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# EQUIPMENT FOR RATIONAL SECURING OF CARGO ON RAILWAY WAGONS

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Utrustning för rationell säkring av last  
på järnvägsvagnar

(jvgRASLA)

NILS ANDERSSON, PETER ANDERSSON, ROBERT BYLANDER,  
SVENSÖKJER-PETERSEN & BOB ZETHER - MARITERM AB

**Title/Titel:** Equipment for Rational Securing of Cargo on Railway Wagons  
Utrustning för rationell säkring av last på järnvägsvagnar  
(jvgRASLA)

**Author/Författare:** Nils Andersson, Peter Andersson, Robert Bylander, Sven Sökjer.Petersen & Bob Zether - MariTerm AB

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**REFERAT (syfte, metod, resultat):**

Syftet med projektet har varit att förenkla, effektivisera och minska kostnaderna för en korrekt genomförd lastsäkring på järnvägsvagnar. Detta åstadkommes i första hand genom förbättrad utrustning på vagnarna, genom en bättre anpassning mellan denna utrustning och säkringsmaterial samt att lastsäkringen görs enligt en realistisk säkerhetsnivå.

Föreskrifter, standarder och praxis samt nuvarande metoder och utrustning har kartlagts och analyserats ur både teknik- och kostnadssynpunkt. Utifrån analysen har förslag på utrustning och åtgärder tagits fram.

I projektet har det tagits fram förslag på utrustning i en järnvägsvagn för flexibel och effektiv lastsäkring, förslag på nya realistiska krav på generella accelerationer, förslag på en förenklad provningsmetod av lastsäkringsarrangemang, förslag på realistiska krav på styrkan i vagnarnas sidor, gavlar och mellanväggar samt förslag på riktlinjer för lastning och säkring av palletiserat gods. Även behovet av starkare rangerkrokar för ökad säkerhet till sjöss har utretts. Om förslagen realiserats innebär det att fler järnvägsvagnar kommer att ha en fullgod lastsäkring till lägre kostnader vilket leder till ökad säkerhet i trafik och på terminal samt mindre godsskador. Detta kommer att underlätta överföring av gods till järnvägen. Rapporten skall kunna användas av industrin i samband med upphandling av transporttjänster, av järnvägsoperatörer och vagnbyggare vid specifikation av krav på nya vagnar men även av myndigheter vid utarbetande av nya föreskrifter.

**ABSTRACT (aim, method, results):**

The aim with the project has been to simplify, improve and decrease costs by a correct securing of cargo on railway wagons. This is achieved by improved equipment on the railway wagons, better adaption between this equipment and portable securing material and that the cargo securing is done according to a realistic level of safety.

Rules, regulations and practice and existing methods and equipment has been investigated and analysed from technic and cost point of view. From the analysis equipment and actions has been proposed.

In the project it has been developed proposal to equipment in a railway wagon for flexible and efficient cargo securing, proposal to new realistic acceleration requirements, proposal to a simplified test method of loading methods, proposal to realistic strength demands on wagons sides, ends and partition walls, proposal to guidelines for stowage and securing of palletised cargo. The need of increased strenght of shunting hooks for improved safety at sea has also been analysed. If the proposals are received it will lead to more railway wagons having an adequate cargo securing to a lower cost which lead to increased safety at transports and in terminals and less damage to the cargo. This will make it easier to transfer cargo to the railway. The report could be used by the industry when purchasing transports, by railway companies when specifying demands on new railway wagons but also by authorities when working out new regulations.

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# EQUIPMENT FOR RATIONAL SECURING OF CARGO ON RAILWAY WAGONS (jvgRASLA)





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**(jvgRASLA)**

**Research report by:**

Nils Andersson	MariTerm AB
Peter Andersson	”
Robert Bylander	”
Sven Sökjer-Petersen	”
Bob Zether	”

**January 2004**

**The report is mainly financed by  
VINNOVA and Banverket.**



## PREFACE

In the summer 2001 the RASLA project “Equipment for rational securing of cargo on vehicles” was completed. In this project a lot of information was presented that clarified important factors concerning cargo securing. In addition some prototypes of new cargo securing equipment were installed on a cargo securing vehicle, which afterwards have been used at exhibitions as well as for cargo securing trainings. The RASLA project was considered as a large success.

With this background the question was raised if it would be possible to do a similar project for railway wagons, as there are about the same lack of rational cargo securing equipment for railway transports as for road transports. The interest from the industry, the Swedish Agency for Innovation Systems (Vinnova) and the national Swedish rail authority (Banverket) was large, and the project started in the summer 2002. The project is named “Equipment for rational securing of cargo on railway wagons” with acronym jvgRASLA.

The following companies and organisations have been financing the project by economical contribution or by own work:

Ancra ABT AB	Midwaggon
Autonordic	Nordisk Transport Rail AB
AvestaPolarit	Nordwaggon AB
Banverket	Ovako Steel AB
BK Tåg AB	Rail Combi AB
ExTe Fabriks AB	SCA Transforest AB
Green Cargo	RAILOG AB
Gunnebo Industrier AB	SSAB Oxelösund AB
Hydro Kemi	Stora Enso Transport and Distribution AB
Inlandsgods AB	SÖDRA
Kemira Kemi AB	Train Tech Engineering Sweden AB
K Industrier AB	VINNOVA
Länsförsäkringar	Volvo Logistics AB

MariTerm has coordinated the project and done most of the work. Other companies contributing with own work are: Ancra ABT AB, Autonordic, ExTe Fabriks AB, Green Cargo, Gunnebo Industrier AB, K Industrier AB, Midwaggon and TrainTech Engineering Sweden AB.

All financiers as well as a representative from the Swedish Railway Inspectorate (Järnvägsinspektionen) have been invited to the four project meetings that have been held from October 2002 to January 2004.

We wish to thank all involved for valuable contribution to the project.

Höganäs, 2004-01-30

MariTerm AB  
Peter Andersson  
Project manager

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## SUMMARY AND RECOMMENDATIONS

### • CARGO SECURING METHODS ACCORDING TO UIC

To show that a loading method secures the load in a sufficient way for railway transport, impact tests (lengthways) and running tests (sideways) could be performed. The impact test can be performed rather easy but the running test takes long time and/or is very expensive. If the arrangements could be tested in the same way as arrangements intended for road transports the development of new cargo securing methods for railway transport would be simplified. It is recommended that the arrangements are allowed to be tested sideways in the same way and for the same forces as for road transports. Special consideration must, however, be taken to the vibrations that occur in a railway wagon.

### • IMPACT TESTS AND TESTS WITH NAIL JOINTS AND WEBBINGS CARRIED OUT IN THE PROJECT

#### Impact tests

Impact tests with a wagon loaded with steel pipes, a wagon with trailer loaded with paper reels and a wagon with cars were carried out in the project. The purpose was to check whether the loading methods used could withstand the longitudinal stresses exerted during railway operating. The following was concluded:

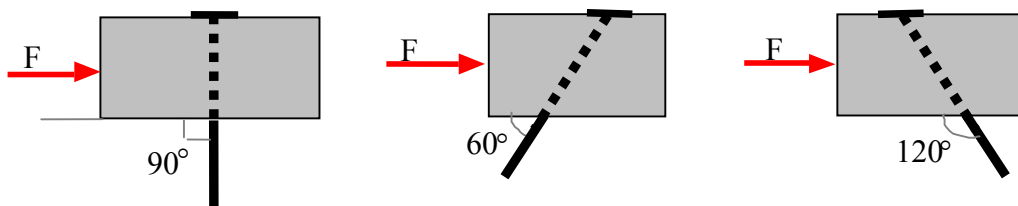
- Sections with steel pipes without any securing shifts much more than the 50 cm stipulated in the UIC Loading Guidelines.
- To avoid damages to wagons and goods it is recommended to use loop lashings for steel pipes in bundles even if the UIC loading guidelines 1.4.7 allow transportation of pipes stowed between stanchions without additional securing.
- Less number of nails than stipulated in the UIC Loading Guidelines is needed when securing laying paper reels for none hump and fly shunting.
- Less scotch height than stipulated by UIC could be used when securing laying paper reels for none hump and fly shunting.
- Scotches of frigolit do not have enough strength to secure laying paper reels.

#### Nail joints

The purpose of the tests with nailed scotches was to establish how large accelerations a cargo securing arrangement with nailed scotches can withstand before the nailed scotches fail. The results could be used to find alternatives to the  $\phi$  5 mm nails prescribed by UIC (the reference nail).

Besides a list of the force capacity of different nail types (reference nail's force capacity is 2500 N (250 kg)), the following was concluded from the nail tests:

- The force capacity per nail is larger when it is nailed to a plywood floor than to a wooden floor.
- The force capacity per nail varies little when the angle is decreased from 90 to 60 degrees.
- The force capacity per nail is lower for an angle of 120 degrees than for angles of 90 or 60 degrees, see figure below.



### Webbing

The purpose of the tests with tied webbing, webbing with loop and webbing attached to different fittings (hooks and rings) was to establish how large the strength reduction is compared to the breaking strength of the webbing itself. The following was concluded:

- The use of knots reduces the breaking strength of the bindings by approximately 60 %, as stated by UIC.
- One-way system with 20 kN PP webbing and Key-Lock buckle is more than 100 % stronger than the SJ-lashing (22 kN webbing) with the cam lock.

### • ANALYSIS OF THE UIC LOADING GUIDELINES

Some cargo securing arrangements according to “General methods accepted for cargo securing according to chapter 5 in section 1 in RIV Appendix II” and “Loading guidelines for different types of cargo in section 2 in RIV Appendix II” have been analysed and it is calculated which accelerations the different arrangements can withstand in transverse and longitudinal direction for transports with hump and fly shunting as well as for transports without hump and fly shunting. It has been concluded that most of the arrangements can withstand only fractions of the general acceleration requirements.

To open up for new improvements and design of securing systems for rail transports it is strongly recommended to modify the general acceleration requirements to realistic acceleration figures, and to open up for allowance to design securing systems for these accelerations.

Based on the result from the calculations, the following general acceleration requirements are recommended:

- Transverse: 5 m/s<sup>2</sup>
- Longitudinal:
  - at hump and fly shunting: 10 m/s<sup>2</sup>
  - at none hump and fly shunting: 5 m/s<sup>2</sup>
- Vertical: 0 m/s<sup>2</sup>

Due to the vibrations occurring during rail transport, it is, however, needed to have some kind of arrangement limiting the motion sideways due to the vibrations. Battens, top-over lashings with limited strength or friction enhancing inserts can achieve this. When using friction, as only method of securing, the coefficient of friction has to be at least 0.7 and the contact surface shall have damping qualities.



- **DESIGN CRITERIA FOR WAGON SIDES, ENDS, STANCHIONS AND SECURING FITTINGS**

Minimum demands on the strength of cargo securing equipment on railway wagons in Europe according to International Union of Railways (UIC) and in North America according to Association of American Railroads (AAR) are described. As a comparison the strength requirements for cargo transport units and vehicles according to standards are also described.

The regulations according to UIC are in line with both the AAR's and the CTU-standards except for the strength of lengthways securing equipment such as end walls, end stanchions and partition walls. The strength is lower than in corresponding equipment in wagons from North America. The strength of a railway wagon's end walls or end stanchions is even lower than the ones in swap bodies or containers.

To be able to use end and side walls as well as partition walls for cargo securing in a safe and efficient way the following design criteria is proposed to be set up for European railway wagons:

End walls	0.4 × cargo weight evenly distributed over the entire end wall
Side walls	0.3 × cargo weight evenly distributed over the entire side wall
Partition walls	0.4 × half cargo weight evenly distributed over the entire partition wall

- **PROPOSED EQUIPMENT IN A RAILWAY WAGON FOR FLEXIBLE AND EFFICIENT CARGO SECURING**

All parts of a wagon must be designed to reduce or facilitate the cargo securing; bogie, floor, side walls, end walls as well as securing equipment inside the wagons.

As a part of the work to specify a flexible railway wagon that allows rational securing of various types of cargo, foldable side stanchions with an adjustable transverse positioning system and turnable bolsters has been designed in the project.

In a wagon equipped with strong sides and foldable and adjustable side stanchions the following cargo types can be stowed and secured in a rational way:

- paper reels
- square sawn timber
- palletised goods
- pipes
- steel plates
- board packages

Cargo types that more easily can be transported in a wagon equipped with turnable bolsters are:

- square sawn timber
- pipes
- steel plates

If wagons are equipped with the stanchions/bolsters the number of single trips could be reduced.

- **COMPARISON OF CARGO SECURING COST BETWEEN RAILWAY AND ROAD TRANSPORT**

The cost of some different railway securing arrangements is compared with equivalent securing arrangements designed for road transport.

The cost for cargo securing is almost in all cases lower for railway transport. The main reasons are

- In several cases the cargo is allowed to slide lengthways at railway transport. This is not an option in road transports and the securing arrangement will be extensive, if the load is not blocked in forward direction.
- The UIC guidelines for cargo securing are designed for lower dimensioning forces than road transport, see chapter 5.
- The different types of goods used in the comparison are suitable for railway transports as they are taken from the UIC-guidelines.

A conclusion is that it is not easy to make the cargo securing arrangements easier and more cost efficient than what is stipulated by the UIC guidelines (RIV Appendix II, Section 2). Instead the cost saving potential is to give the railway wagons a more multi-purpose design to increase the utilisation and to design handling equipment efficient to shorten the time for securing with lashings.

One interesting question that this comparison has excluded is the range of goods damages. Are there differences between the modes of transports regarding goods damages? And if so, is it because of different cargo securing, different acting forces on the cargo or different cargo securing regulations?

- **LOADING AND SECURING OF PALLETISED CARGO**

Since the only regulations in RIV Appendix II for palletised goods deals with the formation of the goods on the pallets, a proposal of instructions for the securing of palletised cargo has been developed within the project.

- **SECURING OF RAILWAY WAGONS IN FERRY TRAFFIC**

It has been studied under which conditions wagons may be transported in train ferries without running the risk of tipping. The existing equipment on wagons that allows fastening of securing arrangements is reviewed and the properties of six different types of wagons are studied. The strength of this equipment, required to withstand the stresses induced by operation of seven different train ferries in certain conditions on the Baltic Sea, is also determined.

The maximum significant wave height that the Baltic Sea's train ferries normally operate in is 4.0 m (moderate bad weather). None of the seven ships can operate in such weather without running the risk of having wagons tipping over. For one ship only, replacing older tow hooks

with holding down brackets without increasing the number of securing points on the wagons, this problem could be solved.

It is concluded that it must be more economic to put restrictions on the wave height in which the train ferries may operate than to equip all freight wagons with new stronger securing fittings for ferry transport in the Baltic Sea. Future wagons equipped with holding down brackets will allow for a revision of these restrictions, as older wagons are taken out of use.

If the wagons are equipped with holding down brackets and the ships are equipped with securing fittings maximum 1.5 meters apart in the longitudinal direction, each lashing could take up a force of 80 kN. Such an arrangement would allow most of the train ferries to operate in wave heights up to 4 meters.

#### • **RECOMMENDATION**

Based on the results from the jvgRASLA project, the following is recommended:

1. To establish new realistic general acceleration requirements that also are allowed to be used as a base for design of cargo securing arrangements for rail transports.
2. It should be possible to perform tests of loading methods for sideways accelerations in the same way and for the same forces as for road transports. Special consideration must, however, be taken to the vibrations that occur in a railway wagon.
3. To establish harmonised realistic strength demands on sides, ends and partition walls of railway wagons enabling rational cargo stowage and securing in the wagons. The strength demands are proposed to be in line with the standard EN 283.
4. To establish guidelines for stowage and securing of palletised cargo in railway wagons.
5. To require improved strength of the shunting hooks for new railway wagons improving the possibility for safe transports in ferry traffic. Restrictions for which significant wave height train ferries may operate in should be introduced.
6. To investigate reasons for cargo damages during railway transportation and to develop means to avoid such.

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## SAMMANFATTNING OCH REKOMMENDATIONER

### • LASTSÄKRINGSMETODER ENLIGT UIC

För att testa om lastsäkringsarrangemang kan godkännas för transport på järnväg görs stötprov (längdriktningen) och rullprov (sidled). Stötprov kan utföras relativt enkelt medan rullprov tar lång tid och/eller är mycket kostsamma. Om arrangemangen kunde testas i sidled på samma sätt som det görs för arrangemang för landsvägstransporter skulle framtagningen av nya lastsäkringsmetoder för järnvägstransport underlättas. Det rekommenderas att proven görs på samma sätt och för att klara samma påkänningar som vid landsvägstransport. Särskild hänsyn måste dock tas till de vibrationer som uppkommer i en järnvägsvagn.

### • STÖTPROV OCH PROV MED SPIKFÖRBAND OCH SURNINGAR SOM UTFÖRTS INOM PROJEKTET

#### Stötprov

Målet med de stötprov som genomförts i projektet (en vagn lastad med stålrör, en vagn med trailer lastad med pappersrullar och en vagn lastad med personbilar) var att kontrollera om lastningsätten klarar de påkänningar som uppkommer vid järnvägstransport. Följande slutsatser kunde dras:

- Sektioner med stålrör utan lastsäkring flyttade sig mycket längre än de 50 cm som anges i UICs lastningsanvisningar.
- För att undvika skador på vagnar och gods så rekommenderas det att säkra buntar med stålrör med loopsurningar även om UICs lastningsanvisning 1.4.7 tillåter transport av stålrör utan lastsäkring om de är lastade mellan sidostöttor.
- Det krävs färre antal spik när man säkrar liggande pappersrullar än vad som anges i UICs lastningsanvisningar utan rangering över vall.
- Det krävs lägre klosshöjd när man säkrar liggande pappersrullar än vad som anges i UICs lastningsanvisningar utan rangering över vall.
- Frigolitklossar har inte tillräcklig styrka för att användas vid säkring av liggande pappersrullar.

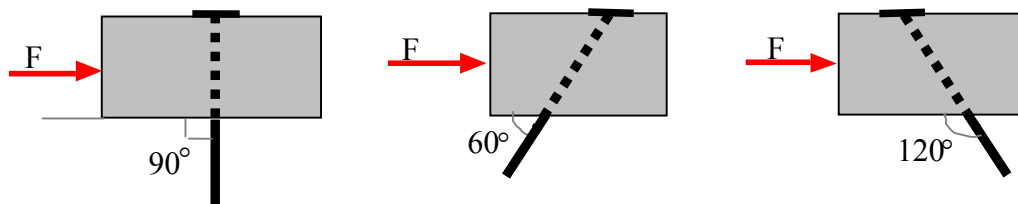
#### Spikförband

Målet med proven var att fastställa hur stora accelerationer lastsäkringsarrangemang med spikade klossar kan motstå innan klossarna släpper. Resultaten kan användas för att ge alternativ till de spikar med diameter 5 mm som anbefalls av UIC (referensspik).

Förutom ett värde på maximal kraft för olika spiktyper (kraft per referensspik är 2500 N (250 kg)) kunde följande slutsatser dras av spikproven:

- Den maximala kraften per spik är större när den spikas i ett golv av plywood än i ett golv av träplank.
- Den maximala kraften per spik varierar endast lite när spikens vinkel minskas från 90 till 60 grader.

- Den maximala kraften per spik är lägre vid en spikvinkel av 120 grader än för en vinkel av 90 eller 60 grader.



### Surrningband

Målet med proven med knutna band, band med ögla och band fastsatta i olika surrningsfästen var att fastställa hur mycket bandens brottstyrka reduceras. Följande slutsatser kunde dras:

- För ett knutet band reduceras brottstyrkan med ca 60 %, vilket är angivet av UIC.
- Engångssystem med 20 kN PP band och Key-Lock lås är mer än 100 % starkare än en SJ-surrning (22 kN band) med kamlås.

### • ANALYS AV UIC LASTNINGSINSTRUKTIONER

Några lastsäkringsarrangemang enligt generella lastsäkringsmetoder enligt kapitel 5 i del 1 av RIV Appendix II samt lastningsexempel för olika typer av gods i sektion 2 av RIV Appendix II har analyserats. Det har beräknats vilka accelerationer de olika arrangemangen klarar i transversell och longitudinell riktning vid transport med rangering över vall och vid transport utan rangering över vall. Slutsatsen är att de flesta av arrangemangen endast kan motstå en bråkdel av de generella påkänningskraven.

För att öppna upp för förbättringar och nya innovationer av lastsäkringssystem för järnvägstransporter rekommenderas starkt att ändra de generella påkänningsvärdena till mer realistiska värden samt att öppna upp för möjligheten att dimensionera lastsäkringssystem efter dessa accelerationer.

Baserat på resultaten av beräkningarna kan följande dimensionerande accelerationer rekommenderas:

- Transversellt:  $5 \text{ m/s}^2$
- Longitudinellt:
  - vid transport med rangering över vall:  $10 \text{ m/s}^2$
  - vid transport utan rangering över vall:  $5 \text{ m/s}^2$
- Vertikalt:  $0 \text{ m/s}^2$

På grund av de vibrationer som uppstår vid järnvägstransport är det dock nödvändigt med någon typ av arrangemang som begränsar rörelse i sidled. Träreglar, överfallssurrningar med begränsad styrka eller friktionsmellanlägg kan åstadkomma detta. När man använder friktion som enda lastsäkringsmetod skall friktionskoefficienten vara åtminstone 0,7 och kontaktytan skall ha dämpande egenskaper.

**• DIMENSIONERINGSKRAV FÖR LASTSÄKRINGSUTRUSTNING**

Minimikrav på lastsäkringsutrustnings styrka för järnvägsvagnar i Europa enligt International Union of Railways (UIC) och i Nordamerika enligt Association of American Railways (AAR) är beskrivet. Som jämförelse beskrivs också kraven på lastbärare och fordon enligt standarder.

Föreskrifterna enligt UIC är i linje med både AAR's regler och standarderna för fordon och lastbärare förutom när det gäller styrkan för lastsäkringsutrustningen i längdled, såsom vagnsgavlar, gavelstolpar och mellanväggar. Styrkan är lägre än i motsvarande utrustning i vagnar från Nordamerika. Styrkan i en vagns gavlar eller gavelstöttor är t.o.m. lägre än för gavlar i växelflak och containrar.

För att kunna använda gavlar och sidor samt mellanväggar vid lastsäkring på ett säkert och effektivt sätt föreslås följande dimensioneringskrav för europeiska järnvägsvagnar:

Gavlar	0,4 × lastvikten jämnt fördelad över hela gaveln
Sidor	0,3 × lastvikten jämnt fördelad över hela sidan
Mellanväggar	0,4 × halva lastvikten jämnt fördelad över hela mellanväggen

**• FÖRESLAGEN UTRUSTNING I EN JÄRNVÄGSVAGN FÖR FLEXIBEL OCH EFFEKTIV LASTSÄKRING**

Alla delar av en järnvägsvagn måste vara konstruerad för att reducera eller underlätta lastsäkringen: boggi, golv, sidor, gavlar så väl som säkringsutrustningen inuti vagnarna.

Som en del av arbetet med att specificera en flexibel järnvägsvagn som tillåter rationell säkring av olika typer av last har fällbara sidostöttor som är flyttbara i sidled samt uppvikbara underlägg tagits fram i projektet.

I en vagn med starka sidor och fällbara, justerbara stöttor kan följande godstyper lastas och säkras på ett rationellt sätt:

- pappersrullar
- virkespaket
- pallat gods
- rör
- stålplåt
- paket med plywood/träfiberskivor

Lasttyper som lättare skulle kunna transporteras i en vagn utrustad med uppvikbara underlägg är:

- virkespaket
- rör
- stålplåt

Om vagnar utrustas med stöttorna/underläggen kan antalet tomdragningar reduceras.

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- **JÄMFÖRELSE AV KOSTNADER FÖR LASTSÄKRING MELLAN JÄRNVÄGS- OCH LANDSVÄGSTRANSPORT**

Kostnaden för olika lastsäkringsarrangemang vid transport på järnväg jämförs med motsvarande arrangemang dimensionerade för landsvägstransport.

Kostnaden för lastsäkringen vid järnvägstransport är lägre för i stort sett samtliga godsslag. De främsta anledningarna är:

- I flertalet fall tillåts godset glida i längdled vid lastning på järnvägsvagn. Detta är inte möjligt vid landsvägstransport och lastsäkringsarrangemanget blir därför omfattande om inte lasten är förstängd mot framstammen.
- Lastningsanvisningarna enligt UIC är dimensionerade för lägre accelerationer än de för landsvägstransport, se kapitel 5.
- De olika godsslagen som har används är typiskt järnvägsgods eftersom det finns instruktioner för dem i UICs riktlinjer.

En slutsats är att det inte är lätt att göra lastsäkringsarrangemangen mer kostnadseffektiva än vad som är angivet i UICs riktlinjer (RIV Appendix II, Sektion 2). Istället ligger den kostnadsbesparande potentialen i att konstruera järnvägsvagnar som är mer flexibla för att öka utnyttjandegraden samt att konstruera utrustning som reducerar tiden för lastsäkring med surringar.

En intressant aspekt som denna jämförelse inte har behandlat är omfattningen av godsskador. Är det skillnader mellan transportslagen när det gäller godsskador? Och om så är fallet, är detta pga. olika lastsäkring, olika påkännande krafter eller olika lastsäkringsregler.

- **LASTNING OCH SÄKRING AV PALLETISERAT GODS**

Eftersom de enda instruktionerna i RIV Appendix II för palletiserat gods behandlar godsets placering och fastsättning på pallen har ett förslag på lastningsinstruktioner för pallgods tagits fram inom projektet.

- **SÄKRING AV JÄRNVÄGSVAGNAR OMBORD PÅ FARTYG**

Det har undersökts i vilka situationer som vagnar kan transporteras till sjöss utan att riskera att tippa. Existerande utrustning på vagnar som används till nedsurning till fartygsdäcken har undersökts och sex olika typer av vagnar har studerats. Styrkan i utrustningen som krävs för att motstå krafterna som uppkommer ombord på sju olika tågfärjor som trafikerar Östersjön har också undersökts.

Tågfärjor i Östersjön opererar normalt i en signifikant våghöjd som är högst 4,0 m. Ingen av de sju fartyg som har studerats kan operera i sådant väder utan att löpa risken att järnvägsvagnarna tippas. För endast ett fartyg kan problemet lösas genom att gamla rangerkrokar byts ut mot lika många kraftigare surningsfästen.

Slutsatsen som har dragits är att det måste vara mer ekonomiskt att sätta restriktioner på vilka våghöjder i vilka tågfarjor får operera än att utrusta alla järnvägsvagnar som skall transporteras på Östersjön med nya starkare surrningsfästen. Nya vagnar med starka surrningsfästen kommer att innebära att restriktionerna så småningom kommer att kunna revideras, när de gamla vagnarna försvinner.

Om järnvägsvagnarna utrustas med surrningsfästen istället för rangerkrokar och fartygen utrustas med surrningsfästen med ett maximalt längsgående avstånd på 1,5 meter kan vagnens fästen ta upp en kraft av 80 kN vardera. Med ett sådant surrningsystem skulle de flesta tågfarjorna kunna operera i våghöjder upp till 4 meter

#### • REKOMMENDATIONER

Baserat på resultaten från jvgRASLA projektet kan följande rekommenderas:

1. Fastställa nya realistiska krav på generella accelerationer som även är tillåtna att användas vid dimensionering av lastsäkringsarrangemang.
2. Prov av lastsäkringsarrangemang för påkänningar i sidled skall kunna utföras på samma sätt som för landsvägstransporter. Särskild hänsyn måste dock tas till de vibrationer som uppkommer i en järnvägsvagn.
3. Fastställa harmoniserade realistiska krav på styrkan i järnvägsvagnars sidor, gavlar och mellanväggar för att kunna uppnå en rationell lastning och lastsäkring. Styrkekraven föreslås vara i enlighet med standarden EN 283.
4. Fastställa riktlinjer för lastning och säkring av palletiserat gods i järnvägsvagnar.
5. Kräva ökad styrka i rangerkrokar för nya järnvägsvagnar för att öka säkerheten vid sjötransporter. Restriktioner för i vilka signifikanta våghöjder tågfarjor får operera bör införas.
6. Undersöka orsakerna till godsskador som uppkommer vid järnvägstransport samt att ta fram åtgärder för att undvika dessa.



# 1 INTRODUCTION

## 1.1 Background

Insufficient securing of cargo during transports gives a risk for damages to cargo and railway wagons as well as persons, working in the chain of transports or are involved in any other way. Besides that great values are in stake when cargo is damaged, cargo coming loose can hit other trains, damage tracks and electric wires and lead to severe accidents. Cargo falling out when opening the doors or sliding walls can injure the unloading personnel.

At inspections of railway wagons carried out by the Swedish Railway Inspectorate and the Swedish Coastguard many wagons with insufficiently secured cargo are often found.

At discussions with personnel involved in loading and securing of cargo the defectiveness is often explained by that it is difficult and costly to secure with the equipment present on the railway wagons today. The regulations are rather unclear and the practical conditions to do a proper work are missing. This is a problem noted among others by representatives for the industry.

When the number of cargo transports is increasing the accessibility on the roads is decreasing and the effect on the environment is increasing. Due to this it is desirable to transfer more cargo from road to railway. One of the obstacles to do so is the damage on cargo occurring when transported on railway.

## 1.2 Purpose and scope of work

The aim with the project has been to simplify, improve and decrease costs by a correct securing of cargo on railway wagons.

In the project the following has been dealt with:

- Mapping and analysis of existing rules and standards for cargo securing on railway wagons.
- Mapping and analysis of existing rules and standards for wagons superstructure and cargo securing equipment.
- Propose methods to simplify the testing of new cargo securing arrangements.
- Inventory of existing cargo securing equipment on railway wagons and other CTU's.
- Identification of required cargo securing functions.
- Propose cargo securing equipment making the cargo securing more efficient.
- Costs for cargo securing at railway transports compared with the one at road transports.
- Propose cargo securing instructions for palletised cargo.
- Securing of railway wagons in ferry traffic.

### **1.3 Expected field of application**

If railway wagons are better equipped the safety will increase and less cargo will be damaged, which will make it easier to transfer cargo to the railway from other modes of transport.

This report could be used by the industry when purchasing transports, by railway companies when specifying demands on new wagons and by authorities when improving guidelines for cargo securing for rail transportation.

## **2 RULES, REGULATIONS AND STANDARDS FOR CARGO SECURING**

Rules, regulations and standards for cargo securing exist on national as well as international level for rail, road and sea transports.

In this chapter the general requirements of cargo securing for rail transports in Europe as well as in North America are mapped as well as corresponding requirements for road and sea transports. The requirements for rail transports are compared with the requirements for the other modes of transport.

### **2.1 General requirements of cargo securing for rail transports**

Below existing general rules, regulations and standards for cargo securing are mapped including the American requirements according to AAR (Association of American Railroads).

#### **2.1.1 UIC general acceleration requirements**

The regulations are the same for almost all European countries. The general accelerations to be taken into account according to UIC are as follows:

Lengthways in the wagon

- up to four times the weight of the load (4 g) for goods that are rigidly secured,
- up to one times the weight of the load (1 g) for goods that can slide lengthways in the wagon

Crossways in the wagon

- up to 0.5 times the weight of the load (0.5 g)

Vertically

- up to 0.3 times the weight of the load (0.3 g) (encourages the displacement of the goods)

For wagons not subject to hump and fly shunting, wagons in block trains, wagons used in combined transport trains with containers, swap bodies, semi-trailers and lorries, where appropriate with trailers as well as wagons fitted with long-stroke shock absorbers the lengthways force is limited to one times the weight of the load (1 g).

The forces should be considered as quasi-static.

There are, however, three levels of cargo securing according to UIC. See chapter 3.1.

**2.1.2 AAR general acceleration requirements**

When a specific figure is not involved and when an object or load is secured using applicable securing devices, the load restraint values shown below must be observed unless all carriers involved in the movement agree otherwise.

Direction of Restraint	G Force to Yield
Longitudinal	3.0 Gs Total load restraint in each direction should equal three times object weight.
Lateral	2.0 Gs Total load restraint in each direction should equal two times object weight.
Vertical	2.0 Gs Total load restraint should equal the lightweight of the carrying wagon or two times object weight whichever is less.

*Restraint values for Open Top loading*

**2.1.3 IMO/ILO/UN ECE**

**Guidelines for packing of cargo transport units (CTUs).**

These guidelines are worked out in cooperation with the international organisations IMO, ILO and UN ECE.

The stresses to be taken into account in CTUs according to IMO/ILO/UN ECE are as follows:

Lengthways in the wagon

- Wagons subject to shunting 4.0 g
- Combined transport 1.0 g

Sideways in the wagon

- 0.5 g in combination with  $1 \pm 0.3$  g vertically

**2.1.4 EN 12195-1**

**Load restraint assemblies on road vehicles – Safety – Part 1: Calculation of lashing forces.**

In this standard it is stated how lashing and blocking forces should be calculated. The accelerations that should be used at combined transports on railway are as follows:

- lengthways 1.0 g (0.6 g for tipping)
- sideways 0.5 g (in combination with 0.7 g vertically downwards for sliding)

**2.1.5 VDI 2700 Blatt 7 (Germany)**

**VDI Richtlinien, Ladungssicherung auf Straßenfahrzeugen, Ladungssicherung im Kombinierten Ladungsverkehr (KLV).**

In this standard the forces arising during a combined transport only is stated. In addition there are some examples on how to secure cargo in different cargo carriers. There is also an example showing how to calculate required strength in securing devices.

For the calculation with regard to load-securing, the following quasi-static forces, expressed as multiples of the weight (g) of the load, are to be assumed:

- in the longitudinal direction forwards and backwards, 1.0 g,
- in the transverse direction to both sides, 0.5 g,
- in the vertical direction upwards and downwards, 0.3 g in addition to the static weight.

**2.1.6 ÖNORM V 5750-1 (Austria)**

**ÖNORM V 5750-1:1990 07 01 Cargo securement; forces involved**

The accelerations according to this standard that should be used at transports on railway are as follows:

Lengthways in the wagon

- Wagons subject to shunting 4.0 g
- Combined transport 2.0 g

Sideways in the wagon 0.4 g in combination with  $1 \pm 0.3$  g vertically

**2.2 General requirements of cargo securing for road and sea transports**

Forces, which could arise during transports on road and sea according to most national regulations, international standards and other literature, are as follows:

**Road**

- forwards 1.0 g, alternatively 0,8 g
- sideways and backwards 0.5 g (0.7 g for tipping according to VDI 2700 and EN 12195-1)

**Sea**

Sideways	Baltic Sea	0.5 g
	North Sea	0.7 g
	Unrestricted	0.8 g

Lengthways	Baltic Sea	0.3 g in combination with $1 \pm 0.5$ g vertically
	North Sea	0.3 g in combination with $1 \pm 0.7$ g vertically
	Unrestricted	0.4 g in combination with $1 \pm 0.8$ g vertically

### 2.3 Comparison of general requirements of cargo securing for different modes of transport

In this section values are presented on forces that could arise during transports, according to UIC (rail), IMO (sea) and international standards (road). Two examples (sliding and tipping) are used to show how much securing that is needed for a specific piece of cargo exposed to the accelerations at the different transport modes.

Mode of transport	Forwards	Backwards	Sideways
Rail	4.0 g	4.0 g	0.5 g <sup>d</sup>
Rail (block train and combined transport)	1.0 g	1.0 g	0.5 g <sup>d</sup>
Road	1.0 g	0.5 g	0.5 g
Sea Baltic Sea	0.3 g <sup>a</sup>	0.3 g <sup>a</sup>	0.5 g
North Sea	0.3 g <sup>b</sup>	0.3 g <sup>b</sup>	0.7 g
Unrestricted	0.4 g <sup>c</sup>	0.4 g <sup>c</sup>	0.8 g

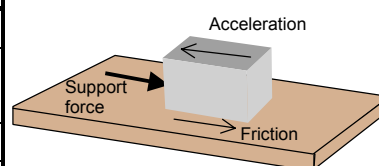
The above values should be combined with static gravity force of 1.0 g acting downwards and a dynamic variation of:

- a/ ± 0.5 g      b/ ± 0.7 g      c/ ± 0.8 g      d/ ± 0.3 g (at sliding only)

#### Sliding

- Required support force for a 1000 kg cargo unit with friction 0.3 against the floor for different modes of transport is shown below.

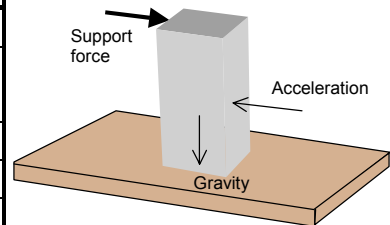
Mode of transport	Forwards	Backwards	Sideways
Rail	37 kN	37 kN	2.9 kN
Rail (block train and combined transport)	7.0 kN	7.0 kN	2.9 kN
Road	7.0 kN	2.0 kN	2.0 kN
Sea Baltic Sea	1.5 kN	1.5 kN	2.0 kN
North Sea	2.1 kN	2.1 kN	4.0 kN
Unrestricted	3.4 kN	3.4 kN	5.0 kN



Tipping

- Required support force at the top of a 1000 kg cargo unit with a height/width-ratio of 3.0 for different modes of transport is shown below.

Mode of transport	Forwards	Backwards	Sideways
Rail	18 kN	18 kN	0.8 kN
Rail (block train and combined transport)	3.3 kN	3.3 kN	0.8 kN
Road	3.3 kN	0.8 kN	0.8 kN
Sea Baltic Sea	0.7 kN	0.7 kN	0.8 kN
North Sea	1.0 kN	1.0 kN	1.8 kN
Unrestricted	1.7 kN	1.7 kN	2.3 kN







### 3 CARGO SECURING METHODS ACCORDING TO UIC

A mapping of the general UIC methods for cargo securing as well as the UIC specific cargo securing guidelines for different types of cargo is made. In chapter 5 calculations are carried out of which accelerations these methods and guidelines can withstand. As a comparison some information and methods from AAR is included.

#### 3.1 Different levels of cargo securing requirements

In the UIC loading guidelines (RIV Appendix II) the following three levels of cargo securing requirements are found:

1. General forces arising during transport on rail in section 1, chapter 2.
2. General methods of loading and securing in section 1, chapter 5.
3. Specific instructions for cargo securing of different cargo types in section 2.

The general forces arising during transport are described in the previous chapter, section 2.1.1.

As far as is understood these general forces are never used for real design of cargo securing arrangements. Instead the general methods or the specific instructions should be used.

According to UIC loading guidelines, section 1 chapter 1.2; any types of cargo securing are permitted, provided they meet the requirements of the general methods described in section 1. In reality it seems, however, to be so that securing arrangements according to section 2 is the only methods accepted by load securing inspectors. If the actual type of cargo is not included in section 2, an arrangement has to be agreed upon by the involved UIC member countries before the goods may be transported by rail.

If this procedure is intended to be used also for goods in combined cargo transport units, as trailers, swap bodies, containers etc. is unclear.

#### 3.2 Equipment accepted for cargo securing

The following equipment is accepted for cargo securing according to the UIC guidelines section 1:

- Walls, sides, doors and sliding doors with sufficient strength (chapter 2.3)
- Stanchions (chapter 2.5)
- Securing devises (chapter 2.6)
  - Rings
  - Hooks
  - Eyelets
  - Other suitable parts of the wagon
- Built in cargo securing equipment (chapter 2.7)

- Partition walls
- Loading cradles
- Indirect fastening equipment
- Wheel scotches
- Timbers and nails (chapter 5.4.3)
- Friction enhancing inserts (chapter 5.5.5)
- Cradles (chapter 5.6)

Sheeting devices, type curtain sides etc., is according to chapter 2.4 not allowed to be used as cargo securing devices.



According to chapter 1.5 goods may be assembled to form “load units” by a round-turn lashings made of steel strips, steel wires, synthetic or woven straps with a break load of at least the values given below.



- 5 kN (500 kg) for palletised goods weighing up to 500 kg
- 7 kN (700 kg) for palletised goods weighing over 500 kg, square sawn timber, wooden boards, edge sawn timber, cellulose bales, etc.
- 10 kN (1000 kg) for wooden sleepers, stone or concrete slabs, etc.
- 14 kN (1400 kg) for packages and coils of sheet steel, bundles of steel pipes, steel profiles and bars, coils of wire rods steel strips, steel billets, stacks of plywood and hardboard slabs, blocks of stone etc.
- 20 kN ( 2000 kg) for binding together several sheet steel coils

- 40 kN (4000 kg) for binding together steel pipes, where a dovetailed layer is resting on a scotched layer.

Rings, eyelets and hooks made of steel rod with a diameter of at least 16 mm may be used for direct lashing of the following cargo weights if two fittings (one on each side of the wagon) are used:

- Up to 10 tons on flat wagons
- Up to 5 tons for covered wagons.

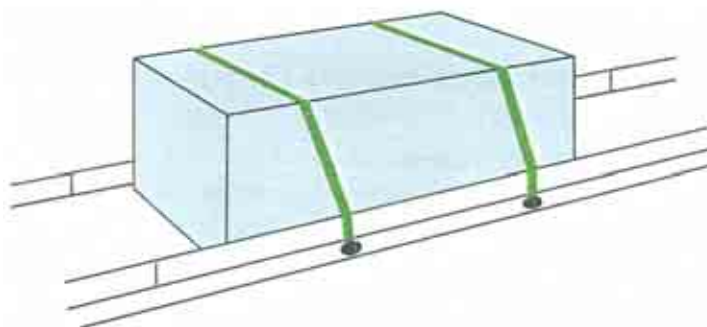
Eyelets and rings designed for the securing of tarpaulins can be used for securing the following cargo weights:

- Up to 2 tons for direct lashing
- Up to 4 tons for indirect (top-over) lashing

According to chapter 2.7 five tons of cargo only can be secured in longitudinal direction by a partition wall over a width of at least 2400 mm and a height of 700 mm. If two partition walls are used in combination, the walls can secure seven tons of cargo in longitudinal direction.

Nails used for cargo securing during rail transports should, according to the UIC guidelines section 1 chapter 5.4.3, be round in shape and have a diameter of 5 mm. Such nails do not exist on the north European market, see section 3.4 below. Timbers used for blocking should have an effective height of 5 cm to prevent longitudinal movement and 3 cm to prevent transverse movement.

Indirect fastenings (top-over lashings, see below) should, according to chapter 5.5.4, have a breaking strength of 10 – 40 kN (1000 – 4000 kg), with an initial tension (pretension) of at least 3 kN (300 kg)



Friction enhancing inserts must deliver a friction coefficient of at least 0.7 according to chapter 5.5.5.

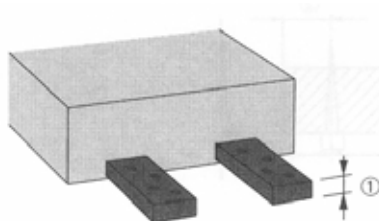
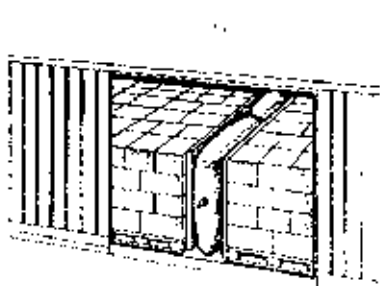
### 3.3 General methods accepted for cargo securing

The general methods for cargo securing according to the UIC loading guidelines are in general described below.

Chapter 5.1 of section 1 of the loading guidelines contains the basic principles for cargo securing. The goods must lay / stand in such a way that it is prevented from lifting, falling, sliding, rolling and tipping in longitudinal as well as transverse direction. The cargo must also be prevented from being damaged during the transport.

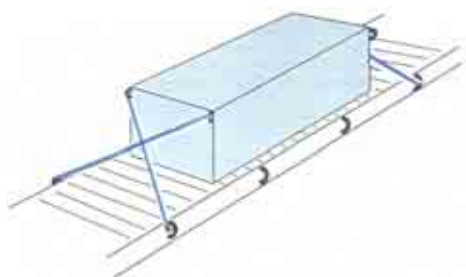
The following general methods for cargo securing are accepted according to the UIC guidelines section 1:

- Blocking
  - Filling of empty spaces by pallets, air bags or bracings (chapter 5.4.2)
  - Nailed timbers (chapter 5.4.3)

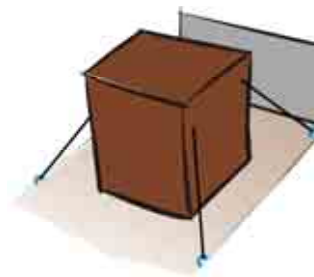


① Effective height minimum 3 resp. 5 cm

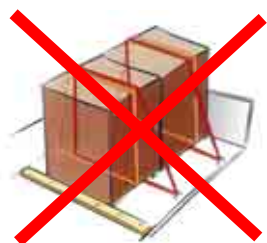
- Direct lashing, cross or straight lashings, (chapter 5.4.4). Where goods are secured by direct lashings only, the lashings must act both in longitudinal and transverse direction. This means that loop and spring lashings, see below, may not be used, as such lashings are acting in one direction only.



*Cross lashing (Direct)*



*Straight lashing (Direct)*



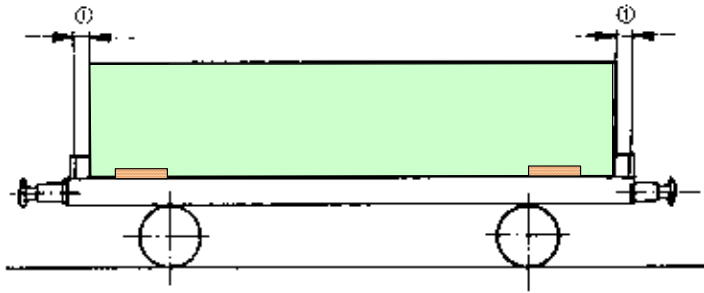
*Loop lashing*



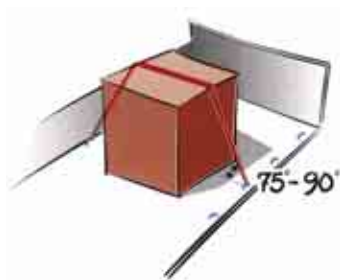
*Spring lashing*

*Loop lashing and spring lashing are not direct lashing methods according to UIC.*

- Arrangements allowing longitudinal sliding (chapter 5.5)



- Indirect lashing, top-over lashing, (chapter 5.5.4)

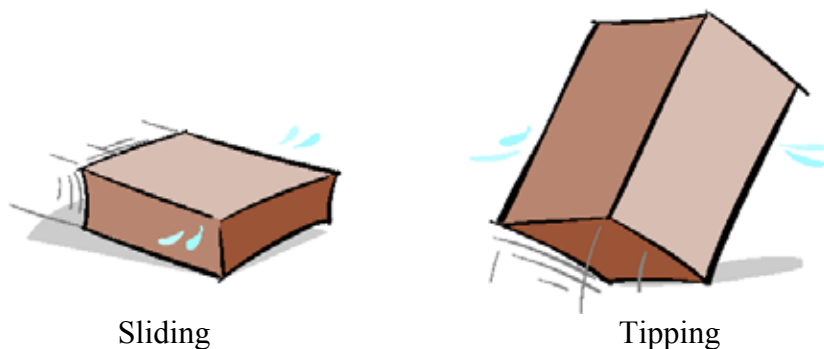


- Increased friction (chapter 5.5.5)



### 3.4 Acceptable methods for preventing longitudinal and transverse sliding, tipping and rolling

Below a general description is given of the basic acceptable methods for preventing longitudinal and transverse sliding, tipping and rolling of the goods according to the UIC guidelines. It is not guaranteed that all aspects have been considered, as the guidelines are very difficult to interpret.



### 3.4.1 Acceptable methods to prevent longitudinal sliding

Longitudinal sliding may be prevented by any of the following methods:

1. Blocking against gables, partition walls or stanchions. According to chapter 5.4.1 the goods must be compact loaded alternatively empty space to be filled by empty pallets, bracings or air bags. The goods must be blocked up to at least 10 cm of its height.
2. Nailed timbers. The max allowed goods weight blocked by nailed timbers is found in chapter 5.4.3 as well as required number of nails.
3. Direct lashings (cross or straight lashings) with strength according to chapter 5.4.4.
4. Free sliding in longitudinal direction. Such arrangements should have clearances in longitudinal direction according to chapter 5.5.2.
5. Indirect lashings (top-over lashings) may be used to limit potential sliding in longitudinal direction according to chapter 5.5.4.

### 3.4.2 Acceptable methods preventing transverse sliding

Transverse sliding may be prevented by any of the following methods:

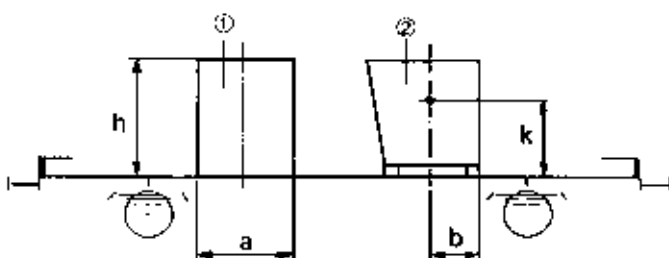
1. Blocking against walls, sides or stanchions. The goods is regarded as blocked if the distance between the goods and the blocking device on each side is maximum 10 cm, see footnote to chapter 5.4.1. Gaps larger than 10 cm may be filled by empty pallets, air bags etc.
2. Nailed timbers. The max allowed goods weight blocked by nailed timbers is found in chapter 5.4.3 as well as required number of nails.
3. Direct lashings (cross or straight lashings) with strength according to chapter 5.4.4.
4. Friction enhancing inserts with a friction coefficient of at least 0.7. According to chapter 5.5.5 friction enhancing inserts alone is not enough to prevent goods from falling off the wagons. This means that other functions as sides, walls or stanchions must be used in combination with friction inserts. By using friction inserts it is, however, assumed that the distance to the blocking devices may be larger than 10 cm.

**NOTE!** Indirect lashings (top-over lashings) alone are not accepted for preventing transverse sliding. If this is the case also in cargo transport units intended for combined transports is unclear.

### 3.4.3 Acceptable methods preventing tipping

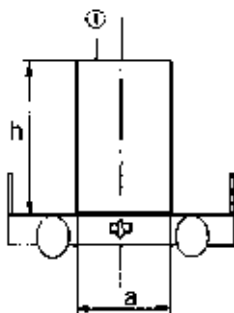
Tipping may be prevented by any of the following methods:

1. According to chapter 5.4.1 goods liable to tipping must be secured by sides or walls to at least the height of their centre of gravity.
2. According to chapter 5.7 goods must be prevented from tipping in longitudinal direction if  $a/h$  or  $b/k$  is less than 0.7, see figure below.

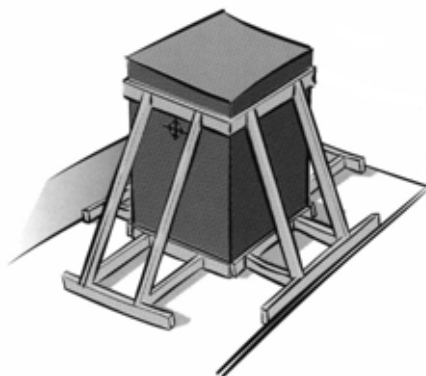


This means that the goods must be prevented from tipping if the height of the goods is larger than:  $1.4 \times$  the length of the goods.

3. According to chapter 5.7 goods must be prevented from tipping in transverse direction if  $a/h$  or  $b/k$  is less than 0.5. This means that the goods must be prevented from tipping if the height of the goods is larger than:  $2 \times$  the width of the goods.



4. According to chapter 5.7 tipping can be prevented by:
  - compact loading without gaps and by binding the outer units together by round-turn lashings with strength according to chapter 1.5.
  - direct lashings (cross or straight lashings)
  - supports on the sides or underneath



**NOTE!** Indirect lashings (top-over lashings) alone are not accepted for preventing tipping. If this is the case also in cargo transport units intended for combined transports is unclear.

### **3.4.4 Acceptable methods preventing rolling**

Rolling may be prevented by any of the following methods:

1. According to chapter 5.6 rolling can be prevented by fixed walls, sides, stanchions, scotches, trestles or cradles.
2. Requirements on securing of rolling units with the axis in transverse direction are found in chapter 5.6.1.
3. Requirements on securing of rolling units with the axis in longitudinal direction are found in chapter 5.6.2.
4. Wheel and track based vehicles and machinery are to be secured against longitudinal and transverse movement using scotches or by direct lasing according to chapter 5.6.3.

## **3.5 Test of new loading methods**

### **3.5.1 Impact tests according to UIC**

New loading methods may be tested in longitudinal direction by impact tests. The tests are described in Table 4 of the UIC guideline section 1. A test is carried out by shunting the wagon loaded according to the method to be tested (test wagon) against another wagon (impact wagon). The impact wagon shall have a total weight of 80 tons and be un-braked. The same result will be achieved if the impact wagon is shunted against the test wagon.

The test program for wagons subject to fly and gravity shunting conditions is as follows:

Two impacts in the same direction,

- 1<sup>st</sup> impact at 5-7 km/h
- 2<sup>nd</sup> impact at 8-9 km/h



followed, without any adjustment of the load fastenings, by

- counter-chock at 8-9 km/h

The need to carry out a counter-chock must be assessed on the basis of the results of the two previous impacts with account taken, where appropriate, of the features of the goods carried and loading type.

The test program for wagons not subject to fly or gravity shunting conditions is as follows:

Two impacts in the same direction, both at 3-4 km/h.

### **3.5.2 Running tests according to UIC**

New loading methods may be tested in transverse direction by running tests or tests on the dynamic rig.

When conducting a running test a wagon with the suggested loading arrangement is transported on a part of a railway track. The distances between the cargo and the wagon's sides are measured and marked before the departure and at the arrival. Any movement among the cargo is noted. A number of these trips are carried out. If the movement of the cargo is sufficiently low the test trips will proceed during 1 – 2 years. If there are no accidents during this period the loading arrangement will be approved.

The German Railways' dynamic rolling rig is located in Munich. When testing in the rig a recorded part of a railway track is used to give correct accelerations.

### **3.5.3 Impact tests according to AAR**

An impact test for open top wagons may be carried out by shunting the wagon loaded according to the method to be tested (test wagon) against another wagon (impact wagon). The impact wagon shall have a total weight of 250000 lb (113 tons) and be un-braked. The same result will be achieved if the impact wagon is shunted against the test wagon.

The test program for wagons subject to fly and gravity shunting conditions is as follows:

Three impacts in the same direction,

- 1<sup>st</sup> impact at approx. 6.4 km/h
- 2<sup>nd</sup> impact at approx. 9.7 km/h
- 3<sup>rd</sup> impact at 12.9 km/h (tolerance +0.8, -0.5 km/h)

followed, without any adjustment of the load fastenings, by

- counter-chock at 12.9 km/h (tolerance +0.8, -0.5 km/h)

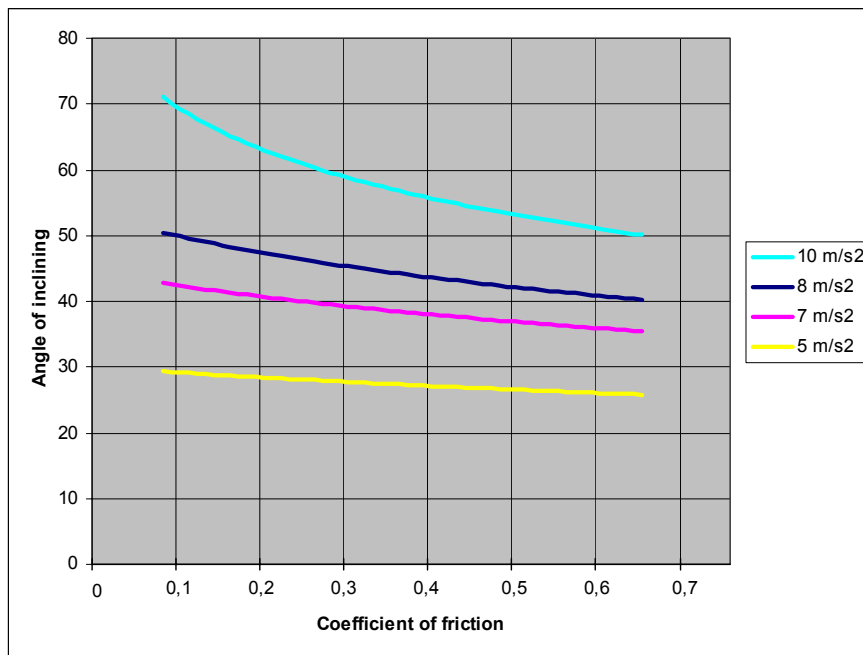
**3.5.4 Tests of loading methods for transport on road and at sea**

The Swedish National Road Administration, the Swedish Maritime Administration and the IMO Model course 3.18 propose the following practical method for the determination of the efficiency of a securing arrangement.

The cargo (alternatively one section of the cargo) is placed on a lorry platform or similar and secured in the way intended to be tested.

The securing arrangement is tested by gradually increasing the inclination of the platform to an angle ( $\alpha$ ) according to the formulas and diagram below. The inclination is a function of the following parameters:

- the combination of horizontal and vertical accelerations for the intended mode of transportation
- the coefficient of friction  $\mu$  between the cargo and the platform bed or between cargo units if stapled



*Required angle of inclination as a function of acceleration and friction.  
Vertical acceleration is 9.81 m/s<sup>2</sup>.*

The required heeling angle  $\alpha$  for a known coefficient of friction  $\mu$  is determined by the following equation:

$$m \times g(\sin \alpha - \mu \times \cos \alpha) = m \times g(a_h - \mu \times a_v)$$

Where the left part represents the required securing force in the test condition and the right part the required securing force for the design accelerations.

