sciendo

CzOTO 2019, volume 1, issue 1, pp. 978-986

THE ROLE OF FASTENING LOADS IN THE SAFETY MANAGEMENT OF INTERMODAL TRANSPORT OF TRUCK SEMI-TRAILERS

doi: 10.2478/czoto-2019-0124
Date of submission of the article to the Editor: 02/11/2018
Date of acceptance of the article by the Editor: 23/12/2018

Robert Sałek[1] – *orcid id: 0000-0002-5416-9448*
Michał Słabik[2] – *orcid id: 0000-0003-0281-7981*
[1]Czestochowa University of Technology, **Poland,** *robert.salek@wz.pcz.pl*
[2]Ewals Cargo Polska, **Poland**

Abstract: Ensuring transport safety is one of the key areas of transport companies' operations. Management and organization processes not only in the intermodal transport are associated with decision-making in regard to adequate load securing, which is exposed to the inertia forces resulting from the movement of transport means. Regardless, the responsibility of individual entities in the process and the applicable insurance, the basic aspect to ensure transport safety is the correct securing of the cargo. In the article, the authors present elements of calculation models for different methods of securing cargo. Calculations were performed for the selected type of load on the specific semi-trailer meeting the requirements of the XL Code adapted for intermodal transport. The analysis of safety management in transport in the aspect of decision-making about the method of securing the cargo was also made.
Keywords: management, transport, intermodal, transport safety

1. INTRODUCTION

Road transport is currently the largest, most expensive and dangerous branch of transport. The fact that it is the most dangerous is mainly due to the large morbidity rate, which is caused by, amongst other reasons, a rapid increase of participants of transport by road, as well as the difference between the amount of vehicles, and the state of the infrastructure (Antonowicz and Majewski, 2014). Its impact on the natural environment is also significant (Santos, 2017). The approach to safety management of transport is a systemic nature as a part of an environmental management system (Ingaldi and Klimecka-Tatar, 2015), where four main aims can be distinguished (Szymanek, 2010):

1. The minimalisation of the risk of road occurrences- prophylactic methods.
2. The minimalisation of accidents- active methods of increasing safety.
3. The minimalisation of the results of accidents and occurrences- passive methods of increasing safety.

4. The minimalisation of occurrences and road disasters - crisis management.

These aims reflect the consecutive stages in road safety management system, and each of these stages consists of a set of methods, technologies and procedures which ensure the smallest possible risk of unexpected road occurrences. Research carried out by McIlroy et al. additionally shows a diverse approach to road safety in a multicultural context (McIlroy et al., 2019). A multitude of tools and methods used in modelling road safety, emphasizes the importance of this aspect in the functioning of the socio-economic environment (Stojanová and Blašková, 2017, Farid et al., 2019, Martins Gomes et al., 2019, Tyler, 2019). Rosolinoa Vaiana et al. in their work about the judgement of the performance of road safety underlines the fact that, all transport systems are characterized by a high complexity, as well as a high level of danger towards people. Therefore, it is very important to evaluate the risk of potential danger in a comprehensive manner. In order to do this, an indicator of the performance of road safety has been implemented, called the Risk Index. The RI is meant to inform about danger factors, as well as about the risk of road occurrences. The main coefficients influencing the safety of road transport also include vehicle factors, such as any defects, size and technical conditions, which also concern securing the load on the vehicle (Vaiana et al., 2014).

Likewise, M. Alonsoa et al. underline in their work the effect of the load, or precisely the way it's placed and secured, on the dynamic behaviour of the vehicle. They present a methodology, which allows to determine the level of safety used for the predictable evaluation of vehicles (Alonsoa et al., 2018).

Safety in road transport depends on many factors (see more: Wegman, 2017, Utriainen et al., 2018), but in a great matter relies on the correct securing of the cargo. Carriers and especially drivers are obliged to secure the transported load in a proper way, which prevents its reposition under the influence of inertia. It is important to point out the significance of proper securing of the load and the influence it has on the driver's and the environment's safety. The decisions, which are made in order to determine the correctness of how the load is secured, are connected to a series of certain actions, which are aimed at specifying the amount and type of lashings needed. The education and motivation of the driver by the management staff plays a significant role in the correct approach to securing the load. It is also up to them to be responsible for providing the equipment and taking care of its technical condition (Nævestad et al., 2018). Another factor determining the safety of freight transport are legal aspects defining the working time and schedules of drivers (Goel, 2018). A very important is also correct distribution of the cargo inside trailer, only even load distribution can guarantee predictable vehicle behaviour, also axle weight distribution should be considered. For example, drive axle has an upper and lower limit and none of those cannot be exceed. By doing a number of calculations, it is possible to make a decision, which lashing technique should be used and how many of straps are needed to assure the safety during transport.

