Load Restraint Guide

PART 2

for

Engineers and Designers

SECTION F

Calculating Restraint Requirements

CONTENTS

The following contains specialised information useful to engineers and designers for the design and selection of load restraint systems.

1 PERFORMANCE STANDARDS

Loads must be restrained to prevent unacceptable movement during all expected conditions of operation. The load restraint system must, therefore, satisfy the following requirements:

(i) The load should not become dislodged from the vehicle.

(ii) Any load movement should be limited, such that in all cases where movement occurs, the vehicle's stability and weight distribution cannot be adversely affected and the load cannot become dislodged from the vehicle.

Loads that are permitted to move relative to the vehicle include loads that are effectively contained within the sides or enclosure of the vehicle body such as:

- (a) Loads which are restrained from moving horizontally (limited vertical movement is permissible);
- (b) Very lightweight objects or loose bulk loads (limited horizontal and vertical movement is permissible);
- (c) Bulk liquids (limited liquid movement is permissible);

To achieve this, the load restraint system must be capable of withstanding the forces that would result if the laden vehicle were subjected to each of the following separately:

0.8 'g' deceleration in a forward direction,

0.5 'g' deceleration in a rearward direction,

0.5 'g' acceleration in a lateral direction,

and to 0.2 'g' acceleration relative to the load in a vertical direction.

Note:* *'g' (the acceleration due to gravity), is equal to 9.81 metres/sec/sec for the purpose of these standards.

2 METHODS OF LOAD RESTRAINT

When selecting and calculating the strength of various restraint systems for loads that are contained or secured on the vehicle, consideration should be given to each of the following load restraint methods:

(i) tie-down to clamp the load against the body structure;

(ii) containing the load within the body structure;

(iii) blocking the load against a body structure or attachment; and

(iv) attaching the load directly to the body structure.

3 DESIGN FOR TIE-DOWN METHOD

Tie-down loads are restrained by friction between the load and the vehicle. Friction can also restrain items of load in contact with other items of load.

The friction is a result of the weight of the load and the extra clamping force applied by the lashings.

3.1 Friction Force

The friction force (F) can be calculated by multiplying the friction coefficient (μ) by the normal force (N) between the load and deck or any other surface the load sits on (see Figure F.1):

$$F = \mu \times N$$

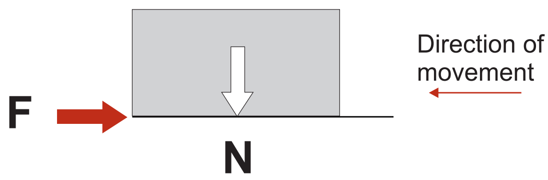


Fig. F.1 **FRICTION FORMULA**

The normal force N is the weight (N_W) of the load plus the tie-down force (N_L) from the combined vertical components of the lashing tensions.

$$N = N_W + N_L$$

N_L is dependent on the lashing angle(s) and the lashing tension(s) and is equal to the sum of all of the lashing tensions on each side of the load, multiplied by the angle effect E (see Figure F.3).

3.2 Friction Coefficient

The friction coefficient (friction factor) is used to compare the load restraint friction force between two surfaces. The static friction coefficient applies before movement begins and the dynamic friction coefficient applies once movement occurs. Note that the dynamic friction coefficient is often 20% to 30% less than the static friction coefficient although it can sometimes be more than 30%. The static friction coefficient can be measured by two methods. These are a tilt test and a horizontal push/pull test, which should give the same result.

The tilt method involves tilting the deck with the load on it and measuring the angle of tilt when the load just begins to move. The friction coefficient is the tangent of the angle of tilt (θ) to the horizontal.

$$\mu = \tan\ \theta$$

The push/pull test involves pushing or pulling the load on a horizontal deck and measuring the friction force (F) required to start the load moving. The friction coefficient is the ratio of the friction force to the weight of the load (N_w).

$$\mu = F \div N_w$$

Where the design of a restraint system relies on the weight of the load plus lashing pre-tension, the static friction coefficient should be used. Where the design relies on the weight of the load plus tensioning by load shift (see Section F 3.7) the dynamic friction coefficient must be used. Some typical static friction coefficients are listed in Table F.1.

