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Load restraint with allsafe products. Part two: choosing a load securing system – a systematic analysis

Wykorzystanie metod zabezpieczenia ładunków przedsiębiorstwa allsafe. Część 2: analiza systemowa doboru systemu zabezpieczenia ładunku w naczepie ciężarowej

Abstract

This is the second part of an article concerning allsafe products (first is available in TT 1/2018, pp. 71–86) – it focuses on the planning role in the supply chain and the mechanisms that need to be taken into account during the process of the road transportation. Furthermore, the paper presents the results of an investigation that relates to the proper functioning of the supply chain in the distribution of 12,000 [kg] of strawberries. A weighted average method was used in reference to an analysis of load securing based on the products of three producers with the aim of indicating the safest and most modern way to secure the load in a semi-trailer. Rules of proper load placement and restraint inside the semi-trailer are also addressed, together with a loading plan associated with the analysis of the technical parameters of a semi-trailer and load securing systems.

Keywords: Road transport, provisions of law, transport centre, transport operation, load-carrying semi-trailer, management, logistic system, cargo security systems

Streszczenie

W drugiej części prezentowanego opracowania (pierwsza dostępna jest w numerze TT 1/2018, s. 71–86) zwrócono uwagę na rolę prawidłowego przebiegu planistycznego łańcucha dostaw analizowanego ładunku w funkcjonowaniu nowoczesnego transportu drogowego. Przedstawiono mechanizmy, jakie muszą być uwzględnione przy organizacji takiego specjalnego przewozu towaru. Zaprezentowano efekty związane z prawidłowym przebiegiem łańcucha dostaw przewozu 12 000 [kg] truskawek. Zastosowano metodę wagową (średniej ważonej), analizując systemy zabezpieczenia ładunków trzech producentów i określając najbezpieczniejszy i najnowocześniejszy sposób zabezpieczenia ładunku w nowoczesnej naczepie ciężarowej dla analizowanego ładunku. Opisano również zasady prawidłowego umieszczenia i zabezpieczenia ładunku na części przewozowej (towarowej) na naczepie drogowej oraz kompleksowy plan załadunku związany z analizą parametrów technicznych dla naczepy ciężarowej oraz systemów zabezpieczenia ładunków.

Słowa kluczowe: Transport drogowy, przepisy prawne, środek transportowy, operacja transportowa, naczepa ciężarowa, system logistyczny, system zabezpieczenia ładunków

1. Introduction

In Poland, the food product market is undergoing constant growth – its worth is currently estimated at PLN 240 billion and it constitutes the largest segment of retail trade. Food transportation has its own rules that apply both to fresh products (including those that require temperature-controlled conditions). It can be said that the organoleptic and physical-chemical qualities of transported products are mainly influenced by the choices of transport packaging made by producers and distributors. Box pallets, plastic containers, thermal trolleys and insulation covers are just some of the packaging options. In order to make the process of road transportation safe, the provision of proper load restraint is significant as properly secured cargo assures not only the stability of the vehicle but also the safety of the driver and other road users. According to statistics, almost 25 [%] of accidents involving trucks in the European Union, result from the improper securing of loads [10]. The responsibility for transport safety rests with the consignor, people preparing the transport, the forwarder and the driver; however, the responsibility of ensuring that the load is secure rests with the driver. The cargo needs to be transported in such a way that does not endanger other road users or the cargo itself. Thus, it is important to use certified, reliable and tested securing systems that guarantee load safety. As road cargo transport constitutes the core of European transport, it is vital to make it no only effective, but also safe. During shipment, objects need to be fundamentally safe and secure – they should not be able to move, tilt, roll in any direction, fall off the vehicle or make the vehicle tip over as a result of jolts or vibrations. Proper load restraint increases the safety of operatives engaged in loading activities, drivers and other road users, such as pedestrians, and also the safety of the vehicle and the cargo. The load needs to be positioned in such a way that prevents human injury or disturbing the stability of the vehicle during transit. The aim of this article is to identify the safest way of transporting 12,000 [kg] of strawberries in the semi-trailers which were selected in the first part of the paper. The results of the analysis of load restraint systems were based on technical data from the three different semi-trailers.

2. Method and materials

This article touches upon the overall problem of the appropriate selection of a vehicle that meets the required technical, constructional and safety standards, complies with the consignor's requirements and is suitable for the given type of load. A comparative method was chosen in order to select the best securing system for the transportation of 12,000 [kg] of strawberries. This method may help the road carrier to select a load securing system that will ensure the safe and successful completion of the task, complying with legal regulations and the needs of the client, at the lowest possible cost. The research tool chosen for this purpose was the weighted average method. The aim of this paper is to select an appropriate method of load restraint, which in this case would be 12,000 [kg] of strawberries with respect to the technical parameters of a semi-trailer, in compliance with the relevant legal regulations.

The first step of proper selection is to determine the intrinsic requirements to be met in transport order, and define the importance of the requirement. The next step is to specify the technical features of the primary and additional parameters for the given vehicle in relation to the previously set requirements. Then, load restraint methods of three restraint manufacturers were compared in the analysed transportation task.

The following parameters were chosen as criteria [9]:

- compliance with legal requirements (homologation) and the possibility of using it in the previously selected semi-trailer,
- meeting requirements concerning the chosen load,
- securing load against damage or theft,
- vehicle's assessment for active and passive safety,
- operational efficiency of vehicle,
- supervision of load securing system.

Levels of relevance (weight) are defined using a scale from 0–10 [8]:

The most important factors were allocated grade (10) and the least important factors, grade (1).

- The first part of the table (Sections I–V) defines the requirements demanded in relation to the vehicle.
- Section IV adopted a degree of relevance according to the scale:
  0 – unimportant
  2 – less important
  4 – advisable
  6 – important
  8 – very important
  10 – necessary
- In the case of a lack of certainty regarding the value of a particular criterion, an intermediate value is adopted (e.g. 3, 5 , etc.).
- The comparative analysis of figures and requirements (with data included in information materials on vehicles) results in the choice of an appropriate type of a vehicle.