2. METHODOLOGY OF RESEARCH

The examined load are 4 identical concrete tanks. Each one has the following dimensions: 1,665 x 1,665 x 2,830 m (length x width x height) and mass of 5000 kg. The tanks are loaded onto a tautliner mega trailer, which complies with the EN 12642 XL norms, and is adapted to intermodal transport in the Huckepack mode, which is by using special railway wagons in rail transport. Additionally, the trailer has special mounts, which holds it to the deck during water transport.

The trailer described above was built on the base of the Krone Mega Liner trailer, on behalf of one of the biggest European transport companies. It belongs to the group of so called ''universal trailers'', which allow to load, secure and transport a wide array of typical loads on pallets, baskets, stands or other transport units which can be fixed without the use of special equipment. The capacity (which can be utilized) of such a trailer is 17 x 2 pallet spaces, which means that in the case of loading a so called palletized loading unit or a box pallets, 3 units can be load one of top of another. This gives 102 units of the actual trailer capacity, so about 101m³ capacity inside of the trailer. Trailer is equipped with 16 straps with the following parameters: Lashing capacity LC= 2500 [daN] and the standard tension force of the ratchet of STF=350 [daN]. All of the straps are permanently fixed to the floor, allowing to immobilise the load. During the transport, two groups of forces have effect on the vehicle: the weight of the load and inertia.

The weight of the load is the force that the load on the vehicle has (or how it presses) on the floor of the vehicle (Madej et al., 2017). It is equal to earth's acceleration g=9.80665 [m/s²], multiplied by the mass of the load, which has effect mainly on the friction force between the load and the floor of the trailer. The second, more important force, which has place in the vehicle, is the force of inertia. In accordance to Newton's III law of dynamics, it is the force resulting from the accelerating, braking and the change of direction of the vehicle. The force value for a vehicle is:

$$F_b = -m \times a \qquad (1)$$

Where:

F_B– the value of the force of inertia [N]

m – the mass of the load [kg]

a – the value of acceleration [m/s²]

The values of acceleration, which should be used when securing the load in compliance with the EN 12195-1:2009 norm has been presented in table 1 for road transport and in table 2 for sea transport.

Table 1

Acceleration coefficient for road transport

The direction of the force	Lengthwise		Transversely		Vertically downwards
	Forward	Backward	Shifting	Tilting	
Lengthwise	0,8	0,5	X	X	1,0
Transversely	X	X	0,5	0,5/0,6	1,0

Source: (CEN - EN 12195-1:2009, p. 11)

Table 2

Acceleration coefficient for water transport

Sea area	The direction of the force	Lengthwise	Transversely	Vertically
A	Lengthwise	0,3	X	0,5
	Transversely	X	0,5	1,0
B	Lengthwise	0,3	X	0,3
	Transversely	X	0,7	1,0
C	Lengthwise	0,4	X	0,2
	Transversely	X	0,8	1,0

Source: (CEN - EN 12195-1:2009, p. 12)

For the calculation, in the table, the following values shall be adapted:
Stf – 350 [daN] = 3500 [N], - The maximum tension that the strap tensioner is capable of generating when operated by hand,
Lc – [2500 daN] = 25000 [N], - A parameter of the strap, this is the maximum force that the strap is capable of holding, Lashing capacity,
m – 5000 [kg] – the mass of a single package,
μ – The friction coefficient between the package and the floor.
Selected acceleration coefficients for road transport:
c_x – 0,8 forwards,
c_x – 0,5 backwards,
c_y – 0,5 sideways,
c_z – 1,0 vertically.
Selected acceleration coefficients for water transport (category A sea area):
c_x – 0,3 forwards and backwards,
c_y – 0,5 sideways,
c_z – 0,5 vertically for longitudal movement,
c_z – 1,0 vertically for lateral movement,
The vertical angle of the lashings bounding the load – 89º,
f_s – Safety factor 1,25 longitudally to the direction in which the trailer is moving,
f_s – Safety factor 1,1 horizontally to the direction in which the trailer is moving.
The described load was transported only by the means of road and water transport (category A sea area), therefore the calculations are made only for this example.