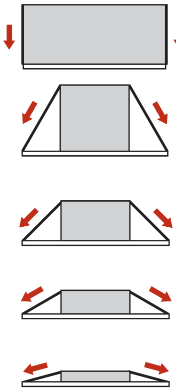
TYPICAL STATIC FRICTION COEFFICIENTS	
Load surfaces	**Friction coefficient**
Wet or greasy steel on steel	0.01 – 0.1
Smooth steel on smooth steel	0.1 – 0.2
Smooth steel on rusty steel	0.2 – 0.4
Smooth steel on timber	0.3 – 0.4
Smooth steel on conveyor belt	0.3 – 0.4
Smooth steel on rubber load mat	0.6 – 0.7
Rusty steel on rusty steel	0.4 – 0.7
Rusty steel on timber	0.6 – 0.7

Table F.1

These figures are a guide and should not be used for the design of a load restraint system. Where accurate information is not available, testing of the load should be performed or a conservative value chosen. The tests should take into account all possible combinations of surface conditions that might be encountered such as, wet, dry or greasy.

3.3 Lashing Angles

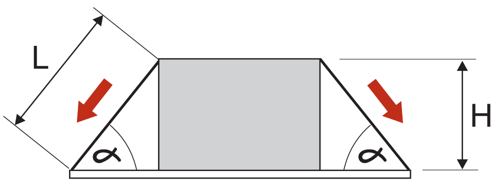
If a tie-down lashing is not vertical between the load and the tie point, its effectiveness is reduced below 100% (see Figure F.2). This is called the tie-down 'angle effect' (E).



APPROX. ANGLE	TIE-DOWN ANGLE EFFECT	TIE-DOWN EFFECTIVENESS
90°	1.00	100%
60°	0.85	85%
45°	0.70	70%
30°	0.50	50%
15°	0.25	25%

Fig. F.2 **TIE-DOWN ANGLE EFFECT**

The angle effect can be calculated by dividing the height of the load by the length of the lashing between the load and the tie point on the vehicle (see Figure F.3). The angle effect is the sine of the lashing angle (α) relative to the horizontal ($E = \sin\alpha$).



Angle effect (E) = Height of Load (H) ÷ Length of Lashing (L)

Fig. F.3 **CALCULATING THE TIE-DOWN ANGLE EFFECT (E)**

The tie-down force from each lashing is the sum of the lashing tension on each side of the load, multiplied by the angle effect.

3.4 Lashing Pre-tension

The pre-tension is the force in the lashing provided by a mechanical tensioner or a knot.

To maintain the friction force during normal driving, the load must always remain in contact with the deck during road vibration and over bumps. To achieve this, the tie-down lashings must be pre-tensioned to provide a minimum clamping force of 20% of the weight of the load.

Average lashing pre-tensions are shown in Table F.2. Note that the figures shown in the table are operator and equipment dependent. The pre-tension on one side of a load is normally greater than the pre-tension on the other side unless the tensioner is positioned on top of the load. The differences of pretension caused by friction between the lashing and the load can be in the ratio of 4:1. In some circumstances, it is advisable to establish the pre-tension that can be achieved by the equipment, and by each operator, using in-line load indicators.

AVERAGE PRE-TENSION			
Lashing	**Size**	**Tensioner**	**Pre-tension**
Rope	10 mm & 12 mm	Single Hitch Double Hitch	50 kg 100 kg
Webbing Strap	25 mm 35 mm 50 mm 50 mm 50 mm	Hand Ratchet Hand Ratchet Truck Winch Hand Ratchet (push up) Hand Ratchet (pull down)	100 kg 250 kg 300 kg 300 kg 600 kg
Chain	7mm & above	Dog Turnbuckle	750 kg 1000 kg

Table F.2 (Also appears in Section K – Tables)

Where 75 and 100 mm webbing straps are used, their tensioners may not achieve as much pre-tension as the 50 mm tensioners, even though their lashing capacity is greater. The larger tensioners are sometimes designed for different purposes. Check their rating with the manufacturer.

The pre-tension achieved with chain tensioners is approximately the same for 7 mm, 8 mm, 10 mm and 13 mm chains.