The solution to the equation is:

$$\alpha = 2 \times \arctan \left[ \frac{-1 + \sqrt{1 + \mu^2 - \mu^2 \times a_v^2 + 2 \times \mu \times a_v \times a_h - a_h^2}}{\mu + \mu \times a_v - a_h} \right], \quad \mu \neq \frac{a_h}{1 + a_v}$$

$$\alpha = 2 \times \arctan \left[ \frac{a_h}{1 + a_v} \right], \quad \mu = \frac{a_h}{1 + a_v}$$

Where:

- $\mu$  Coefficient of friction
- $a_h$  the design horizontal acceleration in [g]
- $a_v$  the design vertical acceleration in [g]
- $g$  gravity acceleration 9.81 m/s<sup>2</sup>

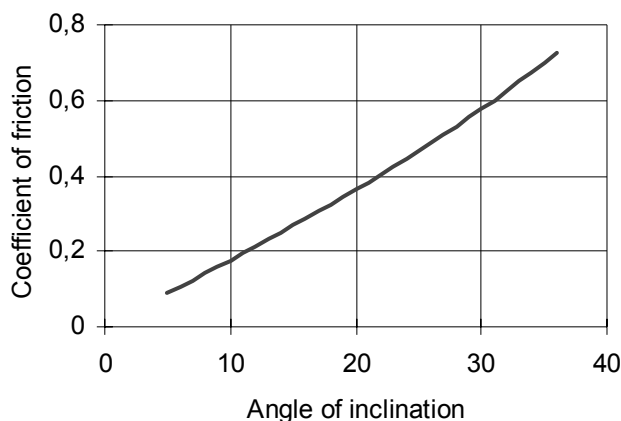
For securing arrangements where the cargo is not allowed to slide the static coefficient of friction is used, else the dynamic friction. If the dynamic friction is unknown it is to be taken as 70% of the static friction.

The securing arrangement is regarded as complying with the requirements if the cargo is kept in position with limited movements when inclined to the prescribed inclination ( $\alpha$ ).

The test method will subject the securing arrangement to stresses and great care should be taken to prevent the cargo from falling off the platform during the test. If large weights are tested the entire platform should be prevented from tipping as well.

The static coefficient of friction can be determined by the following test:

The cargo (alternatively one section of the cargo) is placed on a lorry platform. The inclination of the platform is gradually increased. The angle of inclination ( $\alpha$ ) is read off when the cargo starts to slide. The coefficient of friction ( $\mu$ ) is  $\mu = \tan(\alpha)$  or as illustrated in the diagram below.



*Friction as a function of the angle of inclination.*



*Test of securing arrangement for road transport.*

### **3.5.5 Improved tests for sideways accelerations at railway transport**

There are some problems with the two test methods mentioned in section 3.5.2. Either they take long time and are a potential risk in the traffic during the test period (running tests) or they are very expensive (test rig). A test in the test rig costs about SEK 1.5 million, which usually is a too large expense for testing a cargo securing arrangement. Other problems with the running tests are that the standard of the track could change in the future or the transport way could be changed.

It would be desirable to have a test program that is as easy to perform as the one for tests in lengthways direction, impact tests. Such a test is the one used for road and sea transports, see section 3.5.4. It is recommended that securing arrangements for rail transport are allowed to be tested in the same way and for the same forces as for road transports. Special consideration must, however, be taken to the vibrations that occur in a railway wagon.

### 3.6 Specific instructions for securing of different cargo types according to UIC

Section 2 of the UIC loading guidelines contains instructions for loading and securing of different types of cargo. The instructions are very condensed, which makes them very difficult to understand.

Below the securing arrangement for some of these instructions are described.

#### 3.6.1 Flap 2 – Metal products

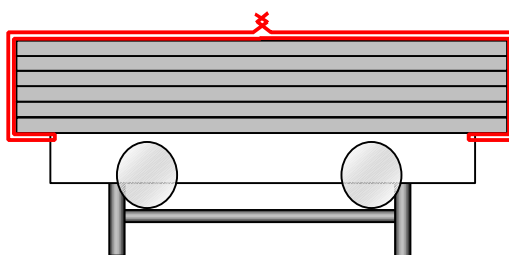
A large number of different loading guidelines are found for metal products.

- **Loading guidelines 1.2.5 – Medium and heavy plates (un-greased and especially wide)**

These guidelines are valid for plates stacked on top of each other with intermediate timbers. The plates are wider than the effective width of the wagon (no stanchions).

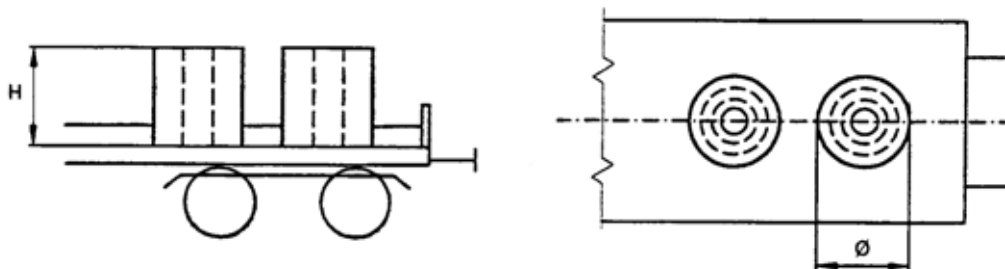
In longitudinal direction the plates are secured by the end walls and the plates may not be stowed over the top of the end walls. The distance to the end walls is optional and any distance is acceptable from zero and upward.

In transverse direction the only securing required is top-over lashings consisting of 4 annealed wire strands ( $\varnothing$  5 mm) drawn doubled from ring to ring on the wagon over the cargo. One securing should be used per approximately every 3 m, independently of the weight of the cargo. Each plate or stack of plates should be secured by at least 2 lashings.



- **Loading guidelines 1.3.2 - Un-greased hot-rolled coiled sheet**

Coiled sheet loaded “eye to sky” may be stowed directly on the wagon floor or on two parallel longitudinal soft wood timbers. If there is no tipping risk of the coils, no additional securing (no blocking and no lashing) is required in longitudinal or transverse direction.



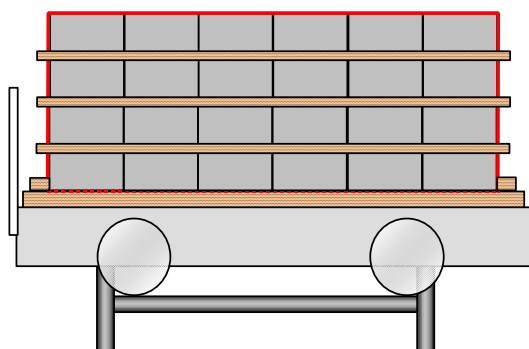
▪ **Loading guidelines 1.6.1 – Steel section (un-greased)**

Steel sections of varied dimensions without packaging stowed in several layers with intermediate wooden timbers, may be secured according to the below.

The bottom layer is to be secured in transverse direction by stanchions or nailed timbers.

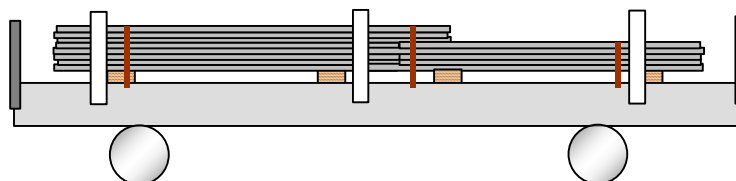
Layers over the lowest may be secured by round-turn lashings to the lowest layer alternatively by top-over lashings. All lashings with a breaking strength of at least 14 kN (1400 kg). One lashing should be used per 6 m length, but minimum 2 lashings per section independently of the section weight.

If steel bars are lying with the flanges down, no lashings are required!

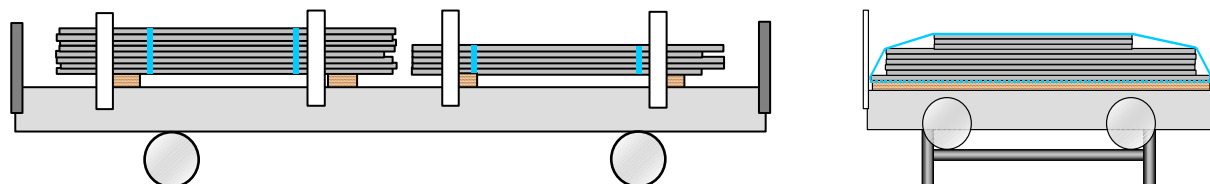


- **Pink loading guidelines 100/74-101-99 and 1/74-104-99 (SJ, DB) heavy plates**

For wagons equipped with fixed self-tensioning chain lashings, it is allowed to secure stacked heavy plates in transverse direction by two top-over lashings per section.



Alternatively the bottom plates are secured in transverse direction by nailed timbers (if not secured directly by stanchions) and remaining plates in upper layers are secured by two round-turn lashings with a break load of min 20 kN (2000 kg).



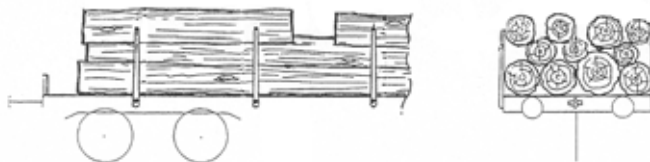
In both cases the wagons must be equipped with stanchions, but there are no restrictions regarding maximum distance between plates and stanchion.

### 3.6.2 Flap 3 – Wooden products

Under this flap, instructions for among others logs and sawn timber in packages are found.

▪ **Loading guidelines 2.1 – Rough logs**

Stanchions on the sides may only secure logs, as long as the top of the logs is below the top of the stanchions. End walls on the wagons are not required. For some types of stanchions, intermediate lashings, binding the stanchions together, are required.

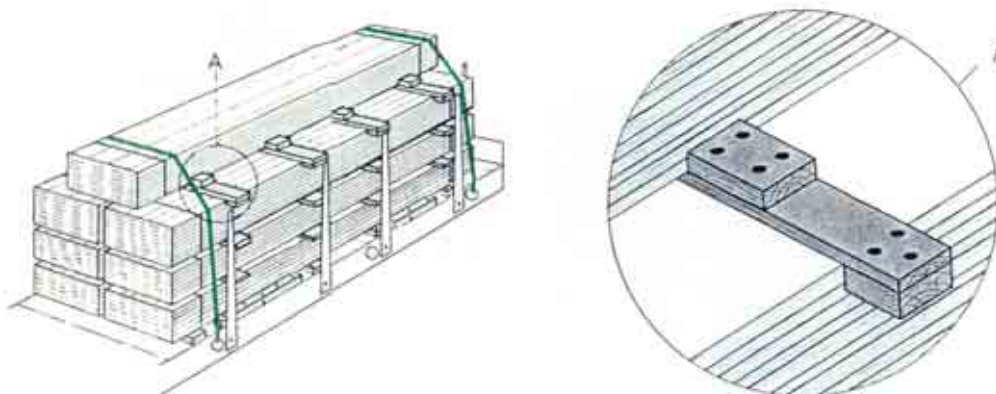


▪ **Loading guidelines 2.2.2 – Square sawn timber in packages**

Sawn timber in packages stowed in several layers may be secured according to below.

The bottom layer is prevented from sliding sideways by nailed timber or stanchions. The layers above are secured to the lowest layer by two round-turn lashings with a break load of at least 7 kN (700 kg). Alternatively the top layers are secured by blocking according to the sketch below.

Independently of the way the top layers are secured, two top-over lashings with a breaking strength of 10 kN should be used per section. Alternatively one top-over lashing with a breaking strength of 40 kN (4000 kg) should be used.



**3.6.3 Flap 5 – Paper products**

Instructions are found for standing and laying paper reels as well as for wood pulp in bales. No instructions are found for paper sheets on pallets.



- **Loading guidelines 4.1.1 – Rolls of paper loaded on the roll (eye to side)**

Rolls stowed eye to side are to be secured in longitudinal direction by the ends of the wagon or by nailed wooden scotches every 3 to 4 roll.

The second layer shall be prevented from sliding in transverse direction by friction enhancing inserts.

There are no requirements for the securing of the first layer in transverse direction. Nor is there any requirement regarding maximum stowage height in relation to the width of each staple eliminating the risk of transverse tipping.

- **Loading guidelines 4.1.3 – Rolls of paper loaded upright (eye to sky)**

Rolls stowed in parallel rows may not be additionally secured if the distance to the sides is less than 10 cm. If the distance is larger, transverse movement will have to be prevented by filling material between the rolls and the sides, by nailed timbers or by friction enhancing inserts. Rolls in a second layer must be secured by friction enhancing inserts.

Rolls stowed in a sick-sack pattern must be stowed minimum 10 cm from the sides and secured in transverse direction by filling material between the rolls and the sides, by nailed timbers or by friction enhancing inserts. Rolls in a second layer must be secured by friction enhancing inserts at distances larger than 10 cm to the sides.

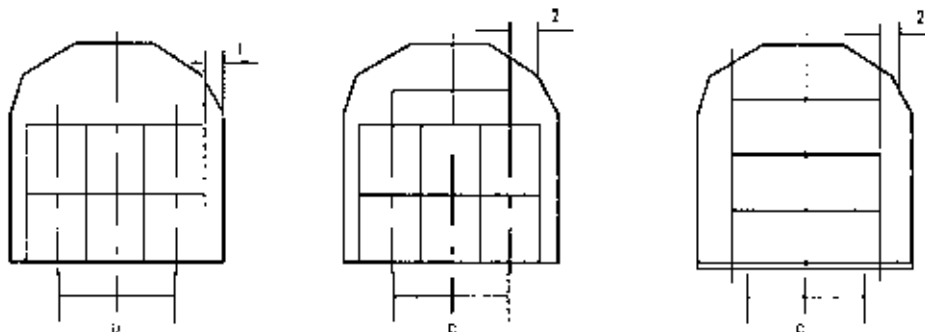
The height of the rolls or the staples of rolls must not be larger than  $1.4 \times$  the diameter of the rolls. It is not indicated how to secure rolls exceeding the given value.

- **Loading guidelines 4.1.4 – Rolls of paper and wood pulp loaded upright (eye to sky)**

These guidelines are valid for listed bogie wagons and permanently coupled wagon units with strengthened sliding walls and fixed end walls.

Due to the stronger sides, also rolls stowed in a sick-sack pattern may be stowed closer to the sides than 10 cm. If the distance between the rolls and the vertical part of the sides is less than 10 cm no additional securing is required. If the distance exceeds 10 cm, transverse movement will have to be prevented by filling material between the rolls and the sides, by nailed timbers or by friction enhancing inserts. Rolls in a second layer must be secured by friction enhancing inserts at distances exceeding 10 cm.

Note: no part of the roll staple may be stowed closer to the sloping roof than 10 cm. See figure below.



1/ Max 10 cm

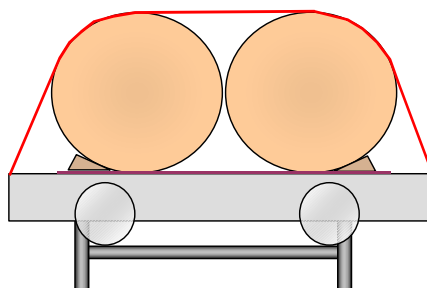
2/ Min 10 cm

- **Loading guidelines 4.1.2 and 4.1.6 – Rolls of paper loaded “gunshot” (eye to end)**

Rolls loaded eye to end shall either be secured tightly between the wagon’s ends or if the wagon is fitted with special devices for fixing scotches, rolls could be loaded in close succession starting from the end walls. Free space should be in the middle of the wagon.

- **Proposal to loading guidelines 4/80-101-00 Rolls of paper loaded “gunshot” (eye to end) side-by-side.**

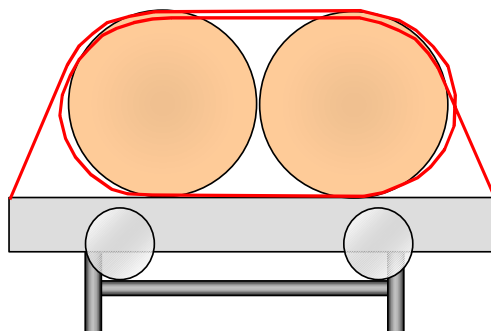
Rolls are lying in pairs and are secured by un-nailed scotches, top-over lashings and friction enhancing inserts. Empty space should be in the middle of the wagon only.



- **Proposal to loading guidelines 4/81-102-01 and 4/81-101-02 Rolls of paper loaded “gunshot” (eye to end).**

In 4/81-102-01 rolls are lying in pairs and are secured by un-nailed scotches. The scotches are bound together in pairs by webbing, lying under the rolls. Empty space (lengthways) should be in the middle of the wagon only.

In 4/81-101-02 rolls are lying in pairs and are secured by two loops per section. Empty space (lengthways) should be in the middle of the wagon only.



### 3.6.4 Flap 10 – Barrels

Two guidelines for barrels are presented.

- **Loading guidelines 10.2 – Barrels in wagons with sliding walls**

Barrels may be stowed in two layers if panels are placed between the layers.

It is allowed to secure the second layer in transverse direction by friction enhancing inserts only. Alternatively timber scotches should be used.

### 3.6.5 Flap 11 – Palletised load units

Under this flap instructions for the securing of the goods on the pallets are found only. No instructions are found on how to secure the pallets in the wagons. According to information there is no problems with transportation of pallets on rail, and thus no instructions is required. It is unclear if this means that pallets may be stowed and secured in any way in wagons in optional number of layers. In chapter 11 of this report a proposal for instructions of securing of palletised cargo is given.

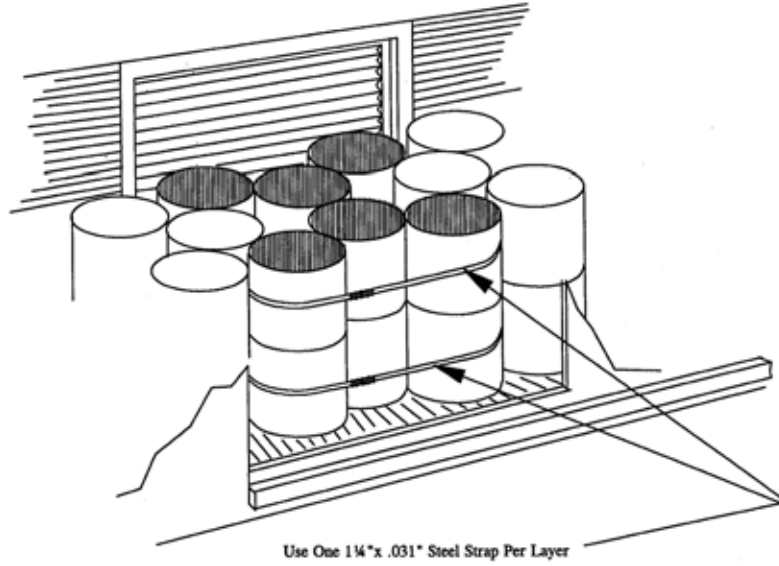
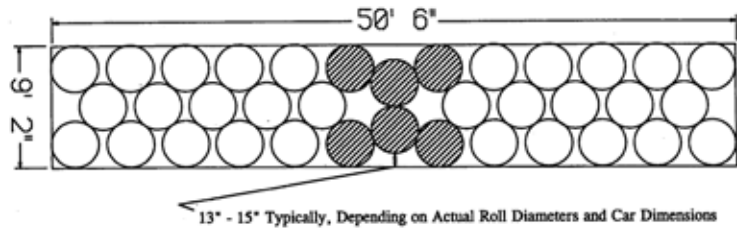
### 3.6.6 Examples of cargo securing according to AAR

AAR (Association of American Railroads) has a large number of instructions for various products. When loaded in a closed car the cargo does not has to be secured lateral if the distance to the (strong) walls is less than 12” (approximately 30.5 cm). Otherwise it should be blocked, for instance by nailed timber or friction enhancing inserts. The cargo should always be secured in the door area.

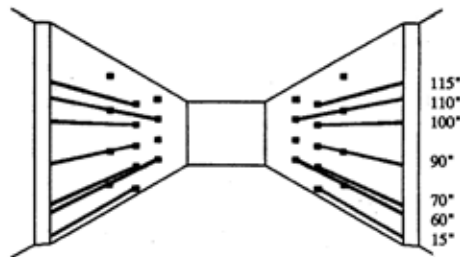
Examples of loading instructions by the AAR.

**ROLL PAPER/PULPBOARD IN CLOSED CARS**

Ex. 1

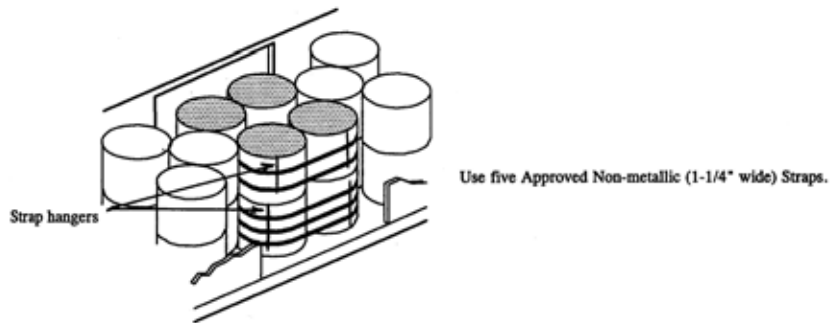
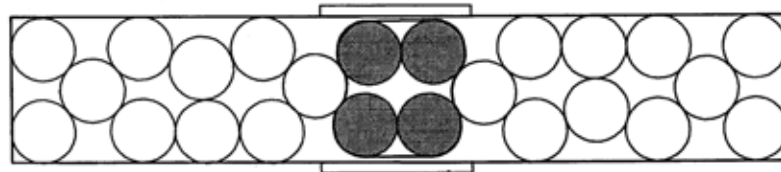


Ex. 2

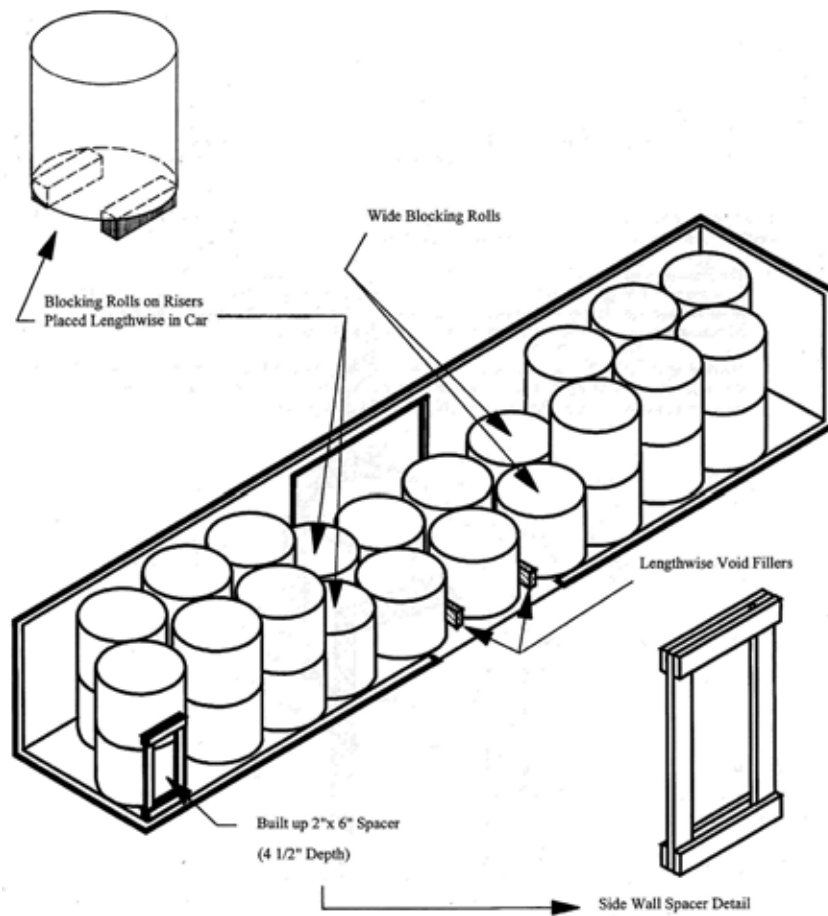


Position Anchor Straps As Closely As possible To Heights Shown  
Use 1 1/4" x .031" Steel Strapping

Ex. 3

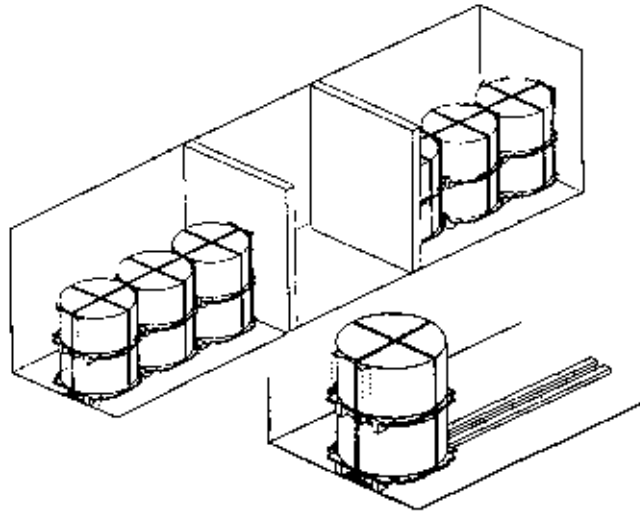


Ex. 4



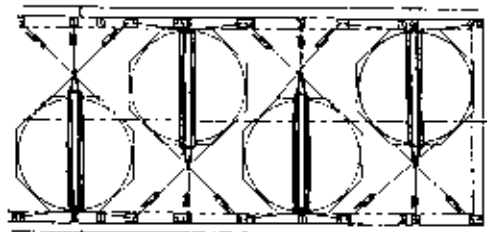
**METAL COILS**

Ex. 1 – GIS 628



- Blocked lengthways.
- Blocked sideways by nailed timber.
- 2:nd layer secured by rubber mats and steel straps.

Ex. 2 – GIS 643



Side View



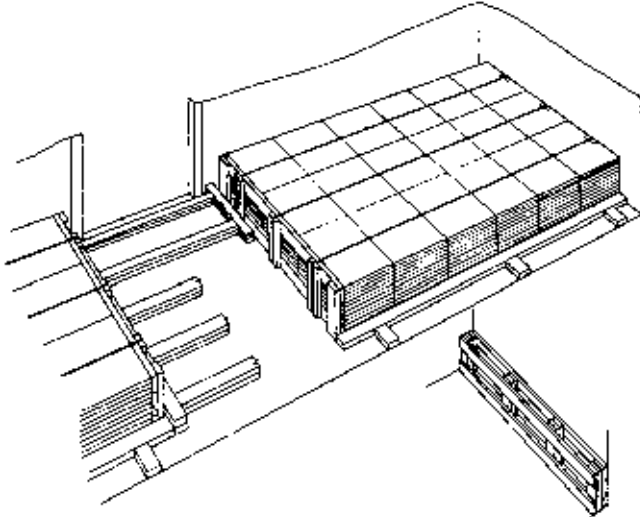
End View

Secured by two spring lashings and one top-over lashing, break load 110 kN (11 ton).

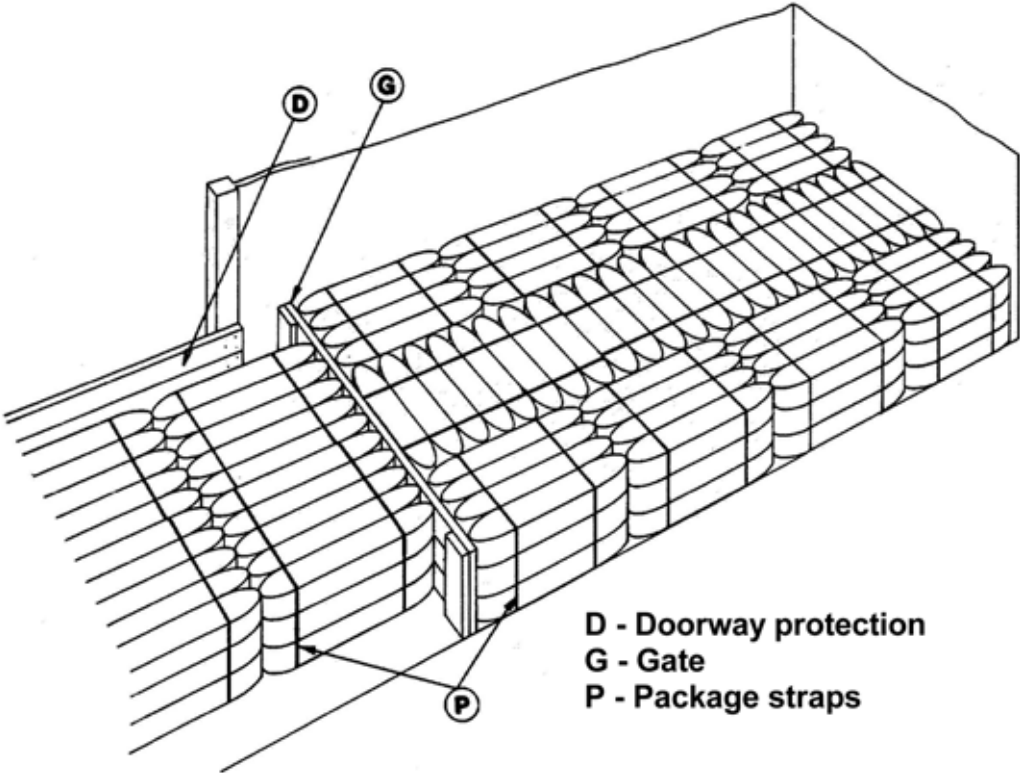
**HIGH DENSITY METALLIC COMMODITIES IN CLOSED CARS**

DP 37

Ex. 1



Ex. 2

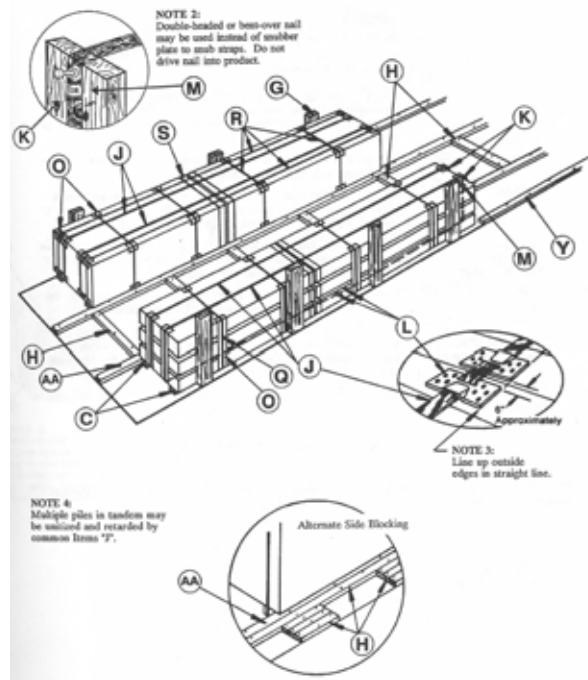


**FLAT ROLLED STEEL PRODUCTS, CUT LENGTHS, MULTIPLE UNITS.**  
 Placed Lengthwise in Car Against Side Walls, Single Packages or Multiple Tiered Packages

FIG. NO. 3  
 FLAT ROLLED STEEL PRODUCTS, CUT LENGTHS, MULTIPLE UNITS  
 Placed Lengthwise in Car Against Side Walls, Single Packages  
 Or Multiple Tiered Packages

Item	No. of Pkts.	Description
AA	1 per pile	Lumber 1" x 3" minimum, to extend from end of car through doorway or full length of car. To be placed outside of and approximately 2" from inner "L". Secure to floor with 3" nails spaced not more than 18" apart. If responsible to end full length, seal at exposed portions. Not required when the open vacuum space between piles and between the load and car sides does not exceed 12".
C	As required	Wooden slats, male beveled. Secured to packages by longitudinal items "R".
Q	3 every 4 feet. At least 2 per car.	Lumber 1" x 3" with length sufficient to extend beyond top of pile. Locate and secure to car side with a maximum of three 3" nails. Use optional.
H	1 every 4 feet	Lumber 1" x 3" minimum, with length equal to distance between items "AA". Secure each to floor with a maximum of three 3" nails under 12" long, two nails. May also be applied lengthwise if space will not permit otherwise application. See paragraph 12.8. Use additional pieces as required to fill space between items "AA". Secure to floor with a maximum of two 3" nails. If full length parallel sections are used, secure to floor with 3" nails not more than 18" apart.
J	2 each row	2" x (50) or equivalent high-tensile strips. Run through item "L" and secure to items "K" where used.
K	1 each item "J" at doorway end of car	2" x 4" minimum lumber, length approximately equal to height of pile. Use only with multiple tiered packaged piles.
L	As required	Rails (plate or other similar approved device). Nail to the floor, one plate per floor board or walking groove. Locate near center of car. See paragraph 11.
M	1 each item "K"	Slabber plates or equivalent. Nail to items "K" where used. A double-headed nail may be used to slab strips. See paragraph 12.9.
D	As required	Pressure angles, 20 gauge x 4" wide, secured to prevent displacement. Manufactured edge pressure giving equal protection may be used. Not required on upright package piles when items "S" are used.
Q	Minimum 2 placed close-wire on each multiple tiered pile	Unit load bars. Minimum 2" x (50) or equivalent high-tensile strips (Package data have been eliminated for clarity).
R	Minimum 2 each direction	Package ties. High-tensile post strips or high-tensile wires (Shown as single package only).
S	As required	Winter slats, lumber or other suitable material between adjacent packages to prevent chafing or damaged ends. Use optional.
Y	As required	Doorway protection 1" x 3" lumber, minimum. Extend beyond doorway and secure to floor with 3" nails. Nail every 24" car construction permitting.

NOTE 1: Height of piles, including slats, is set in cleared width of the end-walld package or car.





## 4 IMPACT TESTS AND TESTS WITH NAIL JOINTS AND WEBBINGS CARRIED OUT IN THE PROJECT

This chapter shows results from tests carried out within the jvgRASLA-project.

### 4.1 Impact tests

#### 4.1.1 Purpose

The purpose of impact tests is to check whether the loading methods used and loose fastenings could withstand the longitudinal stresses exerted during railway operating.

#### 4.1.2 Test conditions

The tests were conducted in accordance with the conditions described in Table 4.1 Section 1 RIV Appendix II, see section 4.4.1 above.

#### 4.1.3 Loading methods tested in the project

Impacts tests were carried out in Malmö 203-02-12. Green Cargo supplied required wagons, locomotives, shunting area and shunting personnel, Ovako Steel supplied steel pipes, StoraEnso supplied trailer with paper reels and MariTerm made the required documentation. The following was tested:

- Wagon 1; loaded with greased steel pipes in bundles
- Wagon 2; loaded with a trailer that was loaded with laying paper reels
- Wagon 3; loaded with cars

The tests are also documented on a video, which could be ordered from MariTerm AB.

#### **Wagon 1 – Greased steel pipes**

The impact tests were carried out with a Kbis-wagon loaded with 18 ton greased steel pipes in bundles from Ovako Steel in Hofors. The cargo was distributed in two sections, 9 tons each.

One of the sections was secured by two indirect fastenings (top-over lashings) and the other was unsecured. At the first impact (6 km/h) the section secured by indirect fastenings shifted 28 cm and the unsecured shifted 45 cm. At the second impact (9 km/h) the section secured by indirect fastenings shifted additional 39 cm and the unsecured bunged into the end wall (additional 45 cm). The total shifting for the section secured by indirect fastenings was 67 cm and for the unsecured section it was 90 cm. If the end wall had not stopped the shifting it should have been considerable more than 90 cm.

The section that originally was secured by indirect fastenings was re-secured by two loop lashing pairs. No readjustment of the section was carried out. At the first impact (6.5 km/h) the section shifted 17 cm. At the second impact (9 km/h) the section shifted additional 28 cm. The total shift was thus 45 cm.

The results and photos from the tests are shown below.

	Impact speed	Shift	
		Section secured by indirect fastenings	Unsecured section
<b>1<sup>th</sup> impact</b>	6.0 km/h	28 cm	45 cm
<b>2<sup>nd</sup> impact</b>	9.0 km/h	39 cm	to end wall 45 cm
<b>Total</b>		<b>67 cm</b>	<b>&gt; 90 cm</b>
		<i>Section secured by loop lashing pairs</i>	
<b>1<sup>th</sup> impact</b>	6.5 km/h	17 cm	
<b>2<sup>nd</sup> impact</b>	9.0 km/h	28 cm	
<b>Total</b>		<b>45 cm</b>	



Sections before the tests



Section secured by indirect fastenings after the 1<sup>st</sup> test



Section secured by indirect fastenings after the 2<sup>nd</sup> test



Section secured by two loop lashing pairs

### **Wagon 2 – Wagon (combi) with a trailer loaded with paper reels**

The impact tests were carried out with a wagon loaded with a trailer. The trailer was loaded with laying paper reels (eye to side) from StoraEnso in Grycksbo. The reels were placed two or three in breadth in a total of 12 rows. The roll diameter was about 1.1 m, the total number of reels was 34 and the total weight of the reels was 22 424 kg.



Behind each reel there was a small stop wedge, not nailed to the platform. The cargo was secured by corner protection and totally eight indirect fastenings (top-over lashings) made of 4-tons web lashings. The corner protections consisted of deals nailed together in 90-degree angle. The last row of reels was secured by scotches nailed to the platform.

Totally six impact tests were carried out at a speed of about 4 km/h. The reason for making the tests was to evaluate different scotch alternatives at the last row.

#### **Impact test 1**

The last row with reels was secured by six (two at each reel) wooden scotches (height about 15 cm). Each scotch was nailed with three 3” nails. The impact speed was 3.8 km/h. No larger movement among the reels could be detected. It could be concluded that this securing method is sufficient for lengthways securing even if the scotch height and number of nails was less than required by the UIC loading guidelines 4.1.1.

#### **Impact test 2**

The wooden scotches were replaced by scotches of frigolit (Styrofoam). The frigolit was of a soft quality. Two scotches were put behind each reel. The scotches was fixed by a 2×4”-batten nailed with 4”-nails, totally six nails. The impact speed was 5.5 km/h. The scotches collapsed and the reels shifted to the pallets placed between the reels and the rear doors, about 5 cm.

**Impact test 3**

The cargo was readjusted after test 2 (stop wedges where put in place). The last row was secured by rubber scotches with a height of about 19 cm. The scotches were fixed by a 2×4"-batten nailed with 4"-nails, totally six nails. The impact speed was 3.8 km/h. The reels bounced against the scotches but stayed in their original positions. It could be concluded that this securing method is an alternative to wooden scotches. If using rubber scotches a recycle system is needed.

**Impact test 4**

The cargo was readjusted after test 3 by correcting the stop wedges. The same rubber scotches as in test 3 were used, but this time no batten was placed behind the scotches. The impact speed was 3.9 km/h. There was a larger movement among the reels than in test 3 and it was concluded that a nailed batten is needed for fixing the scotches.

**Impact test 5**

The cargo was readjusted after test 4 by correcting the stop wedges. This time larger frigolit scotches and by a better (stiffer) quality than in test 2 were used. The scotches were fixed by a 2×4"-batten. The impact speed was 4.0 km/h. The scotches were almost undamaged and no larger movement among the reels could be detected.

**Impact test 6**

The same scotches as in test 5 were used. The cargo was not readjusted after test 5. The impact speed was 4.2 km/h. This time the scotches collapsed. It could thus be concluded that also frigolit scotches of a stiffer quality could not be used to take up shunting forces.

The table and photos below summarize the result of the impact tests.

<b>Impact test</b>	<b>Speed</b>	<b>Securing of the last row with reels *</b>	<b>Note</b>
1	3.8 km/h	6 wooden scotches, about 15 cm high, nailed with three 3"-nails each.	The reels stayed in their original positions.
2	5.5 km/h	6 frigolit scotches, soft quality, fixed with a nailed batten.	Scotches collapsed.
3	3.8 km/h	Rubber scotches about 12 cm high, fixed by a nailed wooden batten.	The reels bounced against the scotches but stayed in their original positions.
4	3.9 km/h	Rubber scotches, as above, without any support.	Larger movement among the reels than in test 3.
5	4.0 km/h	6 frigolit scotches, stiff quality, fixed with a nailed batten.	No larger movement among the reels.
6	4.2 km/h	Retest of scotches in test 5 without readjustment of the cargo.	Scotches collapsed.

\* In addition to the scotches behind the last row with reels, a small stop wedge was placed behind each reel. The stop wedges were not nailed. The cargo was also secured by totally eight indirect fastenings. Long corner protections were used.



1<sup>th</sup> test – nailed wooden scotches



2<sup>nd</sup> test – frigit scotches (soft) before the test



2<sup>nd</sup> test – frigit scotches(soft) after the test



3<sup>rd</sup> test – Rubber scotches + nailed batten



4<sup>th</sup> test – Rubber scotches without batten



5<sup>th</sup> test – frigit scotch (stiff) before test



6<sup>th</sup> test – frigit scotch (stiff) after the second test

### **Wagon 3 – Cars**

Two impact tests were carried out with a car transport wagon loaded with two cars, one Volvo 740 and one Volvo 440. The cars were placed with their fronts in the shunting direction.

The Volvo 740 was lashed with four direct fastenings each with a breaking strength of 10 kN (2×500 kg). According to the UIC loading guidelines 7.2, the strength of each lashing should be at least 40 kN (4 ton). The lashings were attached in the car’s towing eyelet (front end) and in the rear tow hook.

The Volvo 440 was secured with four steel scotches. The scotches were suited to the wagon.

### **First impact test**

At the first impact test the rear lashings of the Volvo 740 broke at a sharp edge on the wagon. The Volvo 440 moved forward as the scotches broke loose, probably due to poorly performed application

### **Second impact test**

Before the second test the Volvo 740 was lashed in a way so the sharp edge was avoided. At the test the left rear lashing broke at the tow hook. The Volvo 440 “climbed” up on the scotches but slid back to its original position.



Volvo 740 with lashings in towing eyelet and tow hook. Scotchies were not in contact with the wheels (only precaution).



Volvo 740 with lashings in towing eyelet and tow hook. Volvo 440 secured with one scotch per wheel.



Volvo 440 secured with one scotch per wheel.

#### 4.1.4 Summary and conclusions

##### Greased steel pipes

The following conclusions could be drawn from the impact tests with greased steel pipes:

- Sections with pipes without any securing shifts much more than the 50 cm that is stipulated in the UIC Loading Guidelines.
- Sections with pipes secured by indirect fastenings shifts about 50% longer than sections that are secured by loop lashing pairs.
- Only sections secured by loop lashing pairs shifted a shorter distance than 50 cm, after the second impact.
- To avoid damages to wagons and goods it is thus recommended to use loop lashings for steel pipes in bundles even if the UIC loading guidelines 1.4.7 allow transportation of pipes stowed between stanchions without additional securing.

### **Trailer loaded with paper reels**

The following conclusions could be drawn from the impact tests with laying paper reels in a trailer for none hump and fly shunting:

- Less number of nails than stipulated in the UIC Loading Guidelines is needed.
- Less scotch height than stipulated by UIC could be used.
- Scotches of rubber could be used as an alternative to wooden scotches if a nailed batten fixes them.
- Scotches of frigolit do not have enough strength to endure shunting.

### **Cars**

The following conclusions could be drawn from the impact tests with cars on a car transport wagon:

- It is important that lashings with sufficient strength are used when cars are secured without scotches.
- Cars secured with scotches can climb up on the scotches. After the test the car slid back and resumed its original position. Enough distance to the cargo plane above must thus be sought for.
- Scotches must be well attached to the wagon.

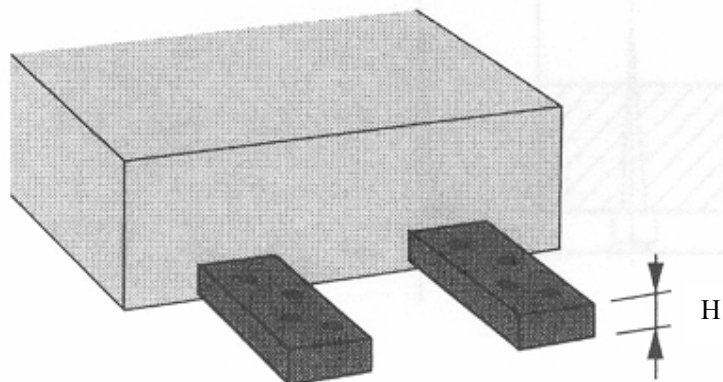
## **4.2 Nail joints**

### **4.2.1 Purpose**

Tests with nail joints were carried out in two different wagons in Malmö 2003-04-24. Gunnebo Industrier was responsible for the tests, Green Cargo supplied the wagons and MariTerm made the required documentation.

The purpose of the tests was to establish how large forces nailed battens can take up. The results could be used to estimate which accelerations the cargo can withstand when secured according to UIC (RIV Appendix II, Section 1, 5.4.3). As the UIC:s loading guidelines applies to a specific type of nail, a number of different nails were tested to find alternatives to the prescribed round  $\phi$  5 mm nail with a minimum length of 90 mm (40 + 50). This particular nail is not obtainable on the Scandinavian market.



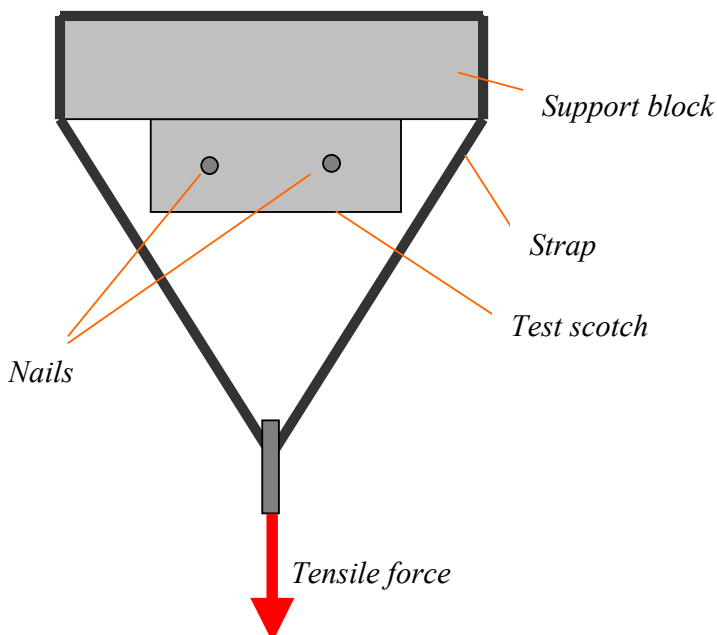


The figure shows an example of how the cargo can be secured against movement in one direction. In this example two scotches with 4 nails each has been used as support. According to UIC this arrangement will constitute support for a cargo mass of 12000 kg (1500 kg × 8 nails) in transverse direction (if  $H \geq 5$  cm).

**4.2.2 Tests**

**Procedure:**

At the tests carried out, a wooden test scotch was nailed to the wagon floor with two nails. The material of the wagon floor consisted of either wood or plywood. A strap was drawn around a support block simulating the goods. A tensile force was obtained in the strap by a tensioner, see below.



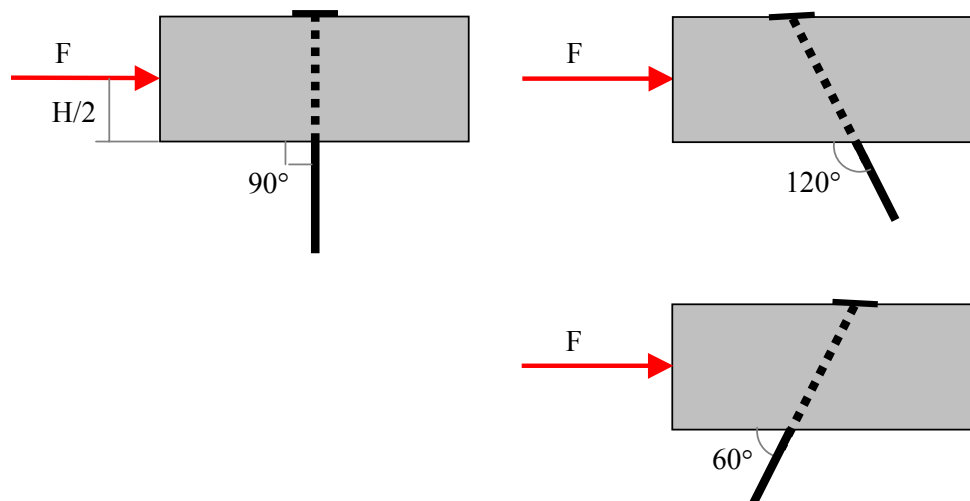
The magnitude of the tensile force was measured by a dynamometer when the test scotch had moved 10 mm. The reason why this distance was chosen was because it was close to the breaking strength of the nail joint and increase in the tensile force was rarely detected beyond this displacement.



The photo below shows the test environment at Svealast terminalen in Malmö. In this case the scotch is being nailed in the wagon with the plywood floor.



In most tests the nails were nailed to the floor in an angle of  $90^\circ$  to the surface. Some tests were performed with an angle of  $60^\circ$  and  $120^\circ$  to the surface, see below. The height of the wooden scotches was either 5 cm or 4 cm.

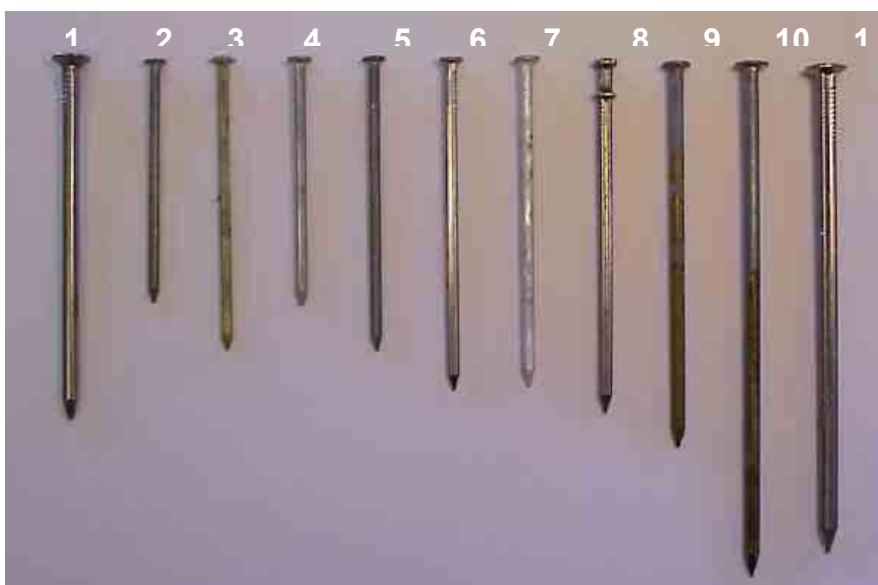


**Used equipment:**

The following equipment was used in the tests:

- Nail gun or hammer
- Dynamometer
- Strap
- Manual tensioner (Used to exert the tensile force)
- Wooden scotches (5x10 cm and 4x10 cm about 30 cm long)
- Support block
- One Cargo wagon with wooden floor and one with plywood floor

The following nails were tested:



1. 5×110 (Diameter 5 mm, length 110 mm) Smooth bright (*Reference nail, used in the UIC guidelines*)
2. 2.8×75 Grooved HDG (Hot dipped galvanized)
3. 2.8×90 Grooved HDG
4. 3.1×75 HDG
5. 3.1×90 Grooved HDG
6. 3.4×100 bright
7. 3.4×100 HDG
8. 3.7×100 double headed bright
9. 3.8×120 Grooved HDG
10. 4.5×160 Smooth HDG
11. 5.1×150 Jagged bright

### 4.2.3 Summary and conclusions

The results of the tests are shown for each specific nail in the table below. In each case the force (expressed in kg) was measured when the nailed scotch had moved approximately 10 mm. The reference nail (5×110 Smooth Bright), which is used in the UIC guidelines, is shown on top of the table.

Type of nail	No.	Angle	Scotch (cm)	Wagon floor	Direction	Breaking force/nail (kg)	Max allowed force/nail (kg)
5×110 Smooth Bright	1	90°	5×10	Wood	Parallel to fibres	250	125
5×110 Smooth Bright	1	90°	5×10	Wood	"	260	130
5×110 Smooth Bright	1	90°	5×10	Wood	Crosswise fibres	285	142
5×110 Smooth Bright	1	90°	5×10	Plywood	-	320	160
5×110 Smooth Bright	1	120°	5×10	Plywood	-	270	135
5×110 Smooth Bright	1	120°	5×10	Plywood	-	265	132
5×110 Smooth Bright	1	60°	5×10	Plywood	-	310	155
2.8×75 Grooved HDG	2	90°	5×10	Plywood	-	240	120
2.8×75 Grooved HDG	2	90°	4×10	Plywood	-	310	155
2.8×90 Grooved HDG	3	90°	4×10	Wood	Parallel to fibres	165	82
3.1×75 HDG	4	90°	5×10	Plywood	-	285	142
3.1×90 Grooved HDG	5	90°	5×10	Plywood	-	350	175
3.4×100 Bright	6	90°	5×10	Wood	Parallel to fibres	160	80
3.4×100 Bright	6	90°	5×10	Plywood	-	255	127
3.4×100 HDG	7	90°	5×10	Wood	Parallel to fibres	230	115
3.4×100 HDG	7	90°	5×10	Plywood	-	320	160
3.7×100 Doubleheaded Bright	8	90°	5×10	Wood	Parallel to fibres	175	87
3.7×100 Doubleheaded Bright	8	90°	5×10	Plywood	-	240	120
3.8×120 Grooved HDG	9	90°	5×10	Wood	"	275	137
3.8×120 Grooved HDG	9	90°	5×10	Plywood	-	355	177
4.5×160 Smooth HDG	10	90°	5×10	Wood	Parallel to fibres	270	135
5.1×150 Jagged Bright	11	90°	5×10	Wood	Parallel to fibres	305	152
5.1×150 Jagged Bright	11	60°	5×10	Wood	"	300	150
5.1×150 Jagged Bright	11	60°	5×10	Wood	Crosswise fibres	380	190
5.1×150 Jagged Bright	11	90°	5×10	Plywood	-	405	202

In the table above the force per nail is shown. From the results, the following can be concluded:

- The breaking force per reference nail is 2500 N (250 kg).
- The force capacity per nail is larger on a plywood floor than on a wooden floor.
- The force capacity per nail varies little as the angle is decreased from 90 to 60 degrees
- The force capacity per nail is lower for an angle of 120 degrees than for angles of 90 or 60 degrees. This result was definitely not expected.

The values in the column “Max allowed force/nail” are calculated using the values in the column “Breaking force/nail” together with a **safety factor** of 2. This is the most common safety factor when dimensioning cargo securing arrangements.

The result gives an idea of how many nails that are required to replace the reference nail. For example: it takes about 16 nails of type 3.4×100 Bright to replace 10 reference nails, when used on wooden floor, and 13 nails when used on floor of plywood. The results for all nails are shown in the table below.

Tests for some of the nails were made for one of the floor types only (only wood – nail no. 3 and 10, only plywood – nail no. 2, 4 and 5). The missing values for these nails have been calculated with a quotient of 0.75 between the value for wood and the one for plywood

$$\left[ \frac{\text{Value on wood}}{\text{Value on plywood}} = 0.75 \right].$$

Type of nail	No.	Number of nails to replace ten (10) 5×110 Smooth Bright (reference nail, UIC)	
		Wood	Plywood
5×110 Smooth Bright <small>Reference nail, UIC</small>	1	10	10
2.8×75 Grooved HDG	2	14	13
2.8×90 Grooved HDG	3	15	15
3.1×75 HDG	4	12	11
3.1×90 Grooved HDG	5	9.5	9.1
3.4×100 Bright	6	16	13
3.4×100 HDG	7	11	10
3.7×100 Doubleheaded Bright	8	14	13
3.8×120 Grooved HDG	9	9.1	9.0
4.5×160 Smooth HDG	10	9.3	8.9
5.1×150 Jagged Bright	11	8.3	7.9

## 4.3 Webbings

Tests with webbings have been carried out by ANCRA ABT in their factory in Vårgårda 2003-11-07.

### 4.3.1 Purpose

The purpose of the tests with tied webbing, webbing with loop and webbing attached to different fittings (hooks and rings) has been to establish how large the strength reduction is compared to the breaking strength of the webbing itself.

In the regulation of UIC (RIV Appendix II, Section 1, chapter 5.5.4) it is stated that the use of knots reduces the breaking strength of the bindings by approximately 60%. Some retailers of cargo securing devices say that the value is about 20% other say 50%. By doing these tests the true value could be stated.

### 4.3.2 Equipment

The following equipment was used:

#### Type of lashings

1. Webbing of polypropylene (PP) with marked breaking strength 20 kN (2.0 ton), width 50 mm
2. Webbing of polyester (PE) with marked breaking strength 30 kN (3.0 ton), width 50 mm
3. Webbing of polyester (PE) with marked breaking strength 48 kN (4.8 ton), width 50 mm
4. SJ-lashing (with snare and cam lock), of polyester with marked breaking strength 22 kN (2.2 ton), width 35 mm

#### Type of fittings

- A Adjustable hook
- B Key-Lock buckle
- C Panfitting, round



A



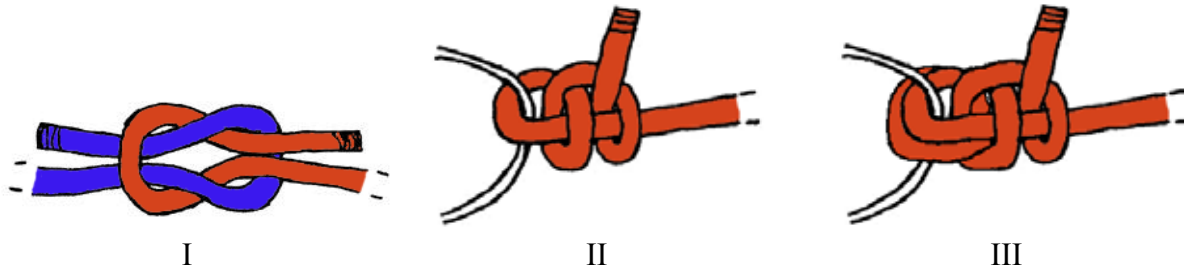
B



C

**Type of knot**

- I Reef-knot
- II Clove hitch
- III Clove hitch with an extra hitch



In all tests that were performed with knot I (Reef-knot) the webbing slide in the knot and no force could be measured.

