tfk

Report 2004:6 E

MariTerm AB

Verification of level of basic parameters important for the dimensioning of cargo securing arrangements
(VERIFY)

ROLF NORDSTRÖM
PETER ANDERSSON
SVEN SÖKJER-PETERSEN

ISBN 91 88752 73 9

TFK – Transport Research Institute

Strandbergsgatan 12
SE-112 51 Stockholm
SWEDEN
Tel: +46 8 652 41 30
Fax: +46 8 652 54 98
E-post: info@tfk.se
Internet: www.tfk.se

MariTerm AB

Box 74
SE-263 21 Höganäs
SWEDEN
Tel +46 42 333100
Fax +46 42 333102
E-post: info@mariterm.se
Internet: www.mariterm.se

PREFACE

The principles in the new CEN- and VDI-standards makes cargo securing arrangements more extensive and costly compared to dimensioning according to the Nordic cargo securing regulations and the IMO/ILO/UN ECE Guidelines with IMO Model Course 3.18.

The principles in the CEN- and VDI-standards have been questioned by Nordic interests due to the following:

1. The Nordic regulations have been in force for many years and have in practice shown a satisfactory degree of safety.

2. Manufacturers and suppliers of cargo securing equipment have to a large extent, financed the work with the CEN-standard.

The ambitions of this project have been to find out which basic parameters that can be regarded as the most correct and thus should be used as a base for the dimensioning of cargo securing systems; the parameters according to the new standards or the parameters used in the Nordic and IMO/ILO/UN ECE regulations. The project has been financed through contributions and services from the following companies and organisations:

- Swedish Forest Industries Federation
- Finnish Forest Industries
- Norske Skog
- SCA Transforest AB
- Holmen Paper AB
- The Vocational Training and Working Environment Council (Transport Trades), TYA
- Dept. of Physics and Engineering Physics, Chalmers

Rolf Nordström, TFK – Transport Research Institute, in co-operation with Peter Andersson and Sven Sökjer-Petersen, MariTerm AB, has compiled the tests and the report.

TFK and MariTerm thanks all those who in different ways have supported the accomplishment of the study.

September 2004

Stockholm	Höganäs
TFK – Transport Research Institute	MariTerm AB
Leif Andersson	Peter Andersson
CEO	MD

INDEX

SUMMARY AND RECOMMENDATIONS

In this study, the deviations between the IMO/ILO/UN ECE Guidelines for Packing of Cargo Transport Units with the IMO Model Course 3.18 and the CEN- and VDI-standards regarding some basic parameters have been examined.

The IMO/ILO/UN ECE Guidelines uses the static friction factor (µs) while the CEN- and VDI-standards are using dynamic friction factors in combination with over top lashings. The dynamic friction factors are, according to the IMO/ILO/UN ECE Guidelines and the CEN-standard, to be taken as 70% of the static friction factors (0.7 × µs). The study shows that it is physically correct to use the static friction in combination with over top lashings.

The IMO/ILO/UN ECE Guidelines and the VDI-standard takes the full pretension force (STF) into account for both sides for over top lashings while the CEN-standard stipulates a 50% reduction on the opposing side of the tensioner. It has been shown that securing arrangements according to the principals in the IMO/ILO/UN ECE Guidelines provide adequate safety against tipping sideways independently of which side the tensioner is placed.

All sets of principles agrees on 0,5 g (5 m/s^2) as dimensioning lateral acceleration for sliding, but the CEN- and VDI-standards call for an increased acceleration value of 0,7 g (7 m/s^2) when dimensioning securing arrangements against tipping. It is evident from the study that the lateral acceleration of 0,5 g (5 m/s^2) which should be used according to the IMO/ILO/UN ECE Guidelines does include a satisfactory safety margin. Sliding and tilting motions are induced by the same accelerations and there have been found no valid ground for the inconsistency of using two different lateral dimensioning accelerations as in the CEN and VDI-standards.

Contrary to the IMO/ILO/UN ECE Guidelines, the CEN- and VDI-standards include no instructions on how to consider internal friction between vertical sides of piles in tipping equations. Cargo unites bound together with round turn lashings are considered as solid blocks, regardless of the cargo and what type of lashing equipment that is being used. The tests have shown that round turn lashings have a very limited effect on the tipping stability of piles and it is shown in the study that over top lashings prevent tipping much more effective than round turn lashings.

The VDI-Standard 2700 part 9 stipulates that only 75% of the diameter of a standing paper reel may be used as effective due to week edges of the reels. For laying reels 85% of the width of the reel may be regarded as effective. In the IMO/ILO/UN ECE Guidelines and the CEN-standard no such reduction of the effective width is stipulated besides that extra measures may be required for goods not rigid in form. The study shows that paper reels of customary quality can be recognized as rigid in form and no correction for weak edges is needed.

Based on the results of this study, it is strongly recommended to base dimensioning of cargo securing arrangements on the principles in the IMO/ILO/UN ECE Guidelines as these in all respects contains a satisfactory safety margin.

1 INTRODUCTION

1.1 Background

As consequence of the new European CEN-standard EN 12195-1 and the corresponding German VDI-standard 2700 for dimensioning of cargo securing arrangements and due to some principle divergences in the basic parameters the present Nordic cargo securing regulations are questioned. The Nordic principles have been practised since long and in general they correspond with the principles in the IMO/ILO/UN ECE ”Guidelines for packing of cargo transport units” and the IMO Model Course 3.18.

The following deviations in basic parameter values between the IMO/ILO/UN ECE Guidelines for Packing of Cargo Transport Units and the CEN- and VDI-standards can be found:

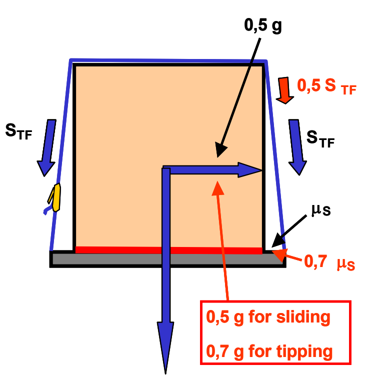
1. The IMO/ILO/UN ECE Guidelines uses the static friction factor (μs) while the CEN- and VDI-standards are using dynamic friction factors in combination with over top lashings. The dynamic friction factors are to be taken as 70% of the static friction factors (0.7 x μs).

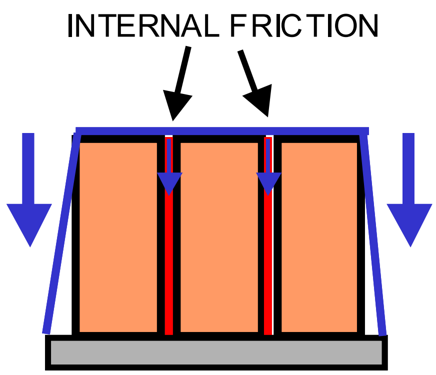
2. The IMO/ILO/UN ECE Guidelines and the VDI-standard take the full pretension force (STF) into account for both sides for over top lashings while the CEN-standard stipulates a 50% reduction on the opposing side of the tensioner, when tensioner are used on one side only.

