CARGO SECURING DURING TRANSPORT ON THE RABA VEHICLE

Martin Vlkovský[1]

Summary: The article deals with the evaluation of the transport experiment in Hungary using a Raba truck in order to show the deficiencies of the input data used for the purpose of cargo securing on vehicles. Statistical evaluation provides an overview of basic statistical characteristics, including the interpretation of significant values. The article contains model of loading, which illustrates the problem of using average – normatively set values of acceleration coefficients when determining the inertial forces acting during transport.

Key words: cargo securing, transport, inertial forces, acceleration coefficients, statistical characteristics.

INTRODUCTION

In the Czech Republic, nearly 400,000 tons of material (1), which must be properly fastened, is transported every year. A range of fixing means with different resistances is used for fastening. Generally, the most commonly used means of fastening are textile lashing straps, on which the article is focused.

Selection of suitable lashings strap is based primarily on expected inertial forces that are active during transport (based on the weight of the cargo, the technical condition of vehicles, communication quality, etc.). To simplify the whole process software support, which is using input data related to cargo and transport (see above) and the requirements of the relevant standards is often used nowadays (e.g. EN 12195-1:2011 *Securing loads on road vehicles – Safety – Part 1: Calculation of securing forces*).

Due to the fact that, the size of the inertial forces acting on the cargo during transport can only be assumed, the outputs from empirical studies are used (see EN 12195-1:2011). Presented results of empirical studies are statistically processed (averaged) and used as a source of data, e.g. for the aforementioned software support for loading and thus serve to select the appropriate lashing capacity of lashing straps.

The subject of this article is to point out the deficiencies of the use of averaged data from empirical studies on practical example by using data from the transport experiment conducted on the transport truck RABA.

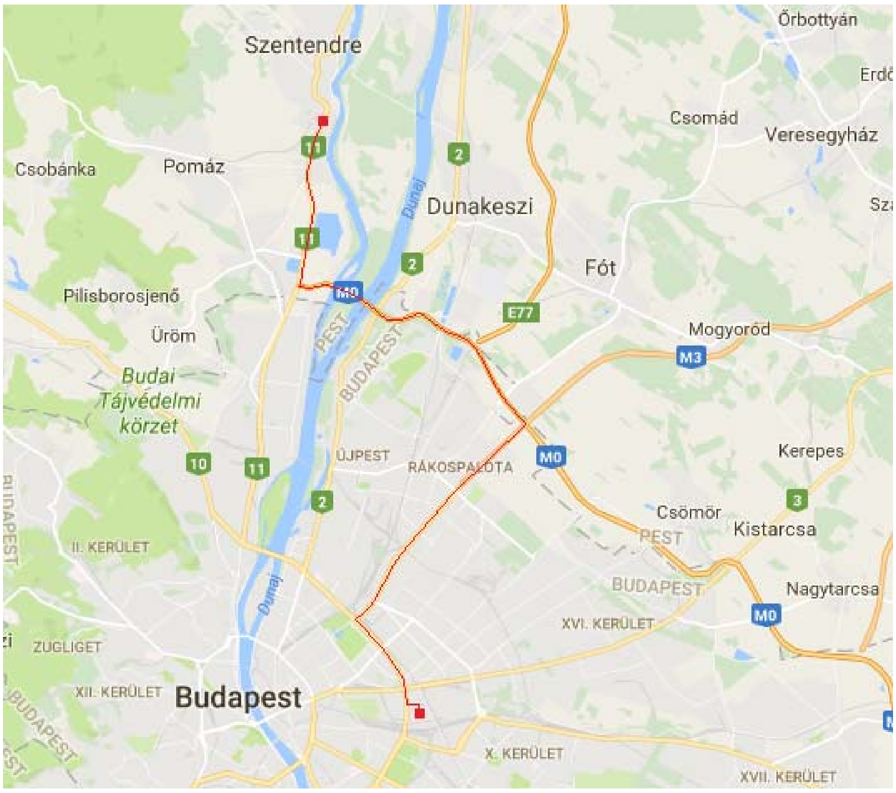
[1] Ing. Martin Vlkovský, Ph.D., University of Defence, Faculty of Military Leadership, Department of Logistics, Kounicova 65, 662 10, Brno, Tel.: +420 973 443 003, E-mail: martin.vlkovsky@unob.cz

