LOGGING INDUSTRY RESEARCH ASSOCIATION

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PROJECT REPORT

- SAFETY IN LOG TRANSPORT -

An investigation into load securing devices and methods

P. R. 23

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N.Z. LOGGING INDUSTRY RESEARCH ASSOCIATION (INC.)

P.O. Box 147 Rotorua New Zealand

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An investigation into load securing
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Furthermore, the success of this work was made possible through the generosity of all of the organisations represented on the log load securing devices committee. Of particular note, N.Z. Forest Products Limited and Kaingaroa Logging Company made their staff and vehicles available, free of charge, for considerable periods of time. The enthusiasm and co-operation shown by all members of the committee and others involved has resulted in this work being an excellent example of co-operative research. It demonstrates a very responsible attitude on the part of those people involved in the transportation of logs in this country.

ABSTRACT

This report summarises the details and results of work carried out by an industry committee concerning the safety of log transport in on- and off-highway situations in New Zealand.

Background events leading to this work are covered. Results from the work include the nature of forces exerted on logging trucks and trailers as determined from field tests. The use of these results in making recommendations to update a code of practice is discussed. A copy of the recommendations made is included in the report.

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1. INTRODUCTION

1.1 BACKGROUND

Safety in Log Transport not only concerns those directly involved in the logging industry but also members of the general public. Vehicles carrying logs regularly cross paths with a significant proportion of the population. The regulations which govern log cartage on public highways are enforced by the Ministry of Transport. However, as most, if not all, logging trucks must travel on a private road in a forest at sometime during their log haul they must also comply with regulations enforced by the Department of Labour through its 'SAFETY CODE FOR BUSH UNDERTAKINGS". This code of practice, which is more detailed than the Ministry of Transport regulations, is the subject of this report and will be continually referred to.

The Bush Code (as it is commonly called) has been in force for a number of years. The Department of Labour ensures that from time to time the regulations are updated to keep abreast of new technology and changing practices. It was a proposed revision of the code in 1982 which spurred this investigation.

In recent years a number of deaths have occurred from accidents involving logging trucks in this country. Some of these accidents appear to have been the direct result of failure of load securing devices on the vehicles involved. In particular, a fatal accident which occurred in the Nelson area in 1982 caused concern by a number of related organisations about the equipment being used to secure log loads on trucks.

During that year a number of investigations began simultaneously. The N.Z. Logging Industry Research Association (LIRA) began work to survey and examine the various types of log load securing devices being used, to determine those which best satisfied the criteria of; sufficient strength for safety, and practical sizes and weights for installation and removal. Coinciding with this work, the Institute of Road Transport Engineers North Island, N.Z. (IRTE), began work to investigate the forces applied to these types of vehicles during their work. The IRTE contracted the Department of Scientific and Industrial Research (DSIR) to undertake a series of tests on a logging truck and trailer unit to demonstrate the techniques of dynamic force measurement. In doing this, it was hoped to gain a better understanding of the forces involved as well as the function and behaviour of log load securing devices.

When it was discovered that all of these organisations were working along similar lines, a move was made to co-ordinate their efforts.

The investigations which followed marked the first time in this country that scientific and engineering tests have been carried out to formulate improved regulations to govern the devices and methods used for securing log loads on road transport vehicles. This report discusses the work of a committee formed within the industry to conduct tests and make recommendations to the Department of Labour for the updating and improving of its Bush Code.

1.2 SURVEY OF SECURING DEVICES IN USE : (Bay of Plenty, September 1982)

As part of the initial project work in this area LIRA staff conducted a survey to determine the details of the load securing devices in use in the industry at the time. Basically the survey was done to find out two things. The first was to check in general how industry was complying with the code in force at the time, and the second, to see if there was any relation between the sizes of the load securing devices being used and the time required to install and remove them from a log load.

As work got under way in this area a number of unanswered questions surfaced.

- What is the exact purpose of each type of load securing device?

- What different types of load securing devices are required for different truck and trailer configurations? (i.e. - do fixed stanchion trucks require different load securing devices from drop stanchion trucks?)