3. All sets of principles agree on 0.5g as dimensioning sideways acceleration for sliding, but the CEN- and VDI-standards call for an increased acceleration value of 0.7g when dimensioning securing arrangements against tipping.

4. Contrary to the IMO/ILO/UN ECE Guidelines, the CEN- and VDI-standards include no instructions on how to consider internal friction between vertical sides of rows in tipping equations, but consider cargo unites bound together with round turn lashings as solid blocks, regardless of the weight and the dimensions of cargo and what type of lashing equipment that is being used

5. The VDI Standard 2700 part 9 stipulates that only 75% of the diameter of a standing paper reel may be used as effective due to week edges on the reels. For laying reels 85% of the width of the reel may be regarded as effective. In the IMO/ILO/UN ECE Guidelines and the CEN-standard no such reduction of the effective width is stipulated besides that extra measures may be required for goods not rigid in form.





The principles in the new CEN- and VDI-standards makes the cargo securing arrangements more extensive and costly compared to dimensioning according to the IMO/ILO/UN ECE Guidelines.

A power point presentation illustrating the divergences in the basic dimensioning parameters as well as the influence on required cargo securing arrangements and transportation costs can be downloaded from: www.mariterm.se - In English – Cargo Securing – Reports.

1.2 Objective

The objective of the VERIFY-project is to validate the basic parameters that should be used for the dimensioning of cargo securing arrangements, the ones practised in the IMO/ILO/UN ECE Guidelines or the ones suggested by the new CEN- and VDI-standards.

1.3 Accomplishment of the project

The following basic principals for cargo securing have been studied:

1. Tipping stability for paper reels depending on edge weakening
2. Evaluation of pretension force as a function of the friction of the corner protection
3. Evaluation of differences in cargo securing effects for corner protections with different friction
4. Evaluation of the differences in cargo securing effect for over top compared to round turn lashings
5. Static or dynamic friction in combination with over top lashing
6. Dimensioning acceleration sideways for unstable packages

2 TEST AT SCA IN SUNDSVALL AUGUST 18TH AND 19TH 2004

2.1 Tipping stability for paper reels depending on edge weakening

A number of different paper reels with different dimensions were tested in standing and laying position.

Execution

1. A report was studied on earlier performed tipping tests at SCA
2. The theoretical tipping angle for the paper reels was calculated by use of the height and width relation.
3. The efficient supporting paper reel diameters were calculated.
4. The paper reels were tilted and the actual tipping angle was measured.

Equipment

Paper reels
Tipping table
Square ruler
Overhead crane

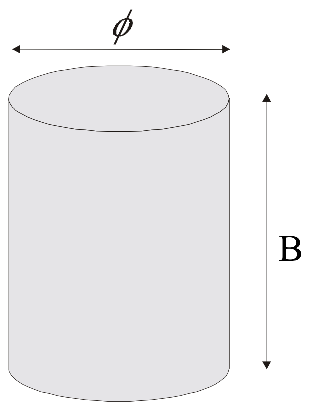
Standing reels

Paper quality	***Dimensions** [mm]*		***Theoretical tipping angle** [1] [°]*	***Valid tipping angle** [°]*	***Effective diameter** mm]*	***Correction factor***
	B	ϕ	α [1]	β	ϕ_e [2]	k_ϕ [3]
News-print	1700	1260	36.5	35.5	1212	0.962
”-	820	1155	54.6	54.0	1129	0.977
”-	1610	1090	34.1	34.0	1086	0.996
LWC	860	1000	49.3	49.3	1000	1.000

1 $\alpha = \arctan\left(\frac{\phi}{B}\right)$

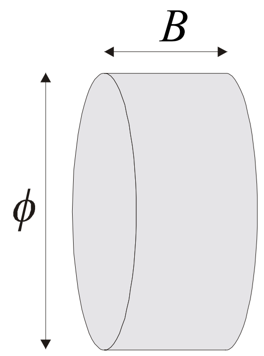
2 $\phi_e = B \cdot \tan\beta$

3 $k_\phi = \frac{\phi_e}{\phi}$



Laying reel

Paper quality	*Dimensions [mm]*		*Theoretical tipping angle* [1] *[°]*	*Valid tipping angle [°]*	*Effective diameter mm]*	*Correction factor*
	B	ϕ	α [1]	β	ϕ_e [2]	k_ϕ [3]
News-print	820	1155	35.4	34.1	782	0.954



1. $\alpha = \arctan\left(\frac{B}{\phi}\right)$

2. $B_e = \phi \cdot \tan\beta$

3. $k_B = \frac{B_e}{B}$

Comments:

As can be seen in photo 1-6 most of the paper reels was tested by tilting on a concrete floor. The tip angle was determined by balancing of the reel on the edge. This method gives a higher edge pressure than if the reel is tipped on an inclined platform as in photo 5. For paper reel dimensions with low height and good tipping stability there is a risk that sliding occurs before tipping. To avoid sliding before tipping on the tipping table in some cases a friction rubber was used as can be seen in photo 6. As the edge pressure compresses this sheet of rubber, the tipping point is slightly influenced.

Conclusions:

The tests of paper reel stability showed that reels of Newsprint, Fine Paper, LWC, Craft Liner etc may be considered as rigid in form as regards to cargo securing.

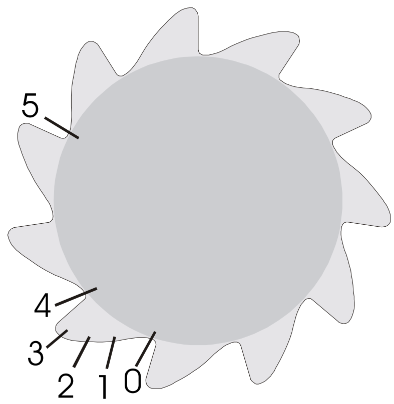
According to VDI 2700 part 9 75% only of the diameter may be considered valid width for stability for standing reels and 85% only of the breadth of for laying reels. This reduction is obviously exaggerated and unnecessary for customary paper qualities.

2.2 Evaluation of pretension force as function of the friction of the corner protection

EXECUTION

1. The pretension force on both sides of a over top lashing was measured when different types of corner protectors were used.

2. The force was determined at pretension to different points on the gears of the gearwheel on the lashing ratchet, see figure below.



EQUIPMENT

Paper reels	*4 pieces*
Tipping table	
Corner protector	*different types*
Web lashing	*1 piece, LC 1600 daN, STF 400 daN*
Dynamometer	*2 pieces*
Shackle	*4 pieces*

Pull down test

Corner protector	Point on the gears of the gearwheel, see figure above	***Force on the tensioning side*** *[kg]*	***Residual force on the other side*** *[kg]*
Plastic	0	460	320
	1	440	340
	2	425	340
	3	380	360
	4	590	380
Wood	0	485	282
	1	470	280
	2	450	280
	3	425	282
	4	575	320
Plastic + talc	0	490	338
	1	460	340
	2	430	342
	3	375	362
	4	580	382
	5	Max 745	Max 522
Plastic + rubber	0	405	130
	1	390	135
	2	385	135
	3	375	140
	4	540	152

The tests are documented in photos 7-11.