The evaluation scale for the standard deviation of each parameter is between 0 and 1 where:

- Parameters of the vehicles initially chosen are written in the second part of the table in Section VI.
- Further, in Section VII standard deviation is determined where:
  0 – significant divergence
  0.3 – divergence
  0.5 – average deviation
  0.7 – minor deviation
  1 – in accordance with the requirements

Weights are multiplied by standard deviation.

The obtained *results are* written in Section VIII and points in each column are added up. The following vehicles are given sections IX, X, XI.

- The highest obtained sum of points is the basis for choosing the most appropriate means of transport with regard to meeting the previously adopted requirements.

A summary table presents examined technical features of vehicles (scale 1 to 10, See Table 1). The more a parameter matches our expectations, the higher rating it gets. The points are then multiplied by weights and the results are divided by the sum of all weights. The next table (see Table 2) contains technical and operating features of the evaluated vehicles (1 to 10 scale) defining how a particular transport feature deals with the comparative factor (e.g. speed and maximum acceleration, driving force depending on engine speed). Again, the more a parameter matches our expectations, the higher rating is given. The points are then multiplied by weights and the results are divided by the sum of all weights. In terms of technical requirements, the following parameters were adopted [8]:

- external parameter characteristics in semi-trailers,
- load securing systems and methods,
- loading-unloading systems in vehicles.

Final selection of a vehicle (semi-trailer) was carried out with the use of weighted average – comparative method, which is average value of technical parameters with weights assigned in such a way, that elements with higher value, have greater impact on the average The type of load and conditions set forth by the consignor are the main criteria that are taken into account. If all weights are the same (all elements are of equal relevance), the weighted average equals the arithmetic average [8]:

$$Zr\ \text{weighted} = \frac{\sum_{i=1}^{n} \text{value}_i \cdot \text{weight}_i}{\sum_{i=1}^{n} \text{weight}_i}$$

Priority – $\sum_{i=1}^{n} \text{value}_i \cdot \text{weight}_i$

Conventional standard deviation – $\sum_{i=1}^{n} \text{weight}_i$

The total of points achieved by a vehicle were divided by total of priority points = weighted average

Choices were facilitated by a substantive analysis that covers, inter alia, research methods and systems of load securing in semi-trailers. Legal requirements and temperature-atmospheric conditions are presented in the first part of the article. A comparative table presents load restraint systems from three producers that modern cooling semi-trailers are equipped with (Table 1) [1–3].

Table 1. Comparison of load restraint systems in cooling semi-trailers

Load restraint system/product	Allsafe	Schmitz cargobull	Loadlok
double-deck system with ATD tracks for flush insertion into the side wall	yes – ATD II system	yes	yes
double-deck system with tracks for gluing and screwing	yes – ATD I system	no	yes
loading beam	yes – several types of beams of different sizes and end pieces (depending on track type) and blocking capacity: 1) classic PL 1000[daN] BC 1100 [daN] 2) heavy duty PL 1350 [daN]/BC 1100 [daN] 3) space 1000 PL [daN]/BC 1100 [daN]	yes	yes
loading beam which may be used as blocking beam	yes – each beam has blocking capacity (BC)	no	no
beams can be stowed under the roof	yes	yes	yes
accessories: release rod	yes	no	yes
accessories: place for hidden release rod	yes	no	no
accessories: beam stop for ATD tracks	yes	no	no
robust loading beam for steel container which may be used for blocking	yes – STD beam with load capacity PL 1000 [daN] and blocking capacity BC 1100 [daN]	no	no
combi tracks	yes	yes	yes
blocking beams to combi tracks	yes – KAT beams of different sizes and load capacity from 800 [daN] to 2800 [daN]	yes	yes
cargo bar with rubber foot	yes – SAM Profi with range 600 [mm]	yes	yes
system for securing roll containers	yes – JF system	no	no
system for roll containers working in temperatures below zero	yes – system with elements inserted at any place of a track	no	no
system for roll containers working in temperatures above zero	yes – system with elements sliding in the track	no	no
clamp fitting to secure roll containers	yes – KERL JF with capacity 500 [daN]	no	no
clamp fitting to secure roll containers with different dimension	yes – KERL JF fittings for containers of three diameters – 25 [mm], 35 [mm] and 45 [mm]	no	no
additional fittings for roll containers securing	Yes – end fitting – KERL JF fix and middle fitting – KERL JF slide	no	no
temperature bulkhead	no	no	yes
temporary temperature wall	no	no	yes

2.1. Characteristics of researched objects

The transportation of food products is demanding and requires specific temperature conditions in vehicles that have been adapted for that purpose. Furthermore, the transport process must not have an impact on the quality of the food. The following points are important considerations in the transportation of food products [7]:

1) Compliance with temperature control requirements for foodstuffs is vital during the distribution process;
2) The chosen means of transport should ensure preservation of the cold chain;
3) Meeting optimum hygiene and cleanliness standards is essential;
4) Vehicles should be equipped with waterproof sealed and non-slip flooring;
5) Workers who deal with loading and unloading should have valid medical checks and use proper protective clothing;
6) The vehicle should meet generally accepted technical standards and be equipped with load restraint systems;
7) The load area should not have acute angles that are hard to reach or clean;
8) Vehicles used for transport of foods should be properly labelled and authorised to carry out food transportation.

The comparative study was based on the following three modern semi-trailers set up for the transportation of strawberries and equipped with load securing systems that meet with the producer's approval:

1) Wielton O4NS34CT refrigerated semi-trailer;
2) Krone Cool Liner refrigerated semi-trailer with Thermo King O4SLX;
3) Krone COOL LINER – 04THERMO refrigerated semi-trailer.

The aim of the analysis is to determine load securing systems used in presented trailers, and ways of securing that can be implemented during loading/unloading.