**4.3.3 Tests**

**1. Breaking strength of webbing in straight pull**

Each webbing was tested twice in a straight pull and the results are shown in the table below.

No.	Webbing	Test 1	Test 2	Average breaking strength
1	20 kN PP	22.2 kN	22.2 kN	22.2 kN
2	30 kN PE	33.6 kN	33.6 kN	33.6 kN
3	48 kN PE	48.4 kN	48.9 kN	48.6 kN



*Test with 20 kN PP webbing.*

**2. Strength of tied webbing**

Each webbing was tested twice with knot II and III respectively. The webbing was tied to fitting C (Panfitting). The results are shown in the table below.

<b>Knot</b>	<b>Webbing</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Average reduction of strength<sup>1</sup></b>
II Clove hitch	1	11.6 kN	11.6 kN	48 %
II Clove hitch	2	11.2 kN	14.3 kN	62 %
II Clove hitch	3	19.6 kN	22.0 kN	57 %
III Clove hitch +	1	10.6 kN	10.8 kN	52 %
III Clove hitch +	2	14.0 kN	12.2 kN	61 %
III Clove hitch +	3	21.2 kN	21.4 kN	56 %



*Test with webbing tied to fitting C.*

**3. Strength of webbing attached to fitting**

Webbing 3 was tested with an adjustable hook (A) and webbing 1 and 2 was tested with a Key-Lock buckle (B). The results are shown in the table below.

<b>Fitting</b>	<b>Webbing</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Average reduction of strength<sup>1</sup></b>
A Adj. hook	3	40.7 kN	40.7 kN	16 %
B Key-Lock buckle	1	16.3 kN	15.0 kN	30 %
B Key-Lock buckle	2	17.8 kN	17.3 kN	48 %

<sup>1</sup> Calculated with breaking strength from test 1

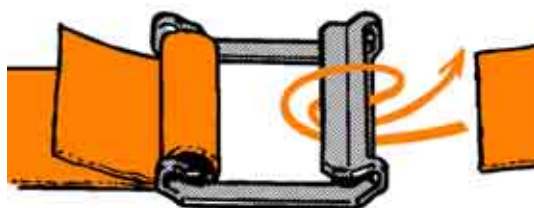




*Test with adjustable hook*



*Test with Key-Lock*



*Webbing attached by a Key-Lock*

**4. Strength of “SJ-lashing”**

Webbing 4 (the SJ-lashing) was tested six times. Two times with knot I, two times with knot II and two times with the end snared. In all of the tests the webbing broke at the cam lock.

<b>Knot</b>	<b>Test 1</b>	<b>Test 2</b>	<b>Note</b>	<b>Average reduction of strength<sup>2</sup></b>
II Clove hitch	7.1 kN	6.2 kN	Breakage appeared in, or adjacent to, the cam lock, NOT at the knot.	70 %
II Double clove hitch	6.5 kN	6.5 kN	Breakage appeared in, or adjacent to, the cam lock, NOT at the knot.	70 %
Snare	6.5 kN	6.5 kN	Breakage appeared in, or adjacent to, the cam lock, NOT at the snare.	70 %



*Test with SJ-lashing with clove hitch at the cam lock.*

<sup>2</sup> Calculated with marked breaking strength (22 kN)

#### 4.3.4 Summary and conclusions

From the results, the following can be concluded:

- The use of knots reduces the breaking strength of the bindings by approximately 60 %, as stated by UIC.
- One-way systems with 20 kN PP webbing should be used together with Key-Lock buckles or similar. The strength of a lashing is more than 40 % higher for webbing attached with a Key-Lock than for tied webbing.
- Webbing of 30 kN PE should not be used together with Key-Lock buckles.
- The one-way systems with 20 kN PP webbing and Key-Lock buckle is more than 100 % stronger than the SJ-lashing (22 kN webbing) with the cam lock.

## 5 ANALYSIS OF THE UIC LOADING GUIDELINES

In this chapter different securing arrangements designed according to the UIC regulations are analysed.

### 5.1 Bases for the analysis

As mentioned in chapter 3 the UIC regulation contains the following three levels of design criteria for cargo securing:

- General acceleration figures arising during transit according to § 1.3 in section 1 in RIV Appendix II
- General methods accepted for cargo securing according to chapter 5 in section 1 in RIV Appendix II
- Loading guidelines for different types of cargo in section 2 in RIV Appendix II

In this part of the report the arrangements according to the design criteria 2 and 3 above are analysed and it is calculated which accelerations the different arrangements can withstand in transverse and longitudinal direction for hump and fly shunting as well as for non hump and fly shunting.

The achieved accelerations are compared with the general acceleration figures according to criteria 1 above and recommendations are given for modification of the general acceleration figures.

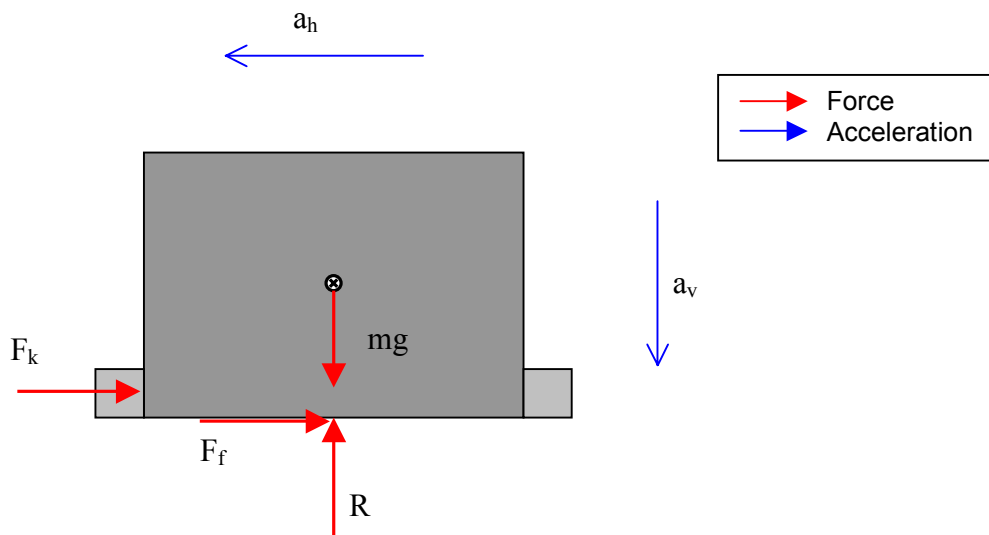
### 5.2 Nail joints

#### 5.2.1 Purpose

The purpose of this analysis is to calculate how large accelerations a securing arrangement can withstand when it is designed according to the UIC:s guidelines (RIV Appendix II, Section 1, 5.4.3). Below formulas are set up for calculation of the maximum acceleration a securing arrangement can withstand when blocked by battens nailed to the floor. In the calculations a safety factor of 2 is used to cover uncertainties in the measurements. This safety factor is normally used for cargo securing equipment. With this safety factor it can be concluded that the reference nail  $\emptyset$  5 mm can withstand a force of about 125 kg or 1250 N, see chapter 4.

#### 5.2.2 Calculations

Below the forces and accelerations acting on the cargo during vertical and horizontal accelerations are shown.



Equilibrium of forces:

$$\uparrow R - m \cdot g = m \cdot a_v \Rightarrow R = m \cdot (a_v + g)$$

$$\rightarrow F_k + F_f = m \cdot a_h \Rightarrow a_h = \frac{F_k + F_f}{m}$$

Force of friction:

$$F_f = \mu \cdot R = \mu \cdot m \cdot (a_v + g)$$

**Guidelines according to UIC:**

According to UIC one nail  $\varnothing$  5 mm should be used per 1500 kg cargo weight to avoid movement crosswise in the wagon. This gives the following equations:

$$F_k = F_n \cdot n = F_n \cdot \frac{m}{1500}$$

$$a_h = \frac{F_n \cdot \frac{m}{1500} + \mu \cdot m \cdot (a_v + g)}{m} = \frac{F_n}{1500} + \mu \cdot (a_v + g)$$

Lengthways in the wagon the following is valid:

*Hump and fly shunting*

1 nail per 100 kg

$$a_h = \frac{F_n}{100} + \mu \cdot (a_v + g)$$

*None hump and fly shunting*

1 nail per 400 kg

$$a_h = \frac{F_n}{400} + \mu \cdot (a_v + g)$$

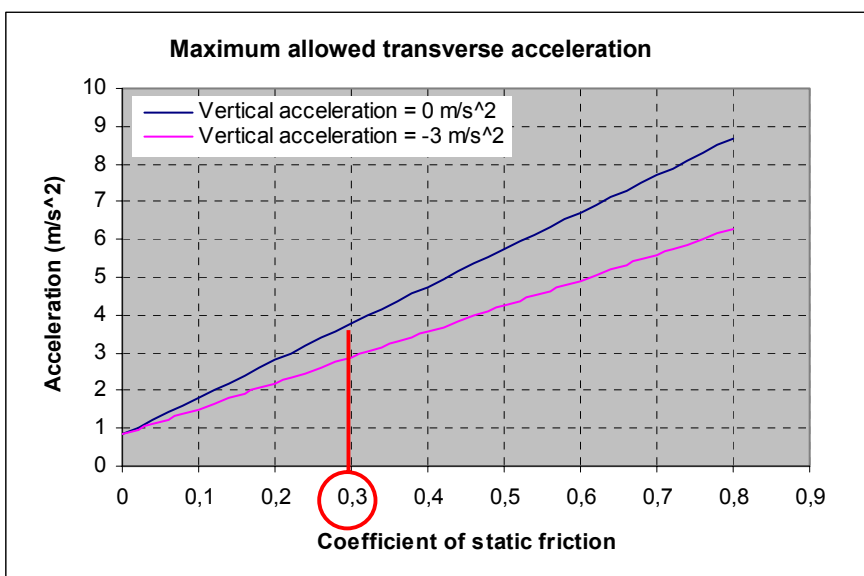
m = mass

n = number of nails in each direction

F<sub>n</sub> = magnitude of force allowed per nail (1250 N per reference nail)

### 5.2.3 Results

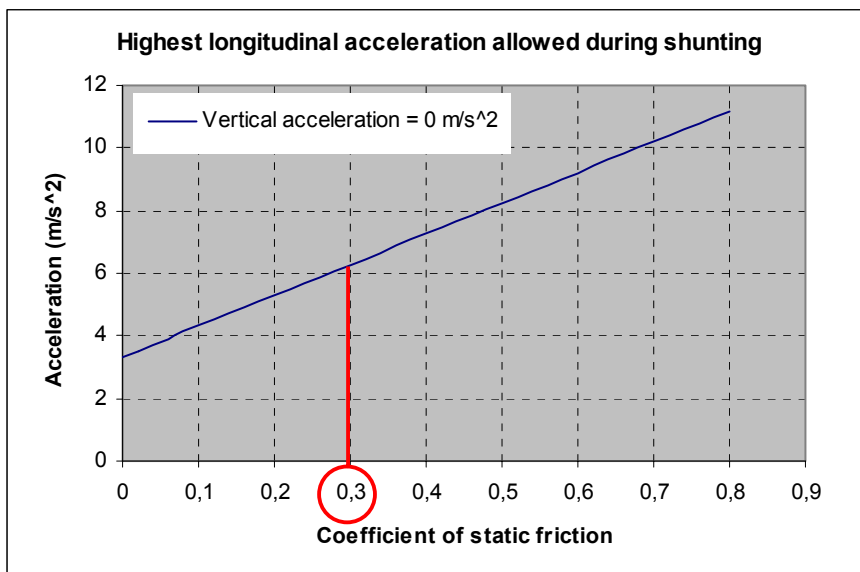
The diagram below shows that the largest allowed transverse acceleration is about 3.8 m/s<sup>2</sup> when no vertical acceleration is taken in consideration and the coefficient of friction between the cargo and the wagon floor is 0.3. The allowed transverse acceleration decreases to 2.9 m/s<sup>2</sup> when the vertical acceleration is -3 m/s<sup>2</sup>.



**1 nail per 1500 kg**

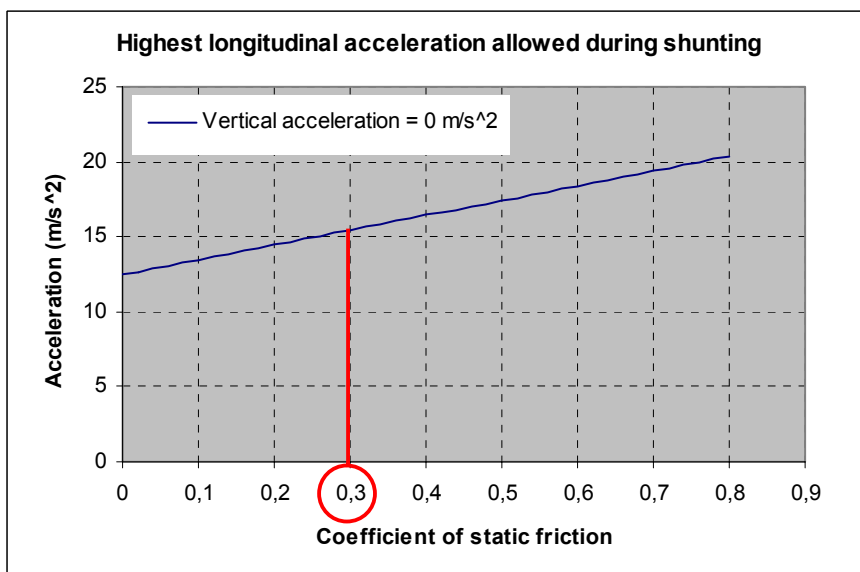
A lowest realistic coefficient of friction of 0.3 is used in all of the calculations. This value is taken from Securing of Cargo TFK 1998:2E.

The diagram below shows the corresponding accelerations in longitudinal direction for an arrangement not subjected to hump and fly shunting. Largest allowed longitudinal acceleration is 6.1 m/s<sup>2</sup> when a vertical acceleration of 0 m/s<sup>2</sup> is acting on the cargo.



**None hump and fly shunting: 1 nail per 400 kg**

The largest allowed acceleration during hump and fly shunting is according to the diagram below, 15.4 m/s<sup>2</sup>, when no vertical acceleration is taken into consideration.



**Hump and fly shunting: 1 nail per 100 kg**

### 5.2.4 Summery

The results are summarized in the table below, where the largest allowed acceleration in respectively transverse and longitudinal direction is shown. The vertical acceleration is taken into account during transverse movement. In longitudinal direction the occurrence of hump and fly shunting is taken in to account. The coefficient of friction is set to 0.3 in all cases.

Shunting	Vertical acceleration (m/s <sup>2</sup> )	Transverse acceleration (m/s <sup>2</sup> )	Longitudinal acceleration (m/s <sup>2</sup> )
	<i>Values taken from general guidelines</i>	<i>Values derived from calculations</i>	
None hump and fly	0	3.8	6.1
None hump and fly	-3.0	2.9	-
Hump and fly	0	3.8	15.4

According to the general UIC:s guidelines a securing arrangement should be designed for the following accelerations:

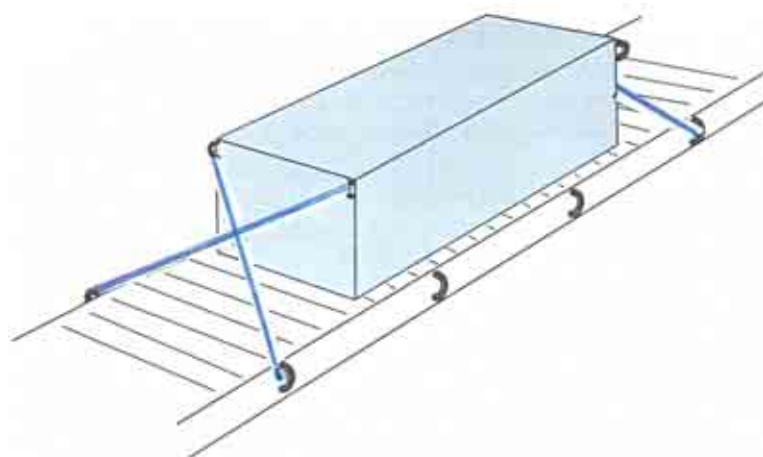
Shunting	Vertical acceleration (m/s <sup>2</sup> )	Transverse acceleration (m/s <sup>2</sup> )	Longitudinal acceleration (m/s <sup>2</sup> )
	<i>Values taken from general guidelines</i>	<i>Values derived from calculations</i>	
None hump and fly	0	-	10
None hump and fly	-3.0	5	-
Hump and fly	0	-	40

The largest allowed transverse acceleration for the specific nail guidelines reaches about 60% of the general UIC requirements. Corresponding for the longitudinal acceleration is about 40% for hump and fly shunting and 60% for none hump and fly.

### 5.3 Cross Lashings

#### 5.3.1 Purpose

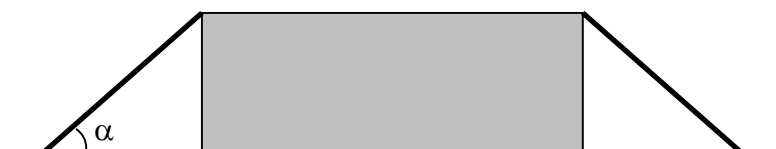
The purpose of this analysis is to calculate how large accelerations a securing arrangement can withstand when it is designed according to the UIC:s guidelines (RIV Appendix II, Section 1, 5.4.4). The maximum load of the lashings is considered to be half of its breaking strength, which gives a safety factor of 2. The figure below shows an example where the cargo is secured by cross lashings.



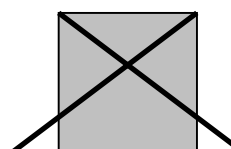
### 5.3.2 Loading guidelines

According to the UIC guidelines, the following is valid:

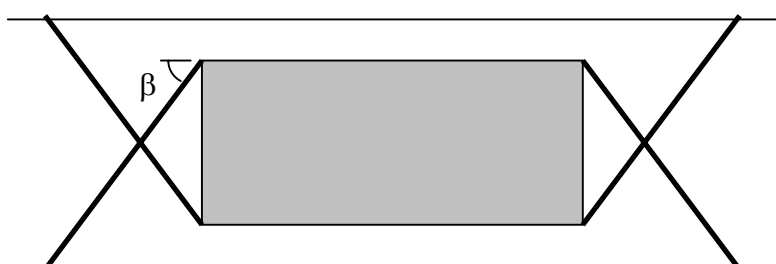
*Side view*



*End view*



*Top view*



$\alpha$  = vertical angle and  $\beta$  = longitudinal angle

Direct fastenings placed lengthways in the wagon may be considered correctly dimensioned if the breaking strength (= twice the tensile load) of the bindings in each direction (longitudinal as well as transverse) is at least

*Wagons subjected to hump and fly shunting*

32 kN

*Wagons not subjected to hump and fly shunting*

10 kN

per 1 000 kg of load

There are no guidelines concerning the angles in which the lashings are to be fastened. Because of this the angles are assumed to be in the interval of 30° - 60°.

### 5.3.3 Calculations

Below the cargo with lashings is shown from three different views.



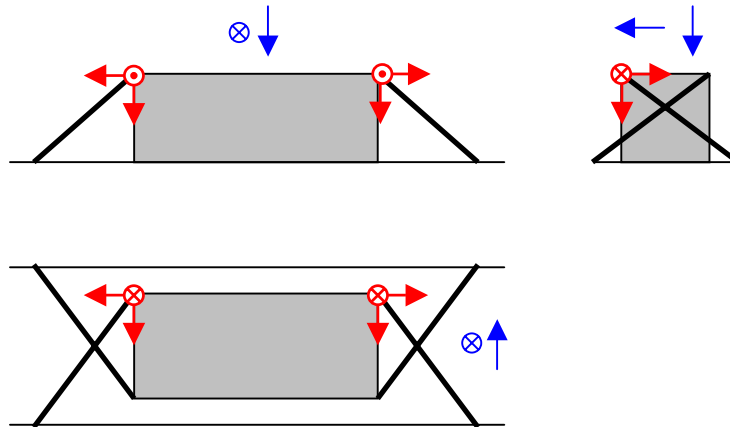
The tensile force in each direction per lashing is:

$$F_v = F \cdot \sin \alpha$$

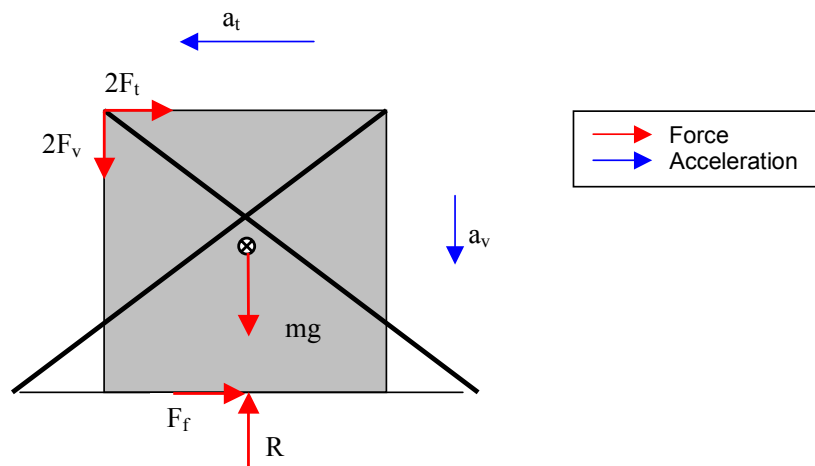
$$F_t = F \cdot \cos \alpha \cdot \sin \beta$$

$$F_l = F \cdot \cos \alpha \cdot \cos \beta$$

Below the forces in the lashings during transverse acceleration are shown.



The figure below shows the forces acting on the cargo during transverse acceleration.



Equilibrium of forces:

$$\uparrow R - m \cdot g - 2 \cdot F_v = m \cdot a_v \Rightarrow R = m \cdot (a_v + g) + 2 \cdot F_v$$

$$\rightarrow F_f + 2 \cdot F_t = m \cdot a_t \Rightarrow a_t = \frac{F_f + 2 \cdot F_t}{m}$$

Force of friction:

$$F_f = \mu \cdot R = \mu \cdot [m \cdot (a_v + g) + 2 \cdot F_v]$$

Transverse acceleration:

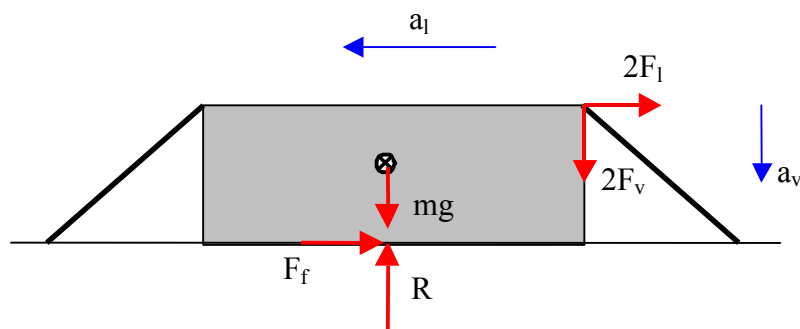
$$a_t = \frac{\mu \cdot [m \cdot (a_v + g) + 2 \cdot F_v] + 2 \cdot F_t}{m} = \frac{\mu \cdot [m \cdot (a_v + g) + 2 \cdot F \cdot \sin \alpha] + 2 \cdot F \cdot \cos \alpha \cdot \sin \beta}{m}$$

$$a_t = \mu \cdot (a_v + g) + \frac{2 \cdot F \cdot (\mu \cdot \sin \alpha + \cos \alpha \cdot \sin \beta)}{m}$$

The UIC guidelines with safety factor  $\eta = 2$  included give the following:

$$F = 32 \cdot m / \eta = 16 \cdot m \quad | \quad F = 10 \cdot m / \eta = 5 \cdot m$$

The figure below shows the forces acting on the cargo during longitudinal acceleration.



Longitudinal acceleration:

$$a_l = \frac{\mu \cdot (m \cdot g + 2 \cdot F_v) + 2 \cdot F_l}{m} = \frac{\mu \cdot (m \cdot g + 2 \cdot F \cdot \sin \alpha) + 2 \cdot F \cdot \cos \alpha \cdot \cos \beta}{m}$$

$$a_l = \mu \cdot g + \frac{2 \cdot F \cdot (\mu \cdot \sin \alpha + \cos \alpha \cdot \cos \beta)}{m}$$

The static coefficient of friction between the cargo and the surface is assumed to be 0.3. In the calculations the dynamic coefficient of friction is used, which is estimated to be 70% of the static coefficient according to EN 12195-1.

The largest stresses in the lashings appear when the vertical angle is 60°. (This goes for both transverse and longitudinal direction). When the acceleration acts in transverse direction, the largest stresses appear when the longitudinal angle is 30°. In longitudinal direction the largest stresses appear when the longitudinal angle is 60°.

5.3.4 Results

The largest allowed transverse acceleration (in  $m/s^2$ ) during hump and fly shunting is shown for several different combinations of the longitudinal ( $\beta$ ) and vertical ( $\alpha$ ) angles, see table below. The lowest allowed acceleration ( $15 m/s^2$ ) occurs when the longitudinal angle equals  $30^\circ$  and the vertical angle equals  $60^\circ$ . The vertical acceleration is  $-3 m/s^2$ , which is the worst-case scenario when using the UIC:s guidelines.

*Longitudinal angle  $\beta$*

	$30^\circ$	$35^\circ$	$40^\circ$	$45^\circ$	$50^\circ$	$55^\circ$	$60^\circ$	
<i>Vertical angle <math>\alpha</math></i>	$30^\circ$	18.7	20.7	22.6	24.4	26.0	27.5	28.8
$35^\circ$	18.4	20.3	22.1	23.8	25.4	26.8	28.0	
$40^\circ$	18.0	19.8	21.5	23.1	24.5	25.8	27.0	
$45^\circ$	17.5	19.2	20.7	22.2	23.5	24.7	25.8	
$50^\circ$	16.9	18.4	19.8	21.1	22.3	23.4	24.4	
$55^\circ$	16.1	17.5	18.7	19.9	21.0	22.0	22.8	
$60^\circ$	15.3	16.4	17.5	18.6	19.5	20.4	21.1	

*Max allowed transverse accelerations at hump and fly shunting with  $a_v = -3 m/s^2$*

According to the table above the worst case appears when  $\alpha = 60^\circ$ , and  $\beta = 30^\circ$ . At these angles the maximum allowed transverse acceleration is  $15.9 m/s^2$  for hump and fly shunting when the vertical acceleration is discarded from, eg  $a_v = 0 m/s^2$ .

The largest allowed longitudinal acceleration during hump and fly shunting is shown below. The lowest allowed acceleration ( $16 m/s^2$ ) occurs when both the longitudinal and vertical angle equals  $60^\circ$ .

*Longitudinal angle  $\beta$*

	$30^\circ$	$35^\circ$	$40^\circ$	$45^\circ$	$50^\circ$	$55^\circ$	$60^\circ$	
<i>Vertical angle <math>\alpha</math></i>	$30^\circ$	29.42	28.12	26.65	25.02	23.23	21.32	19.28
$35^\circ$	28.62	27.39	25.99	24.45	22.76	20.95	19.02	
$40^\circ$	27.61	26.46	25.16	23.71	22.14	20.44	18.64	
$45^\circ$	26.41	25.35	24.15	22.81	21.36	19.79	18.13	
$50^\circ$	25.02	24.06	22.96	21.75	20.43	19.01	17.49	
$55^\circ$	23.46	22.6	21.63	20.54	19.36	18.09	16.74	
$60^\circ$	21.74	20.99	20.14	19.19	18.16	17.06	15.88	

*Max allowed longitudinal accelerations at hump and fly shunting with  $a_v = 0 m/s^2$*

For none hump and fly shunting with a vertical acceleration of  $-3 m/s^2$ , the max allowed transverse acceleration is  $5.7 m/s^2$ .

*Longitudinal angle  $\beta$*

	<b>30°</b>	<b>35°</b>	<b>40°</b>	<b>45°</b>	<b>50°</b>	<b>55°</b>	<b>60°</b>
<b>30°</b>	6.81	7.45	8.05	8.6	9.11	9.57	9.98
<b>35°</b>	6.73	7.33	7.9	8.43	8.91	9.34	9.73
<b>40°</b>	6.61	7.17	7.7	8.2	8.65	9.06	9.41
<b>45°</b>	6.45	6.97	7.46	7.92	8.33	8.71	9.04
<b>50°</b>	6.25	6.73	7.17	7.58	7.96	8.3	8.61
<b>55°</b>	6.02	6.44	6.84	7.21	7.54	7.85	8.12
<b>60°</b>	5.75	6.12	6.46	6.78	7.08	7.34	7.58

*Max allowed transverse accelerations at none hump and fly shunting with ( $a_v = -3 \text{ m/s}^2$ )*

According to the table above the worst case appears when  $\alpha = 60^\circ$ , and  $\beta = 30^\circ$ . At these angles the maximum allowed transverse acceleration is  $6.4 \text{ m/s}^2$  for none hump and fly shunting when the vertical acceleration is discarded from, e.g.  $a_v = 0 \text{ m/s}^2$ .

Max allowed acceleration in longitudinal direction when the wagon isn't subjected to hump and fly shunting is  $6.4 \text{ m/s}^2$  as shown below.

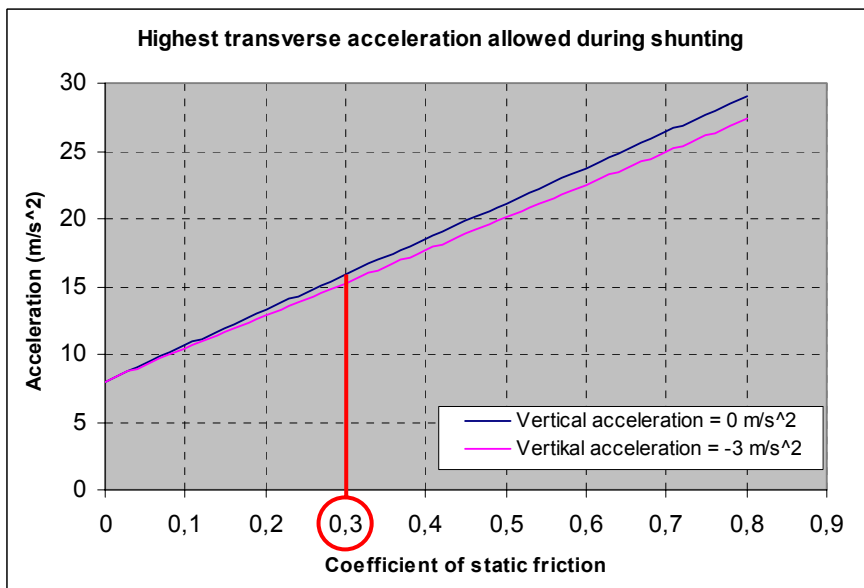
*Longitudinal angle  $\beta$*

	<b>30°</b>	<b>35°</b>	<b>40°</b>	<b>45°</b>	<b>50°</b>	<b>55°</b>	<b>60°</b>
<b>30°</b>	10.61	10.2	9.74	9.23	8.68	8.08	7.44
<b>35°</b>	10.36	9.97	9.54	9.06	8.53	7.96	7.36
<b>40°</b>	10.04	9.69	9.28	8.83	8.33	7.8	7.24
<b>45°</b>	9.67	9.34	8.96	8.55	8.09	7.6	7.08
<b>50°</b>	9.24	8.93	8.59	8.21	7.8	7.36	6.88
<b>55°</b>	8.75	8.48	8.17	7.84	7.47	7.07	6.65
<b>60°</b>	8.21	7.97	7.71	7.41	7.09	6.75	6.38

*Max allowed longitudinal accelerations at none hump and fly shunting with  $a_v = 0 \text{ m/s}^2$*

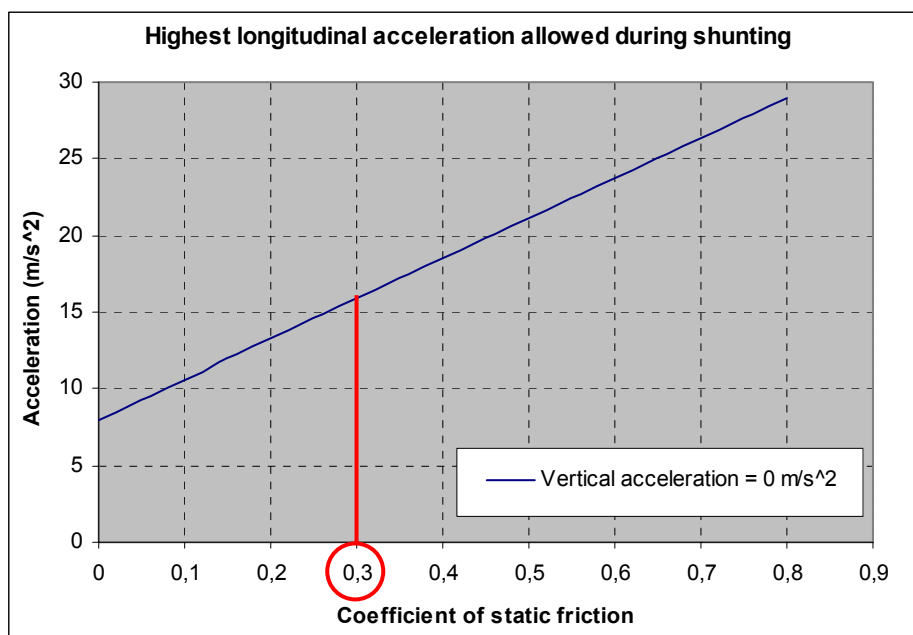
According to the table above the cargo can withstand the largest accelerations when the vertical angle is  $30^\circ$ . In consideration of sliding, it would be optimal to fasten the lashings with a vertical angle ( $\alpha$ ) of  $0^\circ$ . When doing so the risks of tipping increase considerably. These risks have not been taken in consideration in this example.

In the following diagram the largest allowed transverse acceleration is shown as a function of the static coefficient of friction, during hump and fly shunting. The vertical ( $\alpha$ ) and longitudinal angle ( $\beta$ ) of the lashings is fixed at  $60^\circ$  and  $30^\circ$  respectively.



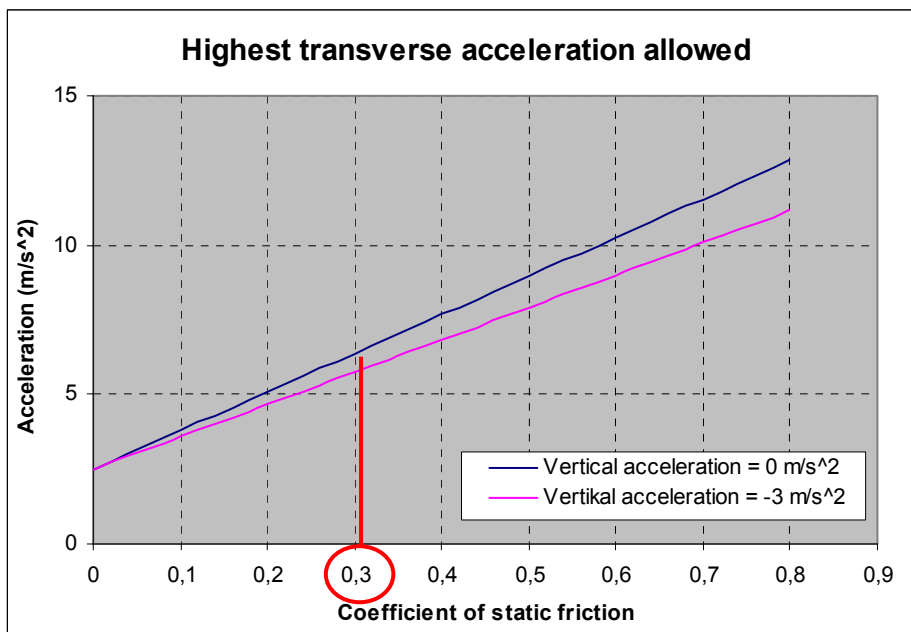
**Max allowed transverse acceleration at hump and fly**

Below the corresponding largest allowed longitudinal acceleration is shown. In this case both vertical and longitudinal angles are 60°.



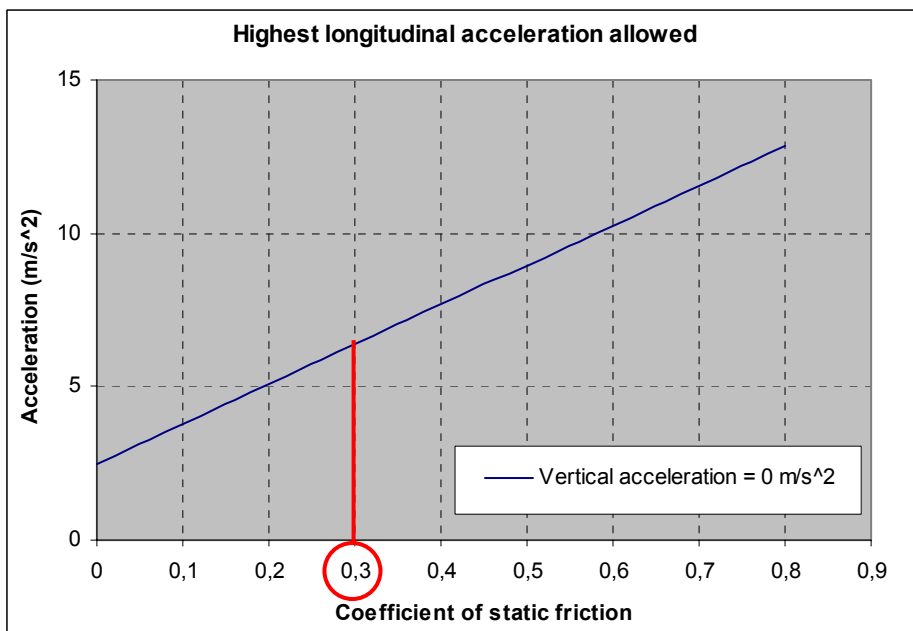
**Max allowed longitudinal acceleration at hump and fly shunting**

Following diagram shows the largest transverse acceleration allowed at none hump and fly shunting. The vertical angle ( $\alpha$ ) equals 60° and the longitudinal angle ( $\beta$ ) equals 30°.



**Max allowed transverse acceleration at none hump and fly shunting**

Finally the diagram below shows the largest longitudinal acceleration at none hump and fly shunting. The vertical and longitudinal angle equals 60°.



**Max allowed longitudinal acceleration at none hump and fly**

### 5.3.5 Summery

The result is put together in the table below, where the largest allowed acceleration in transverse and longitudinal direction is shown. The vertical acceleration is taken in to account during transverse movement. In longitudinal direction the occurrence of hump and fly shunting is taken in to account.

Shunting	Vertical acceleration (m/s <sup>2</sup> )	Transverse acceleration (m/s <sup>2</sup> )	Longitudinal acceleration (m/s <sup>2</sup> )
Hump and fly	0	(16)	16
Hump and fly	-3	15	-
None hump and fly	0	(6.4)	6.4
None hump and fly	-3	5.7	-

The UIC:s guidelines are below for reference.

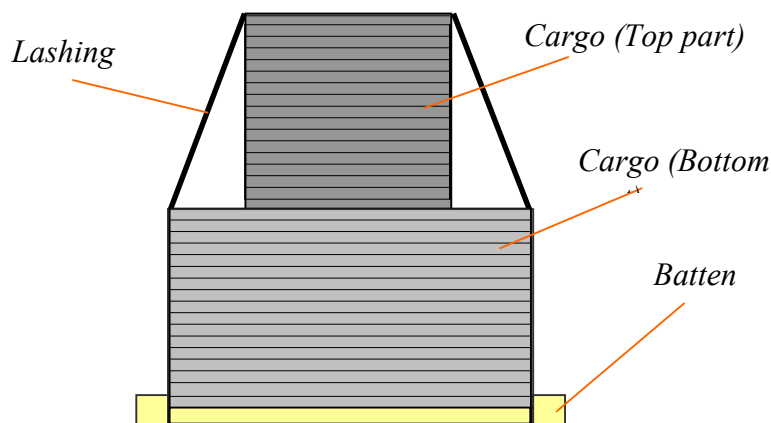
Shunting	Vertical acceleration (m/s <sup>2</sup> )	Transverse acceleration (m/s <sup>2</sup> )	Longitudinal acceleration (m/s <sup>2</sup> )
Hump and fly	0		40
Hump and fly	-3	5	-
None hump and fly	0		10
None hump and fly	-3	5	-

The largest allowed transverse acceleration for the specific lashing guidelines reaches about 110% of the general guidelines (300% at hump and fly shunting). Corresponding for the longitudinal acceleration is about 40% at hump and fly shunting and 60% at none hump and fly shunting.

## 5.4 Top-over lashings

### 5.4.1 Purpose

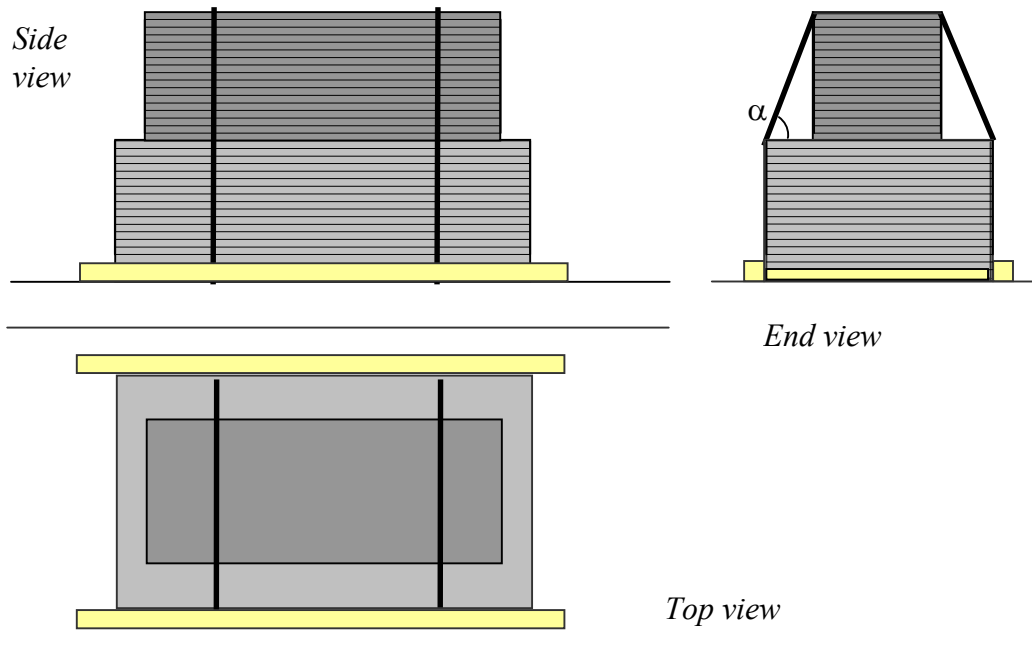
The purpose of this analysis is to check how large accelerations the cargo can withstand when it is secured by top-over lashings according to the UIC guidelines. The figure below shows an example were the cargo is secured by bottom blocking battens and top-over lashings.



The top part only of the cargo will be taken into consideration in this analysis. The pretension force (F) in the lashings is assumed to be about 10% of the breaking strength.

### 5.4.2 Calculations

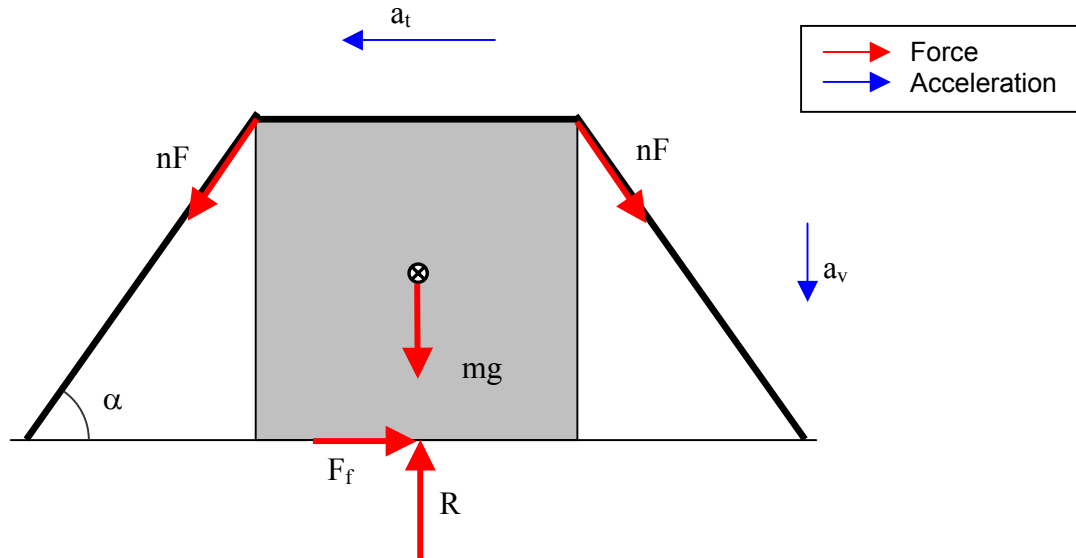
Below is the cargo shown from three different views secured by top-over lashings.



In this case the cargo is free to slide in longitudinal direction. This emphasizes that the longitudinal acceleration can be large during a short period of time.

The figure below shows the forces acting on the cargo when exposed to vertical and transverse accelerations. The friction between the lashing and cargo is neglected as well as the elongation of the lashing.





Equilibrium of forces:

$$\uparrow R - m \cdot g - 2 \cdot n \cdot F \cdot \sin \alpha = m \cdot a_v \Rightarrow R = m \cdot (a_v + g) + 2 \cdot n \cdot F \cdot \sin \alpha$$

$$\rightarrow F_f = m \cdot a_t \Rightarrow a_t = \frac{F_f}{m}$$

Force of friction:

$$F_f = \mu \cdot R = \mu \cdot [m \cdot (a_v + g) + 2 \cdot n \cdot F \cdot \sin \alpha]$$

Transverse acceleration as function of the pretension in the lashing  $F$ :

$$a_t = \frac{F_f}{m} = \mu \cdot (a_v + g) + \frac{\mu \cdot 2 \cdot n \cdot F \cdot \sin \alpha}{m}$$

$n$  = Number of lashings

**Example:**

Sliding of top part in transverse direction:

The mass of the top part of the cargo is assumed to be 30 ton (30000 kg) and it is secured by 2 lashings with an angle ( $\alpha$ ) of 45°. The coefficient of friction is 0.3 and the vertical acceleration acting at the time is -3 m/s<sup>2</sup>. According to UIC section 5.5.4, the breaking strength of the lashings is assumed to be 40 kN, and the pretension force  $F$ , thus 4 kN (4000 N). These precautions give the following equation:

$$a_t = \mu \cdot (a_v + g) + \frac{\mu \cdot 2 \cdot n \cdot F \cdot \sin \alpha}{m} = 0.3 \cdot (-3 + 9.81) + \frac{0.3 \cdot 2 \cdot 2 \cdot 4000 \cdot \sin 45^\circ}{30000} = 2.2 \text{ m/s}^2$$

If the vertical acceleration is neglected the following equation may be derived:

$$a_t = \mu \cdot g + \frac{\mu \cdot 2 \cdot n \cdot F \cdot \sin \alpha}{m} = 0.3 \cdot 9.81 + \frac{0.3 \cdot 2 \cdot 2 \cdot 4000 \cdot \sin 45^\circ}{30000} = 3.1 \text{ m/s}^2$$

The max transverse acceleration that an arrangement secured by top-over lashings designed according to the UIC guidelines for a cargo weight of 30 ton is thus 2.2 m/s<sup>2</sup> if the vertical acceleration is set to -3.0 m/s<sup>2</sup> and 3.1 m/s<sup>2</sup> if it's set to zero.

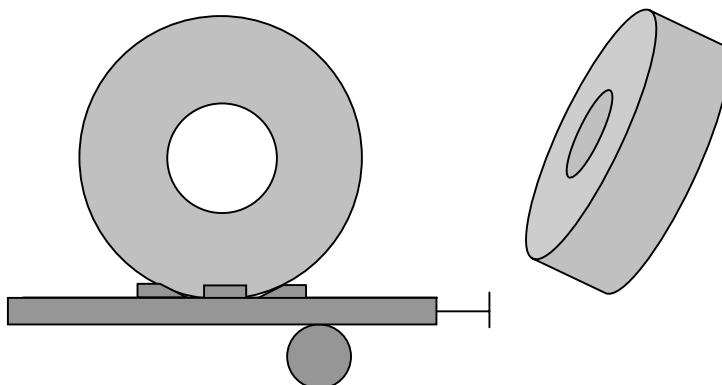
### 5.4.3 Summary

The cargo can be exposed to accelerations of up to 2.2 m/s<sup>2</sup> in transverse direction when secured with top-over lashings according to the UIC guidelines. This is about 45% of the general UIC requirements. If the vertical acceleration is set to zero the cargo securing arrangement may withstand accelerations of up to 3.1 m/s<sup>2</sup> (60% of the general UIC requirements). The cargo is able to slide in longitudinal direction, and therefore no analysis has been made in this direction.

## 5.5 Coiled sheet

### 5.5.1 Purpose

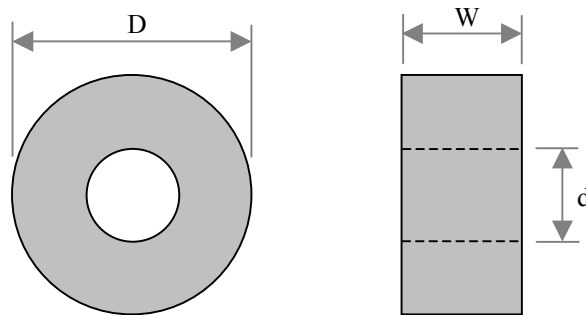
The purpose of this analysis is to calculate how large accelerations coils may be exposed to when secured according to the UIC:s guidelines (RIV Appendix II, Section 2, Loading guidelines 1.3.1). A coil may slide or tilt/roll in either transverse or longitudinal direction. At least two pitched scotches in each longitudinal direction are to be used to prevent the coil to slide or roll. In transverse direction at least one scotch is used (at each side) to prevent it from sliding. The picture below shows a rough sketch of the coil.



### 5.5.2 Loading guidelines

When calculating the largest allowed accelerations according to UIC, the worst-case scenario appears when the coils are loaded individually.

According to UIC the width (W) should be at least half of the diameter (D) when loaded individually. Below the dimensions of the coil is shown.



Lengthways in the wagon the pitched scotch should be at least 12 cm high and have a pitch angle of approximately 35° as shown below.



The coil shall be secured with at least two scotches in each running direction. Number of nails in the scotches on each side should total be:

1 nail / 500 kg of load

1 nail / 2000 kg of load

Across the wagon:

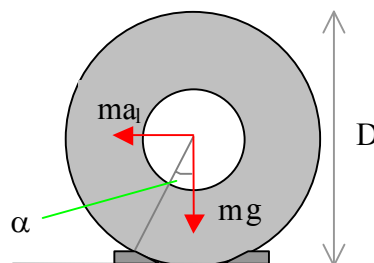
Number of nails in the scotches on each side should be:

1 nail / 1500 kg (At least two nails per scotch)

### 5.5.3 Calculations

Equations for motions in different directions are set up below.

Rolling in longitudinal direction:



Moment equilibrium:

$$m \cdot g \cdot \frac{D}{2} \cdot \sin \alpha - m \cdot a_l \cdot \frac{D}{2} \cdot \cos \alpha = 0 \Rightarrow a_l = g \cdot \tan \alpha$$

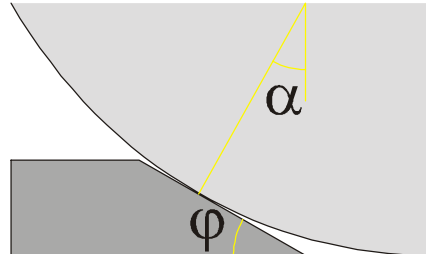
The coil will be prevented from rolling over the scotch when  $a_t \leq g \tan \alpha$ .

The reaction forces against the floor and scotch is not taken into consideration as they doesn't influence on the result).

The height of the scotch will only matter if the angle  $\alpha$  falls short of the pitch angle, as illustrated below.

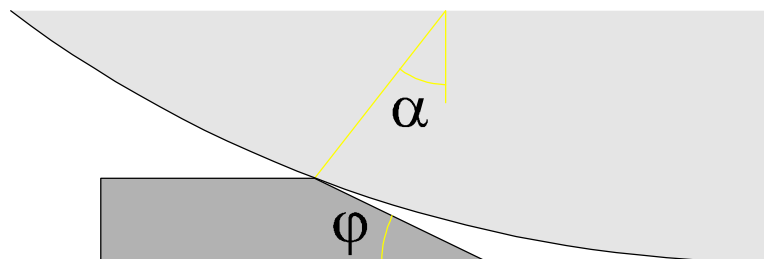
Case 1:

$$\alpha = \varphi \Rightarrow a_t = g \cdot \tan \varphi$$

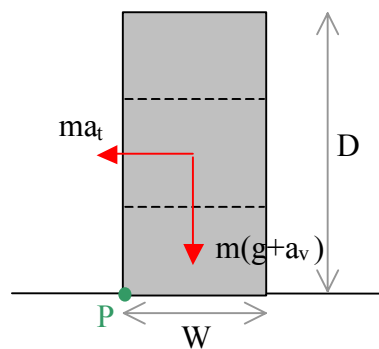


Case 2:

$$\frac{D}{2} \cdot (1 - \cos \alpha) = h \Rightarrow \alpha = \arccos \left( 1 - \frac{2 \cdot h}{D} \right) \Rightarrow a_t = g \cdot \tan \left( \arccos \left[ 1 - \frac{2 \cdot h}{D} \right] \right)$$



Tipping in transverse direction:



Moment equilibrium around point P:

$$m \cdot (g + a_v) \cdot \frac{W}{2} - m \cdot a_t \cdot \frac{D}{2} = 0 \Rightarrow a_t = \frac{W}{D} \cdot (g + a_v)$$

Sliding in transverse direction:

The sum of the friction force caused by the increased pressure from the scotch and the decreased pressure (from the coil) on the floor equals zero. This emphasises that the

calculations can be made as if the pitch angle were 90° (regular scotch), se chapter 5.2.2. This will only be valid when the coil doesn't roll up on the scotch.

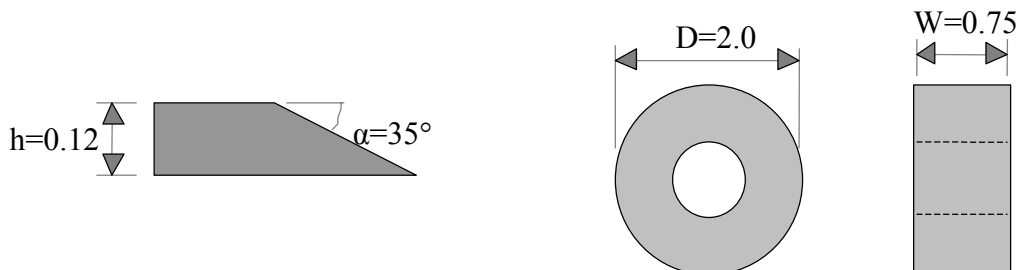
**Numerical example:**

The largest allowed accelerations avoiding motions are calculated below for a typical coil.

The figures show the dimensions of the selected coil.

Coefficient of friction = 0.3

Vertical acceleration = -3 m/s<sup>2</sup> and -0 m/s<sup>2</sup> respectively (during transverse sliding)

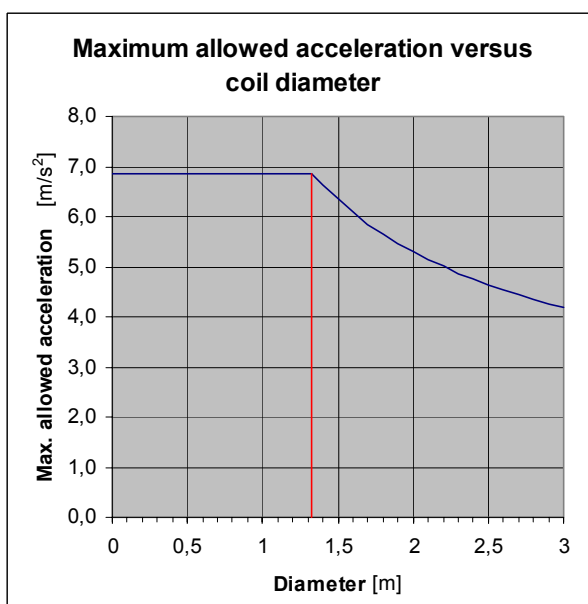


Rolling in longitudinal direction:

$$\alpha = \arccos\left(1 - \frac{2 \cdot h}{D}\right) = \arccos\left(1 - \frac{2 \cdot 0.12}{2.0}\right) = 28.4^\circ$$

$$a_l = g \cdot \tan \alpha = 9.81 \cdot \tan 28.4^\circ = 5.3 \text{ m/s}^2$$

The diagram below shows the largest allowed acceleration as a function of the coil diameter for a scotch height of 12 cm. The red line in the diagram marks the limit of 1.33 meter. For coils with diameters of 1.33 m or smaller, calculations are to be performed with the equation in case 1 above. For diameters larger than 1.33 meter the equation in the second case is applied.