1. REAL TRANSPORTATION – MEASUREMENT OF ACCELERATION COEFFICIENT

1.1 Route and conditions of transportation

Transportation, which was the subject of measurement, was carried out for over two days on 2016-10-12 and 2016-10-13 in the Republic of Hungary. Transport route (see Figure 1) with a length of 26 km lead from Budapest to Szentendre on the motorway and roads of I. and II. class. Measurements were made on both days on one truck RABA with type designation H18.206DAEL-002 and load capacity of 6700 kg (2).

The vehicle was in good condition with almost 90 thousand km mileage. For the purpose of the experiment the vehicle was laden with pallet units of a total weight of 5120 kg. The vehicle was driven by the same professional driver during both days.



Source: Google maps, modified

Fig. 1 – Transport route

During the two days were almost ideal climatic conditions for transportation. The roadway was dry, visibility was good and during transport, there were no rainfalls. The first day – 2016-10-12 was transportation conducted at time 7:49:35-8:33:20 during rush hour and at the time of 7:31:15 – 8:16:20 on the second day – 2016-10-13.

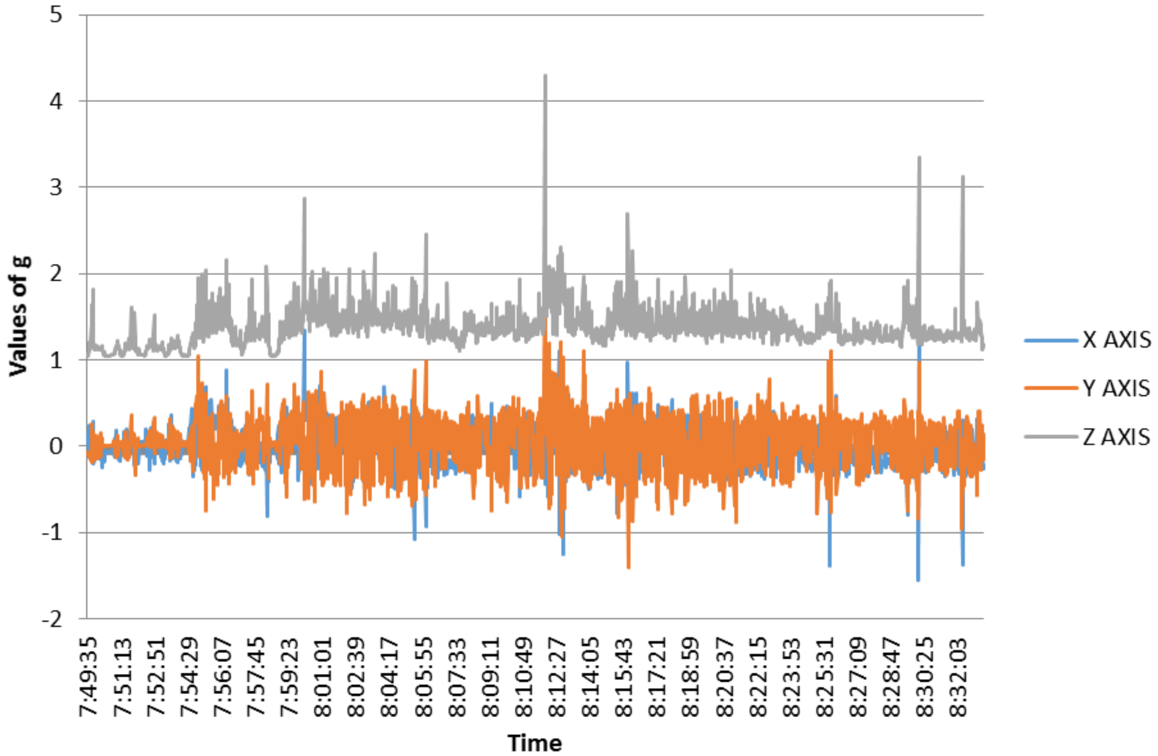
During the two days of measurements the same two accelerometers OM-CP-ULTRASHOCK 5-CERT with datalogger and calibration certificate, which measured acceleration (acceleration coefficients) in three axes (*x, y*, and *z*) were used.