2.1.1. Characteristics of Wielton 04NS34CT cooling trailer with Loadlok products

The trailer's superstructure is a self-supporting construction made of glued insulated panels, isolated with non-freon polyurethane foam (without thermal bridges), with outer sheets made of glass-fibre laminate (gelcoat). The internal covering layer sheet is made from steel and has a hard PVC film coating. The thickness of the side walls is 60 [mm], secured with aluminium skirting boards up to a height of 300 [mm] and either insert 'an' here or make the noun 'board' plural, depending upon your intended meaning aluminium board with a width of 250 [mm], at a height of 1200 [mm] from the floor. The front wall thickness is 100 [mm], it is reinforced and equipped with cool air ducts. The self-supporting floor is 100 [mm] thick and enables a forklift truck to go inside easily. The non-slipping floor has drainage channels made of stainless steel. The rear wing door creates a 100 [mm]-thick wall, with a frame made of stainless steel (Fig. 1) [6]. The door is secured with four hinges and two revolving rod locks. The O4NS 34 CT – FRC cooling chamber can house thirty-three standard European pallets. Moreover, Thermo King and Carrier Transicold chillers provide cooling. Optionally, trailers can be equipped with an aluminium floor and

a moveable bulkhead. Up to twenty-two decking beams may be installed in the body. Recessed, or surface anchor rails offer optimum load securing through the complete load length [16].

Further analysis of the means of transport that is used for transport of strawberries will focus on two modern means of transport labelled as FRC, in accordance with ATP (the Agreement on the International Carriage of Perishable Foodstuffs and on the special equipment to be used for such carriage.

F – means of transport – chiller trailer.

R – heavy insulation (*K* coefficient $k = 0.4$ [(W/(m²K)].

C – class C – cooler vehicle equipped with devices maintaining temperatures of +12°C to –20°C inclusive.

Fig. 1. Wielton O4NS34CT refrigerated semi-trailer (FRC)

External features and load securing systems are presented in Table 2 [3, 6].

Table 2. External features and load securing systems of Wielton O4NS34CT refrigerated semi-trailer (FRC) with Loadlok products

External features	Securing systems
LOCKS GASKET EXTENSION LADDER	NON-SLIP FLOOR
RUBBER BUFFERS HANDLES SUPPORT LEGS	LOAD FITTING TRACKS STRIP ON THE SIDE WALLS
HINGES ROLL-STOPS BUMPING BLOCK	VERTICAL WALL MOUNTED RAILS
TEMPERATURE SENSOR VENTILATION FLAP	ADDITIONAL SCUFF RAIL ON THE SIDE WALLS
TEMPERATURE SENSOR REFRIGERATOR AND TEMEPRATURE RECORDER	LONGITUDINAL BEAM
DOUBLE-DECKER LOADING SYSTEM	LOADLOCK SYSTEM MOVABLE FLOOR SECTIONS

The most important load securing systems offered by the producer are [3, 6]:

- double-deck system, and movable floor sections (Fig. 2),
- system of load securing tracks on side walls, vertical and horizontal rods (Fig. 3).

Fig. 2. Double-decker loading system, Loadlock system and movable floor sections

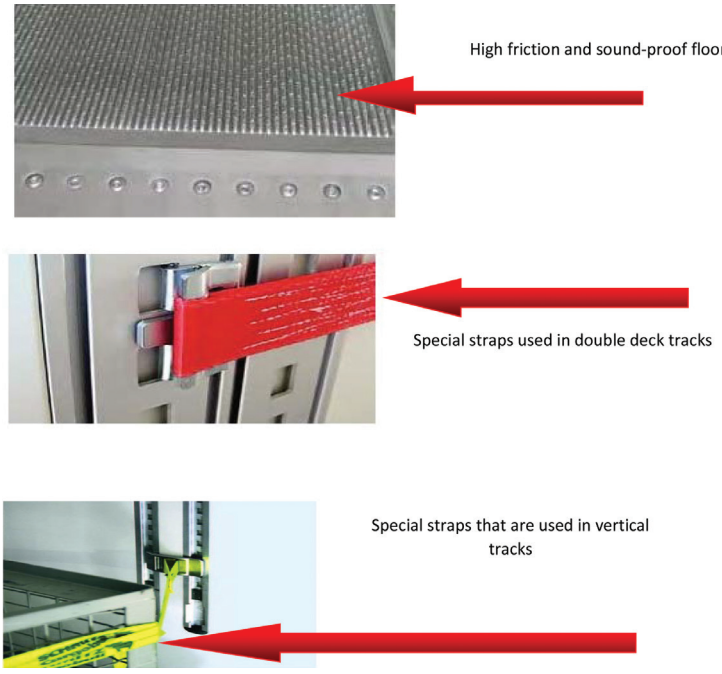


Fig. 3. System of load securing tracks on side walls; vertical and horizontal rods

Non-slip floor with friction coefficient μ – 0.5 (Fig. 4) [3, 6].

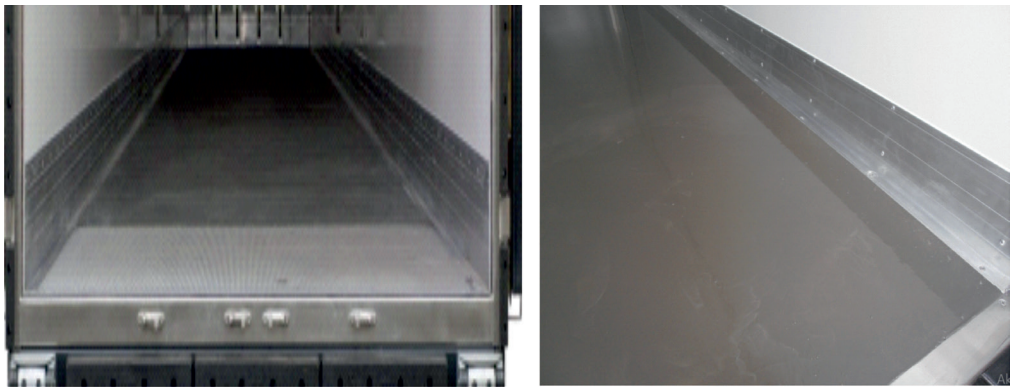


Fig. 4. Non-slip floor

2.1.2. Characteristics of Krone Cool Liner double deck with Thermo King SLX 300 and allsafe loading systems

The Krone Cool Liner has a continuous chassis. Tensile forces are transferred to the chassis – this protects the superstructure during vehicle coupling and uncoupling. The forces involved when docking to the ramp are also absorbed by the chassis. Aluminium profiles ensure good front wall protection and optimal air-flow. The aluminium kick strip is bonded to the side walls and welded to the one-piece, aluminium floor plate in such a way that it is water-tight (Fig. 5) [4]. The side walls are made of GRP panels and the trailer is equipped with ATD tracks for double-deck loading. Furthermore, the trailer has a bolted evaporator guard which is 5 [mm] thick and 68 [mm] high. During the docking manoeuvre, the tail is protected by one horizontal, delta-shape bumper and two impact buffers. The stainless steel rear gantry is suitable for docks and ramps. The door hinges are recessed at the sides to enable optimal door-opening angles.