3. COMPARISON OF CARGO SECURING METHODS AND RESULTS

In order to calculate the forces, which may appear during the transport, we should start by the inertia forces minus the friction forces. The following formula was used:

$$F_b = \left(c_{x,y} - \mu \times c_z\right) \times m \times g \tag{2}$$

The results obtained have been presented in table 3, as a set of forces which have to be eliminated by the use of lashing. The values take into account are the maximum values of the force coefficients that could affect the load during transport using each means of transport according to CEN - EN 12195-1:2009.

Table 3
Juxtaposition of inertia forces

The force of inertia	Road transport μ = 0,55	Road transport μ = 0,3	Water transport μ = 0,55	Water transport μ = 0,3
Shifting forwards	1225,831	2451,663	122,583	735,499
Shifting backwards	-245,166	980,665	122,583	735,499
Shifting sideways	-245,166	980,665	-245,166	980,665
Tilting forwards	1835,549	1835,549	50,571	50,571
Tilting backwards	-674,277	-674,277	50,571	50,571
Tilting sideways	-404,971	-404,971	-404,971	-404,971

Source: own study

Negative values mean that the friction force value is greater than potential inertia force and it does not require any additional protection against shifting.

3.1. First method – bounding the load from the top

The first considered method, will be the simplest bounding the load from the top with lashings. The number of lashings, which is required to secure the load, arranged due to the correct weight distribution in the middle of the trailer and secured as on the following figure:

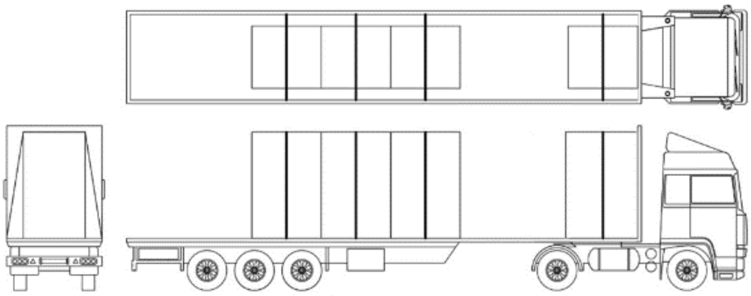

Fig. 1. The arrangement and the layout of the tanks with the lashings bound from the top. Source: own study

Calculating the amounts of the required lashings result from the following norm: : EN 12195-1:2009. The formula describing the tension needed to hold the load in place is:

$$F_T \geq \frac{(c_{x,y} - \mu \times c_z) \times m \times g}{2n \times \mu \times sin\alpha} \times f_s \tag{3}$$

Whereas the amount of lashings needed to hold the load in place is calculated by the formula:

$$n \geq \frac{(c_{x,y} - \mu \times c_z) \times m \times g}{2\mu \times sin\alpha \times F_{T1}} \times f_s \tag{4}$$

Where:

f_s – safety factor,

n – number of lashings,

F_T – the force needed to hold the load in place,

F_{T1} – the nominal force of the ratchet taken from the label,

$sin\alpha$ – the vertical angle created between the lashing and the trailers floor.

3.2. Second method – spring lashing with loop

Another type of securing the load technique, which could be used in this case is the so called spring lashing. This is a securing method which utilises not only the increase of the friction between the load and the floor of the trailer, but also the real blocking abilities of the straps, which is described by the *Lc* parameter of the lashing, as is calculated in the following formula:

$$m \times g \times c_x - m \times g \times c_z \times f_\mu \times \mu - F_R\left(\sum_{i=1}^{q} f_\mu \times \mu \times sin\alpha + \sum_{i=1}^{q} cos\alpha \times cos\beta_{x,y}\right) = 0 \tag{5}$$

In the case when two symmetrical lashings are used, the formula can be simplified to the below form:

$$LC \geq \frac{(c_{x,y} - \mu \times f_\mu \times c_z) \times m \times g}{2 \times (cos\alpha \times cos\beta_{x,y} + \mu \times f_\mu \times sin\alpha)} \tag{6}$$

The specificity of the spring lashing method is presented on figure 2.

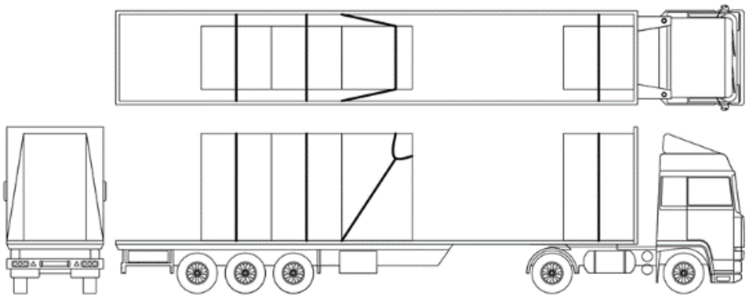

Fig. 2. The arrangement of cargo with the spring lashing for the spread apart tanks.
Source: own study

