer; 5- rear wheel rotation angle transducer; 6- frame weights; 7- driving drawbar; 8- front axle wheels; 10- front steered axle; 11- column of movable frame; 12-– lower connector of movable frame; 13- upper connector of movable frame

a)



b)

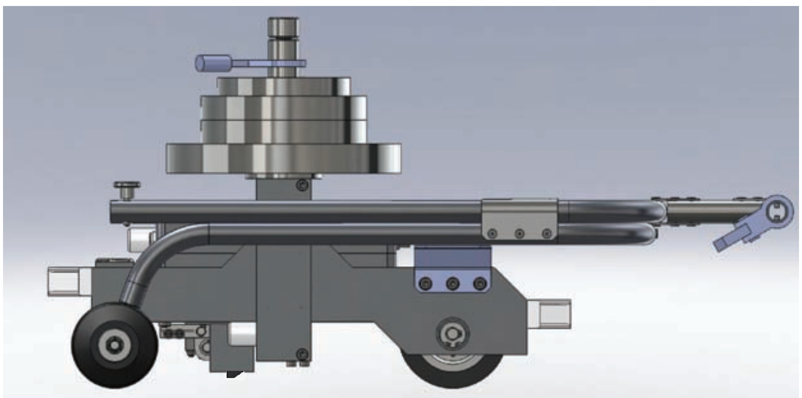


Fig. 7. Side view of the μ-PW device- result of assembly drawing; a- the device with unfolded drawbar; b- the device with folded drawbar

The real device is equipped with a control panel that allows to control the available functions (Fig. 8). View the control panel is shown in Figure 9. Panel allows:

– turning device on and off,

– starting the force transducer test procedure,
– starting a wireless connection with computer, in order to sending measurements results or to perform device service,
– displaying the measurement result and other device messages,
– choosing a mode of measurement,
– starting and stopping a measure,
– controlling of device moving speed.