3.5 How Many Lashings? - Using Tie-down Load Tables

The following load tables can be used to determine the maximum weight that can be restrained by each lashing. The tables include loads with or without blocking in front, on medium friction (μ = 0.4) and high friction (μ = 0.6) surfaces. They take into account the required minimum clamping force of 20% of the weight of the load.

If the tie-down provides the required 0.5 'g' sideways and rearward restraint it will also provide a 0.5 'g' forward restraint. The tables have also been compiled on the assumption that the blocking has the capacity to provide the additional 0.3 'g' forward restraint to meet the 0.8 'g' forward restraint requirement.

To find the number of lashings required, divide the total weight of the load by the weight that each lashing can restrain.

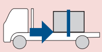
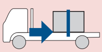
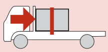
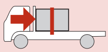
MAXIMUM WEIGHT EACH 10 OR 12 mm ROPE CAN RESTRAIN (USING SINGLE HITCH)					
FRONT OF LOAD BLOCKED?		**NO**		**YES**	
HOW MUCH FRICTION?		**MEDIUM** μ = 0.4 (Smooth Steel on Timber)	**HIGH** μ = 0.6 (Rubber Load Mat)	**MEDIUM** μ = 0.4 (Smooth Steel on Timber)	**HIGH** μ = 0.6 (Rubber Load Mat)
Minimum average rope tension 50 kg.					
ROPE ANGLE	ANGLE EFFECT (E)				
90°	1.0	100 kg	300 kg	400 kg	500 kg
approx. 60° to 90°	0.85 to 1.0	85 kg	255 kg	340 kg	425 kg
approx. 45° to 60°	0.70 to 0.84	70 kg	210 kg	280 kg	350 kg
approx. 30° to 45°	0.50 to 0.69	50 kg	150 kg	200 kg	250 kg
approx. 15° to 30°	0.25 to 0.49	25 kg	75 kg	100 kg	125 kg

Table F.3 (Also appears in Section K – Tables)

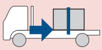
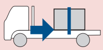
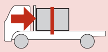
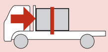
MAXIMUM WEIGHT EACH 10 OR 12 mm ROPE CAN RESTRAIN (USING DOUBLE HITCH)					
FRONT OF LOAD BLOCKED?		**NO**		**YES**	
HOW MUCH FRICTION?		**MEDIUM** μ = 0.4 (Smooth Steel on Timber)	**HIGH** μ = 0.6 (Rubber Load Mat)	**MEDIUM** μ = 0.4 (Smooth Steel on Timber)	**HIGH** μ = 0.6 (Rubber Load Mat)
Minimum average rope tension 100 kg.					
ROPE ANGLE	ANGLE EFFECT (E)				
90°	1.0	200 kg	600 kg	800 kg	1000 kg
approx. 60° to 90°	0.85 to 1.0	170 kg	510 kg	680 kg	850 kg
approx. 45° to 60°	0.70 to 0.84	140 kg	420 kg	560 kg	700 kg
approx. 30° to 45°	0.50 to 0.69	100 kg	300 kg	400 kg	500 kg
approx. 15° to 30°	0.25 to 0.49	50 kg	150 kg	200 kg	250 kg

Table F.4 (Also appears in Section K – Tables)

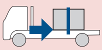
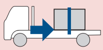
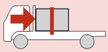
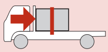
MAXIMUM WEIGHT EACH 50 mm WEBBING STRAP CAN RESTRAIN					
FRONT OF LOAD BLOCKED?		**NO**		**YES**	
HOW MUCH FRICTION?		**MEDIUM** µ = 0.4 (Smooth Steel on Timber)	**HIGH** µ = 0.6 (Rubber Load Mat)	**MEDIUM** µ = 0.4 (Smooth Steel on Timber)	**HIGH** µ = 0.6 (Rubber Load Mat)
Minimum average strap tension 300 kg.					
STRAP ANGLE	ANGLE EFFECT (E)				
90°	1.0	600 kg	1800 kg	2400 kg	3000 kg
approx. 60° to 90°	0.85 to 1.0	510 kg	1530 kg	2040 kg	2550 kg
approx. 45° to 60°	0.70 to 0.84	420 kg	1260 kg	1680 kg	2100 kg
approx. 30° to 45°	0.50 to 0.69	300 kg	900 kg	1200 kg	1500 kg
approx. 15° to 30°	0.25 to 0.49	150 kg	450 kg	600 kg	750 kg

