Inclination tests to determine the static friction factor for different material combinations

Tests performed in Höganäs 2007-04-10/11/12

2007-05-14
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1 Preamble

MariTerm AB has on behalf of SIS performed practical tests of static friction using the Swedish cargo securing vehicle to test various friction surfaces and measure the static friction. During the tests, the test procedure prescribed by EN 12195-1 was followed.

The tests were performed in Höganäs, Sweden, on April 10^{th} – 12^{th} 2007. The weather was dry and the temperature just below +10° C.

1.1 Attendance

The following persons were attending the tests:

Nils Andersson	*MariTerm i Höganäs AB*
Petra Hugoson	*MariTerm i Höganäs AB*
Sven Sökjer-Petersen	*MariTerm i Höganäs AB*
Anders Hernebrant	*BJ Trucks AB*

1.2 Test equipment

Below is a description of the cargo and the equipment that was used during the tests.

1.2.1 Cargo

A wooden box a pallet made of sawn wood. The pallet had the following dimensions:

Length: 1200 mm
Breadth: 800 mm
Height: 530 mm

The pallet weighed 1000 kg.

A wooden box on a wood pallet with a plane wood surface underneath.

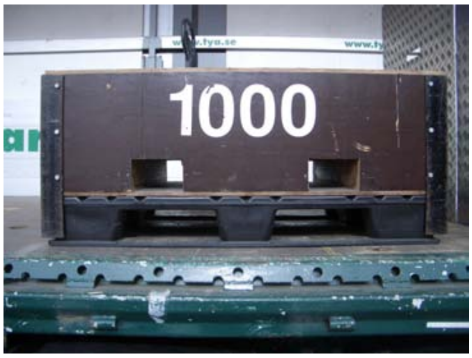
Length: 1200 mm
Breadth: 800 mm
Height: 530 mm

The pallet weighed 1000 kg.

A wooden box on a plastic pallet.

Length: 1200 mm
Breadth: 800 mm
Height: 530 mm

The pallet weighed 1000 kg.



A concrete block with rough and smooth surface.

Length: 950 mm
Breadth: 800 mm
Height: 450 mm

The block weighed 750 kg.

A heat exchanger with steel feets.

Length: 2100 mm
Breadth: 800 mm
Height: 1750 mm

The exchanger weighed 2000 kg.

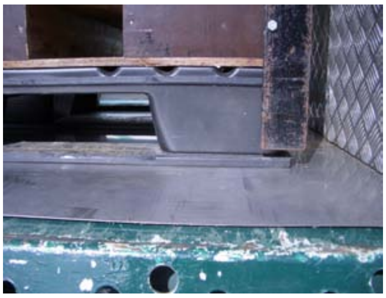
1.2.2 Platform surfaces

The following platform surfaces were used during the tests.

Fabric base laminate/ plywood

Grooved aluminium

Steel sheet



Wooden battens

Shrink film

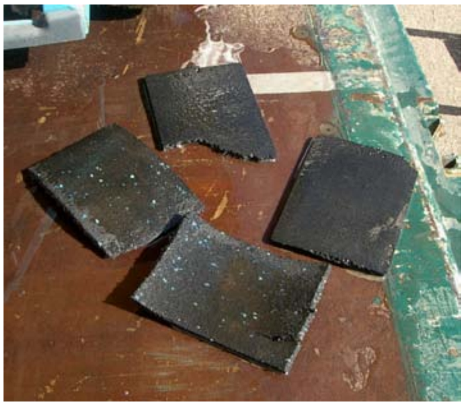
1.2.3 Inclinometer

To measure inclination angles, a Tajima Slant 100 bubble vial inclinometer was used.

1.2.4 Rubber anti-slip mats (rubber)

Marotech MT Premium anti-slip mats were used during the tests.

thickness: 8 mm



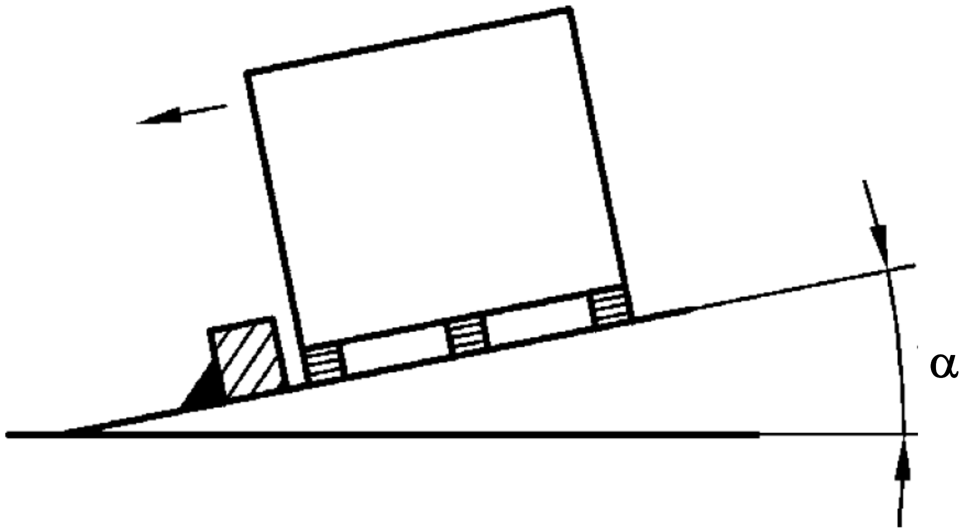
1.2.5 Accelerometer

A 3-Axis Accelerometer Vernier LabPro with three -5 to +5 g accelerometers mounted in one small black unit was used to measure the accelerations in X, Y, Z axes.

