EXECUTIVE SUMMARY OF THE RESEARCH PROJECTS COMBISEC AND DESTINY

The basic design accelerations for road and intermodal rail transports are currently not the same, which is unfavourable for intermodal traffic. The question has therefore been raised whether cargo securing arrangements designed according to the road principles also can withstand the accelerations that may occur during intermodal rail transports.

The following horizontal static acceleration values, expressed in parts of the gravity acceleration g = 9.81 m/s^2, are valid for the design of securing arrangements for road transports:

- Forward in the driving direction of the vehicle: 0.8 g
- Backward: 0.5 g
- Sideways: 0.5 g

For design purposes these acceleration values are combined with the gravity acceleration 1 g acting downward. It is assumed that the horizontal accelerations do not act simultaneously in the different directions.

As a first step to investigate which accelerations to apply for the design of securing arrangements for combined rail transports, MariTerm AB performed the research project **CombiSec**. This project was aimed at identifying cargo securing methods that are in accordance with valid road regulations and that could provide a sufficient and acceptable level of cargo securing during combined transports by rail. The project included test shunting of 19 intermodal units and inspections of 100 loading units before and after intermodal transport.

As a second step, with combined efforts by UIC, UIRR and MariTerm AB within the **DESTINY** project, dynamic test transports were carried out between eight European terminals. Furthermore, inspections were performed in 131 loading units to determine the current level of cargo securing.

Inspections of cargo in test transports in the CombiSec project

During the CombiSec project, the securing of a wide range of cargoes was documented during test transports of more than 100 loading units. The selection of units for studying as test transports where carried out by two different principles:

1. Multiple loading units with identical cargoes were documented by eight industry representatives in the project, throughout the whole transport chain on selected relations in Europe as shown in the map below. In total, 40 loading units were part of this schedule.

2. 60 random loading units where selected at rail terminals and documented prior to and after the rail haulage on six trains between Malmö and Årsta in Sweden.

Map showing the transport relations covered by test transports in the CombiSec project.

For each unit the cargo type and properties, type and classification of the loading unit as well as the means of cargo securing were documented. The original position of the cargo was marked on the platform floor and any movement was noted upon arrival at the destination. The cargoes in the loading units were at best secured to the road regulations.

In most of the 100 inspected loading units, no signs of significant accelerations in any direction could be detected. However, the cargo had shifted noticeably in the longitudinal direction in all the loading units in one of the trains from Årsta to Malmö, due to shunting at excessive speed.

There is a tendency of wandering for unlashed cargo during intermodal transports by rail due to vibrations. The movement of the cargo occurred randomly.

There were no indications of significant accelerations in the transverse direction in any of the inspected units. The curtain sides of XL trailers have in these test transports proved to be able to safely contain the cargo within the unit without showing any noticeable deflection, even when the cargo was unlashed.

Shunting tests performed within the CombiSec project

Within the CombiSec project, shunting tests were performed in accordance with the UIC Loading Guidelines for combined transports with 19 loading units supplied by the projects industry representatives. The following types of loading units and cargoes were used in the tests:

Type of cargo	Type of CTU
Square-sawn timber packages	Trailer
Paper reels	Container
Paper reels	Trailer
Bags on pallets	Trailer
Octabins	Trailer
Liner reels	Trailer
Mixed cargo	Trailer
Lying concrete elements	Trailer
Standing concrete elements	Trailer
Barrels on pallets	Trailer

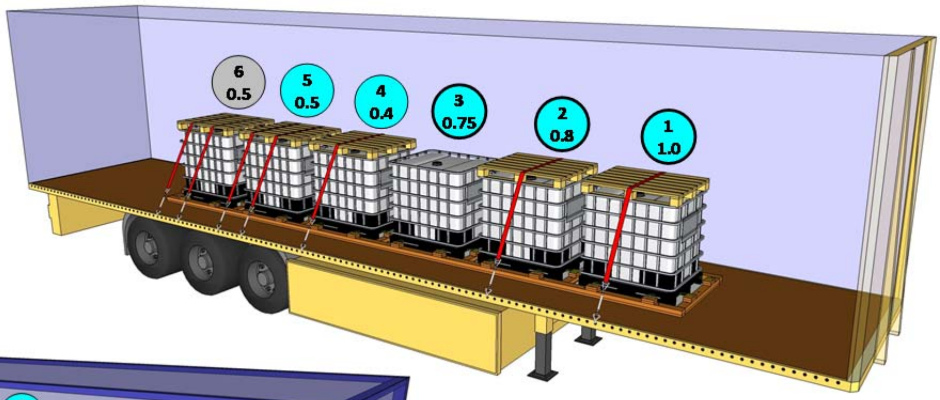
Type of cargo	Type of CTU
Paper pallets	Swap body
Cable drums	Trailer
Single drum vibratory roller	Trailer
Steel pipes	Trailer
Truck cabin	Trailer
Palletised cargo	Trailer
Steel coils	Trailer
Steel sheet metal	Trailer
Paper pulp	Swap body

