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ESSENTIAL TECHNIQUES FOR FASTENING LOADS IN ROAD TRANSPORT

Summary. During the transportation of goods, damage and destruction of the transported cargo constitute a very large part of the damage. The most common direct cause of damage is an improper arrangement and securing of the transported load. An improperly secured load may pose a threat to the transporters and bystanders. Incorrectly secured loads can fall from the vehicle, obstruct movement, and cause injury or death. In addition, improperly secured loads can cause injury or death in heavy braking or a collision. The way the load is distributed and secured on the vehicle can negatively affect driving behaviour, making it difficult to control the vehicle. This article presents the conditions related to the transport of loads in road transport, describes both the forces that act on the load during the journey of a vehicle and the most important techniques for securing loads in road transport.

Keywords: transport, load, transport safety, load securing techniques, forces acting on load

1. INTRODUCTION

The organisation of cargo transport using road transport requires considering various transport technologies [2, 4, 5]. Choosing the right type of cargo transport is a complex process related to the appropriate organisation of cargo transport [6, 8].

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In the process of transport, the load and its components should be secured against slipping, overturning, rolling and shifting due to vibrations in any direction by, for example, locking, restraint or friction. This protection is intended to protect people involved in loading works, vehicle drivers, other road users, drivers, pedestrians, cyclists, as well as the load and the vehicle itself. Transported loads should be positioned in the vehicle in such a way that they do not injure people, cause vehicle instability during transport, and do not change their position or move in the vehicle or fall out of the vehicle.

Guidelines for the safe securing of loads are based on the laws of physics related to friction, dynamics and strength of materials. However, the mere application of these rights may prove very difficult in practice. Solutions for securing loads, defining the forces acting on the load and the strength of load-bearing structures, requirements for fastening and accessories are included in the following International Organization for Standardization (ISO) and European standards (EN):

- EN 12195-1 - calculation of clamping forces,
- ISO 1496, ISO 1161 - ISO - in the field of containers,
- EN 12195-2 - in the field of cargo securing belts,
- EN 12195-4 - in the field of steel fastening ropes,
- EN 12195-3 - in the field of lashing chains,
- EN 12640 - for fixing points,
- EN 12642 - in the field of cargo securing on-road vehicles, construction of vehicle boxes for the transport of goods,
- EN 12641-1 - for swap bodies for vehicles and vehicles for the carriage of goods (Part I concerning the minimum sheet metal requirements),
- EN 12641-2 - for swap bodies and vehicles for their carriage (Part II regarding curtain sheets),
- EN 283 - for testing swap bodies,
- EN 284 - concerning the dimensions and general requirements of class C swap bodies,
- ISO 27955 - in the scope of requirements and tests for cargo securing in passenger cars and multipurpose vehicles,
- ISO 27956 - in the scope of requirements and tests for cargo securing in vans.

The international guidelines for cargo securing in road transport are based on the European standard EN 12195-1: 2010 and are not legally binding. However, they provide many necessary frameworks and practical information, instructions and tips to enable participants of the transport chain to achieve conditions of safe loading following legal requirements and standard. International carriers should bear in mind that individual countries have specific requirements about cargo securing, which are not covered in these guidelines. It is therefore always necessary to inquire about the specific requirements in force with the competent authorities of the country concerned. In the case of transport of dangerous goods, international legal requirements are laid down in the ADR agreement. According to ADR, the securing of loads is considered sufficient if it complies with the European standard EN 12195-1: 2010. Improper placement or fastening of the load leads to road accidents, therefore, the load should be secured in such a way that it does not endanger the safety of road traffic, human health and life, property and the environment.

The main recommendations regarding the method of securing loads in road transport are included in the Polish Regulation of the Minister of Infrastructure of 25 January 2018 on the method of cargo transport [7] and they state that:

- the cargo space should be kept clean,

- the cargo should be placed on the floor of the cargo area of the vehicle in a way that ensures its stability,
- the centre of gravity of the load should be as low as possible and closest to the longitudinal axis of the vehicle,
- cargo placed on the floor of the cargo area of a vehicle of categories N2, N3, O3 and O4 should be secured in such a way as to prevent its tilting, displacement or overturning and in such a way as to balance the forces resulting from acceleration or braking: in the direction of travel: 80% of the load weight; laterally: 50% of the load weight; in the opposite direction of travel: 50% of the load weight,
- the load is secured using at least one of the following methods: locking, blocking (local or total), lashing with straight lashings, top-over lashing,
- the distribution and securing of cargo should be checked during each loading, partial unloading or reloading, and after sudden braking or another event that may negatively affect the securing of the cargo,
- the arrangement and securing of cargo should be checked: during each loading, partial unloading or reloading, as well as after sudden braking or any other event that could negatively affect the securing,
- it is allowed to secure the cargo with lashing straps having transverse cuts less than 10% of the cross-section,
- it is allowed to mark elements of cargo securing and securing with minor damages, provided that the marking is legible.