The 3-axis accelerometer sensor was mounted on the platform floor and accelerations were measured along three axes during one inclination test.

1.3 Description of the test

To determine the static friction between the friction surfaces inclination tests according to EN 12195-1, Annex C were performed. The static friction according to the standard *"states how lightly a cargo will slide if the cargo platform is tilted. A simple method to find static friction factor is to incline a cargo platform carrying the cargo in question and measure the angle at which the cargo starts to slide. This gives the static friction μ = tan α. Great care should be taken by using e.g. blocking devices in a short distance to the cargo to prevent the cargo from falling off the platform during the test."*



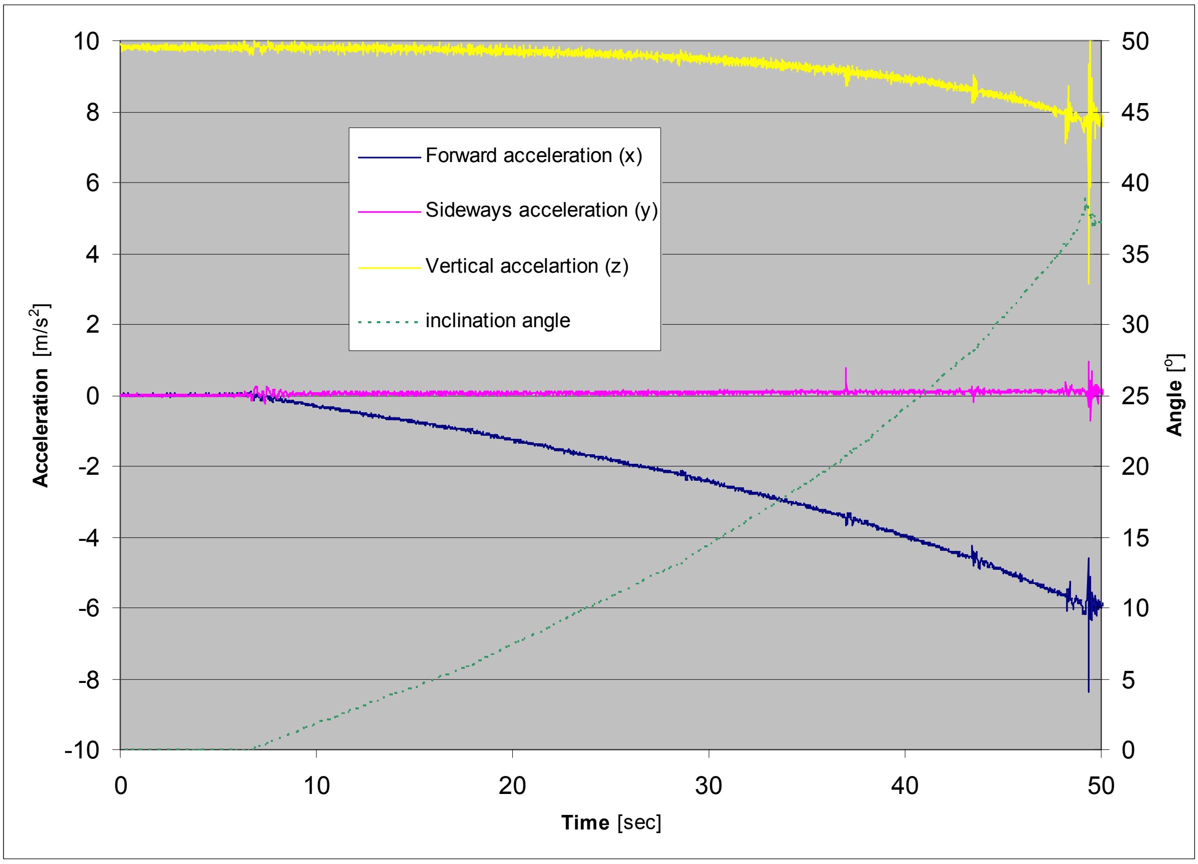
The following combinations of cargo and platform surfaces were tested:

	Fabric base laminate/ plywood				Grooved aluminium				Stainless steel				Sawn wood battens				Shrink film
	Without ASM[1]		With ASM		Without ASM		With ASM		Without ASM		With ASM		Without ASM		With ASM		Without ASM
	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry
Sawn wood pallet	x	x	x	x	x	x	x	x	x	x	x	x					x
Plane wood	x	x		x	x	x	x	x	x	x		x					
Plastic pallet	x	x	x	x	x	x	x	x	x	x	x	x					
Steel crate	x	x	x	x	x	x		x	x	x							
Concrete rough													x		x		
Concrete smooth													x	x	x	x	

[1] ASM – Anti-slip mats

Each combination of surfaces was tested five times. The more than 250 inclination tests were made during 20 hours. Some of the tests had to be repeated because the cargo grasp on support or cargo was placed so closed to the blocking board and it was difficult to judge when the sliding started. Therefore the values were rejected and test was repeated. To state the static friction factor the average of 3 middle values was taken.