- Should there be a standard requirement stated in the Bush Code for different configurations and load securing device types?

These questions were raised repeatedly during the survey in informal discussions with truck drivers.

As it was not practical or possible to establish the grade of each chain or the core type of each rope being used, a number of assumptions were made. All chain was assumed to be T Grade (80) or higher and in good condition and wire rope was assumed to be of fibre core type.

Applying the existing Bush Code regulations to the above assumptions resulted in the following minimum sizes to meet code requirements :

8 mm diameter chain and/or 13 mm diameter wire rope.

Only 7 of the 38 with belly strop/chains and 52 of the 105 with throw-over strop/chains in use at the time of the survey met or exceeded the requirements of the Bush Code. Of the combinations only 5 complied with the Code. Hence more than 50% of the log cartage units in operations could have been contravening the Code in existence at that time, and certainly didn't meet the proposed regulations.

Table 1 below summarises the results further.

Table 1 : Summary of Survey

Load Types	No. of Trucks	%	Stanchion Types	No. of Trucks	%
Long Logs	108	68	Fixed	69	44
Short logs	47	29	Folding	86	54
Combination	4	3	Combination	4	2
	159	100%		159	100%

Securing Device Type

Type	Belly Strop/ Chain	Throwover Strop/Chain	Combination
Wire Rope and Chain	36	103	-
Chain	2	2	7
Synthetic Webbing	-	-	1
Other	-	-	-
TOTALS	38	105	8
(%)	24%	66%	5%

In some areas where haulage was completely off-highway there was some disagreement with the Code requirement as it was stated, and some of the devices in use in these areas did not conform with the Code. However, in general, drivers were found to be very safety conscious and each had their own idea on the sizes of load securing devices necessary to maintain safety.

In studies done to determine the relation between strop size and installation time, indications were that there was no direct relation between size of strop or chain and time required to install or remove it. Furthermore, it was noted that extra time required to throw over the strops or chains resulting from a failure on the first try, generally was a function of the size and shape of the top logs on the load rather than on the size of the load securing device being thrown over.

1.3 WORKING GROUP FORMATION

The investigation work into load securing devices came about through the common interest of a number of organisations. In November 1982 research staff from LIRA met with members of the IRTE and formed the basis for the future co-operative work to be undertaken.

Also, the DSIR was approached to handle the technical details of truck and trailer tests which were being planned.

The IRTE had previously contracted them to do tests regarding drawbar failures on heavy transport trailers.

A demonstration day was organised by the IRTE to display the work of the DSIR in performing dynamic force measurement on logging truck frames and load securing devices. Members of the logging and log transport industry were invited to view the demonstration and attend an IRTE meeting afterward to discuss the problems involved with specifying log load securing devices. This meeting took place in Rotorua on 26 November 1982. The outcome of the meeting was to act on a motion:

"That in co-operation with the Department of Labour (DOL), the Ministry of Transport (MOT), the Department of Scientific and Industrial Research (DSIR), and the Logging Industry Research Association (LIRA), a working group be formed to make further investigations into a code of practice for the transport of logs".

Following that meeting, representatives of the various organisations were invited to participate in the working committee. The group formed included the following members :

Name	Organisation	Representing
J. Wilkinson (Chairman)	Institute of Road Transport Engineers	Manufacturers
J. Stulen (Secretary)	Logging Industry Research Association	Industry/ Research
P. Baas	Department of Scientific and Industrial Research	Testing/ Research
C. Singh	Ministry of Transport	Inspection/ Regulation
L. McIsaac	Department of Labour	Inspection/ Regulation
N. Peterken	Road Transport Association N.Z. Truck-Trailer Manufacturers Federation	Manufacturers
R. Slade	N.Z. Forest Products	User/ Maintenance
J. Britton	Kaingaroa Logging Co	User/ Maintenance
R. Clotworthy	Maroa Logging	User/ Maintenance
K. Steel	Nelson Pine Forest	User/ Maintenance

Further details of this group's work is contained in Section 3 of this report.

