Load Security Testing of Logs
A Summary Report for the Log Transport Safety Council

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1. Executive Summary

This report summarises a series of tests that have been undertaken in order to determine what improvements could be made to the load securing of logs, especially in terms of reducing driver injuries and workload.

Since logs transported by trucks use a bolster/stanchion arrangement the load is restrained from shifting transversely. The primary consideration for the lashing systems is that it provides adequate restraint in the forward direction. Current New Zealand regulations stipulate that the load security system should prevent movement of the load when the load is subjected to an acceleration of up to 1.0 g in the forward direction.

Trial 1 was a series of tests conducted in July 2003 at the Williams and Wilshier yard, in Rotorua New Zealand. These tests examined the current use of using transport chain, an alternative approach using 75 mm webbing strap, and a Spectra rope/chain combination that is being trialled at the Port of Tauranga. Braking and tilt tests were used to measure the performance of the restraint system.

Trial 2 was conducted in August 2003 at Cookes New Zealand testing facilities in Auckland. Two tests were conducted, one on the Spectra rope to determine its breaking strength, the other to determine the pretension achievable by 75 mm web tensioners.

Trial 3 consisted of a series of tests conducted by Ian Wright of Ian Wright and Associates and VicRoads in August 2003 at the Midway Pty. Ltd. Chip Mill in Geelong, Victoria Australia. These tests examined the use of hand winches and auto tensioners with 50 and 75 mm web lashings (2 and 3 tonne rating respectively) subjected to brake deceleration and tilt tests. The coefficient of friction of logs was also measured using a specially constructed and instrumented test rig.

Trial 4 was a final series of tests that was conducted in December 2003 at the Williams and Wilshier yard in Rotorua.

The test programme confirmed that webbing restraints are not suitable for log load security. A large number of straps are required if they are to prevent load shift through pretension. If the load shift method is used, the amount of movement required to achieve adequate clamping forces is excessive, typically greater than 1metre. Automatic tensioners do not overcome these limitations.

2. Recommendations

The following modifications to the current log load securing requirements are recommended:

1. Change subsection 6 on page 74 of the Truck Loading Code by deleting the diagrams and stating that the restraints must be anchored on the chassis, bolster or on the stanchions close to the bolster.

2. Change Subsection 4 “Loading” on page 68 to allow:

- Logs with a reasonable coefficient of friction that overhang the rear bolster by at least 300mm and the front bolster by at least 150mm are to be secured with a minimum of 2 chains, where one is at the rear bolster and the other is either a belly chain or at the front bolster. A belly chain is preferred.
- Logs with less than 300mm of rear overhang but have more than 150mm of front and rear overhang must be secured by chains at the front and rear bolsters and a belly chain (3 chains). The belly chain may be from chassis to chassis or simply around the centre of the load.
- Logs that have a low dynamic coefficient of friction (less than approximately 0.4) such as spring logs, must be secured with at least 3 chains and may require other means of securing, depending on the condition of the logs.
- The Lashing Capacity of belly chains and front bolster chains may be reduced to 2.3 tonne (4.6 tonne breaking strength) if the packets of logs being secured weigh less than 10 tonne.

3. Change section 4 “Load Restraint Specification” subsection 2 on page 73 to require all chains to have a minimum Lashing capacity of 3 tonne rather than 3.2 tonne (6.4 tonne breaking strength).

3. Introduction

The current regulations for log load securing are outlined in the New Zealand Truck Loading Code (Land Transport Safety Authority 1999) and the Department of Labour bush code. The following picture illustrates the restraint requirement in terms of acceleration (g) for the various directions.