3.3. Third method – spring lashing with the use of a pallet

The last method which is worthwhile looking at, is another way of the spring lashing method, based on blocking the load using a pallet, placed vertically, against to the cargo and braced to the floor with diagonal lashing. This lashing type doesn't apply any pressure directly to the cargo at rest, but starts to resist the moment the load starts to press against the pallet, acting as a blocking device. The appropriate height of the pallet also prevents the cargo from tipping over. The value of the force which this kind of lashing can resist is equal to:

$$BC = LC \times 2 \times cos\alpha \times cos\beta \quad (7)$$

The following figure shows the layout of the lashings on the load for the considered method.

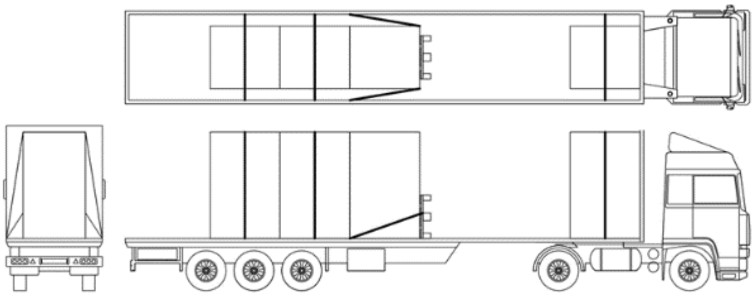

Fig. 3. The arrangement of the spread apart tanks and the layout of the straps using pallet.
Source: own study

Blocking the cargo by using a pallet is much more efficient than the earlier described method of spring lashes. The same strap is fixed to the floor on both sides of the trailer, which means that it doesn't function as a direct lashing which uses the LC parameter, but as a half-loop, which means that the LC parameter can be considered as double in value.

3.4. Results of research

The following table is a summary and juxtaposition of the calculations carried out earlier. Included in it are the amounts of lashings needed to secure the whole cargo, and for the arrangement of the goods as seen on the figures above. The first tank is placed at the front wall of a trailer, while the other three tanks are four metres away from it. The table collates three different ways of securing the load, and each of these methods is calculated upon with two possible friction coefficients beard in mind, in each of the considered directions of forces.

Table 4
Juxtaposition of the required amount of lashing devices.

	Over top lashing		**Spring lashing (loop)**		**Spring lashing (pallet)**	
For μ	μ=0,55	μ=0,3	μ=0,55	μ=0,3	μ=0,55	μ=0,3
Shifting forwards	14	45	blockade + 2	blockade + 23	blockade + 2	blockade + 16
Shifting backwards	0	24	0	18	0	18
Shifting sideways	0	24	0	18	0	18
Tipping forwards	6	6	blockade	blockade	blockade	blockade
Tipping backwards	1	1	1	1	1	1
Tipping sideways	0	0	0	0	0	0
Shifting forwards	14	45+6=51	blockade +2, total of 4 + loop	blockade +23, total of 25 + loop	blockade +2, total of 3 + pallet	blockade +18, total of 19 + pallet

Source: own study

As it appears from the table above, the correct choice of the securing method has a very significant meaning for the safety of the transport, as well as for the practicality of the solution itself. In an extreme case, we could need even 51 straps to secure four tanks, what in real life situation is almost impossible and would take very long time to apply the spansets. It is also important to notice that a standard trailer is equipped with approx. 16 to 18 spansets on board. A better method, that can be taken from table above, would be to use any of the two remaining method. However, the friction coefficient has to be always taken into account. In conclusion, when using the correct method and an accordingly high friction coefficient in order to secure the load, it would be enough to utilise only three straps and one pallet only.

4. CONCLUSION

As can be seen from the above examples and the results of the related calculations, it can be observed that a strictly intuitional approach can be very wrong. The example of the described tanks is not one of the most complicated cargo type which we can encounter, nevertheless the calculations show that a reckless approach, may bring many problems along with it. Especially cargo units that are not placed directly against front wall of the trailer are a very real threat, if they are secured intuitionally solely with the over top lashing, which is a very ineffective method, as can be seen from the previous juxtapositions. The table which concludes all the results draws a picture of how important many smaller details are, details, which can seem to be insignificant or even not taken into account during the loading itself.

