THE EVALUATION OF VARIOUS MATERIALS USED FOR LASHING UNIT LOADS AND NON-STANDARDISED CARGO

ICHCA INTERNATIONAL RESEARCH PAPER #18

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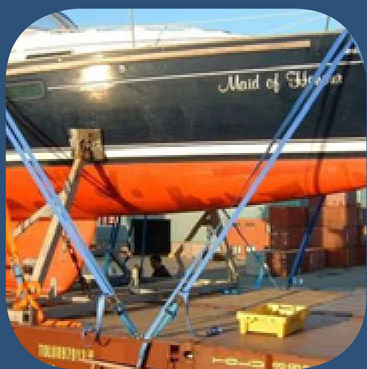

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INTRODUCTION

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TABLE OF CONTENTS

PICTURES, TABLES & GRAPHS

TABLES

PICTURES

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1 | LASHING UNIT LOADS AND NON-STANDARD CARGO

For the purposes of this paper we will consider the properties of the three most popular and commonly used types of lashing materials. These are chain, wire and fabricated web lashings.The requirements for lashing unit loads and non-standardised cargo are contained in the **Code of Safe Practice for Cargo Stowage and Securing (CSS Code) 2011 Edition**.

Section 1.7 of the CSS Code (Equipment) states that:

"The ship's cargo securing equipment should be:

- *Available in sufficient quantity*
- *Suitable for its intended purpose, taking into account recommendations of the Cargo Securing Manual, if provided*
- *Of adequate strength*
- *Easy to use and well maintained"*

The maximum securing load (MSL) of any chosen type of lashing material is shown in **Table 1** below.

The CSS Code does not specify the capacity of the various lashings to be used for non-standard cargo. It is up to the user to:

- Choose the preferred method (wire, chain or web)
- Establish the amount of lashing required by calculation (as described in Annex 13 of the CSS Code)
- Use the lashings in accordance with the guidelines in the CSS Code and the Cargo Securing Manual

There are no specific set limits for the elongation or pre-tension of lashings under the CSS Code. However, the final lashing configuration must fall within the acceptable IMO limits given for accelerations and forces acting on the cargo (e.g. longitudinal, transverse and vertical accelerations, sliding and tipping forces, wind and sea forces, friction etc.).

These forces form the basis for calculations to discover whether or not the lashing configuration to be used is sufficient according to Annex 13 of the CSS Code.

However, the CSS code states clearly that whichever type of lashing system is chosen (chain, wire or web), different materials shall not be mixed when lashing the same load.

This is because different lashing materials behave differently under various environmental and load conditions. For example, the elasticity of each material is different and materials would reach their MSL at different times when coming under load.

In such a case each lashing would be exerting a different force, with some lashing(s) reaching their MSL while others are only part of the way towards it. In addition, different materials have different coefficients of expansion and do not behave in the same way under various thermal and climatic conditions.

DETERMINATION OF MSL FROM BREAKING STRENGTH

Material	MSL
Shackles, deck-eyes, twist locks, lashing rods, D-rings, stackers, bridge fittings, turnbuckles of mild steel	50% of breaking strength
Fibre rope	33% of breaking strength
Wire rope (single use)	80% of breaking strength
Wire rope (re-useable)	30% of breaking strength
Steel band (single use)	70% of breaking strength
Chains	50% of breaking strength
Web lashings	50% of breaking strength

TABLE 1

DETERMINATION OF MSL FROM BREAKING STRENGTH

Source: Section 4.2 CSS Code

Note: MSL denotes the Maximum Securing Load - the term used to define the load capacity for a device used to secure cargo to a ship

2 | WIRE ROPE LASHING

In former times, wire rope lashing was extensively used for securing non-standard cargo on board ships, but the introduction of polyester lashing systems is gradually replacing wire rope. However, wire rope is still available in various sizes, usually as 16mm, 6x12 fc construction with a breaking strength of about 7.5mt. Wire is readily available almost anywhere in the world.

Lashing wire is normally used in conjunction with bulldog clips, shackles and turnbuckles to form an 'assembly' as shown in **Picture 1**.

Securing with wire is a time-consuming process and often done incorrectly. Coils of wire are heavy and have to be cut into the required lengths. Once cut, the wire has to be formed into bights at the end(s), fastened with bulldog grips, secured with shackles and tightened by turnbuckles. All these components must be certified to confirm the MSL of the 'assembly' (a lashing is only as good as its weakest part).

There are a number of problems with wire:

- Injuries have often been experienced with sharp wire slivers, and coiled ends hitting crew or stevedores and/or scratching the cargo
- In bad weather when the lashings need tightening, it is difficult and dangerous work with the number of pieces involved
- It is a labour-intensive task
- It is slow to rig and remove. Single-use wire rope corrodes easily and presents a handling and disposal problem
- Once used, the MSL of wire must be down-graded to 30 percent of its breaking load, or disposed of
- It can 'cut' into, or damage delicate cargo

Experiments have disclosed that wire will slip through the grips at a load of about 70 per cent of its nominal breaking strength (Section 2.5 of the CSS Code emphasises that wire clips should be adequately tightened and greased, so that the 'dead end' of the wire is visibly compressed).

When a new wire rope is used to lash a piece of cargo the lashing may stretch by 2 per cent or more of its original length, but wire rope has no specific yield limit and elongates steadily until it fails.

As noted by the **UK P&I Carefully to Carry (C2C) Committee**, experience continues to show that incorrect application of bulldog grips is the most common cause of wire lashing failure.

Tests indicate that where an eye is formed around a thimble in the correct manner the lashing arrangement will hold secure with loads up to or even in excess of 90% of the nominal break-load (NBL). It is usual and recommended to allow not more than 80%.

Where the correct procedures are not followed slippage is likely to occur at much reduced loads.

PICTURE 1 Wire lashings used to secure pipes on deck

3 | CHAIN LASHING

Generally speaking, chains are used for specific purposes. They are mainly used for securing containers, ro-ro cargo and heavy lift items. In many cases the chain is manufactured to an appropriate length and link size, with fittings attached.

Chain is heavy to handle especially in long lengths. (e.g. timber deck lashing chains). Shorter lengths of chain can be quite useful on ro-ro vessels. But, if it is necessary to secure a whole project cargo, the chain has to be bought in long lengths and then cut to the required size. Bear in mind that such project cargo can require seven or eight kilometres of chain.

Cutting and passing the chain around large pieces of cargo is heavy work. Then, at the end of the voyage, there are numerous miscellaneous lengths remaining that need to be disposed of.

Some of the main problems experienced with chains include:

- Chain does not render well when led round corners etc. and can damage cargo
- It is heavy and slow to use, and difficult and dangerous to handle at heights
- Chain needs to be certified, inspected, maintained, and adds to the vessel's constant
- The added constant is costly in terms of lost carrying capacity and carbon footprint
- Chain has relatively low elasticity and low elongation and may snap under sudden forces
- Chain can damage delicate cargo where it is in contact
- The links can deform easily due to improper use and for this reason **a chain with links deformed more than 3 per cent should not be used**
- Chain has virtually zero shock absorbing properties It is difficult to tighten while at sea

As noted by classification and certification agency **DNV**: *"Chain lashings often become slack after some time, due to motions of ship and cargo, and slack chains with low elasticity will give jerking forces on securing points, cargo and lashings."*

The more elastic web lashings, with proper pre-tensioning, will largely avoid this problem. Modern web lashings also have improved resistance to ripping and chafing.