Sliding in longitudinal direction:

See chapter 5.2.2

1 nail per 500 kg (during hump and fly shunting). Each reference nail  $\varnothing$  5 mm can withstand a force  $F_n$  of 1250 N.

$$a_l = \frac{F_n}{500} + \mu \cdot g = \frac{1250}{500} + 0.3 \cdot 9.81 = 5.4 \text{ m/s}^2$$

1 nail per 2000 kg for none hump and fly shunting

$$a_l = \frac{F_n}{2000} + \mu \cdot g = \frac{1250}{2000} + 0.3 \cdot 9.81 = 3.6 \text{ m/s}^2$$

Tipping in transverse direction:

$$a_t = \frac{W}{D} \cdot (g + a_v) = \frac{0.75}{2.0} \cdot (9.81 - 0) = 3.7 \text{ m/s}^2$$

Sliding in transverse direction:

See chapter 5.2.2

1 nail per 1500 kg

With a vertical acceleration of  $-3 \text{ m/s}^2$ :

$$a_t = \frac{F_n}{1500} + \mu \cdot (g + a_v) = \frac{1250}{1500} + 0.3 \cdot (9.81 - 3) = 2.9 \text{ m/s}^2$$

With a vertical acceleration of  $-0 \text{ m/s}^2$ :

$$a_t = \frac{F_n}{1500} + \mu \cdot g = \frac{1250}{1500} + 0.3 \cdot 9.81 = 3.8 \text{ m/s}^2$$

**5.5.4 Summery**

The result is put together in the list below were largest allowed acceleration in transverse and longitudinal direction is shown. The vertical acceleration is taken into account during transverse movement.

Longitudinal rolling =  $5.3 \text{ m/s}^2$

Longitudinal sliding =  $5.4 \text{ m/s}^2$  |  $3.6 \text{ m/s}^2$

Transverse tipping =  $3.7 \text{ m/s}^2$

Transverse sliding =  $2.9 \text{ m/s}^2$

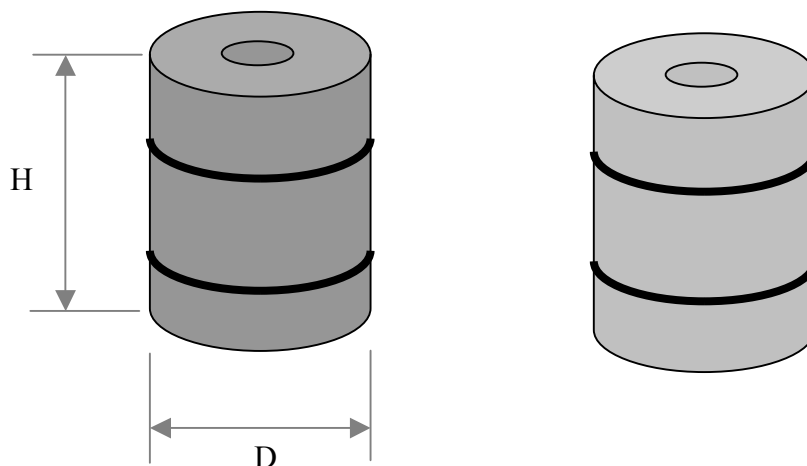
Transverse sliding without vertical acceleration =  $3.8 \text{ m/s}^2$

The largest allowed acceleration to avoid transverse tipping for the specific coil guidelines reaches about 75% of the general guidelines and to avoid transverse sliding about 60% of the general guidelines. The corresponding figures for the longitudinal acceleration is about 15% for hump and fly shunting and 35% for none hump and fly shunting.

## 5.6 Ungreased hot-rolled coiled sheet

### 5.6.1 Purpose

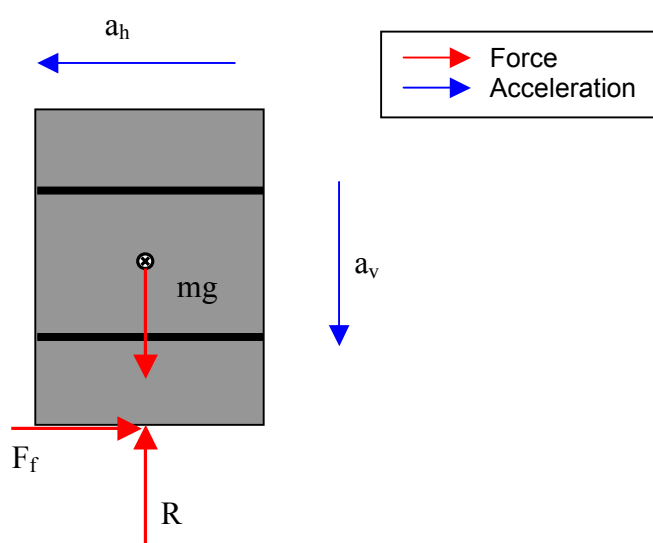
The purpose is to analyse at what magnitude of acceleration the coil starts to slide, or when it tilts. According to UIC (RIV Appendix II, Section 2, Loading guidelines 1.3.2) the diameter (D) should be at least 70% of the height (H), see picture below. No securing is required\*.



### 5.6.2 Calculations

#### Sliding

The figure below shows the forces acting on the cargo during horizontal sliding.



\* In Sweden lateral securing using guide-pieces is obligatory

Equilibrium of forces:

$$\uparrow R - m \cdot g = m \cdot a_v \Rightarrow R = m \cdot (a_v + g)$$

$$\rightarrow F_f = m \cdot a_h \Rightarrow a_h = \frac{F_f}{m}$$

Force of friction:

$$F_f = \mu \cdot R = \mu \cdot m \cdot (a_v + g)$$

Largest horizontal acceleration that can act on the coil before it starts to slide is:

$$a_h = \frac{\mu \cdot m \cdot (a_v + g)}{m} = \mu \cdot (a_v + g)$$

Transversal direction:

The largest allowed transverse acceleration to avoid sliding is calculated according to the formula below. The vertical acceleration according to UIC is  $-3 \text{ m/s}^2$ .

$$a_t = \mu \cdot (a_v + g) = 0.3 \cdot (-3 + 9.81) = 2.0 \text{ m/s}^2$$

If the vertical acceleration is set to  $0 \text{ m/s}^2$  the following calculation is valid:

$$a_t = \mu \cdot g = 0.3 \cdot 9.81 = 2.9 \text{ m/s}^2$$

Longitudinal direction:

The largest allowed longitudinal acceleration to avoid sliding is calculated according to the formula below. No vertical acceleration is to be considered in this case, according to UIC.

$$a_l = \mu \cdot (a_v + g) = 0.3 \cdot (0 + 9.81) = 2.9 \text{ m/s}^2$$

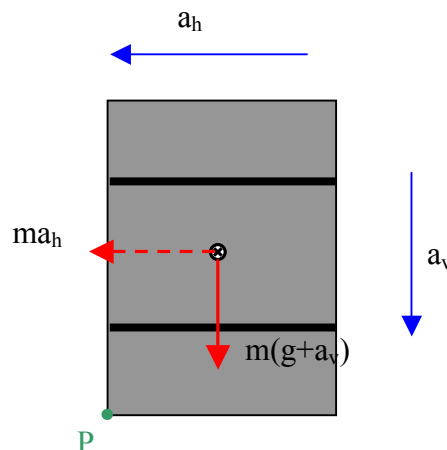
### **Tipping**

The figure below shows the forces acting on the cargo during horizontal sliding.



Moment equilibrium around point P:

$$m \cdot (g + a_v) \cdot \frac{D}{2} - m \cdot a_h \cdot \frac{H}{2} = 0 \Rightarrow a_h = \frac{D}{H} \cdot (g + a_v)$$



In this analysis the diameter (D) will be 70% of the height (H), because it's the worst case (according to the UIC:s guidelines) when considering tipping.

Transversal direction:

$$a_t = \frac{D}{H} \cdot (g + a_v) = 0.7 \cdot (9.81 - 3) = 4.8 \text{ m/s}^2$$

Longitudinal direction:

$$a_l = \frac{D}{H} \cdot (g + a_v) = 0.7 \cdot (9.81 - 0) = 6.9 \text{ m/s}^2$$

### 5.6.3 Summery

The result is put together in the list below were largest allowed acceleration in respectively transverse and longitudinal direction is shown. The vertical acceleration is taken in account during transverse movement.

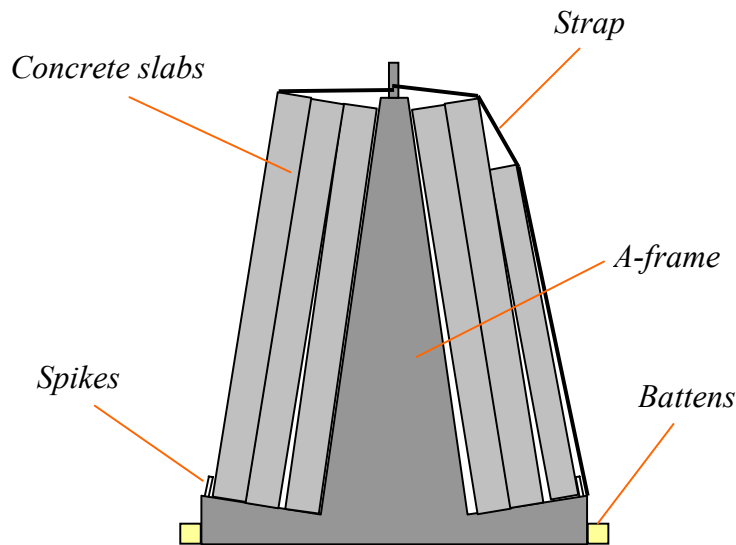
Longitudinal tipping = 6.9 m/s <sup>2</sup>	(about 15% of general acceleration)
Longitudinal sliding = 2.9 m/s <sup>2</sup>	(about 7% of general acceleration)
Transverse tipping = 4.8 m/s <sup>2</sup>	(about 100% of general acceleration)
Transverse sliding (a <sub>v</sub> = -3 m/s <sup>2</sup> ) = 2.0 m/s <sup>2</sup>	(about 40% of general acceleration)
Transverse sliding (a <sub>v</sub> = 0 m/s <sup>2</sup> ) = 2.9 m/s <sup>2</sup>	(about 60% of general acceleration)

## 5.7 A-frame

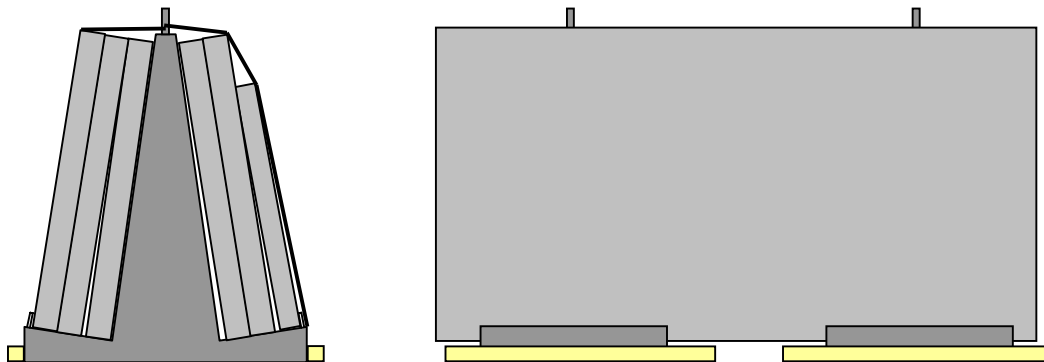
### 5.7.1 Purpose

The purpose of this analysis is to calculate how large accelerations concrete blocks can be exerted to, when positioned in an A-frame. According to the UIC:s guidelines (RIV Appendix II, Section 2, Loading guidelines 6.2), each of the two straps securing the slabs should be able

to resist a tensile force up to 10 kN before it breaks. The max allowed securing load in the straps is considered to be half of the break load.

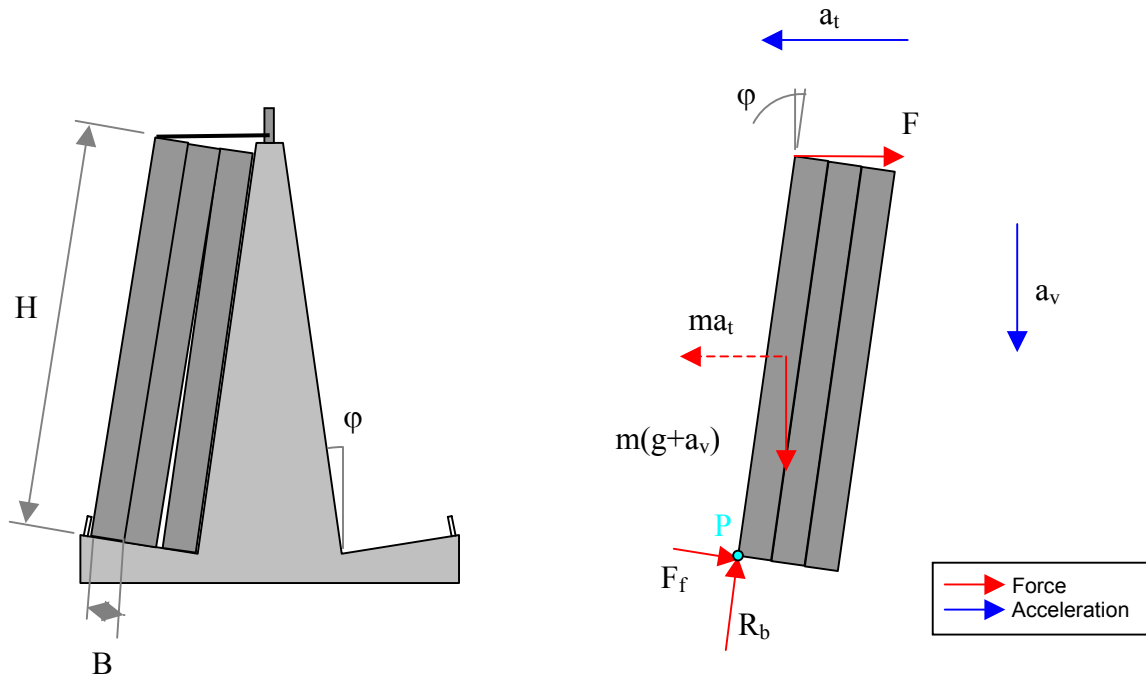


In transverse direction the concrete blocks can either tilt or slide of the A-frame. In this analysis tipping only will be dealt with, because no test has been made on how large forces the spikes can withstand. Battens will prevent the entire frame from moving in transverse direction. This analysis corresponds to the one made in chapter 5.2. No analysis will be made in longitudinal direction either, as both blocks and frame are free to slide.



### 5.7.2 Calculations

Below dimensions of interest are shown to the left and to the right the forces acting on the cargo during vertical and transverse accelerations are shown. To simplify the calculation, the internal friction between the blocks is neglected.



Moment equilibrium:

$$m \cdot (g + a_v) \cdot \left( \frac{B}{2} \cdot \cos\varphi + \frac{H}{2} \cdot \sin\varphi \right) + 2 \cdot F \cdot H \cdot \cos\varphi - m \cdot a_t \cdot \left( \frac{H}{2} \cdot \cos\varphi - \frac{B}{2} \cdot \sin\varphi \right) = 0 \Rightarrow$$

$$a_t = \frac{m \cdot (g + a_v) \cdot (B \cdot \cos\varphi + H \cdot \sin\varphi) + 4 \cdot F \cdot H \cdot \cos\varphi}{m \cdot (H \cdot \cos\varphi - B \cdot \sin\varphi)}$$

**Example:**

H = 2 m, B = 0.2 m,  $\varphi = 12^\circ$ , m = 3 × 6 ton = 18 ton, F = 10/2 kN = 5000 N,  $a_v = 0 \text{ m/s}^2$ .

$$a_t = \frac{m \cdot (g + a_v) \cdot (B \cdot \cos\varphi + H \cdot \sin\varphi) + 2 \cdot F \cdot H \cdot \cos\varphi}{m \cdot (H \cdot \cos\varphi - B \cdot \sin\varphi)} =$$

$$= \frac{18000 \cdot (9.81 - 0) \cdot (0.2 \cdot \cos 12^\circ + 2 \cdot \sin 12^\circ) + 2 \cdot 5000 \cdot 2 \cdot \cos 12^\circ}{18000 \cdot (2 \cdot \cos 12^\circ - 0.2 \cdot \sin 12^\circ)} = 3.7 \text{ m/s}^2$$

The largest allowed acceleration according to the calculations above is  $3.7 \text{ m/s}^2$  to avoid the three blocks from tipping outward.

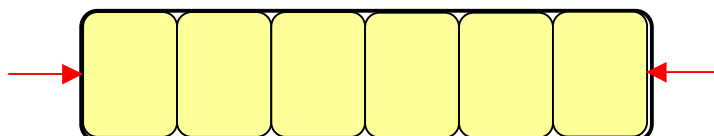
**5.7.3 Summery**

The cargo can be exposed to a transverse acceleration up to  $3.7 \text{ m/s}^2$  before the strap is overloaded and the concrete blocks tilt. This corresponds to about 75 % of the general guidelines according to UIC.

## 5.8 Wood pulp in bales

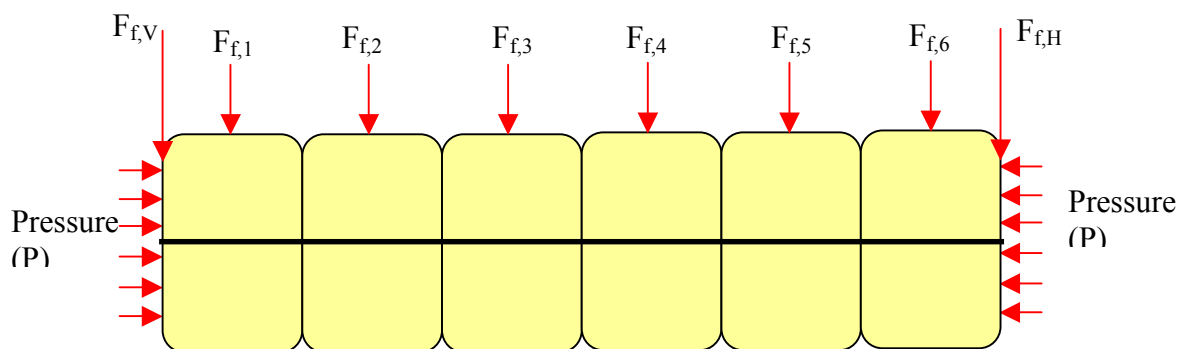
### 5.8.1 Purpose

The purpose of this analysis is to find out how large accelerations the bales can be exerted to before they start to slide. The figure below shows a top view of 6 bales of wood pulp bounded together, according to the guidelines: RIV Appendix II, Section 2, Loading guidelines 4.2.2.



### 5.8.2 Calculations

Below the bales and the forces acting in horizontal direction are seen from above.



Total Force of friction acting on the group of bales:

$$F_f = F_H + F_V + \sum_{N=1}^6 F_{f,N} = 2 \cdot \mu \cdot P + \mu \cdot g \cdot \sum_{N=1}^6 m_N$$

Largest allowed transverse acceleration

$$F_f = a_t \cdot \sum_{N=1}^6 m_N \Rightarrow a_t = \frac{2 \cdot \mu \cdot P}{\sum_{N=1}^6 m_N} + \mu \cdot g$$

#### Example:

The masses,  $m_1 - m_6$  is 500 kg each.

Pressure P equals 5000 N.

The coefficient of friction against all surfaces is 0.3.

$$a_t = \frac{2 \cdot \mu \cdot P}{\sum_{N=1}^6 m_N} + \mu \cdot g = \frac{2 \cdot 0.3 \cdot 5000}{6 \cdot 500} + 0.3 \cdot 9.81 = 3.9 \text{ m/s}^2$$

Largest allowed transverse acceleration is 3.9 m/s<sup>2</sup> if no vertical acceleration is considered.

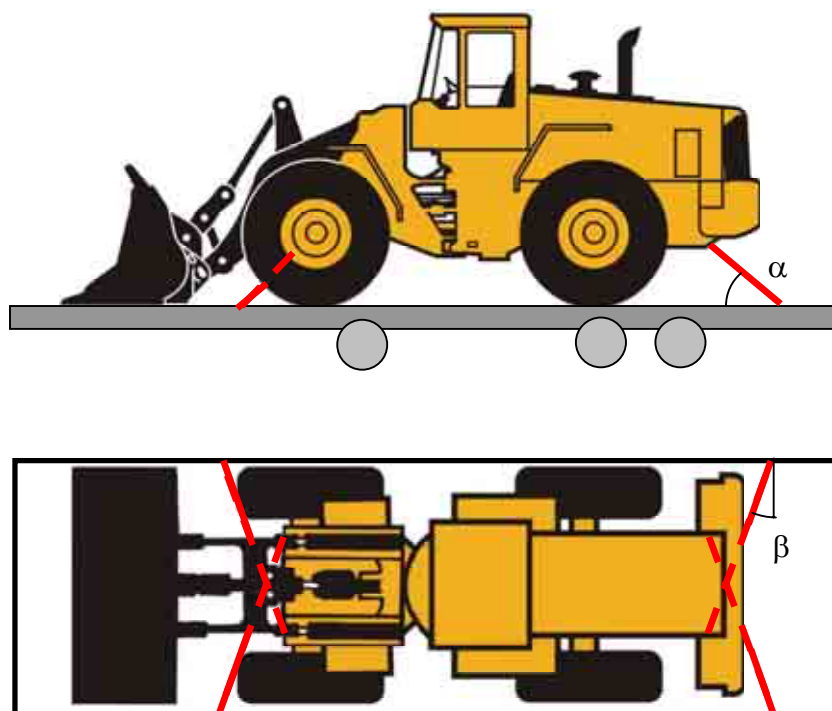
### 5.8.3 Summary

The calculations above show that the arrangement can withstand a transverse acceleration of 80% of the general acceleration. If the pressure from each side of the group is neglected, the obtained transverse acceleration will decrease from 3.9 m/s<sup>2</sup> to 2.9 m/s<sup>2</sup>, which is 60% of the general acceleration in transverse direction.

## 5.9 Vehicles

### 5.9.1 Purpose

The purpose of this analysis is to calculate how large accelerations vehicles can be exposed to when secured according to the UIC:s guidelines (RIV Appendix II, Section 2, Loading guidelines 7.2). The max allowed securing load of the lashings is considered to be half of its breaking strength. The sketch below shows a typical securing arrangement for a wheel loader.



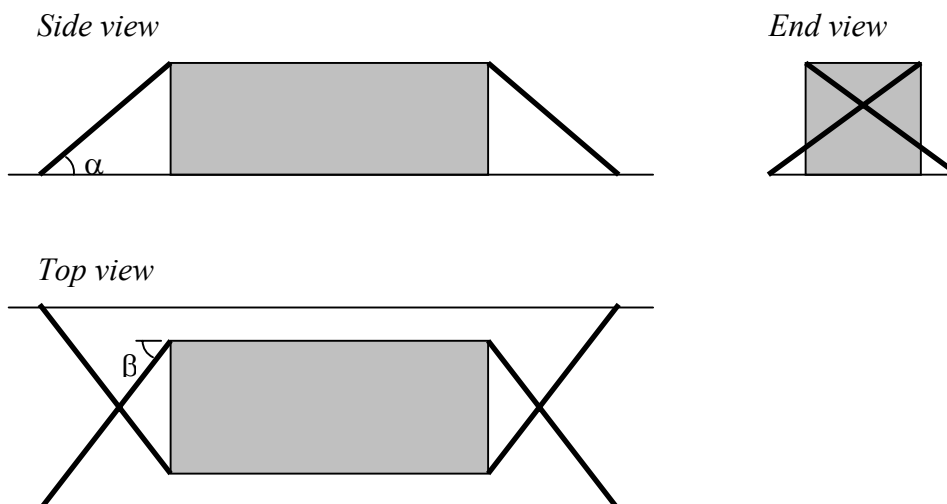
### 5.9.2 Loading guidelines

The following guidelines are valid according to UIC.

Vehicle weight up to:		Breaking strength of binding material	Breaking strength of binding material
Wheeled vehicles	Caterpillar vehicles		
3 t	5 t	40 kN	20 kN
8 t	10 t	80 kN	40 kN
15 t	25 t	125 kN	80 kN
30 t	50 t	200 kN	125 kN
40 t	60 t	320 kN	200 kN

### 5.9.3 Calculations

Below the cargo with lashings is shown from three different views.



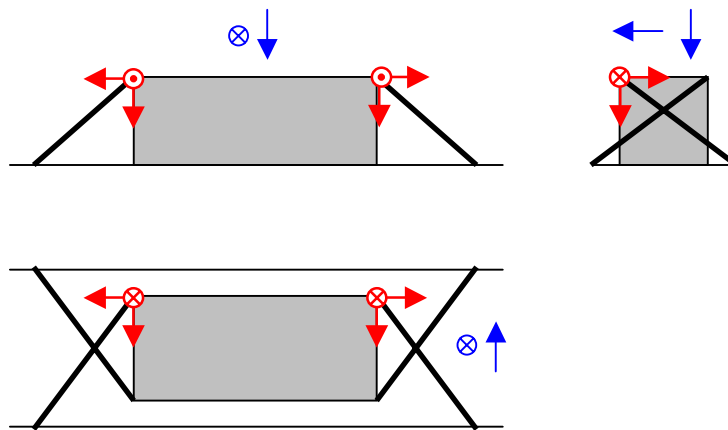
The tensile force in each direction for one lashing is:

$$F_v = F \cdot \sin \alpha$$

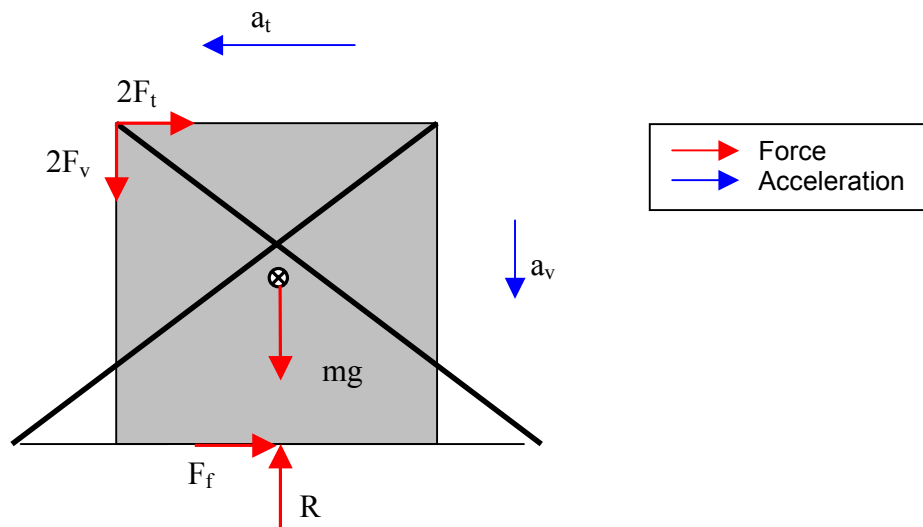
$$F_t = F \cdot \cos \alpha \cdot \sin \beta$$

$$F_l = F \cdot \cos \alpha \cdot \cos \beta$$

Below the forces from each lashing during transverse acceleration are shown.



The following forces are acting on the cargo during transverse acceleration.



Equilibrium of forces:

$$\uparrow R - m \cdot g - 2 \cdot F_v = m \cdot a_v \Rightarrow R = m \cdot (a_v + g) + 2 \cdot F_v$$

$$\rightarrow F_f + 2 \cdot F_t = m \cdot a_t \Rightarrow a_t = \frac{F_f + 2 \cdot F_t}{m}$$

Force of friction:

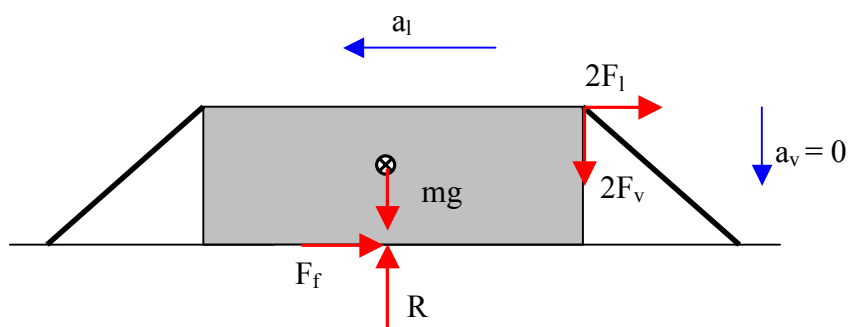
$$F_f = \mu \cdot R = \mu \cdot [m \cdot (a_v + g) + 2 \cdot F_v]$$

The transverse acceleration is calculated according to the following formula:

$$a_t = \frac{\mu \cdot [m \cdot (a_v + g) + 2 \cdot F_v] + 2 \cdot F_l}{m} = \frac{\mu \cdot [m \cdot (a_v + g) + 2 \cdot F \cdot \sin \alpha] + 2 \cdot F \cdot \cos \alpha \cdot \sin \beta}{m}$$

$$a_t = \mu \cdot (a_v + g) + \frac{2 \cdot F \cdot (\mu \cdot \sin \alpha + \cos \alpha \cdot \sin \beta)}{m}$$

Below the forces acting on the cargo during longitudinal acceleration are shown.



The longitudinal acceleration is calculated according to the following formula:

$$a_l = \frac{\mu \cdot (m \cdot g + 2 \cdot F_v) + 2 \cdot F_l}{m} = \frac{\mu \cdot (m \cdot g + 2 \cdot F \cdot \sin \alpha) + 2 \cdot F \cdot \cos \alpha \cdot \cos \beta}{m}$$

$$a_l = \mu \cdot g + \frac{2 \cdot F \cdot (\mu \cdot \sin \alpha + \cos \alpha \cdot \cos \beta)}{m}$$

**Example:**

In this example a wheeled vehicle with a mass of 30 ton is analysed. According to the guidelines the breaking strength of the binding material is to be minimum 200 kN for hump and fly shunting and 125 kN for none hump and fly shunting. The angles  $\alpha$  and  $\beta$  is set to  $45^\circ$  respectively  $30^\circ$ . The static coefficient of friction between the cargo and the surface is assumed to be 0.3. As the securing arrangements allow a certain degree of movement to obtain full load in the lashings, the dynamic coefficient is used, which is estimated to be 70% of the static coefficient.

Max allowed transverse acceleration for hump and fly shunting to avoid transverse sliding is:

$$a_t = \mu \cdot (a_v + g) + \frac{2 \cdot F \cdot (\mu \cdot \sin \alpha + \cos \alpha \cdot \sin \beta)}{m} =$$

$$= 0.7 \cdot 0.3 \cdot (-3 + 9.81) + \frac{2 \cdot 200000 / 2 \cdot (0.7 \cdot 0.3 \cdot \sin 45^\circ + \cos 45^\circ \cdot \sin 30^\circ)}{30000} = 4.8 \text{ m/s}^2$$



When neglecting the vertical acceleration the following formula is derived:

$$a_t = \mu \cdot g + \frac{2 \cdot F \cdot (\mu \cdot \sin \alpha + \cos \alpha \cdot \sin \beta)}{m} =$$

$$= 0.7 \cdot 0.3 \cdot 9.81 + \frac{2 \cdot 200000 / 2 \cdot (0.7 \cdot 0.3 \cdot \sin 45^\circ + \cos 45^\circ \cdot \sin 30^\circ)}{30000} = 5.4 \text{ m/s}^2$$

Max allowed longitudinal acceleration for hump and fly shunting to avoid longitudinal sliding is:

$$a_t = \mu \cdot g + \frac{2 \cdot F \cdot (\mu \cdot \sin \alpha + \cos \alpha \cdot \cos \beta)}{m} =$$

$$= 0.7 \cdot 0.3 \cdot 9.81 + \frac{2 \cdot 200000 / 2 \cdot (0.7 \cdot 0.3 \cdot \sin 45^\circ + \cos 45^\circ \cdot \cos 30^\circ)}{30000} = 7.1 \text{ m/s}$$

Max allowed transverse acceleration for none hump and fly shunting to avoid transverse sliding is:

$$a_t = 0.7 \cdot 0.3 \cdot (-3 + 9.81) + \frac{2 \cdot 125000 / 2 \cdot (0.7 \cdot 0.3 \cdot \sin 45^\circ + \cos 45^\circ \cdot \sin 30^\circ)}{30000} = 3.5 \text{ m/s}^2$$

When neglecting the vertical acceleration the following formula is derived:

$$a_t = 0.7 \cdot 0.3 \cdot 9.81 + \frac{2 \cdot 125000 / 2 \cdot (0.7 \cdot 0.3 \cdot \sin 45^\circ + \cos 45^\circ \cdot \sin 30^\circ)}{30000} = 4.2 \text{ m/s}$$

Max allowed longitudinal acceleration for none hump and fly shunting to avoid longitudinal sliding is:

$$a_t = 0.7 \cdot 0.3 \cdot 9.81 + \frac{2 \cdot 125000 / 2 \cdot (0.7 \cdot 0.3 \cdot \sin 45^\circ + \cos 45^\circ \cdot \cos 30^\circ)}{30000} = 5.2 \text{ m/s}$$

#### 5.9.4 Results

The largest allowed transverse acceleration (in  $\text{m/s}^2$ ) during hump and fly shunting is shown for several different combinations of the longitudinal ( $\beta$ ) and vertical angle ( $\alpha$ ). See table below. The shaded area shows the most realistic combinations of  $\alpha$  and  $\beta$ .

*Longitudinal angle  $\beta$*

	<i>10°</i>	<i>20°</i>	<i>30°</i>	<i>40°</i>	<i>50°</i>	<i>60°</i>	<i>70°</i>	<i>80°</i>
<i>10°</i>	2.8	3.9	5.0	5.9	6.7	7.4	7.8	8.1
<i>20°</i>	3.0	4.1	5.0	5.9	6.7	7.3	7.8	8.1
<i>30°</i>	3.1	4.1	5.0	5.8	6.6	7.1	7.6	7.8
<i>40°</i>	3.2	4.1	4.9	5.6	6.2	6.8	7.1	7.4
<i>50°</i>	3.3	4.0	4.7	5.3	5.8	6.2	6.5	6.7
<i>60°</i>	3.2	3.8	4.3	4.8	5.2	5.5	5.8	5.9
<i>70°</i>	3.1	3.5	3.9	4.2	4.5	4.7	4.9	5.0
<i>80°</i>	3.0	3.2	3.4	3.6	3.7	3.8	3.9	4.0

*Max allowed transverse accelerations at hump and fly shunting,  $a_v = -3 \text{ m/s}^2$*

According to the table above the worst case appears when  $\alpha = 60^\circ$ , and  $\beta = 30^\circ$ . At these angles the maximum allowed transverse acceleration is  $4.9 \text{ m/s}^2$  for hump and fly shunting when the vertical acceleration is discarded from, e.g.  $a_v = 0 \text{ m/s}^2$ .

The largest allowed longitudinal accelerations during hump and fly shunting are shown below.

*Longitudinal angle  $\beta$*

	<i>10°</i>	<i>20°</i>	<i>30°</i>	<i>40°</i>	<i>50°</i>	<i>60°</i>	<i>70°</i>	<i>80°</i>
<i>10°</i>	8.8	8.5	8.0	7.3	6.5	5.6	4.6	3.4
<i>20°</i>	8.7	8.4	8.0	7.3	6.6	5.7	4.7	3.6
<i>30°</i>	8.5	8.2	7.8	7.2	6.5	5.7	4.7	3.8
<i>40°</i>	8.0	7.8	7.4	6.9	6.2	5.5	4.7	3.9
<i>50°</i>	7.4	7.2	6.8	6.4	5.9	5.3	4.6	3.9
<i>60°</i>	6.6	6.4	6.2	5.8	5.4	4.9	4.4	3.9
<i>70°</i>	5.6	5.5	5.4	5.1	4.8	4.5	4.2	3.8
<i>80°</i>	4.6	4.5	4.4	4.3	4.2	4.0	3.8	3.6

*Max allowed longitudinal accelerations at hump and fly shunting,  $a_v = 0 \text{ m/s}^2$*

The corresponding allowed accelerations when the wagon is not subjected to hump and fly shunting for both transverse and longitudinal direction are shown in the tables below.

		Longitudinal angle $\beta$							
		$10^\circ$	$20^\circ$	$30^\circ$	$40^\circ$	$50^\circ$	$60^\circ$	$70^\circ$	$80^\circ$
Vertical angle $\alpha$	$10^\circ$	2.3	3.0	3.6	4.2	4.7	5.1	5.4	5.6
	$20^\circ$	2.4	3.1	3.7	4.3	4.7	5.1	5.4	5.6
	$30^\circ$	2.5	3.1	3.7	4.2	4.6	5.0	5.3	5.4
	$40^\circ$	2.6	3.1	3.6	4.0	4.4	4.8	5.0	5.1
	$50^\circ$	2.6	3.0	3.4	3.8	4.2	4.4	4.6	4.7
	$60^\circ$	2.6	2.9	<b>3.2</b>	3.5	3.8	4.0	4.2	4.2
	$70^\circ$	2.5	2.7	3.0	3.2	3.3	3.5	3.6	3.7
	$80^\circ$	2.4	2.5	2.7	2.8	2.9	2.9	3.0	3.0

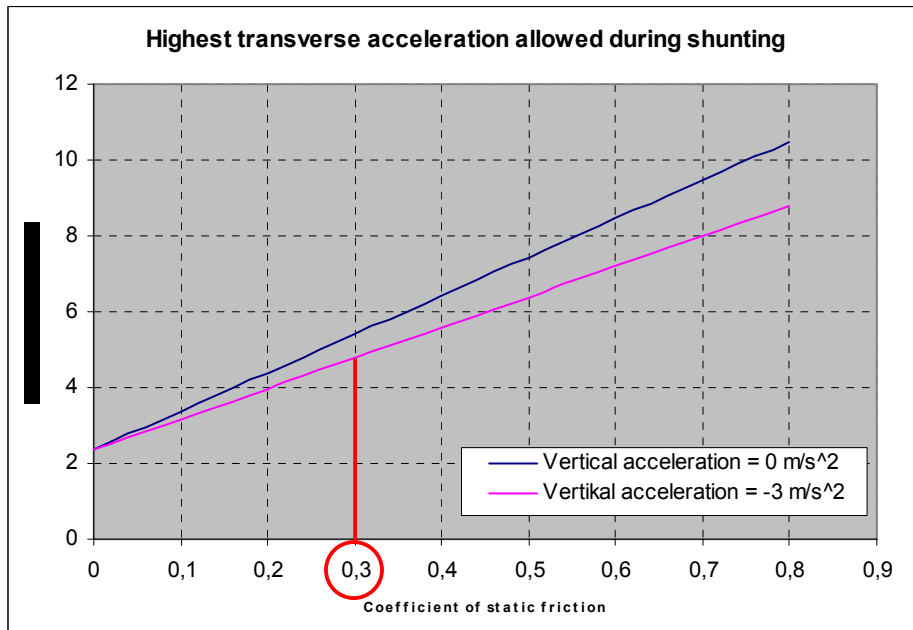
Max allowed transverse accelerations at none hump and fly shunting,  $a_v = -3 \text{ m/s}^2$

According to the table above the worst case appears when  $\alpha = 60^\circ$ , and  $\beta = 30^\circ$ . At these angles the maximum allowed transverse acceleration is  $3.9 \text{ m/s}^2$  for none hump and fly shunting when the vertical acceleration is discarded from, e.g.  $a_v = 0 \text{ m/s}^2$ .

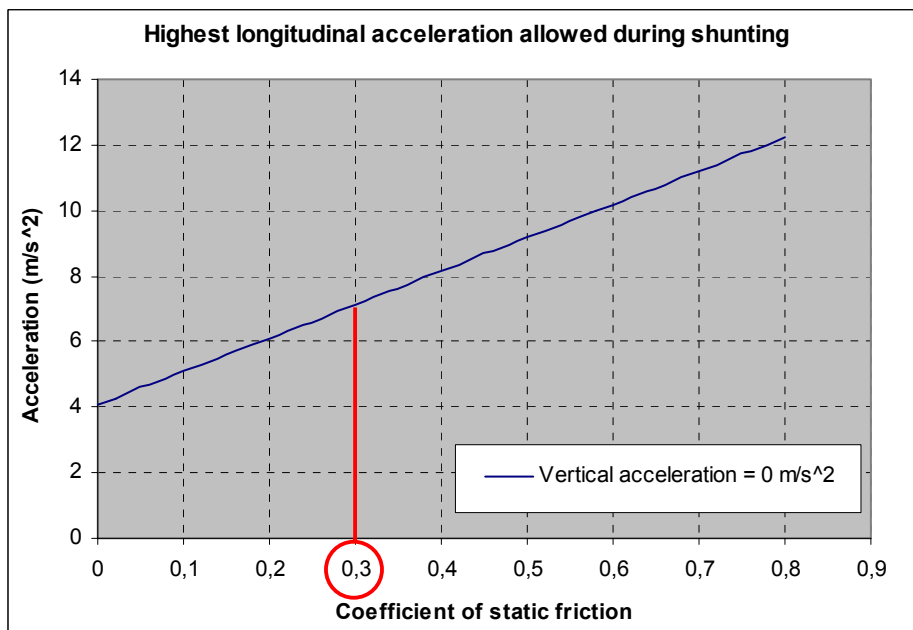
		Longitudinal angle $\beta$							
		$10^\circ$	$20^\circ$	$30^\circ$	$40^\circ$	$50^\circ$	$60^\circ$	$70^\circ$	$80^\circ$
Vertical angle $\alpha$	$10^\circ$	6.3	6.1	5.8	5.4	4.9	4.3	3.6	2.9
	$20^\circ$	6.2	6.0	5.8	5.4	4.9	4.3	3.7	3.0
	$30^\circ$	6.1	5.9	5.6	5.3	4.8	4.3	3.7	3.1
	$40^\circ$	5.8	5.6	5.4	5.1	4.7	4.2	3.7	3.2
	$50^\circ$	5.4	5.3	5.1	4.8	4.5	4.1	3.7	3.2
	$60^\circ$	4.9	4.8	4.6	4.4	4.2	<b>3.9</b>	3.5	3.2
	$70^\circ$	4.3	4.2	4.1	4.0	3.8	3.6	3.4	3.1
	$80^\circ$	3.6	3.6	3.6	3.5	3.4	3.3	3.2	3.1

Max allowed longitudinal accelerations at none hump and fly shunting,  $a_v = 0 \text{ m/s}^2$

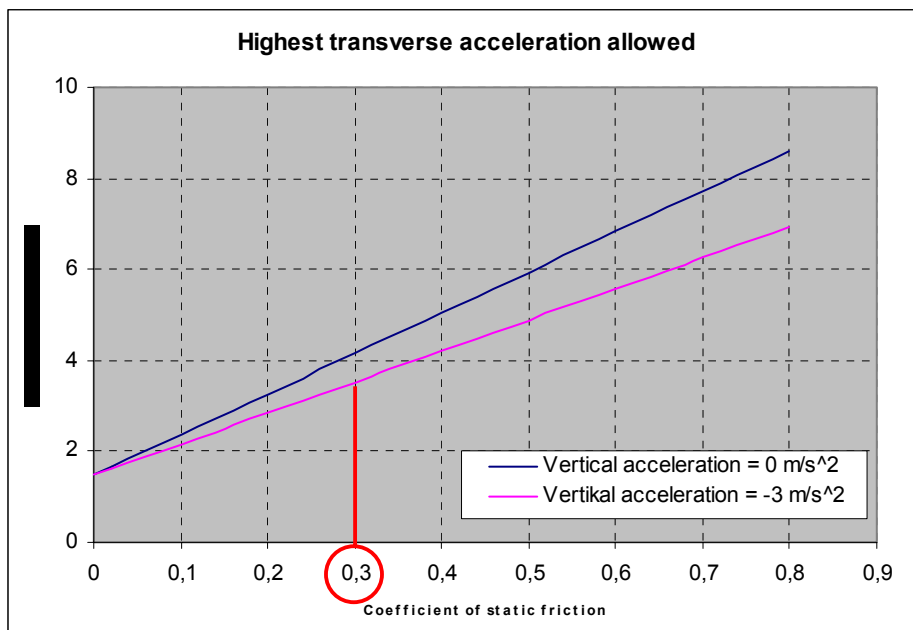
The diagram below shows the largest allowed transverse acceleration as a function of the static coefficient of friction, during hump and fly shunting. The vertical angle ( $\alpha$ ) and longitudinal angle ( $\beta$ ) of the lashings is fixed at  $45^\circ$  and  $30^\circ$  respectively. The mass of the vehicle is 30 ton.



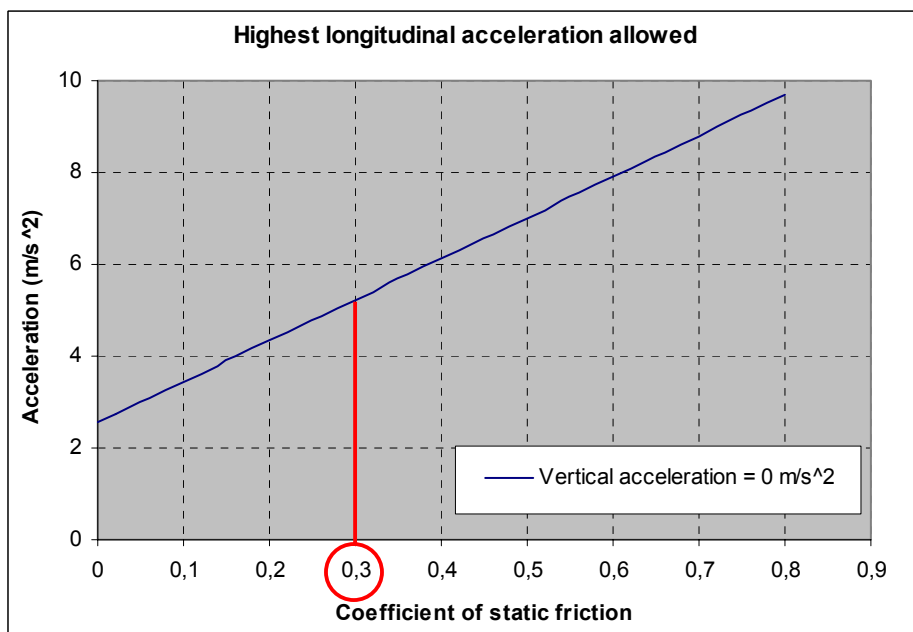
The following diagram shows the corresponding largest allowed longitudinal acceleration at hump and fly shunting.



Following diagram shows the largest transverse acceleration allowed at none hump and fly shunting. Otherwise the conditions are the same as for the two previous diagrams.



Finally the largest longitudinal acceleration at none hump and fly shunting.



### 5.9.5 Summery

The results are put together in the table below were the largest allowed accelerations in respectively transverse and longitudinal direction are shown. The vertical acceleration is taken in account during transverse movement. The longitudinal and vertical lashing angles are assumed to be between 30° and 60°.

Shunting	Vertical acceleration (m/s <sup>2</sup> )	Transverse acceleration (m/s <sup>2</sup> )	Longitudinal acceleration (m/s <sup>2</sup> )
Hump and fly	0	4.9	4.9
Hump and fly	-3	4.3	-
None hump and fly	0	3.9	3.9
None hump and fly	-3	3.2	-

The UIC:s guidelines is shown in table 4.10.6 for comparison.

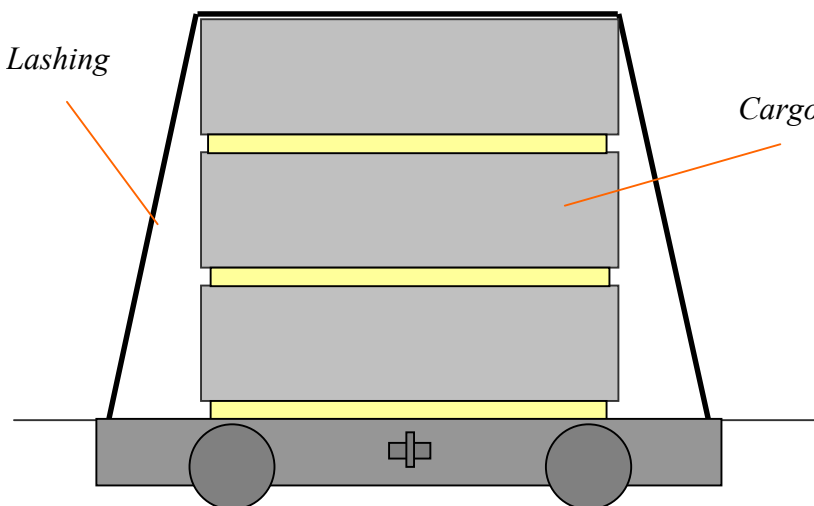
Shunting	Vertical acceleration (m/s <sup>2</sup> )	Transverse acceleration (m/s <sup>2</sup> )	Longitudinal acceleration (m/s <sup>2</sup> )
Hump and fly	0		40
Hump and fly	-3	5	-
None hump and fly	0		10
None hump and fly	-3	5	-

The largest allowed transverse acceleration for the specific lashing guidelines reaches about 85% of the general guidelines (65% for none hump and fly shunting). Corresponding for the longitudinal acceleration is about 10% for hump and fly shunting and 40% without.

## 5.10 Plywood slabs

### 5.10.1 Purpose

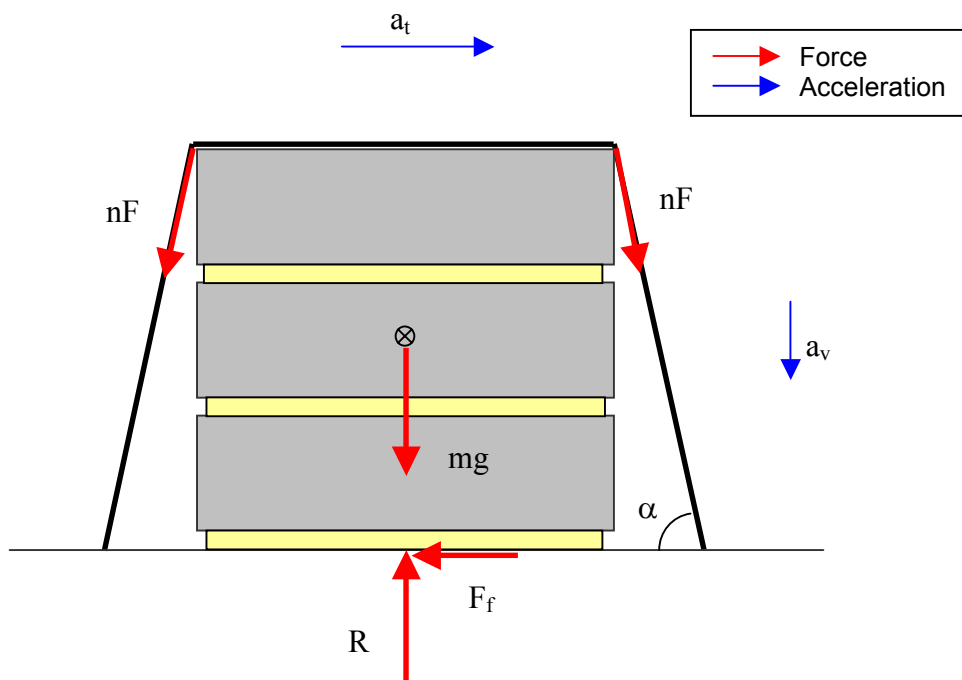
The purpose of this analysis is to calculate how large accelerations plywood slabs can be exposed to when secured according to the UIC:s guidelines (RIV Appendix II, Section 2, Loading guidelines 2.9). When using indirect fastenings, each section should be secured by two lashings with a breaking strength of at least 40 kN.



The maximum pretension force (F) in the lashings will be about 10% of the breaking strength. No analysis of largest allowed longitudinal acceleration will be made, since it's free to slide in that direction.

5.10.2 Calculations

The forces acting on the cargo during vertical and transverse accelerations are shown below.



Equilibrium of forces:

$$\uparrow R - m \cdot g - 2 \cdot n \cdot F \cdot \sin \alpha = m \cdot a_v \Rightarrow R = m \cdot (a_v + g) + 2 \cdot n \cdot F \cdot \sin \alpha$$

$$\rightarrow F_f = m \cdot a_t \Rightarrow a_t = \frac{F_f}{m}$$

Force of friction:

$$F_f = \mu \cdot R = \mu \cdot [m \cdot (a_v + g) + 2 \cdot n \cdot F \cdot \sin \alpha]$$

The maximum allowed transverse acceleration to avoid transverse sliding is thus:

$$a_t = \frac{F_f}{m} = \mu \cdot (a_v + g) + \frac{\mu \cdot 2 \cdot n \cdot F \cdot \sin \alpha}{m}$$

n = Number of lashings

**Example:**

Sliding in transverse direction:

The mass of the cargo equals 10 ton and is secured with 2 lashings with an angle ( $\alpha$ ) of 80°. The coefficient of friction is 0.3 and the vertical acceleration acting at the time is  $-3 \text{ m/s}^2$ . The pretension F is 4000 N

$$a_t = \mu \cdot (a_v + g) + \frac{\mu \cdot 2 \cdot n \cdot F \cdot \sin \alpha}{m} = 0.3 \cdot (-3 + 9.81) + \frac{0.3 \cdot 2 \cdot 2 \cdot 4000 \cdot \sin 80}{10000} = 2.5 \text{ m/s}^2$$

The largest allowed transverse acceleration is  $2.5 \text{ m/s}^2$  according to the calculations above.

When discarding from the vertical acceleration the following formula is derived:

$$a_t = \mu \cdot g + \frac{\mu \cdot 2 \cdot n \cdot F \cdot \sin \alpha}{m} = 0.3 \cdot 9.81 + \frac{0.3 \cdot 2 \cdot 2 \cdot 4000 \cdot \sin 80}{10000} = 3.4 \text{ m/s}^2$$

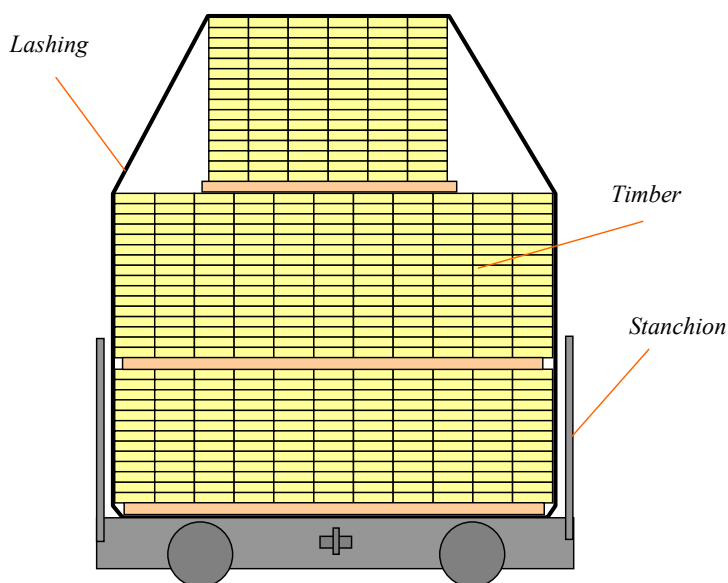
**5.10.3 Summery**

The cargo can be exposed to accelerations of up to  $2.5 \text{ m/s}^2$  in transverse direction when a vertical acceleration of  $-3 \text{ m/s}^2$  acts and  $3.4 \text{ m/s}^2$  when there is none. In this example the largest allowed transverse acceleration for the specific guidelines reaches about 50% of the general guidelines.

**5.11 Square-sawn timber**

**5.11.1 Purpose**

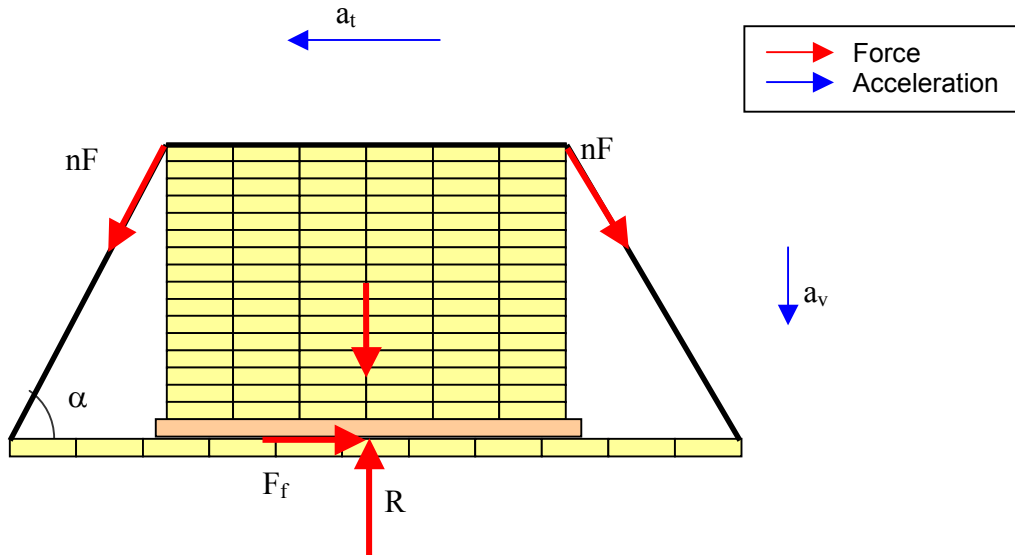
This analyse requires the same strategy as in chapter 5.4. The stanchion will prevent bottom part of the timber to move in transverse direction. The sketch below shows a typical arrangement. The top part of the cargo is fastened to the lower parts with 2 lashes and directly to the wagon with another 2 lashes.