Placing the tank directly on the floor of the trailer or on wooden spacers comes to mind at this point. On first thought, spacers seem to be an obvious element, even if it is only in order to correct any possible inequalities of the tanks Surface, to avoid the tank rocking in any way, but in the end, they turn out to have a very big influence on the possibility of the tank shifting in any way. As wooden spacer decrease friction factor to 0,3 only when concrete against trailers floor coefficient is 0,55, what can be observed in juxtaposition above makes huge difference in final calculation.

In a similar way, any dirt, water or especially ice can change the friction coefficient, which can lead to a dangerous situation. Currently, in practice, the vehicle bodies themselves guarantee a significant durability of the side and back walls, which simplifies the securing of the load, minimizes the amount of required securing elements, and shortens the time needed to secure the load itself. It is important to bear in mind that knowledge and experience also are very important factors, because even the most modern and most durable vehicle bodies and securing elements have their endurance limits, which can be easily exceeded, if used incorrectly.

REFERENCES

Alonsoa, M., Mántarasb, D.A., Luquec, P., 2018. *Methodology for determining real time safety margin in a road vehicle*, Transportation Research Procedia 33, 331–338, https://doi.org/10.1016/j.trpro.2018.10.110.

Antonowicz, M., Majewski, J., 2014. *O bezpieczeństwie w transporcie lądowym – zarys problematyki*, Logistyka, 2, 5109-5199.

Farid, A., Abdel-Aty, M., Lee, J., 2019, *Comparative analysis of multiple techniques for developing and transferring safety performance functions*, Accident Analysis and Prevention,122, 85–98, doi.org/10.1016/j.aap.2018.09.024

Goel, A., 2018. *Legal aspects in road transport optimization in Europe,* Transportation Research Part E: Logistics and Transportation Review, 114, 144–162, https://doi.org/10.1016/j.tre.2018.02.011.

Ingaldi, M., Klimecka-Tatar, D., 2015. *Environmental management systems*, Quality. Production. Improvement, No. 2(3), 12-23, DOI:10.30657/qpi.2015.03.02

Madej, B., Madej, R., Kurcz, J., 2017. *Zasady załadunku pojazdów i mocowania ładunków*. Akademia Transportu i Przedsiębiorczości, Warszawa.

Martins Gomes, M., Pirdavani, A., Brijs, T., Souza Pitombo, C., 2019. *Assessing the impacts of enriched information on crash prediction performance*, Accident Analysis and Prevention, 122, 162–171, doi.org/10.1016/j.aap.2018.10.004

McIlroy, R.C., Plant, K.A., Hoque, M.S., Jianping, W., Kokwaro, G.O., Vũ, N.H., Stanton, N.A., 2019. *Who is responsible for global road safety? A cross-cultural comparison of Actor Maps*, Accident Analysis & Prevention, 122, 8-18, https://doi.org/10.1016/j.aap.2018.09.011.

Nævestad, T-O., Hesjevoll, I.S., Phillips, R.O., 2018. *How can we improve safety culture in transport organizations? A review of interventions, effects and influencing factors.* Transportation Research Part F, 54, 28–46, doi.org/10.1016/j.trf.2018.01.002.

Santos, G., 2017. *Road transport and* CO^2 *emissions: What are the challenges?,* Transport Policy, 59, 71–74, https://doi.org/10.1016/j.tranpol.2017.06.007

Stojanová, H., Blašková, V., 2018. *Cost benefit study of a safety campaign's impact on road safety*, Accident Analysis and Prevention, 117, 205–215, https://doi.org/10.1016/j.aap.2018.04.012.

Szymanek, A., 2010. *Zasada "głębokiej obrony" a zarządzanie bezpieczeństwem transportu,* Logistyka, 2, 901-909.

Tyler, N., 2017. *Safety accessibility and sustainability: The importance of micro-scale outcomes to an equitable design of transport systems*, IATSS Research, 41, Issue 2, 57-65, doi.org/10.1016/j.iatssr.2017.06.002.

Vaiana, R., Iuele, T., Astarita, V., Festa D.C., Tassitani, A., Rogano, D., Zaffino, C., 2014. *Road safety performance assessment: a new road network Risk Index for info mobility*, Procedia - Social and Behavioral Sciences, 111, 624 – 633, DOI: 10.1016/j.sbspro.2014.01.096.

Utriainen, R., Pöllänen, M., Liimatainen, H., 2018. *Road safety comparisons with international data on seriously injured*, Transport Policy, 66, 138–145, https://doi.org/10.1016/j.tranpol.2018.02.012.

Wegman, F., 2017. *The future of road safety: A worldwide perspective,* IATSS Research, 40, Issue 2, 66-71, https://doi.org/10.1016/j.iatssr.2016.05.003.