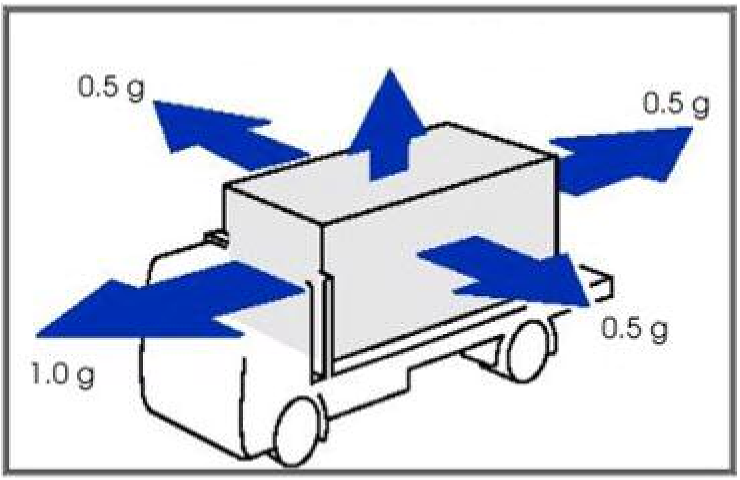

Figure 1. New Zealand load restraint requirements.

In general, loads may be restrained either by direct restraint or by tie-down restraints that rely on friction. Direct restraints are not dependent on friction when securing the load to the vehicle. An example of direct restraint is the use of twist locks to secure containers.

Restraints that rely on friction apply a clamping or downward force on the load as a means of increasing the horizontal force required to make the load slide. These systems can be divided into two categories:

- One that relies on pretension to the clamping forces. This method is dependent on maintaining adequate pretension throughout the journey.
- Tensioning by load shift method where the load is permitted to shift a controlled distance as a means of tensioning the restraints up to the limit of their breaking strength.

From an occupational safety and health perspective, the weight of chains are of concern. A typical 7.3 mm chain weighs approximately 7 kg and strain injuries have been reported from repeated throwing of the chains over the loads. For a truck-trailer unit with a multi-bolster trailer, there can be as many as nine chains required per load. Twitches used to tension chains also pose a risk with injuries resulting from the considerable forces required to operate them.

This report summarises a series of tests aimed at finding methods of securing logs on logging trucks and trailers that improve driver and road safety and reduce the time required to secure the loads. The tests also provided the opportunity to trial the load securing certification test procedures proposed in the Yellow Draft of the Land Transport Load Security Rule 42001.

The tests focused on restraint in the forward direction as meeting that requirement ensures that the rearward restraint requirement is also met and the bolsters and stanchions provide the restraint in the lateral direction.

Trial 1 was a series of tests conducted in July 2003 at the Williams and Wilshier yard, in Rotorua New Zealand. These tests examined current methods using transport chain, alternative methods using 75 mm webbing strap (4 tonne lashing capacity), and a Spectra rope/chain lashing alternative currently being trailed at the Port of Tauranga. Braking and tilt tests were undertaken.

Trial 2 was conducted in August 2003, at Cookes New Zealand testing facilities in Auckland. Two tests were conducted, one on the Spectra rope to determine its breaking strength, the other to determine the pretension that can be generated by 75 mm web tensioners.

Trial 3 consisted of a series of tests that were conducted in August 2003 at the Midway Pty. Ltd. Chip Mill in Geelong, Victoria Australia. These tests included brake and tilt tests, an investigation into hand winches and auto tensioners with 50 and 75 mm web lashings (2 and 3 tonne rating respectively) and the measurement of the coefficient of friction of logs using a specially constructed rig.

Trial 4 was a final series of tests conducted in December 2003, at the Williams and Wilshier yard in Rotorua to confirm and refine the findings.

4. Trial 1: Rotorua July 2003

4.1. Tilt Test Results

Current restraint requirements were initially examined using a tilt test. Figure 2 and Figure 3 show the arrangement used for those tests. An inclinometer was used to provide a continuous measurement of the tilt angle. The load consisted of 6.1 meter logs, 16 tonne of payload.

Figure 2. Tilt testing the load restraint system.

Figure 3. Tilt testing, no restraints.

The table below lists the main results. The maximum tilt angle indicates the maximum angle achieved at the onset of load movement.