1.4 WORKING GROUP OBJECTIVES

At the first meeting held by the working group an overall objective was formulated. This was :

"To establish safe and sensible working regulations for the securing of log loads on logging trucks and trailers through :

(a) analysing test results from tests done in November by the DSIR,

(b) making recommendations for, and carrying out further testing,

(c) defining the specific functions of various log load securing devices,

(d) making recommendations for revisions to the Department of Labour's safety code for Bush Undertakings, Part 2 : Transportation."

1.5 GLOSSARY OF TERMS

In meeting the above objectives one of the first tasks to be completed was the glossary of terms. It was necessary to establish the common terminology used in this sector of the industry to enable intelligent and understandable discussion to take place between all concerned. The terms which were defined are all listed below. They are listed in order from the truck frame upwards, followed by ancillary equipment.

SUBFRAME - The common base joining log cartage gear to a truck chassis.

BOLSTER BED - The frame member which is mounted to the sub-frame and supports the bolster assembly.

BUNK - The frame member mounted directly to the sub-frame, which supports the log load (figure 2, item 1).

BOLSTER - The frame member which is swivel mounted onto the bolster bed and which supports the log load. (figure 1, item 4).

STANCHION - The upright(s) attached to the bolster or bunk ends, which constrain the load within the width limits of the vehicle. (Also called "side arm").

FIXED - The stanchion is attached to the bolster or bunk ends in a fixed permanent position (usually welded) and cannot move relative to the bolster or bunk ends. (figure 1, item 5).

DROP - The stanchion is pinned to the bolster or bunk end and can be swung down to release the load. It is held in place by a "wraparound strop". (figure 1, item 2)

DROP IN - The stanchion is held in position by two pins. To facilitate piggy-back loading of the trailer one pin may be removed and the stanchion swung inwards, rotating around the other hinge pin. (figure 2, item 2).

EXTENSION PIN - The uppermost section of the stanchion upright. It is good practice to remove the pins during a return trip to comply with vehicle height regulations and to keep the pins from falling out. The pins are usually then stored in a carrier on the rear of the cab. (Also called "stanchion extension"). (figure 1, item 1).

CHOCK BLOCK - A wedge shaped section sliding in the bolster or bunk channel and held in position by a "chock block chain", which constrains the log load within the width limits of the vehicle. Previously used commonly with large native logs. (figure 2, item 3.)

REMOVABLE CRADLE - This is an assembly onto which wood may be pre-loaded and subsequently attached to a truck for cartage.

Ancillary Equipment

BELLY STROP/CHAIN - The wire rope or chain which is placed around the load at any position(s) in a complete circle and is attached on to itself and tensioned using a "load binder".

THROW OVER STROP/CHAIN - The wire rope or chain which is fixed to the top of one stanchion, passes across the top of the load, through guides (when using drop stanchions) and is attached to the bolster or bunk end on the other side. (figure 1, items 6, 8.)

CHOCK BLOCK CHAIN - The chain used to set and hold the chock blocks in a fixed position relative to the bunk or bolster. (figure 2, item 4.)

LONGITUDINAL STROP/CHAIN - The wire rope or chain running lengthwise along the truck or trailer and over the top of the load. It is fastened at the front and the rear of each unit and tensioned by a "load binder". It is only used to secure cross loaded shortwood.

WRAPAROUND STROP - The section of wire rope used to keep the stanchion in an upright position. The wraparound strop is released from the opposite side of the truck from the drop stanchion side to facilitate removal of the load from the vehicle. (Also called "bolster strop, cradle strop"). (figure 1, item 3.)

LOAD BINDER - The device for maintaining tension on a securing strop or chain (e.g. belly chain) around a load. (Also called "twitch, rack".)

BINDER CHAIN - Any chain used for binding or holding a load on a truck. Examples include throw over chain, belly chain, longitudinal chain.