5.11.2 Calculations

The figure below shows the forces acting on the top part of the cargo during vertical and transverse accelerations. The pretension force (F) of the lashings is assumed to be about 10% of the breaking strength.



Equilibrium of forces:

$$\uparrow R - m \cdot g - 2 \cdot n \cdot F \cdot \sin \alpha = m \cdot a_v \Rightarrow R = m \cdot (a_v + g) + 2 \cdot n \cdot F \cdot \sin \alpha$$

$$\rightarrow F_f = m \cdot a_t \Rightarrow a_t = \frac{F_f}{m}$$

Force of friction:

$$F_f = \mu \cdot R = \mu \cdot [m \cdot (a_v + g) + 2 \cdot n \cdot F \cdot \sin \alpha]$$

Maximum allowed transverse acceleration to avoid transverse sliding:

$$a_t = \frac{F_f}{m} = \mu \cdot (a_v + g) + \frac{\mu \cdot 2 \cdot n \cdot F \cdot \sin \alpha}{m}$$

n = Number of lashings

**Example:**

Sliding in transverse direction (Top part):

The mass of the top part of the cargo equals 5 ton and is secured by 4 lashings with an angle ( $\alpha$ ) of  $45^\circ$ . Two of the lashings have a breaking strength of 10 kN and a pretension of 1 kN (1000 N), the other 2 lashings have a breaking strength of 7 kN and a pretension of 0.7 kN (700 N). The coefficient of friction is 0.3 and the vertical acceleration acting at the time is  $-3 \text{ m/s}^2$ .

$$a_t = \mu \cdot (a_v + g) + \frac{\mu \cdot 2 \cdot n \cdot F \cdot \sin \alpha}{m} =$$

$$= 0.3 \cdot (-3 + 9.81) + \frac{0.3 \cdot 2 \cdot 2 \cdot (1000 + 700) \cdot \sin 45^\circ}{5000} = 2.3 \text{ m/s}^2$$

The largest allowed transverse acceleration is 2.3 m/s<sup>2</sup> according to the calculations above.

When discarding from the vertical acceleration the following formula is derived:

$$a_t = \mu \cdot g + \frac{\mu \cdot 2 \cdot n \cdot F \cdot \sin \alpha}{m} = 0.3 \cdot 9.81 + \frac{0.3 \cdot 2 \cdot 2 \cdot (1000 + 700) \cdot \sin 45^\circ}{5000} = 3.2 \text{ m/s}^2$$

The largest allowed transverse acceleration when the vertical acceleration is set to zero is 3.2 m/s<sup>2</sup> according to the calculations above.

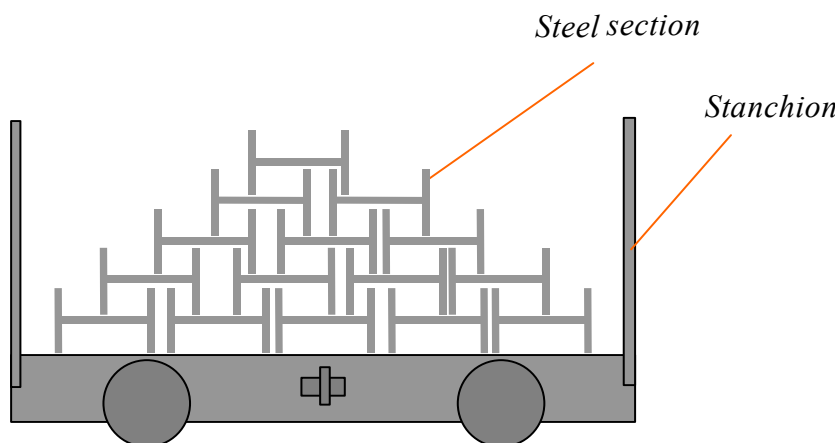
### 5.11.3 Summery

The cargo can be exposed to accelerations of up to 2.3 m/s<sup>2</sup> in transverse direction when a vertical acceleration of -3 m/s<sup>2</sup> acts and 3.2 m/s<sup>2</sup> when there is none. In this example the largest allowed transverse acceleration for the specific guidelines reaches about 45% of the general guidelines.

## 5.12 Steel sections

### 5.12.1 Purpose

The purpose is to analyse at what magnitude of acceleration a steel sections starts to slide when secured according to UIC (RIV Appendix II, Section 2, Loading guidelines 1.6.1) the steel sections can be placed directly on the wagon floor as long as they are lying flange side down as shown below.

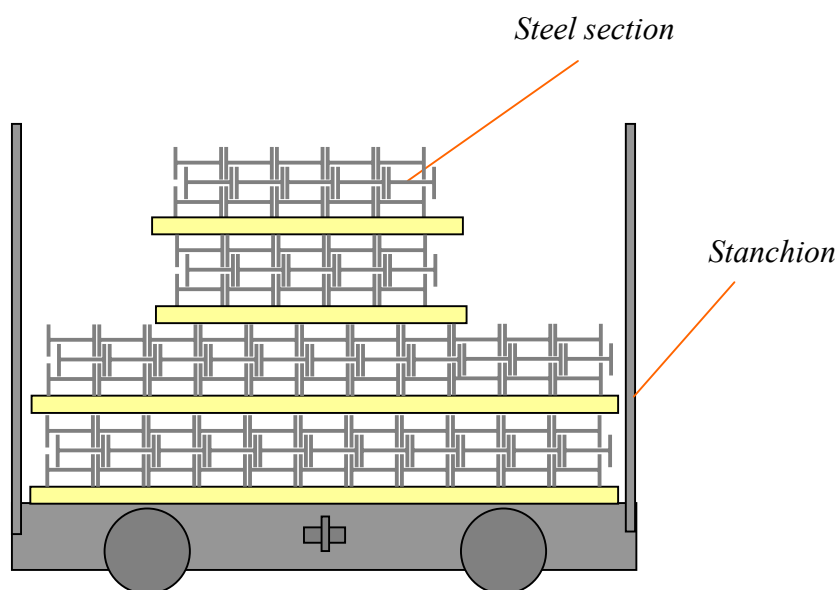


The purpose of lying the steel sections flange down is to increase the friction against the wagon floor. In this analysis the coefficient of friction will still be the minimum 0.3.

### 5.12.2 Loading guidelines

According to the guidelines, steel sections lying flange down require no additional securing.

The figure below shows an arrangement of H-beams stacked on top of each other. Since the effective height of the stanchions above the steel bars is more than 10 cm, the sections would not need any additional securing.



The picture below shows an example of how H-beams may be stacked in accordance with the UIC guidelines.



### 5.12.3 Calculations

The steel sections will be treated as one package when calculating how large accelerations they can be exerted to without sliding.

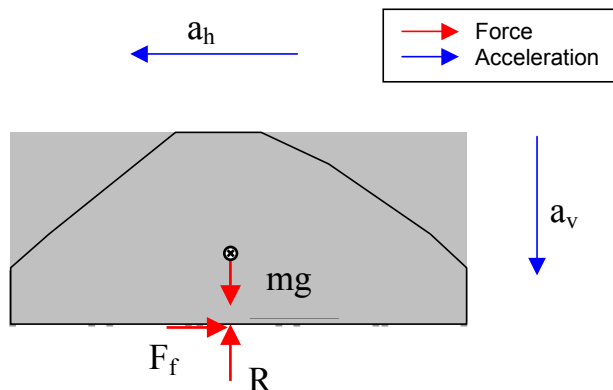
Equilibrium of forces:

$$\uparrow R - m \cdot g = m \cdot a_v \Rightarrow R = m \cdot (a_v + g)$$

$$\rightarrow F_f = m \cdot a_h \Rightarrow a_h = \frac{F_f}{m}$$

Force of friction:

$$F_f = \mu \cdot R = \mu \cdot m \cdot (a_v + g)$$



Largest horizontal acceleration that can act on the sections before they start to slide:

$$a_h = \frac{\mu \cdot m \cdot (a_v + g)}{m} = \mu \cdot (a_v + g)$$

Transversal direction:

Largest allowed transverse acceleration when considering sliding. The vertical acceleration to be calculated with according to UIC is  $-3 \text{ m/s}^2$

$$a_t = \mu \cdot (a_v + g) = 0.3 \cdot (-3 + 9.81) = 2.0 \text{ m/s}^2$$

When calculation is carried out without any vertical acceleration the largest allowable transverse acceleration may be derived from the following formula:

$$a_t = \mu \cdot g = 0.3 \cdot 9.81 = 2.9 \text{ m/s}^2$$

Longitudinal direction:

Largest allowed longitudinal acceleration when no vertical acceleration is acting.

$$a_l = \mu \cdot (a_v + g) = 0.3 \cdot (0 + 9.81) = 2.9 \text{ m/s}^2$$

### 5.12.4 Summery

The result is put together below were the largest allowed acceleration in respectively transverse and longitudinal direction is shown. The vertical acceleration is taken into account

during transverse movement. The steel sections will start to slide at rather low accelerations; this won't be a problem as long as it's within reasonable properties.

Longitudinal sliding = 2.9 m/s<sup>2</sup>  
 Transverse sliding (a<sub>v</sub> = -3 m/s<sup>2</sup>) = 2.0 m/s<sup>2</sup>  
 Transverse sliding (a<sub>v</sub> = 0 m/s<sup>2</sup>) = 2.9 m/s<sup>2</sup>

### 5.13 Recommendations on modified general acceleration figures

The analyses made in this chapter are put together in the table below.

Load case	Allowable accelerations (in m/s <sup>2</sup> )							
	Vertical acc.	Transverse acc.			Longitudinal acc.			
		*	**	tipping	sliding *	sliding **	tipping	rolling
Nail joints	0	3.8	-	15.4	6.1	-	-	
	-3	2.9	-	-	-	-	-	
Cross Lashings	0	15.9	6.4	-	15.9	6.4	-	
	-3	15.3	5.8	-	-	-	-	
Top-over Lashing	0	3.1	-	-	-	-	-	
	-3	2.2	-	-	-	-	-	
Coiled sheet	0	3.8	3.7	5.4	3.6	-	5.3	
	-3	2.9	-	-	-	-	-	
Ungreased hot-rolled coiled sheet	0	2.9	-	2.9	-	6.9	-	
	-3	2.0	4.8	-	-	-	-	
A-frame	0	-	3.7	-	-	-	-	
Wood pulp in bales	0	3.9	-	-	-	-	-	
Vehicles	0	4.9	3.9	4.9	3.9	-	-	
	-3	4.3	3.2	-	-	-	-	
Plywood slabs	0	3.4	-	-	-	-	-	
	-3	2.5	-	-	-	-	-	
Square sawn timber	0	3.2	-	-	-	-	-	
	-3	2.3	-	-	-	-	-	
Steel sections	0	2.9	-	2.9	-	-	-	
	-3	2.0	-	-	-	-	-	

\* *Hump and fly shunting*

\*\* *None hump and fly shunting*

The figures in the table clearly shows that most of the by UIC accepted securing arrangements does not fulfil the general acceleration requirements.

To open up for new improvements and design of securing systems for rail transports it is strongly recommended to modify the general acceleration requirements to realistic figures, and to open up for allowance to design securing systems for these accelerations.

Based on the result from calculations in this chapter, the following general accelerations are recommended:

- **Transverse:**  $5 \text{ m/s}^2$
- **Longitudinal:**
  - at hump and fly shunting:  $10 \text{ m/s}^2$
  - at none hump and fly shunting:  $5 \text{ m/s}^2$
- **Vertical:**  $0 \text{ m/s}^2$

Due to the vibrations occurring during rail transport, it is, however, needed to have some kind of arrangement limiting the motion due to the vibrations. Battens, top-over lashings with limited strength or friction enhancing inserts can achieve this. When using friction, as only method of securing, the coefficient of friction has to be at least 0.7 and the contact surface shall have damping qualities.

## 6 DESIGN CRITERIA FOR WAGON SIDES, ENDS, STANCHIONS AND SECURING FITTINGS

Minimum demands on the strength of cargo securing equipment on railway wagons in Europe according to International Union of Railways (UIC) and in North America according to Association of American Railroads (AAR) are described below. As a comparison the strength requirements for cargo transport units and vehicles according to standards are also described.

Train Tech Engineering Sweden AB has contributed with input on design criteria according to UIC requirements.

In this chapter references are made to the following literature:

- ERRI - Report from European Rail Research Institute
- UIC - Leaflet from International Union of Railways
- RIV II - Appendix II to the Regulations governing the reciprocal use of wagons in international traffic (UIC)
- OTLR - Open Top Loading Rules (AAR)
- C - Section C, Car Construction – Fundamentals and Details (AAR)
- C II - Section C, Part II, Volume 1 – Specifications for Design, Fabrication and Construction of Freight Cars (AAR)

### 6.1 Wagon types

#### 6.1.1 UIC

The wagons in Europe are divided in thirteen main classes:

##### Open wagons

- Class "E" – Normal open wagon
- Class "K" – 2 axle flat wagon
- Class "L" – 2 axle special flat wagon
- Class "O" – 2 axle flat wagon with sideboards
- Class "R" – 4 axle flat wagon

##### Closed wagons

- Class "G" – Closed wagon
- Class "H" – Special closed wagon

##### Special wagons

- Class "F" – Special open wagon
- Class "I" – Isolated/Refrigerator wagon
- Class "S" – 4+ axle special flat wagon
- Class "T" – Wagon with opening roof
- Class "U" – Special wagon
- Class "Z" – Tank wagon

Payload limits are often about 25 to 30 ton for two axle wagons or 50 ton and above for multi axle wagons.

The strength requirements according to UIC are described in this chapter for “Covered wagons with fixed or movable roofs and sides conforming to UIC 571-1 and 571-3 and class T wagons” and “High-sided open wagons conforming to UIC 571-1 and 571-2”. “Wagons with a fully opening roof complying with UIC 571-3 and wagons with folding roofs” are not described.



Open wagon – Kbps-x

Open wagon – Laeilpr  
(with weather protection)

Open wagon – Ldgs



Open wagon – Elos



Special wagon – Smmnps



Special wagon – Fas



Covered wagon – Gbs



Covered wagon – Hbins



Covered wagon – Hbis

### 6.1.2 AAR

The wagons in North America are divided in nine main classes:

- Class "X" - Box Car Types
- Class "R" - Refrigerator Car Types
- Class "V" - Ventilator Car types
- Class "S" - Stock Car types
- Class "H" - Hopper Car Types
- Class "F" - Flat Car types
- Class "L" - Special Car types
- Class "T" - Tank Car types
- Class "G" - Gondola Car types



In each class the wagons are subdivided depending on payload. The three most common payloads are 50 ton, 70 ton and 100 ton.

This chapter describes the strength of the Box car types and some of the Flat car types. The recommended practices for design and construction also have rules for Hopper Cars and Gondola cars but it is only the Box car types and Flat car types that are used for general cargo.



Box car – 50 ton



Box car – 70 ton



Box car – 100 ton



Flat car – 70 ton  
(with weather protection)



Flat car – 70 ton



Flat car – 100 ton



Gondola car – 70 ton



Gondola car – 100 ton



Hopper car – 50 ton



Hopper car – 50 ton

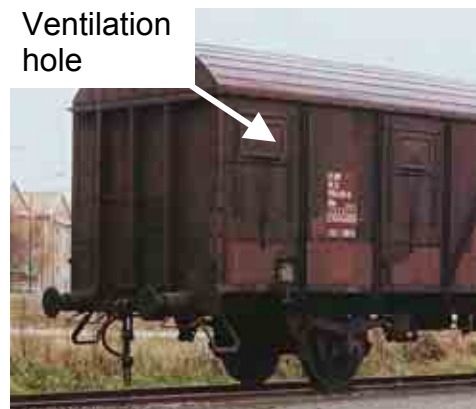
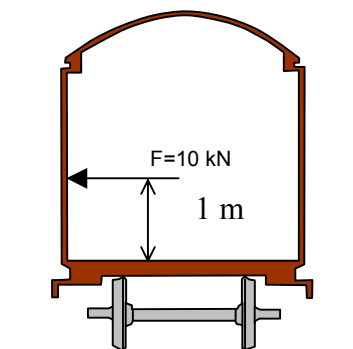
## 6.2 Fixed sides / Side walls

### 6.2.1 UIC

#### Covered wagons

Sides with body pillars must be able to withstand a transverse force of 8 kN (800 kg) acting at a height of one metre above the wagon floor on a pair of opposite body pillars. A residual deformation of maximum 2 mm is acceptable. (ERRI RP 17/UIC 577)

Sides with metal construction must be able to withstand a transverse force of 10 kN (1000 kg) acting at a height of one metre above the wagon floor on the body side at a point located below the end loading hole (or ventilation hole) and in the centre-line of this hole. A residual deformation of maximum 3 mm is acceptable. A 100×100 mm hardwood rod shall be used when applying the force. (ERRI RP 17/UIC 577)



An approximated calculation to give the maximum force that can be supported by the side of a typical wagon (Gbs 611) is shown below. As an assumption the wagon has eight body pillars per side. The calculations do not take any benefits from other possible distributions of the force into consideration, such as evenly distributed over the entire side. The possibility of a collapse of the whole side when all pillars are tested at the same time has also not been investigated.

#### Input data

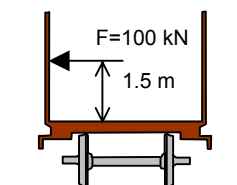
Payload (P):	26 ton
Number of stanchions (N)	8
Test force per stanchion (F):	8 kN
g:	9.81 m/s <sup>2</sup>

The force expressed in parts of the payload:  $\frac{N \times F}{g \times P} = \frac{8 \times 8}{9.81 \times 26} = 0.25$

The calculation gives thus a maximum allowable force on the wagon side of 0.25 times the maximum payload of the wagon. As the test force is approximately applied at half the height of the side (1 m above the wagon floor) the force can be considered to be evenly distributed over the entire side, if the moment is calculated from the wagon floor.

#### High-sided open wagons

Sides must be able to withstand a transverse force of 100 kN (10 ton) acting at a height of one and a half metre above the wagon floor applied to the four centre pillars. A residual deformation of maximum 1 mm is acceptable. (ERRI RP 17/UIC 577)



An approximated calculation to give the maximum force that can be supported by the side of a typical wagon (Eaos) is shown below. The test force is converted being evenly distributed from top to bottom.

#### Input data

Payload (P):	58 ton
Height of side wall (H):	2.02 m
Height to force (h):	1.5 m
Test force (F):	100 kN
g:	9.81 m/s <sup>2</sup>

Moment due to test force,  $M_T = F \times h = 100 \times 1.5 = 150 \text{ kNm}$

Moment due to evenly distributed cargo,  $M_D = \frac{Q \times H}{2} = \frac{Q \times 2.02}{2}$

$$M_T = M_D \Rightarrow Q = 149 \text{ kN}$$

The force expressed in parts of the payload:  $\frac{Q}{g \times P} = \frac{149}{9.81 \times 58} = 0.26$

The calculation gives thus a maximum allowable force evenly distributed over the entire wagon side of 0.26 times the maximum payload of the wagon.

## 6.2.2 AAR

For Box car side walls there are not mentioned any maximum force demands in the AAR regulations. There are however a maximum force demand when designing adjustable or fixed side wall fillers in Box cars. Box cars equipped with adjustable side wall fillers at diagonally opposite sides of car, for filling void space crosswise of car, may be used provided such space do not exceed 38 cm. Box cars equipped with full side wall fillers at both sides in both ends of car, for filling void space crosswise of car, may be used provided such space do not exceed 15 cm from each side of car. The wall fillers shall be designed to withstand a lateral force equivalent to 25% of the weight of cargo, (= 0.25 g). The force shall be uniformly distributed over the entire face of the wall filler. (C II - 4.1.16.1)

The effects of centrifugal force acting on loads with high centre of gravity shall be provided in the car design. For this computation a lateral acceleration of 0.3 g shall be used. (C II - 4.1.14.3)

Lateral pressure of granular, lump or pulverized bulk material shall be considered in the design of wagons in which such pressure may be active. If the weight of the cargo is 4.8 ton per meter of length the lateral force from the cargo in a typical closed top 70-ton Box car is 10 ton per meter of length. The lateral force is to be distributed vertically so that it is a maximum at the floor line decreasing uniformly to zero at the top surface of the cargo. (C II - 4.1.14.1)

## 6.3 Sliding sides

### 6.3.1 UIC

The modern covered wagons built for goods transportation of today are all equipped with sliding sides but only a few wagons have strengthened sliding sides according to the requirements noted below.

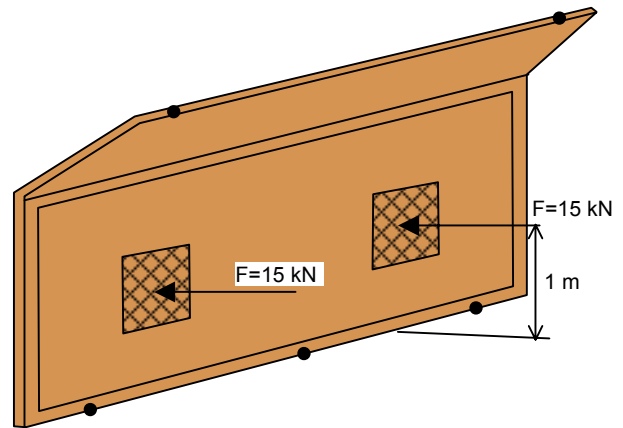
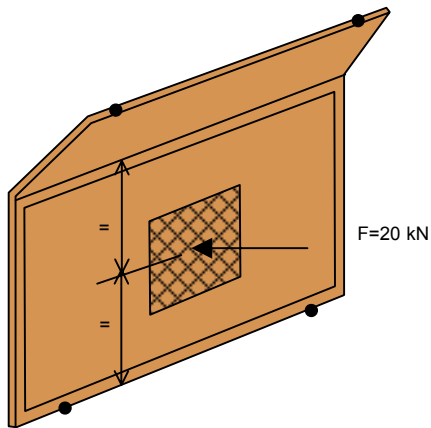
Sliding sides less than 2.5 m in length must be able to withstand:

- a transverse force of 8 kN (800 kg) due to pressure from the load acting in the centre of the side over an area of 1 m<sup>2</sup>.
- a transverse force of 5 kN (500 kg) on each support point of the side.

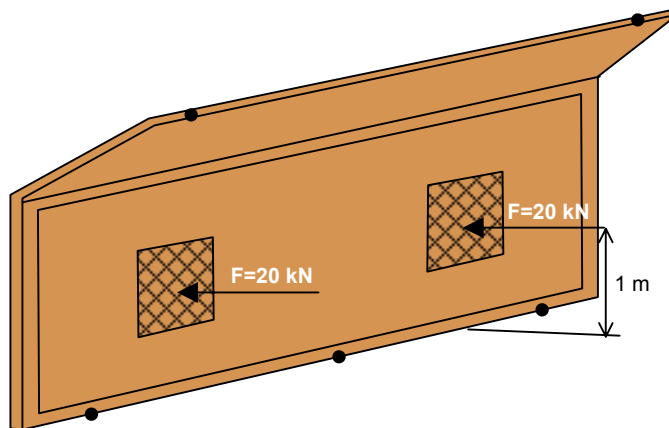
Sliding sides with a length between 2.5 and 5 m must be able to withstand a transverse force of 20 kN (2000 kg) due to pressure from the load acting in the centre of the side over an area of 1 m<sup>2</sup>.

Sliding sides with a length between 5 and 7 m must be able to withstand transverse forces of 15 kN (1500 kg) due to pressure from the load acting at a distance from the two ends of the side equal to ¼ of its length and at a height of 1m, over an area of 1 m<sup>2</sup>.

Sliding sides with a length exceeding 7 m must be able to withstand transverse forces of 20 kN (2000 kg) due to pressure from the load acting at a distance from the two ends of the side equal to ¼ of its length and at a height of 1m, over an area of 1 m<sup>2</sup>.

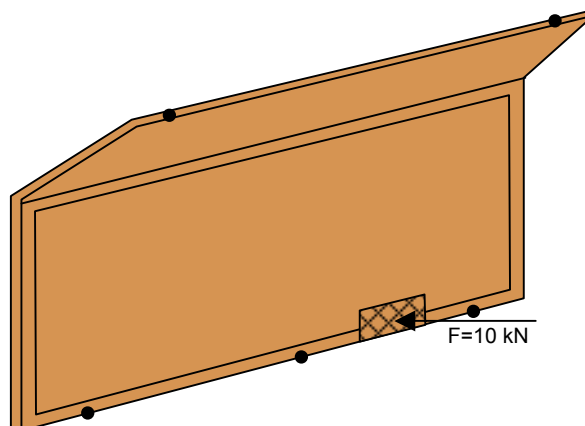


Sliding sides with length between 2.5 and 5 m. Sliding sides with length between 5 and 7 m.



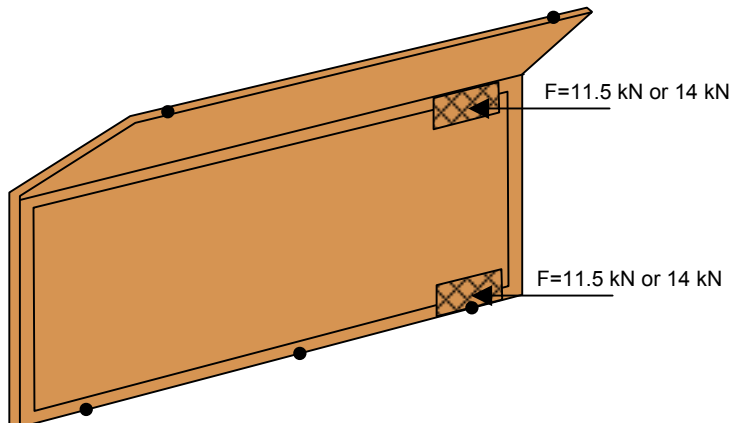
Sliding sides with length exceeding 7 m.

All sliding sides must be able to withstand a force of 10 kN (1000 kg) acting on the lower cantrail of the sliding side, between two articulated points, directly above the floor, over an area of 200×300 mm.



No damage or residual deformation is acceptable. (ERRI RP 17/UIC 577)

In addition the sliding sides must withstand a force, caused by trains crossing, applied on the articulation points near the end of the side wall, directly above the floor of the wagon and in the roof area. For 2-axle wagons and bogie wagons fitted with 2 or more sliding panels on each side the force shall be 11.5 kN (1150 kg). For bogie wagons fitted with 2 sliding panels on each side the force shall be 14 kN (1400 kg).



(ERRI RP 17/UIC 577)

Approximated calculations to give the maximum forces that can be supported by the side of typical wagons are shown below. The calculations do not take any benefits from other possible distributions of the force into consideration.

Length of sliding sides	2.5 m < L < 5 m	5 m < L < 7 m	7 m < L
<b>Input data</b>			
Wagon type	Hbillns 762	Hbbins 881	Habbins 941
Payload:	29 ton	30 ton	63.5 ton
Number of sliding sides (N):	4	2	2
Test force (F):	20 kN	2×15 kN	2×20 kN
g:	9.81 m/s <sup>2</sup>	9.81 m/s <sup>2</sup>	9.81 m/s <sup>2</sup>

The force expressed in parts of the payload:  $\frac{F \times N}{g \times P}$

The calculations gives maximum allowable forces on the wagon sides according to the table below.

Wagon type	Hbillns 762	Hbbins 881	Habbins 941
<b>Maximum force on side</b> (P = maximum payload of wagon)	0.28×P	0.20×P	0.13×P

As the test forces is applied at half the height of the sides (1 m above the wagon floor for side length above 5 m) the force can be considered to be evenly distributed over the entire side, if the moment is calculated from the wagon floor.

## 6.4 Doors

### 6.4.1 UIC

#### Covered wagons

**Sliding doors** must be able to withstand:

- a transverse force of 8 kN (800 kg) due to pressure from the load acting in the centre of the door over a square of 1 m side.
- a transverse force of 5 kN (500 kg) on each support point of the door.

No damage or residual deformation is acceptable.

An approximated calculation to give the maximum force that can be supported by the door of a typical wagon (Gbs 611) is shown below. The calculations do not take any benefits from other possible distributions of the force into consideration.

#### Input data

Payload (P):	26 ton
Usable loading length (L):	12.7 m
Door width (W):	2.5 m
Test force (F):	8 kN
g:	9.81 m/s <sup>2</sup>

The force expressed in parts of the payload: 
$$\frac{F}{g \times P \times \frac{W}{L}} = \frac{8}{9.81 \times 26 \times \frac{2.5}{12.7}} = 0.16$$

The calculation gives thus a maximum allowable force on the wagon door of 0.16 times the maximum payload of the wagon (in relation to the length of the door compared to the loading length). As the test force is applied at half the height of the side the force can be considered to be evenly distributed over the entire side, if the moment is calculated from the wagon floor.

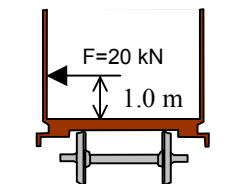
**Double-leaf doors** must be able to withstand

- a transverse force of 8 kN (800 kg) due to pressure from the load acting in the centre of each door leaf over a square of 1 m side.
- a transverse force of 5 kN (500 kg) on each articulated point of the door.

A residual deformation of maximum 2 mm is acceptable of the door itself but no damage or residual deformation is acceptable in the locking, running or guide mechanisms.

#### High-sided open wagons

The side doors must withstand a force of 20 kN (2000 kg) applied at a height of 1 m above floor level in the centre of the doorway.



An approximated calculation to give the maximum force that can be supported by the door of a typical wagon (Eaos) is shown below. The calculations do not take any benefits from other possible distributions of the force into consideration.

Input data

Payload (P):	58 ton
Usable loading length (L):	12.7 m
Door width (W):	1.8 m
Test force (F):	20 kN
g:	9.81 m/s <sup>2</sup>

The force expressed in parts of the payload: 
$$\frac{F}{g \times P \times \frac{W}{L}} = \frac{20}{9.81 \times 58 \times \frac{1.8}{12.8}} = 0.25$$

The calculation gives thus a maximum allowable force on the wagon door of 0.25 times the maximum payload of the wagon (in relation to the length of the door compared to the loading length). As the test forces is applied approximately at half the height of the door (1 m above the wagon floor) the force can be considered to be evenly distributed over the entire door, if the moment is calculated from the wagon floor.

**6.4.2 AAR**

The two general types of box car doors are the plug door and the sliding (corrugated) door. Box car doors are typically installed at half length of the carside. However, offset doors are not uncommon. Door widths tend to be 10' or 12' (16' doubles). The type and locations of doors is most often dictated by shippers to maximize the flexibility of the box car for a particular operation.

The sliding door is weather resistant and excludes direct light. However, it is not flush with the inside of the wagon when in the closed position. Most sliding doors are of the "free rolling" design in which the two bottom rollers are always sitting on the door track.

The plug door is designed to close with a final inward movement that positions (or "plugs") the interior of the door flush with the interior of the wagon. This flush feature increases the uninterrupted wall space of the wagon, and facilitates the use of insulation in the door.

For side doors there are not mentioned any maximum lateral force demands in the AAR regulations.



## 6.5 Side stanchions

### 6.5.1 UIC

Two side stanchions positioned so that they are facing each other must together be able to withstand a transverse, horizontal force of 35 kN (3.5 ton) directed towards the outside of the wagon and applied 500 mm from the bearing centre (swivelling stanchions) or 500 mm from the upper securing clamp (removable stanchions). (ERRI RP 17/UIC 577)



#### Swivelling side stanchions

A swivelling side stanchion should have a total length of 1655 mm and a cross-section (max 120×85 mm) according to the figure below. It is recommended that the stanchions be made of steel with breaking strength of at least 520 MPa.

A calculation as below gives the maximum allowed bending moment without residual deformation for the stanchion to be approximately 8.7 kNm (0.87 tonm).

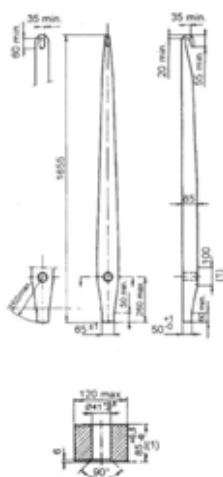
$$\text{Bending moment per stanchion} = \frac{35}{2} \times 0.5 = 8.7 \text{ kNm}$$

#### Removable side stanchion

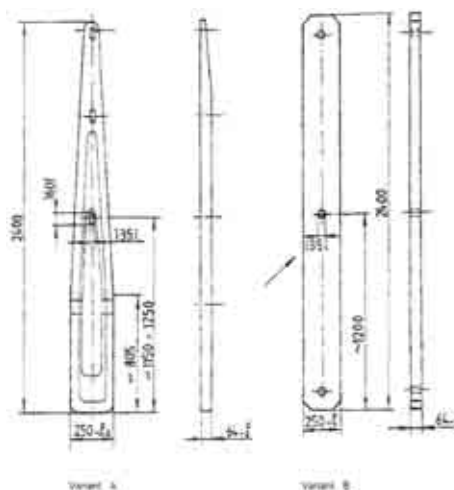
A removable side stanchion should have a total length of 2400 mm and a cross-section of the fixable part, 250×64 mm, according to the figure below. The moment of resistance at the critical part should be at least 28 cm<sup>3</sup>. The stanchions must be made of steel with breaking strength of at least 520 MPa ( $R_m$ ). (UIC 578)

A simple calculation as below, with a typical yield strength ( $R_{eL}$ ) of 310 MPa, gives the maximum allowed bending moment without residual deformation for the stanchion to be approximately 8.7 kNm (0.87 tonm).

$$\text{Bending moment per stanchion} = \sigma \times \frac{R_{eL}}{R_m} \times W = 520 \times \frac{310}{520} \times 28000 = 8.7 \text{ kNm}$$



Swivelling side stanchion



Removable side stanchions

### 6.5.2 AAR

Stake pockets and their attachments are to be designed to withstand loads of 104 kN (10.4 ton) applied laterally outward at the top edge, and 272 kN (27.2 ton) applied vertically to the bottom surface of the stake pocket without yielding. (C-109)



Temporarily stanchions (stakes) should, as a minimum, be made of hardwood of a quality specified in the Manual. The stakes should be at least 4 in. × 5 in. (10×12.5 cm) (OTLR 13.7.1). Unless otherwise specified, each pair of side stakes must be tied together across the top of the load. There are not mentioned any maximum lateral force demands for side stanchions in the AAR regulations.

## 6.6 End walls

### 6.6.1 UIC

The end wall is a welded steel construction and consists of main vertical beams, horizontal beams and a cover plate of metal or plywood.

An end pillar must be able to withstand a longitudinal force of 40 kN (4 ton) acting at a height of one metre above the wagon floor. A residual deformation of maximum 1 mm is acceptable. (ERRI RP 17/UIC 577)

An approximated calculation to give the maximum force that can be supported by the end of a typical wagon (Hbis) is shown below. The calculations do not take any benefits from other possible distributions of the force into consideration.

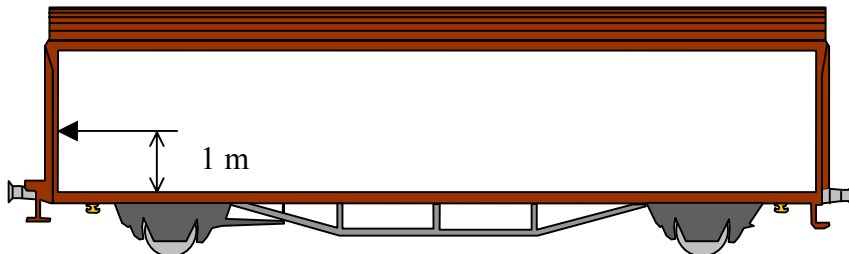
Input data

Payload (P): 30 ton  
 Test force per end pillar (F): 40 kN  
 Number of pillars per end (N): 2  
 g: 9.81 m/s<sup>2</sup>

The force expressed in parts of the payload:  $\frac{N \times F}{g \times P} = \frac{2 \times 40}{9.81 \times 30} = 0.27$

The calculation gives thus a maximum allowable force on the wagon end of 0.27 times the maximum payload of the wagon. As the test force is applied approximately at half the height of the end (1 m above the wagon floor) the force can be considered to be evenly distributed over the entire end, if the moment is calculated from the wagon floor.

Ends with cover plate of metal construction must be able to withstand a longitudinal force of 18 kN (1.8 ton) acting at a height of one metre above the wagon floor on the end wall. A residual deformation of maximum 2 mm is acceptable. A 100×100 mm hardwood rod shall be used when applying the force. (ERRI RP 17/UIC 577)



**6.6.2 AAR**

Box cars

The ends of Box cars shall be designed to withstand a horizontal force induced by the lading as shown in the table below (C II - 4.1.12). In the table a column with the force expressed in parts of the payload is inserted.

Nominal capacity of wagon in tons	Total force in tons on end	Total force in parts of payload	Percent of total force uniformly distributed on top half	Percent of total force uniformly distributed on bottom half
50	86	1.7	35-45	65-55
70	100	1.4	35-45	65-55
100	118	1.2	35-45	65-55

The “total force in parts of payload” is calculated according to the following example:

The maximum force that can be supported by the end of a 70-tons Box car is shown below.

Input data

Payload (P): 70 ton  
Maximum force per end (F): 100 ton

The force expressed in parts of the payload:  $\frac{F}{P} = \frac{100}{70} = 1.4$

The calculation gives thus a maximum allowable force on the wagon end of 1.4 times the maximum payload of the wagon. The force is distributed over the wagon end according to the table above.

For wagons equipped with special cushioning devices, the above longitudinal forces may be reduced.

**Flat wagons**

The bulkheads on Flat wagons shall be designed for a force equal to the design coupler force multiplied by 75 percent of the ratio of load limit to gross weight on rails. The force shall be considered as a uniformly distributed load over the face of the bulkhead with a resultant at mid height. (C II - 4.1.13)

An approximated calculation to give the maximum force that can be supported by the end of a 70-tons Flat car is shown below.

Input data

Payload (P): 70 ton  
Design coupler force (D): 5670 kN  
Load limit (L): 74 ton  
Gross weight on rails (G): 100 ton  
g: 9.81 m/s<sup>2</sup>

Force on bulkhead (F):  $F = D \times 75\% \times \frac{L}{G} = 5670 \times 0.75 \times \frac{74}{100} = 3147 \text{ kN}$

The force expressed in parts of the payload:  $\frac{F}{g \times P} = \frac{3147}{9.81 \times 70} = 4.6$

The calculation gives thus a maximum allowable force on the wagon end of 4.6 times the maximum payload of the wagon. The force is uniformly distributed over the face of the wagon end.

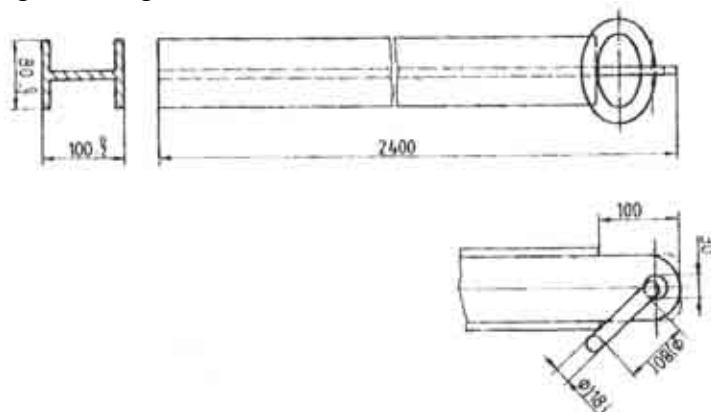


Bulkhead flat car

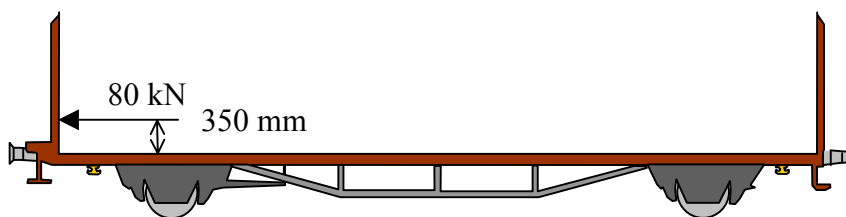
### 6.7 End stanchions

#### 6.7.1 UIC

An end stanchion should have a total length of 2400 mm and a cross-section of 100×80 mm all the way according to the figure below.



Each end stanchion fitted to the wagon must withstand a force of 80 kN (8 ton) directed towards the outside of the wagon, applied 350 mm above the top surface of the floor. No residual deformation is permitted. (ERRI RP 17/UIC 577)



An approximated calculation to give the maximum force that can be supported by the end of a typical wagon (Rs 691) is shown below. The test force is recalculated being evenly distributed over the end stanchions. The calculations do not take any benefits from other possible distributions of the force into consideration.

Input data

Payload (P):	57.5 ton
Height of stanchions (H):	2.04 m
Height to force (h):	0.35 m
Test force per stanchion (F):	80 kN
Number of stanchions per end (N):	2
g:	9.81 m/s <sup>2</sup>

Moment due to test force,  $M_T = N \times F \times h = 2 \times 80 \times 0.35 = 56 \text{ kNm}$

Moment due to evenly distributed cargo,  $M_D = \frac{Q \times H}{2} = \frac{Q \times 2.04}{2}$

$M_T = M_D \Rightarrow Q = 55 \text{ kN}$

The force expressed in parts of the payload:  $\frac{Q}{g \times P} = \frac{55}{9.81 \times 57.5} = 0.10$

The calculation gives thus a maximum allowable force on the wagons end stanchions of 0.10 times the maximum payload of the wagon. The maximum allowed bending moment without residual deformation for a stanchion is approximately 28 kNm (2.8 tonm).

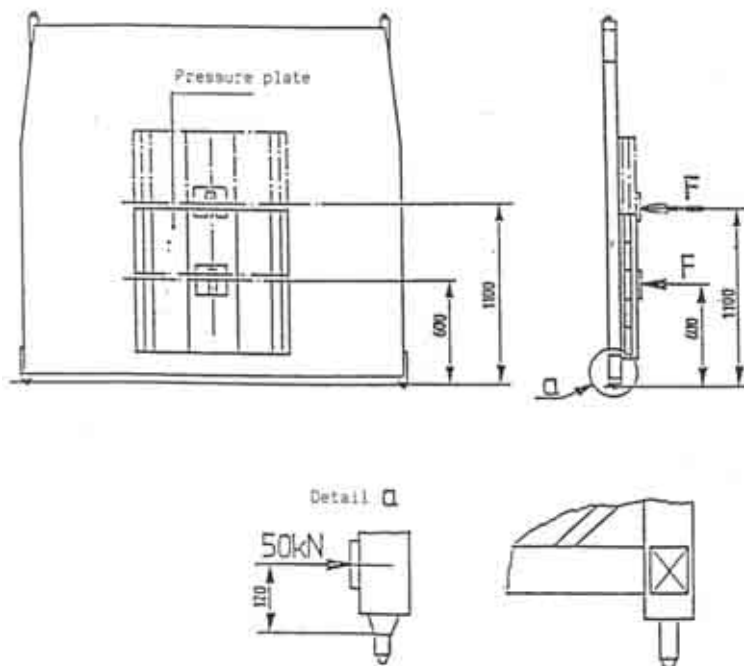
## 6.8 Bulkheads / Partition walls

### 6.8.1 UIC

The dimension criteria for lockable partitions are taken from "ORE, Question B12, Standardisation of Wagons", sector 4.1.4 and appendix A 2-2. The B 12-report describes a static test method for partitions and the following demands are stated regarding the force that the partitions shall be able to withstand.

When the partition is locked a force which corresponds to a buffing impact on a load of 5 ton at a speed of 13 km/h and which simulates the stresses produced by a palletised load is applied:

- to a square surface area of 1 m<sup>2</sup>, first at 600 and then 1100 mm above floor level. After the test it must be possible to operate and lock the partition without difficulty. Permanent deformation must not exceed 5 mm. There must be no damage to the locking mechanism. The magnitude of the force is determined from a diagram and it depends on how large the deflection of the partition wall is. When applied at 600 mm and with a force of 34 kN (3.4 ton) the deflection shall be maximum 43 mm. When the force is 100 kN (10 ton) the deflection shall be maximum 30 mm. When applied at 1100 mm the deflection shall be maximum 60 mm (34 kN) and 34 mm (100 kN).
- to the seat of the lower lock via a pressure plate measuring 100×100 mm, a force increasing up to 50 kN is applied. There must be no damage and no permanent deformation.



An approximated calculation to give the maximum force that can be supported by the partition wall of a typical wagon (Hbillns) is shown below. The calculation is conservative using the theoretical lowest allowed value on test force on the wall. The test force is recalculated being evenly distributed over the side. The calculations do not take any benefits from other possible distributions of the force into consideration. The half payload is used because a partition wall usually never blocks more than half of the load.

Input data

- Payload (P): 29 ton
- Height of side wall (H): 2.33 m
- Height to force (h): 1.1 m
- Test force (F): 34 kN
- g: 9.81 m/s<sup>2</sup>

$$\text{Moment due to test force, } M_T = \frac{1}{2} \times \left( \frac{F}{2} \times \frac{h}{2} + \frac{F \times H}{4} \right) = \frac{1}{2} \times \left( \frac{34}{2} \times \frac{1.1}{2} + \frac{34 \times 2.33}{4} \right) = 14.6 \text{ kNm}$$

$$\text{Moment due to evenly distributed cargo, } M_D = \frac{Q \times H}{8} = \frac{Q \times 2.33}{8}$$

$$M_T = M_D \Rightarrow Q = 50 \text{ kN}$$

$$\text{The force expressed in parts of half the payload: } \frac{Q}{g \times \frac{P}{2}} = \frac{50}{9.81 \times \frac{29}{2}} = 0.35$$

The calculation gives thus a maximum allowable force on the partition wall of 0.35 times the half maximum payload of the wagon. The force is evenly distributed over the partition wall.

According to RIV II – 2.7.1 up to 5 ton cargo may be loaded against one partition wall.

**6.8.2 AAR**

There are two kinds of bulkheads at the American railroad, pneumatic and non-pneumatic. Both are for Box cars. A pneumatic bulkhead is equipped with an air bag between a main bulkhead and a secondary bulkhead. The design forces is however the same for both types. (C II - 4.1.15)

The following forces should be used:

Nominal capacity of wagon in tons	Total force over entire bulkhead	Total force over lower half of bulkhead
50	72 ton	58 ton
70	86 ton	69 ton
100	100 ton	80 ton

A calculation to give the maximum force that can be supported by the bulkhead of a typical wagon with payload 70 ton is shown below.

The force expressed in parts of the payload:  $\frac{F}{P} = \frac{86}{70} = 1.2$

The calculation gives thus a maximum allowable force on the bulkhead of 1.2 times the maximum payload of the wagon. The force is evenly distributed over the bulkhead.

If using special cushioning devices, specified by AAR, the forces are reduced to the following:

Nominal capacity of wagon in tons	Total force over entire bulkhead	Total force over lower half of bulkhead
50	36 ton	29 ton
70	43 ton	35 ton
100	50 ton	40 ton

A calculation to give the maximum force that can be supported by the bulkhead of a wagon with payload 70 ton and using special cushioning devices is shown below.

The force expressed in parts of the payload:  $\frac{F}{P} = \frac{43}{70} = 0.6$

The calculation gives thus a maximum allowable force on the bulkhead of 0.6 times the maximum payload of the wagon. The force is evenly distributed over the bulkhead.

The strength of the bulkheads can be tested by impact tests. (C-304 and C-314)  
The procedure is as follows:

The test wagon should be impacted into a series of three wagons at 6.4, 9.7, 12.9 and 16 km/h. A reverse impact should be at 16 km/h. The three wagons should be 70-ton wagons loaded to



maximum capacity. Two tests should be conducted. One when loaded to full height and one when loaded to half height. In the full height test the test wagon should be loaded with cardboards to half the load limit of the wagon. In the half height test the test wagon should be loaded with concrete blocks or equivalent to minimum 40% the stencilled load limit of the wagon.

In addition to the two bulkheads types mentioned above there are a column type bulkheads. They are also for Box cars and special cushioning devices are needed.

The strength of the column type bulkheads can be tested by impact tests as below. (C-325)

The test wagon should be impacted into a series of three wagons at 6.4, 9.7, 12.9 and 16 km/h. A reverse impact should be at 12.9 km/h. The three wagons should be 70-ton wagons loaded to capacity. Two tests should be conducted. One when loaded to full height and one when loaded to half height. In the full height test the test wagon should be loaded with a representative shipping container load to half the load limit of the wagon. In the half height test the test wagon should be loaded with a representative shipping container load to minimum 40% the stencilled load limit of the wagon.

## **6.9 Securing devices (rings, hooks, chains)**

### **6.9.1 UIC**

#### **Lashing points**

For the direct or indirect fastening of goods, securing rings, eyelets or hooks made from steel rod with diameter of at least 16 mm should be used. When using two securing points (facing each other) a load weight of maximum 10 ton can be secured for flat wagons and maximum 5 tons for covered wagons. (RIV II – 2.6)

#### **G-type**

The number of securing devices shall be between 28 and 36, depending on type of wagon, and located in two rows on the walls.

Securing rings must be made of round-bar iron with a diameter of at least 14 mm. Each device must be able to withstand a tensile force of 85 kN at an angle of 45° to the floor surface and 30° to the longitudinal centre-line of the wagon. (UIC 571-1)

#### **E-type**

Open wagons with walls shall have devices made of round-bar iron of at least 16 mm in diameter. (UIC 571-1)

#### **K-type**

Flat wagons shall have rings and fastening bars made of round-bar iron of at least 16 mm diameter. Fastening devices in the floor shall withstand a tensile force of 170 kN at an angle of 45° to the floor and 30° to the longitudinal centre-line of the wagon. (UIC 571-1)

#### **Os-type**

The wagon shall be equipped with sheeting rings made of round-bar iron of at least 16 mm diameter. (UIC 571-1)

**H-type**

Wagons equipped with securing devices in the floor. Each device must be able to withstand a tensile force of 85 kN (8.5 ton) at an angle of 45° to the floor surface and 30° to the longitudinal centre-line of the wagon. (UIC 571-1)

**Ea-type**

Wagons shall be equipped with fixed securing rings. The rings should be made of round bar iron of at least 16 mm diameter. They must be able to withstand a force of 40 kN at an angle of 45° to the floor and 30° to the centre line of the wagon. (UIC 571-2)

**Lashings**

The strength in the lashing equipment shall have at least the minimum break load:

- 10 kN (1000 kg) when binding together opposite side stanchions. (RIV II – 2.5)
- 32 kN (3200 kg) per 1 000 kg cargo when wagons are exposed for normal shunting bumps and 10 kN (1000 kg) per 1 000 kg cargo for wagons in blocked trains and wagons in combi trains, swap bodies, semi-trailers and trucks. (RIV II - 5.4.4)

The breaking strength for indirect fastenings is between 10 – 40 kN (1 – 4 ton) depending on the weight, the length and the surface of the cargo. The initial tension is at least 3 kN (300 kg). (RIV II - 5.5.4)

**6.9.2 AAR**

Lading strap anchors should be of swivel type and designed for a breaking strength of 125 kN (12.5 ton). The lading strap anchors consist of a welded bar with a diameter of ¾ in. (C-106) Only lading straps and wires are allowed to be fastened in the anchors, not cables, rods or chains. For the securing of bands U-bolts or closed I-bolts with at least ¾ in. in diameter can be used. (OTLR 14.5)

When securing tractors, harvestors, bulldozers, grading equipment or cranes etc. chains are to be used. The chains should be of 3/8" alloy steel and shall withstand a 66 kN (6.6 ton) minimum proof test. All chain assemblies shall meet or exceed chain capacity. The chains should be equipped with a T-hook with minimum break strength of 204 kN (20.4 ton). In addition the chains should be equipped with shock absorbers. (C-320)

When securing with chains a safety factor of 4:1 should be used, (OTLR 21.1.4), and the following formula:  $Chains\ required = \frac{Weight\ of\ cargo}{WLL}$ , where WLL is the lashings'

maximum securing load. Minimum four chains are required. For cargo subject to rolling twice as much chains are needed. Minimum four chains are required, two in each direction. (OTLR 5.3)

To secure chains to the wagons U-bolts may be used. For a chain with maximum securing load (MSL) of 32 kN (3.2 ton) a U-bolt with minimum 147 kN (14.7 ton) breaking strength should be used. For a chain with MSL of 54 kN (5.4 ton) a U-bolt with minimum 226 kN (22.6 ton) breaking strength should be used. (OTLR 21.8.4)

Nylon webbing is not approved for use as securing for open top loading. (OTLR 20.1.3) In general, webbing may not be used to provide the required longitudinal or lateral restraint. Approved web tie-down systems may be used to provide only the vertical load restraint.

*Tie-downs required* =  $\frac{\text{Weight of cargo}}{WLL}$ , where WLL is the lashings' maximum securing load. (OTLR 20.4.11.1)

Air bags should have a working pressure of at least 0.02 MPa (0.2 bar) and bursting pressure of at least 0.17 MPa (1.7 bar). (OTLR 12.1.6)

## 6.10 Standards for trailers, swap bodies and containers

For comparison three standards for trailers, swap bodies and containers are described below.

### 6.10.1 EN 12642

**Securing of cargo on road vehicles – Body structure of commercial vehicles – Minimum requirements.**

#### **Front end wall**

The front end wall should, without permanent deformation, withstand a force of 0.4 times the maximum payload of the vehicle, however not more than 50 kN (5 ton). The force should be evenly distributed over the front end wall.

A calculation to give the maximum force that can be supported by the front end wall of a trailer with payload (P) 29 ton is shown below.

The force expressed in parts of the payload:  $\frac{F}{P} = \frac{5}{29} = 0.17$

The calculation gives thus a maximum allowable force on the front end wall of 0.17 times the maximum payload of the trailer. The force is evenly distributed over the wall.

#### **Rear end wall**

The rear end wall should, without permanent deformation, withstand a force of 0.25 times the maximum payload of the vehicle, however not more than 31 kN (3.1 ton). The force should be evenly distributed over the rear end wall.

A calculation to give the maximum force that can be supported by the rear end wall of a trailer with payload (P) 29 ton is shown below.

The force expressed in parts of the payload:  $\frac{F}{P} = \frac{3.1}{29} = 0.11$

The calculation gives thus a maximum allowable force on the rear end wall of 0.11 times the maximum payload of the trailer. The force is evenly distributed over the wall.

#### **Side wall**

**Box type body.** The side wall should, without permanent deformation, withstand a force of 0.3 times the maximum payload of the vehicle. The force should be evenly distributed over the side wall.

**Cover/stake body type.** The side wall should, without permanent deformation, withstand a force of 0.3 times the maximum payload of the vehicle. The force should be evenly distributed with  $0.24 \times P$  on the lower rigid part (the sideboard) and  $0.06 \times P$  on the rest of the side wall.

**Curtainsider.** There are no demands on the strength of the side. Fittings for securing of cargo is mandatory required and should be used.

### **6.10.2 EN 283**

#### **Swap bodies – Testing.**

##### **End wall**

The end walls should, without permanent deformation, withstand a force of 0.4 times the maximum payload of the swap body. The force should be evenly distributed over the end wall.

##### **Side wall**

**Box type body.** The side wall should, without permanent deformation, withstand a force of 0.3 times the maximum payload of the swap body. The force should be evenly distributed over the side wall.

**Cover/stake body type.** The side wall should, without permanent deformation, withstand a force of 0.3 times the maximum payload of the swap body. The force should be evenly distributed with  $0.24 \times P$  on the lower rigid part (the sideboard) and  $0.06 \times P$  on the rest of the side wall.

**Curtainsider.** The curtain side should, without permanent deformation, withstand a force of 0.3 times the maximum payload of the swap body. The force should be evenly distributed with  $0.24 \times P$  on a surface up to a height of 800 mm and  $0.06 \times P$  on the rest of the side wall. At the test the side should be covered with 5 mm plywood or similar and is not allowed to deflect more than 300 mm.

### **6.10.3 Freight containers ISO 1496-1. 1990/1998**

Containers should be dimensioned for lengthways accelerations of 2 g that could occur when shunting at railway transport. Sideways it should be dimensioned for accelerations that could occur on board a ship in motion.

**End wall**

End walls on a container should withstand a force of 0.4 times the maximum payload of the container. The force should be evenly distributed over the end wall.

After a test with a force as above no residual deformation or damage should occur that render the container unsuitable for use.

**Sidewall**

Sidewalls on a container should withstand a force of 0.6 times the maximum payload of the container. The force should be evenly distributed over the sidewall.

After a test with a force as above no residual deformation or damage should occur that render the container unsuitable for use.

**Cargo securing devices**

There is no demand on containers having cargo securing devices, but if the container have such devices there are requirements on their strength.

There are two kind of securing devices. Devices located in the base structure of the container (anchor points) and devices located in any part of the container other than their base structure (lashing points).

Typical number of anchor points

40 ft	16 pcs.
30 ft	12 pcs.
20 ft	10 pcs.

The number of lashing points is not specified.