Table 1. Maximum tilt angle using 2 chains, twitched.

Lashing Position	Max Tilt Angle, θ (degrees)	Calculated Acceleration[1]
2 chains, twitched, through lugs	41	0.65 g
2 chains, twitched, through lugs	30	0.50 g
2 chains, chassis to chassis	37	0.60 g
2 chains, chassis to chassis	43	0.68 g
No restraints	34	0.56 g

4.2. Emergency Brake Tests

Following the tilt tests, emergency braking tests were conducted. The log lengths used were 6.1 m and 3.7 m. An Autostop Maxi Brake Meter, mounted in the cab of the truck, was used to record the deceleration levels. The test vehicle consisted of a loaded log truck pulling a loaded trailer. The logs on the truck were double restrained to provide a barrier between the trailer and the cab of the truck as a safety measure while the logs on the trailer were restrained by the lashing system being tested. The vehicle combination was driven up to about 30 kph and then full brakes were applied. The results are summarised in Table 2 below.

Table 2. Test 1: Eemergency braking test results.

Restraint Type & Configuration	Log Length (m)	Max Deceleration (g)	Load Movement
2 x chains twitched: front & rear bolster (current NZ regulations)	6.1	0.73	Up to 400 mm
2 x chains twitched: chassis to chassis	6.1	0.73	Up to 400 mm
2 x spectra rope twitched: front and rear bolster (as recommended by current practice)	6.1	0.78	1000 to 1200 mm
2 x 75 mm webbing: chassis to chassis, hand ratchets, "avg. tension"	6.1	0.78	Up to 1200 mm
3 x 75 mm webbing: chassis to chassis, tighten hand ratchets as much as physically possible	6.1	0.69	Significant log movement
1x Belly chain twitched	6.1	0.81	Significant log movement
1x Belly chain twitched: attached through trailer (piggy back) anchor	6.1	0.76	Significant log movement
1x Belly chain twitched + 1x rear bolster chain twitched	6.1	0.72	No log movement

[1] The NZ requirement is 1.0 g in the longitudinal direction.

1x Belly chain twitched + 1x rear chain twitched: chassis to chassis	6.1	0.79	No log movement
1x Spectra Rope Belly strap twitched + 1x chain twitched at rear bolster	6.1	0.78	No log movement
2x bolster chains, ratchet winched	6.1, loose stack	0.81	Up to 400 mm
1x rear bolster chain ratchet winched+1x belly chain twitched	6.1, loose stack	0.75	middle log slid out (hit front group) rest moved up to 400 mm
Front Packet: 2x bolster chains winched+1x belly wire rope. Rear Packet: 2x bolster chains winched+1x belly chain twitched, chassis to chassis	3.7	0.70	No load movement
Front Packet: 2x bolster chains winched+1x belly wire rope. Rear Packet: 1x Spectra rope belly, twitched+1xbolster chain at rear, winched	3.7	0.74	No load movement
Front Packet: 2x bolster chains winched+1x belly wire rope. Rear Packet: 1x75mm webbing belly+1xchain rear bolster winched.	3.7	0.73	Rear packet moved 800 mm (hit front packet)

4.3. Comments

Both the tilt and brake tests showed some variability. Possible explanations for the variability are the condition of the logs; whether they are smooth, wet, covered with bark, or irregularly shaped. The stacking or packing of the logs may also significantly affect the performance of the load securing system with packets neatly or tightly packed having increased friction between the individual logs.

Although the webbing is much lighter to throw over a packet of logs, none of the tests where webbing was used resulted in satisfactory load security. In all the cases, the logs moved more than what could be considered to be acceptable and in some cases they fell off the test vehicle.

5. Trial 2: Rope and tensioner test

Tests were conducted on a flat bed tensile test machine at Cookes, Auckland in order to determine the pre-tension that can be achieved with 75 mm web tensioners (ratchet type) and the breaking strength and elongation of Spectra/Kevlar rope.