During one inclination test the vibrations were measured with the accelerometer. The measurement shows that during the whole inclination the cargo is exerted to small high frequency shocks due to engine vibrations. The result is plotted below.



The sudden peaks of vibration at the times 37, 43 and 48 seconds are the results of movement of different parts of the telescopic piston.

The different material contacts were firstly tested as dry. The tests in wet condition followed after these tests. The surfaces were sprinkled with a large amount of water with a hose as can be seen in following photo.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2 Results

In annex A the detailed results of each inclination test are presented.

The static friction factor was calculated according to the following formula:

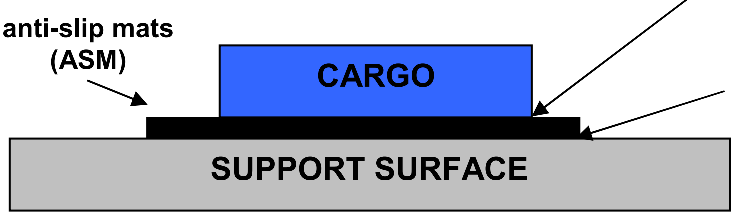
$$\mu = \tan \alpha$$

From test values without anti-slip mats an average of the 3 middle values of the inclination angles was taken. The highest and the lowest value were deleted.

Each value from the tests with anti-slip mats contains comments describing the sliding surface as X – surface, Y – surface or X, Y surfaces. X – surface represents sliding between the cargo (sawn wooden pallet, plane wood, plastic pallet, steel crate, concrete rough and concrete smooth) and the anti-slip mats during the inclination tests. Y- surface represents the sliding between the anti-slip mats and support (fabric base laminate/ plywood, grooved aluminium, stainless steel and sawn wooden battens). X,Y – surfaces represent sliding in both surfaces[2]. Sliding in both surfaces means that some of the anti-slip mats moved together with the cargo and some of them stayed on the support surface.

For calculation of static friction factor between the specific cargo and the anti-slip mats it was taken an average of all X and X, Y values from the tests with this cargo. For calculation of static friction factor between the anti-slip mats and the support surface it was taken an average from all Y and X, Y values from the tests with this support.

Sliding surfaces



X – surface between the cargo (sawn wood pallet, plane wood, plastic pallet, concrete rough, concrete smooth, steel crate) and anti-slip mat

Y – surface between the anti-slip mat and support surface (plywood, grooved aluminium, sawn wood, stainless steel)

[2] Four pieces of anti-slip mats were used for all cargo types except for the heat exchanger (steel crate) where six anti-slip mats were used.

The average measured friction, proposed friction and the margin between the measured and proposed values are given in table below.

Contact surfaces	Dry			Wet		
	average measured μ	proposed μ	margin %	average measured μ	proposed μ	margin %
Sawn wood pallet - fabric base laminate/ plywood	0,58	0,50	86,6	0,73	0,50	68,8
Plane wood - fabric base laminate/ plywood	0,38	0,35	91,1	0,67	0,35	51,9
Plastic pallet - fabric base laminate/ plywood	0,36	0,30	83,2	0,29	0,25	85,3
Steel crate - fabric base laminate/ plywood	0,57	0,50	87,8	0,57	0,50	87,2

Sawn wood pallet - grooved aluminium	0,54	0,50	93,4	0,67	0,50	74,1
Plane wood - grooved aluminium	0,35	0,30	86,3	0,49	0,30	61,5
Plastic pallet - grooved aluminium	0,25	0,20	81,2	0,22	0,20	92,8
Steel crate - grooved aluminium	0,39	0,35	88,9	0,62	0,35	56,0

Sawn wood pallet - stainless steel	0,37	0,35	93,6	0,59	0,35	59,8
Plane wood - stainless steel	0,29	0,25	87,2	0,57	0,25	43,6
Plastic pallet - stainless steel	0,19	0,15	80,9	0,22	0,15	69,6
Steel crate - stainless steel	0,25	0,20	79,2	0,37	0,20	54,5

Concrete rough - sawn wood battens	0,84	0,75	89,3	-	-	-
Concrete smooth - sawn wood battens	0,71	0,60	84,1	0,67	0,60	89,5

Wooden pallet - shrink film	0,44	0,40	90,5

Sawn wood - rubber	0,90	0,80	88,8	0,72	0,65	89,7
Plane wood – rubber	0,78	0,70	89,6	0,78	0,70	90,0
Plastic pallet – rubber	0,60	0,50	83,1	0,71	0,50	70,8
Steel crate - rubber	0,79	0,70	88,6	0,78	0,70	89,4
Concrete rough - rubber	0,86	0,75	86,9	-	-	-
Concrete smooth – rubber	0,87	0,75	86,0	0,71	0,60	85,1
Rubber - fabric base laminate/ plywood	0,78	0,70	90,2	0,79	0,70	88,9
Rubber - grooved aluminium	0,83	0,65	78,3	0,73	0,65	88,7
Rubber - stainless steel	0,78	0,60	77,1	0,69	0,60	86,97

Final table with proposed static friction factors:

<table>
<tr><th>Contact surfaces</th><th>Dry</th><th>Wet</th></tr>
<tr><td></td><td>proposed μ</td><td>proposed μ</td></tr>
<tr><td>Sawn wood pallet - fabric base laminate/ plywood</td><td colspan="2">0,50</td></tr>
<tr><td>Plane wood - fabric base laminate/ plywood</td><td colspan="2">0,35</td></tr>
<tr><td>Plastic pallet - fabric base laminate/ plywood</td><td>0,30</td><td>0,25</td></tr>
<tr><td>Steel crate - fabric base laminate/ plywood</td><td colspan="2">0,50</td></tr>
</table>