The German company allsafe GmbH & Co. KG equipped the trailer with two basic systems of load securing, designed for food transport at controlled temperatures [1]:

The double-deck ATD system enables the transport of cargo on two levels, secures delicate loads from damage and enables the transportation of twice the amount of pallets (Fig. 6) [1, 4, 12].

Fig. 5. Krone Cool Liner double deck with Thermo King SLX 300

Fig. 6. ATD double-deck system consists of two elements: loading ATD beam and vertical airline tracks

Table 3. External features and load securing systems of Krone Cool Liner double deck with Thermo King SLX 300 and the allsafe loading systems

External features	Securing systems
Single locks Invisible solid reinforcements Cooling unit	The blocking beam is improved for an increased load capacity
Tracks for telescopic rails and tension straps Two temperature zones Soundproof floor	The blocking beams can be positioned anywhere along the profile
Double-deck system: DOUBLE DECK Adjustable beams HDR Technology increases the resistance of the interior walls to dents	ATD system – ATD loading beams with big loading capacity. Special lashing straps can be used for the double-decker rails
Outer surface – zinc coating Pivoting circulation wall Pallet stoppers	Special lashing straps can also be used in the double-decker rails for additional load securing.
Ferroplast body	Movable floor panels
Insulated ventilation and venting flap	JF system for roll containers

In addition to the elements presented above, there were additional solutions used in the trailer such as special straps and release rods (Figs. 7 & 8) [1, 4].

Fig. 7. ATD system – ATD loading beams with big loading capacity

SAM Profi cargo bars with rubber feet produced by allsafe with additional frames protecting smaller items of cargo.

Fig. 8. Technical solutions (vertical bars) of load protection in refrigerated trailer Krone Cool Liner with ATD double-deck with Thermo King SLX 300

Other features that are worth mentioning are: a pallet stop system, a high friction flooring, connected with a kick strip and rubber-footed cargo bars (SAM Profi by allsafe) that increase the security of transported food products (Fig. 9) [1, 4, 13].

Fig. 9. Vertical and horizontal tracks securing cargo in side walls

Vertical tracks from the double-deck ATD system by allsafe that was previously mentioned. The roof insulating system is another significant securing measure (Fig. 10) [1, 4, 13].

Fig. 10. Insulated roof filled with polyurethane foam, covered with steel sheet (up to 40 mm)

The complex equipment of the presented trailer intended for the carriage of strawberries is shown in (Fig. 11) [1, 4, 11].

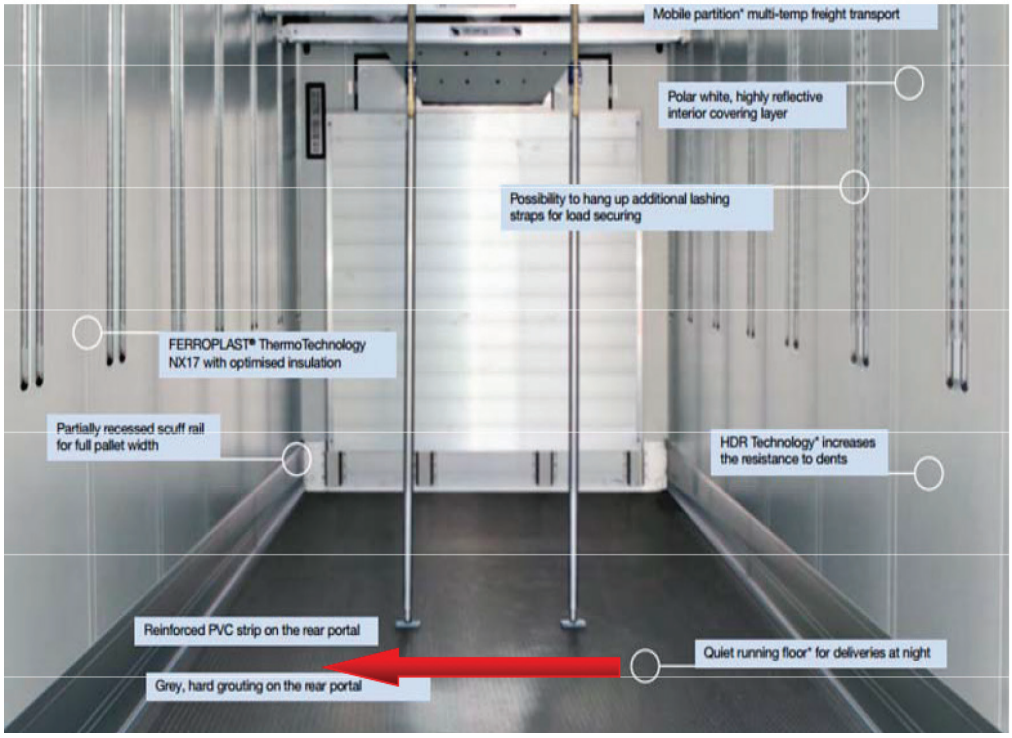


Fig. 11. Complex equipment of a trailer intended for safe food transportation

The JF system consists of the following elements: two airline guide rails installed in the walls and modular fittings KERL JF, KERL slide, KERL fix, which immobilise wheeled containers in a chosen place along the track (Fig. 12) [1, 4].