Comments:

The pulling force on the ratchet side was intentionally limited to 400 – 500 kg in position 0 though it was possible to straighten the lashing much more.

As is shown in the tests with corner protector of plastic + talc and tightened to position 5 it was possible to reach a pretension of 745 kg on the tensioner side and 522 kg on the opposing side with a web lashing marked STF 400 daN, see photo 44. The pretension was easily achieved without big effort or extension device.

It was determined most likely that ratchet tensioner will be pulled at least to position 4 and often to position 5. This will give a safety margin on the pre tension on both sides of the lashings in relation to the marked STF value.

When using plastic corner protectors the tension force became almost the same on both sides when the ratchet was tightened to position 3.

To study the effect of high friction between the web lashing and the corner protection, rubber was placed in between. Such extreme friction is very rare and was used to study the effect of different frictions only.

During the tests it was noted that the pretension in a web lashing drops rapidly immediately after it is tightened. The drop in pretension stops after some minutes.

Conclusions

The tests clearly show that there is a difference in pretension on the two sides when tensioner is used on one side only.

The tests did, however, also show that it is very easy to get pretensions far above the marked STF also on the opposing side.

To get a remaining pretension on a high level it is very important to train persons performing cargo securing to retighten lashings some minutes after the initial tightening and then every now and then during the transport. If this were performed a great increase of safety would be achieved.

2.3 Evaluation of differences in cargo securing efficiency for corner protections with different friction

Paper reels were secured by over top lashings and corner protection forces with different friction. The effects on the securing arrangement were tested by the following steps:

EXECUTION

Sliding and tipping tests were performed with paper reels secured by over top lashings. Corner protectors with low and high friction were used.

1. The over top lashings were tightened by hand and the pretension was read on the dynamometer indicators.

2. The pretension on the tensioner side was adjusted so that almost the same value was achieved in all tests.

3. The tipping table was inclined so that tipping and sliding occurred respectively and the heeling angle was measured.

4. During tipping a pile with a height of 2705 mm was used containing 3 paper reels weighing 485, 473 and 465 kg seen from below. The reel diameter was 1000 mm. During the sliding tests the two lower reels were used only.

5. The distance between lashing points on the tipping table was about 2.3 m.

During the sliding tests a slippery sheet was placed on the tipping table and the surface was prepared with talc to achieve as low friction as ever possible, see photo 12. This was made intentionally in order to get a noticeable sliding distance for the reels.

EQUIPMENT

Paper reels	2 respectively 3 pieces
Tipping table	
Overhead crane	For lifting
Truck	For holding
Folding rule	
Square ruler	
Web lashing	1 piece, LC 1600 daN, STF 400 daN
Dynamometer	2 pieces
Shackle	5 pieces
Turnbuckle	1 piece
Corner protectors	Different types

Sliding test (tensioner on the high side)
(Tensioning was made to a pre determined value and was adjusted finely by use of a turn-buckle)

Corner protector	***Paper quality***	**Dimension** [mm]		***Pile weight** [kg]*	***Angle** [°]*	***Sliding** [mm]*	**Force in the lashing** [kg]	
		Pile height	*Ø*				*High side*	*Low side*
Plastic	Newsprint	1800	1000	958	0	0	500	380
			Sliding start		34	54	550	375
					40	194	670	450
					45	244	740	470
Rubber	Newsprint	1800	1000	958	0	0	500	225
			Sliding start		36	122	580	200
					40	155	635	235
					45	224	760	290

Sliding test (tensioner on the low side)
(Tensioning was made to a pre determined value and was adjusted finely by use of a turn-buckle)

Corner protector	***Paper quality***	**Dimension** [mm]		***Pile weight [kg]***	***Angle [°]***	***Sliding [mm]***	**Force in the lashing** [kg]	
		Pile height	*Ø*				*High side*	*Low side*
Plastic	Newsprint	1800	1000	958	0	0	370	500
			Sliding start		34	135	555	355
					40	235	680	450
					45	275	730	490
Rubber	Newsprint	1800	1000	958	0	0	190	500
			Sliding start		22	23	300	320
					30	108	480	220
					35	176	600	220
					40	221	685	242
					45	263	780	280

The sliding tests are documented in photos 12-14.

At 45 degrees angle the tipping table fall over and the test had to be terminated at that angle.

Comments:

Sliding started a little earlier when corner protectors with high friction was used than when corner protectors with low friction was used. During extreme angles the movement was, however, almost the same regardless of type of corner protector.

The effect was the same regardless of which side the tensioner was placed.

During extreme angles the movement was of the same magnitude independently of type of corner protector and on which side the tensioner was placed.

Conclusions:

The friction between corner protector and the lashing as well as on which side of the package the tensioner is placed influence on the start of sliding but have no significant influence on the total sliding during extreme conditions.

Tipping test (tensioner on the high side)
(Tensioning was made to a pre determined value and was adjusted finely by use of a turn-buckle)

Corner protector	*Paper quality*	**Dimension** [mm]		*Pile weight [kg]*	*Angle [°]*	*Gap on high side [mm]*	**Force in the lashing** [kg]	
		Pile height	*Ø*				*High side*	*Low side*
Plastic	Newsprint	2705	1000	1423	0	0	510	345
			Tipping start		34	10	522	345
					40	32	700	420
Rubber	Newsprint	2705	1000	1423	0	0	480	185
			Tipping start		36	10	495	175
					40	20	560	220
					0	0	220	340

Tipping test (tensioner on the low side)
(Tensioning was made to a pre determined value and was adjusted finely by use of a turn-buckle)

Corner protector	*Paper quality*	**Dimension** [mm]		*Pile weight [kg]*	*Angle [°]*	*Gap on high side [mm]*	**Force in the lashing** [kg]	
		Pile height	*Ø*				*High side*	*Low side*
Plastic	Newsprint	2705	1000	1423	0	0	375	520
			Tipping start		30	10	495	365
					35	15	530	370
					40	30	630	425
					0	0	335	400
Rubber	Newsprint	2705	1000	1423	0	0	190	490
			Tipping start		26,5	10	320	320
					35	20	475	280
					40	30	565	270
					0	0	160	370

The tipping tests are documented in photos 15-22. During the tests the paper reel pile was prevented from sliding by use of a wood frame, see photos 17, 18, 20 and 22. The measured gap is the distance between the bottom of the pile on the high side and the platform.

At 40 degrees angle the tipping table fall over and the test had to be terminated at that angle.

Comments:

Tipping started a little earlier when the tensioner was placed on the low side than on the high side. On the other hand the gap during extreme angles was almost the same independently of tensioner side.

With the tensioner on the high side a gap occurred a little earlier with low friction corner protectors compared to high friction corner protector. This is natural considering that the pretension force is the same on the high side but lower on the low side when corner protectors of high friction are used.

Tipping occurred earliest with the tensioner on the low side when corner protectors of high friction were used. Also this was expected.