<table>
<tr><td>Sawn wood pallet - grooved aluminium</td><td colspan="2">0,50</td></tr>
<tr><td>Plane wood - grooved aluminium</td><td colspan="2">0,30</td></tr>
<tr><td>Plastic pallet - grooved aluminium</td><td colspan="2">0,20</td></tr>
<tr><td>Steel crate - grooved aluminium</td><td colspan="2">0,35</td></tr>
</table>

<table>
<tr><td>Sawn wood pallet - stainless steel</td><td colspan="2">0,35</td></tr>
<tr><td>Plane wood - stainless steel</td><td colspan="2">0,25</td></tr>
<tr><td>Plastic pallet - stainless steel</td><td colspan="2">0,15</td></tr>
<tr><td>Steel crate - stainless steel</td><td colspan="2">0,20</td></tr>
</table>

<table>
<tr><td>Concrete rough - sawn wood battens</td><td>0,75</td><td>0,75[3]</td></tr>
<tr><td>Concrete smooth - sawn wood battens</td><td colspan="2">0,60</td></tr>
</table>

<table>
<tr><td>Wooden pallet - shrink film</td><td>0,40</td><td>-</td></tr>
</table>

<table>
<tr><td>Sawn wood - rubber</td><td>0,80</td><td>0,65</td></tr>
<tr><td>Plane wood – rubber</td><td colspan="2">0,70</td></tr>
<tr><td>Plastic pallet – rubber</td><td colspan="2">0,50</td></tr>
<tr><td>Steel crate - rubber</td><td colspan="2">0,70</td></tr>
<tr><td>Concrete rough - rubber</td><td>0,75</td><td></td></tr>
<tr><td>Concrete smooth – rubber</td><td>0,75</td><td>0,60</td></tr>
<tr><td>Rubber - fabric base laminate/ plywood</td><td colspan="2">0,70</td></tr>
<tr><td>Rubber - grooved aluminium</td><td colspan="2">0,65</td></tr>
<tr><td>Rubber - stainless steel</td><td colspan="2">0,60</td></tr>
</table>

[3] Estimated to be the same as for dry contact surface. The results for dry and wet smooth concrete were the same.

It is further proposed that if the friction is unknown or if the surfaces are not clean or free from frost, ice or snow a value of **0,2** should be used **for road transport** and **0,3 for sea areas A, B, C**.
Mostly the same static friction factors for dry and wet conditions are proposed for most of the contact surfaces. Most of the measured values are similar or even higher in wet conditions than in dry. If the dry value is higher than the wet value two values are proposed to be used.

3 Conclusions

During the three days of testing more than 250 inclination tests with various material combinations in dry and wet conditions to determine static friction factor were performed. The Swedish cargo securing vehicle was used for inclination tests. The same cargo and platform surfaces were used during all tests. The inclination tests were performed according to EN 12195-1. Vibrations were measured during one inclination test which showed that the cargo is exerted to small high frequency shocks due to engine vibrations during all tests. To create wet conditions the materials were sprinkled with a large amount of water from a hose. It is very surprising that many of the material contacts in wet condition have similar or even higher static friction than in dry condition. For wood it is known that very dry wood has lower friction than wet wood. Also wood and steel on grooved aluminium and stainless steel showed higher values in wet than in dry condition which is very surprising. Only plastic pallet on fabric base laminate/ plywood and smooth concrete respectively sawn wood on rubber surface had lower values in wet than in dry condition. Comparison of the proposed values with values from the standard EN 12195-1, Annex C, Table C.1 is given in the following table.

Contact surfaces	**Dry**	**Wet**	**μ in existing EN 12195-1**
	proposed μ	**proposed μ**	
Sawn wood pallet – fabric base laminate/ plywood	0,50		0,5
Plane wood – fabric base laminate/ plywood	0,35		-
Plastic pallet – fabric base laminate/ plywood	0,30	0,25	-
Steel crate – fabric base laminate/ plywood	0,50		-
Sawn wood pallet – grooved aluminium	0,50		0,4
Plane wood – grooved aluminium	0,30		-
Plastic pallet – grooved aluminium	0,20		-
Steel crate – grooved aluminium	0,35		-
Sawn wood pallet – stainless steel	0,35		-
Plane wood – stainless steel	0,25		-
Plastic pallet – stainless steel	0,15		-
Steel crate – stainless steel	0,20		-

Contact surfaces	Dry proposed μ	Wet proposed μ	μ in existing EN 12195-1
Concrete rough – sawn wood battens	0,75	0,75[4]	-
Concrete smooth – sawn wood battens	0,60		-
Wooden pallet – shrink film	0,40	-	0,3
Sawn wood - rubber	0,80	0,65	-
Plane wood – rubber	0,70		-
Plastic pallet – rubber	0,50		-
Steel crate - rubber	0,70		
Concrete rough - rubber	0,75	-	-
Concrete smooth – rubber	0,75	0,60	-
Rubber - fabric base laminate/ plywood	0,70		-
Rubber - grooved aluminium	0,65		
Rubber - stainless steel	0,60		-

[4] Estimated to be the same as for dry contact surface. The results for dry and wet smooth concrete were the same.