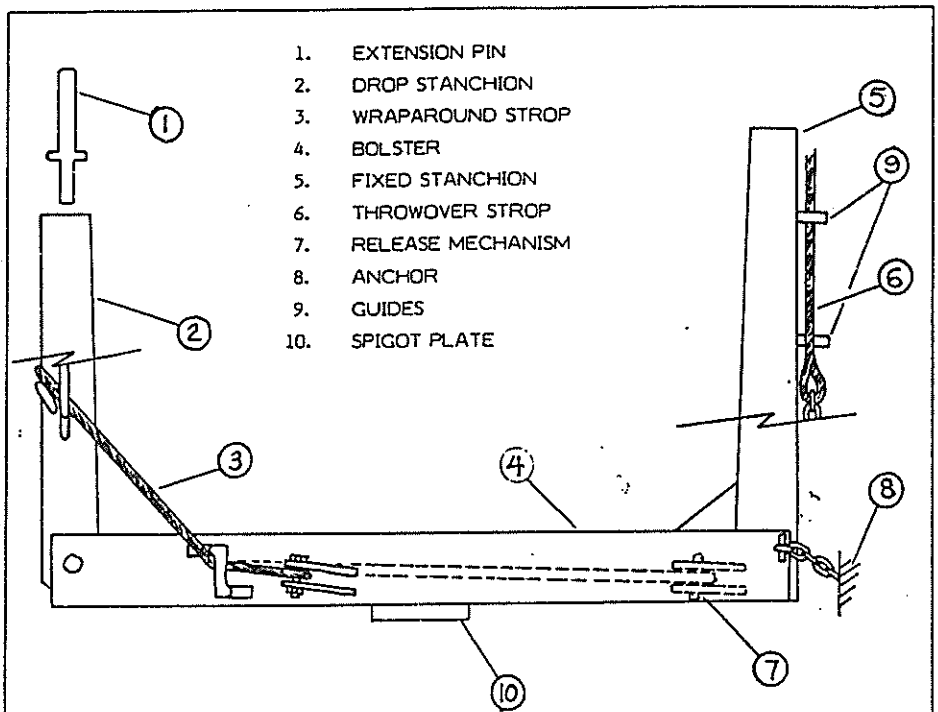


FIGURE 1 - BOLSTER ASSEMBLY

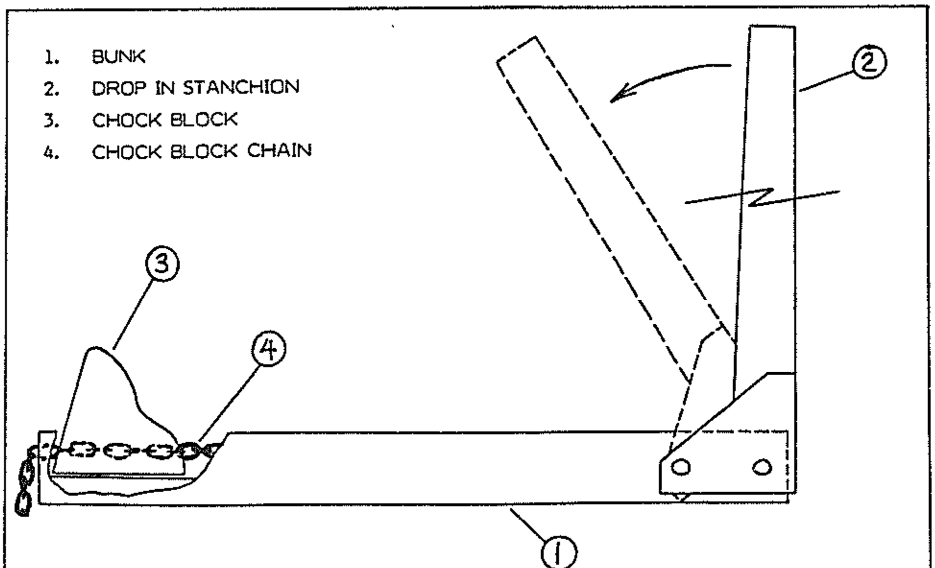


FIGURE 2 - BUNK ASSEMBLY

2. TESTS AND RESULTS

2.1 FORCE MEASUREMENT TESTS : SET 1

INTRODUCTION

The following is a summary of tests done from 19 November 1982 to 26 November 1982. The tests were carried out at N.Z. Forest Products Limited, (NZFP), Kinleith by the Auckland Industrial Development Division (AIDD) of the Department of Scientific and Industrial Research (DSIR).