Table F.5

(Also appears in Section K – Tables)

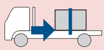
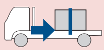
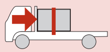
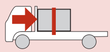
MAXIMUM WEIGHT EACH 8 mm CHAIN CAN RESTRAIN					
FRONT OF LOAD BLOCKED?		**NO**		**YES**	
HOW MUCH FRICTION?		**MEDIUM** μ = 0.4 (Smooth Steel on Timber)	**HIGH** μ = 0.6 (Rubber Load Mat)	**MEDIUM** μ = 0.4 (Smooth Steel on Timber)	**HIGH** μ = 0.6 (Rubber Load Mat)
Minimum average chain tension 750 kg.					
CHAIN ANGLE	ANGLE EFFECT (E)				
90°	1.0	1500 kg	4500kg	6000 kg	7500 kg
approx. 60° to 90°	0.85 to 1.0	1275 kg	3825 kg	5100 kg	6375 kg
approx. 45° to 60°	0.70 to 0.84	1050 kg	3150 kg	4200 kg	5250 kg
approx. 30° to 45°	0.50 to 0.69	750 kg	2250 kg	3000 kg	3750 kg
approx. 15° to 30°	0.25 to 0.49	375 kg	1125 kg	1500 kg	1875 kg

Table F.6

(Also appears in Section K – Tables)

Example:

The following example shows how to find the number of lashings using the load tables F.3, F.4, F.5, F.6:

"A vehicle is carrying an 8 tonne load. The load is blocked against a strong headboard (minimum capacity 30% of the weight of the load). The load is supported on timber dunnage that provides medium friction. The height of the load is 1.2 metres and the length of the lashing between the top of the load and the tie point is 1.6 metres on each side. How many ropes, webbing straps or chains are required?"

The angle effect (E), is 1.2 metres (H) divided by 1.6 (L) metres;

ie. the angle effect, E = 1.2 ÷ 1.6 = 0.75

Refer to the tables:

- The angle effect is 0.75, therefore the third row (0.70 to 0.84) applies.
- The friction is classed as medium and the load is blocked, therefore the third column of weight applies.
- The maximum weight that can be restrained by each lashing can then be selected (third row, third column).

To find the number of lashings required, divide the weight of the load by the weight selected:

- A rope with a single hitch will restrain 280 kg. (Table F.3)
  The number of ropes required is 8000 ÷ 280 = 29
- A rope with a double hitch will restrain 560 kg. (Table F.4)
  The number of ropes required is 8000 ÷ 560 = 15
- A webbing strap will restrain 1680 kg. (Table F.5)
  The number of straps required is 8000 ÷ 1680 = 5
- A chain will restrain 4200 kg. (Table F.6)
  The number of chains required is 8000 ÷ 4200 = 2

3.6 How Many Lashings? - By Calculation.

The number of lashings in the above example (with a weight of 8000 kg and a friction coefficient of 0.4) can be calculated using the actual lashing angle. This may result in fewer lashings being required.

The load must be restrained to 0.8 'g' in the forward direction. As the front of the load is blocked, the tie-down needs only to provide 0.5 'g' forward, sideways and rearward restraint, if the blocking is capable of providing the additional 0.3 'g' forward restraint.

Therefore, the amount of tie-down restraint required is,

$$F = 0.5\text{ 'g' } \times N_W = 0.5 \times 8000 = 4000 \text{ kg.}$$

The friction force F_W from the weight of the load is,

$$F_W = \mu \times N_W = 0.4 \times 8000 = 3200 \text{ kg.}$$

The friction force F_L required from the tie-down lashings is the difference between the total restraint force required and the friction force from the weight of the load,

$$F_L = F - F_W = 4000 - 3200 = 800 \text{ kg.}$$

The required tie-down force N_L is calculated by dividing the friction force F_L by the friction factor μ,

$$N_L = F_L \div \mu = 800 \div 0.4 = 2000 \text{ kg.}$$

As the lashings are not vertical, the angle effect (E) must calculated,

$$E = H \div L = 1.2 \div 1.6 = 0.75.$$

The tie-down force from one lashing is calculated by multiplying twice the lashing pre-tension (T), by the angle effect (E).