Fig. 12. JF system

There are two types of modular fittings KERL JF: insert and remove at any position for transport in temperature below zero and non-removable in every position for transport above zero. Another type of fitting is KERL sidle, these are used between cargo units, in cases where there is no need to use the larger KERL JF fitting, and the space between cargo has to be decreased, this type of fitting is advisable (Fig. 13) [1, 4]. The last type of fitting is KERL fix – this is used at the beginning of the track, close to the front wall. It prevents the first pallet unit from moving forward and protects the front wall from damage (Fig. 14) [1, 4].

Fig. 13. KERL JF Modular fitting system

The described trailer is equipped with a tail lift (Fig. 14) [1, 4].

Fig. 14. Tail lift

2.1.3. Characteristics of the Krone 04 COOL LINER – THERMO refrigerated trailer with load securing systems Liner Doppelstock

The circulation wall and the flexible air ducts provide effective air circulation for constant cooling throughout the entire cargo area. The cooling airflow is directed at roof height, it then descends over the freight towards the floor and flows through the pallets, along the side walls and beneath the pallets, back to the bulkhead. Many significant companies that specialise in food transport use Schmitz coolers as the products meet strict HACCP standards. The interior of the trailer has no recesses; moreover, the tracks attached to the walls secure cargo and enable double-deck loading, reducing the possibility of damage and increasing hygiene standards.

The trailer's body is a self-supporting construction made of glued insulated panels isolated with non-freon polyurethane foam (without thermal bridges) with outer sheets made of glass-fibre laminate (gelcoat) (Fig. 15) [5, 9].

Fig. 15. Krone 04 COOL LINER – THERMO semi-trailer Liner Doppelstock

Technical equipment of a trailer and load securing systems are presented in Table 4 [5].

Table 4. Technical equipment of the Krone COOL LINER – THERMO trailer and load securing systems Liner Doppelstock

External features	Securing systems
Additional refrigeration equipment Pallet stoppers	Load securing beams
Air ducts Refrigeration unit	Non-slip floor
Double-deck track Two temperature zones	Additional scuff rails on the side wall.
Guide tracks inserted into side walls compliant with HACCP standards.	Vertical telescopic rods can also be installed as horizontal beams modular fittings compliant with EN 12640
Optional side door	Supporting track
Tail lift Four locks	Longitudinal beam
ROOF	Sandwich type panels covered with steel, temperature sensor pipe, roof lamps, door lighting switch, insulated ventilation and venting flap
FRONT WALL	Strengthened sandwich type panels to improve air circulation, the interior wall is made of a 5 [mm] sheet, the front wall has a cut out for the Carrier and Thermo King units
SIDE WALLS	Steel homogenous sandwich type panels varnished outside, PVC coated inside, aluminium, [300] mm high strip inside, lateral tracks leading to double deck beams 1 600 [mm] high
BACK DOOR	Wing door, set of 3 door hinges V2A, replaceable seal, double locking levers

Figure 16 shows a trailer equipped with fittings that secure the load, compliant with EN 12640, with a loading capacity up to 2 tonnes [5].

Fig. 16. Load securing fitting in the front wall, in accordance with EN 12640

Table 5. Technical parameters and load securing requirements for the examined vehicles

Parameters and basic requirements	**Requirements and technical parameters of refrigerated semi-trailers**										
	Krone COOL LINER – THERMO trailer with load securing systems Liner Doppelstock			**Wielton NS34CT refrigerated semi-trailer with Loadlok products**			**Krone Cool Liner Doppelstock double deck refrigerated semi-trailer and Thermo King SLX 300 with load securing system produced by allsafe**				
Details	Requirements	Value	Requirements and parameters	Standard deviation	Points	Requirements and parameters	Standard deviation	Points	Requirements and parameters	Standard deviation	Points
KERL JF modular fittings	+	10	+	1	0	+	1	0	+	1	10
Tracks and rails on side walls	+	10	+	1	10	+	1	10	+	1	10
Non-slip floor	+	10	+	1	10	+	1	10	+	1	10
ATD II system	+	4	+	1	4	+	1	4	10	0	10
Double deck system	+	6	-	0	0	+	1	6	+	1	6
Load securing beams	+	10	+	1	10	+	1	10	+	1	10
Securing bars possible to install	+	10	+	1	10	-	0	0	+	1	10

Parameters and basic requirements	Requirements and technical parameters of refrigerated semi-trailers										
	Krone COOL LINER – THERMO trailer with load securing systems Liner Doppelstock			Wielton NS34CT refrigerated semi-trailer with Loadlok products			Krone Cool Liner Doppelstock double deck refrigerated semi-trailer and Thermo King SLX 300 with load securing system produced by allsafe				
Vario lock	+	8	-	0	0	-	0	0	+	1	8
Securing bars	+	10	+	1	10	+	1	10	+	1	10
JF System	pneumatic	10	-	0	0	-	0	0	pneumatic	1	10
TOTAL			141			130			**183**		
$\sum_{i=1}^{n} \text{mean}_i$			1.43			1.32			**1.86**		

3. Research results

The results of the research into the technical parameters and load securing requirements for the examined vehicles are presented in Table 5. Adding together all the points assigned to the trailers for each of the assessed criteria produced the following results:

1. Wielton NS34CT refrigerated semi-trailer with Loadlok products – 130 points/1.30.
2. Krone Cool Liner Doppelstock refrigerated semi-trailer and Thermo King SLX 300 with load securing system produced by allsafe – **183/1.86**.
3. Krone COOL LINER – THERMO trailer with load securing systems Liner Doppelstock – 141 points/1.43.

Taking into consideration the technical features and the results achieved through the weighted average method, the Krone Cool Liner double deck refrigerated semi-trailer and Thermo King SLX 300 with load securing systems by allsafe is optimal to perform the transport of strawberries (see Table 5) [4, 5, 6].

For practical reasons, additional empirical research was conducted to shed more light on the proper planning and the carrying out of the presented transport operation. The most advantageous solution for this type of load is the creation of a pallet transport unit. Compliant with the requirements of pallet package, eight layers may be placed on one pallet which makes four packages in each layer. A logistical analysis of load securing during transport operation is presented in (Fig. 17) [11].