PICTURE 2
Cargo secured with chains and levers

4 | FABRICATED WEB LASHING

Fabricated web lashings are normally made from polyester and are produced in a wide variety of sizes, strengths and capacities. Web lashings are suitable for nearly all types and sizes of load.

Web lashings are light and easy to handle, usually equipped with hooks and ratchet tensioners, and can be provided with a wide range of end attachments.

Being soft, flat and pliable, web lashings are very cargo friendly and unlikely to cause damage. As a result, notes the **North of England P&I Club**, web lashings:

"may be used for securing a wide range of valuable cargo items, many of which cannot be secured by other means. These include contact sensitive items that may not be provided with lashing points."

The following are web lashing core properties were obtained from one specialist manufacturer:

- Light weight
- Non-corrosive
- Good resistance to heat
- Excellent electrical insulation properties
- Good chemical resistance
- Working temperatures range from -40°C to +100° C
- No fibre optic core and will not create sparks in explosive or hazardous environments
- Maximum elongation permitted is only 3% at WLL (working load limit) i.e. MSL

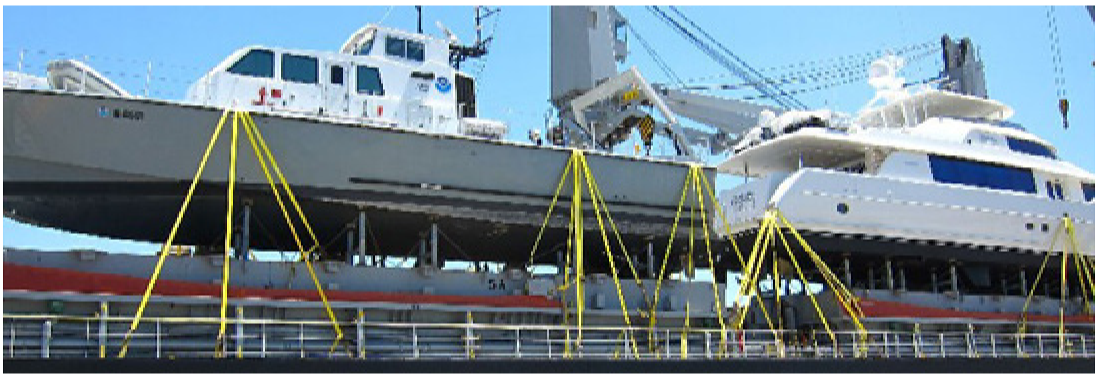
The elongation of web lashings will depend on the specific content and design of the weave. Normally, the elongation of webbing in the useable range is likely to be about 3 per cent.

Fabricated web lashings have good elasticity and will return to their original length. Web lashings of good quality are normally reusable.

Webbing has stretch characteristics similar to wire rope but, unlike wire rope, does not deform permanently at high tension and will return to its original length.

Polyester webbing - the most common type - has the least elongation and is soft, pliable and safe to use with a high shock absorbing capacity of up to 90%.

Nylon is not recommended as a lashing material due to its high elongation. This material also loses 20 per cent of its strength when wet.



PICTURE 3

Fabricated web lashings are considered 'best practice' for the type of cargo shown here because they exert less point load on the cargo than either chain or wire, and so are less liable to damage these sensitive items. Web lashings also have shock-absorbing capabilities

PICTURE 4

PICTURE 5

Pictures 4 and 5 show a heavy-duty ratchet web lashing -suitable for even the heaviest loads such as battle tanks

Key guidance for using web lashings
Only use web lashings manufactured to BS EN 12195-2:2001 that are marinised and certified at 3 per cent elongation
Only use lashings which are clearly marked with a rated assembly strength
Regularly check the system for cuts and frays in the webbing
Never use a bar or lever to tighten the tensioner - this is extremely dangerous
Protect the system from sharp edges
Keep away from alkalis and strong acids
Do not use for lifting
Do not tie knots in the webbing to shorten it
When the tensioner is a ratchet, ensure that there have been at least 2 complete turns of the central pinion after threading

PICTURE 6

An example of delicate high value cargo lashed with web lashings. Web lashings, being soft, flat and pliable, are very cargo friendly.

5 | THE CHOICE OF LASHING MATERIAL

Nowhere does the CSS Code require any particular lashing material or lashing method to be used, or not used.

However, the Code does note that:

- *The proper stowage and securing of cargoes is of the utmost importance for the safety of life at sea. Improper stowage and securing of cargoes has resulted in numerous serious ship casualties and caused injury and loss of life, not only at sea but during loading and discharge*
- *The accelerations acting on a ship in a seaway result from a combination of longitudinal, vertical and predominately transverse motions. The forces created by these accelerations give rise to the majority of securing problems*
- *The hazards arising from these forces should be dealt with by taking measures both to ensure proper stowage and securing of cargo on board and to reduce the amplitude and frequency of ship motions*

All the materials discussed in this paper can be used in most circumstances, but the choice in each case should be based on the material's suitability for, and effects on, the cargo in question. The potential for damage is of course a paramount issue - both to the cargo and the lashing material itself.

Utlimately, the choice of lashing material comes down to experience. As stated in the CSS Code:

"*The guidance given herein should by no means rule out the principles of good seamanship, neither can it replace experience in stowage and securing practice*."

5.1 Friction

Items of cargo will either slide or tip over depending upon their shape, centre of gravity, and the coefficient of friction between cargo and deck. There are many types of lashing equipment and many types of dunnage material. Only those that are appropriate for the particular cargo should be used, and used correctly, to increase friction, to support the piece of cargo and to prevent it from moving. Annex 13 of the CSS Code provides extensive advice on friction, dunnage, optimum lashing angles and acceleration data.

If it is not possible to achieve the required lashing angles, or if there are insufficient lashing points, it may be necessary to employ sea fastenings or chocks to prevent cargo movement.

Sea fastenings may be used in conjunction with conventional lashing wires, chains or webbing straps. The decision to use sea fastenings will be independent of the type of lashing material.

The larger the friction coefficient of the contact surfaces between cargo and deck/dunnage, the larger will be the force required to slide the item of cargo. (Item 7.2 of Annex 13 gives a table of friction coefficients). The coefficient of friction is one of the inputs into the equations required to determine if the lashings are adequate.

There is nothing in IMO regulations, or in any of the input data to the lashing calculations, that discriminates or differentiates between one type of lashing material and another. The only input is MSL.

PICTURE 7 | Typical non-standard cargo of wind turbine components - in this case windmill blades made from fibreglass and composites that can reach 63m or more in length

6 | THE ADVANTAGES OF ELASTICITY IN LASHING

As noted in Chapter 4, fabricated web lashing is the best type of lashing for elasticity. It will store energy for short periods and will revert to its original length. Wire and chain will not do this in the same way.

The importance of elasticity is that it 'stores' energy when stretched and releases it when the load reduces. Hence the load is always restrained, but it can flex. Think here of a sky-scraper or tall building. When an earthquake occurs they are designed and built to flex and sway, thanks to an elaborate system of dampers. It is the same with ships. They bend and flex, and we talk about bending moments. If you are on a large vessel you can literally see it bending in a seaway.