The gap during extreme angles was of the same magnitude independently of type of corner protector and which side the tensioner was placed on.

There was never a risk that the pile should turn around inside the lashing during the tests.

Conclusions:

The friction between corner protector and lashing and on which side the tensioner is placed have no significant influence on the tipping risk during extreme conditions.

2.4 Evaluation of the differences in cargo securing efficiency for over top compared to round turn lashings

EXECUTION

1. Tipping tests were performed with piles of paper reels secured by two over top lashings and two round turn lashings respectively.
2. The tests were performed with four piles of paper reels on a cassette. Each pile contained 3 paper reels.

During the test the pretension was measured by use of a Delog-instrument, see photo 45.

EQUIPMENT

Paper reels	
Cassette	
Trucks	*For lifting and support*
Square ruler	
Folding rule	
Web lashing	*3 pieces, LC 1600 daN, STF 400 daN*
Delog-instrument	
Corner protector	

12 paper reels in 4 piles were used in the tests. The weight of the reels was about 480 kg each and had a diameter of about 1000 mm. Each pile contained 3 reels with a height of about 2720 mm and a total weight of 1440 kg. The total weight of the 4 piles was thus about 5760 kg.

The tests were performed with 2 over top lashings and with 2 round turn lashings around the upper and next upper reels respectively. For the over top lashings the tensioners was placed on one hand on the high side and on one hand on the low side.

It was not possible to measure the pretension in the round turn lashing in the location were the tensioner was placed so it was measured in the next location beside.

It was noticeable that the round turn lashing was difficult to apply and a ladder was required, see photo 36.

Paper reels secured by over top lashings, tensioner on the high side

Paper quality	**Dimension** [mm]		*Pile weight [kg]*	*Angle [°]*	*Gap on high side [mm]*	**Force in the lashing** [kg]	
	Pile height	*Ø*				*High side Band 1 resp Band 2*	*Low side Band 1 resp Band 2*
Newsprint	2720	1000	1440	0	0	416 492	356 444
		Tipping start		24	4	465 544	358 412
				28	16	514 600	
				31	25	605 690	
Residual force measured in the lashings after the test				0	0	280 363	368 465

The test is documented in photos 23-29.

The test was terminated when the gap was more than 25 mm to avoid collapse of the piles.

Paper reels secured by over top lashings, tensioner on the low side

Paper quality	**Dimension** [mm]		*Pile weight [kg]*	*Angle [°]*	*Gap on high side [mm]*	**Force in the lashing** [kg]	
	Pile height	*Ø*				*High side Band 1 resp Band 2*	*Low side Band 1 resp Band 2*
Newsprint	2720	1000	1440	0	0	453 456	550 530
		Tipping start		25	4	485 510	463 447
				31	15	526 550	456 482
				34	30	562 615	505 540

The test is documented in photos 30-35.

The test was terminated when the gap was more than 25 mm to avoid collapse of the piles.

Paper reels secured by round turn lashings

Number of piles	***Paper quality***	***Dimension** [mm]*		***Pile weight** [kg]*	***Angle** [°]*	***Gap on high side** [mm]*	**(Force in the lashing *[kg]*)**
		Pile height	*Ø*				
4	Newsprint	2720	1000	1440	0	0	370 upper 380 lower
			Tipping start		20	4	
					22,5	20	
					24	35	
					25	75	collapse

The test is documented in photos 36-43.

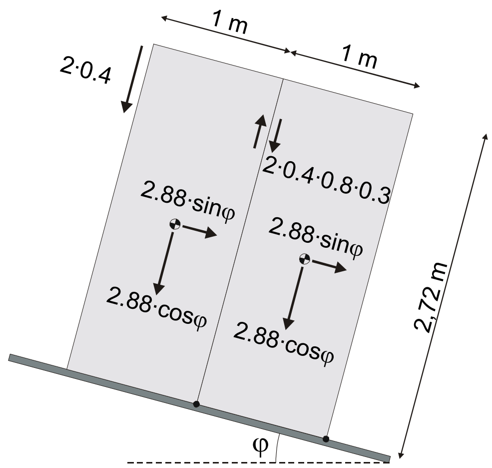
At about 25 degrees angle the piles started to collapse and was captured by the supporting truck, see photo 41.

The theoretical self stability for the reels is calculated as arc tan (1000/2720) = 20.2 degrees and in spite of the lashing a gap started to occur at about that angle, when secured by round turn lashings.

Conclusions:

The tests of the securing effect with 4 piles of paper reels distinctly show that over top lashings more effectively prevents tipping than round turn lashings. The effect of round turn lashings is marginal only and does not increase the stability of the piles more than just over the self stability. To consider round turn lashings as a valid measure for prevention of tipping without considering the horizontal acceleration, the height/width relation, the weight of piles, pretension in the lashings and the internal friction as is recommended in VDI 2700 part 9 is obviously not correct.

An equilibrium equation made with the IMO Model Course 3.18 principles shows that over top lashings can withstand the forces from an inclination of 27 degrees without a gap, please see below. This is close to the point at which a gap started to be visible at the tests.

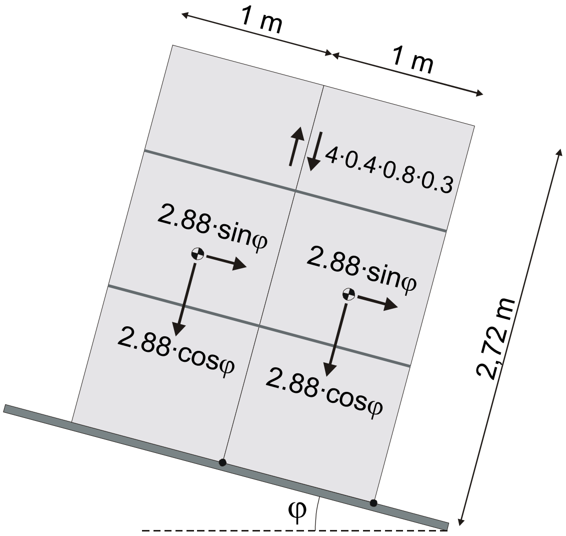


$$\overset{\curvearrowright}{A} \qquad 2\cdot 2.88\cdot\sin\varphi\cdot\frac{2.72}{2}=7.83\cdot\sin\varphi$$

$$\overset{\curvearrowleft}{A} \qquad 2\cdot 2.88\cdot\cos\varphi\cdot\frac{1.0}{2}+2\cdot 0.4\cdot 1.0+2\cdot 0.4\cdot 0.8\cdot 0.3\cdot 1.0=1.0+2.88\cdot\cos\varphi$$

	φ	$7.83\cdot\sin\varphi$	$1.0+2.88\cdot\cos\varphi$
	22°	2.93	3.67
	23°	3.06	3.65
	24°	3.18	3.63
	25°	3.31	3.61
	26°	3.43	3.59
→	**27°**	**3.55**	**3.57**
	28°	3.68	3.54

An equilibrium equation for the round turn securing arrangement gives a theoretical stability angle without gap of 23 degrees as is shown below. This also corresponds with the test results.