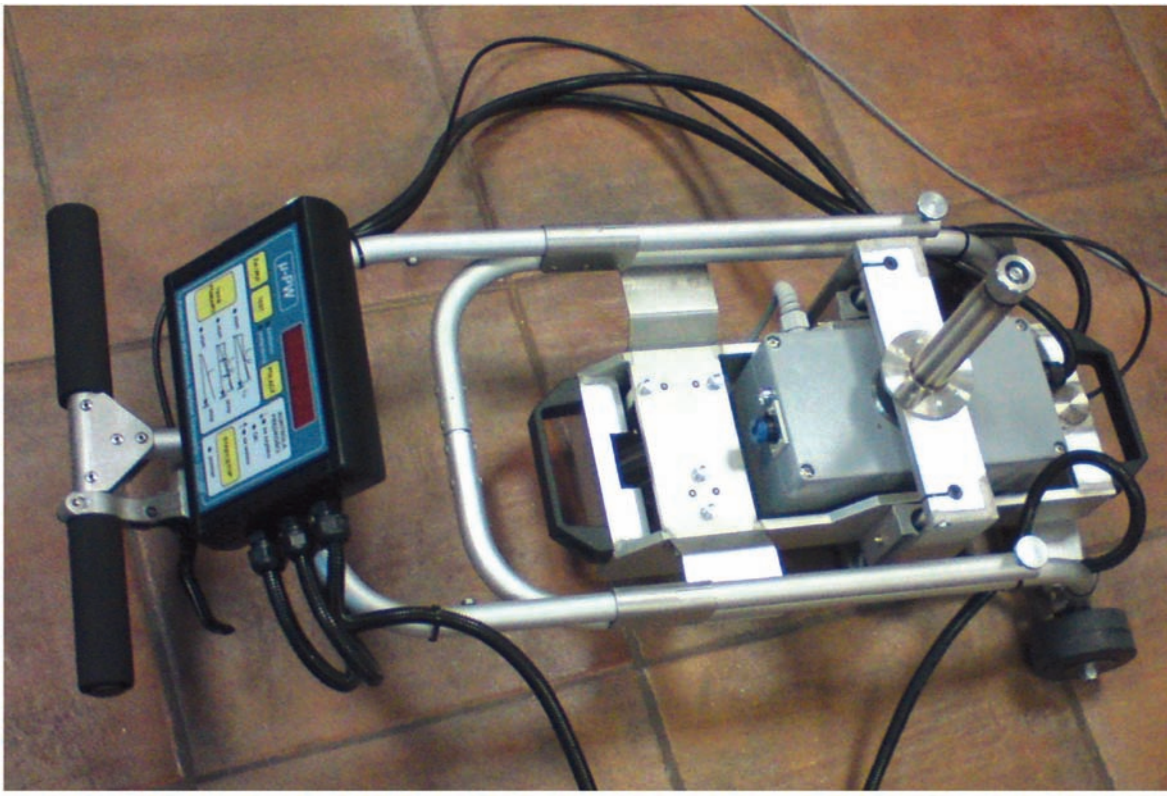


Fig. 8. View of real μ-PW device, with control panel mounted to its drawbar

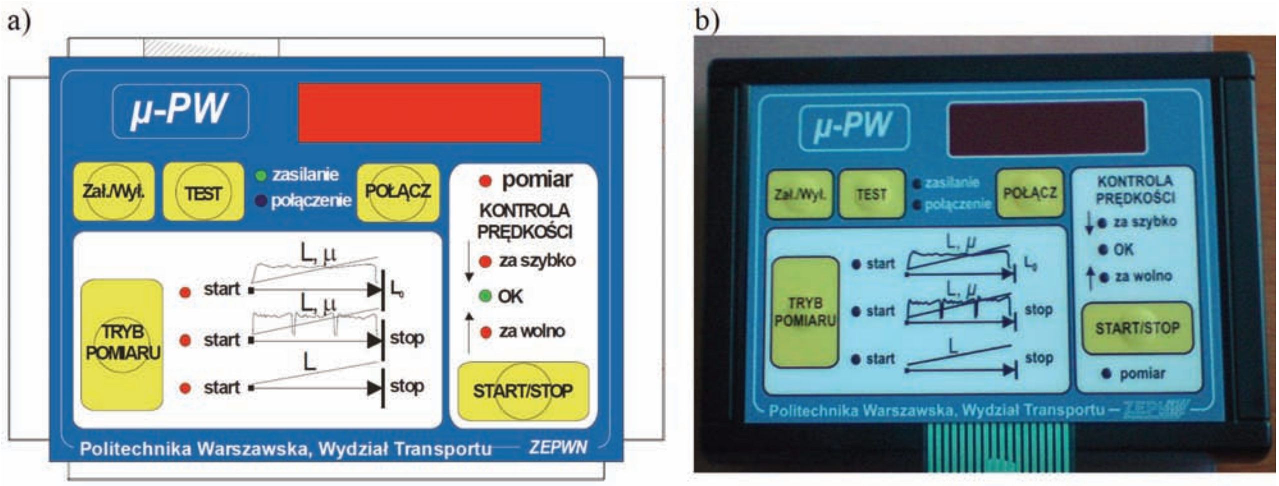


Fig. 9. Control panel of μ-PW device; a) project of panel; b) view of real panel

The measurement process is automated and can be done in three ways:
- measurement of friction coefficient on road section of fixed length,
- measurement of friction coefficient on road section of any length, until the measure is turned off,
- measurement of the travelled distance length (without forces measurement).

The measurement result is displayed on the control panel as values of friction coefficient, calculated for the entire travelled distance and travelled distance length. It's also possible to send the measurement results to the computer in order to prepare a measurement report or to perform an additional analysis of measurement results. Example measurement result, obtained using the *μ-PW* device is presented in Figure 10.