4 Proposed friction table

From measured results and values from existing standard the following table is proposed to be used in the revised standard.

<table>
<tr><th rowspan="2">Combination of materials in the contact surface</th><th>Dry</th><th>Wet</th></tr>
<tr><th>μ</th><th>μ</th></tr>
<tr><td colspan="3">Sawn wood</td></tr>
<tr><td>Sawn wood - fabric base laminate/ plywood</td><td>0,50</td><td>-</td></tr>
<tr><td>Sawn wood - grooved aluminium</td><td colspan="2">0,50</td></tr>
<tr><td>Sawn wood - shrink film</td><td>0,40</td><td>-</td></tr>
<tr><td>Sawn wood - steel sheets</td><td>0,40</td><td>-</td></tr>
<tr><td>Sawn wood stainless steel sheet</td><td colspan="2">0,35</td></tr>
<tr><td colspan="3">Plane wood</td></tr>
<tr><td>Plane wood - fabric base laminate/ plywood</td><td colspan="2">0,35</td></tr>
<tr><td>Plane wood – grooved aluminium</td><td colspan="2">0,30</td></tr>
<tr><td>Plane wood - stainless steel sheet</td><td colspan="2">0,25</td></tr>
<tr><td colspan="3">Plastic pallet</td></tr>
<tr><td>Plastic pallet - fabric base laminate/ plywood</td><td>0,30</td><td>0,25</td></tr>
<tr><td>Plastic pallet - grooved aluminium</td><td colspan="2">0,20</td></tr>
<tr><td>Plastic pallet - stainless steel sheet</td><td colspan="2">0,15</td></tr>
<tr><td colspan="3">Shrink film</td></tr>
<tr><td>Shrink film - fabric base laminate/plywood</td><td>0,40</td><td>-</td></tr>
<tr><td>Shrink film - grooved aluminium</td><td>0,40</td><td>-</td></tr>
<tr><td>Shrink film - steel sheets</td><td>0,40</td><td>-</td></tr>
<tr><td>Shrink film - shrink film</td><td>0,40</td><td>-</td></tr>
<tr><td colspan="3">Cardboard boxes</td></tr>
<tr><td>Cardboard box - cardboard box</td><td>0,50</td><td>-</td></tr>
<tr><td>Cardboard box - wood pallet</td><td>0,50</td><td>-</td></tr>
<tr><td>Big bags</td><td colspan="2"></td></tr>
<tr><td>Big bag - wooden pallet</td><td>0,40</td><td>-</td></tr>
<tr><td colspan="3">Steel and metal sheets</td></tr>
<tr><td>Steel crate - fabric base laminate/ plywood</td><td colspan="2">0,50</td></tr>
<tr><td>Steel crate – grooved aluminium</td><td colspan="2">0,35</td></tr>
<tr><td>Steel crate – stainless steel sheet</td><td colspan="2">0,20</td></tr>
<tr><td>Oiled metal sheets - oiled metal sheets</td><td>0,10</td><td>-</td></tr>
<tr><td>Flat steel bars - sawn wood</td><td>0,50</td><td>-</td></tr>
<tr><td>Unpainted rough steel sheets - sawn wood</td><td>0,50</td><td>-</td></tr>
<tr><td>Painted rough steel sheets - sawn wood</td><td>0,50</td><td>-</td></tr>
<tr><td>Unpainted rough steel sheets - unpainted rough steel sheets</td><td>0,40</td><td>-</td></tr>
<tr><td>Painted rough steel sheets - painted rough steel sheets</td><td>0,30</td><td>-</td></tr>
<tr><td>Painted steel barrel - painted steel barrel</td><td>0,20</td><td>-</td></tr>
<tr><td>Concrete</td><td></td><td></td></tr>
<tr><td>Concrete rough – sawn wood battens</td><td>0,75</td><td>0,75[5]</td></tr>
<tr><td>Concrete smooth – sawn wood battens</td><td colspan="2">0,60</td></tr>
</table>

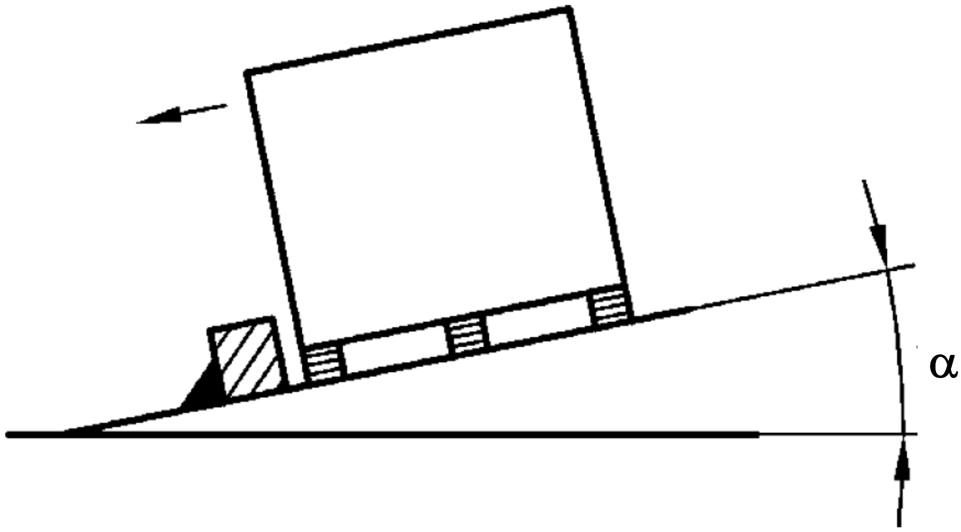
[5] Estimated to be the same as for dry contact surface. The results for dry and wet smooth concrete were the same.