$$\overset{\curvearrowright}{A} \qquad 2\cdot 2.88\cdot\sin\varphi\cdot\frac{2.72}{2}=7.83\cdot\sin\varphi$$

$$\overset{\curvearrowleft}{A} \qquad 2\cdot 2.88\cdot\cos\varphi\cdot\frac{1.0}{2}+4\cdot 0.4\cdot 0.8\cdot 0.3\cdot 1.0=0.384+2.88\cdot\cos\varphi$$

	φ	$7.83\cdot\sin\varphi$	$0.384+2.88\cdot\cos\varphi$
	18°	2.42	3.12
	19°	2.55	3.11
	20°	2.68	3.09
	21°	2.81	3.07
	22°	2.93	3.05
→	**23°**	**3.06**	**3.04**
	24°	3.18	3.02

3 TESTS AT HOLMEN PAPER IN NORRKÖPING AUGUST 30TH 2004

3.1 Static or dynamic friction in combination with over top lashings

A number of different arrangements for cargo securing were tested to check if dimensioning with static friction in combination with over top lashing is sufficient.

Steps in the performance:

Friction tests

EXECUTION

1. The friction between the paper reel that should be used in the retardation tests and the loading platform on the truck at the spot of location was measured by a drag tests (a web lashing was placed around the paper reel and the drag force was increased until sliding occurred).

2. The drag force was measured by use of a dynamometer, see photo 47.

3. The coefficient of friction was calculated.

EQUIPMENT

Paper reel	1 piece
Truck	
Web lashing	1 piece, for dragging
Dynamometer	1 piece, for measuring

Drag tests

Paper quality	***Dimensions*** *[mm]*		***Weight*** *[kg]*	***Drag force*** *[kg]*	***Friction coefficient***
	B	ϕ			
Newsprint	1135	1000	600	325	0,54
				320	0,53
				330	0,55
			Mean value		0,54

Retardation tests

EXECUTION

1. The test truck was accelerated to a speed of 65 – 70 km/h and the brakes were then fully engaged.

2. The acceleration was measured by use of accelerometers in the driving direction as well as vertically. The accelerometers were placed on a paper reel standing close to the front wall and secured by a over top lashing pre tensioned to about 400 kg.

3. The test reel was placed 20 cm behind a blocking and secured by a over top lashing.

4. The pre tension on both sides of the lashing was measured by use of dynamometers before and after each test. The tests were repeated with reduced tension until sliding occurred, see photo 48-49.

EQUIPMENT

Paper reels	2 pieces (weight 600 kg, height 1135 mm, diameter 1000 mm and the distance between the lashing points and the reels on each side was 690 mm)
Truck	
Web lashings	2 pieces
Dynamometer	2 pieces (for measuring of pre tension)
Accelerometer	2 pieces

Test no	Speed [km/h]	Pre tension before [kg]		Pre tension after [kg]		Movement [mm]
		1	2	1	2	
1	65	320	280			0
2	70	320	280			0
3	70	295	205	280	220	0
4	70	220	180	220	180	0
5	73	150	150	170	140	0
6	73	125	125	215	175	45

In test number 6 only a movement of the reel occurred, see photo 50. This movement was smooth and without jerks according to the observer sitting secured at the rear on the loading platform, see photo 51.

The sum of required pre tension in the both lashing parts was calculated for the measured accelerations on one hand for dynamic friction and on the other hand for static friction as can be seen in the table below.

Test no	Measured retardation [m/s²]		Required pre tension for dynamic friction [kg]	Required pre tension for static friction [kg]	Applied pre tension [kg]
	Highest value	Mean value			
1	7,3	6,76	572	190	600
2	7,7	6,95	608	215	600
3	9,3	6,97	612	218	500
4	8,0	6,96	610	217	400
5	8,8	7,14	644	240	300
6	8,3	7,27	668	257	250

The accelerations measured during test number 6 are shown in the diagram below.

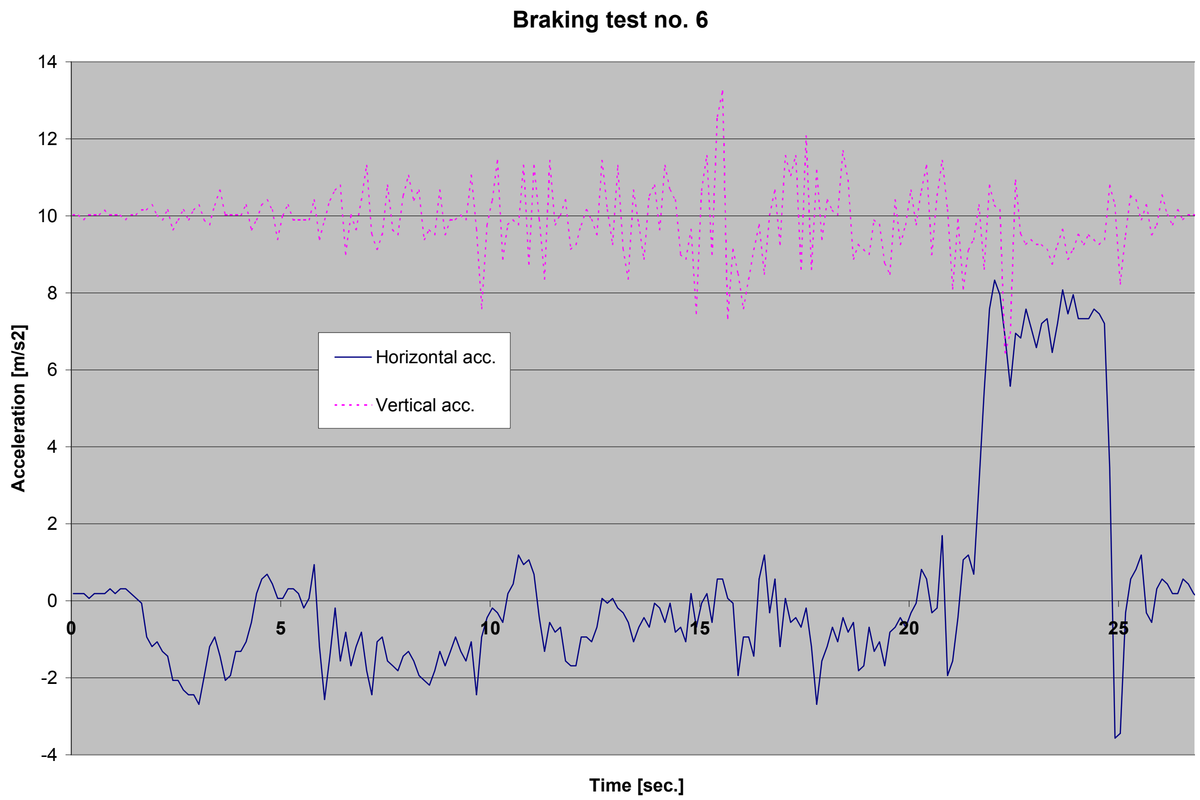


Figure 3-1 Measured accelerations during test number 6. The horizontal mean acceleration during the braking was 7,27 m/s².