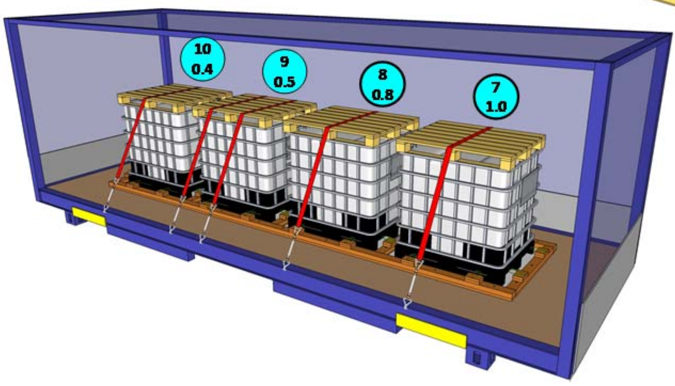
The cargo securing fulfilled the road regulations in 13 of the 19 units only. None of the units were in compliance with the instructions in the UIC Loading Guidelines. Despite this, cargo movements in the longitudinal direction were very limited, and it could be concluded that it is sufficient to secure cargo in loading units for combined road/rail transports according to the road regulations as long as shunting is carried out at speeds of 3-5 km/h.

Dynamic test transports within the DESTINY project

Test transports were performed with identical cargo items secured to withstand different acceleration levels. The cargo items were stowed and secured in a trailer and a swap body respectively. The cargo transport units were sent between different terminals in Europe to cover different rail nets, wagon types and handling equipment.

Water filled IBCs on plastic pallets weighing about 1000 kg were used as test cargoes. For reference, one of the IBCs was however filled with concrete. The IBCs were placed on laminate boards and were bottom blocked by timber frames, although they had the freedom to move 75 mm in any horizontal direction. Friction enhancing rubber and different lashing pre-tensions were used to achieve different limiting accelerations for the IBCs.





Prior to the tests, the friction factor, the lashing angle and the pre-tension in each lashing were carefully measured. The pre-tension was measured and adjusted throughout the tests to maintain the same level of securing. The table below gives the limiting horizontal acceleration for each of the ten IBCs.

Trailer

IBC no	Number of lashings	Weight [kg]	Friction factor μ	Horizontal acceleration [g]	Lashing angle [°]	Pre-tension [kg]	Cargo	Rubber
1	1	1102	0,75	1,0	60	208	Water	yes
2	1	1105	0,75	0,8	60	39	Water	yes
3	0	1089	0,75	0,75	*Unlashed*		Water	yes
4	1	1100	0,23	0,4	60	481	Water	no
5	2	1111	0,23	0,5	60	383	Water	no
6	2	1039	0,23	0,5	60	359	Concrete	no

Swap Body

IBC no	Number of lashings	Weight [kg]	Friction factor μ	Horizontal acceleration [g]	Lashing angle [°]	Pre-tension [kg]	Cargo	Rubber
7	1	1099	0,75	1,0	60	207	Water	yes
8	1	1098	0,75	0,8	60	39	Water	yes
9	2	1107	0,23	0,5	60	380	Water	no
10	1	1098	0,23	0,4	60	477	Water	no

Accelerometers were placed on the floor at the front end of each loading unit to record the average acceleration and duration of each significant shock throughout the voyage. Additional accelerometers were placed on the floor at the back of each loading unit and on top of two IBCs (no. 5 and 6). These were used to record detailed acceleration graphs of some shocks. The purpose of the two devices that were placed on top of the cargo was to compare the response of an IBC filled with water to that of the IBC filled with concrete. Four of the accelerometers were also equipped with a GPS receiver.

The recorders were triggered when the following levels were exceeded:

- Horizontal accelerations: 0.5 g
- Vertical accelerations: 0.7 g

The route of the two test units, consisting of six different legs, is given in the map below.