The record of highest respectively lowest coefficient of acceleration took place every second with a frequency of 512 Hz (3) for each axis.

1.2 Statistical evaluation of conducted transportation

To ensure the desired precision average values of the accelerometers are used for statistical evaluation. Values are subsequently compared with the basal variant (vector) of acceleration coefficient of the EN 12195-1:2011 (0,8; 0,6; 2). Value resulting from the standard for the *z* axis is 1g, but the record for a given axis was performed not from 0g, but from 1 g, therefore the shift of axis in included in the basal variants of 2g.

Situation at given days of measurement can be seen in graphs of Figures 2 and 3, which show the average values of the acceleration coefficients.



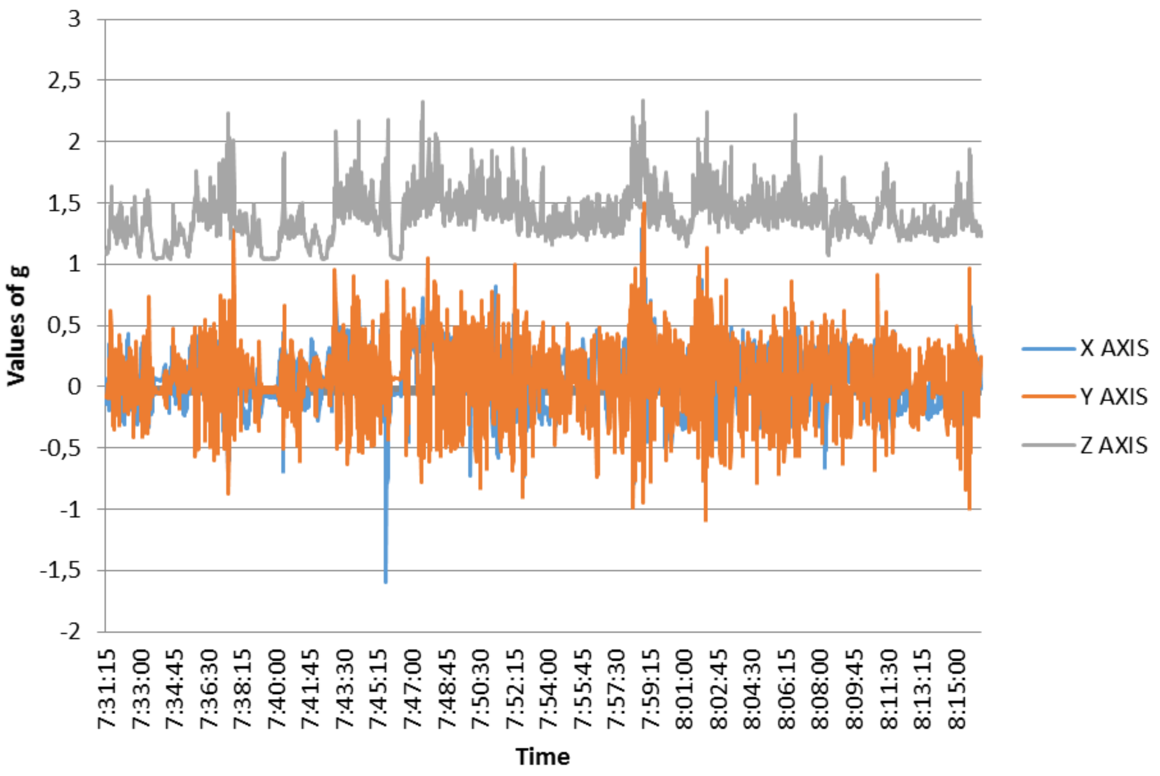
Source: Author

Fig. 2 – Measured values of the acceleration coefficients of 2016-10-12 (average values)

Standing in traffic jams, respectively intersections, where the values are almost zero and extreme fluctuations, are obvious from the curves of acceleration coefficients functions in each axis. The extreme fluctuations are subject of article and are caused mostly by bumpy road (holes, ruts, potholes, tracks etc.).