Conclusions:

From the acceleration tests it may be concluded that the vertical (dynamic) accelerations are negligible, which also was noticed by the observer on the loading platform. The measured retardation was about 8 m/s², which means that 10 m/s² used in accordance with the IMO/ILO/UN ECE Guidelines contains a safety margin which is not the case for the CEN- and VDI-standards, which stipulates a forward dimensioning acceleration of 8 m/s².

During the test braking, which was made with a truck of good quality and on dry asphalt, the brakes were more or less locked which could be confirmed by signs of wheel traces on the test area.

Calculations made, considering the current lashing angles and the measured acceleration, shows that a total pre tension of about 600 kg (about 300 kg on each side) had been required to prevent the reel from sliding based on dynamic friction (70% of static) between paper reel and the loading platform. Corresponding calculation for static friction gives a required total pre tension in both lashing parts of about 250 kg (about 125 kg on each side).

The paper reel started to slide and moved just a short distance when the pre tension was reduced to 250 kg. It can thus be concluded that it is physically correct to use the **static friction** in combination with over top lashings when cargo securing arrangements are dimensioned.

3.2 Dimensioning acceleration sideways for unstable packages

EXECUTION

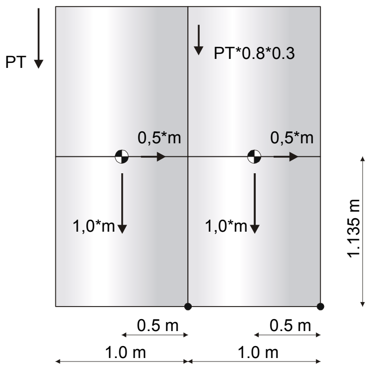
1. A truck equipped with a supporting side wheel was loaded with goods to full admissible weight.
2. The load consisted of 20 paper reels weighing about 600 kg each divided into 10 piles, 5 sections and 2 layers, see photo 52.
3. The reels were secured against tipping sideways by over top lashings.
4. The middle section was separated from the others and equipped with dynamometers on each side of a over top lashing.
5. On the tensioner side of the middle section the lashing was equipped with a turnbuckle for fine adjustment.
6. The truck was driven in a sharp bend (circle with diameter of about 25 meter) while the horizontal and vertical accelerations were measured, see photo 53-54.
7. Accelerometers were mounted on the backside of one of the reel piles at a height of about 1.5 meter above the platform.
8. The pre tension in the lashing over the middle section was measured before and after each test.
9. The pre tension was successively reduced for each test until the tension required for dimensioning according to the IMO/ILO/UN ECE Guidelines was attained.
10. Tests were carried out with the tensioner applied both on the high and low side.

EQUIPMENT		
	Paper reels	20 pieces
	Truck	1 piece
	Supporting side wheel	1 piece
	Over top web lashings	7 pieces (2 extra over the end sections for safety)
	Dynamometer	2 pieces
	Turnbuckle	1 piece
	Accelerometer	2 pieces

Tipping test

Paper quality	Number of piles per section	Pile height [mm]	Diameter [mm]	Weight per pile [kg]
Newsprint	2	2*1135=2270	1000	1200

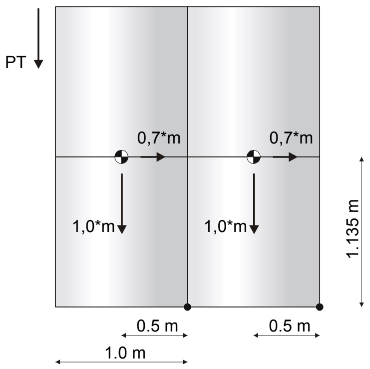
The required pre tension for dimensioning according to the IMO/ILO/UN ECE Guidelines with a lateral acceleration of 5.0 m/s^2 considering the effect of internal friction between the reels is **130 kg**, see below.



$$0.5 \cdot m \cdot 1.135 \cdot 2 - 1.0 \cdot m \cdot 0.5 \cdot 2 - PT \cdot (1.0 - 0.8 \cdot 0.3 \cdot 1.0) = 0$$

$$\Rightarrow PT = \frac{1200 \cdot (1.135 - 1.0)}{(1 + 0.24)} = 130\ kg$$

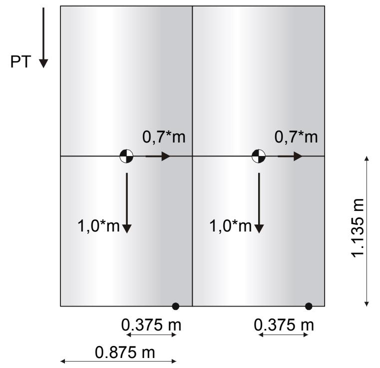
Required pre tension for dimensioning according to the EN 12195-1 standard with two tensioners with a lateral acceleration of 7.0 m/s^2 without considering the effect of internal friction is **707 kg**, see below.



$$0.7 \cdot m \cdot 1.135 \cdot 2 - 1.0 \cdot m \cdot 0.5 \cdot 2 - PT \cdot 1.0 = 0 \quad \Rightarrow$$

$$\Rightarrow PT = \frac{1200 \cdot (1.589 - 1.0)}{1} = 707\ kg$$

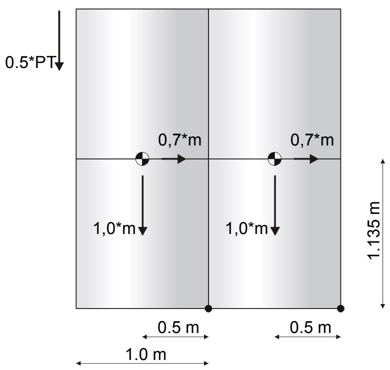
Required pre tension for dimensioning according to standard VDI 2700 part 9 with a lateral acceleration of 7.0 m/s^2 and 25 % reduced width due to edge weakening without considering the effect of internal friction is **1150 kg**, see below.



$$0.7 \cdot m \cdot 1.135 \cdot 2 - 1.0 \cdot m \cdot 0.375 \cdot 2 - PT \cdot 0.875 = 0 \quad \Rightarrow$$

$$\Rightarrow PT = \frac{1200 \cdot (1.589 - 0.75)}{0.875} = 1150\ kg$$

Required pre tension for dimensioning according to the EN 12195-1 standard with the lateral acceleration 7.0 m/s^2 and one tensioner without considering the internal friction is **1414 kg**, see below.



$$0.7 \cdot m \cdot 1.135 \cdot 2 - 1.0 \cdot m \cdot 0.5 \cdot 2 - 0.5 \cdot PT \cdot 1.0 = 0 \quad \Rightarrow$$

$$\Rightarrow PT = \frac{1200 \cdot (1.589 - 1.0)}{0.5} = 1414\ kg$$

Tipping test with the tensioner on the high side

Test no	**Pre tension before [kg]**		**Pre tension after[kg]**		**Highest lateral acceleration**	**Comments**
	High side	***Low side***	***High side***	***Low side***	***a_h [m/s^2]***	
1	600	390			4.95	Heavy wheel touch
2	600	390			4.18	Light wheel touch
3	210	110	110	170	3.93	Slight wheel touch only
4	130	100	90	150	4.06	Almost no wheel touch

Tipping test with the tensioner on the low side

Test no	Pre tension before [kg]		Pre tension after[kg]		Highest lateral acceleration a_h [m/s²]	Comments
	High side	*Low side*	*High side*	*Low side*		
5	80	130	60	110	4.06	Almost no wheel touch

The accelerations measured during tests 1 and 5 are shown in the diagrams below.