In short, ships are built to flex. Lashings must therefore permit some elasticity or they will simply snap under load (like chain) especially in heavy weather with long pieces of cargo stowed over hatch-covers

When the ship itself deflects, the deflection is transferred to the cargo via the lashings. Because the steel of a ship has elastic properties, the ship itself is elastic. When placed under load, the steel of the hull flexes and moves elastically, returning to its original shape every time.

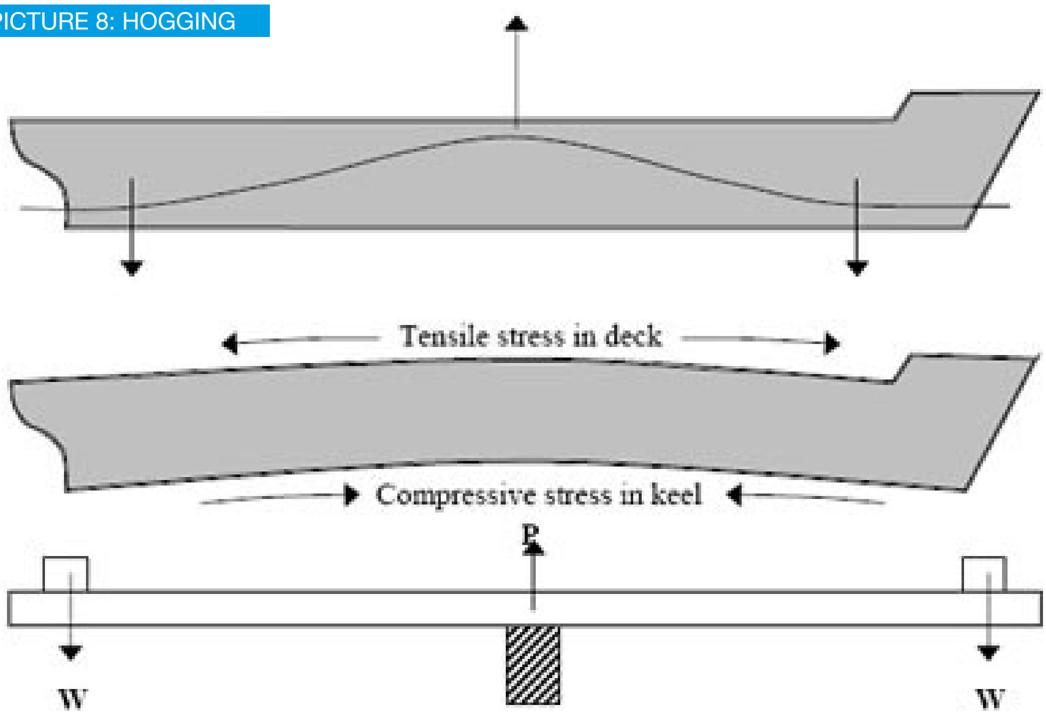
The motions of a ship in heavy seas are a complex combination of pitching, rolling, surging, heaving, yawing, swaying, hogging, sagging, and pounding

When passing through large waves, the whole ship undulates and groans. Big ships are designed to twist and contort in heavy seas, much like airplane wings that bend in turbulence. If they were not flexible, they would break

In heavy seas, this elasticity in the hull ensures the vessel's survival, but it causes a problem for securing. This is because the cargo and the ship are moving relative to each other. The cargo is not necessarily moving relative to a fixed platform

There are numerous video examples now on YouTube of ship bending due to wave motion.

PICTURE 8: HOGGING



6.1 Types of ship bending

Hogging: If the forces of buoyancy are concentrated around the amidships section, the ship will tend to move downwards at the bow and stern while the section amidships will tend to move upwards. In this situation, the deck's structural members are being subjected to tensile stress, while the bottom structure is under compressive stress. **See Picture 8**

Sagging: If the forces of buoyancy are concentrated under the bow and stern of the ship the ship will tend to move upwards at the ends and trough amidships. In this situation, the deck's structural members are under compressive stress while the bottom structure is being subjected to tensile stress. **See Picture 9**

Hogging and sagging occur from the movement of waves passing along the hull. The crest of a wave at each end of the ship combined with a trough amidships will amplify sagging, while a crest amidships combined with a trough at both ends will amplify hogging.

The stresses caused by these situations can be calculated using the load curves, stress and sheer curves, and the bending moments table. Manual or electronic calculators also exist to find the value of the stresses on the hull. The maximum permissible stress values can be found in the ship's stability book.

6.2 Dynamic stresses and constraints

When a ship is under way, some situations create additional stresses. They are caused primarily by the effect of waves on the hull in rough seas. Two of these are pounding and panting.

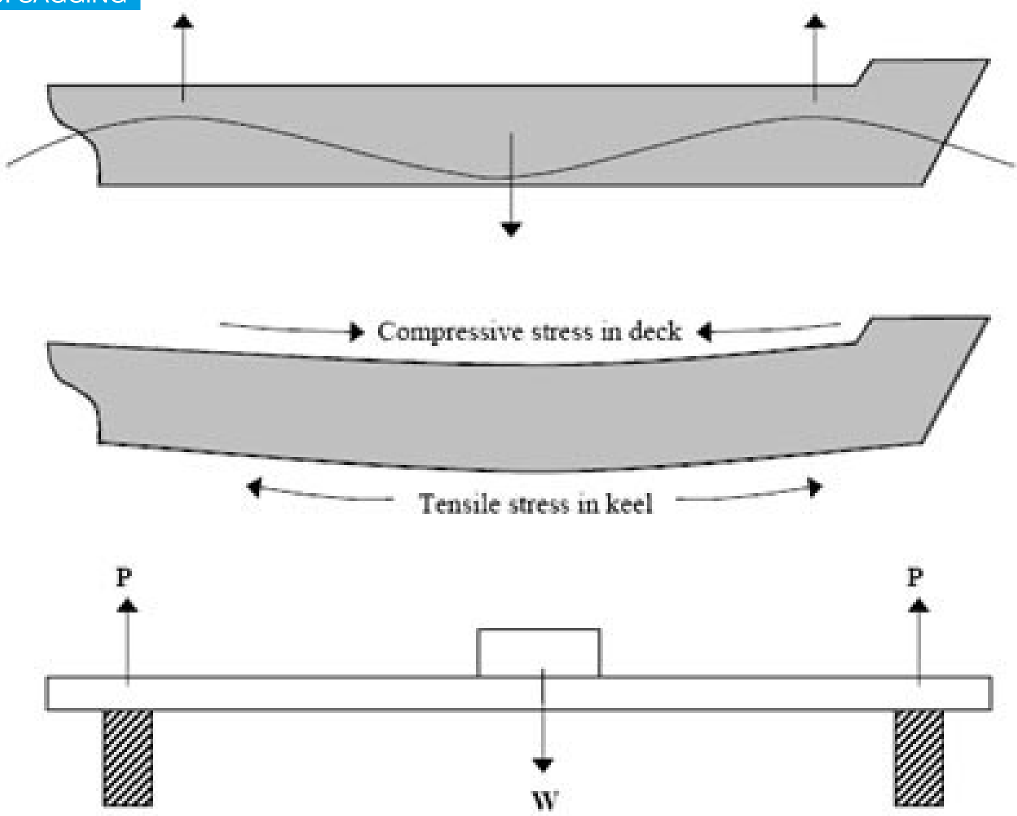
Pounding: When a ship sails in heavy seas, it pitches. It can happen that the bow rises over the crest of a wave and emerges completely out of the water. When the bow comes back down on the water, it can be subjected to a major impact, which is called pounding. The hull plating at the bow end of the ship must be reinforced to avoid bending of the plating. This stress can also occur at the ship's stern, but to a lesser degree.