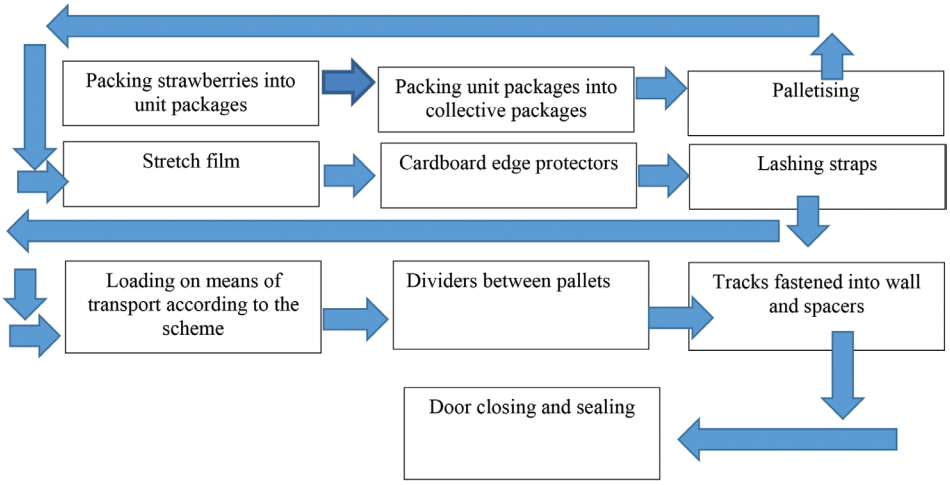
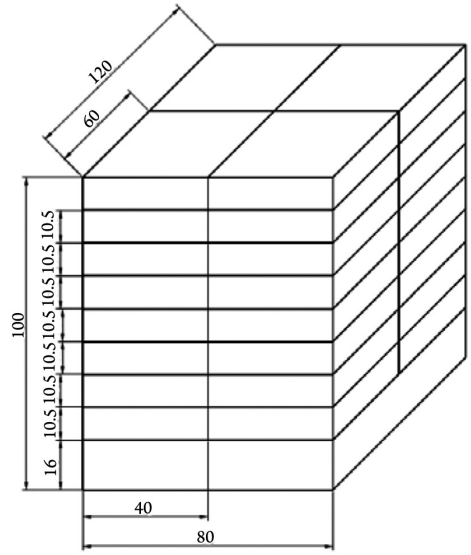


Fig. 17. Technical scheme of load securing during transport operation

Calculation of weight and size of a pallet unit
size:
length: 1200 [mm]
width: 800 [mm]
heigth: 105 [mm] x 8 + 160 [mm] = 1000 [mm]

weigth:
cargo weight: 4 x 5 [kg] x 8 = 160 [kg]
pack weight: 4 x 0.355 [kg] x 8 = 11.36 [kg]
pallet weight: 18 [kg]
pallet unit weight = cargo weight + pack weight + pallet weight = 160 [kg] + 11.36 [kg] + 18 [kg] = 189.36 [kg]

Load unit scheme is presented in (Fig. 18) [11].



(Fig. 18) [11] Calculated load unit scheme – dimensions in [cm]

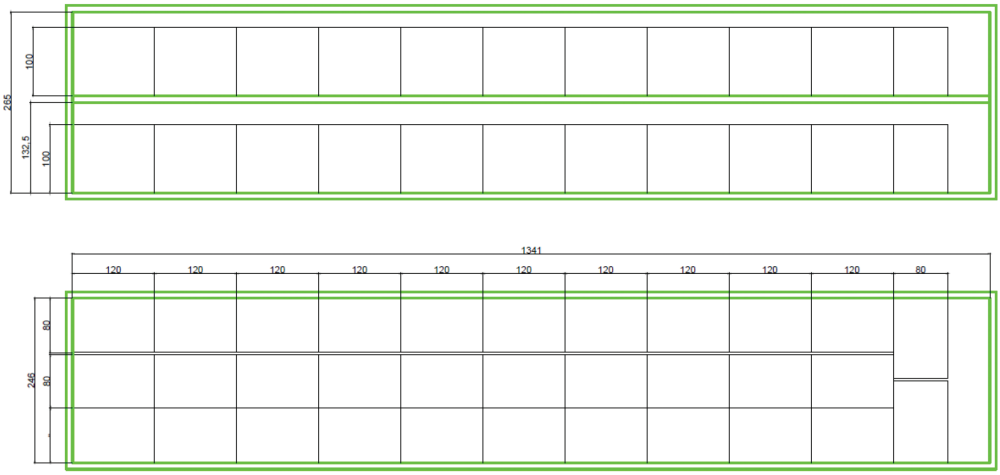


Fig. 19. [11] Example of pallet distribution in a refrigerated semi-trailer with a double-deck loading system

The analysed transport consisted of the carriage of a 12,000 [kg] load – the amount of pallets was calculated on the basis of empirical analysis:

- load weight: 12,000 [kg]
- load unit weight: 189.36 [kg]
- number of load units: 12,000 [kg]/189.36 [kg] = 63.37 [pcs.]