(Note: A factor of two is used because the lashing clamps on boths sides of the load.)

In this example, tie-down force from one lashing,

$$2T \times E = 2T \times 0.75 = 1.5T.$$

To obtain the number of lashings (n) required, divide the required tie-down force N_L by the tie-down force from one lashing,

$$n = 2000 \div 1.5T = 1333 \div T.$$

Taking into account differences in tension on each side of the load, typical average tie-down pre-tensions are:

- rope with a single hitch, 50 kg
- rope with a double hitch, 100 kg
- webbing strap, 300 kg
- chain. 750 kg

Therefore, the number of lashings are:

- rope with a single hitch, 1333 ÷ 50 = 27
- rope with a double hitch, 1333 ÷ 100 = 14
- webbing strap, 1333 ÷ 300 = 5
- chain. 1333 ÷ 750 = 2

It is now necessary to check that the tie-down lashing pre-tension provides a minimum clamping force of 20% of the weight of the load.

The total tie-down force (N_L) must be at least equal to 20% of the weight of the load (N_W),

$$N_L \div N_W = 2000 \div 8000 = 0.25 \text{ (or 25\%)},$$

which is greater than the 20% N_W required.

3.7 How Many Lashings? - Tensioning By Load Shift

Specialised load restraint systems can be designed to incorporate load shift to increase lashing tension. As the load shifts forward under heavy braking, the lashings stretch and clamp the load harder against the deck thus increasing the friction force.

These systems must allow for very small forward load shifts only and must be capable of absorbing the energy required to stop the moving load.

Sideways movement must be prevented to avoid degrading stability. Where the system is restrained by tie-down in the sideways and rearwards directions, the required restraint must be achieved using the clamping forces resulting only from the weight of the load and the initial lashing pre-tension.

To allow the lashing to stretch under forward load shift, the lashing must be prevented from slipping on the load by:

- attaching it to the load;
- passing it through the load;
- passing it in front of an obstruction or protrusion on the load; or
- providing sufficient friction between the load and lashing.

The forward load shift must be limited by controlling the amount of stretch in the lashings. The lashings must therefore have a high stiffness or low stretch characteristic. Steel chain and steel strapping can be suitable, whereas **rope and webbing** are much more elastic, allowing too much load shift and **should not be used unless part of a properly designed load restraint system.**

When multiple lashings are used, there is a possibility that one lashing might reach its lashing capacity well before the rest and break during load shift. This could occur because of many factors including, uneven slippage of the lashing on the load; uneven pre-tension of the lashings; mixed sizes of lashings; a large number of lashings; and uneven flexibility of both the vehicle and load. The system design must account for these factors. As these systems are unpredictable by design, they must be validated by physical testing to 0.8 'g' in the forward direction.

The friction force (F) can be calculated by multiplying the dynamic friction coefficient (μ_D) by the force (N) between the load and deck. The force N is the weight of the load plus the tie-down force.

The tie-down force from each lashing is the sum of the lashing tension on each side of the load, multiplied by the angle effect. The tension in any lashing must not exceed the manufacturers' lashing capacity.

4 DESIGN FOR CONTAINING OR BLOCKING

When designing for containing (see Section J, page 247 for definition of Contained Load and Section E, page 140 for more information) or blocking, if there is no tie-down (ie indirect restraint) to resist the vertical 0.2 "g" nominated in the Performance Standards, the effect of friction between the deck and the load and between layers of load must be neglected in assessing restraint capacity. This is because when the vehicle hits a bump, the resulting jolt can break the friction contact between the items of load. Even a load resting on very high friction rubber load mat can "walk" to the low side of the trailer during a journey, if it is not tied down.

The effect of a raised side coaming rail must be neglected when assessing restraint capacity, if the load is not tied down as the load could jump over the coaming rail in a bump.

When designing vehicle structures such as headboards, loading racks, barriers, curtain sides, side gates and drop sides the following 'loading cases' should be taken into account:

Stable single load	restraint forces act at the lower edge of a free-standing structure or are distributed over the height of the load with a fully supported structure.
Unstable single load	restraint forces are distributed unevenly over the height of the load.
Stacked load	restraint forces are distributed over the height of each item of load
Point load	restraint force acts at point of contact
Loose bulk load	restraint forces are evenly distributed over the height of the load
Impact load	restraint forces could be very high (simulation or testing required).