Panting: When waves hit the bow and stern of a ship, they create variations in pressure that tend to push the plating in and out. This is panting. The framing at the ship's ends must be reinforced to prevent exaggerated movement of the hull plating.

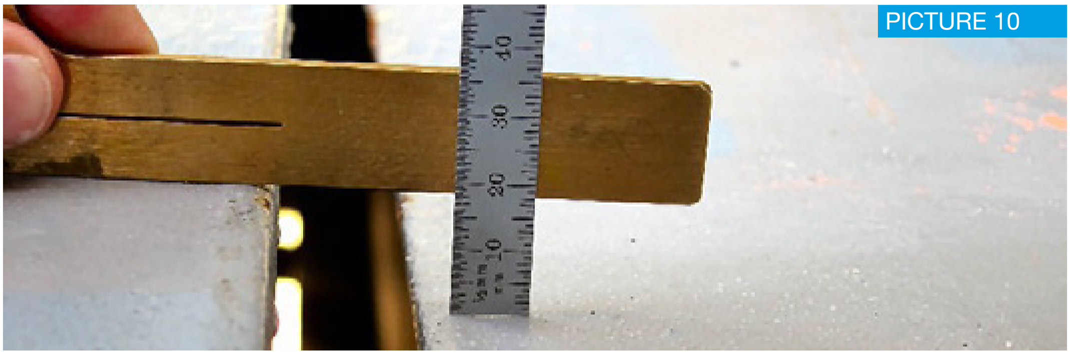
6.3 Hatch-cover deflection

Not only do ships bend and flex themselves, but hatch-covers are also flexible to allow for variations in load, sea conditions and temperature. This is why hatch-covers have built-in expansion joints. Not only does cargo need to be lashed to prevent it from moving, but it has to be lashed to allow for flexing of the hull. With short items of

PICTURE 9: SAGGING



cargo this is relatively unimportant, but with long pieces of cargo such as windmill blades it is a very important factor (as shown in **Chapter 5, Picture 7**, windmill blades can be 63 metres or more in length).



PICTURE 10

Picture 10 above shows hatch-cover deflections being measured. Picture 11 below shows dunnage settling over deflection of hatch-cover

The flexing of a vessel in a seaway can cause large deflections in the hull, which in turn exert excessive stresses on the cargo, the lashings, and the frames. Chains transfer almost 100 per cent of this stress to the cargo in a sharp jerking force, especially if they are slightly slack. Webs have a slower and more gradual response, due to their inherent elasticity (**Picture 10** above shows hatch-cover deflections being measured).

PICTURE 11

At any given moment, we cannot predict what deflections may be encountered on a particular vessel because this depends on many variable factors: the ship, the sea conditions, the cargo and the position of the stowage. Remember, ships are not rigid. They bend and deflect.

There are many dynamics between ship and cargo, not confined to the cargo movement itself. The amount of deflection on any given ship or cargo may be calculated by experts. **But, excessive motion of the ship should be limited as far as possible as per the CSS Code Chapter 6.**

7 | EXCESSIVE ACCELERATIONS

Measures to avoid excessive accelerations include:

- Heaving to
- Alteration of course or speed, or a combination of both
- Early avoidance of areas of adverse weather and sea conditions
- Timely ballasting or de-ballasting to improve the behaviour of the ship, taking into account actual stability conditions

Keeping the ship's motions to a minimum prevents the likelihood of accidents on board and minimises the possibility of items of cargo shifting.

7.1 Methods to assess the efficiency of securing arrangements for non-standardised cargo

Having decided on a lashing configuration it is necessary to test that the arrangement satisfies the IMO requirements by one of four methods described in the CSS Code Annex 13.

7.1.1. Rule-of-thumb method (CSS Code Section 5, Annex 13)

The total of the MSL values of the securing devices on each side of a unit of cargo (port as well as starboard) should equal the weight of the unit. This method, which implies a transverse acceleration of 1g (9.81 m/s2), applies to nearly any size of ship, regardless of the location of stowage, stability and loading condition, season and area of operation.

7.1.2. Advanced calculation method (CSS Code Section 7)

The formulae and inputs required are given in Annex 13 of the CSS Code

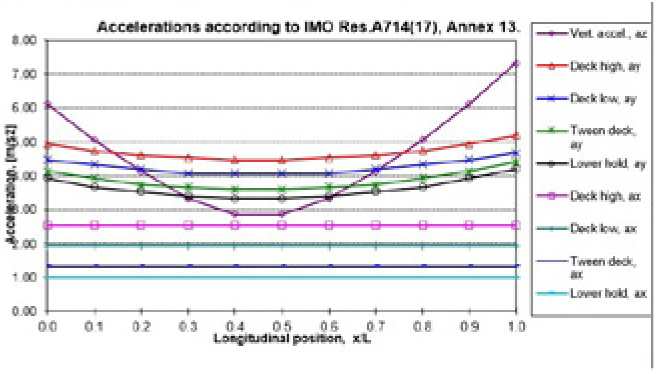
7.1.3. The alternative calculation method (CSS Code Section 7.3)

This method is similar to the Advanced Method, but more precise concerning horizontal securing angles.

7.1.4. Computer programs

There are a number of computer programs based on the above equations that will perform these calculation for you, based on the number and MSL of lashings, frictional coefficient, accelerations, weight of cargo, GM, speed, length of vessel, etc. For example, **DNV** has developed a programme based on the IMO requirements called LashCon. There are others.

LashCon is an MS EXCEL-based calculation tool for evaluation of semi- and non-standardised securing arrangements. The program calculates accelerations and balance of forces in semi- and non-standardised lashing arrangements in accordance with Annex 13 of the CSS Code.



PICTURE 12 Example of part of a LasCon result showing acceleration curves

Remember: There is nothing in IMO regulations, or in any of the required input data to the lashing calculations, that discriminates or differentiates between one type of lashing material and another. The only input is MSL.

There is another way to look at accelerations, and lashing calculations, as eloquently stated in the **North of England P&I publication Cargo Stowage and Securing** under caution:

"The calculations have been formulated with a number of basic understandings in mind, most of which are good seamanship practice

It is assumed that the ship will not roll to an angle of greater than 30 degrees to port and to starboard and that it will not pitch heavily or slam into oncoming swell waves. Also it is understood that the ship will not be running before large stern or quartering seas such that excessive rolling and pitching motions are experienced.

If the ship's motions are very large then clearly the accelerations used within the calculations will be incorrect. The good seamanship answer to this is heaving to, i.e. when the ship is approaching an area of adverse weather and/or high sea or swell conditions, actions should be taken to minimise the motion of the ship by altering course and/or speed."

7.2 Cargo Securing Manual specifications for portable cargo securing devices

This sub-chapter of any Cargo Securing Manual should describe the number of, and the functional and design characteristics of, the portable cargo securing devices carried on board the ship,. Written descriptions should be supplemented by suitable drawings or sketches if deemed necessary.