EQUIPMENT

The test vehicle was a Kenworth logging truck W924R (GM 8V92 TA engine) with a Road Runner off-highway jinker trailer (9 ft bunk). NZFP stanchions were fitted to the vehicle.

Loading and unloading was undertaken with a CAT 966 front end loader, a large Wagner log stacker and a grapple log loader.

Electrical resistance strain gauges were attached to the structure at the positions indicated in figure 4 (page 17) and figure 5 (page 18). Strain gauges measure engineering strain which is change in the length of the material divided by the original length. Stress is the force per unit of area. For this report Stress/Strain has been taken as being equal to Young's modulus, a constant for the material. All tensile strains and tensions have been marked as positive, compressive strains are marked negative. Unless otherwise stated, zero values are from a truck empty state.

Strop tensions were measured by inserting into the strop lengths strain gauged tension links specifically constructed for this project. Refer to figure 6 (page 19). All the gauges were wired up to the instrumentation in the vehicle cab. During the tests the signals from the gauges were amplified and filtered before being recorded, seven at a time on a FM tape recorder (HP 3968A). A voice commentary was also recorded on an eighth channel.

The strop tension links were calibrated against a precision strain gauge load cell by applying a load with a wrecker truck, refer to figure 7 (page 19). The calibration signal from each tension link was recorded on the tape recorder prior to the tests involving each particular strop.

The strops used were:

- throw over strop - 13 mm wire and 10 mm chain with pear and hook connector.
- wraparound strop - 19 mm wire

- belly strop - 13 mm wire for first test, synthetic webbing and finally high tensile chain and hammer lock connectors.

The degree of uncertainty in the measurement of the strains and tensions is estimated to be ± 10%.

TEST PROGRAMME

1. The gauges were monitored as the truck was loaded by the CAT 966. The CAT driver was asked "not to be too gentle". Gross vehicle weight was targeted at 48.0 tonne for all of the tests, which gave a payload weight of 32.5 tonne.

2. The vehicle was parked sidewards on a slope, and anchored from tipping over with wire ropes attached to two other logging trucks. The throw-over stops were connected, and the wrap around strops released. The resultant change in tensions were recorded as the logs tried to fall off. Refer to figure 8 (page 20).

3. The rig was cleared, and reloaded with the Wagner log stacker while gauges were being monitored.

4. The throw-over strops were reconnected very loosely and stanchions tripped.

5. The rig was then driven to gang site 11, and reloaded with the grapple loader. The grapple loader driver was asked to be fairly rough particularly when dragging logs around the stanchions, and hitting the stanchions. When loading was complete, the belly strop was attached.

6. On the return trip to the mill, recordings were made on rough unsealed road, tarsealed road and during normal manoeuvring in the yard.

7. After the truck had been repositioned, as in 2 above, the drop stanchions were released with the belly strop attached.

8. The rig was reloaded, and drop stanchions released with two lengths of synthetic webbing, positioned at approximately 1/3 log length from each end, used as belly strops. Refer to figure 9 (page 20).

9. The above test was repeated for a third time, using on this occasion a high breaking strain chain with hammer lock connectors.

10. With a loaded rig, low speed turns and figure eight turns were performed on a hard seal area. Vehicle speed was then increased for high speed turns up to a maximum at which the driver still felt safe. Refer to figure 3 (page 17).

11. The next test was to drive the rig on a typically rough

off-highway metal road containing a variety of hills, corrugations, turns etc. At one stage, the vehicle was driven at steady speeds between 10 kph and highest safe speed (50 kph) in 10 kph steps.