The stability of each item of load can be determined by reference to Section B.3, page 43.

A single load is a single item or a unitised number of items that are placed in a single layer on the deck. Such unitised loads are, for example, pallets with the load wrapped and strapped to the pallet or strapped packs such as bricks. Items stacked loosely on a pallet cannot be considered a single load, no matter how much friction is between them. They must be considered as separate loose single items.

A stacked load is a number of loose single items or unitised packs of items, stacked on top of each other and includes pallets stacked two-high, loose cartons and many stretch wrapped pallet loads.

Loose loads that cannot be stacked are considered as a loose bulk load.

To satisfy the Performance Standards the side restraint system must not only prevent the load dislodging from the vehicle, it must not allow the load to shift in such a way that makes the vehicle unstable.

Remember, the higher the centre of mass of the load, the greater is the effect of any load shift on the stability of the vehicle. For example, if a relatively lightweight loose bulk volume load with a centre of mass 1500 mm above the trailer deck shifts sideways during a sudden swerve, bulging a side curtain outwards, the effect on the vehicle stability could be much more severe than a single level of heavy pallets moving 50 mm to 100 mm sideways.

The testing requirements for loads that are not tied down, are contained in Section I (How to Certify a Load Restraint System).

5 DESIGN FOR UNITISING

Pallets and packs can be loaded against a headboard or supported by other load. The integrity of a pallet or pack can be tested, as follows:

- restrain the pallet or pack in the same way that it would be transported;
- where the pallet or pack will be supported by a headboard or by other load to a headboard, tilt the pallet or pack to 30 degrees (equivalent to a minimum horizontal acceleration of 0.5 'g');
- where the pallet or pack will not be supported by a headboard or supported by other load to a headboard, tilt the pallet or pack to 53 degrees (equivalent to a minimum horizontal acceleration of 0.8 'g');
- if the packing arrangement or layers in the pallet or pack are not symmetrical when viewed from above, rotate the pallet or pack 90 degrees and repeat the above tests.

The pallet or pack should not show any slippage or significant distortion during these tests.

6 DESIGN FOR DIRECT ATTACHMENT

Where a load is directly attached to a vehicle, the following two cases should be considered:

- *The restraint system provides no additional clamping force to the vehicle.*

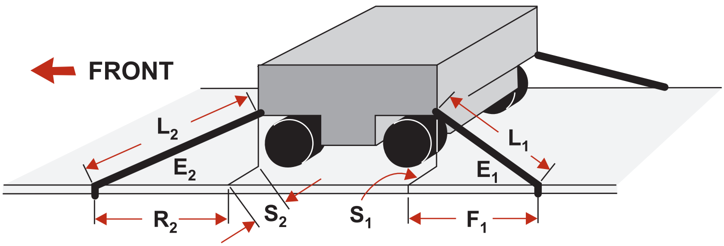
  The friction forces between the load and the deck should not be considered in this case eg. shipping container twistlocks.

- *The restraint system is pre-tensioned or angled to provide additional clamping force to the vehicle.*

When load movement produces increased tension in lashings which are angled downward, additional clamping forces result. The friction forces between the load and the deck can be added to the direct restraint forces eg. sideways restraint of steel tracked equipment.

6.1 Lashing Angles

The angle of the lashing determines the tension that develops in the lashing to restrain a load. The effectiveness of direct lashings (the angle effect E) can be calculated by measuring the horizontal distance in the direction of restraint, from the tie point on the load to the tie point on the vehicle and dividing it by the length of the lashing (see Figure F.4).



For lashing L_1

Angle Effect (E_1) Forwards = Distance (F_1) ÷ Length of Lashing (L_1)

Angle Effect (E_1) Sideways = Distance (S_1) ÷ Length of Lashing (L_1)

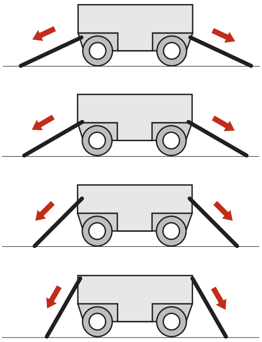
For lashing L_2

Angle Effect (E_2) Rearwards = Distance (R_2) ÷ Length of Lashing (L_2)

Angle Effect (E_2) Sideways = Distance (S_2) ÷ Length of Lashing (L_2)

Fig F.4 **CALCULATING THE DIRECT LASHING 'ANGLE EFFECT'**

As direct lashings become more vertical, they become less effective in providing horizontal restraint (see Figure F.5).