Combination of materials in the contact surface	Dry	Wet
	μ	μ
Wall on wall without intermediate layer (concrete/concrete)	0,70	-
Finished part with wooden intermediate layer on wood (concrete/wood/wood)	0,50	-
Ceiling on ceiling without intermediate layer (concrete/lattice girder)	0,70	-
Steel frame with wooden intermediate layer (steel wood)	0,50	-
Ceiling on steel frame with wooden intermediate layer (concrete/wood/steel)	0,55	-
Rubber anti-slip mat (rubber)		
Sawn wood - rubber	0,80	0,65
Plane wood - rubber	0,70	
Plastic pallet - rubber	0,50	
Steel crate - rubber	0,70	
Concrete rough - rubber	0,75	-
Concrete smooth - rubber	0,75	0,60
Rubber - fabric base laminate/ plywood	0,70	
Rubber - grooved aluminium	0,65	
Rubber - stainless steel	0,60	

If the friction is unknown or if the surfaces are not clean or free from frost, ice or snow a value of **0,2** should be used **for road transport** and **0,3 for sea areas A, B, C**.

5 Proposed practical method for the determination of the friction factors

The friction factor μ states, how lightly a cargo will slide if the loads platform is tilted. A simple method to find μ is to incline a load platform carrying the cargo in question and measure the angle at which the cargo starts to slide. This gives the friction $\mu = \tan \alpha$. Great care should be taken by using e.g. blocking devices in a short distance to the load to prevent the cargo from falling off the platform during the test.

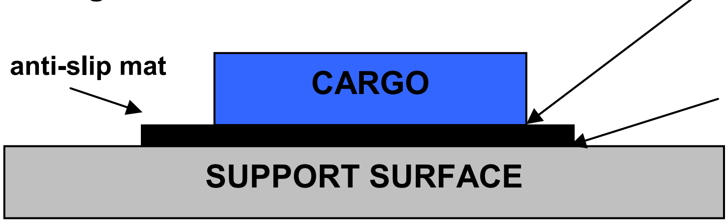


Five inclination tests must be performed with the same combination of materials in the contact surface. The highest and the lowest values are deleted and the friction factor is determined as an average of the three middle values. This average should be rounded down to the nearest 0,05 value in such a way that the established value must not be higher than 95 % of the measured value according to the following formula.

$$\frac{\textit{established value}}{\textit{measured value}} \leq 0{,}95$$

Annex A – Inclination tests do determine the static friction factor – results

Sliding surfaces



X – surface between the cargo (sawn wood pallet, plane wood, plastic pallet, concrete rough, concrete smooth, steel crate) and anti-slip mats

Y – surface between the anti-slip mats and the support surface (plywood, grooved aluminium, sawn wood, stainless steel, shrink film)

Fabric base laminate/ plywood surface

Dry surface

Wet surface

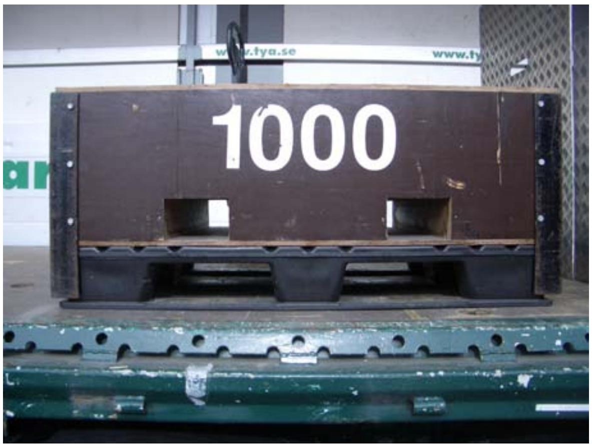
Platform		Fabric base laminate/ plywood											
		Without anti-slip mats						With anti-slip mats					
		dry			wet			dry			wet		
Cargo	Test values*	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ
Sawn wood	1	28,5	0,54		35	0,70		36^{Y}	0,73		36^{Y}	0,73	
	2	29,5	0,57		35,5	0,71		$37,5^{Y}$	0,77		$37^{X,Y}$	0,75	
	3	30	0,58	0,58	36	0,73	0,73	38^{Y}	0,78	0,78	$37^{X,Y}$	0,75	0,76
	4	30,5	0,59		36,5	0,74		38^{Y}	0,78		$37,5^{X,Y}$	0,77	
	5	34	0,67		37,5	0,77		$39,5^{Y}$	0,82		38^{Y}	0,78	
Plane wood	1	19	0,34		33,5	0,66					$38^{X,Y}$	0,78	
	2	19,5	0,35		34	0,67					$40^{X,Y}$	0,84	
	3	21	0,38	0,38	34	0,67	0,67				$40^{X,Y}$	0,84	0,84
	4	22,5	0,41		34	0,67					40^{X}	0,84	
	5	22,5	0,41		35,5	0,71					$41,5^{X,Y}$	0,88	
Plastic pallet	1	18	0,32		14	0,25		29^{X}	0,55		35^{X}	0,70	
	2	19,5	0,35		16	0,29		30^{X}	0,58		$35,5^{X}$	0,71	
	3	20	0,36	0,36	16,5	0,30	0,29	30^{X}	0,58	0,58	37^{X}	0,75	0,74
	4	20	0,36		16,5	0,30		30^{X}	0,58		37^{X}	0,75	
	5	22	0,40		18,5	0,33		$30,5^{X}$	0,59		$37,5^{X}$	0,77	

* The values in all tables are ordered in adjusted sequence from the lower to the higher value. Mainly the value from the first test of each series was higher then others.