For the first day of measurement 7878 values were acquired. A total of 133 values were outside of normatively set limits which represents 1,69% of the total. Relatively insignificant value exceeds the norm even 2 times, it was a total of 6 values, which represent only 0,08% of the total.

On the second day of measurement was obtained 8118 values. A total of 146 of them exceeded the normatively set limits which represents 1,80% of the total. Only 3 values exceeded the norm twice.



Source: Author

Fig. 3 - Measured values of the acceleration coefficients of 2016-10-13 (average values)

Highest, respectively lowest readings (extremes) for both days of measurements are for overview listed in Table 1.

Tab. 1 – Highest, respectively lowest measured values

Day	**10/12/2016**			**10/13/2016**		
Axis	**X**	**Y**	**Z**	**X**	**Y**	**Z**
Highest values	1,7450	2,0050	4,2950	1,2900	1,5050	2,3350
Lowest values	–1,5550	–1,4000	-	–1,5950	–1,0850	-

Source: Author

Primarily during the first day of measurements has occurred in the y-axis value of more than 3.3 times beyond the normative limit (c_y = 0,6). Values in the axis *z* then more than 2,1 times greater than those set by norm (c_z = 1,0, resp. 2,0). Both values have moreover occurred at the same time. On the second day of measurement extreme values tended to be lower. An exception is the lowest value for the *x*-axis, but it did not even exceed the double of the normative set values.

For deeper analysis basic statistical characteristics showed for overview in Table 2 were calculated.

Tab. 2 – Selected statistical characteristics of the transport experiment

Day	**10/12/2016**			**10/13/2016**		
Axis	**X**	**Y**	**Z**	**X**	**Y**	**Z**
Arith. mean	0,0267	0,0506	1,3794	0,0972	0,0573	1,3891
Modus	–0,1900	0,0000	1,2700	0,2750	0,0000	1,4000
Median	0,0100	0,0300	1,3450	0,0800	0,0350	1,3750
Variance	0,0657	0,0943	0,0447	0,0574	0,0899	0,0354
Kurtosis	1,9564	0,5569	20,9682	0,8620	0,6163	1,9724
Skewness	–0,0547	–0,0524	2,6042	–0,3270	–0,0387	0,8511

Source: Author

The arithmetic average indicates all values in limit set by standards. The problem is, without dispute, only random outliers that may cause release of cargo for reasons of greater than anticipated inertial forces at the axis (axes).

Modus is often influenced by standing at traffic jams and at junctions and depending on the engine vibration is usually value in the *y*-axis around 0, or directly as zero in this case.

The kurtosis is much more interesting. Frequency distribution on the first day of measurements on the *x*-axis and the second day in the *z*-axis is almost 2, indicating a slightly sharper frequency distribution in comparison with a standard normal distribution. The frequency distribution on the axis of the first measurement day is extremely sharp (leptokurtic), the kurtosis value is almost 21. It follows that in the frequency distribution occurred very high values (4).

The skewness coefficient points to a slightly asymmetrical frequency in *z*-axis values from the first day measurements; e.g. the majority of the measured values is below average.

If we use the relative comparison, the kurtosis of *z*-axis is almost 11 times greater at the first day of the measurement than at the second day of measurement. For the coefficient of skewness it is on the same axis more than three times of the value from the second day of measurement.

1.3 Model of loading and securing the cargo

In order to demonstrate the effect of different values of the size of the inertial forces a simple model of loading was created. As an input parameter will be used for a given axis the values from the moment when there was the most extreme value affecting cargo (value 4,2950). Input values for the model are shown in Table 3.

The calculation to determine the inertial force (F_T), which fixing method has to resist, in this case it is the lashing resistance of lashing strap, is performed for illustration. The calculation is performed for one piece of lashing strap; in real conditions it can be put into the calculation for a larger number of pieces.

For comparison is also performed calculation using a set of normative values of acceleration coefficients (F_{Tn}). For putting into the formula (1) the values of the standard EN 12195-1:2011 are used, for *m* and α angle have been used model values of 2000 kg (two pallet units side by side) and 80°, which correspond to the usual conditions and standard way of securing the cargo at the compartment of the vehicle.