This article presents the conditions related to the transport of loads, describes both the forces that act on the load during the journey of the vehicle and the methods of securing loads in road transport.

2. THE FORCES ACTING ON LOADED VEHICLE

The force of gravity acting on the load is 1.0 G. During road transport, the forces acting on the load can reach up to 80% of this value. The following forces act on the load while driving:

- inertia force (when braking),
- centrifugal force (on the horizontal curve to the right),
- centrifugal force (on a horizontal curve to the left),
- the inertial force (acceleration response).

Each vehicle has a certain permissible total weight. It is not allowed to exceed the specified values for the weight of the load. Penalties for exceeding the load capacity of the vehicle in Polish conditions range from PLN 500 to PLN 5,000. Before starting the transport, the weight of the transported load is determined. In the case of liquids, it should be considered that not every one litre of liquid weighs one kilogram (for example, 1 litre of sulfuric acid in a 96-98% solution weighs about 1.84 kg). The headboard and the rear wall can take up to 40% of the permissible vehicle load, and the sideboard load cannot exceed 30% of the cargo weight. When the vehicle accelerates or moves along a horizontal curve, the forces that can act on the load are approximately half of its weight, and when the vehicle brakes sharply, the forces acting on the load can be as much as 80% of the weight of the load. The friction force slightly prevents the load from shifting during transport (the friction coefficient is 0.3).

The centre of gravity of the transported load also plays an important role during transport. The higher the load centre of gravity, the more likely it is to tip over when subjected to horizontal forces. If the centre of gravity of the load is in the vertical plane close to the edge of the load, the load will tend to tip over towards that edge. For heavy loads, the centre of gravity can be an important factor in positioning and securing the load on the vehicle to ensure proper weight distribution. The higher the centre of gravity of the vehicle-load combination is, the more likely it is to overturn.

3. TECHNIQUES FOR FASTENING LOADS IN ROAD TRANSPORT

Proper cargo securing plays a very important role in the transport of goods. If the load is improperly transported, it may be damaged. It should be added that the person ordering the transport of the shipment to a logistics company or intermediary is responsible for the correct packing of the goods and possibly if required by the size or type of shipment, for placing it on a pallet. The basic methods of securing loads include:

- block mounting,
- locking,
- top-over lashings,
- fastening with straight lashings,
- combinations of the methods mentioned.

Blocking is a type of cargo securing, the elements of which are based on fixed elements and rigid structures of the load box. The load is immobilised directly or indirectly by filling the voids between the load and the fixed elements of the load box, which in practice blocks all horizontal movements of the load. The spaces between the cargo and fixed parts of the cargo box are to be reduced to a minimum, especially those between the cargo and the headboard. If possible, the load should be leaned against the front wall.

Correct securing of cargo with the use of immobilising devices requires tight stowage of the packages by leaning them against the stationary components of the load box, as well as by using stowage materials between packages. If the cargo does not completely fill the spaces between the headboards and the sidewalls and is not stably fastened to the cargo box, the voids must be filled with stowage materials creating wedge forces, ensuring that the cargo is effectively immobilised. These forces must fully correspond to the weight of the load. The most frequently used dunnage materials to fill gaps between the load box and the load include [1]:

- pallets - if the empty space exceeds the height of the euro-pallet (144 mm), to immobilise the load, the empty space can be filled with the pallets placed at the end. If the free space between the side walls on one side is less than the height of the pallet, then the free space can be filled with other material, including boards,
- disposable and reusable airbags. The airbags are filled with compressed air, which is usually taken from the installation of a truck. They are easy to install, and airbag suppliers are required to provide instructions for use and recommendations for the correct pressure and load-bearing capacity. Airbags prevent damage to the cargo, however, it should be remembered that under no circumstances should they be used as a stowage material that rests against the front door or moving surfaces or partition elements,
- a framework strut - use of framework struts is applicable in a situation where there are large voids between the load and the locking elements. These frames must have very strong wooden struts. The spreader frames must be positioned so that the spreaders are at right