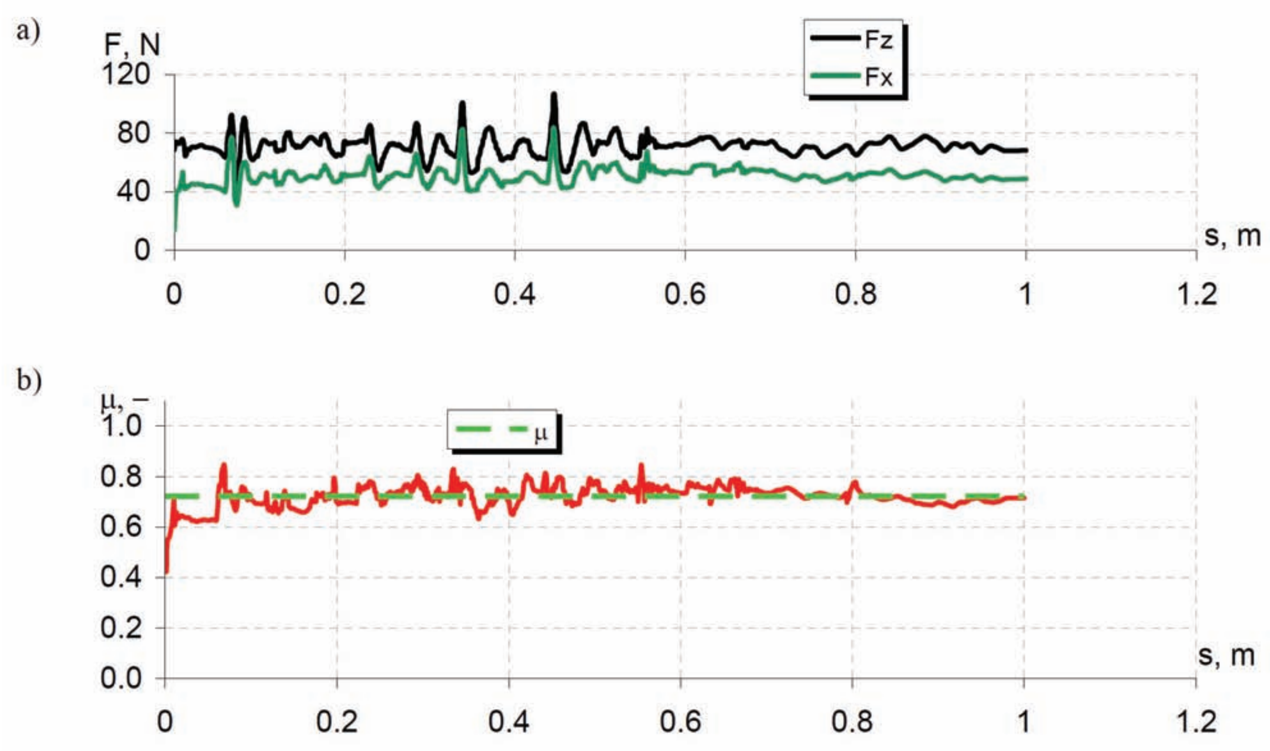


Fig. 10. Example measurement results obtained using μ-PW device on the road surface of smooth, dry asphalt (travelled measurement section length 1m); a) normal load F_z and friction force F_x transmitted by rubber specimen; b) friction coefficient μ- measurement result and average value

4. Summary

Built measuring device *μ-PW* actually measures the coefficient of friction between rubber specimen and road surface. The measurement result can not be directly applied to the reconstruction of road accident.

The use of measurement results in the process of a road accident reconstruction requires to establish the correlation between the measurement result and car tire-road grip coefficient. Such a correlation is possible on the basis of a experimental research series, which have been planned in the next stage of work, with the participation of real car tires.

Planned and obtained device properties, which enable to establish measurement conditions, important for the rubber specimen interaction with road surface, are conducive to positive results.

It is also necessary to establish a method of measurement results calculation, presentation form and the way of use in the road accident reconstruction process. These issues are the subject of further work.

References

[1] Luty, W., *Prawno-techniczne aspekty oceny przyczepności nawierzchni drogi w miejscu zdarzenia drogowego*, Logistyka 4/2010.

[2] Luty, W., Wieczorek, M., *Wpływ wybranych własności gumy bieżnika na jej przyczepność do nawierzchni drogi*, Zeszyty Naukowe Instytutu Pojazdów Politechniki Warszawskiej 1(77)/2010.
[3] http://www.ibdim.edu.pl/
[4] http://www.highwaysmaintenance.com/skidtext.htm
[5] PN-EN13036-4:2004(U), *Drogi samochodowe i lotniskowe - Metody badań - Część 4: Metoda pomiaru oporów poślizgu/poślizgnięcia na powierzchni: próba wahadła*.
[6] *Portable skid resistance tester*, http://www.mastrad.com/pendul.htm
[7] http://www.vti.se
[8] http://www.brakerbox.com
[9] Navin, F., Drag *sled and automobile skidding, an analytical relationship,* by University of British Columbia President, SYNECTICS RSR Corp. Vancouver, USA SPECIAL PROBLEMS 2009 Orlando, Florida, April 2009.
[10] Bartlett, W., Baxter, A., Schmidt, B., Stanard, T., Wright W., *Comparison of drag-sled and skidding-vehicle drag factors on dry roadways*, SAE Technical paper series 2006-01-1398.
[11] http://www.wessextestequipment.co.uk/Products/Tortus.aspx
[12] http://engtech.ca/projects/2004/drag_sled
[13] http://dps.sd.gov