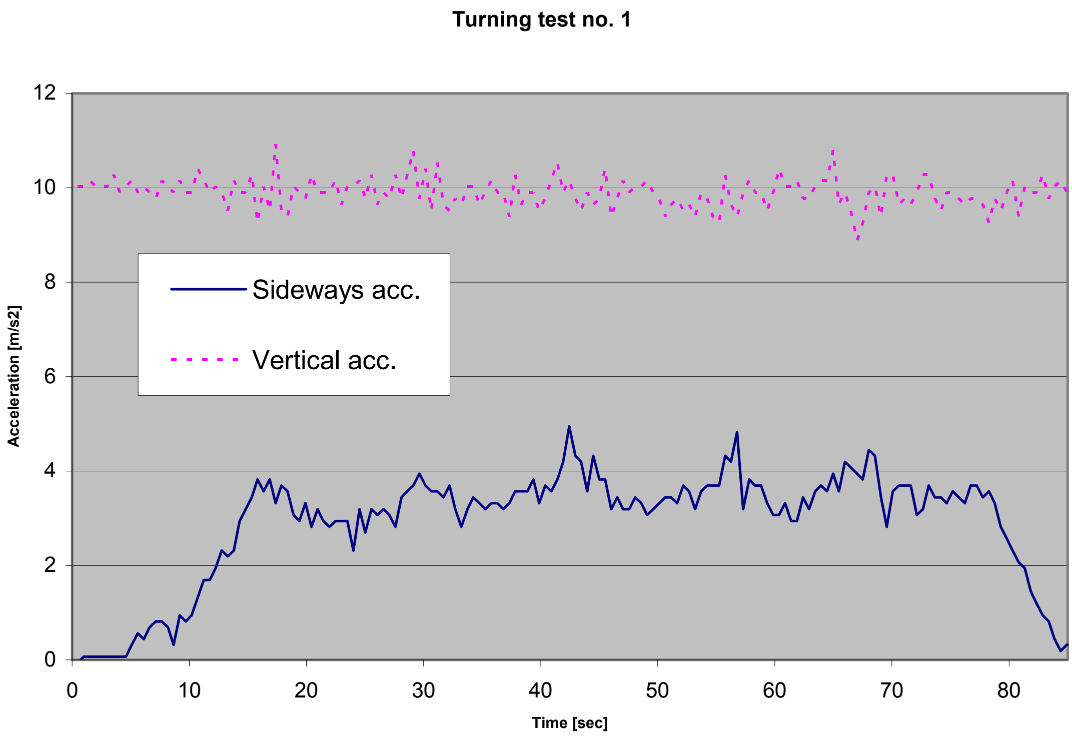


Figure 3-2 Measured accelerations in test no 1. When the highest peaks for the horizontal acceleration were generated, the supporting side wheel touched the ground.

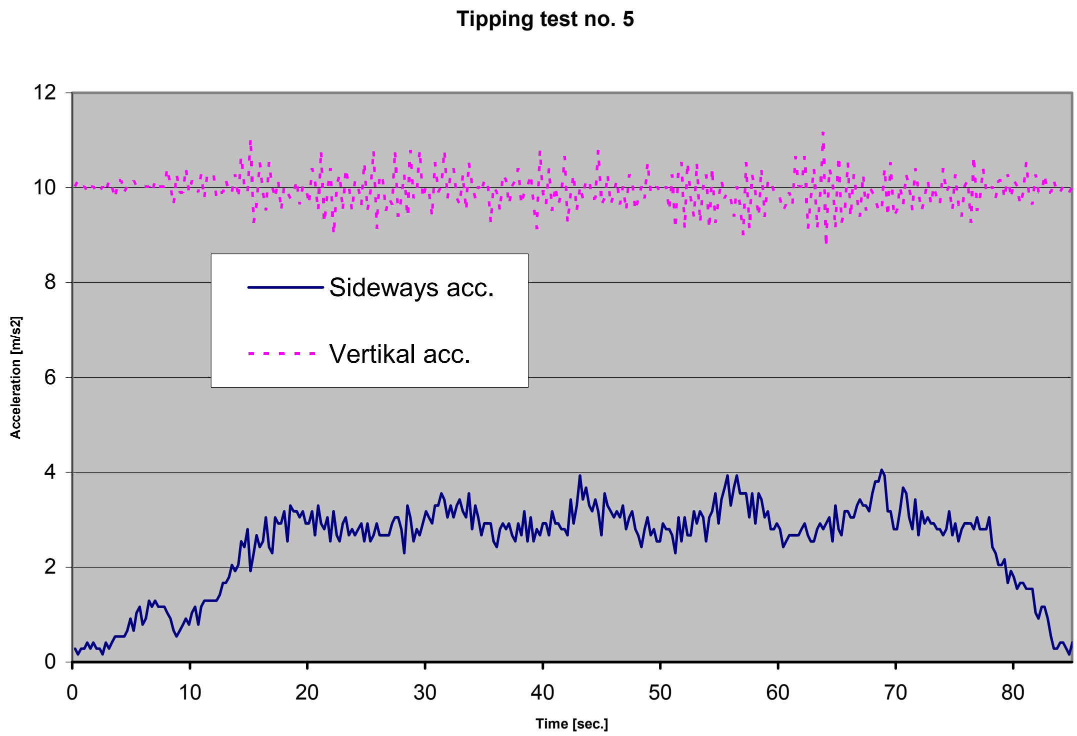


Figure 3-3 Measured accelerations in test no 5. When the highest peaks for the vertical acceleration were generated, the supporting side wheel just almost touched the ground.

Conclusions:

According to the driver the truck was, during the tests, driven in a way he would never have dared to without the supporting side wheel. In spite of this only in short time periods lateral accelerations close to 4.0 m/s^2 was reached. This clearly shows that the lateral acceleration of 5 m/s^2, which should be used for dimensioning of the securing against tipping according to the IMO/ILO/UN ECE Guidelines, does include a safety margin.

For dimensioning of the securing against tipping according to the VDI 2700 and EN 12195-1 standards a pre tension on the tensioner side of 700 - 1400 kg would be required. Corresponding pre tension on the high side according to the IMO/ILO/UN ECE Guidelines is about 130 kg.

The test results show that the pre tension on the tensioner side could be reduced to 130 kg without risk of un controlled movements of the reel piles though the truck would have tipped over unless there had been a supporting side wheel. This result was also achieved with the tensioner on the low side with only 80 kg pre tension on the high side before the test.