Anchor points (devices located in the containers base structure) should withstand a force of 10 kN (1000 kg) applied in any direction. Lashing points should withstand a force of 5 kN (500 kg) applied in any direction. All securing devices should be tested with a force equal to 1.5 times the rated load. The force should be applied for 5 minutes. After a test no residual deformation or damage should occur that render the container unsuitable for use.

**6.11 Summary and recommendations**

The strength requirements of different parts of the wagons are summarized in the table below. The original required test forces have been expressed in parts of payloads for typical wagons. Comparison data for trailers, swap bodies and containers are included in the table.

Item	Regulation	Maximum force as part of the payload	
Fixed sides	Gbs 611	UIC	0.25
	Eaos	UIC	0.26
	Box car	AAR	0.25
Sliding sides	Hbillns 762	UIC	0.28
	Hbbins 881	UIC	0.20
	Habbins 941	UIC	0.13
Doors	Gbs 611	UIC	0.16
	Eaos	UIC	0.25
End walls	Hbis	UIC	0.27
	70 t Box car	AAR	1.4
	70 t Flat car	AAR	4.6
End stanchions	Rs 691	UIC	0.10
Partition walls	Hbillns 762	UIC	0.35 (half payload)
	70 t Box car	AAR	1.2
	70 t Box car with special cushioning devices	AAR	0.6
Front end wall	Trailer	EN 12642	0.17
	Swap body	EN 283	0.4
	Container	ISO 1496-1	0.4
Rear end wall	Trailer	EN 12642	0.11
	Swap body	EN 283	0.4
	Container	ISO 1496-1	0.4
Side wall	Trailer	EN 12642	0.3
	Swap body	EN 283	0.3
	Container	ISO 1496-1	0.6

The regulations according to UIC are in line with both the AAR's and the CTU-standards except for the strength of lengthways securing equipment such as end walls, end stanchions and partition walls. The strength is lower than in corresponding equipment in wagons from North America. The strength of a railway wagon's end wall or end stanchions is even lower than the ones in swap bodies or containers.

As mentioned the strength requirements on the sides according to UIC are in general sufficient. A problem is that only a few wagons with sliding sides are build according to the regulations. In most of the wagons it is not allowed to secure the cargo against the sides (open wagons), which means that the cargo has to be secured in a way not as rational as blocking against the sides.

The lashing points' strength according to UIC is for different wagon types between 40 – 170 kN, which should be considered as sufficient. The requirements for some wagon types are specified as a diameter of the round-bar (16 mm). The diameter is however irrelevant and the breaking strength only should be stated.

**Recommendations**

To be able to use end and side walls as well as partition walls for cargo securing in a safe and efficient way the following design criteria is proposed to be set up for European railway wagons:

End walls	$0.4 \times$ cargo weight evenly distributed over the entire end wall
Side walls	$0.3 \times$ cargo weight evenly distributed over the entire side wall
Partition walls	$0.4 \times$ half cargo weight evenly distributed over the entire partition wall

It is further recommended to specify requirement for lashing points. The testing angles and the strength only should be specified.



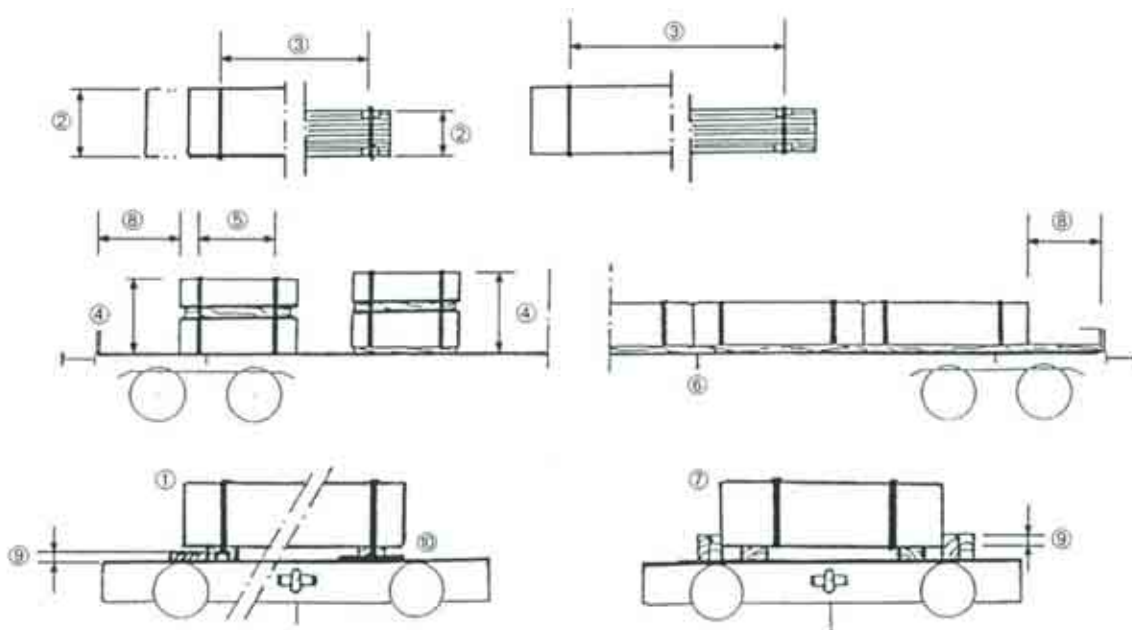


## 7 IDENTIFICATION OF REQUIRED CARGO SECURING FUNCTIONS FOR SOME CARGO TYPES

This chapter deals with the general requirements on railway wagons in order to obtain a rational securing for some types of cargo. The required functionality for each type of cargo has been specified.

### 7.1 Steel sheet

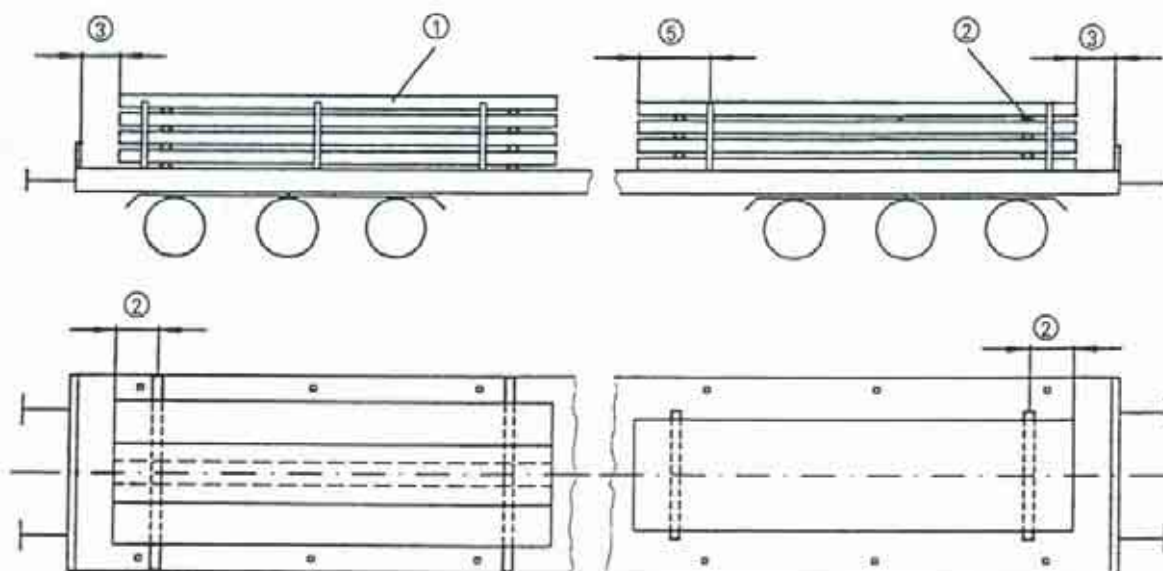
The securing of steel sheet in packages is regulated by Chapter 1.2.3 in RIV Loading Guidelines, App II, Section 2. The sheets should be bound together into packages. The packages should be bound together both sideways and lengthways. The loading method prescribed in the guidelines permits the goods to slide in longitudinal direction in the wagon (minimum clearance 50 cm). The slabs should be blocked by nailed timber sideways. If the packages include timbers bound in lengthways, friction inserts can secure them sideways.



*If the wagons have strong ends no minimum clearance is needed and the wagons loading area could be better utilised. A system for adjustable transverse blocking would exclude the use of guide-pieces and higher stacks with more tiers could be allowed (depending on blocking height). A floor with high friction ( $\mu$  at least 0.7) and/or damping qualities would exclude the need of friction inserts and/or guide-pieces. It is important to know the strength of the ends and the blocking.*

## 7.2 Steel slabs

The securing of steel slabs is regulated by Chapter 1.6.9 in RIV Loading Guidelines, App II, Section 2. The loading method prescribed in the guidelines permits the goods to slide in longitudinal direction in the wagon. Since the slabs have a rough surface no maximum allowed distance is needed sideways to the side stanchions due to risk for sliding.



This type of cargo is generally heavy and has to be distributed over an as wide area as possible, creating intermediate spaces between the stacks. Since the steel slabs are allowed to slide the centre of gravity of the cargo may shift, causing non allowed boogie pressure both lengthways and sideways.

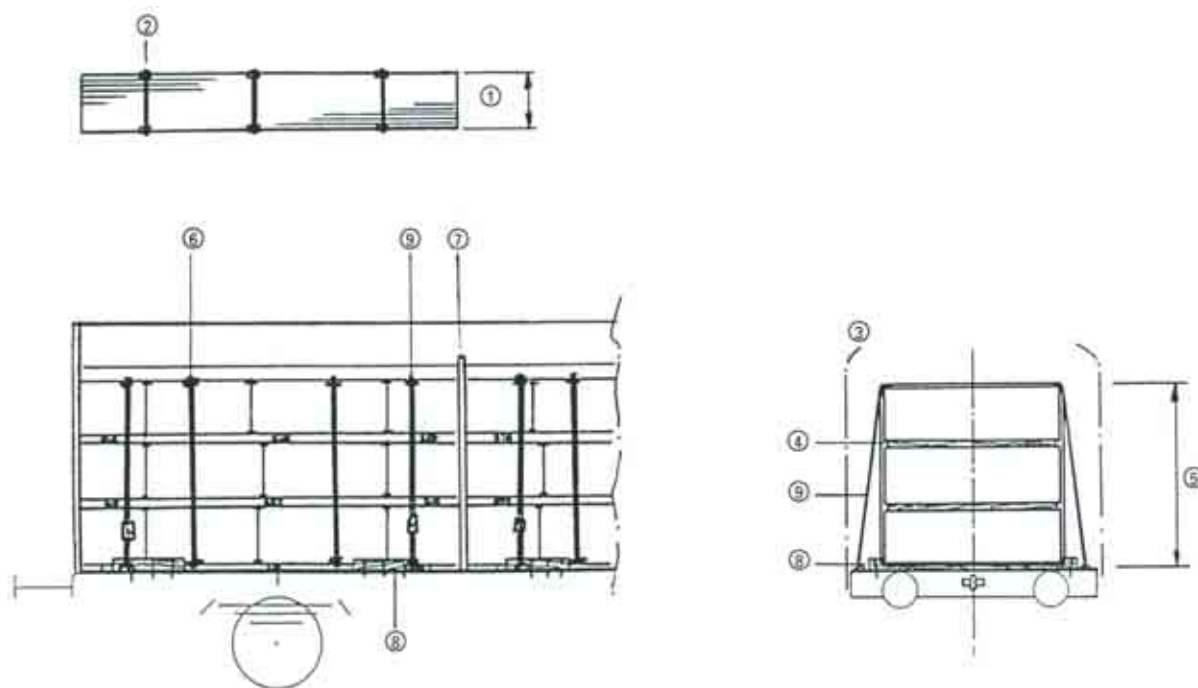
The height of the stacks is to be less than their width and no more than four tiers are allowed, since there are a large permitted distance between side stanchions and slabs. The minimum effective height of the stanchions is to be 10 cm.

The guidelines state that when the goods is secured by only two stanchions the slabs must extend beyond them by at least 50 cm for hump and fly shunting and 30 cm for none hump and fly shunting.

*If the wagons have strong end walls no required minimum clearance lengthways would be needed. A system for adjustable transverse blocking would allow higher stacks with more tiers (depending on blocking height). A continuous side blocking will exclude the demand of two pair of stanchions always securing the slabs. It is important to know the strength of the blocking.*

### 7.3 Plywood slabs

The securing of plywood slabs is regulated by Chapter 2.9 in RIV Loading Guidelines, App II, Section 2. The slabs should be bound into packages and the stacks with packages should be bound together.



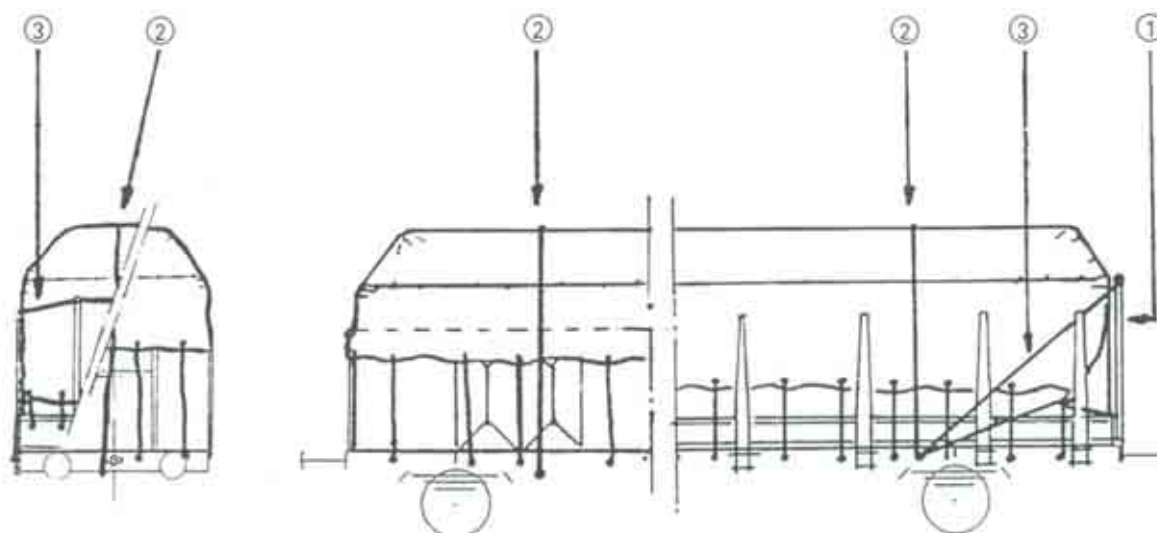
The guidelines state that the stacks of plywood slabs shall be prevented from sliding in longitudinal direction by either partition walls or by filling the intermediate space between them.

The guidelines allow two methods for sideways securing in the wagon. The first method is blocking by timber nailed to the floor. This type of securing is only possible to perform on wooden floors. In the other method minimum two indirect fastenings with tensioning devices secure the stacks.

*If it were possible to secure the indirect fastenings anywhere over the entire length of the wagon it would facilitate a proper placement of them. A blocking arrangement with adjustable transverse positioning could replace nailed timber, indirect lashings and even the bindings around the stacks. It is important to know the strength of the blocking.*

### 7.4 Compressed bales

The securing of peat and similar substances in compressed bales is regulated by Chapter 3.1 in RIV Loading Guidelines, App II, Section 2. The regulations calls for the bales to be loaded in compact or rigid formation.

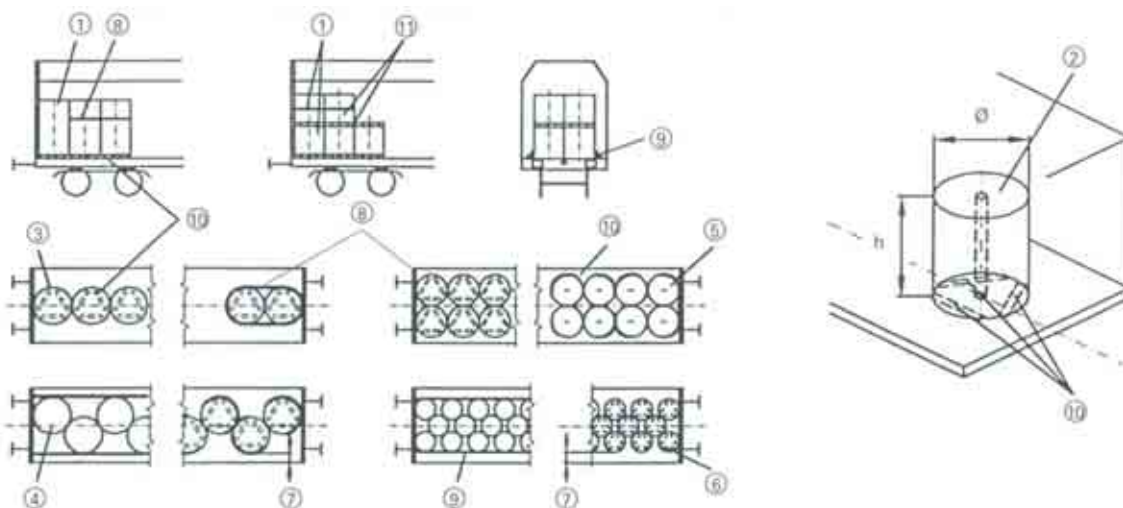


Bales should be loaded in tiers of similar height, packed as tightly as possible against one another. The outer bales of each tier shall lie directly against the walls or side stanchions. If the bales are secured against the walls or sides of the wagon the strength of the walls/sides should be clearly marked.

*A system for adjustable transverse blocking would allow the bales to be packed tightly together and against the blocking regardless of their dimensions. It is important to know the strength of the blocking.*

## 7.5 Rolls of paper

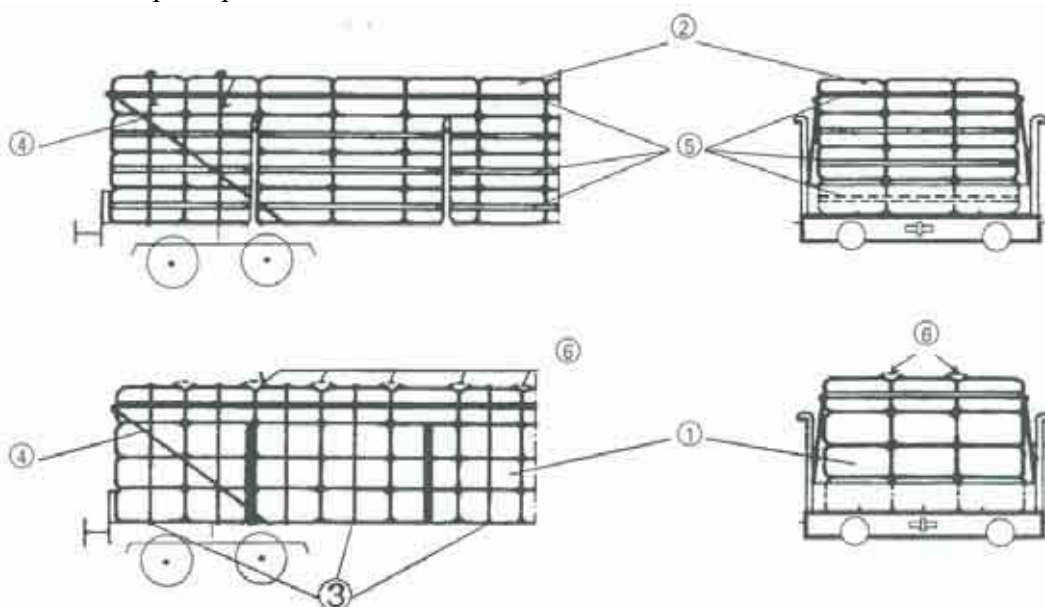
The securing of rolls of paper loaded upright is regulated by Chapter 4.1.3 in RIV Loading Guidelines, App II, Section 2. The regulations call for the rolls to be loaded in wagons with sliding walls and fixed end walls. The rolls are loaded in different patterns and are secured lengthways by the end walls and are able to slide if appropriate. Rolls whose diameter is less than 7/10 (hump and fly) or 6/10 (not hump and fly) of their height must be bound together. Sideways the rolls are secured by nailed guide-rails or friction-enhancing inserts.



*If the wagons were equipped with partition walls there would be no need for binding rolls together. It is important to know the strength of the partition walls. If the wagons had a floor with high friction ( $\mu$  at least 0.7) and/or damping qualities and/or strong sides there would be no need for nailed guide-rails or friction-enhancing inserts.*

### 7.6 Wood pulp in bales

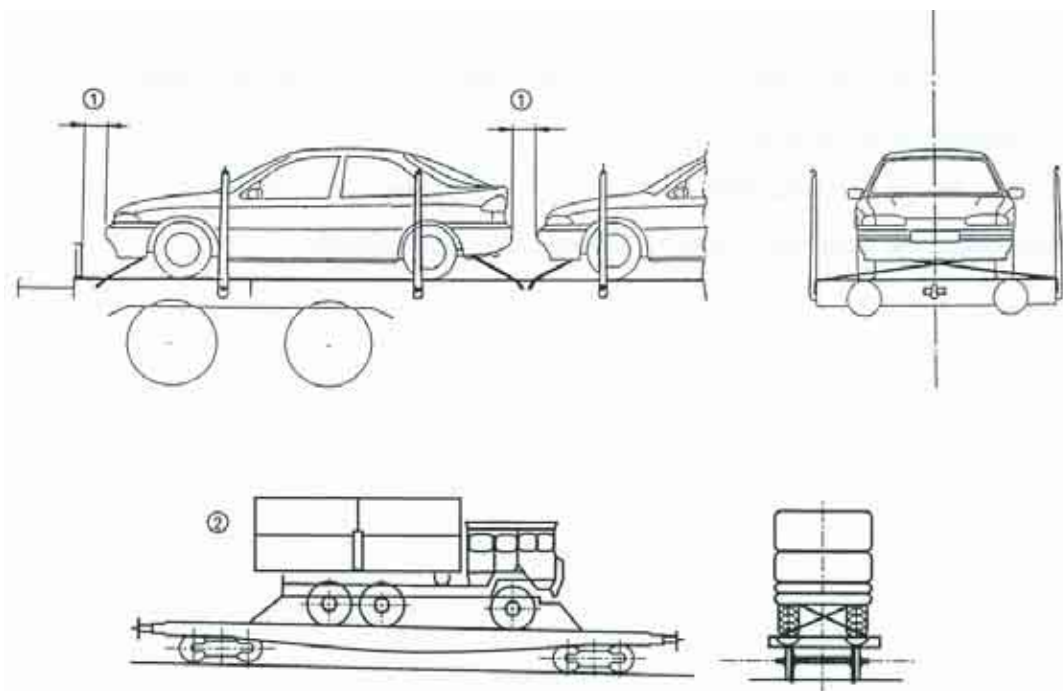
The securing of wood pulp in bales is regulated by Chapter 4.2.1 in RIV Loading Guidelines, App II, Section 2. The regulations call for the bales to be spread over the full loading surface without gaps. Each stack of bales should be secured with an indirect fastening (③). This requires the distance between the lashing fittings to be so small that each fastening can be applied at an adequate position.



*A system for adjustable transverse blocking would give no space between the blocking and the bales, which will reduce the number of lashings. It is important to know the strength of the blocking.*

### 7.7 Vehicles and machinery on wheels or caterpillar tracks, secured with fastenings

The securing of vehicles and machinery on wheels or caterpillar tracks, secured with fastenings is regulated by Chapter 7.2 in RIV Loading Guidelines, App II, Section 2.



The lashing points should be arranged in such way that all fastenings can be applied in a favourable angle even when the vehicles are stowed closely behind one another.

The prescribed strength of the binding material is listed in the table below:

<i>Vehicle weight up to:</i>		<i>Breaking strength of binding material</i>	<i>Breaking strength of binding material</i>
<i>Wheeled vehicles</i>	<i>Caterpillar vehicles</i>		
<i>3 t</i>	<i>5 t</i>	<i>40 kN</i>	<i>20 kN</i>
<i>8 t</i>	<i>10 t</i>	<i>80 kN</i>	<i>40 kN</i>
<i>15 t</i>	<i>25 t</i>	<i>125 kN</i>	<i>80 kN</i>
<i>30 t</i>	<i>50 t</i>	<i>200 kN</i>	<i>125 kN</i>
<i>40 t</i>	<i>60 t</i>	<i>400 kN</i>	<i>200 kN</i>

The table shows that for heavy vehicles the strength of the binding material is very high.

*If it were possible to secure the fastenings anywhere over the entire length of the wagon it would facilitate the appliance of the fastenings in favourable angles. Some lashing points should have an increased strength enabling rational securing of heavy machinery. It is important to know the strength of the lashing points.*

## 7.8 Required cargo securing functions

The following required functions for cargo securing arrangements, in order to get a rational securing of various types of cargo, have been identified in the survey conducted in this chapter:

- Strong end walls
- Strong sides
- Partition walls
- Adjustable sideways blocking
- Floor with high friction
- Floor with damping qualities
- Possibility to secure fastenings anywhere over the entire length of the wagon
- Strong securing points
- Marking of strength on securing points

Strong end walls	– More cargo should be able to be loaded tight to the end walls when exposed to hump and fly shunting.
Strong sides	– Cargo could more easily be secured sideways.
Partition walls	– Minimum two partition walls with capacity to block half the cargo weight.
Sideways blocking adjustable in sideways direction	– Side stanchions or sideboards should be able to be adjusted in sideways direction to eliminate space between them and the cargo.
Floor with high friction	– Floor with a friction of at least 0.7 will in many cases exclude the need for nailing timber or the use of friction-enhancing inserts.
Floor with damping qualities	– Floor that reduces vibrations will in many cases exclude the need for nailing timber or the use of friction-enhancing inserts.
Possibility to secure fastenings anywhere over the entire length of the wagon	– The distance between the lashing points should be sufficiently small, which enables lashings to be placed in optimal positions.
Strong securing points	– Some lashing points should be of increased strength, enabling them to withstand large lashing forces when heavy cargo is secured and enabling the use of chains.
Marking of strength	– All equipment as well as the wagons side walls and end walls should be marked with the strength from a cargo securing view.





## **8 EXISTING EQUIPMENT FOR CARGO SECURING ON RAILWAY WAGONS, VEHICLES AND OTHER CTU'S**

This chapter shows some of the different equipment that is used today to secure cargo on railway wagons, vehicles and other CTU's. The chapter is divided into two parts, one for railway wagons and one for other cargo carriers. The second part is included as information since there is more cargo securing equipment developed for those cargo carriers than for railway wagons.

The wagons superstructure (side walls, ends and stanchions) is described in chapter 6.

### **8.1 Equipment on railway wagons**

This chapter presents examples of various types of equipment that may be used for the cargo securing on railway wagons. The information has been collected directly from manufacturers or at the fairs "transport logistic 2003" in Munich and "Nordic Rail 2003" in Jönköping.

#### **8.1.1 Sideboards**

Sideboards usually consist of sheet steel. They are attached between side stanchions. Sideboards are found on open wagons.

#### **8.1.2 Side stanchions**

Side stanchions usually consist of pressed sheet steel. Side stanchions are usually found on open railway wagons.

#### **8.1.3 Blocking stanchions**

Stanchions made of galvanized plate, equipped with elastic taps and that fits into holes located both in the loading platform and in the roof. The blocking stanchions are movable to be adjusted to the cargo, see photo below.



*Movable blocking stanchions in a railway wagon.*

#### **8.1.4 Wedges**

Wedges made of thick steel plate with taps that fits into holes in the loading platform. The wedges are movable to be adjusted to the cargo, see photo below.



*Movable wedges in a railway wagon.*

#### **8.1.5 Partition walls**

Many railway wagons are equipped with partition walls, which can be used for blocking cargo lengthways in the wagons.



*Partition wall in a railway wagon.*

#### **8.1.6 Partition boards**

Partition boards are, compared with partition walls, of a weaker design and they cannot be locked into the loading platform. The partition boards usually consist of hanging plywood boards.

#### **8.1.7 Sideways blocking bars**

The photos below show a wagon equipped with profiles, which can be placed on the floor along the sides. Each profile is about 2 cm high and is fastened by four pegs. The profiles can be adjusted sideways in steps of about 10 cm. When not in use the profiles are located in tracks in the floor across where the profiles make the floor plane. A problem that may occur is that the tracks are damaging the ends of standing paper reels, which exclude this type of cargo in wagons equipped with this type of bars. Since the profiles are rather thin they might bend when blocking cargo sideways and then not fit in the tracks.



*Profiles along the sides.*



*Tracks across the floor.*

### 8.1.8 Securing by friction

Friction is important when securing cargo. According to UIC the coefficient of friction shall be at least 0.7 for securing the cargo sideways. It is however not enough to secure by friction only, the cargo has also to be secured by walls, sideboards or stanchions. The photo below shows a block train (the Tube) with cars secured by friction only.



*Cars secured by friction only.*

### 8.1.9 Moveable side stanchions

Fixed side stanchions often leaves too much space left between the cargo and the stanchions (more than 10 cm). If the stanchions are moveable sideways a lot of cargo securing can be avoided.

For some types of cargo the stanchions are not needed. When transporting this kind of cargo it is desirable to be able to put the stanchions away or, even better, fold them in to the floor. An easy way to move the stanchions simplifies the loading/unloading.



*Stanchion possible to move sideways and to fold in to the floor.*



*Stanchions possible to move sideways.*



#### **8.1.10 Cradle for coils**

The pictures below show cradles for coils. Both cradles have arms for sideways blocking that can be adjusted depending on the width of the coil. The wagons are very efficient for the transportation of coils but not flexible to be able to take other cargo.



*Cradles for coils with adjustable blocking arms*

#### **8.1.11 Wagon sides**

Wagons with strong sides are often of an old model (G-type) and thus not rational to use. The modern wagons, with sliding walls/sides, do not have sides with enough strength so the cargo can be secured against them.

An important task for the railway industry is to equip the wagons with sides that are rational when loading/unloading and that can be used for cargo securing.

*The wagon sides consist of aluminium panels. Similar sides on road trailers have enough strength to be used for cargo securing.*



### 8.1.12 Timber transports

Below is shown two examples of securing equipment for timber transports. The example from Austria consists of stanchions of large profiles and lashings. There are covered holes in the platform for the stowing the lashings. The example from Sweden has stanchions used at road transports and no lashings. The end walls are of a strong kind. The example from Norway is rather the same as the Swedish one but do not have such strong end walls.



*Example from Austria*



Example from Sweden



Example from Norway

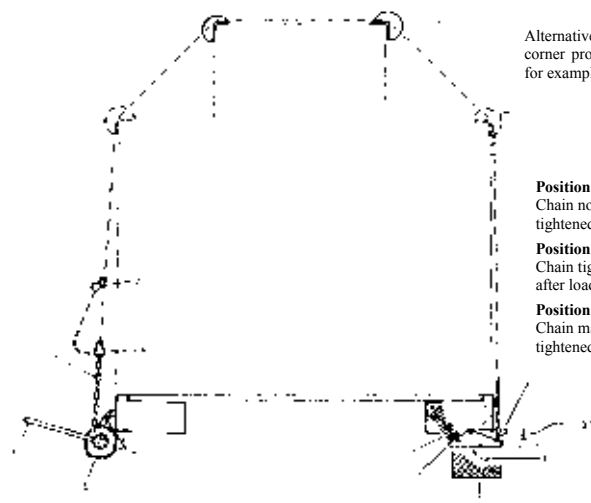
### 8.1.13 Lashing points

Railway wagons can be equipped with lashing points, but it is not a requirement. The strength in the lashing points and equipment used for lashing purposes (lashing and ratchets) shall according to RIV Appendix II have at least the following minimum break load:

- For tie down (top-over lashing) and for binding together opposite side stanchions 10 kN (1000 kg).
- When cargo units are bounded together, per 1 000 kg:
  - 32 kN (3200 kg) for wagons that are exposed for normal shunting bumps.
  - 10 kN (1000 kg) for wagons in blocked trains and trains in combi trains, swap bodies, semi-trailers and trucks.

### Securing arrangement on open wagons and open sided wagons

- Lashing instructions

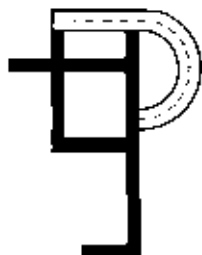


Alternative placement of corner protectors suitable for for example sawn timber.

- Position I**  
Chain not tightened
- Position II**  
Chain tightened after loading
- Position III**  
Chain maximal tightened

1. 8 mm chain lashing, long part. Maximal working Load 800 kg. L=9 m
2. 8 mm chain lashing, short part. Max allowed Load 800 kg. L = 0.9 m
3. S-hook to "shorten" the chains long part end.
4. Pear shaped lock loop
5. Chain ratchet
6. Stick for tightening of chain. Are stored in a holder on the side of the wagon.
7. Lock
8. Two pull springs
9. Lever
10. Storage for the long part of the chain when it is not in use.
11. Corner protection.

- Lashing points, 100 kN (10 tonnes)



Wagons are equipped with five lashing points per side. Maximum Securing Load per lashing point is 100 kN.

**Automatic pre-tension**

One reason for cargo shifting can be that the cargo has been packed together during transport so the lashings have been slack. This problem is obvious for cargoes like sawn timber. Problems with loose lashings are eliminated by a construction pressing the cargo against the loading platform more or less under a constant pressure. The construction maintains a pre-tension of 7500 kN (750 kg) in the lashing. This cargo securing system is mounted under the wagon so that only the lashing with its hook sticks up via a slit in the loading platform. The lashing is placed over the cargo and is attached in one of the hooks that are mounted in the loading platform on the opposite side. On the outside of the wagons there is notches for bolt heads that are used when the lashing should be tightened or released.



Here is a picture of the automatic pre-tensioner. It consists of 3 gas driven springs together with a chain that via a gear constantly keeps the lashing tightened.



It is easy to tight and untight the lashing. Only a lever, box spanner or similar for a 19 mm bolt head is needed.

**8.1.14 Lashing points in various types of wagons**

For transports of cargo on railway there is various numbers of wagon models. The wagon types are equipped with different kinds of cargo securing devices, making the wagons suitable for the type of cargo they are intended to transport.

**G-type**

The number of securing devices shall be between 28 and 36 (14 – 18 per side), depending on type of wagon, and located in two rows on the walls.



Securing rings must be made of round-bar iron with a diameter of at least 14 mm. Each device must be able to withstand a tensile force of 85 kN at an angle of 45° to the floor surface and 30° to the longitudinal centre-line of the wagon. When not in use, they shall be flush to the floor, for not damaging the load.

**E-type**

Open wagons with walls and no roof shall have 8 securing devices made of round-bar iron of at least 16 mm in diameter, on each side of the outside of the walls.

**K-type**

Flat wagons shall have rings and fastening bars made of round-bar iron of at least 16 mm diameter.

Fastening devices in the floor shall withstand a tensile force of 170 kN at an angle of 45° to the floor and 30° to the longitudinal centre-line of the wagon.

On each side, wagons shall be fitted with 6 or 8 steel stanchions and on each end with 2 long steel stanchions and 2 collapsible stanchions.

**Os-type**

Flat wagons shall have the sides and ends of the wagon provided with stanchions. 10 steel stanchions on each side and at least 2 steel stanchions at each end.

The wagon shall also be equipped with 12 sheeting rings made of round-bar iron of at least 16 mm diameter, on the outside edge of the floor on each side, and 4 along each end.

4 securing rings, of 16 mm diameter must also be affixed to the same edge along each sidewall.

**H-type**

Wagons equipped with securing devices in the floor, shall have between 8 and 12 devices per side depending on type of wagon. They shall be located at the wagon walls.

Each device must be able to withstand a tensile force of 85 kN (8.5 ton) at an angle of 45° to the floor surface and 30° to the longitudinal centre-line of the wagon. When not in use, they shall be flush to the floor, for not damaging the load.

**Ea-type**

The wagons shall be fitted with 13 securing rings on each sidewall and 2 securing rings on each end wall. Some types of Ea-wagons shall be fitted with 16 securing devices inside the walls. The rings should be made of round bar iron of at least 16 mm diameter. They must be able to withstand a force of 40 kN at an angle of 45° to the floor and 30° to the centre line of the wagon.

**R-type**

Wagons shall be fitted with securing devices as defined in the table below.

	Rs	Re	Rm
24 – 36 rings on the outside of the wagon	x		x
14 – 18 hooks on the outside of the wagon	x		x
8 rings on each end	x	x	x
12-18 fastening bars		x	
12-18 securing device in the floor		x	

### 8.1.15 Lashing mat

The lashing mat enables effective goods handling on the railways. The system allows a more efficient securing and unloading.

The lashing mat is applied to the cargo as a single unit. There is no need for separate lashing and securing of different parts. Nor is there any need to design special solutions to keep the load together. The lashing mat sits tight over the goods and keeps it together in all directions.

The lashing cover is made from PP fabric with a PP coating and the straps are of polyester. The permitted load at the lashing points is 25 kN (2.5 ton).

A manufacturer of paper reels has tested the lashing mat but still had problems with wandering of the reels.



*Lashing mat on railway wagon*

## 8.2 Equipment on vehicles and other CTU's

This chapter presents examples of various types of equipment that may be used for the cargo securing on vehicles, trailers, semi-trailers and swap bodies. The information has been collected directly from manufacturers or at the fairs “Lastbil 2000” and “Lastbil 2002” in Jönköping, “IAA 2000” in Frankfurt and “transport logistic 2003” in Munich.

### 8.2.1 Partition walls

There are several solutions for securing cargo in lengthways direction. Since most partition walls are attached to longitudinal rails in the loading platform and the roof, they are most common in CTUs with fixed walls.

The partition wall in the picture below is able to block 1/3 of the CTUs payload (according to the manufacturer) when subjected to a forward acceleration of 0.8×g (according to VDI 2700 Blatt 2). The walls can be folded and secured in the CTUs roof when not in use.



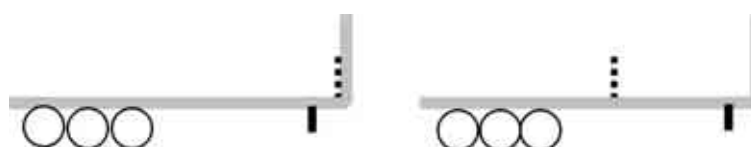
*Foldable wall that can block 8 tonnes of cargo from shifting at a force of 0.8×g.*

In the example below the cargo shifting device consist of two separate parts. They are placed in pairs to cover the whole breadth of the CTU, or as single parts. Each device is attached in 2+2 securing rails. The system can block a cargo weight of up to 15 tonnes when it is exposed to a forward force of 0.8×g (according to the manufacturer).



*Cargo shifting device that can block 15 tonnes of cargo from shifting at a force of 0.8×g.*

With a movable blocking device, which can be placed at any position up to 3 m behind the forward wall in a CTU, there are good possibilities to block heavy cargo that cannot be placed against the forward wall. The blocking device should be able to slide or easily be lifted in place in the CTU.





### 8.2.2 Blocking beam

Some vehicles are equipped with a blocking beam fixed in the container locking fittings. The beam can be equipped with different types of lashing eyes or holes for stanchions. The advantage with this type of beam is the possibility to get a rigid and strong blocking device also at a distance from the headboard. The disadvantage is that the beam can only be locked in positions where the vehicle is equipped with container locking fittings. The beam is heavy and could be difficult to handle for a single driver.

Other types of blocking beams could be fixed in securing rails along the vehicle in the loading area or in the side beams. Some beams on the market are of limited strength and designed for securing of cargo in a rearward direction only.



A1



A2



B

Picture A1 and A2 shows a beam suitable for securing rearwards while picture B shows a device that, according to the manufacturer, can block a 25 tonnes steel coil when exposed to a forward acceleration of  $0.8 \times g$ . Below is shown various equipment to block cargo, lengthways and sideways.



*Lengthways blocking*



*Sideways blocking*



*Blocking bar in combination with spring lashings.*

### 8.2.3 Back plate lift

The strength in back plate lifts varies depending on what has been ordered from the buyer. The lifting force is clearly marked and is usually between 500 – 3000 kg. The weight varies with how far out on the plate the cargo is placed. Which tension the back plate lift can handle in upward position, when used as a blocking device, is normally not marked. A back plate lift shall have a hydraulic or a mechanical locking device if used for blocking cargo in rear direction.

### 8.2.4 Roll front

The roll front shown in the picture below are made of aluminium, mounted in a container, and dimensioned to withstand a force equal to 40% of payload, 64 kN (6.4 tonnes), evenly distributed over the roll front without failure or unacceptable permanent deformation.



*Container with a roll front.*

### 8.2.5 Board/beams across the floor

This type of equipment is used to block cargo primarily rearwards.

A lock beam is attached by clamping to the cover laths or on the sideboards in the vehicle.



*Lock beam*

This type of equipment can block a limited cargo weight only. The beam can withstand a point load at the centre of the beam of 3000 N (300 kg).

Liftable loading platforms are used to obtain two separate load levels in a vehicle. The extra plane usually consists of beams and is hoisted up under the roof when cargo of substantial height is transported. The beams in the liftable loading platform may be used to block cargo in both forward and rearward directions for e.g. a non-continuous top layer of cargo. The correlation between the weight of the cargo and the strength of the beam must however be considered. The beam in the picture below can withstand a load of 10 kN (1000 kg).



*Blocking with liftable loading platform beam.*

A lock beam, see photo below, can withstand a load of 7000 N (700 kg). This lock beam needs to be attached into special rails in the sides of the vehicle.



*Lock beam*

### **8.2.6 Cargo care stanchions**

Stanchions used to fix stacks of cargo are especially used in box type bodies used for distribution traffic. The stanchions (for example a clamp beam) are expanded between loading platform and roof, or between the walls in the box type body. There are also stanchions that are attached into special holes in walls or loading platform and roof.



*Clamp beam*

Stanchions have various capabilities to take up loads, which mostly depends on the way the stanchions are attached into the vehicle. If a clamp beam is loaded with a point load in the centre, it will be capable to take up force of 100 kg (before sliding arises).

### 8.2.7 Laths

Laths of aluminium have greater stiffness than those of wood with equal dimensions. The strength of the wooden laths depends upon the quality of the wood. The mean break load of fine quality wood is approximately  $45 \text{ N/mm}^2$  (95% >  $30 \text{ N/mm}^2$ ), while it is approximately  $20 - 30 \text{ N/mm}^2$  (95% >  $12 \text{ N/mm}^2$ ) for wood of poorer quality. The break load of aluminium varies between  $130 - 260 \text{ N/mm}^2$ .

One disadvantage of aluminium laths is that they may easily deform if subjected to shocks to its ends (when e.g. dismantled). The deformed boards may then fit badly in the fittings on the cover stanchion. It is on the other hand easier to spot damages on the aluminium boards than on the wooden ones.

### 8.2.8 Attachments for wedges

Alongside vehicles can be equipped with rails, which are provided with holes that can be for example used to mount wedges. In this way the vehicle becomes more flexible when it comes to arrange blocking sideways of above all, rolling cargo.



### 8.2.9 Coil well

A vehicle can be equipped with a coil well in the centre of the loading platform. Over the coil well it is normally placed hatches that covers the well and make it possible to load cargo all over the loading platform. When there is a transport of for example steel coils, the hatches is taken away and the steel coil is placed in the well. The well can often be combined with support holes in which stanchions can be placed as blocking device both forward and behind the cargo, see pictures below.





*Coil wells*

### 8.2.10 Lashing mat

Tyres are normally secured with top-over lashings, which often is an unsatisfying solution. An alternative, which has been proven satisfying for tyres, is a lashing mat. The mat is built in three sections to make it easier to unload the cargo. When securing the cargo the mat is placed on top of the first section of tyres and is then rolled over the other sections in pace with the tyres is loaded.

Having a loos lashing mat means that the cargo transport units is not tied up for one type of cargo only. However, if there is possibility to tie up some cargo transport units for the actual type of transports, the lashing mat can be mounted hanging in straps into the roof of the cargo transport units, which would simplify the cargo securing work both when loading as well as unloading the cargo.

The weight of the mat including the lashings sewn into the cloth is about 10 kg per part.



*Lashing mat for the securing of tyres.*

### 8.2.11 Airbag mat

Tests has been done with a cargo securing system consisting of inbuilt airbags, see photo below. These tests have shown that it works very well as cargo securing, however two problems have arise, it takes long time to empty the airbags, and the entire system will fail if even a small leakages arises in the airbag.



*Airbag used to secure paper reels loaded on a cassette.*

### 8.2.12 Spring lashing

#### With cloth

A spring lashing which is sewn into a cloth has greater possibility to secure cargo consisting of several small units. A spring lashing together with a cloth with the dimensions of  $0.8 \times 3.4$  m that has 2 lashings in each end (see picture below), used for securing of steel pipes, would block about 10 tonnes cargo in forward direction (20 tonnes in rearward direction).



*Spring lashing with cloth*

**With round turn sling**

If the cargo is loaded in several layers it can be appropriate to use a round turn lashing, in which there are “transverse lashings” sewn into the round-sling, see picture below. This type of sling is much faster to apply than if an ordinary lashing should be arranged as a sling for use as a spring lashing.



*Test with elements of concrete secured with a spring lashing consisting of a round sling and four transverse lashing sewn into it.*

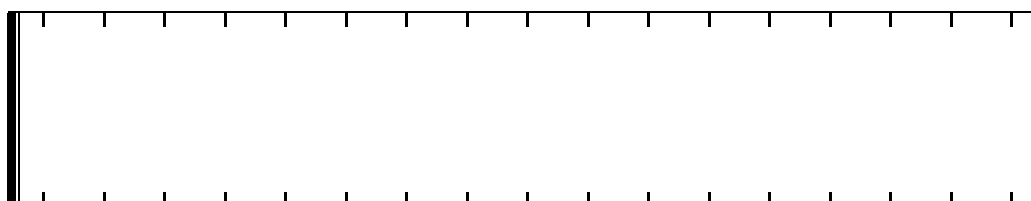
**8.2.13 Strength, number and placement of lashing points**

The number of lashing points a vehicle is equipped with is for most types of cargo too few. In most cases there are lashing points with an individual distance of 1.2 m between them, and they are placed on the inside of the sideboards or sidewalls.

It can be practical to consider the dimensions of a euro pallet (800×1200 mm) when deciding how many lashing points that would be sufficient. The pallet can be placed both lengthways and sideways. To be able to secure every section with at least one top-over lashing, following distances should be optimum:

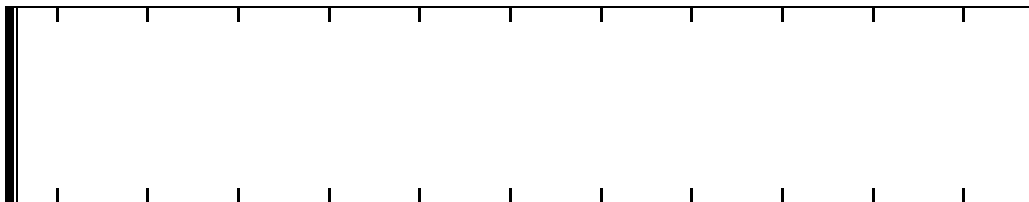
For pallets placed sideways – 0.4 m from the headboard followed by an individual distance of 0.8 m. It would give the following placement, starting from the headboard:

0.4 – 1.2 – 2.0 – 2.8 – 3.6 – 4.4 – 5.2 – 6.0 – 6.8 – 7.6 – 8.4 – 9.2 – 10.0 – 10.8 – 11.6 – 12.4 – 13.2 a total of 17 per side.

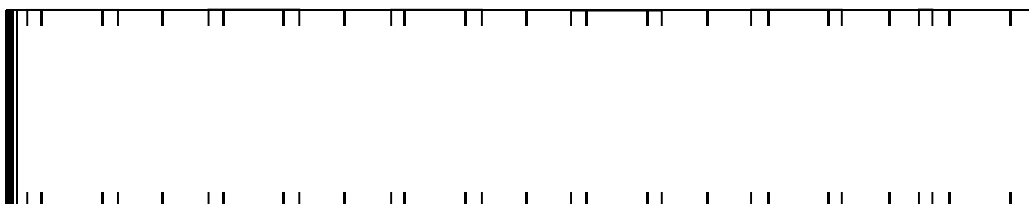


For pallets placed lengthways – 0.6 m from the headboard followed by an individual distance of 1.2 m. This would give following placements starting from the headboard:

0.6 – 1.8 – 3.0 – 4.2 – 5.4 – 6.6 – 7.8 – 9.0 – 10.2 – 11.4 – 12.6 a total of 11 per side.



These two lines of measures does not coincide in any point, so to be able to place an top-over lashing at the centre of every section it would need 17 + 11, a total of 28, lashing points per side for a 13.6 m semi trailer.

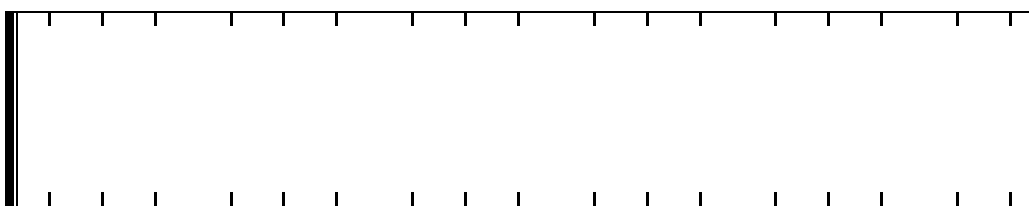


An optimisation for the euro pallet size should give various distances according to the following: 0.5 - 0.7 - 0.7 - 1.0 - 0.7 - 0.7 - 1.0 etc.

This should give the following placements:

0.5 - 1.2 - 1.9 - 2.9 - 3.6 - 4.3 - 5.3 - 6.0 - 6.7 - 7.7 - 8.4 - 9.1 - 10.1 - 10.8 - 11.5 - 12.5 - 13.2, a total of 17 lashing points per side.

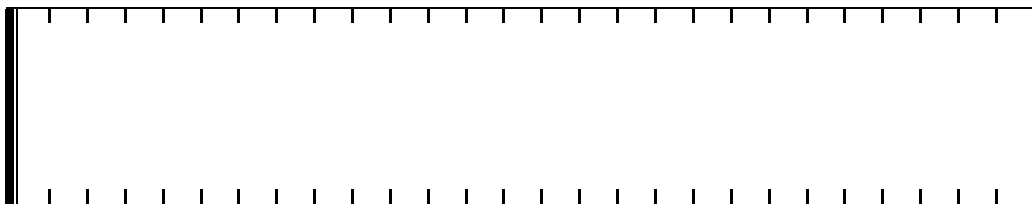
With this line of measures the lashing points would be placed max 0.1 m from the centre of each section. For other dimensions of the cargo it must however be regarded as inconvenient to have some distances as large as 1.0 m.



A more flexible solution for cargo with other dimensions than the euro pallet, from a cargo securing point of view, should be a placing of the lashing points with an individual distance of 0.5 m according to the following:

0.5 - 1.0 - 1.5 - 2.0 - 2.5 - 3.0 - 3.5 - 4.0 - 4.5 - 5.0 - 5.5 - 6.0 - 6.5 - 7.0 - 7.5 - 8.0 - 8.5 - 9.0 - 9.5 - 10.0 - 10.5 - 11.0 - 11.5 - 12.0 - 12.5 - 13.0, a total of 26 lashing points per side.

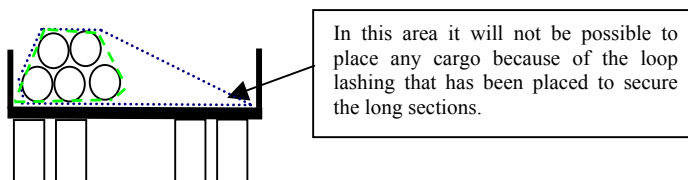
In this case the lashings would be placed max 0.2 m from the centre of each section of euro pallets. This proposal gives however a greater number of lashing points.



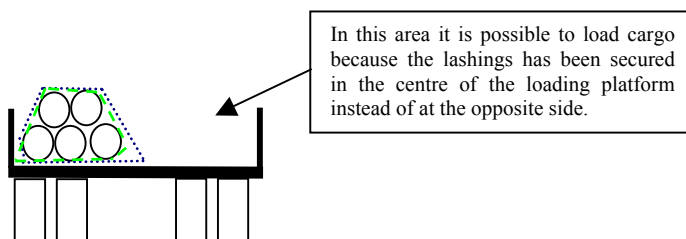
A modification of the side beam, which makes it possible with a continuous placement of lashings, should solve the problem.

**8.2.14 Centrally placed lashing points**

Normally there are lashing points placed lengthways in a vehicle only, which means that it is not possible to attach any lashings in the centre of the loading platform. If long sections of cargo are to be secured with loop lashings and loaded together with pallets and cartons, there are often difficulties to secure the load, see figure below.



With the possibility to apply lashings also in the centre of the loading platform, the lashings for the long sections would not interact with the pallets and cartons loaded on the opposite side of the loading platform.



**8.2.15 Side beam**

**Upper part**

More and more vehicles are equipped with side beams, which is designed in a way making it possible to attach lashings anywhere alongside the loading platform. A great flexibility has then been achieved when it comes to attach lashings wherever the cargo is placed on the loading platform.

In some cases it requires an adapter between lashing and side beam. From the user's point of view it is often better to be able to attach an ordinary lashing hook directly in the side beam. It is also important that as many lashing techniques as possible could be used (top-over-, loop- and spring lashing).



*Examples of side beams that gives high flexibility when attaching lashings with or without adapter.*

### **Lower part**

In some vehicles the lower part of the side beam have a heavy L- or U- profile. This side beam can be used to attach end fittings for cargo securing. The presumption to be able to use the lower part of the side beam for cargo securing is that the flange on the profile has sufficient depth so the end fitting of the lashing can't slip.

If the side beam is made of a thin, bent plate it cannot be used for cargo securing. A weak side beam will be bent when the lashings are tensioned. The lashings will then become loose and possible losing their grip and fall off. Another problem can arise when heavy lashings are attached to the framework and are pulled over the side beam and up over the cargo on the loading platform. A weak side beam that consists of a thin plate may be bent and then the lashing will be slack.

A robustly designed lower part of the side beam has two advantages; it can be used to attach lashings and it resists the heavily lashings attached to the framework when pulled over the side beam up to the cargo on the loading platform.

### **Example of flexible side beam**

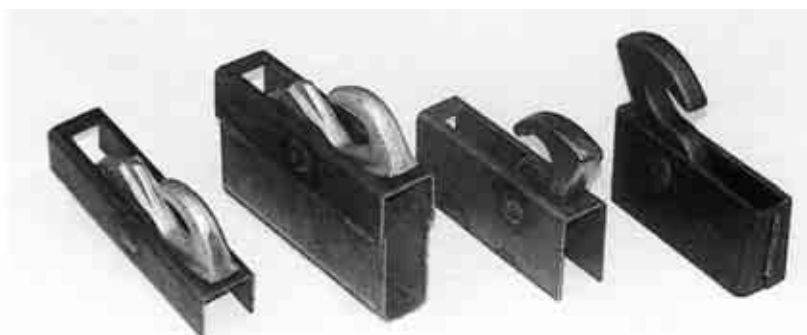
The side beam shown below gives a flexible way to attach top-over-, loop- and/or spring lashings, both on the inside as well as on the outside of the drop sides. The design of the side beam implies that it is easy to clean and that there will not be any accumulation of filth. The side beam can handle a Minimum Break Load (MBL) of 5000 kg without any fracture appears.



*Side beam adapted for flexible lashings on the inside as well as on the outside of the sideboard. The pictures above show the side beam seen from the side and from underneath.*

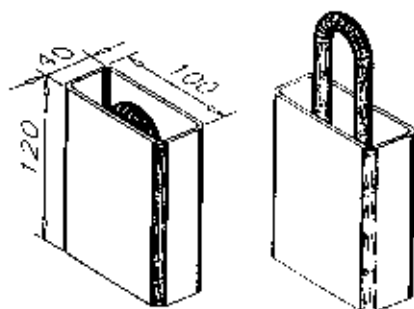
### 8.2.16 Securing fittings

The breaking strength for typical securing fittings used on vehicles is normally between 20 kN to 80 kN (2 ton - 8 ton).