The flat bed tester and the arrangement used for the testing of the web tensioner are illustrated in Figure 4.

Figure 4. Flat bed test set-up for web tensioner tests.

5.1. Web Tensioner Tests

The web tensioner was attached to the webbing in accordance with normal practice. One end of the webbing was attached to an anchor point on the test bed, the other was attached to an electronic load cell. Three test subjects in turn operated the webbing tensioner while the webbing tension was measured continuously by the load cell. The subjects were instructed to apply as much tension as they could realistically achieve without resorting to levers or other aids.

5.2. Web Tensioner Results

The results of the 75 mm ratchet web tensioner tests are tabulated below in Table 3.

Table 3. Ratchet webbing tensioner test results.

Test Number (and person)	Tension (kgf)
1 (Tim)	750
2 (Pete)	800
3 (Tim)	800
4 (Pete)	1050
5 (Tony)	1000

5.3. Spectra Rope Breaking Strength

The Spectra/Kevlar rope that was tested is the same one that was used for the earlier emergency brake tests and is shown in figure 6 below.

Figure 5. Spectra/Kevlar rope lashing.

The rope consisted of a 4 metre length of 12 mm diameter Kevlar rope, with two galvanized eyes spliced into each end. A short chain was connected to each eye, allowing a chain twitch to be used to tension the lashing assembly over the load. For test purposes, the chain assembly was not used since the braking strength of the Spectra rope was of interest, not the entire assembly. The outer nylon protective sheath[2] was stripped from the Kevlar core and a visible inspection was made. Damage was noted to a small number of fibres, predominately around the thimble/eye at either ends of the rope. The spectra rope was mounted to the tensile test machine, as shown below in Figure 6 and a tensile force applied to the rope until it broke.

Figure 6. Spectra rope tensile test set-up.

The breaking strength and elongation were recorded.

[2] The protective sheath does not contribute any strength to the assembly, it merely protects the Kevlar core.

5.4. Spectra Rope Tensile Test Results

The tension required to break the rope was 7,650 kgf. The initial length of the rope was 4.0 m, the final length (at failure) was 4.090 m. The rope stretched 90 mm, or 2.25%. The picture bellow illustrates the elongation in the failed Spectra rope.

Figure 7. Failed Spectra rope.

5.5. Comments

The tension that could be applied ranged from 750kg to 1,000kg depending on the strength of the person operating the winch. This is very similar to the tensions that can be achieved by other webbing tensioners, including automatic tensioners, and by chain twitches.

The damage to a small number of fibres of the Spectra rope near the eye that had been sustained during the brake tests had no affect on the strength of the rope. It is not known how much damage would need to be present before the strength of the rope is affected. The risk of damaging the Kevlar rope fibres near the eye could be reduced through number of measures as illustrated in Figure 8. These measures include:

- Extending the protective nylon rope sheath around the eye thimble
- Braiding wire rope to the ends Kevlar core so that the wire rope is wrapped around the thimble.

Figure 8. Alternative Spectra/Kevlar rope damage prevention.

6. Trail 3: Geelong, Australia

A series of load securing tests were undertaken Ian Wright & Associates on behalf of VicRoads at Midway Pty Ltd. Chip Mill, in Geelong, Australia during August 2003. Peter Baas (TERNZ) and John Long (LTSA) observed the tests.

6.1. Geelong Emergency Brake Tests

Emergency brake tests were undertaken on three log trucks that arrived at the Mill during the day. The vehicles and loads were tested in condition they were in when they arrived at the mill and consequently the web tensions were typical of those normally found in practice. Brake decelerations were measured using two Autostop Maxi Brake Meters that were mounted on the chassis of the vehicles. The results of the tests are summarised in Table 4.

Table 4. Test 4: Emergency braking results.