Map showing the route of the dynamic test transports.
(Red line: Trailer & common track, Blue line: Swap body)

Measurement of movements

The average movement of the IBCs during each leg, which was measured at checks in each terminal, is presented in the tables below for legs 2 through 6.

IBC	Acc. [g]	Longitudinal [cm]	Sideways [cm]
Trailer			
1	**1,0**	0	0
2	**0,8**	0	0
3	**0,75**	0	0
4	**0,4**	0	0
5	**0,5**	0	0
6	**0,5**	0	0
Swap body			
7	**1,0**	0	0
8	**0,8**	0	0
9	**0,5**	0	0
10	**0,4**	3	0

Average movement during each leg, Leg 2 through 6

During the five legs, from Malmö to the final destination in Lübeck, nine of the ten IBCs showed no significant displacement. However, the IBC (no. 10) in the swap body that was secured for 0.4 g consistently moved a few centimetres each time. It was also noted that the two IBCs (no. 5 and 6) secured for 0.5 g in the trailer behaved identically, although one was filled with water and one with concrete. There were no noticeable movement sideways for any IBC.

During the first leg, from Helsingborg to Malmö, via Stockholm, the waggons were subjected to hump and fly shunting. Due to these shunting chocks, all cargo units secured for 0.5 g or less moved significantly, i.e. they moved all the way towards the timber frames or very close to them. The IBC (no. 3) secured for 0.75 g moved slightly, while the reimaging IBC only moved a few millimetres.

Measurement of shocks

In order for cargo to move, the acceleration level during shocks must exceed the threshold value set by the friction factor and other cargo securing measures. However, a shock's ability to move cargo is not only given by the peak value of the acceleration, but also by its duration. These factors are together determining the impulse on the cargo. The cargo may experience significant peak values for horizontal acceleration during rail transport, but these are typically experienced during a fraction of a second and do not generate a large enough impulse to move the cargo any noticeable distance.

During normal intermodal transport on leg 2 through 6, shocks with the following typical characteristics were frequently recorded:

- Mean acceleration: 0.5 – 0.8 g
- Duration: abt 10 - 40 ms

During these shocks, IBCs secured for 0.5 or more did **not** move!

During leg 1 shocks were recorded that clearly indicated that the units had been subjected to hump and fly shunting. These shocks had the following characteristics:

- Mean acceleration: 0.8 – 1.5 g
- Peak acceleration: 1.1 – 3.6 g
- Duration: abt 100 ms

During these shocks, all IBCs secured for 0.75 g or less moved.

Inspection of random units in the DESTINY project

In connection to the dynamic test transports, inspections of the cargo securing in loading units were carried out at seven different terminals in Europe. In total, 131 loading units were inspected. At the inspections, all relevant properties of the loading unit, the cargo and the cargo securing measures, including actual tension in lashings, were documented.

The most probable friction factors between the cargo and the floor as well as in-between cargo layers were estimated based on the condition of the surfaces, the table of friction factors in the European Standard EN 12195-1:2010 and numerous tests performed by MariTerm AB over the past 20 years.

For the cargo in each unit, the actual limiting accelerations of the securing arrangement were then calculated in each direction; forward, backward and sideways. The limiting acceleration is defined as the static acceleration at which it is estimated that the cargo securing arrangement would fail and the cargo would shift. The calculations were based on the principles in the EN 12195-1:2010 standard.

For cargo that had been blocked against a sufficiently strong device, the limiting acceleration has been noted as more than 1.0 g. It should however be noticed that since blocking against curtain sides is not allowed according to current UIC guidelines, no effect of this type of trailer side has been considered in the calculations.

The diagram below shows the **accumulated** percentage of limiting accelerations, i.e. for each acceleration level the diagram shows the percentage of cargo that is secured against that **or a higher** static acceleration.