Platform		Fabric base laminate/ plywood											
		Without anti-slip mats						With anti-slip mats					
		dry			wet			dry			wet		
Cargo	Test values*	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ
Steel crate	1	29	0,55		29,5	0,57		37,5[X]	0,77		37[Y]	0,75	
	2	29	0,55		29,5	0,57		38[X]	0,78		37[X]	0,75	
	3	30	0,58	0,57	30	0,58	0,57	38[X]	0,78	0,79	38,5[X,Y]	0,80	0,79
	4	30	0,58		30	0,58		39[X]	0,81		39[X]	0,81	
	5	30,5	0,59		32,5	0,64		39[X]	0,81		39[X]	0,81	

Sawn wood

Plane wood



Plastic pallet

Steel crate

Grooved aluminium surface

Dry surface

Wet surface

Platform		Grooved aluminium											
		Without anti-slip mats						With anti-slip mats					
		dry			wet			dry			wet		
Cargo	Test values	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ
Sawn wood	1	27	0,51		34	0,67		38,5^{Y}	0,80		36^{Y}	0,73	
	2	28	0,53		34	0,67		40^{Y}	0,84		37^{Y}	0,75	
	3	28	0,53	0,54	34	0,67	0,67	40^{Y}	0,84	0,84	37^{Y}	0,75	0,77
	4	28,5	0,54		34	0,67		40,5^{Y}	0,85		38,5^{Y}	0,80	
	5	29,5	0,57		34,5	0,69		40,5^{Y}	0,85		40^{Y}	0,84	
Plane wood	1	16	0,29		25	0,47		36^{X}	0,73		34^{X,Y}	0,67	
	2	18	0,32		26	0,49		38,5^{Y}	0,80		35^{X,Y}	0,70	
	3	19,5	0,35	0,35	26	0,49	0,49	39,5^{Y}	0,82	0,82	35,5^{Y}	0,71	0,71
	4	20	0,36		26	0,49		40^{X}	0,84		35,5^{X,Y}	0,71	
	5	20	0,36		26,5	0,50		40^{Y}	0,84		37^{X,Y}	0,75	
Plastic pallet	1	13	0,23		11,5	0,20		30,5^{X}	0,59		34^{X,Y}	0,67	
	2	13,5	0,24		12	0,21		30,5^{X}	0,59		34,5^{X,Y}	0,69	
	3	14	0,25	0,25	12	0,21	0,22	30,5^{X}	0,59	0,59	35^{Y}	0,70	0,70
	4	14	0,25		12,5	0,22		31^{X}	0,60		35^{Y}	0,70	
	5	14,5	0,26		14	0,25		32^{X}	0,62		35,5^{X,Y}	0,71	
Steel crate	1	21	0,38		31,5	0,61					37^{X}	0,75	
	2	21,5	0,39		32	0,62					37,5^{X}	0,77	
	3	21,5	0,39	0,39	32	0,62	0,62				38^{Y}	0,78	0,78
	4	21,5	0,39		32	0,62					38^{X}	0,78	
	5	28,5	0,54		32	0,62					38,5^{X,Y}	0,80	