7.3 Pre-tensioning

All lashings require pre-tensioning and the tightness should be checked regularly. If they become slack due to the movement or vibration of ship or cargo, they should be re-tightened. All lashings must have a method of doing this, e.g. wire with turnbuckles, chain with levers, web lashing with ratchets, or other suitable method.

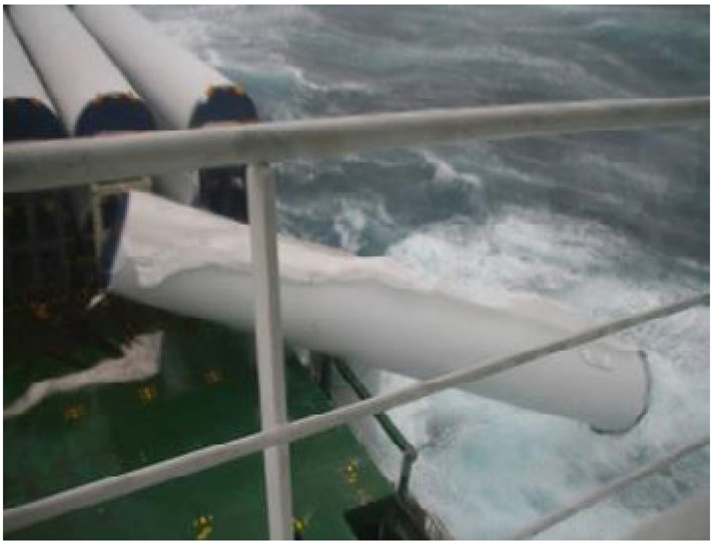
Generally speaking, most cargoes 'settle' during the first 48 hours of a voyage - especially those mounted on dunnage or which have adjustable stacking frames, or boot frames, . Such cargo should be checked frequently and lashings re-tensioned as necessary. **The ease of adjusting web lashings compared with other types of lashing is a huge advantage here.**

In the CSS Code there are no specified 'amounts' for pre-tension, except to say that lashings must be pre-tensioned. As far as possible, lashings should be kept at equal tension.

Aside from web lashing, where the ratchet has a known pre-tension, it is otherwise very difficult to know the amount of pre-tension in wire and chain. It all depends on the force applied, and the length of the extension bars used, which may be much too much or far too little.

In any case, there is no required amount for pre-tension, and no simple way to measure it in use.

PICTURE 13 Poor stowage can result in large claims



7.4 SOLAS

SOLAS (the IMO Convention on Safety of Life at Sea) does not make any specific recommendations regarding cargo securing, but it does say in Chapter 5, Part A, Reg 5:

"Cargo and cargo units carried on or under deck shall be so loaded, stowed and secured as to prevent as far as is practicable, throughout the voyage, damage or hazard to the ship and the persons on board, and loss of cargo overboard."

7.5 Testing standards

MSL testing and certification are the same for all types of lashing. IMO does not differentiate between wire, chain or fabricated web types.

7.6 Distance and route taken by vessel

There are no allowances made in the CSS Code for 'distance travelled', 'short voyages', 'long voyages', etc., except to say in General Principals that:

"Decisions taken for measures of stowage and securing cargo should be based on the most severe weather conditions which may be expected by experience for the intended voyage."

8 | NOTES ON BS EN 12195-2

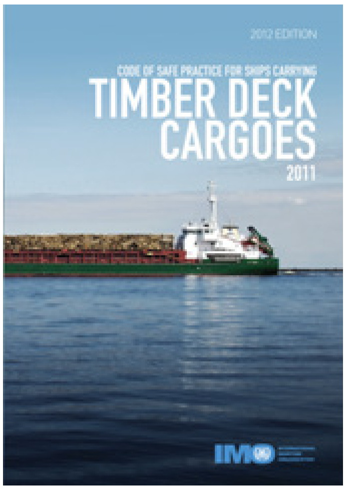
Web lashing is the only form of lashing where any semblance of standard for pretension and elongation is required. This is contained in **British Standard BS EN 12195-2:2001**.

This standard, which refers to load restraint assemblies of road vehicles, says that a web lashing assembly should be tested with a pretension of 0.05 x lashing capacity (which is the amount that can be reasonably applied by human force) up to 3 x lashing capacity. The maximum elongation shall be not more that 7%. But 3 x lashing capacity is far beyond the useable range, and way beyond the allowable MSL, and it gives a false impression of the elongation in the useable range.

The industry standard of 7% is much misunderstood in the maritime world, and very misleading. This is because the actual elongation range of web lashing **when used aboard ships** is in the 'useable' range i.e. from pre-tension to MSL. This is only about 3%. We have confirmed this by independent tests. (See **Appendix 1**)

Although not required by any of the current maritime regulations, some defined range of pre-tension and elongation might be desirable in lashings in order to reassure users, Masters, surveyors, insurers etc., that the product is suitable for the intended purpose. The manufacturer should provide test certificates, or those of conformity, showing the MSL and elongation. The elongation and elasticity of lashing material acts as a shock absorber to dampen forces between ship and cargo. Some defined pre-tension may also be desirable to ensure that lashings are initially neither too tight nor too slack. This should apply to all types of lashing, chain, or wire, or web.

The **IMO Code of Practice for Ships carrying Timber Deck Cargoes 2011** (TDC Code) governs the elongation of all timber deck lashings and applies equally to all types of lashing material. As noted in TDC 5.1.2.2: *"All lashings and components should show an elongation of not more than 5% at 80% of breaking strength."*



This is strictly applicable to the TDC Code, where the lashing strength is expressed as a percentage of breaking strength. In the CSS Code, however, lashing strength is expressed as MSL. The TDC Code specifically permits the use of fabricated web lashings (see **Appendix 2**) and these can now be seen in use on large timber carrying vessels in all the major forestry ports round the world (USA, Canada, New Zealand, Chile etc.).

Now that the TDC Code has set limits of the allowable elongation, previous concerns about the use of web lashings appear to have disappeared.

While these lashings are very long (by the nature of timber deck lashings), this does not appear to give any cause for concern.

9 | CONCLUSIONS AND RECOMMENDATIONS

9.1 Wire lashing

As mentioned earlier, wire will continue to elongate until it fails. Part of the problem with wire is that the wire itself is only part of a lashing 'assembly' that includes wire, grips, turnbuckles and shackles. The assembly of wire lashings is highly dependent on 'human' factors to ensure proper tightness and proper application of bulldog grips. Even then, a wire assembly will fail under different loads depending on how it was assembled. It is not difficult to test the whole arrangement, but there are no particular standards by which to measure such a test. There is no marine standard for the elasticity or elongation of a wire assembly.

Only the MSL of each item in the series is required to be known. So when someone buys a wire lashing arrangement they do not know what the elongation might be because, like the pre-tension, it is not required to be tested or quoted by the manufacturer. Wire has little elasticity, so when it stretches it will not return to its original length, and therefore is liable to become slack quite quickly. If a ship has a rolling period of (say) about 15 seconds, then the cargo lashings are stressed 4 times per minute, 240 times per hour and 5760 times per day.