Breaking strength:  
40 kN / 40 kN / 80 kN / 80 kN  
(4 ton) / (4 ton) / (8 ton) / (8 ton)

*Hooks to be fitted in the side beam. Could be used with lashings equipped with both hooks and rings. When the hook is not in use it can be folded down in the side beam giving a flush platform.*



Breaking strength:  
50 kN (5 ton)

*Fitting with an ability to wiggle towards the platform of 25°.*



Breaking strength:  
80 kN (8 ton)

*Round fitting.*



Breaking strength:  
60 kN (6 ton)

*Forged securing fittings to be fitted in the side beam, front wall or container wall. The strength is guaranteed when wiggled: 20 – 55° towards the vertical plane. Weight 1.2 kg.*



Breaking strength:  
60 kN (6 ton)

*Forged hook for welding. Weight 0.35 kg.*



Breaking strength:  
20 kN (2 ton)

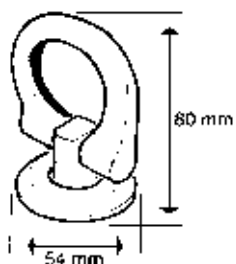
*Rope hook (48×60 mm) for welding. The hook is tested with 12 kN (1.2 ton) – 21 kN (2.1 ton) depending on direction of the force.*



Breaking strength:  
20 kN (2 ton)

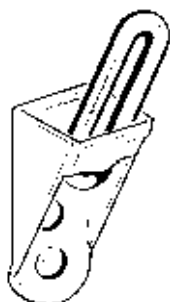
*Recessed galvanised lashing ring. Weight 0.75 – 1.2 kg.*





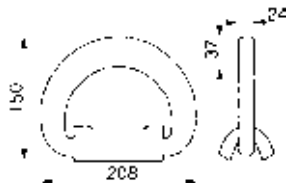
Breaking strength:  
40 kN (4 ton)

*Lashing eye for welding, untreated.*



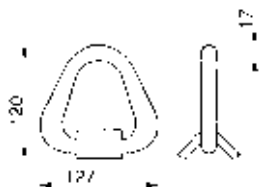
Breaking strength:  
60 kN (6 ton)

*Fitting fully inserted in the floor. To be welded in the structure. Galvanised eye of cast steel.*



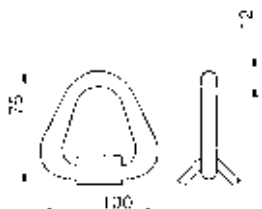
Breaking strength:  
360 kN (36 ton)

*D-ring originally used in the marine sector. Forged and untreated. To be welded. Weight 3 kg.*



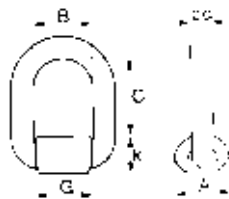
Breaking strength:  
200 kN (20 ton)

*D-ring originally used in the marine sector. Forged eye and sheet steel in hold, untreated. To be welded. Weight 1.8 kg.*



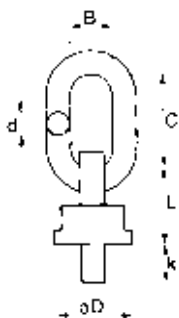
Breaking strength:  
100 kN (10 ton)

*D-ring originally used in the marine sector. Forged eye and sheet steel in hold, untreated. To be welded. Weight 1.5 kg.*



Breaking strength:  
200 kN (20 ton)

*Fitting originally used as lifting equipment. Eye of alloy steel (Grade 8) and hold of St 52, untreated. To be welded. Weight 1.3 kg.*



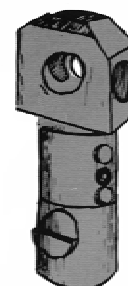
Breaking strength:  
320 kN (32 ton)

*Fitting originally used as lifting equipment. With ball bearing that make the fitting adjusting to the direction of force. Of alloy steel (Grade 8). To be screwed. Weight 3.4 kg.*

Lashing fittings could be placed in support holes for stanchions. These fittings have usually a breaking strength of about 100 kN (10 ton) but are available up to a breaking strength of 320 kN (32 ton).



*Lashing fitting for support hole for stanchion.  
Breaking strength: up to 320 kN (32 ton)*



*Container stacking cone for support hole for stanchion.  
Breaking strength: 100 kN (10 ton)*

### 8.2.17 Lashing winches

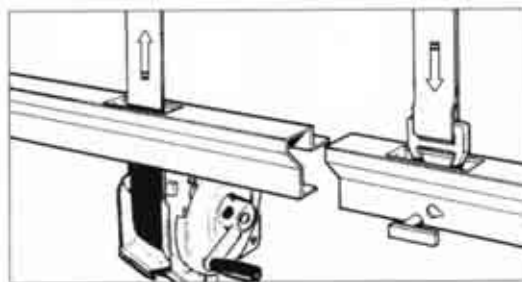
Lashing winches are often fixed on one of the vehicle's sides. On the other side of the platform a fitting for the lashings other end is placed. The winches could be automatic or manual – with or without automatic pretension.

Below is shown a manual winch without automatic pretension.



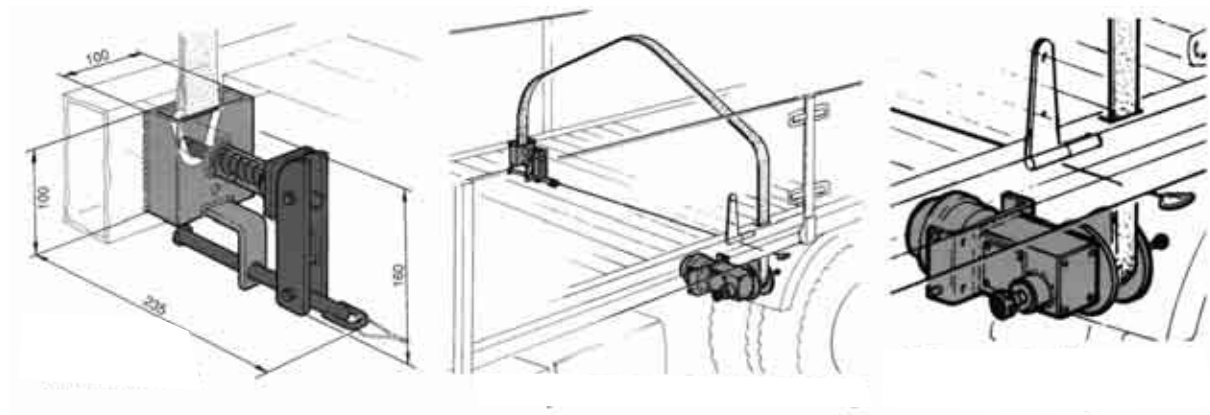
*Winch, breaking strength in winch 60 kN (6 ton).*

If the side beam has a channel for the lashings, the lashings do not have to be drawn outside the sideboard, see figure below. The figure also shows an example on how to secure the loose lashing end with a sprint in the side beam.



*Channel through the side beam for the lashing to a lashing winch for securing inside the sideboards.*

In the figure below an automatic winch with automatic pretension is shown. The tensioner is connected to the vehicles air-system. The pretension is variable but often is a pretension of 4000-5000 N (400-500 kg) used. If there is a malfunction of the air supply the actual pretension is maintained but is no longer automatic. The release of the lashing can be done from the same side as it is tightened. The winch is tested to 50 kN (5 ton), without any residual deformation.



*Automatic winch, tested to 50 kN (5 ton).*

### 8.2.18 Web lashings

The most common web lashing for vehicles is a 4 tonnes (40 kN) with a 9.5 m long part and a short part of 0.5 m, which is attached to a ratchet. There are hooks in both parts.



A 4-ton (40 kN) web lashing including ratchet with a long part of 9.5 m and a short part of 0.5 m.

In most cases 0.5 m is a suitable length on the short part of the web lashing. If however there were a need for placing the ratchet on top of the cargo, a longer webbing part on the short end would be needed. A solution, which gives possibility to various placement of the ratchet, is to provide the ratchet by a longer part of webbing and an adjustable hook. The short part will then be flexible 0.5 – 1.5 m.

Below different types of hooks are shown.



Claw hook  
50 kN (5 tonnes)



Claw hook with snap  
50 kN (5 ton)



Single hook\*  
50 kN (5 ton)



Adjustable hook  
50 kN (5 ton)



D-ring  
60 kN (6 ton)

*Examples of various types of hooks and fittings.*

\* An advantage with a single hook is that it may be used as a triangle to be attached to lashing points.

One way system – 20 kN (2 tonnes) break load			One way system – 40 kN (4 tonnes) break load	
Ratchet	Ratchet	Lock	Ratchet	Lock

### 8.2.19 Chain lashings

Older chain lashings are often made in the grade 5 quality. Break load for grade 5 is 500 N/mm<sup>2</sup>. Another common chain quality that is frequently used today for securing is grade 8 (800 N/mm<sup>2</sup>). Chains exist with short, half long or long links. The strength is not affected of which type of link that is used. It is the grade and the diameter of the material that decides the strength in the chains.

Quality	Diameter, mm	Breakload, kN (ton)
Grade 5	7	50 (5.0)
Grade 5	9	75 (7.5)
Grade 8	9	100 (10)
Grade 8	11	150 (15)
Grade 8	13	200 (20)

Examples of chain tensioners are shown below.



Turnbuckle



Chain tensioner



Tensioner and lengthener

Various types of tensioners for chains

### 8.2.20 Air bags

Airbags are often used to block spaces between sides in box type bodies and cargo units or between cargo units. In a cover/stake body airbags are placed between cargo units. Airbags are easy to use, easy to apply and they practically don't take any place when not in use. They can be used several times if they are handled with care. If the vehicles air system can be used to fill the airbags the use of them is very flexible.

In the table below maximum load (without safety margin) is shown for two various quality of airbags in two different sizes and for three various blocking distances.

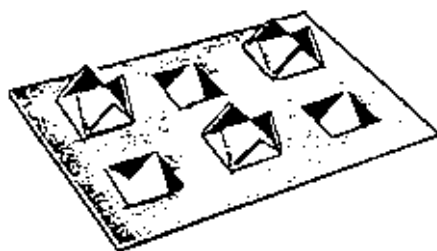
	Distance (cm)	Size (cm)			
		Model "Heavy"		Model "Light"	
		60×110	100×220	60×110	100×220
Max load kN (ton)	10	85 (8.5)	305 (30.5)	30 (3.0)	126 (12.6)
	20	40 (4.0)	205 (20.5)	13 (1.3)	78 (7.8)
	45	-	45 (4.5)	-	12 (1.2)

Max blocking capacity in kN (ton) for airbags (without safety margin)

### 8.2.21 Tag washer

Tag washers are placed between two wooden pallets or between wooden floor and wooden pallet. Tag washers grip into the wooden surface and prevent horizontal movement in the cargo unit. Tag washers are especially effective in combination with top-over lashings. To make tag washers as effective as possible, i.e. to grip into two different surfaces, it requires a minimum cargo weight. It can however be compensated with the pretension in top-over lashings. The table below shows how many tonnes of cargo a tag washer prevents from sliding sideways at a road transport:

Dimension (mm)	Minimum cargo weight for full grip (tons)	Number of tag washers	Max cargo weight which is prevented from sliding (tons)
<b>CIRCULAR</b>			
Ø 48	0.5	2	2
	2	4	4
Ø 62	1	2	2.8
	2.5	4	5.6
Ø 75	2	2	3.6
	4	4	7.2
Ø 95	3	2	4.8
	6	4	9.6
<b>RECTANGULAR</b>			
30 × 57	1	2	2
	2	4	4
48 × 65	1.5	2	2.8
	3	4	5.6



*Example of a rectangular tag washer*

### 8.2.22 Securing by friction

The friction between cargo and loading platform is of great importance for how much cargo securing that is required. Pieces of rubber are used to increase the friction when carriage of, for example, steel products, but also for surfaces like wood against wood, rubber will increase the friction.

### 8.2.23 Securing by vacuum

One variant on top-over lashing is to use vacuum for cargo securing. An airtight cloth that is placed over the cargo will produce pressure against the loading platform, the air inside the cloth is sucked out through small holes in the vehicles loading platform.

If a depression of 0.2 bar ( $0.2 \text{ kg/cm}^2$ ) is achieved it will give a total downward pressure against the loading platform of 600 kN (60 tonnes) in a vehicle with the measurements  $12 \times 2.5 \text{ m}$ . If it is assumed that a top-over lashing gives a pressure against the loading platform of 8 kN (0.8 tonnes), the pressure created by a vacuum system would correspond to 75 top-over lashings.

### 8.2.24 Securing by hydraulic

Hydraulic operated systems are normally accepted for cargo securing only if hydraulic locks are mounted into the system. One example where this type of function is used is back plate lifts. In other systems for example when transporting and securing round timber, a system is used that alerts when the pressure in the system falls.

The figure below shows a log carrier for an automatically securing system for round timber. The lashings are inbuilt in the stakes and are operated from a panel in the vehicles cabin. The lashings are hydraulically tensioned.



*Log carrier with an automatic securing system.*

### 8.2.25 Securing by pneumatic

Many vehicles are today equipped with a pneumatic system for several functions such as spring system, brakes etc. A good idea would be, if possible, to use pneumatic instead of hydraulic when it comes to an automatic securing system. When securing with pneumatic some form of mechanical locks must be used to guarantee the security if a burst of a hose should appear.





## 9 PROPOSED EQUIPMENT IN A RAILWAY WAGON FOR FLEXIBLE AND EFFICIENT CARGO SECURING

Some components for railway wagons for flexible and efficient cargo securing are described below.

### 9.1 Bogie and superstructure

#### 9.1.1 Freight bogie

One way to reduce damages on cargo as well as minimising the need of cargo securing is to have a freight bogie that gives good running characteristics (e.g. low vibrations). The bogie shown below creates new possibilities for transportation of fragile cargo due to its wheel suspension and damping, which allows increased transport volumes on railroad.



*Wheel suspension for 25 ton axleload.*

The reduced vibrations, reduces the risk of cargo movements and opens up for the possibility to secure cargo by increased friction alone.

#### 9.1.2 Floor

In most of the load cases it is preferably to have a high coefficient of friction between the wagon floor and the cargo. To achieve an improved friction, friction-enhancing inserts are used. The inserts are made of rubber, granulated composite rubber, rubber and polyurethane or treated cotton webbing. In addition to a high friction it is important that the inserts have qualities that make them damp the vibrations from the wagon.

For some types of cargo (e.g. standing paper reels) the friction can, however, be too high. For these types it could be better with a soft floor damping the vibrations.

With a wagon floor that is equipped with a fixed, soft friction mat it would not be necessary to use inserts and it would increase the safety when inserts are not used. If the friction mat is placed on a wooden/plywood floor it is also possible to use nailed timber in the wagon.

### **9.1.3 Side walls**

A rational side wall must be strong enough to secure common general cargo against it. If the sides are dimensioned according to the standard EN 283 “Swap bodies – Testing” it is reasonable strong. Another criterion is that the side wall should be easy to operate even if cargo is pressing on it from inside. See chapter 6.

### **9.1.4 End walls**

End wall must be strong enough to secure the whole cargo against it. If the ends are dimensioned according to the standard EN 283 “Swap bodies – Testing” or the container standard “ISO 1496-1” it is reasonable strong. See chapter 6.

## **9.2 Securing inside wagons**

### **9.2.1 Securing fittings**

Fittings for lashings should primarily be placed in the floor along the side walls. To be able to place the lashings in an optimised position the fittings should be a side beam with continuous possibilities to attach lashings. In addition there should be a number of really strong fittings for the attachment of chain lashings for single heavy cargo items.

### **9.2.2 Partition walls**

At a railway transport it is of most importance to have a tight stow lengthways in the wagon. If the wagon is equipped with partition walls that can block half the wagon’s payload each, there is no need to place filling, e.g. empty pallets or air bags between cargo items in longitudinal direction.

### **9.2.3 Stanchions**

For wagons with sides of less strength or for blocking cargo with a large distance to the side walls foldable side stanchions adjustable sideways could be used. An example of foldable side stanchions is described below.

## 9.3 Side stanchions and bolsters

### 9.3.1 Background

As a part of the work to specify a flexible railway wagon that allows rational securing of various types of cargo, side stanchions with an adjustable transverse positioning system and turnable bolsters, has been developed within the jvgRASLA project. The development of the stanchions has been made in co-operation between Autonordic, ExTe, Midwaggon, K Industrier, Green Cargo and MariTerm. Photos of the prototype are shown in section 9.3.5.

In a wagon equipped with strong sides and foldable and adjustable side stanchions the following cargo types can be stowed and secured in a rational way:

- paper reels
- square sawn timber
- palletised goods
- pipes
- steel plates
- board packages

Cargo types that more easily can be transported in a wagon equipped with turnable bolsters are:

- square sawn timber
- pipes
- steel plates

If wagons are equipped with the stanchions/bolsters the number of single trips could be reduced.

When equipping a new wagon with the stanchions and bolsters the extra weight compared to a wagon without the stanchions will be limited to only the weight of stanchions and bolsters. This because the fixed, supporting parts in the wagon floor will be included in the structure of the wagons underframe.

### 9.3.2 Required functions for stanchions

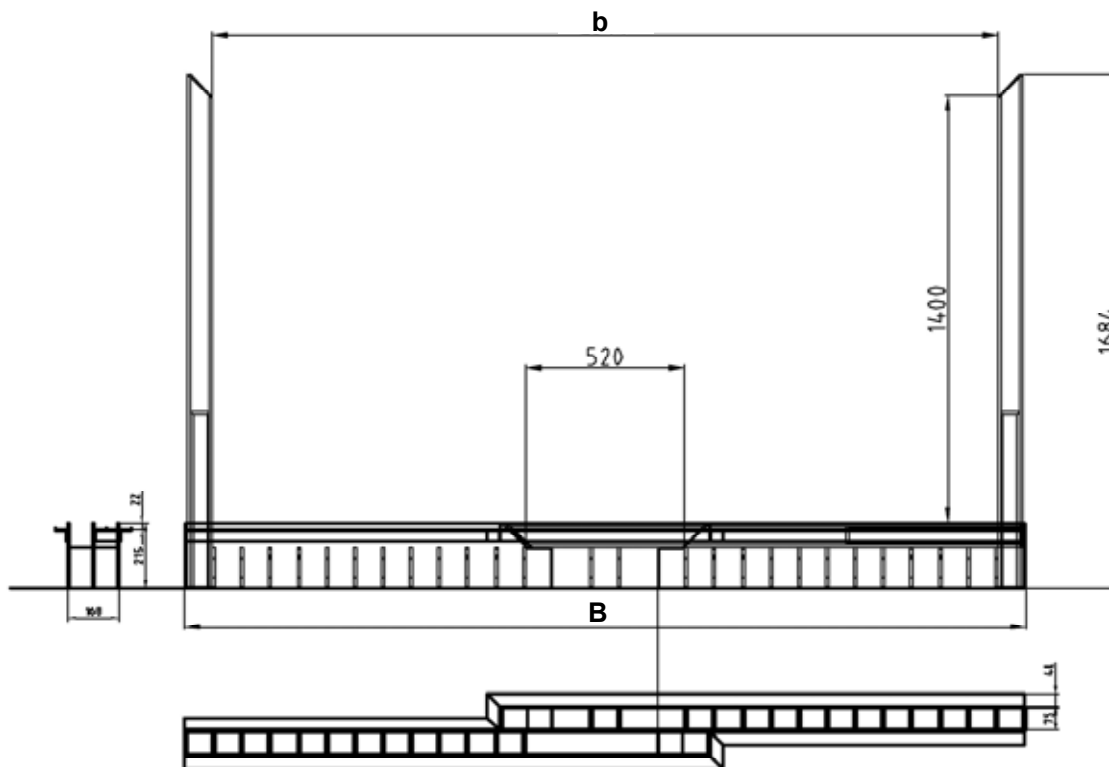
In order to meet the functionality that a rational securing of various types of cargo demands, the stanchions should be:

- sliding in the sideways direction, from 30 cm off the centre of the wagon to its full width.
- foldable into the floor so that the wagon is provided with a smooth floor free from obstacles when the stanchions are not in use. This allows for paper reels to be loaded onto the wagon and forklifts to be operated inside it.
- protected from dirt and waste to gather inside the construction.
- at least 1.4 meter high.
- able to withstand a bending moment equal to that of stanchions for timber loads.
- of as low weight as possible.
- of a robust and user friendly design.

- connected to the wagon to prevent loosening any.

### 9.3.3 Design of stanchions

A gutter with two rows of rectangular, vertical slots is fitted cross the wagon so that the top of the gutter is levelled with the floor. Two stanchions may be placed in any of the slots so that the distance between them can be varied from 52 to 256.6 cm



*The top drawing shows the stanchions from wagons end.  
The lower drawing shows the stanchions from above.*

The stanchions may also be folded into the gutter, creating a smooth floor without obstacles. In this position the stanchions protects the gutter from dirt and waste.

The straightforward design provides an easy and time efficient operability and low demands on maintenance.

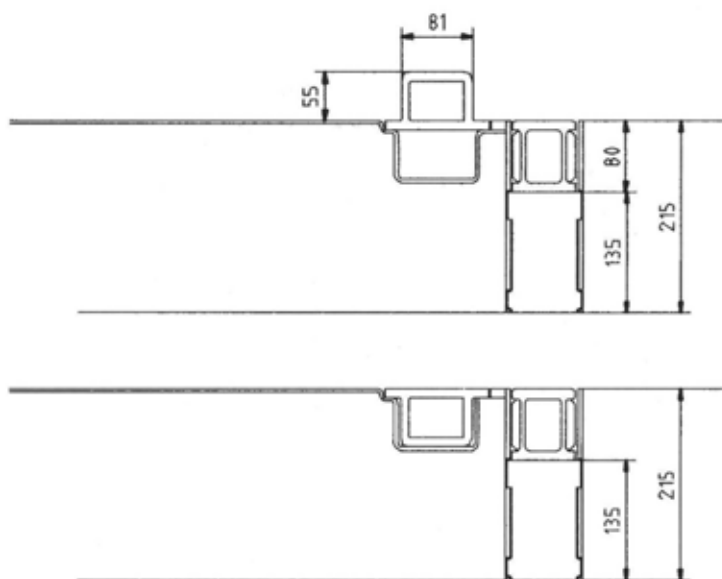
The weight of each stanchion is approximately 12 kg. Its dimensions are given in the figure above.

### 9.3.4 Permanent bolsters

In order to meet the functionality that a rational securing of various types of cargo demands, the bolsters should be:

- foldable into the floor so that the wagon is provided with a smooth floor free from obstacles. This allows for paper reels to be loaded into the wagon and forklifts to be driven inside it.
- at least 55 mm high.
- maximum weight approximately 15 kg.
- protected from dirt and waste to be gathered inside the construction.
- equipped with rubber or wood on top for increased friction.

The bolster is made of a U-profile in aluminium welded to a bottom plate. The plate rests on two supports inside a gutter that is built into the wagon floor. The design lets the bolster be turn upside down and stowed inside the gutter when not in use, thus creating a smooth surface and protecting the construction from dirt.

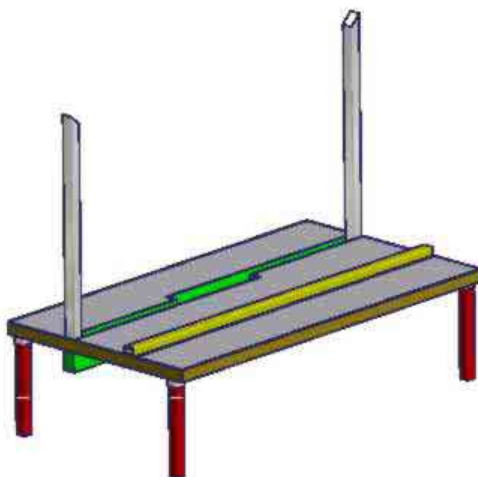


*Bolster and stanchion seen from the wagons side. The bolster is in raised position in the top drawing and flush with the floor in the lower drawing. The stanchion is flush with the floor.*

The weight of each bolster is approximately 15 kg. Its dimensions are given in the figure above.

### 9.3.5 Prototype

A prototype of the stanchions and the bolsters described in the previous sections has been built within the project. As mentioned in section 9.3.1 the extra weight compared to a wagon without the stanchions will be limited to only the weight of stanchions and bolsters, when equipping a new wagon. The prototype is shown below.



*Sketch of the prototype.*



*The prototype with raised stanchions and bolster.*



*The prototype with the stanchions and bolster folded making the floor flush.*

## 10 COMPARISON OF CARGO SECURING COST BETWEEN RAILWAY AND ROAD TRANSPORT

In this chapter the cost of some of the different railway securing arrangements described in chapter 5 will be compared with equivalent securing arrangements designed for road transport. The road cargo securing arrangements are based on the regulations from the Swedish Road Administration TSVFS 1978:10 and VVFS 1998:95. These demands are identical to the demands in the IMO/ILO/UN ECE Guidelines for Packing of Cargo Transport Units.

### 10.1 Bases for the cost comparison

#### 10.1.1 Lashcost

The Transport Research Institute (TFK) in Sweden has developed the LASHCOST-model<sup>1</sup> (LSC) during 2001. The LSC-model is used as a model to calculate the cost (lashing cost) for the different securing arrangements in this chapter. The LSC-model divides the lashing cost in the following six basic elements (the labels refer to the TFK-report):

- Labour cost for cargo securing at loading and unloading - CLSL
- Cost for cargo securing equipment - CMES
- Cost for machines and handling equipment - CLLU
- Cost for Cargo Transport Unit (CTU) and vehicles - CLCV
- Capital cost of the cargo during handling and transport - CLTH
- Cost for cargo securing training - CLTS

Under each basic cost element there are several cost components defined in the LSC-model. Below is only the cost components considered described. A detailed description of the LSC-model can be found in the TFK-report.

All the costs are in Swedish Crowns SEK and expressed as cost per transportation and volume or weight unit.

#### ***Labour cost for cargo securing at loading and unloading - CLSL***

LCLS – Cost for personnel who manually are loading and securing the cargo.

Man-hour × cost/man-hour

LLCU - Cost for personnel who manually are unloading and un-securing the cargo.

Man-hour × cost/man-hour

#### ***Cost for cargo securing equipment - CMES***

PNDS – Purchase cost for one-way cargo securing equipment

Purchase cost per transportation

LRMS – Cost for re-usable cargo securing equipment.

Yearly cost / No. of transportations per year

#### ***Cost for machines and handling equipment - CLLU***

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<sup>1</sup> TFK Rapport 2001:3, Peter Bark, Ann-Sofi Granberg, Gunnar Janson and Rolf Nordström

Not considered in these analysis.

***Cost for Cargo Transport Unit (CTU) and vehicles - CLCV***

Not considered in these analysis.

***Capital cost of the cargo during handling and transport - CLTH***

Not considered in these analysis

***Cost for cargo securing training - CLTS***

Not considered in these analysis

### **10.1.2 Cargo Transport Unit (CTU)**

The valid type of railway wagon can be found in the UIC-guidelines referred for the different type of load cases. In all load case the platform is made of wood.

If not anything else is mentioned the CTU on road is a semi-trailer of cover/stake type with platform made of wood or plyfa.

### **10.1.3 Coefficient of friction**

The coefficient of friction is set to the minimum value  $\mu=0.3$  for railway transport.

In the cargo securing arrangements designed for road transport the coefficient of friction value is taken from the friction value table in VVFS 1998:95 section 5.0.4 or from referred instructions where the friction has been stated by inclining test. In some load cases the minimum value for road transport  $\mu=0.2$  is used.

### **10.1.4 Time consumption – lashings**

The time consumption to perform the different alternatives of lashing is estimated to the following values:

- |                               |                     |
|-------------------------------|---------------------|
| – Scotches or wooden bars     | 2 min/scotch or bar |
| – Nails                       | 0.5 min/nail        |
| – Top-over lashing            | 5 min/lashing       |
| – Loop lashing                | 10 min/lashing      |
| – Spring lashing              | 10 min/lashing      |
| – Straight/cross lashing      | 5 min/lashing       |
| – Round-turn lashing          | 10 min/lashing      |
| – H-brace (pre-manufactured)  | 5 min/H-brace       |
| – Blocking with empty pallets | 1 min/pallet        |

The time value includes securing and un-securing the different alternative methods.



### 10.1.5 Other presumptions

All other presumptions - man-hour cost, lashing costs etc, are taken from the LSC-model shown in the table below:

DESCRIPTION	Label	Unit	Value		
<b>Labour cost</b>					
Labour cost loading personnel	HLLS	SEK/h	183.5		
Labour cost un-loading personnel	HLUC	SEK/h	183.5		
<b>Purchasing cost one way equipment</b>					
One-way web lashing	PNDS2	SEK/m	3.5		
Locking to one-way web lashing	PNDS3	SEK/pcs	5		
Wooden bar	PNDS5	SEK/m	12		
Nails	PNDS8	SEK/pcs	0.8		
Edge protection	PDNS12	SEK/m	3		
Supporting edge beam	PNDS13	SEK/m	24		
Scotches	PNDS14	SEK/pcs	12		
H-brace	PNDS15	SEK/pcs	54		
Empty pallets	PNDS16	SEK/pcs	38.5		
<b>Purchasing cost returnable equipment</b>				<b>Label</b>	<b>Life time</b>
Web lashing with ratchet	PCRS2	SEK/pcs	90	LLMS2	1 year
Chain	PCRS3	SEK/m	30	LLMS3	1 year

Remarks:

- The returnable equipment is used 33 times/year.
- The model doesn't consider different prices for different strength of equipment
- The currency is SEK (Swedish Kronor); 9 SEK  $\approx$  1 EURO

### 10.1.6 Shunting

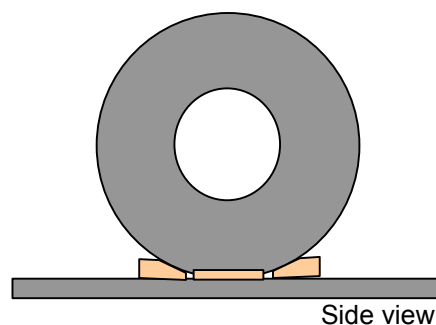
Some of the railway securing arrangements is depending on the way the railway wagon is shunted – hump and fly or none hump and fly. In these load cases the value for hump and fly shunting is stated first and none hump and fly shunting second separated with an vertical bar. Example - required number of nails is 5 | 2.

## 10.2 Coiled sheet

A single coil with metal sheet loaded on roll (with the eye to side) with a weight of 5 tons is to be secured. The coil has no cradle.

**10.2.1 Railway**

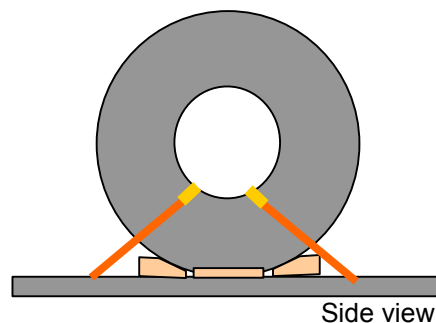
The securing arrangement for railway transport of coiled sheet is described in section 5.5. The securing arrangement consist of two pitched scotches on each side in lengthways direction nailed with 5 | 2 nails each. Across the wagon one wooden bar on each side of the coil is nailed with 3 nails each.



**10.2.2 Road**

According to the Swedish Road Administration regulations TSVFS 1978:10 § 4.1 the securing arrangement for road transport of coiled sheet is like the arrangement for railway with additional lashing. A sufficient way to secure the coil is with two spring lashes. One in each lengthways direction.

The securing arrangement consist also of two pitched scotches on each side in lengthways direction nailed with 2 nails each. Across the vehicle one wooden bar on each side of the coil is nailed with 3 nails each.



**10.2.3 Input to the LSC-model**

The securing arrangements above gives the following input to the LSC –model:

Input	Railway – hump and fly shunting	Railway - non hump and fly shunting	Road
<b>Time consumption for no. of:</b>			
- Scotches/wooden bars	6	6	6
- Nails	26	14	14
- Spring lashings			2
<b>Time consumption [min]</b>	<b>25</b>	<b>19</b>	<b>39</b>
<b>No. of one way equipment</b>			
- Scotches	4	4	4
- Wooden bar [m]	2	2	2
- Nails	26	14	14
- Edge protection [m]			0.5
<b>No. of returnable equipment</b>			
- Web lashing with ratchet			2

**10.2.4 Result**

The calculated cost in the LSC-model for the cargo securing arrangements above for one standing coiled sheet with the cargo weight 5 ton is:

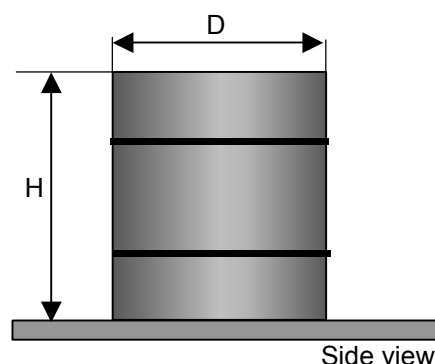
Mode of transport	Cargo securing cost [SEK / coil]
Railway - hump and fly shunting	169
Railway - non hump and fly shunting	141
Road	198

**10.3 Ungreased hot-rolled coiled sheet**

A single coil with ungreased metal sheet is loaded on the end (eye to sky) with the weight of 5 tons and is to be secured. The height and diameter of the coil is  $H \times D = 2 \times 1.4$  m.

**10.3.1 Railway**

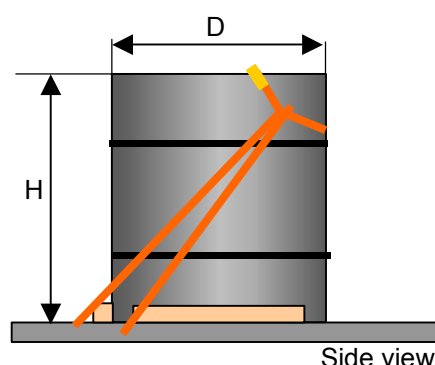
The securing arrangement for railway transport of ungreased hot-rolled coiled sheet is described in section 5.6. There are no need of cargo securing since the diameter  $D = 70\%$  of  $H$ .



**10.3.2 Road**

The cargo securing arrangements for road transport is depending of the coefficient of friction between coil and platform. Since the value is not found in the friction value table the minimum value of  $\mu=0.2$  is used.

The coil is prevented from sideways and backward sliding by bottom blocking consisting of three nailed bars with 4 nails to the platform. In forward direction the coil is secured with a double spring lashing.



**10.3.3 Input to the LSC-model**

The securing arrangements above gives the following input to the LSC –model:

Input	Railway	Road
<b>Time consumption for no. of:</b>		
- Scotches/wooden bars		3
- Nails		12
- Spring lashings		1
<b>Time consumption [min]</b>	<b>0</b>	<b>22</b>
<b>No. of one way equipment</b>		
- Wooden bar [m]		1.5
- Nails		12
- Edge protection [m]		0.5
<b>No. of returnable equipment</b>		
- Web lashing with ratchet		2

### 10.3.4 Result

The calculated cost in the LSC-model for the cargo securing arrangements above for a single coil with ungreased metal sheet loaded “eye to sky” with the cargo weight 5 ton is:

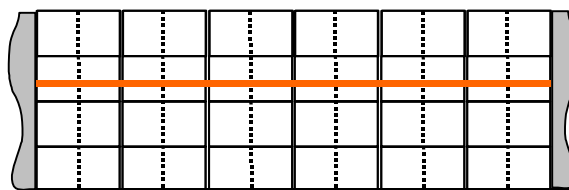
Mode of transport	Cargo securing cost [SEK / coil]
Railway	0
Road	102

## 10.4 Wood pulp in bales

A section with six load units with wood pulp bales is to be secured. In this case one presumption is that the load units are secured lengthways by blocking. The securing arrangement is to prevent sideways sliding. The weight of one load unit with wood pulp bales is 2 tons.

### 10.4.1 Railway

The securing arrangement for railway transport of wood pulp in bales in six load units is described in section 5.8. The six load units are bound together with a horizontal round-turn lashing. In lengthways direction the load units are blocked with other cargo, walls or stanchions.

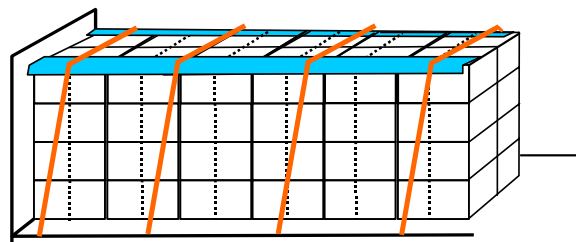


Side view

**10.4.2 Road**

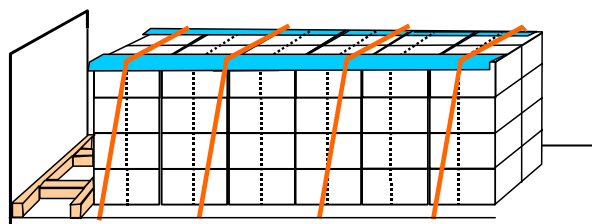
The securing arrangement is taken from an instruction made for Södra Cell AB 2001-12-10. A friction test has given a coefficient of friction between wood pulp bale and platform to  $\mu=0.45$ .

The six load units are secured with 4 top-over lashings. The effect of the lashings is spread out with 2 supporting edge beams.



Side view

If the load units are not blocked forward by the headboard, they have to be bottom blocked with a H-brace.



Side view

**10.4.3 Input to the LSC-model**

The securing arrangements above gives the following input to the LSC –model:

Input	Railway	Road - without H-brace	Road - with H-brace
<b>Time consumption for no. of:</b>			
- Top-over lashing		4	4
- Round-turn lashing	1		
- H-brace (pre-manufactured)			1
<b>Time consumption [min]</b>	<b>10</b>	<b>20</b>	<b>25</b>
<b>No. of one way equipment</b>			
- Supporting edge beam [m]		10	10
- H-brace			1
<b>No. of returnable equipment</b>			
- Web lashing with ratchet	1	4	4

**10.4.4 Result**

The calculated cost in the LSC-model for the cargo securing arrangements above for a section with six load units with wood pulp bales with the total cargo weight of 12 ton is:

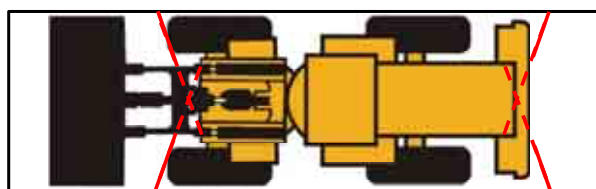
Mode of transport	Cargo securing cost [SEK / cargo section]
Railway	34
Road - without H-brace	313
Road - with H-brace	382

## 10.5 Vehicles

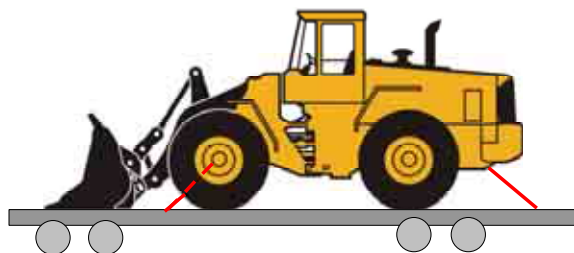
A wheel loader with a weight of 29 tons is to be secured.

### 10.5.1 Railway

The securing arrangement for railway transport of vehicles is described in section 5.9. The wheel loader is secured with 4 cross lashings with a minimum break load of 200 kN | 125 kN.



Top view

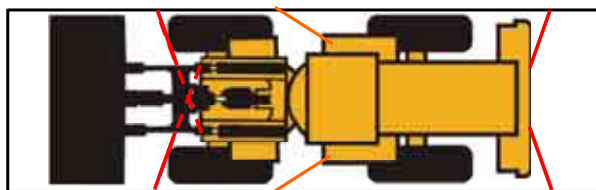


Side view

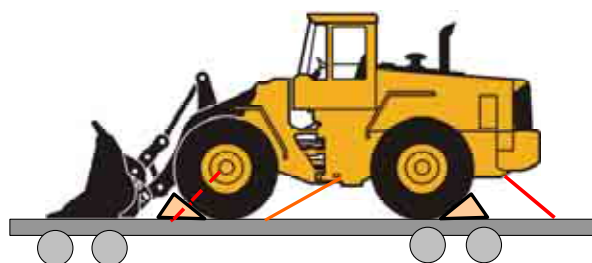
### 10.5.2 Road

The securing arrangement is taken from an instruction made for Volvo Construction Equipment AB and the wheel loader L180. The coefficient of friction is set to  $\mu=0,2$ .

The wheel loader is secured with six cross/straight lashings and with 4 pitched scotches nailed with 2 nails each. The lashings break load must be at least 20 tons.



Top view



Side view

### 10.5.3 Input to the LSC-model

The securing arrangements above using chains with a length of 2 m gives the following input to the LSC –model:

Input	Railway	Road
<b>Time-consumption for no. of:</b>		
- Scotches/wooden bars		4
- Nails		8
- Straight/cross lashing	4	6
<b>Time consumption [min]</b>	<b>20</b>	<b>42</b>
<b>No. of one way equipment</b>		
- Scotches/wooden bars		4
- Nails		8
<b>No. of returnable equipment</b>		
- Chain [m]	8	12

#### 10.5.4 Result

The calculated cost in the LSC-model for the cargo securing arrangements above for a wheel loader with a total cargo weight of 29 ton is:

Mode of transport	Cargo securing cost [SEK / vehicle]
Railway	69
Road	194

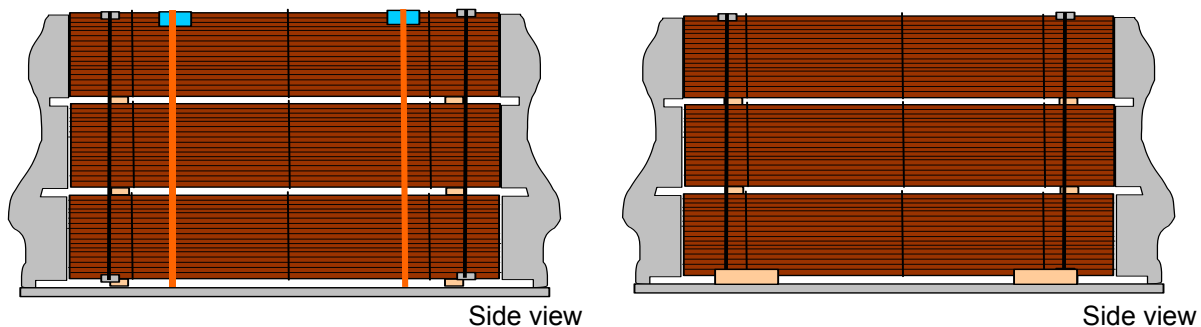
Note! The LSC-model does not count with different prices for chains with different break loads.

## 10.6 Plywood slabs

Smooth-coated plywood slabs are bound into packages with the following dimensions  $H \times L \times B = 0.6 \times 2.0 \times 1.8$  m and a weight each of 750 kg. Three packages on top of each other are bound together to a load unit with at least 2 bindings and timbers in-between the packages. In this case one presumption is that the cargo section is secured lengthways by blocking. The securing arrangement is to prevent sideways sliding and tipping.

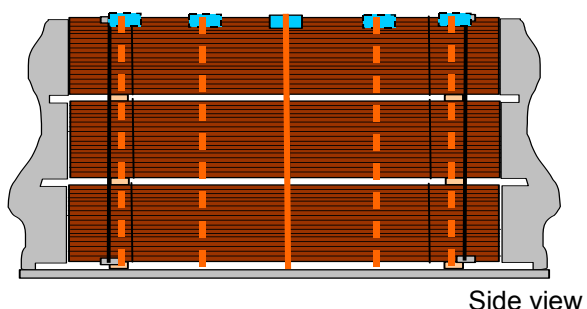
### 10.6.1 Railway

The securing arrangement for railway transport of plywood slabs is described in section 5.10. The cargo section is secured with two top-over lashings and edge protection **or** with 2 wooden bars nailed in place with each 2 nails at each side.



**10.6.2 Road**

The securing arrangement for road transport is depending if the three packages bound together can be seen as rigid in form. If the load unit is rigid in form there is no risk of tipping or sliding in the layers above the bottom cargo layer. Then the securing arrangement is depending on the coefficient of friction between bottom layer and the platform.



If the cargo section is secured with top-over lashings the number of lashings varies from 1 ( $\mu=0.5$ ) up to 5 ( $\mu=0.2$ ).

**10.6.3 Input to the LSC-model**

The securing arrangements above gives the following input to the LSC –model:

Input	Railway– Top-over lashing	Railway– Wooden bars	Road - $\mu=0.2$	Road - $\mu=0.5$
<b>Time-consumption for no. of:</b>				
- Scotches/wooden bars		4		
- Nails		8		
- Top-over lashing	2		5	1
<b>Time consumption [min]</b>	<b>10</b>	<b>12</b>	<b>25</b>	<b>5</b>
<b>No. of one way equipment</b>				
- Wooden bar [m]		2		
- Nails		8		
- Edge protection [m]	0.5		2.0	0.5
<b>No. of returnable equipment</b>				
- Web lashing with ratchet	2		5	1



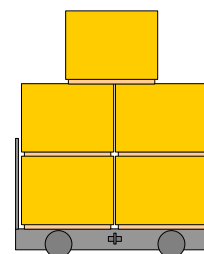
**10.6.4 Result**

The calculated cost in the LSC-model for the cargo securing arrangements above for a section with three packages of plywood slabs with a total cargo weight of 2.25 ton is:

Mode of transport	Cargo securing cost [SEK / cargo section]
Railway – Top-over lashings	38
Railway – Wooden bars	67
Road ( $\mu=0.2$ )	97
Road ( $\mu=0.5$ )	19

**10.7 Square-sawn timber**

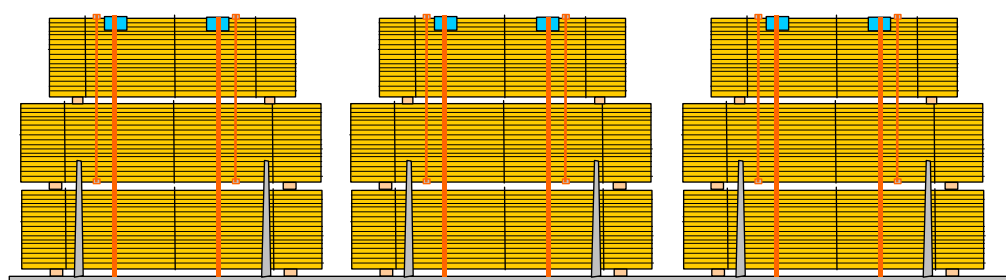
Square-sawn timber, trimmed and bound into packages with 2 fastenings, is loaded in three cargo sections. Each cargo section consists of 5 packages in three layers with a single package in the top layer. The package in the top layer is also shorter than the other packages. The two bottom layers are sideways blocked to the walls/stanchions. The weight of a package is 1.5 tons except for the shorter one, which has a weight of 1 ton. The total weight is  $12 \times 1.5 + 3 \times 1 = 21$  tons.



Front view

**10.7.1 Railway**

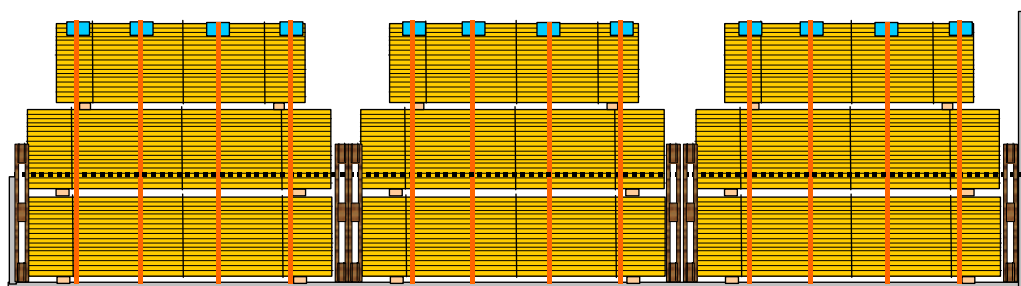
The securing arrangement for railway transport of square-sawn timber is described in section 5.11. Each cargo section is secured with two top-over lashings and the top layer is bound to the underlying layer with two round-turn lashings.



Side view

**10.7.2 Road**

The securing arrangement for road transport is depending on the coefficient of friction and one condition for the following cargo securing arrangement is that the friction is  $\mu=0.4$  or higher. The three cargo sections have to be blocked lengthways by empty pallets. The number of pallets is calculated 6 in this load case. Each cargo section is also secured by 4 top-over lashings.



Side view

### 10.7.3 Input to the LSC-model

The securing arrangements above gives the following input to the LSC –model:

Input	Railway	Road
<b>Time-consumption for no. of:</b>		
- Top-over lashing	6	12
- Round-turn lashing	6	
- Blocking with empty pallets		6
<b>Time consumption [min]</b>	<b>90</b>	<b>66</b>
<b>No. of one way equipment</b>		
- Edge protection [m]	2	4
- Empty pallets		6
<b>No. of returnable equipment</b>		
- Web lashing with ratchet	12	12

### 10.7.4 Result

The calculated cost in the LSC-model for the cargo securing arrangements above for three cargo sections with square-sawn timber with a total cargo weight of 21 ton is:

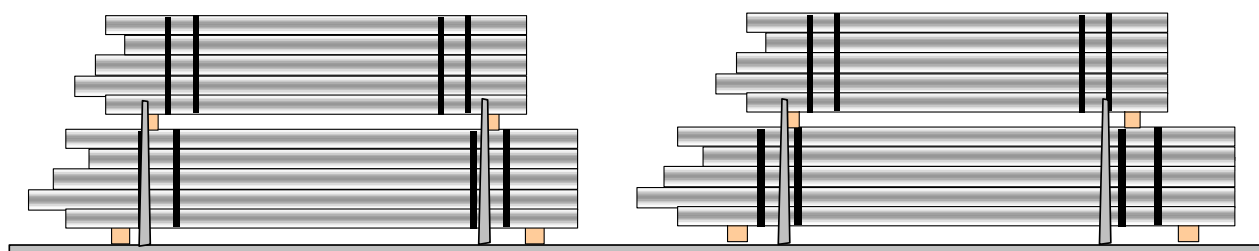
Mode of transport	Cargo securing cost [SEK /CTU]
Railway	317
Road	481

## 10.8 Steel sections

In this load case the cargo sections consist of bundles of oiled steel tubes loaded in two cargo sections and two layers with wooden crossbar in-between. The bundles have different length and weight. The weight of the bottom layer is 5 tons and the top layer 4 tons. The total cargo weight is 18 tons.

### 10.8.1 Railway

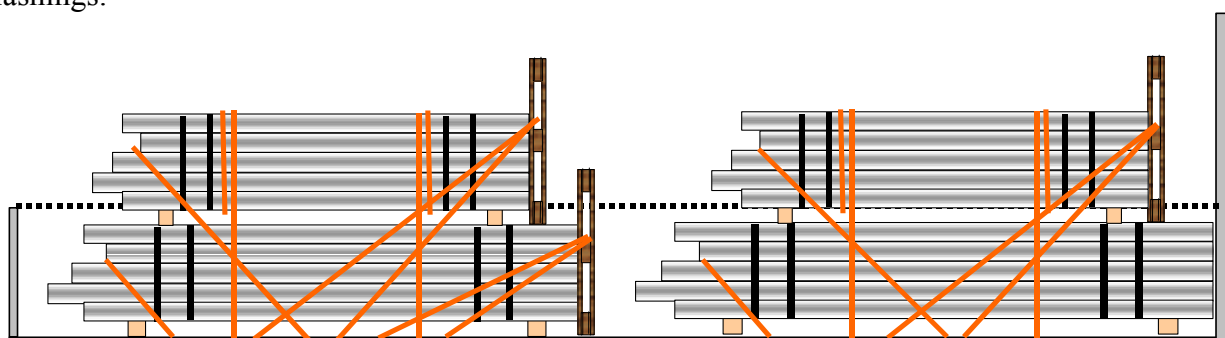
The securing arrangement for railway transport of steel sections is described in section 5.12. According to the guidelines steel sections require no additional securing.



Side view

### 10.8.2 Road

The securing arrangement for road transport is taken from instruction made for Ovako Steel 2002-06-20. Each layer is prevented from forward sliding by 1 double spring lashing (except the bundles blocked by the headboard) and backward by 1 spring lashing. To prevent sideways sliding the sideboards blocks the bottom layers and each top layer is secured with 2 pairs of loop-lashings. The total number of lashings is 7 spring lashings and 4 pair of loop lashings.



Side view

### 10.8.3 Input to the LSC-model

The securing arrangements above gives the following input to the LSC –model:

Input	Railway	Road
<b>Time-consumption for no. of:</b>		
- Spring lashings		7
- Loop lashings		4
<b>Time consumption [min]</b>	<b>0</b>	<b>110</b>
<b>No. of one way equipment</b>		
- Edge protection [m]		2
- Empty pallets		6
<b>No. of returnable equipment</b>		
- Web lashing with ratchet		18

#### 10.8.4 Result

The calculated cost in the LSC-model for the cargo securing arrangements above for two cargo sections with oiled steel tubes with a total cargo weight of 18 ton is:

Mode of transport	Cargo securing cost [SEK /CTU]
Railway	0
Road	627

#### 10.9 Summary

The cost for cargo securing is almost in all cases lower for railway transport. The main reasons are

- In several cases for railway transport the cargo is allowed to slide lengthways. This is not an option in road transports and the securing arrangement will be extensive, if the load is not blocked forward.
- The UIC guidelines for cargo securing are designed for lower dimensioning forces than road transport, see chapter 5.
- The different types of goods in the load cases are suitable for railway transports as they are taken from the UIC-guidelines.

The comparison of cost for cargo securing between railway and road transport are summarized in the table below:

Load case	Unit	Mode of transport			
		Railway		Road	
Coiled sheet	SEK/coil	Hump and fly shunting	169	198	
		None hump & fly shunting	141		
Ungreased hot-rolled coiled sheet	SEK/coil	0		102	
Wood pulp in bales	SEK/cargo section	34		Without H-brace	313
				With H-brace	382
Vehicles	SEK/vehicle	69		194	
Plywood slabs	SEK/cargo section	Top-over lashings	38	$\mu=0.2$	97
		Wooden bars	67	$\mu=0.5$	19
Square-sawn timber	SEK/CTU	317		481	
Steel sections	SEK/CTU	0		627	

A conclusion is that it is not easy to make the cargo securing arrangements easier and more cost efficient than what is stipulated by the UIC guidelines (RIV Appendix II, Section 2). Instead the cost saving potential is to design the railway wagons more multi purpose to increase the utilisation and to design handling equipment efficient to shorten the time for securing with lashings.

One interesting question that this comparison has excluded is the range of goods damages. Are there differences between the modes of transports regarding goods damages? And if so, is it because of different cargo securing, different acting forces on the cargo or different cargo securing regulations?



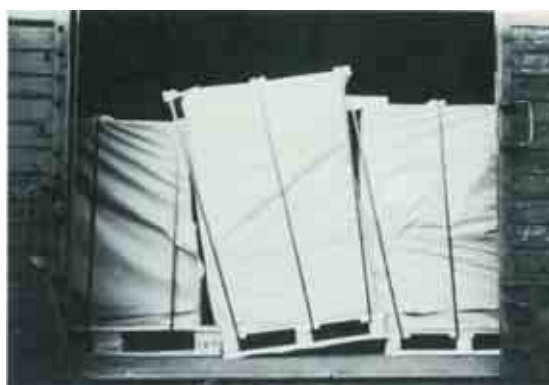
## 11 LOADING AND SECURING OF PALLETISED CARGO

### 11.1 Purpose

Since the only regulations in RIV Appendix II for palletised goods deals with the formation of loads, the purpose of this chapter is to give a proposal of instructions for the securing of such palletised units. Existing rules, guidelines and instructions that apply on a national level within Europe as well as North American regulations have been studied. The results are presented below together with the general regulations in RIV Appendix II.



*Damage due to insufficient strength of stretch/shrink-foil.*



*Damage due to sides not flush with the pallet edges.*



*Damage due to too large spaces sideways.  
Could be avoided by loading the upper pallets with the bottom boards across the wagon.*

### 11.2 Formation of loads

#### 11.2.1 UIC

##### RIV Appendix II Section 1, Chapter 1.5

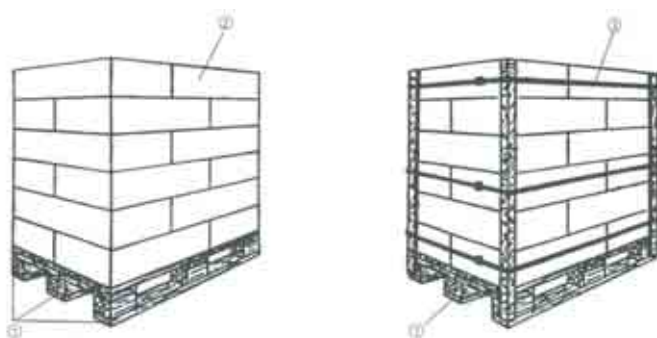
Goods may be assembled to form load units using steel strips, steel wire, synthetic or woven straps with a breaking strength of at least 5 kN (500 kg) for goods weighing up to 500 kg and

7 kN (700 kg) for goods weighing over 500 kg. The straps must be tensioned. Minimum two fastenings shall be used for each pallet. Also shrink-foil or stretch-foil can be used to form load units. The maximum weight of the goods is then approximately 1000 kg. The feet of the pallet must be enclosed in the plastic foil. For shrink-foil, a thickness of approximately 0.15 mm is generally sufficient.

### RIV Appendix II Section 2, Loading guidelines 11.1

Goods should be arranged on the pallet in stable and compact manner, with sides flush with the pallet edges in interlocking layers or stacked in criss-cross formation.

The stability of the load unit is increased by using steel strip, textile or synthetic bands with breaking strength 7 kN (700 kg) to encircle the load vertically and/or horizontally. For easily displaced goods edge protections bound to the load with three horizontal encircling bands could be used. One band should be round the lower tier, one around the middle and one towards the top of the load unit. Other methods to stabilize the load unit are by shrink-foil or stretch-foil of minimum thickness of 0.15 mm (the foil shall also enclose the pallet feet) or the use of inserts of friction-enhancing material, special adhesives or tag washers.



- ① Flat pallets made of wood, plastic, pressboard, etc.
- ② Goods with sides flush with the pallet edges.
- ③ Steel strip, textile or synthetic bands alternatively stretch- or shrink-foil.