Restraint Type & Configuration	Tensioning Method	Max Deceleration (g)	Load Movement
B-train carrying pulp logs; Packet 1 (front):2x75 mm webbing, Packet 2: 2x75 mm webbing, Packet 3 (rear): 2x75 mm webbing+1x50 mm webbing	Hand winches	0.47 average 0.57 peak	Load moved 300 mm
B-Double; Front: 2x75 mm webbing, Middle & Rear: 2x75 mm webbing	Front: Elphinstone auto winch. Separate test afterwards found that the winch produced 635 kgf winch side, 160 kgf, off side. Middle & Rear: Hand winch. Separate tests afterwards found that 1235 kgf winch side and 450 kgf off side could be produced.	0.7	No load movement
B-Double: 2x75 mm webbing on all 3 packets	Exte Luft Man Twin air operated winch. The driver normally added 5 to 6 clicks by hand to the tension. After the brake test it was found that the auto winch only produced 170 kgf on its own. The tension of the webbing during the brake tests is not known.	0.5	Up to 1000 mm (logs protruded through cab guard)

6.2. Geelong Tilt Tests

Tilt tests were conducted using a specially constructed tilt test bed. The test bed was lifted from one end with a crane and a front end loader was used as a protection device just in case the rig overbalanced and tipped over, see figure 9.

Figure 9. Test 3: Tilt test rig in tilted position.

The first series of tests were conducted on split hard wood (HW) logs. The test load weight was 12.7 tonne. In all of the tests where webbing was used to secure the load on the tilt bed, Transking Tightwinder geared hand winches with a 2 to 1 gearing ratio (16 teeth) were used to tension the lashing. The input effort with these winches was estimated to be 30 kgf when tensioning 50 mm webbing. The results are summarised in the tables below.

Table 5. Test 3: Split HW logs tilt testing results.

Restraint Type	Pretension	Tilt Angle (degrees)
5x chains	7.6 tonne (60% of load)	54° - No load movement
4x chains	5.6 tonne (44% of load)	51° - No load movement
3x chains	4.3 tonne (33% of load)	50° - No load movement
2x chains	2.9 tonne (23% of load)	50° - No load movement
2x 50 mm webbing	1.8 tonne (14% of load)	45° - No load movement
2x 50 mm webbing	1.2 tonne (9% of load)	46° - No load movement

The second series of tilt tests consisted of round, wet logs which were peeled (no bark). The test load weighed 9.7 tonne. The result is tabulated below.

Table 6. Test 3: Wet round log tilt test results.

Restraint Type	Pretension	Tilt Angle (degrees)
2x50 mm webbing	2.0 tonne (21% of load)	40° - Logs slid uncontrolled

A variety of friction tests to determine the coefficient of friction for logs were conducted. The test rig is illustrated in Figure 9 and Figure 11.