Thus, the inability of wire to return to the original length is a crucial factor in wire lashings becoming slack. In addition to this, new wire has a permissible MSL of 80% of its breaking load. But we have seen in the foregoing that a new wire assembly can fail at considerably below its nominal breaking load due to failure of the grips. **This leaves wire with little or no reserve capacity beyond the MSL.**

9.2 Chain lashing

At first glance, chain may seem to be the perfect solution to lashing. It has little elasticity or elongation and can be set up 'bar tight'. Unfortunately, some deck cargoes lashed with chain have been lost due to the chains progressively failing in a 'domino' effect. Because chain has very low elasticity and elongation, initially it looks good in port, but then at sea it suddenly snaps under load when the vessel deflects and bends in a seaway.

Chain is often tightened using bars with lever extensions. A very large pre-tension force can be applied in this way which can result in chains being effectively set up too tight and having little reserve capacity. Then if cargo is secured on deck, and the ship and/or hatch-covers deflect in a seaway (which they are designed to do), this deflection is transferred to the lashings and the chains may break under the additional stress.

There is little or no 'damping' effect with chain. This is particularly true with 'on deck' cargo where the accelerations are the greatest.The only way to overcome this would be to insert a hydraulic damper or spring into every chain lashing.

9.3 Fabricated web lashing

On the face of it, fabricated, marinised, web lashing appears relatively light and pliable compared with wire and chain lashings. It seems difficult to imagine that this product can be as good as, or better than, wire or chain. But nothing could be further from the truth. Modern fabricated web lashing is tough, durable, damage-resistant and has excellent characteristics for cargo restraint. It has unique energy storage properties that allow it to remain tight, and exerting a force at all times.

Under the CSS Code there are no requirements regarding elongation. Wire and chain assemblies have neither defined pretension limits nor certified elongation. The only lashing system that has a semblance of industry standard is web lashing.

It would probably be useful if the shipping industry could agree on figures for suitable pre-tension and permissible elongation for lashings employed in securing unit loads and non-standardised cargo on ships. Then manufacturers could make products and systems to conform to these. Then these products could become 'Type Approved' systems. As we have seen, the modern approach to lashing non-standard cargo is by way of calculating the accelerations and then lashing the cargo with lashings of sufficient MSL.

The continued evolution of larger and longer pieces of cargo has brought to the general attention of users that there are gaps in the rules concerning the lashing and securing of cargo under very dynamic conditions.

Under the rules, lashings could theoretically have unlimited elasticity and elongation. It is important to find and define that small window between too much elongation and too little.

In the absence of any such agreements, and in view of the fact that the CSS Code does not fully address the issues of dynamic forces between ship and cargo, or the elasticity of lashing material, it would seem reasonable to say that (for the time being), fabricated web lashings offer the most suitable, effective and the safest form of lashing system in most cases, because they:

- Are widely used and have a good track record in use
- Have an in-built (ratchet) tensioning mechanism which gives a known level of pre-tension
- Do not 'snap' under sudden load like chain, but absorb shocks
- Only have an elongation of about 3% within the WWL
- Once elongated will return to their original length, exerting a force the whole time
- Have sufficient elasticity to absorb shocks without snatching or permanently stretching
- Are the only lashing system that has all these characteristics

There is, however, a drawback to the recommendation. The BS industry standard as previously discussed in **Chapter 8** was originally designed to address the carriage of goods on road vehicles. Thus there is a conspicuous absence of web lashing systems that could be considered suitable for use in a marine transportation environment.

There is only one web securing device available that we have seen that holds a class approval and meets the requirements of the IMO Timber Deck Cargo regulations and this device is not ideally suited to securing project cargoes of the type covered in this document.
The main drawback is that 'standard' ratchet securing devices are finished by a process known as 'sherardizing'. This protects the metal of the device to a degree but arduous use, coupled to severe environmental corrosion factors, mean that the life of such units is limited when re-use is taken into account.

This matter has been discussed at length with a specialist manufacturer, which states that it would ideally recommend the use of a stainless material, but notes that the current 'standard' units would have to be inspected and lubricated after each voyage and are likely, unless ideally maintained, to have a limited lifespan.

None of the foregoing should detract from the recommendation reached, in that **a properly designed polyester webbing ratchet lashing assembly appears, on all the evidence available, to offer the best solution to large project cargo securing on board ocean going vessels.**

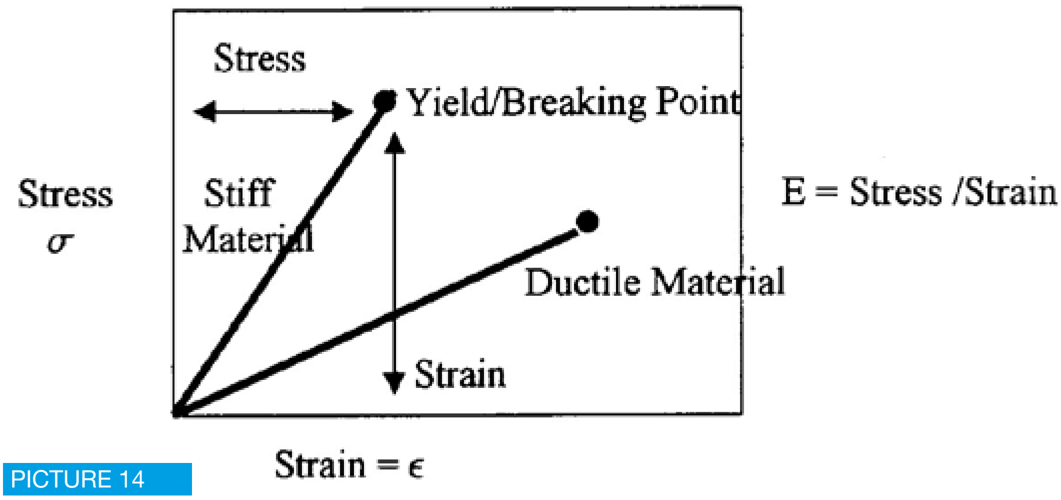
The actual deflections between ship and cargo will vary according to circumstance, size of vessel, and location of cargo. We know of one company that refuses to use chain for lashing deck cargo because it is known to snap suddenly.

This company states: "If you have long units like tower sections, resting on for instance 4 hatch panels, it is problematic using chain lashings. The problem is that the hatch panels movements can be as much as 50-100mm. The panels are moving individually which will result in some chains that will be slackened, while others are over-tensioned and eventually could break."

On the basis of the above, we recommend that all lashings to be used for lashing non-standardised cargo should be certified to have an elongation of not more than 3 per cent at 80 per cent of the certified MSL, and a pre-tension of not more than 10 per cent of their lashing capacity. This should apply to all lashings.

10 | TESTING

The following tests show the behaviour of each type of lashing material under test conditions. Each material was tested to its MSL in stages and then reduced back to zero in similar stages clearly demonstrating the relationship between stress and strain described in Young's Modulus



PICTURE 14

In summary, tests showed that:

- The webbing shows good characteristics of balanced elasticity and elongation
- The wire shows poor characteristics of elasticity and excessive elongation
- The chain shows poor elasticity and very little elongation

Test details for each of the lashing types can be viewed in **Appendix 1** following.