Weight and angle with using of measured values of acceleration coefficient are not determining for calculation according to the standard, because the ratio between the calculated values of the inertial force $F_T : F_{Tn}$, which is decisive for the conclusions, remains the same.

Tab. 3 – Input values of model

Variable	Value	Unit	Note
F_T	?	N	Tension force
F_{Tn}	?	N	Tension force (according norm)
c_x	–0,445	-	Coefficient of acceleration (x axis)
c_y	2,005	-	Coefficient of acceleration (y axis)
c_z	4,295	-	Coefficient of acceleration (z axis)
μ	0,4 (norm)	-	Coefficient of friction
m	2000 (substitute)	kg	Mass of cargo
g	9,81	ms^{-2}	Gravitational acceleration
f_s	1,25 (norm)	-	Safety factor
n	1 (for one straps)	pcs	Number of lashing straps
α	80 (substitute)	°	Angle formed by tying straps to the floor

Source: Author

To calculate searched inertial forces (F_T a F_{Tn}) relationship from standard EN 12195-1:2011 is used:

$$F_T = \frac{(c_{x,y} - \mu \cdot c_z)\, m \cdot g}{2n \cdot \mu \cdot \sin\alpha} f_s \quad [N] \qquad (1)$$

The relationship for determining the F_{Tn} is the same, but with different input data for the acceleration coefficients. For the processing, e.g. MS Excel spreadsheet can be used. Output values are showed for overview in Table 4.

Tab. 4 – Output values of inertial forces

Variable	Results	Unit	Note
F_T (for c_x)	**21537**	N	used the absolute value, direction of F_T is not substantial here
F_T (for c_y)	**8392**	N	
F_{Tn} (for c_x)	**4886**	N	
F_{Tn} (for c_y)	**2443**	N	
S_{TF} (500 daN)	10000	N	common used fastening strap, standard tension force (×2)
n (for F_T)	**3** (2,15)	pcs	required number of fastening straps, rounded to whole pcs
n (for F_{Tn})	**1** (0,49)	pcs	required number of fastening straps, rounded to whole pcs
$F_T : F_{Tn}$ (for c_x)	**4,41**	-	
$F_T : F_{Tn}$ (for c_y)	**3,44**	-	

Source: Author

From Table 4 it is clear that for securing two pallets with a total weight of 2000 kg according to the standard is required one piece of lashings strap, but after substituting the measured values is this method of attachment insufficient. It is necessary to use 3 pieces of lashing straps. Stated output obviously depends on used lashing strap and its lashing resistance and weight of cargo.

From the perspective of acting inertial forces is **the real inertial force at *x*-axis 4,41 times greater than the size assumed by norm**, at *y*-axis it is 3,44 times greater. The calculations of number of lashing straps is no longer required for *y*-axis, because of effecting smaller inertia force.

CONCLUSION

Ensuring the security of cargo, associated technical resources (primarily traffic and transport) and last but not least of people, should be at the first place for every shipment. The article points to the appropriateness of a revision of applied input data into the calculation of expected inertial forces acting during transport, which are often used as input data for the corresponding software support of loading software. Although the transportation model was realized on public roads, the values are problematic in some cases, even 3 times greater than those determined in norm from perspective of standard processes of securing cargo. If these conditions were less favorable (e.g. road class III., unpaved road or movement of the terrain), it can be assumed that the values would be even higher (see e.g. [5]).

Use of the measured extreme values for calculation of inertia forces acting during transport is even worse and inertia force based on measured acceleration coefficient is almost 4,5 times greater, than value used by prescriptive set limits. Although this article is only a partial contribution and to confirm defined hypotheses is needed larger measurement of datas. It can be assumed, that the outputs will be analogous with using of different means of transport, different drivers on different roads. Transportation on roads in the Czech Republic using trucks of Czech production show similar conclusions (see e.g. (6)).

The subject of next research will be obtaining the required amount of data to demonstrate the deficiencies of normatively set limits for needs of logistics (securing of cargo). Comprehensive aim of research is thereafter securing safer transportation at all aspects related to securing of cargo.

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