Sawn wood

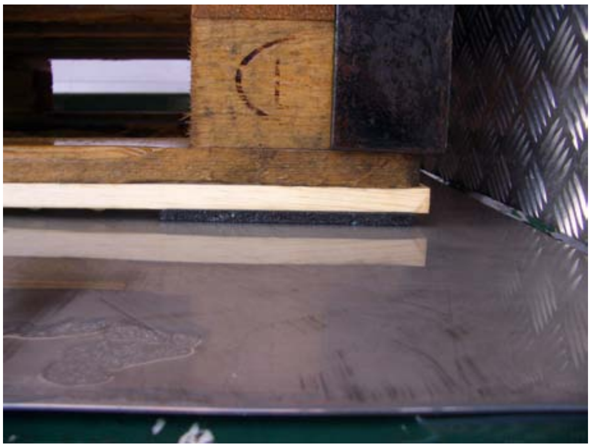
Plane wood

Plastic pallet

Steel crate

Smooth stainless steel surface

Dry surface

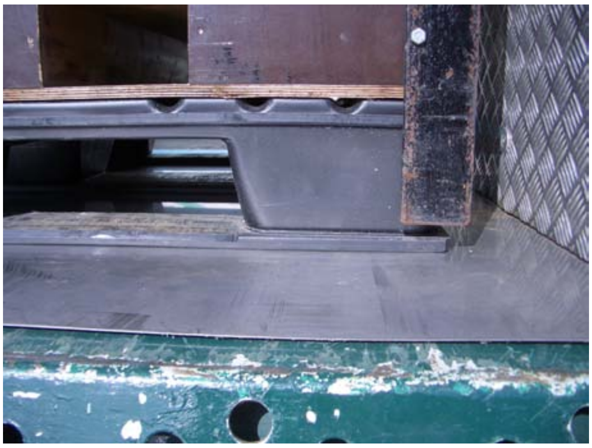


Wet surface

Platform		Smooth stainless steel											
		Without anti-slip mats						With anti-slip mats					
		dry			wet			dry			wet		
Cargo	Test values	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ	inclination angle [°]	μ	average μ
Sawn wood	1	20	0,36		27,5	0,52		37^{Y}	0,75		32^{Y}	0,62	
	2	20,5	0,37	0,37	30	0,58	0,59	38^{Y}	0,78	0,78	33^{Y}	0,65	0,67
	3	20,5	0,37		30	0,58		38^{Y}	0,78		$33,5^{Y}$	0,66	
	4	20,5	0,37		31	0,60		38^{Y}	0,78		$34,5^{Y}$	0,69	
	5	21,5	0,39		32,5	0,64		$38,5^{Y}$	0,80		36^{Y}	0,73	
Plane wood	1	14,5	0,26		29	0,55					$34,5^{Y}$	0,69	
	2	16	0,29	0,29	29,5	0,57	0,57				35^{Y}	0,70	0,71
	3	16	0,29		30	0,58					35^{Y}	0,70	
	4	16	0,29		30	0,58					36^{Y}	0,73	
	5	16,5	0,30		30	0,58					$37,5^{Y}$	0,77	
Plastic pallet	1	10	0,18		12	0,21		$32^{X,Y}$	0,62		$34^{X,Y}$	0,67	
	2	10	0,18	0,19	12	0,21	0,22	$32^{X,Y}$	0,62	0,63	$34^{X,Y}$	0,67	0,68
	3	10,5	0,19		12	0,21		$32,5^{X,Y}$	0,64		$34^{X,Y}$	0,67	
	4	11	0,19		12,5	0,22		$32,5^{X,Y}$	0,64		$34,5^{X,Y}$	0,69	
	5	11	0,19		15	0,27		$32,5^{X,Y}$	0,64		$35,5^{X,Y}$	0,71	
Steel crate	1	13,5	0,24		19,5	0,35							
	2	14	0,25	0,25	20	0,36	0,37						
	3	14	0,25		20	0,36							
	4	14,5	0,26		20,5	0,37							
	5	14,5	0,26		23	0,42							

Sawn wood

Plane wood



Plastic pallet

Steel crate

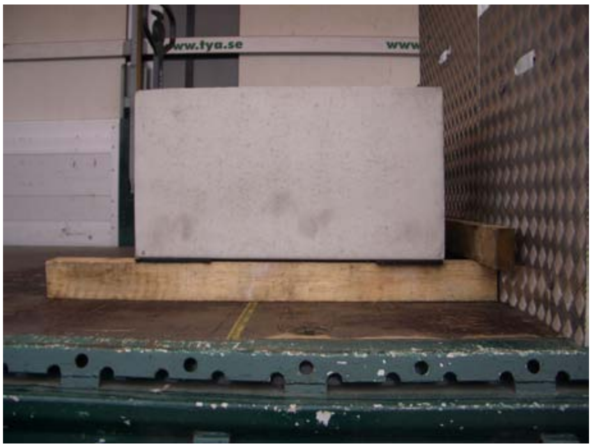
Rough/smooth concrete on wooden battens

Supporting battens		Sawn wood											
		Without anti-slip mat						With anti-slip mat					
		dry			wet			dry			wet		
Cargo	Test values	inclination angle [°]	μ	average μ	inclination angle	μ	average μ	inclination angle	μ	average μ	inclination angle	μ	average μ
Concrete rough	1	38,5	0,80					39^{X}	0,81				
	2	38,5	0,80	0,84				$39,5^{X}$	0,82	0,87			
	3	39,5	0,82					$41,5^{X}$	0,88				
	4	42	0,90					42^{X}	0,90				
	5	42	0,90					42^{X}	0,90				
Concrete smooth	1	34	0,67		33,5	0,66		40^{X}	0,84		34^{X}	0,67	
	2	34,5	0,69	0,71	33,5	0,66	0,67	40^{X}	0,84	0,87	$34^{X,Y}$	0,67	0,69
	3	36	0,73		34	0,67		$41,5^{X}$	0,88		$35^{X,Y}$	0,70	
	4	36	0,73		34	0,67		$41,5^{X,Y}$	0,88		$35^{X,Y}$	0,70	
	5	38	0,78		34,5	0,69		$42,5^{X,Y}$	0,92		38^{X}	0,78	

The wooden battens were blocked against the blocking board.

Rough concrete

Smooth concrete



Dry smooth concrete with anti-slip mats

Wet smooth concrete with anti-slip mats

Sawn wooden pallet on shrink film

Surface		Shrink film		
		Without anti-slip mats		
		dry		
Cargo	Test values	inclination angle [°]	μ	average μ
Wooden pallet	1	23	0,42	
	2	23,5	0,43	0,44
	3	24	0,45	
	4	24	0,45	
	5	24	0,45	

The bottom pallet is “living” (soft). The stack inclines itself. The noted angle was measured between two pallets in stack. Bottom pallet is blocked against movement.