The cargo consists of sixty-four pallet units, and an exemplary way of pallet distribution in a refrigerated semi-trailer is presented in Fig. 19 [11].

$$S_1 = \frac{\left(11 \cdot 189.36\,\text{kg} \cdot 50\,\text{cm}\right) + \left(11 \cdot 189.36\,\text{kg} \cdot 192\,\text{cm}\right)}{11 \cdot 189.36\,\text{kg}} = 121[\text{cm}]$$

$$S_2 = \frac{\left(11 \cdot 189.36\,\text{kg} \cdot 640\,\text{cm}\right) + \left(11 \cdot 189.36\,\text{kg} \cdot 650\,\text{cm}\right)}{22 \cdot 189.36\,\text{kg}} = 640[\text{cm}]$$

$$S_3 = \frac{\left(20 \cdot 189.36\,\text{kg} \cdot 640\,\text{cm}\right) + \left(10 \cdot 189.36\,\text{kg} \cdot 640\,\text{cm}\right) + \left(10 \cdot 189.36\,\text{kg} \cdot 1240\,\text{cm}\right)}{32 \cdot 189,36\,\text{kg}} = 640\,[\text{cm}]$$

$$S_4 = \frac{\left(20 \cdot 189.36\,\text{kg} \cdot 80\,\text{cm}\right) + \left(10 \cdot 189.36\,\text{kg} \cdot 206\,\text{cm}\right) + \left(10 \cdot 189.36\,\text{kg} \cdot 123\,\text{cm}\right)}{32 \cdot 189.36\,\text{kg}} = 122\,[\text{cm}]$$

$S_{(1,2)}(121;640)[\text{cm}]$

$S_{(3,4)}(640;122)[\text{cm}]$

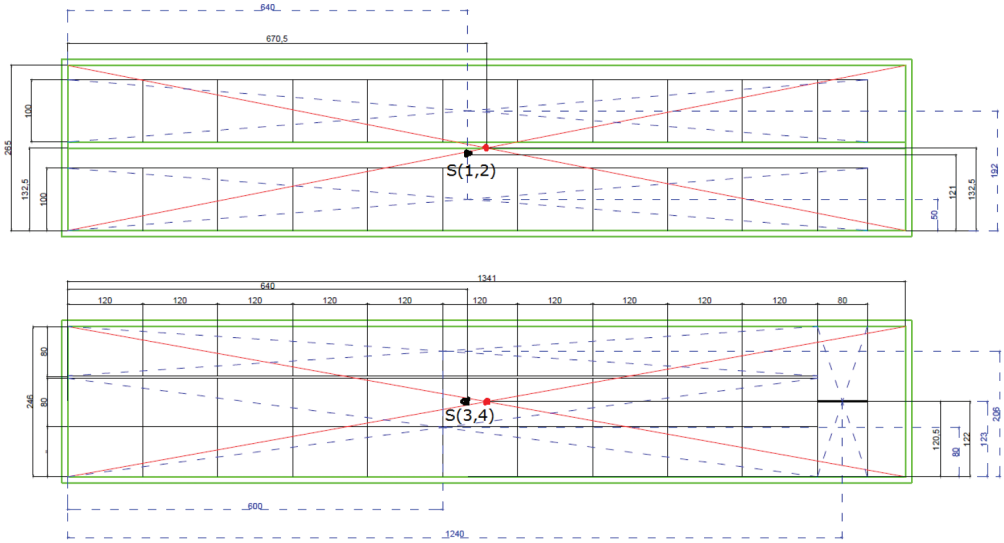


Fig. 20. Determining the centre of gravity in relation to the front wall and floor of the load area

Another significant parameter of a well-planned transport operation is determining the centre of gravity of the vehicle and cargo. The cargo should be placed in such a way that its centre of gravity is as low as possible and as close as possible to the longitudinal axis of the vehicle. This has a significant impact on the stability of the moving vehicle and the safety of the driver, the cargo, and other road users. A procedure for establishing the precise centre of gravity for a load placed in a vehicle is presented in the calculations and picture presented below (Fig. 20) [11].

Determining the centre of gravity enables checking the preliminary permissible maximum axle loads. Determining the axle loads of the trailer was performed with the use of an IT program (Fig. 21) [11]. The total weight of the trailer with the load was 20,000 [kg] (unladen mass 7,960 [kg] + cargo mass 12,000 [kg] = 19,960 [kg]); however, in practice, to use the loading capacity of a vehicle within the maximum permissible laden mass, it is safer to measure axle loads on special scales.

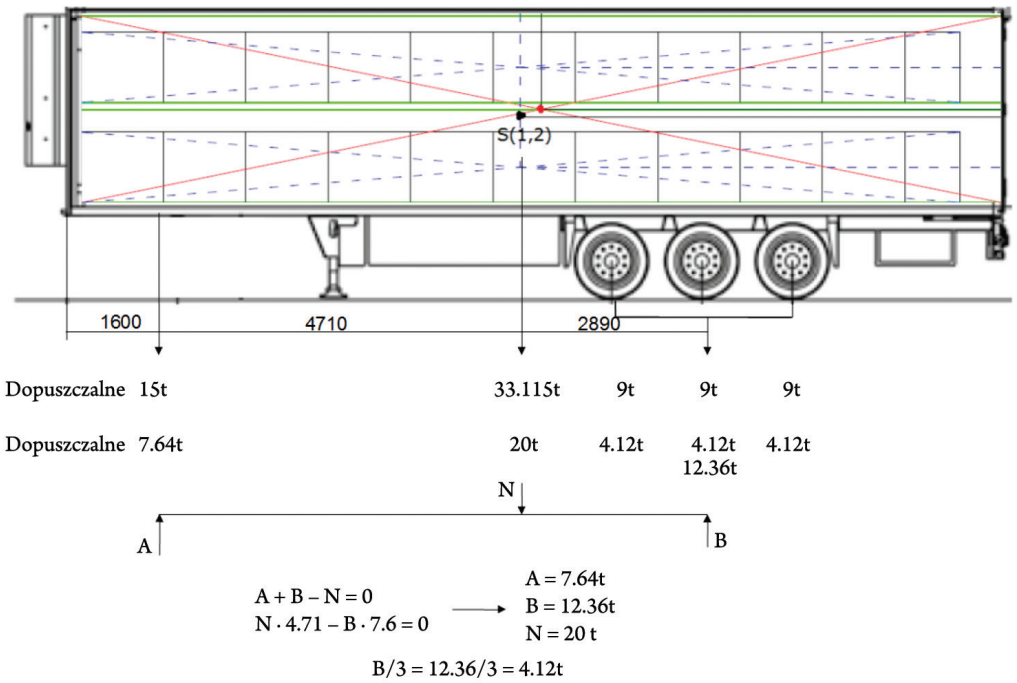


Fig. 21. Axle load calculation with use of determined centre of gravity of the vehicle

In order to select an appropriate method for load securing in a chosen semi-trailer, wall pressure should be calculated as below:
front wall strength:
40% x 12 t = 4.8 t ≤ 5 t
side walls strength:
30% x 12 t = 3.6 t

back wall strength:
25% x 12 t = 3 t ≤ 3.1 t

The producer of the Krone Cool Liner Doppelstock refrigerated semi-trailers with Thermo King SLX 300 allows the following maximum pressure on particular walls (Fig. 23) [4]:

- Front wall: 13.5 t
- Side walls: 10.8 t
- Back wall (door): 8.1 t

Test of the trailer revealed a higher level of strength than the required by the standard EN 12642 (Fig. 22) [4].