ANGLE	DIRECT LASHING ANGLE EFFECT	DIRECT LASHING EFFECTIVENESS
25^0	0.90	90%
30^0	0.86	86%
45^0	0.70	70%
60^0	0.50	50%

Fig F.5 **ANGLED DIRECT LASHINGS - HOW EFFECTIVE?**

A recommended angle for direct lashings is a slope of 1 in 2 or approximately 25 degrees to the horizontal (see Figure F.6). The lashings will then have an effectiveness of 90% (an angle effect of 0.9).

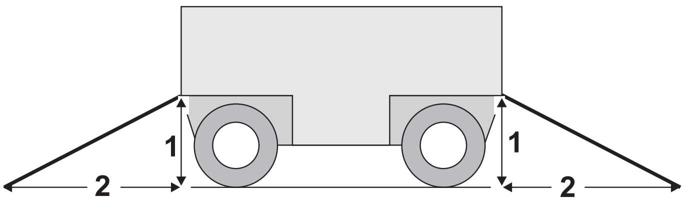


Fig F.6 **RECOMMENDED ANGLE FOR DIRECT LASHINGS**

6.2 Pre-tensioned Direct Lashings

Where a load is restrained by pre-tensioned direct lashings that act in opposite directions, the amount of pre-tension in the lashings can reduce their capacity to restrain the load.

When the load is subjected to a force in one direction, the tension in the lashings opposing the force is increased, whilst the tension in the opposite lashings is reduced. This effect varies depending on the type, length, size or angle of the lashings.

If those lashings where tension has increased are stiffer than the opposite lashings, the force in them will be greater than needed to restrain the load. This is because the more elastic opposite lashings remain partly tensioned.

This effect is more likely to be experienced when different types of lashings such as webbing and chain are used together. Lashings of equal elasticity should be used and should be symmetrically placed to overcome this effect.

6.3 What Strength Chains? - Using Load Tables

The following load tables (see Tables F.7 and F.8) allow selection of the minimum size of chain required when two chains are used to prevent movement in a particular direction. The lashing capacity is listed for loads from 100 kg to 30 tonnes.

The required lashing capacity is greater when:

- restraining heavier loads
- restraining loads in the forward direction
- lashings are angled ineffectively (not opposite to direction of motion).

This table shows the minimum strength (lashing capacity) required for each of two chains directly restraining forward movement.

MINIMUM LASHING CAPACITY - DIRECT RESTRAINT FORWARDS (0.8W) USING TWO CHAINS			
Mass of Load	**Minimum Lashing Capacity**		
(kilograms)	**E = 0.85 to 1.0**	**E = 0.70 to 0.84**	**E = 0.50 to 0.69**
100	48	58	80
200	95	115	160
300	142	172	240
400	189	229	320
500	236	286	400
750	353	429	600
1000	471	572	800
1500	706	958	1200
2000	942	1143	1600
(tonnes)			
3	1.5	1.8	2.4
4	1.9	2.3	3.2
5	2.4	2.9	4.0
6	2.9	3.5	4.8
7	3.3	4.0	5.6
8	3.8	4.6	6.4
9	4.3	5.2	7.2
10	4.8	5.8	8.0
11	5.2	6.3	8.8
12	5.7	6.9	9.6
13	6.2	7.5	10.4
14	6.6	8.0	11.2
15	7.1	8.6	12.0
16	7.6	9.2	12.8
17	8.0	9.8	13.6
18	8.5	10.3	14.4
19	9.0	10.9	15.2
20	9.5	11.5	16.0
21	9.9	12.0	16.8
22	10.4	12.6	17.6
23	10.9	13.2	18.4
24	11.3	13.8	19.2
25	11.8	14.3	20.0
26	12.3	14.9	20.8
27	12.8	15.5	21.6
28	13.2	16.0	22.4
29	13.7	16.6	23.2
30	14.2	17.2	24.0