Based on these results it may be concluded that securing arrangements dimensioned according to the principals in the IMO/ILO/UN ECE Guidelines provide adequate safety against tipping sideways independently of which side the tensioner is placed.

4 GENERAL CONCLUSIONS

From the tests carried out at SCA in Sundsvall and Holmen Paper in Norrköping the following general conclusions can be drawn:

1. Paper reels of customary quality can be recognized as rigid in form and no correction for weak edges is needed.

2. Corner protectors with low friction more easily equalize the tension on both sides of the cargo unit than corner protectors with high friction. If a limited motion of the cargo is taken into consideration the friction of the corner protections doesn't influence on the safety in extreme condition.

3. It is easy to obtain pre tensions in web lashings far above the marked STF also with normal hand power. The first minutes after the tightening the pre tension in a web lashing is, however, reduced due to creeping in the material. To get a remaining pretension on a high level it is thus very important to train persons performing cargo securing to retighten lashings some minutes after the initial tightening and then every now and then during the transport. If this were performed a great increase of safety would be achieved.

4. Round turn lashings have a very limited effect on the tipping stability for high piles and are often very difficult to apply, see photo 46-47 from SCA in Sundsvall.

5. Over top lashings prevent tipping much more effective than round turn lashings.

6. It is physically correct to use the **static friction** in combination with over top lashings when cargo securing arrangements are dimensioned.

7. During the retardation tests a maximum retardation of about 8 m/s^2 was obtained even though the conditions were perfect with dry clean asphalt, new tires on the truck, newly served breaks and light load on the platform only. The retardation of 10 m/s^2, which shall be used according to the IMO/ILO/UN ECE Guidelines, does thus contain a safety margin.

8. The lateral acceleration of 5 m/s^2, which should be used for dimensioning of securing systems against sideways tipping, according to the IMO/ILO/UN ECE Guidelines, does include a safety margin.

9. Securing arrangements dimensioned according to the principals in the IMO/ILO/UN ECE Guidelines provide adequate safety against tipping sideways independently of which side the tensioner is placed.

5 PHOTOS

Photo 1
Test of a NewsPrint reel

Photo 2
Test of a NewsPrint reel

Photo 3
Finding the balance point by hand force on a reel with a weight of more than 500 kg.

Photo 4
Test of reel on tipping table

Photo 5
Preventing the reel from falling down by a forklift truck

Photo 6
Rubber avoiding the reel from sliding before tipping

Photo 7
Corner protection of plastic

Photo 8
Corner protection of wood

Photo 9
Corner protection of wood

Photo 10
Corner protection of plastic with very low friction

Photo 11
Rubber between webbing and corner protection

Photo 12
Sliding tests with corner protections with different friction. Very slippery platform. Tensioner on the high side

Photo 13
Measuring of heeling angle and force in the lashing

Photo 14
Heeling with the tensioner on the low side

Photo 15
Tipping tests with corner protections with different friction. Tensioner on high side

Photo 16
Start of heeling of the pile in relation to the tipping table with a gap of about 10 mm

Photo 17
Continued heeling

Photo 18
Maximum heeling angle before the entire tipping table tilts over.

Photo 19
Maximum heeling of the pile in relation to the tipping table with a gap of about 30 mm

Photo 20
Tipping test with tensioner on low side

Photo 21
Dynamometer for measuring of forces in the lashing

Photo 22
Max heeling with tensioner on the low side

Photo 23
Four piles with a total height of abt 2700 mm and a weight of the 4 piles of abt 5760 kg. Reel diameter abt 1000 mm.

Photo 24
The red low lashing was used to prevent the reels from sliding

Photo 25
Two over top lashings were used together with long corner protections of plastic

Photo 26
Heeling of the piles, with a forklift truck to prevent the reels from falling.

Photo 27
Start of movement of the piles in relation to the cassette deck

Photo 28
Increased gap

Photo 29
Measuring of heeling angle

Photo 30
Measuring of tension force in the lashings

Photo 31
Piles slightly inclined in relation to the cassette deck

Photo 32
Detail of the gap

Photo 33
Increased gap

Photo 34
Gap

Photo 35
Maximum gap, abt 30 mm

Photo 36
Applying of over top lashings. Please note the ladders.

Photo 37
Two round turn lashings plus one bottom lashing for preventing sliding

Photo 38
Just over the self stability of the piles they started to incline in relation to the cassette deck

Photo 39
Continued heeling

Photo 40
Detail of gap

Photo 41
Collapse of piles at 25 degrees

Photo 42
Detail of gap at collapse, abt 75 mm

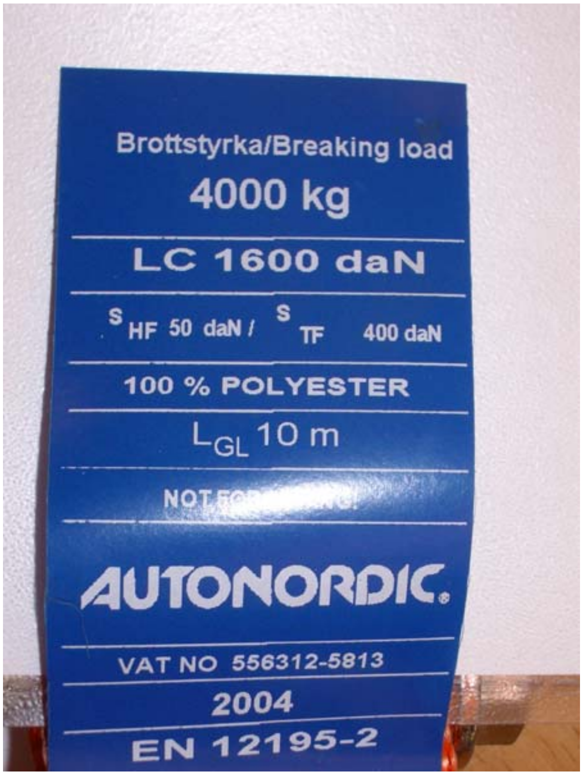


Photo 43
Marking of the web lashings used in the experiments

Photo 44
Measuring of the tension force by a Delog-instrument

Photo 45
Standing reels in a trailer at the SCA mill in Sundsvall

Photo 46
Top view of the reels

Photo 47
Drag test for determination of the static friction coefficient

Photo 48
Retardation test

Photo 49
Braking test

Photo 50
Movement happening during retardation test number 6

Photo 51
Observer tied to the loading platform during retardation test number 6

Photo 52
Paper load during tip tests

Photo 53
Tip test

Photo 54
Truck inclining in tip test

tfk - Tranport Research Institute

Strandbergsgatan 12
SE-112 51 Stockholm
SWEDEN
Tel: +46 8 652 41 30
Fax: +46 8 652 54 98
E-post: info@tfk.se
Internet: www.tfk.se

MariTerm AB

Box 74
SE-263 21 Höganäs
SWEDEN
Tel +46 42 333100
Fax +46 42 333102
E-post: info@mariterm.se
Internet: www.mariterm.se