## 11.3 Existing instructions

### 11.3.1 UIC

- **Loading guideline 11 / 80-002-99 (DB, SNCF)**

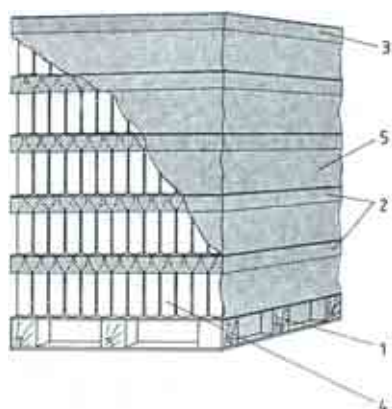
In the pink loading guideline 11 / 80-002-99 (DB, SNCF) examples of how to load and secure palletised loads of empty bottles can be found. The following general guidelines can be obtained from these examples:

- The height of the stack shall not exceed two times the smallest of the pallet dimensions. E.g. the maximum height of a stack on a pallet of 80×120 cm is 160 cm.
- The bottles shall be put in cardboard boxes or trays and the top layer shall be covered with a cardboard lid.
- In order to form a stable load unit, the layers shall be bound together with shrink or stretch foil with a minimum thickness of 150 µm of good quality. The foil must enclose

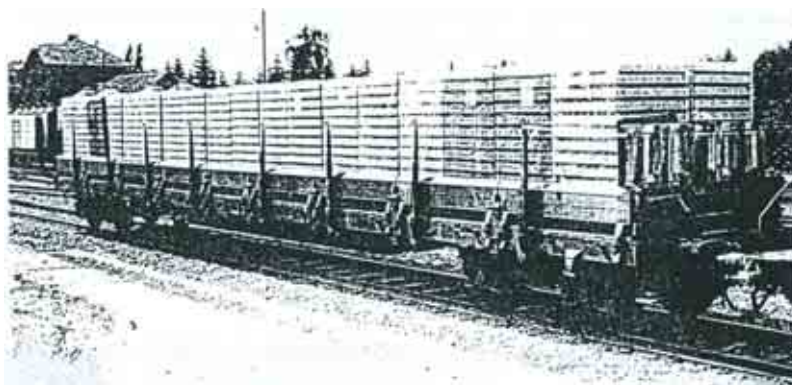


all sides of the pallet including the pallet feet. The foil must not be damaged or subjected too long storage that may reduce the quality.

- The pallets shall be loaded in a compact formation in a single layer, so that it is restricted from movement in all directions. Empty spaces in the lengthways direction are to be filled with empty pallets in an upright position.
- The pallets shall be put in such directions that they fill out the width of the wagon as much as possible.
- If there are no sides or sideboards on the wagon, lashings shall be drawn between the side stanchions to prevent the cargo from falling off the wagon, or the pallets shall be bound together with round-turn lashings to form larger units, blocked by stanchions.



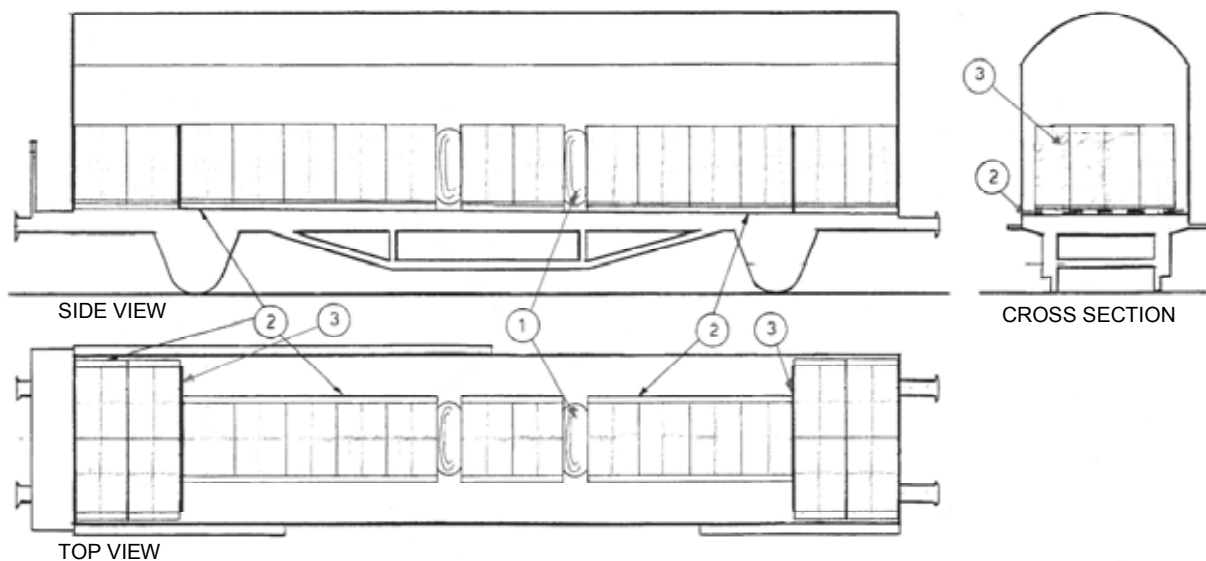
1. Pallet
2. Cardboard plate
3. Cardboard plate, protection
4. Bottle
5. Shrink or stretch foil



*Wagon loaded according to Loading guideline 11 / 80-002-99*

- **Akzo Nobel, Green Cargo**

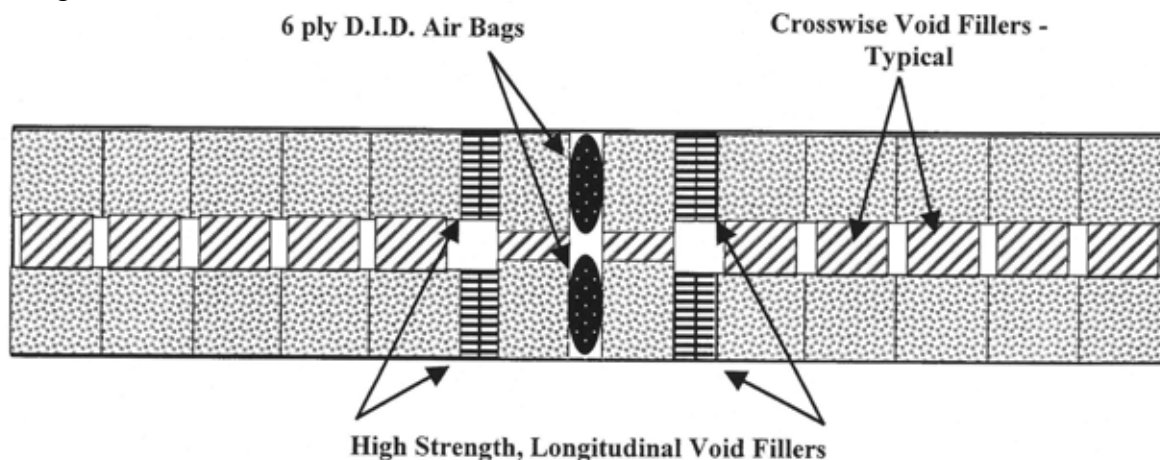
The instruction below is used by Eka Chemicals for pallets with bags weighing 1400 kg each, loaded in GBS-wagons subjected to hump and fly shunting.



- ① Air cushion
  - ② Timbers (2×4”) fastened with one nail for each secured pallet, however not less than two nails per timber, with a minimum diameter of 5 mm and a minimum of 40 mm penetration through the floor.
  - ③ Load distributing plywood sheet with a minimum thickness of 15 mm
- No empty spaces in longitudinal direction are allowed.
  - The pallets are to be wrapt in 14 layers of stretch foil in the lower part and 10 layers in the upper part.

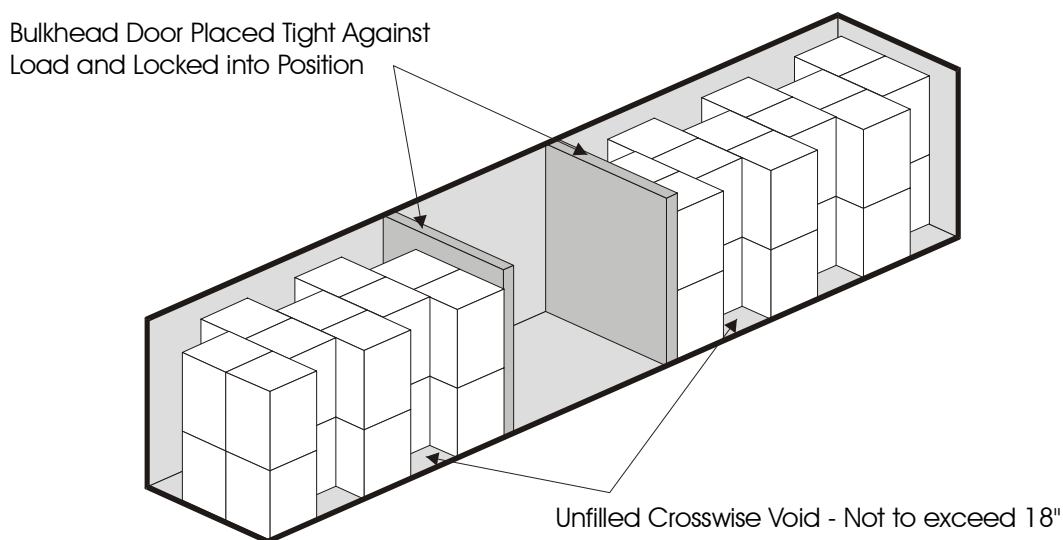
**11.3.2 AAR**

Securing palletised cargo in box cars (closed wagons) is generally done by blocking the cargo lengthways and sideways against the end- and sidewalls. A typical load pattern is shown in the figure below.



*Typical load pattern of wood bins with tomato paste – Top view*

In the figure below an example shows pallets stretch-foiled with three layers over the entire unit and four layers at the top and at the bottom of the unit. The pallet feet shall be included in the wrapping. All lengthwise voids shall be filled. Crosswise void fillers are only needed if the voids exceed 45 cm.



*Load pattern of stretch-foiled pallets*

## 11.4 Proposed instructions for the securing of palletised goods

### WAGONS

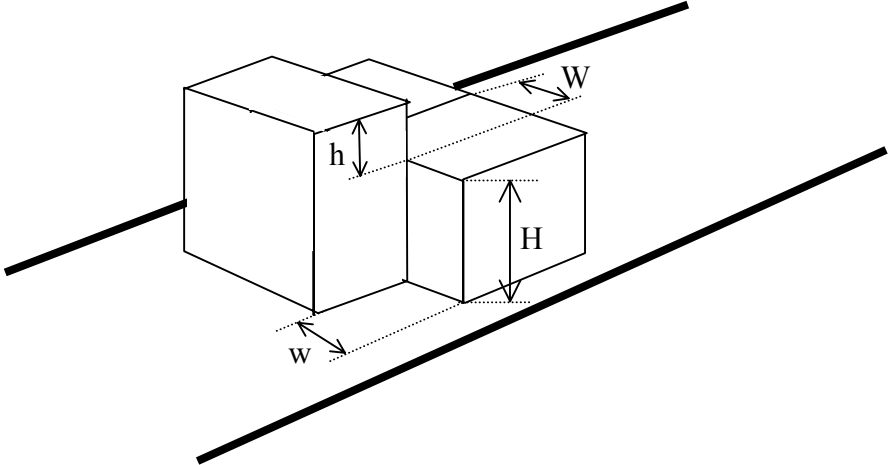
Wagons shall have floor of wood or plywood and strong walls. The floor shall be dry, clean and free from frost, ice and snow. Wagons should be equipped with partition walls.

### SECURING LENGTHWAYS

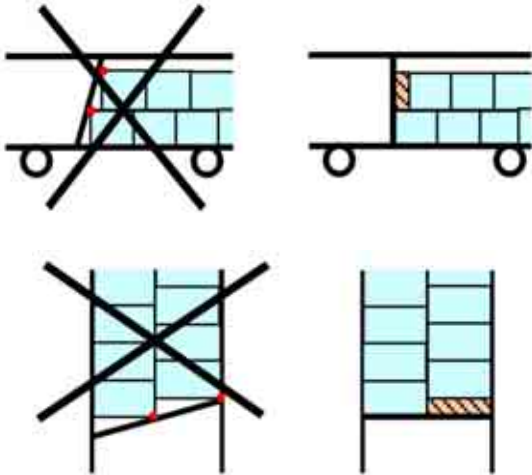
Pallets are to be secured against sliding and tipping lengthways according to the instructions below.

The pallets shall be loaded tight between wagon ends or partition walls without empty spaces in lengthwise direction. Partition walls, partition boards, empty pallets, boards or air bags should, if not block stowed, be used to fill the spaces and secure the pallets.

Each pallet shall have support to at least half its height ( $H \geq h$ ) and half its breadth ( $W \geq w$ ), see figure below. Empty pallets or plywood boards could be used to support the pallets.



When using partition walls they have to be at right angles to both floor and side walls not to damage the goods.



Side view

Top view



*Correct use of partition wall.*

## SECURING SIDWAYS

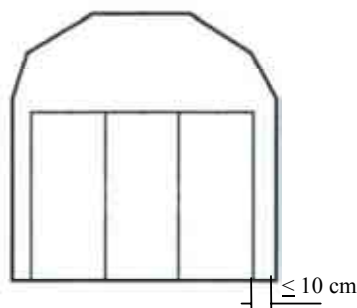
In general the pallets should be stowed in a full bottom layer, especially when there is a second layer. The risk of wandering is extra large when each pallet in the upper layer is light (weight less than ~400 kg).

Pallets are secured against sliding and tipping sideways according to the instructions below.

### A. Avoiding sliding of pallets in one layer or in a bottom layer

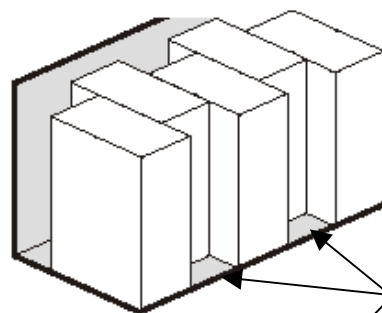
The pallets shall be loaded with a maximum distance to the side walls of 10 cm per side, see figure A1, or in a zig-zag pattern with a maximum distance of 45 cm at one side, see figure A2.

Figure A1



*Distance from pallets to vertical part of the side wall shall be maximum 10 cm when not secured by other means.*

Figure A2



*Unfilled crosswise void –  
Not to exceed 45 cm*

If the distances are exceeded the pallets have to be secured by one of the following techniques:

- filling the void.
- friction enhancing inserts under the pallets ( $\mu \geq 0.7$ ).
- nailed wooden guide-pieces at the sides, 1 nail/2000 kg minimum two per guide-piece.
- tag washers under the pallets.
- top-over lashings. One lashing per 4 ton of cargo for pallets with bottom boards of wood. For other types of pallets number of lashings according to table A3.

Table A3

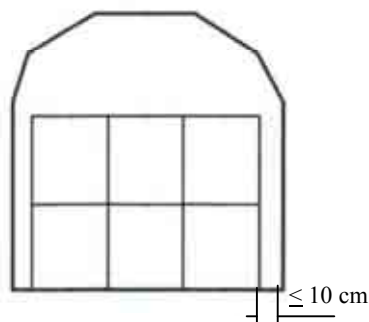
$\mu$ (static)	TOP-OVER LASHING Cargo weight in ton prevented from sliding / wandering*
0.2	0.5
0.3	1.2
0.4	3.2
0.5	4.0

\* The values are valid for a pretension in the lashings of 4000 N (400 kg).

**B. Avoiding sliding of pallets in a second (third or more) layer**

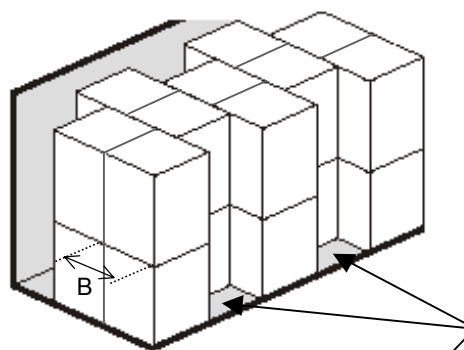
Pallets in the upper layer(s) loaded with the bottom boards <b>across</b> the platform	Pallets in the upper layer(s) loaded with the bottom boards <b>along</b> the platform
<p>The pallets shall be loaded with a maximum distance to the side walls of 10 cm per side, see figure B1, or in a zig-zag pattern with a maximum distance of 45 cm at one side or (if less) ¼ of the pallet’s breadth, see figure B2.</p> <p>If the distances are exceeded the pallets have to be secured by one of the following techniques:</p> <ul style="list-style-type: none"> <li>- filling the void.</li> <li>- friction enhancing inserts under the pallets (<math>\mu \geq 0.7</math>)</li> <li>- top-over lashings according to table B3</li> <li>- vertical round-turn lashings according to the table B3.</li> </ul>	<p>The pallets shall be loaded with a maximum distance to the side walls of 7.5 cm.</p> <p>If the distance is exceeded the pallets have to be secured by one of the following techniques:</p> <ul style="list-style-type: none"> <li>- filling the void.</li> <li>- top-over lashings according to table B3</li> <li>- vertical round-turn lashings according to table B3.</li> </ul>

Figure B1



*Distance from pallets to vertical part of the side wall shall be maximum 10 cm when not secured by other means.*

Figure B2



*Unfilled crosswise void – Not to exceed 45 cm or ¼ of the pallet’s breadth, B.*

Table B3

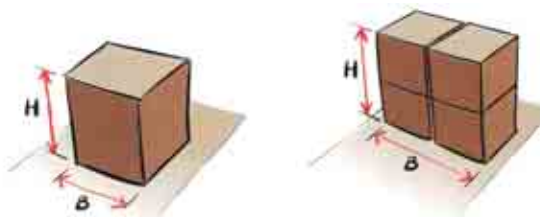
$\mu$ (static)	<b>TOP-OVER LASHING / VERTICAL ROUND TURN LASHING</b> <b>Cargo weight in ton prevented from sliding / wandering*</b>
0.2	0.5
0.3	1.2
0.4	3.2
0.5	4.0

\* The values are valid for a pretension in the lashings of 4000 N (400 kg).

### C. Avoiding tipping of pallets

Narrow, high pallets should not be placed in an outer row or higher layer due to the risk of tipping against the wagons' sides.

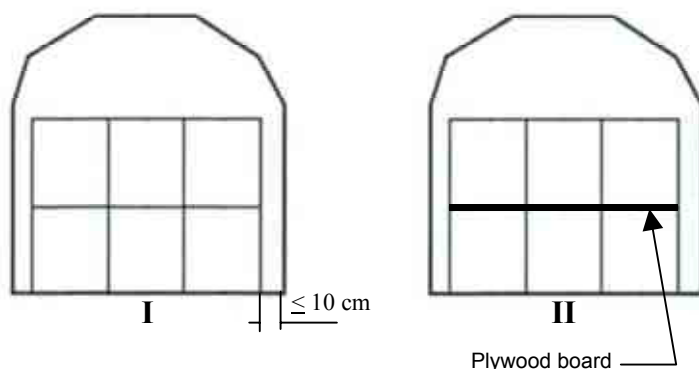
Pallets or a stack of pallets with the ratio  $\frac{H}{B}$ , as in the figure to the right, has to be secured against tipping according to table C2.



The pallets shall be loaded with a maximum distance to the side walls of 10 cm per side. If the height of the pallets is larger than the vertical part of the side wall the distance between the top pallet and the side must be minimum 10 cm, see example I in figure C1. If the distance is exceeded the pallets have to be secured by one of the following techniques:

- filling the void.
- top-over lashings according to table C2
- round-turn lashing according to table C2
- plywood boards between the layers, see example II in figure C1.

Figure C1



- I. Distance from pallets to vertical part of the side wall shall be maximum 10 cm when not secured by other means.
- II. Plywood board between the layers preventing tipping.

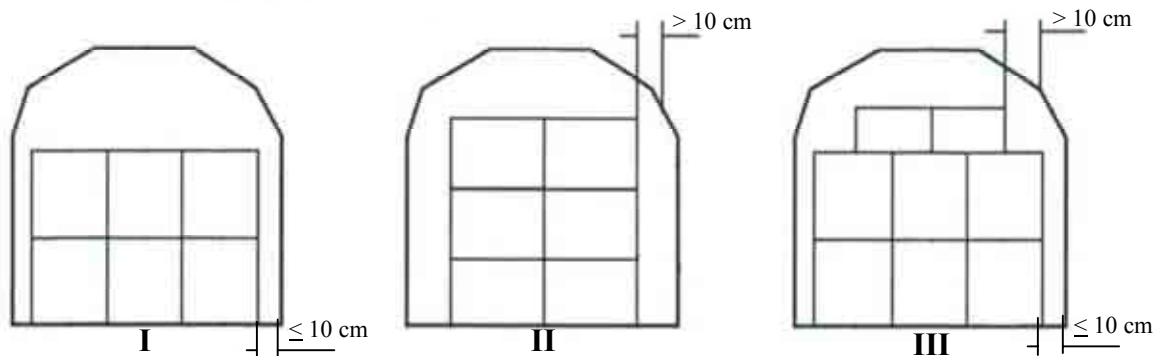
Table C2

TOP-OVER OR VERTICAL ROUND-TURN LASHING					
Cargo weight in ton prevented from tipping					
H/B	1 row	2 rows	3 rows	4 rows	5 rows
0.6	No tipping	No tipping	No tipping	6.8	3.1
0.8	No tipping	No tipping	5.9	2.2	1.5
1.0	No tipping	No tipping	2.3	1.3	1.0
1.2	No tipping	4.9	1.4	0.9	0.7
1.4	No tipping	2.4	1.0	0.7	0.6
1.6	No tipping	1.6	0.8	0.6	0.5
1.8	No tipping	1.2	0.6	0.5	0.4
2.0	No tipping	0.9	0.5	0.4	0.3
2.2	7.9	0.8	0.5	0.4	0.3
2.4	4.0	0.7	0.4	0.3	0.3
2.6	2.6	0.6	0.4	0.3	0.2
2.8	2.0	0.5	0.3	0.2	0.2
3.0	1.6	0.4	0.3	0.2	0.2

\* The values are valid for a pretension in the lashings of 4000 N (400 kg).

**GENERAL SECURING INSTRUCTIONS**

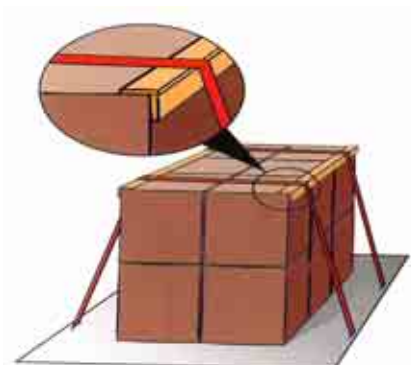
Note. If the height of the pallets is larger than the vertical part of the side wall the distance between the top of the pallet and the side must be minimum 10 cm and thus the pallets shall always be secured by other means, see figure below.



- I. *Distance from pallets to vertical part of the side wall shall be maximum 10 cm when not secured by other means.*
- II. *Distance to sloping part of the side wall shall be minimum 10 and thus the pallets shall always be secured by other means.*
- III. *Distance from pallets to vertical part of the side wall shall be maximum 10 cm when not secured by other means. Distance to sloping part of the side wall shall be minimum 10 and thus the pallets shall always be secured by other means.*

**SUPPORTING EDGE BEAMS**

The top-over lashings should be placed one per section, but in some cases less lashings are needed than the number of sections that are to be secured. Since each unit has to be secured, the effect of the lashings can in these cases be spread out with supporting edge beams. The edge beams can be manufactured profiles or be home made of deals (minimum 25×100 mm) nailed together. At least one lashing should be applied per each end section and per every second section.



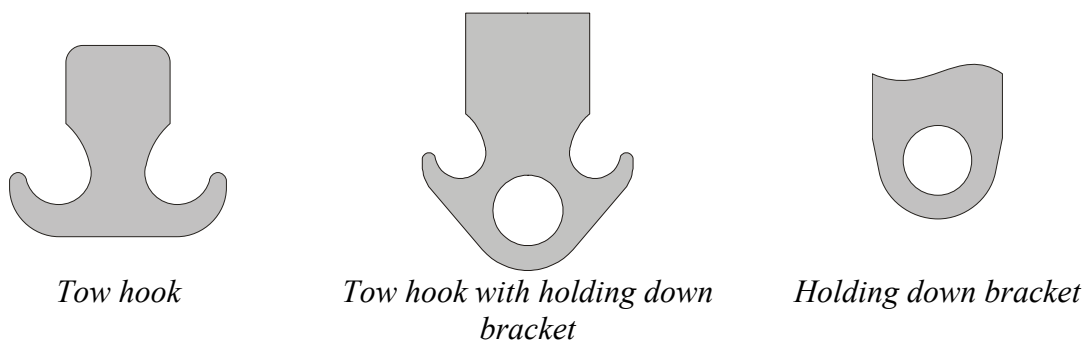


## 12 SECURING OF RAILWAY WAGONS IN FERRY TRAFFIC

It has been studied under which conditions wagons may be transported in train ferries without running the risk of tipping. The existing equipment on wagons that allows fastening of securing arrangements is reviewed and the properties of six different types of wagons are studied. The strength of this equipment, required to withstand the stresses induced by operation in certain conditions on the Baltic Sea, is also determined. These conditions include the worst probabilistic case during a twenty-year period as well as the worst condition that can be expected during normal operations. Characteristics from seven train ferries that operate in the Baltic Sea provided the accelerations used to establish these stresses. These accelerations were also used to determine the maximum allowable wave height in which each ferry may operate, when carrying wagons secured by existing fittings.

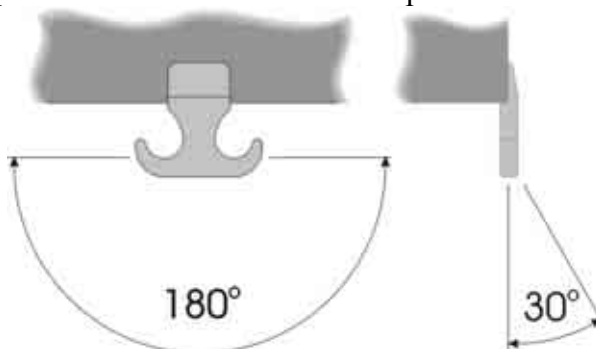
### 12.1 Securing arrangements on existing wagons

There are three different types of hooks / brackets that are found on existing wagons that permits fastening of cargo securing equipment. Older wagons are equipped with *tow hooks*, while newer models are fitted with *tow hooks combined with holding-down brackets* for securing purposes on train ferries. Swedish regulations state that when wagons are to be fitted with 8 brackets, four out of these may be *pure holding-down brackets*.

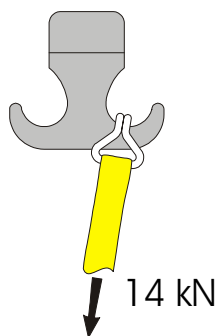


#### 12.1.1 Tow hook

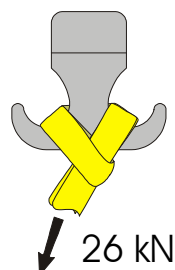
The fitting of the tow hook to the wagon shall be able to withstand a force of 50 kN pulling in a direction within the spherical sector illustrated in the picture below.



The actual strength of the tow hook itself is however less. The older regulations stated that the tow hook was to be made of steel SS 1312 which is equivalent to the FE 360 in the new Swedish standard. Having a yield strength of 225 N/mm<sup>2</sup>, a hook of this steel standard allows for a maximum securing load (MSL) of 14 kN or 26 kN respectively, depending on which out of the two options depicted in the figure below, that is chosen for fastening of the lashings.



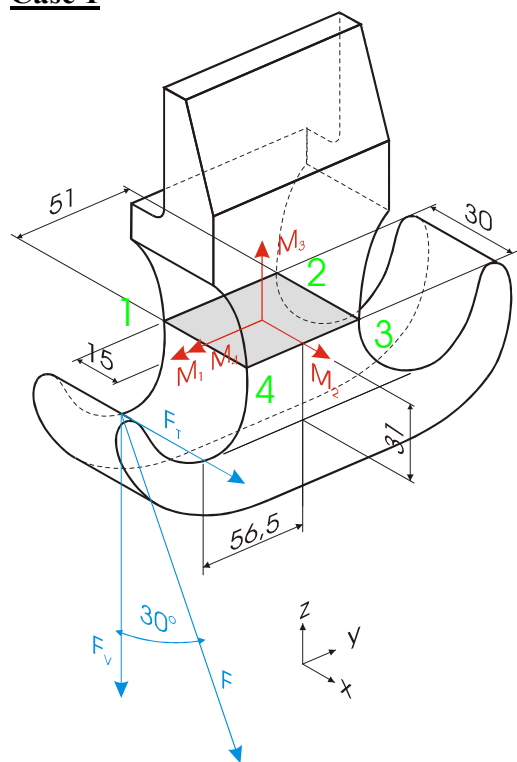
Case 1: Direct fastening to a single hook



Case 2: Fastening with a loop around the neck of the hook.

The calculation of the maximum securing load mentioned above, are carried out for the two cases below. In both cases, the tension  $\sigma_1$  represents the highest stress that occurs in any point of the tow hook, i.e. in point 1. Due to symmetry, in case 2 the stress in point 2 equals that in point 1.

**Case 1**



Section area :

$$A = 30 \times 51 = 1530 \text{ mm}^2$$

Moment of inertia :

$$I_y = \frac{51 \times 30^3}{12} = 114750 \text{ mm}^4$$

$$I_x = \frac{51^3 \times 30}{12} = 331628 \text{ mm}^4$$

$$x_{\max} = 15 \text{ mm}, \quad y_{\max} = 25.5 \text{ mm}$$

$$\sigma_y = 225 \text{ N/mm}^2, \quad \eta_s = 2$$

$$F_v = F \times \cos(30^\circ) = 0.87 F$$

$$F_T = F \times \sin(30^\circ) = 0.50 F$$

$$M_1 = 15 \times F_v = 12.99 F$$

$$M_2 = 56.5 \times F_v = 48.93 F$$

$$M_4 = 31 \times F_T = 15.50 F$$

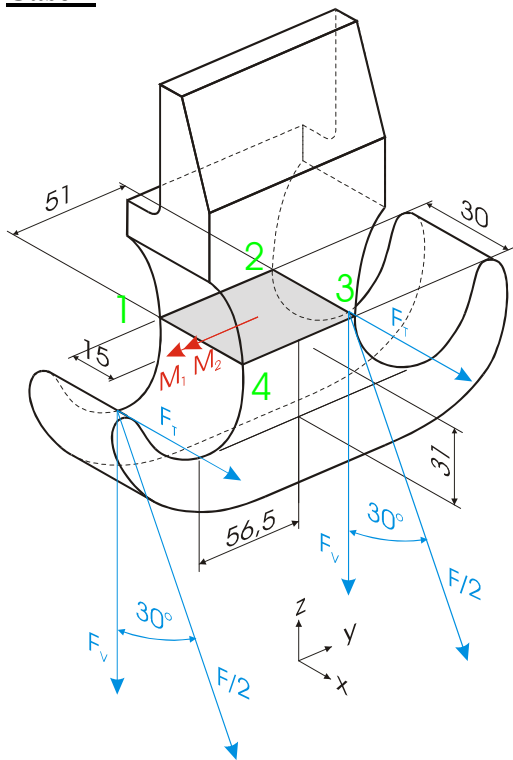
Maximum tension:

$$\sigma_{\max} = \sigma_1 = \frac{F_V}{A} + \frac{M_1 x_{\max}}{I_y} + \frac{M_2 y_{\max}}{I_x} + \frac{M_4 x_{\max}}{I_y} = 8,0527 \times 10^{-3} F$$

Maximum securing load:

$$F \leq \frac{\sigma_y}{\sigma_{\max} \times \eta_s} = 13.97 \text{ kN}$$

**Case 2**



Section area :

$$A = 30 \times 51 = 1530 \text{ mm}^2$$

Moment of inertia :

$$I_y = \frac{51 \times 30^3}{12} = 114750 \text{ mm}^4$$

$$I_x = \frac{51^3 \times 30}{12} = 331628 \text{ mm}^4$$

$$x_{\max} = 15 \text{ mm}, \quad y_{\max} = 25.5 \text{ mm}$$

$$\sigma_y = 225 \text{ N/mm}^2, \quad \eta_s = 2$$

$$F_V = \frac{F}{2} \cos(30^\circ) = 0.87 F$$

$$F_T = \frac{F}{2} \sin(30^\circ) = 0.50 F$$

$$M_1 = 15 \times 2 F_V = 12.99 F$$

$$M_2 = 31 \times 2 F_T = 48.93 F$$

Maximum tension:

$$\sigma_{\max} = \sigma_1 = \frac{2 F_V}{A} + \frac{M_1 x_{\max}}{I_y} + \frac{M_2 y_{\max}}{I_x} = 4.29 \times 10^{-3} F$$

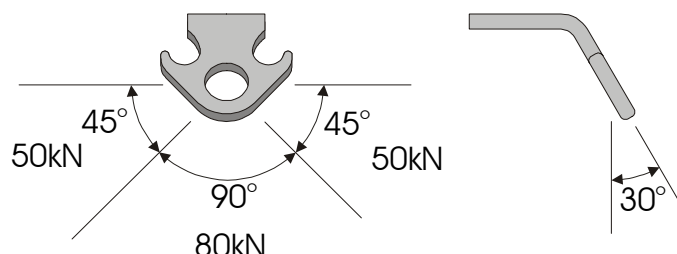
Maximum securing load:

$$F \leq \frac{\sigma_y}{\sigma_{\max} \times \eta_s} = 26.22 \text{ kN}$$

**12.1.2 Strength of holding-down bracket**

The current regulations states that holding down brackets shall be dimensioned to allow for the following maximum securing load:

- 50 kN in the spherical sector from 0° horizontal to 45° downwards in the longitudinal direction and from 0° vertical to 30° outwards in the transversal direction.
- 80 kN in the spherical sector from 45° downwards in one of the wagons longitudinal directions to 45° in the other and from 0° vertical to 30° outwards in the transversal direction



These two criteria apply for all types of holding down brackets, whether it's combined with a tow hook or it's a pure holding down bracket design.

### 12.1.3 Safety factor for calculated strength

IMO's *Code of Safe Practice for Cargo Stowage and Securing* states that when using balance calculation methods for assessing the strength of the securing devices, a safety factor is to be used to take account of the possibility of uneven distribution of forces or reduced capability due to the improper assembly of the devices or other reasons. This safety factor is used to derive the *calculated strength* (CS) from the *maximum securing load* (MSL):

$$CS = \frac{MSL}{\text{safety factor}}$$

In the calculation in this report forces has only been determined for two lashings concurrently and therefore uneven distribution between them has not been considered. The lashing angles used in the calculations are the greatest allowable ones and the centres of gravity are worst-case estimations. Thus the safety factor has been omitted from the calculations of required strength of the lashings and tow hooks as well as the determination of permissible significant wave heights.

## 12.2 Wagon designs

Six types of wagons have been chosen for examination in this report (*See pictures at the end of this section*). Their weight and vertical as well as transverse centre of gravity in maximal load condition is summarized in the table below.

The vertical centre of gravity for an empty wagon has been estimated to 0.8 m above the rail for wagon models with two axles and to 1.0 m for those with four axles. The highest allowed centre of gravity of the cargo has been set to 2.8 m above the rail. The *Shmms* model is special

carrier for coiled sheets loaded “eye to side” with a maximal coil diameter of 2.1 m. Their vertical centre of gravity has been calculated to 2.32 m above the rail.

From *RIV Appendix II section 3.3* it can be derived that the maximum allowed distance from the transverse centre of gravity to the centreline of the wagon is approximately 0.10 m. Due to compression of the springs the cargos vertical centre of gravity is dislocated approximately another 0.10 m.

<b>Wagon model</b>						
	<i>Hbis 763</i>	<i>Lgjs 741</i>	<i>Rs 691</i>	<i>Shmms 892</i>	<i>Kbis 941</i>	<i>Smmnps 951</i>
<i>Weight [in tons]</i>						
Wagon	15.0	11.8	22.5	20.0	14.0	20.3
Max cargo	30.0	28.0	57.5	60.0	26.0	69.7
<b>Total weight</b>	<b>45.0</b>	<b>39.8</b>	<b>80.0</b>	<b>80.0</b>	<b>40.0</b>	<b>90.0</b>
<i>Vertical Centre of Gravity [meters above rail]</i>						
COG wagon	1.00	1.00	0.80	0.80	1.00	0.80
COG cargo	2.80	2.80	2.80	2.32	2.80	1.80
<b>Combined COG</b>	<b>2.20</b>	<b>2.27</b>	<b>2.24</b>	<b>1.94</b>	<b>2.17</b>	<b>1.57</b>
<i>Transverse Centre of Gravity [meters from centerline]</i>						
COG wagon	0.00	0.00	0.00	0.00	0.00	0.00
COG cargo	0.20	0.20	0.20	0.20	0.20	0.20
<b>Combined COG</b>	<b>0.13</b>	<b>0.14</b>	<b>0.14</b>	<b>0.15</b>	<b>0.13</b>	<b>0.15</b>
<i>Towing arrangement [number of units per side]</i>						
Tow hook	2	2	2	2	2	2
Tow hook / Bracket					2	2
Bracket						

To perform calculations regarding lashing forces and transverse accelerations it is necessary to know the position of the hooks and brackets. Their approximate distance to the centreline of the wagon and height above the rail is given in the following table:

<b>Wagon model</b>						
	<i>Hbis 763</i>	<i>Lgjs 741</i>	<i>Rs 691</i>	<i>Shmms 892</i>	<i>Kbis 941</i>	<i>Smmnps 951</i>
<i>Hook / Bracket position</i>						
Dist. to centerline [m]	1.39	1.37	1.39	1.35	1.67	1.45
Height above rail [m]	0.71	0.79	0.71	0.85	0.65	0.79



*Hbis*



*Kbis*



*Shmms*



*Rs*



*Lgjs*

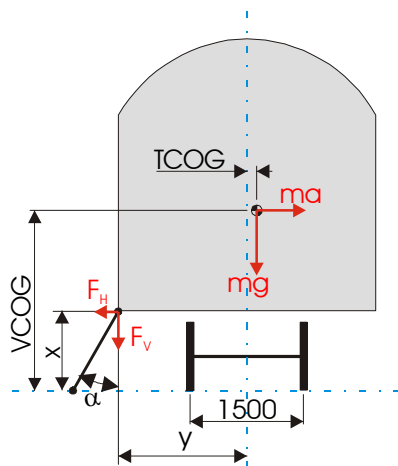


*Smmnps*

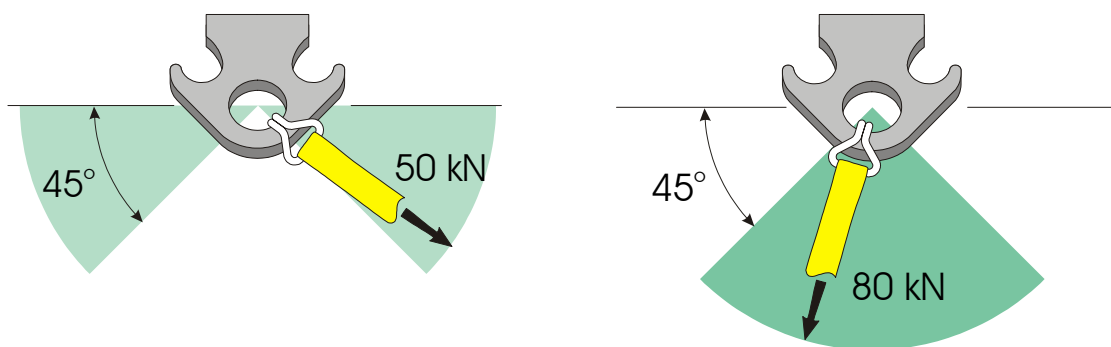
### 12.3 Allowable accelerations for wagons

Utilizing the centres of gravity and weights for each wagon model that was calculated in the previous section in combination with the allowable lashing forces for the different types of towing arrangements and their geometry, it is now possible to derive a maximum allowable transversal acceleration for each wagon model at maximum load condition to avoid tipping.

The greater vertical angle the lashing equipment is applied at, the lesser is its contribution to prevent tipping. As stated in section 12.1.1 and 12.1.2 the vertical lashing angle,  $\alpha$ , may vary between 0 and 30 degrees, and therefore  $\alpha$  is set to 30°.



The longitudinal lashing angle is set to 30°. Thus the allowable lashing force is set to 50 kN for the holding down brackets. In order to achieve a greater lashing capacity which is possible if the longitudinal lashing angle is larger than 45°, the distance between the lashing points in the vessel would have to be less than 1.5 meters.



*The sectors bounding longitudinal lashing angle is set to 45°.*

<b>Wagon type:</b>						
	<b>Hbis 763</b>	<b>Lgjs 741</b>	<b>Rs 691</b>	<b>Shmms 892</b>	<b>Kbis 941</b>	<b>Smmnps 951</b>

VCOG [m]	2.20	2.27	2.24	1.94	2.17	1.57
TCOG [m]	0.13	0.14	0.14	0.15	0.13	0.15
Weigth [ton]	45	39.8	80	80	40	90

*Lashing arrangement*

Tow hooks per side	2	2	2	2	0	0
Brackets per side	0	0	0	0	2	2

*Allowable pulling force on hooks and brackets (total for two hooks)*

Direct lashing	28	28	28	28	100	100
Loop around the neck	52	52	52	52	-	-

*Lashing forces in the transverse plane (total for two hooks)*

Direct lashing						
Fr [kN]	7.0	7.0	7.0	7.0	25.0	25.0
Fv [kN]	12.1	12.1	12.1	12.1	43.3	43.3
Loop around the neck						
Fr [kN]	13.0	13.0	13.0	13.0	-	-
Fv [kN]	22.5	22.5	22.5	22.5	-	-

*Tow hook/ Bracket position*

y [m]	1.39	1.37	1.39	1.35	1.67	1.45
x [m]	0.71	0.79	0.71	0.85	0.65	0.79

*Allowable transversal acceleration [m/s<sup>2</sup>]*

Direct lashing	<b>3.06</b>	<b>2.98</b>	<b>2.83</b>	<b>3.24</b>	<b>4.20</b>	<b>4.52</b>
Loop around the hook	<b>3.33</b>	<b>3.28</b>	<b>2.98</b>	<b>3.41</b>	-	-

## 12.4 Accelerations on ships

In order to calculate some typical accelerations that may act upon a railway wagon at sea, seven train ferries that operate in the Baltic Sea has been studied. Their main characteristics are given in the table below:

Ship	Length [m]	L <sub>pp</sub> [m]	Service Speed [knots]	Breadth [m]	Appr. GM [m]
Ship 1	154,4	142,0	17,5	22,1	2,5
Ship 2	188,8	175,6	17,5	23,7	2,5
Ship 3	158,4	147,3	18,5	22,0	2,5
Ship 4	170,2	158,5	20,0	23,8	2,5
Ship 5	199,0	185,1	22,0	29,6	5,0
Ship 6	186,0	173,0	23,0	25,7	2,5
Ship 7	142,0	132,1	16,5	19,0	2,5



The metacentric height,  $GM$ , varies with the load condition. Thus it has been approximated for each ship.

As can be seen in the figure on the right side, the 2003 edition of IMO “Code of Safe Practice for Cargo Stowage and Securing” states that the highest acceleration that shall be used for transverse tipping for cargo on ‘tween deck is  $6.2 \text{ m/s}^2$  and occurs in the forward end of the ship.

Table 2 – Basic acceleration data

	Transverse acceleration $a_t$ in $\text{m/s}^2$	Longitudinal acceleration $a_l$ in $\text{m/s}^2$
on deck, high	7.1 6.9 6.8 6.7 6.7 6.8 6.9 7.1 7.4	1.8
on deck, low	6.5 6.3 6.1 6.1 6.1 6.1 6.3 6.5 6.7	2.9
‘tween-deck	5.9 5.6 5.5 5.4 5.4 5.5 5.6 5.9 6.2	2.0
lower hold	5.3 5.1 5.1 5.0 5.0 5.1 5.3 5.5 5.9	1.5
	0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1	
	Vertical acceleration $a_v$ in $\text{m/s}^2$	
	7.6 6.2 5.0 4.1 4.2 5.0 6.2 7.6 9.7	

This acceleration is to be multiplied with correction factors for length and speed ( $f_{LV}$ ) and breadth versus metacentric height ( $f_{B/GM}$ ) for each individual ship. The formula below gives the first of this correction factors as a function of  $V$  (speed in knots) and  $L_{PP}$  (length between perpendiculars in meters):

$$f_{LV} = \left( \frac{0.345 \times V}{\sqrt{L_{PP}}} \right) + \left( \frac{58.2 \times L_{PP} - 1034.5}{L_{PP}^2} \right)$$

The second correction factor,  $f_{B/GM}$ , is derived by interpolation from the following table:

B/GM	7	8	9	10	11	12	13 or above
on deck, high	1.56	1.40	1.27	1.19	1.11	1.05	1.00
on deck, low	1.42	1.30	1.21	1.14	1.09	1.04	1.00
‘tween-deck	1.26	1.19	1.14	1.09	1.06	1.03	1.00
lower hold	1.15	1.12	1.09	1.06	1.04	1.02	1.00

$B = \text{breadth}, GM = \text{Metacentric height}$

The maximum transverse acceleration which may be expected for each ship,  $a_{T, \text{corr}}$ , is derived by multiplying the universal acceleration given by IMO by the correction factors  $f_{LV}$  and  $f_{B/GM}$ , and are shown in the table below.

Ship Name	$f_{LV}$	$f_{B/GM}$	$a_{T, \text{corr}}$ [ $\text{m/s}^2$ ]
Ship 1	0,84	1,15	6,0
Ship 2	0,74	1,12	5,1
Ship 3	0,85	1,15	6,1
Ship 4	0,86	1,11	5,9
Ship 5	0,83	1,36	7,0
Ship 6	0,89	1,08	6,0
Ship 7	0,86	1,22	6,5

### 12.5 Allowable significant wave height for train ferries

For operations in a restricted area, reduction of the accelerations calculated in the previous section may be considered. The RINA report *Safety of passenger Ro-Ro vessels* gives this correction factor as:

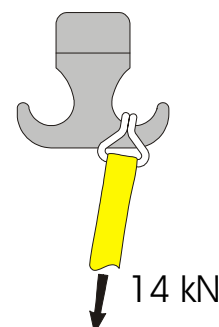
$$f_R = \sqrt[3]{\frac{H_S}{19.6}}$$

where  $H_S$  is the actual significant wave height in the specific sea area and 19.6 is the greatest probabilistic significant wave height in meters during a twenty year period for the North Atlantic.

#### Wagons with towing hooks

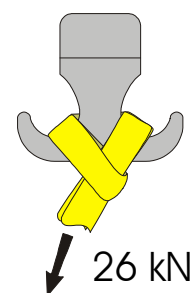
The lowest allowable acceleration was obtained for the *Rs 691* wagon. The acceleration is  $2.83 \text{ m/s}^2$  when the lashings are fastened as in Case 1 and lashings are applied to each of the two hooks. Comparing this acceleration by the transverse accelerations of the different ships and utilizing the formula above, a maximum significant wave height that each ship may operate in can be calculated, as seen in the table below.

Ship	$a_{T, \text{corr}}$	$f_R$	$H_S$
Ship 1	6,0	0,47	2,1
Ship 2	5,1	0,56	3,4
Ship 3	6,1	0,46	2,0
Ship 4	5,9	0,48	2,1
Ship 5	7,0	0,41	1,3
Ship 6	6,0	0,47	2,1
Ship 7	6,5	0,44	1,6



The acceleration is  $2.98 \text{ m/s}^2$  when the lashing equipment is applied as in Case 2. The maximum significant wave height that each ship may operate in with this configuration is presented in the table below.

Ship	$a_{T, \text{corr}}$	$f_R$	$H_S$
Ship 1	6,0	0,50	2,4
Ship 2	5,1	0,58	3,9
Ship 3	6,1	0,49	2,3
Ship 4	5,9	0,50	2,5
Ship 5	7,0	0,43	1,5
Ship 6	6,0	0,50	2,5
Ship 7	6,5	0,46	1,9



**Wagons with holding down brackets**

Two of the wagons that have been studied are equipped with holding down brackets. The *Kbis 941 wagon* permits for the lowest allowable acceleration of these two, i.e.  $4.20 \text{ m/s}^2$ . The following significant wave heights induces transverse accelerations of this magnitude for the seven ships:

Ship	$a_{T, \text{corr}}$	$f_R$	$H_S$
Ship 1	6,0	0,70	6,7
Ship 2	5,1	0,82	11,0
Ship 3	6,1	0,69	6,4
Ship 4	5,9	0,71	7,0
Ship 5	7,0	0,60	4,3
Ship 6	6,0	0,70	6,9
Ship 7	6,5	0,65	5,4



**12.6 Required strength of tow hooks and brackets for specific significant wave heights**

The greatest probabilistic significant wave height that may be expected in the Baltic Sea during a twenty year period is 8.5 meters. It is therefore of interest to investigate what strength that is required in the tow hooks and holding down brackets to withstand the forces they are subjected to due to transverse accelerations induced by waves of this amplitude.

A significant wave height of 4 meters represents an upper limit of the conditions that train ferries in the Baltic Sea normally operate in. Thus calculations of required strength is carried out for this case as well.

The table below gives the pulling force that each tow hook shall be design to withstand at 4.0 and 8.5 meters wave height respectively when transported on the different ships. The calculations are based on the geometry of the *Rs 691 wagon*, which is the one requiring the largest forces to be prevented from tipping. The *Rs wagon* is equipped with two tow hooks per side and the required lashing forces presented below is calculated for a configuration where lashings are applied to both hooks.

Ship	Transverse acceleration [ $\text{m/s}^2$ ]		Required lashing force [kN]	
	$H_S = 4 \text{ m}$	$H_S = 8,5 \text{ m}$	$H_S = 4 \text{ m}$	$H_S = 8,5 \text{ m}$
Ship 1	3,5	4,5	71,0	152,8
Ship 2	3,0	3,9	27,8	97,2
Ship 3	3,6	4,6	75,2	158,1
Ship 4	3,5	4,5	66,9	147,5
Ship 5	4,1	5,3	117,6	212,6
Ship 6	3,5	4,5	68,9	150,0
Ship 7	3,8	4,9	93,2	181,4

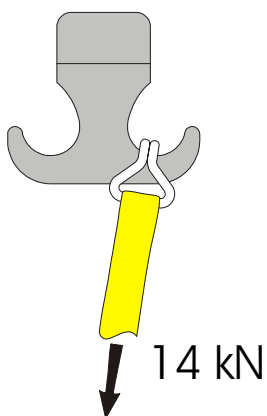
Onboard all ships, accelerations are found to produce lashing forces that exceeds the allowable forces for the two hooks. Even if the *Rs 691 wagons* were to be equipped with holding down brackets, only onboard *Ship 2* operation in a significant wave height up to 4 meters could be allowed.

### 12.7 Results and recommendations

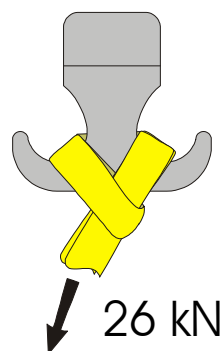
Providing the lashing force is pulling in a direction within a sector from 0 to 30 degrees outwards from the side of the wagon, the following lashing forces may be allowed:

#### Tow hook

When the securing device is applied directly to the hook as in Case 1:

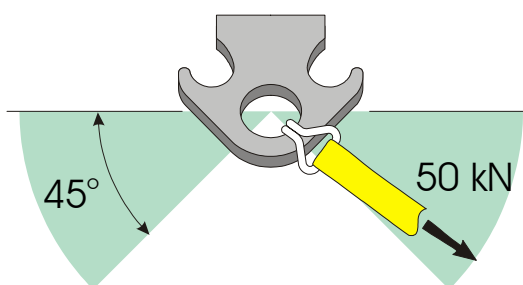


When the securing device is fastened with a loop around the hook as in Case 2:

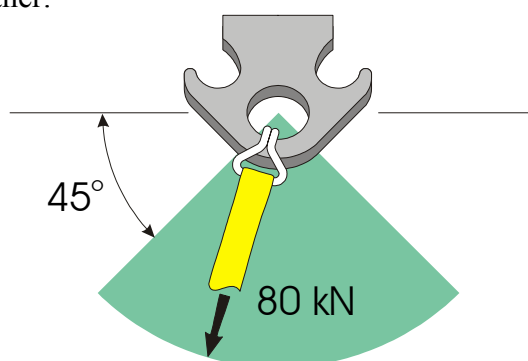


#### Holding down bracket

When pulling in a sector from 0° horizontal to 45° downwards in the longitudinal direction:



When pulling in a sector from 45° downwards in the longitudinal direction to 45° in the other:



*Valid for ships with fitting distances of maximum 1.5 meters.*

The wagon with the largest risk of tipping is the *RS 691 wagon*. It is fitted in accordance with the older regulations and is equipped with two tow hooks per side. The allowable lashing forces are exceeded when the wagon is subjected to a transverse acceleration above  $2.83 \text{ m/s}^2$  when it is secured as in Case 1 and  $2.98 \text{ m/s}^2$  when it is secured as in Case 2.

The maximum significant wave height that the Baltic Sea's train ferries normally operate in is 4.0 m (moderate bad weather). None of the seven ships can operate in such weather without running the risk of having wagons tipping over. For one ship only, replacing older tow hooks with holding down brackets without increasing the number of securing points on the wagons, this problem could be solved.

It is concluded that it must be more economic to put restrictions on the wave height in which the train ferries may operate than to equip all freight wagons with new stronger securing fittings for ferry transport in the Baltic Sea. Future wagons equipped with holding down brackets will allow for a revision of these restrictions, as older wagons are taken out of use.

If the wagons are equipped with holding down brackets and the ships are equipped with securing fittings maximum 1.5 meters apart in the longitudinal direction, each lashing could take up a force of 80 kN. Such an arrangement would allow most of the train ferries to operate in wave heights up to 4 meters.

# **MariTerm AB**

P.O. Box 74, SE-263 21 Höganäs  
Tel. +46 42-333100, Fax. +46 42-333102  
[info@mariterm.se](mailto:info@mariterm.se), [www.mariterm.se](http://www.mariterm.se)

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*English version of VI 2002:7*

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    - 1.1 VINNFORSK - VINNOVAs förslag till förbättrad kommersialisering och ökad avkastning i tillväxt på forskningsinvesteringar vid högskolor. BILAGOR. *For main text see VP 2003:1*
  - 2 Behovsmotiverad forskning och effektiva innovationssystem för hållbar tillväxt. VINNOVAs verksamhetsplanering 2003-2007. *Replaces VP 2002:1. For english version see VP 2002:4, for full swedish version see VP 2002:3*
  - 3 VINNOVAs forskningsstrategi. Strategi för hållbar tillväxt
  - 4 Nationell Innovations- och forskningsstrategi för området Miljödriven teknikutveckling. *Only as PDF*
- ## VINNOVA Policy VP 2002:
- 1 *See VP 2003:2*
  - 2 Nationellt inkubatorprogram
  - 3 Behovsmotiverad forskning och effektiva innovationssystem för hållbar tillväxt. En fördjupad version av VINNOVAs verksamhetsplanering 2003-2007. *For short swedish version see VP 2002:1, for short english version see VP 2002:4*
  - 4 Effective innovation systems and problem-oriented research for sustainable growth. VINNOVA's

strategic plan 2003 - 2007.  
*For swedish version see VP 2002: 1 and 3*

- 5 Nationell strategi för FoU inom området tillämpning av informationsteknik.

### **VINNOVA Report VR 2004:**

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- 2 Nya material och produkter från förnyelsebara råvaror. *Kortversion av VR 2004:1. Ersätter VR 2002:22*
- 3 Evaluation of the NUTEK-VINNOVA programme in Complex Technical Systems 1997-2001. Utvärdering av ett FoU-program i Komplexa Tekniska System 1997-2001
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- 2 Kina störst på mobiltelefoni - konsekvenser för omvärlden (*Telematik 2006*)
- 3 Framtidens fordon - mötet mellan två mobila världar (*Telematik 2006*)
- 4 Efter 11 september 2001: - Kan storebror hejdas? (*Telematik 2006*)
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### **VINNOVA Report VR 2002:**

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- 4 Funktionshinder resmöjligheter. Sammanfattning av senaste årens forskning. *CD with all related reports*
- 5 Organisationsövergångar och unika kulturer. Förändringsdynamik och utvecklingsstöd via Växtkraft Mål 4. *For short version see VR 2002:21*
- 6 Metanoldrivna bilar i Trollhättan - Göteborg. Förstudie. *Only as PDF*
- 7 Hållbart arbete i informationssamhället. Slutrapport från projektet "Callcenter i utveckling - långsiktigt hållbart arbete med kunder på distans"
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- 12 Den nya ekonomin - ett internetperspektiv (*Telematik 2004*). *Short version of VR 2002:11*
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## About/Om VINNOVA

VINNOVA's mission is to *promote sustainable growth* by developing *effective innovation systems* and funding *problem-oriented research*.

VINNOVAs uppgift är att *främja hållbar tillväxt* genom utveckling av *effektiva innovationssystem* och finansiering av *behovsmotiverad forskning*.

Genom sitt arbete ska VINNOVA tydligt bidra till att Sverige utvecklas till ett ledande tillväxtland.

Forskning och innovation för hållbar tillväxt.

I serien VINNOVA Rapport publiceras externt framtagna rapporter, delrapporter, kunskapssammanställningar, synteser, översikter och strategiskt viktiga arbeten från program och projekt som fått anslag av VINNOVA.



VINNOVA är en statlig myndighet  
med uppgift att främja hållbar tillväxt  
genom utveckling av effektiva innovationssystem  
och finansiering av behovsmotiverad forskning.

VERKET FÖR INNOVATIONSSYSTEM – SWEDISH AGENCY FOR INNOVATION SYSTEMS

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VINNOVA, SE-101 58 Stockholm Besök/Office: Mäster Samuelsgatan 56 Tel: +46 (0)8 473 3000 Fax: +46 (0)8 473 3005  
VINNOVA@VINNOVA.se [WWW.VINNOVA.SE](http://WWW.VINNOVA.SE)