Table F.7 (Also appears in Section K – Tables)

This table shows the minimum strength (lashing capacity) required for each of two chains directly restraining sideways or rearwards movement:

MINIMUM LASHING CAPACITY - DIRECT RESTRAINT SIDEWAYS OR REARWARDS (0.5W) USING TWO CHAINS			
Mass of Load	**Minimum Lashing Capacity**		
(kilograms)	**E = 0.85 to 1.0**	**E = 0.70 to 0.84**	**E = 0.50 to 0.69**
100	30	36	50
200	59	72	100
300	89	108	150
400	118	143	200
500	148	179	250
750	221	268	375
1000	295	358	500
1500	442	536	750
2000	589	715	1000
(tonnes)			
3	0.9	1.1	1.5
4	1.2	1.5	2.0
5	1.5	1.8	2.5
6	1.8	2.2	3.0
7	2.1	2.5	3.5
8	2.4	2.9	4.0
9	2.7	3.3	4.5
10	3.0	3.6	5.0
11	3.3	4.0	5.5
12	3.6	4.3	6.0
13	3.9	4.7	6.5
14	4.2	5.0	7.0
15	4.5	5.4	7.5
16	4.8	5.8	8.0
17	5.0	6.1	8.5
18	5.3	6.5	9.0
19	5.6	6.8	9.5
20	5.9	7.2	10.0
21	6.2	7.5	10.5
22	6.5	7.9	11.0
23	6.8	8.3	11.5
24	7.1	8.6	12.0
25	7.4	9.0	12.5
26	7.7	9.3	13.0
27	8.0	9.7	13.5
28	8.3	10.0	14.0
29	8.6	10.4	14.5
30	8.9	10.8	15.0

Table F.8

(Also appears in Section K - Tables)

Example:

The following example shows how to find the number of chains using the load tables:

"Find the minimum Transport Chain size that can be used to restrain an 8 tonne steel wheeled roller on a steel deck (no friction) using two chains to prevent forward movement. The length of chain (L_1) between tie points is 2.0 metres. The distance between the tie points (F_1) measured along the vehicle is 1.5 metres (refer to Figure F.4)".

The angle effect is 1.5 metres (F_1) divided by 2.0 (L_1) metres, i.e. E_1 = 0.75

Refer to Table F.7 and note that as the angle effect is between 0.7 and 0.84, the third column applies.

Read the lashing capacity in the centre column in the 'Mass of Load' 8 tonne row. The minimum lashing capacity is 4.6 tonnes.

From Table C.4, or chain manufacturers' specifications, select chains each with a lashing capacity of at least 4.6 tonnes.

Therefore, the two chains must be at least either 10 mm Transport Chain using claw hooks, or winged grab hooks or 13 mm Transport Chain using plain grab hooks.

6.4 What Strength Chains? - By Calculation

The strength of the chains in the above example (with a weight of 8 tonne) can be calculated using the actual lashing angle. This may result in smaller size chains being required.

The angle effect in the forward direction, E = 0.75.

The required forward restraint (0.8 'g') is, 0.8 x 8000 kg = 6400 kg

Each chain must provide, 6400 kg ÷ 2 = 3200 kg of restraint (on the assumption that any tension in the opposite chains has slackened to zero).

Because of the angle effect the chain tension is;

3200 kg ÷ E = 3200 kg ÷ 0.75 = 4267 kg.

From Table C.4, or chain manufacturers' specifications, select chains each with a lashing capacity of at least 4.267 tonnes.

Therefore two 10 mm Transport Chains using either claw hooks, winged grab hooks or grab hooks are the minimum required.

7 DESIGN FOR COMBINED TIE-DOWN AND DIRECT RESTRAINT

There are many load restraint systems where both tie-down and direct restraint can combine to meet the performance standards.

The methods of calculation outlined above can be used for combined systems.

Cotton module tilt test in side direction.

Cotton module tilt test for rearward and forward direction.

Load testing large hay bales (2.4 m x 1.2 m x 1.2 m). In this case only one webbing strap per row was used and the bales collapsed.

The solution was to use two straps and steel edge protectors. This allowed the bales to stay on the fully tilted truck. Without the edge protectors the webbing straps cut through the bales. With the protectors in place the straps could be fully tensioned.