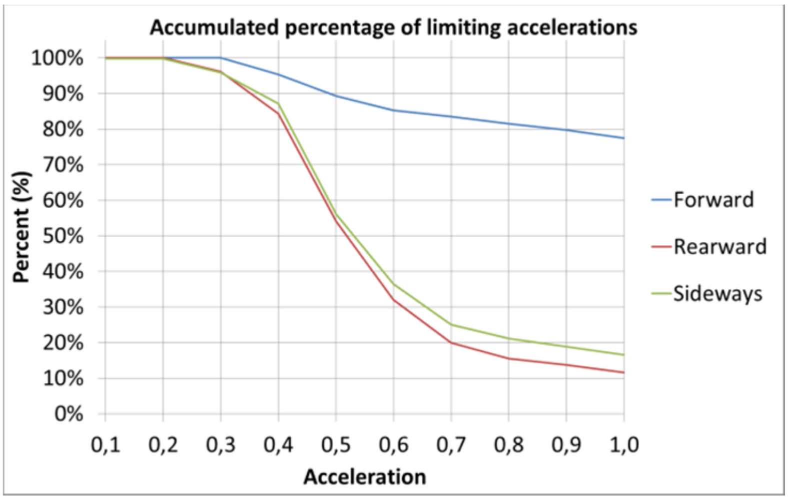


*Diagram showing the **accumulated** percentage of cargo that would **not** shift at different static acceleration levels in each direction for all **inspected** units.*

As can be seen in the diagram, the cargo in 78% of the units would withstand a static acceleration of 1.0 g in the forward direction, while only 12% of the cargo would survive such acceleration in the rearward direction. Remarkably, only 54% of the cargo securing arrangements would actually withstand a static acceleration of 0.5 g in the rearward direction.

The big difference in limiting accelerations to the front and to the rear comes from the fact that most cargo had been blocked in the forward direction but not backward.

The analysis shows that securing sideways and to the rear is done to approximately the same extent. It has been calculated that 57% of the cargo would withstand a static acceleration sideways of 0.5 g.

Conclusions

The results of the inspections in the two projects clearly show that cargo is secured much more thoroughly in the forward direction than to the rear. In the DESTINY project it was shown that only half of the cargo is secured for a static acceleration of 0.5 g or more and only 12% of the cargo is secured for the current design acceleration of 1.0 g to the rear. Blocking is 7.5 times more common in the forward direction than to the rear.

The results of the inspection also show that securing sideways and backward is done to approximately the same extent. Considering that the current design acceleration in the sideways direction according to UIC Loading Guidelines is 0.5 g, it cannot be considered an increased risk to have the same design acceleration in the longitudinal direction.

However, since a great portion of the cargo is not secured against 0.5 g sideways and backward, efforts should be made to educate personnel responsible for loading and securing cargo for combined transports to meet such a requirement. As seen during the inspections, the level of cargo securing can be improved significantly simply by making proper use of the material and equipment already available. The lack of tension in lashings can to some extent be avoided by proper handling of tensioning devices, the use of bigger and more rigid corner protectors on soft cargo and retightening of lashings. Friction can be increased by using already available friction enhancing material.

The result of the tests supports the current wording regarding accelerations during intermodal transports in the draft *IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units (2014-01-31)*, i.e. accelerations with peaks around 1.0 g may occur during normal intermodal transports but these peaks have such a short duration that **for cargo securing purposes** a design acceleration of 0.5 g in the longitudinal as well as in the transverse direction provides a safe level.

When properly applied, the securing principles for cargo securing during road transports may serve as safe guidelines also for combined transports by rail. The only cargo item that moved significantly in the dynamic tests carried out in the DESTINY project was the IBC in the swap body secured for 0.4 g. The other units were displaced a few millimetres only. Due to how the load units are fitted to the railway wagon, cargo in swap bodies may be more sensitive to wandering due to vibrations and low impulse shocks.

A design acceleration of 0.5 g is however only sufficient as long as the wagons are not subjected to hump and fly shunting or shunting at excessive speeds. In the CombiSec project, test shuntings were performed according to the UIC test procedures at speeds of 3-5 km/h.

Recommendations

Based on the findings of the two projects, the following recommendations can be made:

- For static design of cargo securing arrangements for combined rail transport from terminal to terminal with marshalled sorting at appropriate speeds (up to some 5 km/h) a design acceleration in longitudinal direction of 0.5 g can safely be used. Thus, the design accelerations given in Volume 1 of the *UIC Loading Guidelines* should be changed to those found in the *IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units* for this type of traffic.

- For the practical instructions on how to properly secure the cargo, including measures to avoid wandering and rotation due to vibrations, a reference should be made in the *UIC Loading Guidelines* to the *European Best Practice Guidelines on Cargo Securing for Road Transport*.

- Since a great portion of the inspected units were not fulfilling the current regulations, neither for road nor rail transport, efforts should be made to improve the level of securing so that more units can withstand 0.5 g in all directions.

- It should be considered how XL curtain sides can be utilized for blocking in combined rail transports, possibly by influencing the ongoing revision of the EN 12642 standard.