To secure the load against careless loading (e.g. leaving empty space that enables the movement of cargo during braking), it is advisable to use a 'pallet stop' system. According to the back wall resistance calculation, the required resistance preventing the load from moving back is three tonnes. It is necessary then to use barrier tracks with a resistance of 2 t (one for each floor): 2 x 2 t ≥ 3 t (requirement fulfilled).

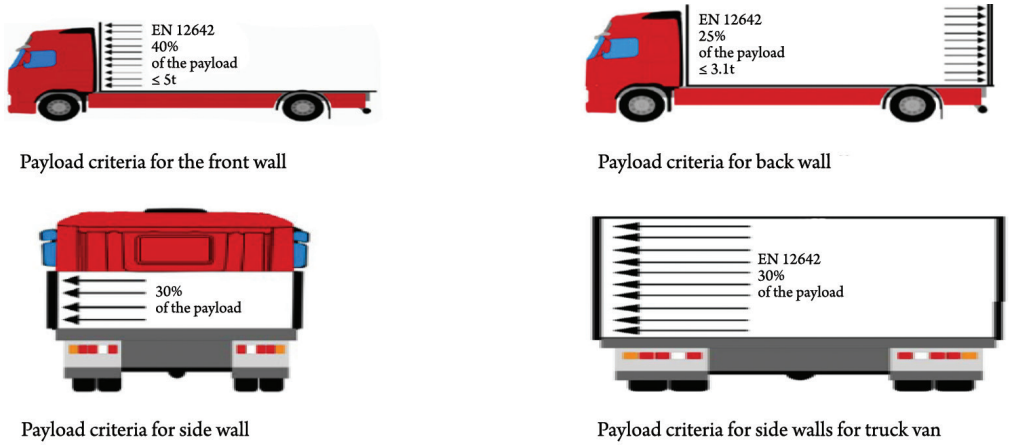


Fig. 22. Payload criteria for walls of box type bodies according to EN12642

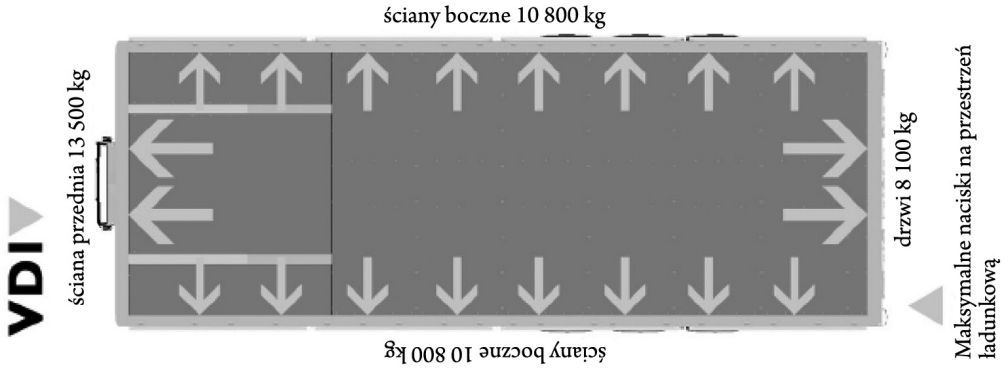


Fig. 23. The strength of side walls in the Krone Cool Liner Doppelstock refrigerated semi-trailer with Thermo King SLX

4. Conclusion

If the load is secured in an improper way, it can not only cause load damage but may also lead to serious economic loss, or tragic road accidents. Achieving technical excellence in the field of load securing has become a goal for many companies who try to outdo each other in new methods, systems and equipment concerned with load securing. The analysis of the technical parameters carried out with the use of the weighted average method and requirements for cargo securing led to the choice of the Krone Cool Liner Doppelstock refrigerated semi-trailer, with Thermo King SLX and allsafe securing systems – this achieved 183 points from the research analysis. The research referred to the technical parameters of a trailer and the requirements that the load securing systems need to meet. The scores achieved by competitive trailers were 141 and 130 points. The key factor that influenced the result most was the usage of modern trailer equipment connected with load securing produced by allsafe. The double deck ATD system by allsafe, allows the loading of sixty-six pallets at a time – the transport task required sixty-four pallets. In the case of the Krone trailer, despite the low rate of loading capacity usage, there would be a need to repeat the transport which would raise the costs. Aside from economic factors, traffic safety parameters also had an impact on the choice of a trailer (EBS with RSP in Schmitz trailer) and an additional 'pallet stop' load securing system that allows either completely avoiding or reducing the required amount of tracks, or reducing the pressure of the load on the front wall that. The analysis of additional parameters influencing safe transport operation revealed that there was a need to use supplementary protection connected with the appearance of free space that may lead to load movement while braking – using a 'pallet stop' system would solve this problem. According to the back wall resistance calculation, the required resistance that would prevent the cargo from moving backwards is three tonnes. It is therefore vital to use two barrier tracks with a resistance of two tonnes (one tonne per floor): $2 \times 2\ t \geq 3\ t$ (requirement fulfilled). It is worth mentioning that the newest directive of the European Parliament and the Council 2014/47/UE of 4 April 2014 on the technical roadside inspection of the roadworthiness of commercial vehicles circulating in the European Union. It was created in order to improve road safety and the environment, the directive establishes minimum requirements for a regime of technical roadside inspections of the roadworthiness of commercial vehicles circulating within the territory of the member states.

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