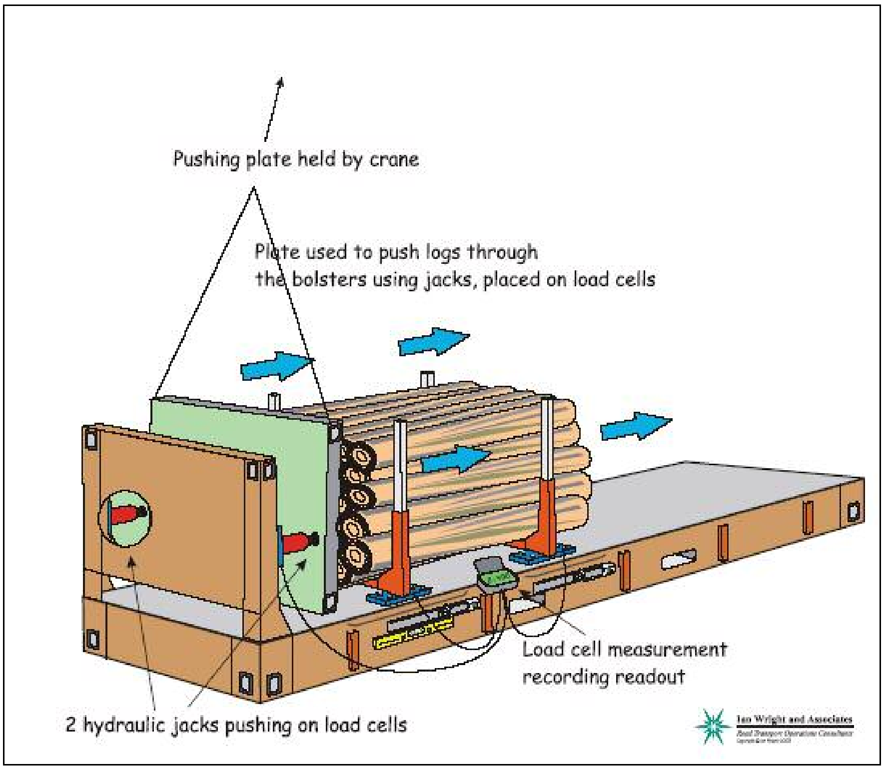

Figure 10. Tilt bed test rig illustration (Ian Wright and Associates).

The hydraulic jacks had load cells mounted between their base and the rigid head plate. The load cells measured the longitudinal (pushing) force against the logs. Note the set-up in the picture on the left is configured to test the top 2/3rds of the load. That is, the head board has been positioned such that the longitudinal force is applied evenly to the top 2/3rds of the load.

Figure 11. Friction test set-up.

The tests included:

- the entire packet of logs pushed by the head board with no tie-down restraints,
- the top 2/3rds of the load pushed, no tie-down restraints,
- the top 2/3rds of the load, with 50 mm webbing providing 1500 kgf of vertical restraint.

The average static friction was approximately 75 to 80% of the weight of the load or approximately the equivalent of 0.75 to 0.8g. Once the logs began to slide the coefficient of friction dropped by approximately 30% which equates to an average dynamic coefficient of friction of that load of approximately 0.5g.

6.3. Comments on Geelong trials

Auto-tensioners were found to work well, providing full tension throughout the trip. The tension generated was similar to that achieved with hand twitches or winches. A simple test is required, however to ensure the auto-tensioners are operating correctly. This could simply require the driver to check the tensioner with the hand lever on a regular basis and if more than 2 clicks can be added, the auto-tensioner should be serviced. Considerable differences in strap tension were measured from one side of the load to the other due to friction between the restraint and the logs.

Mill staff mentioned that typically one truck per day arrives with a "shifted" load and that chain sawing the protruding logs (from the cab guard) is a regular event (more than once a week).

The average dynamic coefficient of friction for the logs tested was approximately 0.5. Considerable differences were found in the friction between the logs through factors such as the log shape, the amount of bark on the logs, the wood type, whether they were wet and the way in which they were stacked.

7. Trial 4: Final Rotorua tests

The final series of tests was aimed at refining the proposed modifications to the log load securing requirements in the Truck Loading Code. The tests also provided the opportunity to trial the load securing certification test procedures that are being considered as part of the Yellow Draft of the Land Transport Heavy Vehicle Load Security Rule 42001 (Mueller and Baas 2003).

The proposed certification test procedure provides a means of testing the restraint system at a lower deceleration of, for example 0.8g, if the required deceleration of 1.0g cannot be applied. Truck brakes are not currently able to generate decelerations much greater than 0.8g. This “overload” procedure requires the friction of the logs to be measured and then a test load multiplying factor to be calculated. The friction of the logs was measured by pulling logs from the top and centre of the load with a loader. A laodcell was placed in the chain attaching the loader to the log being tested as a means of measuring the applied force. See Figure 12.

Figure 12. Log friction coefficient determination using the pull test.

The minimum static coefficient of friction was found to be 0.71. The dynamic coefficient of friction was assumed to be 70 percent of the static value, based on recent research from the *CCMTA Load Security Research Project* (Rakheja, Sauve et al. 1997) and the tests undertaken in Geelong (see above). This resulted in a dynamic coefficient of friction of 0.5 which is very similar to that measured during the Geelong tests.