- angles to the load to be secured so that the pressure exerted by the load is better able to withstand,
- diagonal and transverse strips - immobilisation in the longitudinal direction through the use of diagonal strips is a good method of direct block fastening. This method of cargo locking is particularly effective in containers, as the diagonal slats can be leaned against the stable corner posts of the container. Diagonal and cross rails can similarly be used as a material to fill empty spaces between loads,
 - threshold and plate fastening - applicable if the layers of the stacked packages differ in height. This lashing fixes the base of the top cargo layer. It can also use materials that increase part of the load, for example, pallets. In case the package is not stable and rigid enough for the sill fixture, the same blocking effect can be obtained by using pallets or boards. Depending on the stiffness of the packages, a locking model with a small or large locking surface can be obtained,
 - wooden slats nailed to the load box - in the load box, which has a strong, good-quality wooden floor, the base of the load can be secured with wooden slats nailed directly to the floor,
 - pointed wedges and wedge bearings - are used to block loads of cylindrical shape. If top-over lashings are not used, the height of the block wedge should be at least $R/3$ (that is, one-third of the cylinder radius). If, on the other hand, these wedges are used with top-over lashings, a wedge of 200 mm in height is sufficient. The wedge angle should be approximately 45° . When wooden wedges are nailed to the platform floor, care should be taken not to reduce their strength,
 - sharp-ended wedges, usually with an angle of about 15° - their main function is primarily to keep the cargo of a round shape in place during unloading and loading. Due to the small angle, the wedge usually automatically locks during pressure and does not move. It should be noted that sharp wedges are not used to secure the load,
 - block wedges with an angle of about 45° - are used to prevent shifting of rows of goods with a round cross-section, they must rest on the load box fastening devices. Also, they must be immobilised against the floor by placing angular strips on the last two rows and tied around them with lashings,
 - wedge bearing - with the use of adjustable fastening cross members, that is, chains or screws, two long wedges are immobilised. The transverse attachment must be positioned so that there is a minimum distance of 20 mm between the platform floor and the roll to prevent lateral movement of the bearing. The height of the wedges should be: minimum $R/3$, that is, exactly $1/3$ of the roll radius, if top-over lashings are not used, or at most 200 mm with top-over lashings,
 - lashings - A lashing is an immobilising element such as a chain, wire rope or lashing strap. It is used to bind cargo elements or to bind the cargo to the loading platform or securing elements. Lashings must be placed so that they are in contact only with the load to be secured and the lashing points,
 - top-over lashing - this is a method of securing the load against sliding or tipping utilising the top over lashing. The lashings are tied around the top of the load. This method of attachment may be used to press the load against the floor platform if there are no sidelocks at the base of the load. It should be remembered that friction does not guarantee 100% immobilisation, because during the transport of the load there are vibrations and shocks which cause the load to move, therefore, lashing straps or chains should always be used even when the friction is high,

- loop lashing - it is used to wrap the load with a loop and attach it to the hook on one side of the body. This prevents the load from shifting to the opposite side of the load platform. These lashings are installed in opposite and even pairs, which allows for even distribution of forces. The use of lashings in pairs prevents the load from tipping over, while the use of two pairs of lashings prevents the load from twisting out of the longitudinal plane. The ability of the loop lashings to immobilize the load depends, among other things, on the strength of the lashing points,
- lashing with straight lashings - if the load is equipped with special lashing hooks with a strength corresponding to the lashing strength, it is possible to directly attach the load to the transport platform,
- chain lashings - two factors determine the strength of the chain: the quality of the material from which it is made and the thickness of the links. The chain used should be properly selected for the transported load. Reinforcements or bevels can be used on sharp edges and corners. This prevents damage to the chains. Chain lashings should not be used when tied in a knot or connected by bolts. The edges of the cargo, as well as the lashings, must be protected against damage and abrasion with protective covers. If the lashings show signs of damage, they should be repaired at the manufacturer's or replaced with new ones. The below-mentioned types of damage qualify the defective elements to be replaced: for chains: surface cracks, elongation by more than 3%, wear exceeding 10% of the nominal diameter; for connecting elements and tensioners: deformation, cracks, wear and corrosion. It is advisable to check all links before using chains. They can be used only with the use of appropriate pullers and tensioners with a safe working load as indicated by the manufacturer,
- non-slip mat made of rubber granules is sometimes used as an additional element to prevent the load from moving on the loading platform. The mat is placed under the load, which increases its friction by pressing the weight of the load. A good quality anti-slip mat can increase the safety of the cargo by 60%, which together with the use of straps or chains, ensures high safety during road transport. It should be observed that the mere use of mats does not entitle the use of belts. The use of the mat is simple and quick, and it effectively increases the safety of the transported cargo.

In turn, the irregularities in the securing of loads can be classified into one of the following groups [3]:

- minor irregularity: defects of minor importance occur when the load has been properly secured, but unsafety indications may appear,
- serious deficiency: a serious deficiency exists when the load is not sufficiently secured and the load or parts of it can shift significantly or tilt,
- dangerous irregularity: a dangerous deficiency occurs when road safety is directly jeopardized by the risk of losing the load or parts of it or by a hazard directly derived from the load, or of immediate danger to persons.

4. CONCLUSIONS

The transport activity in the field of road transport is associated with several that must not be neglected to ensure high quality and safety of services provided to customers. Therefore, securing the load during transport plays a very important role. A vehicle is prepared for transport when the load is correctly placed on the floor of the vehicle's load box and the load in

the vehicle is properly secured. The first condition determines the axle load of the vehicle, and the second condition is related to the safety of transport and protection against human losses.

The issues related to the securing of loads presented in this article indicate the existence of many factors that may have negative impacts on the safety of transport. Securing the load is required regardless of the weight of the load. The load must be arranged and secured in such a way that even when braking sharply or passing an obstacle, its position will not shift. Each load will move if the forces exerted by the load as a result of vehicle movement exceed the resistance forces exerted by the environment. Usually, in Polish conditions, load-securing techniques are used to secure loads during transport, as described in this article.

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