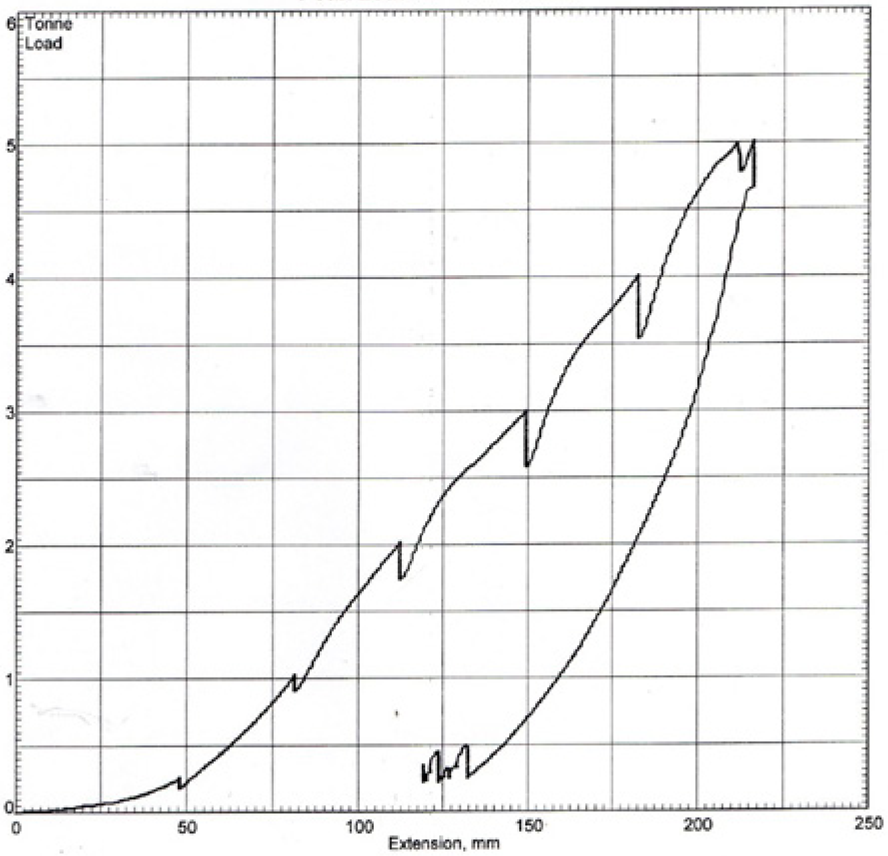
APPENDIX 1

Elongation Tests Conducted on the Three Material Types

1. Elongation test conducted on webbing

ID Number	: 2015-08-21 LASHING TESTING TEST 01
Machine Number	:
Sample Length	: 3m (2m between stitch patterns)
Customer	: Peter Hull Research
Description	: 75mm 15T MBL Webbing
Speed of Test	: 200mm/min
Comment	: Terminated single sling for extension test
Date & Time	: 21/08/2015 12:04:47
Operator	: DB/PH
Test Machine	: AJT 214 85 Tonnes

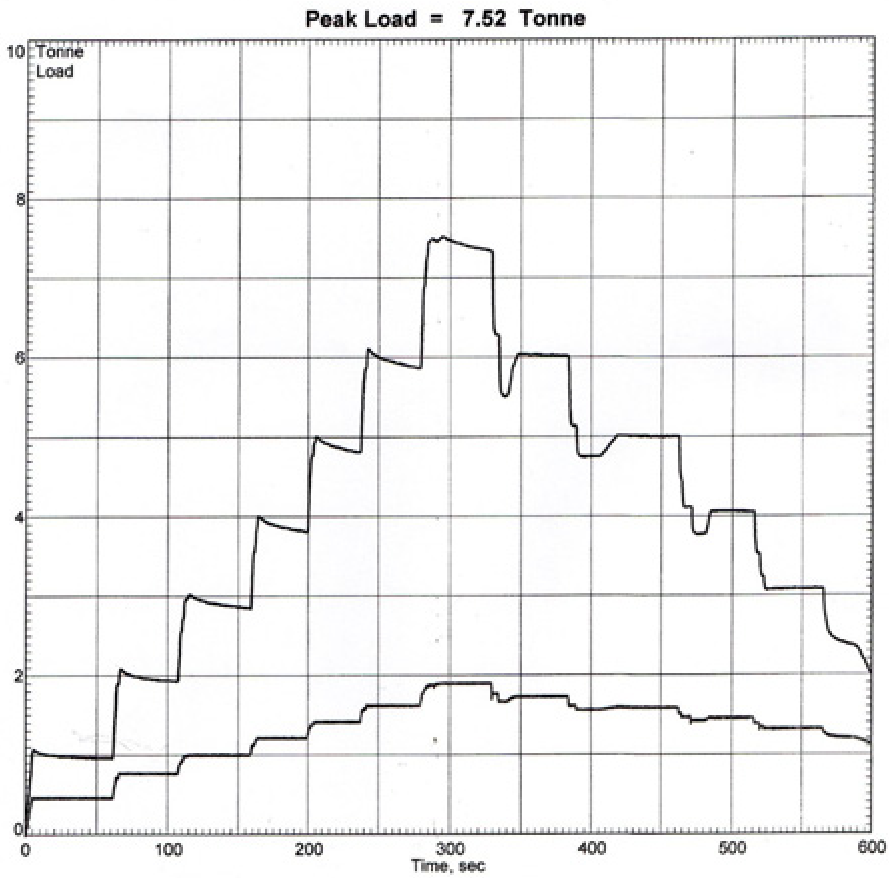
Peak Load = 5.01 Tonne



PICTURE 15

2. Elongation test conducted on wire

ID Number	: 2015-08-21 LASHING TESTING TEST 07
Machine Number	: 3T 5m 16mm Wire Rope Grade 1770
Sample Length	: 5m (1m reference leg measured at 0.25T)
Customer	: Peter Hull Research
Description	: 16mm 6x36 IWRC RHOL Galv 1770N/mm2 JH Liftir
Speed of Test	: 110mm/min
Comment	: test to 7.5T, pausing every 1T to measure extension
Date & Time	: 21/08/2015 15:02:29
Operator	: DB/PH
Test Machine	: AJT 214 85 Tonnes