7.1. Braking Tests

The test setup that was used was, for all practical purposes, the same as that used during the first trial in Rotorua in July 2003. The tests focused on double-bunk loads as these loads often require the use of 3 chains rather than 2 as the log overhang is typically between 150mm and 300mm. Only one of the two packets were tested at a time and the weight of each packet set at 1.67 times the normal maximum weight based on a test deceleration of 0.8g and the logs having a dynamic coefficient of friction of 0.5. An Autostop Maxi Brake Meter was used to measure the brake decelerations. The vehicle speed was approximately 40 kph when the brakes were applied. The front and rear bolster chains were tightened using ratchet type winches and the belly chain was tightened using a twitch. The results of the braking tests are tabulated in Table 7 below.

Table 7. Test 4: Emergency braking test results.

Test No.	Restraint Method	Load Cell Location	Pre-tension (kgf)	Load Movement	Max Tension (kgf)
1	1x chain front + 1x chain rear bolster	rear chain	1,122	No Load movement	1,224
2	1x chain front + 1x chain rear bolster	rear chain	1,122	No Load movement	1,122
3	1x chain front + 1x chain rear bolster	rear chain	1,020	No Load movement	1,122
4	1x chain front + 1x chain rear bolster	rear chain	714	1,000 mm	2,039

5	1x belly chain + 1x chain rear bolster	belly chain	510	300 mm	1,937
6	1x belly chain + 1x chain rear bolster	rear chain	1,428	120 mm	4,793
7	1x belly chain + 1x chain rear bolster	rear chain	1,020	120 mm	1,835
8	1x belly chain + 1x chain rear bolster	rear chain	1,326	50 mm	1,734

7.2. Comments

Brake tests 1, 2 and 3 resulted in no load movement and consequently no significant change in chain tension, which is to be expected.

In tests 4 through 8, load shift occurred with the corresponding increase in chain tension that occurs as the angle of the chain increases, causing a wedging effect. Typically, when the load shifted, the tension in the chains reached nearly 2 tonne except during test 6 when the tension in the rear chain increased to nearly 5 tonne.

8. Discussion

1. The tests have consistently found that sufficient pretension cannot be applied to prevent load shift without significantly increasing the number of lashings used. This means that the tensioning by load shift method of securing is the best option for log load securing.

2. If there is load shift, the load will typically move forward by approximately 300mm when chains are used and 1m or more when webbings are used because of the higher elasticity of webbing. This amount of shift means that webbing is not a suitable means of securing the load. Of note is that the Draft Australian Load Restraint Guide (2003) strongly advises against the use of webbing or rope when the tensioning by load shift method is used.

3. The pretension that can be applied is typically in the order of 750kg and 1,000kg for all restraint types (chain and webbing) and methods of tensioning (manual or automatic tensioners). While the tensions that can be applied manually are often higher initially than that applied by automatic tensioners, the automatic tensioners have the major advantage of ensuring the tension is retained throughout the journey even if the load settles.

4. Although the spectra rope is being used in limited applications, there are some drawbacks for log load securing. Durability is a real issue, since any physical signs of degradation should result in the rope being taken out of service. This contributes to the overall cost of such a system, given that a 4 metre section of the rope can cost $130.00. During the brake tests, it was evident that the spectra rope was not able to restrain the load as well as the chains. Although the rope

does not stretch like web lashings (breaking strength tests indicate the material has low elasticity), it tends to "roll" allowing the logs to move beneath it. It is a requirement of the tensioning by load movement method that the load does not move relative to the restraint. However, the tests revealed some promising results, such as using the Spectra rope as a belly lashing. A belly lashing essentially unitises the packet of logs. Provided at least one rear bolster chain was used to secure the packet, this combination of chain and rope lashing performed as well as the chain belly lashing and a chain lashing at the rear bolster. As a final consideration spectra rope is most likely be considered as a rope under AS/NZS 4345:2001 (SNZ 2001), which may need to be updated.

9. References

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