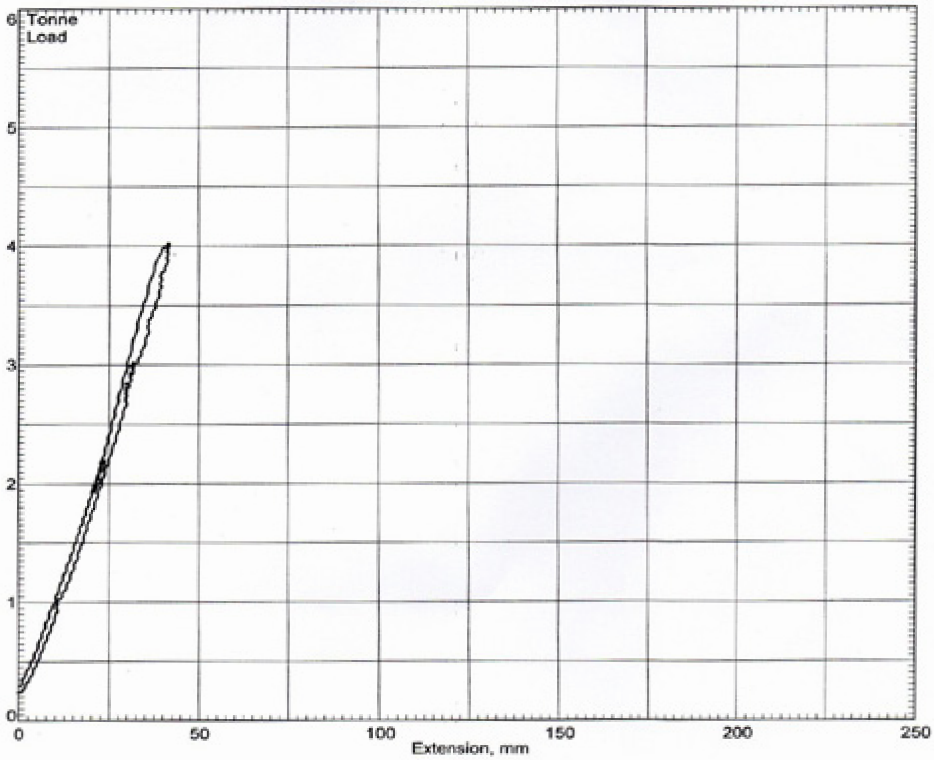


PICTURE 16

3. Elongation test conducted on chain

ID Number	: 2015-08-21 LASHING TESTING TEST 05
Machine Number	: 4T 5m 10mm Grade 10 Chain Sling
Sample Length	: 5m (1m reference leg measured at 0.25T)
Customer	: Peter Hull Research
Description	: 10mm Grade 10 chain sling JH Lifting
Speed of Test	: 110mm/min
Comment	: test to 4T, pausing to measure extension
Date & Time	: 21/08/2015 14:23:48
Operator	: DB/PH
Test Machine	: AJT 214 85 Tonnes

Peak Load = 4.02 Tonne



PICTURE 17

APPENDIX 2

Timber Deck Cargo

PICTURE 18 Tmber deck cargo secured with fabricated web lashing

The requirements for lashing timber deck cargo are clearly set down in the **IMO Code of Safe Practice for Ships Carrying Timber Deck Cargoes 2011 (TDC Code)** and, although they differ from the requirements of the CSS Code, the same materials are used.

Section 2.10.4 of the TDC Code states the three types of lashing equipment that may be used:

1. Chain lashing
2. Wire lashing
3. Fabricated web lashing

According to the Code, whatever type of lashing is used, it must possess the following strength and characteristics:

"5.1.2 All lashings and components used for securing should:

1. *Possess a breaking strength of not less than 133kN*
2. *After initial stressing, show an elongation of not more than 5% at 80% of their breaking strength; and*
3. *Show no permanent deformation after having been subjected to a proof load of not less than 40% of their original breaking strength*

5.1.3 Every lashing should be provided with a tightening device or system so placed that it can safely and efficiently operated when required. The load to be produced by the tightening device or system should be not less than

- *27 kN in the horizontal part; and*
- *16 kN in the vertical part*

5.1.4 Upon completion and after initial securing, the tightening device or system should be left with not less than half the threaded length of screw or of tightening capacity available for future use.

5.1.5 Every lashing should be provided with a device or an installation to permit the length of the lashing to be adjusted."

In Section 5.3 of the Code it states that the spacing of the lashings should be determined by the height of the cargo in the vicinity of the lashings:

"5.3.1 For a height of 2.5 metres and below the maximum spacing should be 3 metres
5.3.2 For heights above 2.5 metres, the maximum spacing should be 1.5 metres."

Thus, for timber deck cargo both the approval and the requirements for the use of lashing and lashing materials are governed by and clearly stated in the TDC Code.

The requirements are the same for all lashings - wire, chain or web lashing. All lashings must comply with the above criteria and must be approved and certified accordingly.

PICTURE 19 Timber deck cargo with lashing set every 1.5 metres (in addition to uprights) according to the IMO TDC Code

CREDITS, SOURCES & REFERENCES

PAGE(S)	REFERENCE	LINK
5	**The Code of Safe Practice for Cargo Stowage and Securing 2011**	http://www.imo.org/en/OurWork/Safety/Cargoes/CargoSecuring/Pages/CSS-Code.aspx
6	**UK P&I Club**	http://www.ukpandi.com/loss-prevention/cargo/carefully-to-carry
7, 14	**DNV GL**	https://www.dnvgl.com
8, 14	**North of England P&I Club**	http://www.nepia.com/publications/loss-prevention-publications/guides
15	**SOLAS**	http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx
16	**Load restraint assemblies on road vehicles**	http://shop.bsigroup.com/ProductDetail/?pid=000000000030147516
23	**The IMO Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 2011**	http://www.imo.org/en/OurWork/Safety/Cargoes/CargoSecuring/Pages/Timber-Code.aspx
25	**Checkmate UK**	http://www.checkmateuk.com
N/A	**Oldendorff Carriers GmbH & Co KG**	https://www.oldendorff.com
N/A	**SpanSet UK Ltd**	http://www.spanset.co.uk
N/A	**United Heavy Lift GmbH & Co KG**	http://www.unitedheavylift.de
N/A	**Skuld P & I Club**	https://www.skuld.com

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Captain Nic Paines is a Master Mariner with command experience on board bulk and forest product carriers. Since leaving the sea he has worked variously as a Marine Consultant, Cargo Superintendent, Surveyor, as an Owners Representative overseeing a fleet of primarily handy sized bulk carrier and as Managing Director of a third party Shipmanagement company. Nic is presently a Director of Newman Giles Paines & Co. Ltd.

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Paul Auston DL. After an early career at sea progressed to working in the textile cordage industry with particular emphasis on developing synthetic materials for use in marine activities. After leaving founded **Checkmate** in 1979 which now comprises 3 operations, in Sheerness Kent, Melksham Wiltshire and Hanoi Vietnam. Has authored or co-written various publications for the ISP and is currently the longest serving member of the panel.

ABOUT ICHCA INTERNATIONAL AND THE ISP TECHNICAL PANEL

Founded in 1952, the International Cargo Handling Coordination Association (ICHCA) is an independent, not-for-profit organisation dedicated to improving the safety, productivity and efficiency of cargo handling and goods movement by all modes and through all phases of national and international supply chains.

ICHCA International's privileged non-government organisation status enables it to represent its members, and the cargo handling industry at large, in front of national and international agencies and regulatory bodies.

ICHCA develops publications on a wide range of practical cargo handling issues, while its Technical Advisory Service provides members with recommendations on a wide range of cargo handling and transport issues, drawing on the experience and expertise of the ICHCA global member community and, in particular, that of the ISP Technical Panel.

Known for many years as the International Safety Panel, ICHCA's ISP Technical Panel represents a formidable body of expertise in cargo handling safety, legislation and operational best practice. Panel membership is strictly by invitation/approval, based on individual members' experience and expertise in their specific field.

Today, the Panel is made up of over 70 practitioners and consultants from more than 20 countries, representing shipping, ports, terminals and land transport; government and enforcement agencies; labour; container design and operations; cargo handling equipment and systems; insurance interests; and other key parts of the cargo handling chain.

This broad cross-section of interests and expertise allows the Panel to evaluate operational and regulatory issues from many angles, and ensures that the viewpoints of many different parties are represented.

The ISP Technical Panel plays a core role within ICHCA International, providing advice and assistance to members; developing ICHCA's extensive range of technical documents and research papers such as this one; and assisting with ICHCA's work on international legislation. The Panel has convened over 70 times since 1991 in more than 25 locations worldwide.

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