12. The above test was repeated, on tarsealed roads with a portion of the driving at steady speeds between 40 kph and 100 kph.

13. At the end of the road run, the load was unloaded by splitting in a reasonably rough manner using a CAT 966 loader.

14. The truck was then reloaded, and unloaded by splitting using the Wagner stacker. Again the driver was asked not to be too gentle.

RESULTS

The tape recorded signals were analysed by replaying the signals two at a time onto a high speed chart recorder. Refer to figures 10 (page 21) and 11 (page 22) for samples of the chart recordings. Strain or load values for particular events could then be identified and tabulated.

Portions of the recording of the truck fixed stanchion strains were also analysed by the computer in order to assess the likelihood of fatigue failures occurring. In essence the computer counts the variations in stress level which occur in a reasonably long recorded sample. Figure 12 (page 23) illustrates the results of a fatigue analysis for the combined road run on gravel and tarsealed road.

The change in static stress and tension due to the dead weight of the load varied considerably during the test period, probably due to the shape and positioning of the logs and the degree of log compaction due to driving.

Table 2 : Static Loading, Strain/Load Measurements

	Truck Fixed Stanchion (Strain $x10^{-6}$)	Trailer Fixed Stanchion (Strain $x10^{-6}$)	Trailer Wraparound Strop (tonne)	Trailer Bolster Bottom (Strain $x10^{-6}$)	Trailer Bolster Top (Strain $x10^{-6}$)
First loading	285	300	4.6	-328	540
Second loading	300	428	3.5	-214	432
Third loading	40	514	6.0	-385	756
Change when logs dropped in belly strop test	242	285	5.7	-285	621
Average	217	382	4.95	-303	587

The following is a summary of the peak loadings:

Table 3 : Summary of Peak Loadings

(Values are zero to peak)

		Truck Fixed Stanchion	Trailer Fixed Stanchion	Trailer Wrap Around Strop	Trailer Bolster Bottom	Trailer Bolster Top
		Strain ($x10^{-6}$)	Strain ($x10^{-6}$)	Tonne	Strain ($x10^{-6}$)	Strain ($x10^{-6}$)
Road Run. Gravel, tarseal and yard manoeuvres		+600 -714	+800	7.8 8.3 (yard)	-657 -700 (yard)	+1027 +1054 (yard)
Slow speed turns		+328 -760	+928	5.8	-614	+880
Bolster trip		+270 -470	+371 -357	7.2	-457	+700
Normal loading with Wagner and CAT 966		-450	+914	5.0	-557	+950
Rough unloading and loading	CAT 966	+260 -685	+886	7.2	-514	+950
	Wagner	+200 -550	+1030	6.6	-714	+1380
	Grapple Loader	-715	+1043	8.1	-614	+1189
+ = tensile strains or wire tension						

Tensions in the throw-over strops were measured when the drop stanchions were released by disconnecting the wraparound strops thereby simulating a wraparound strop failure. On the first release, with the strops hand tight, peak tension was 2.8 tonnes. The tension was 2.6 tonnes peak for the second release with the strops loose. (Refer to figure 13 (page 24)).

The first belly strop test used a strandard NZFP chain and twitch. When the drop stanchions were released, the twitch failed spreading the logs on the ground. The second attempt using two lengths of synthetic webbing attached approximately 1/3 of the log length from each end, also failed to contain the logs in a bundle. The third and fourth attempts used a centrally placed high strength chain, with the tension link attached with hammer lock fasteners. The electrical cable to the tension link failed on both occasions when the logs rolled on the ground; however just before electrical contact was severed, peak readings of 13 tonnes were recorded.

DISCUSSION

1. For the throw-over strops, figure 13 (page 24) illustrates that the hand tight strop tightened quickly to support the load when the drop stanchion was released. With the loose strop there was considerably more fluctuation in tension as the logs moved. As there were only two tests, and the static loading on the structure varied considerably due to the shape and size of the logs, there is insufficient test data to verify whether having the strops tight is advantageous.

2. It appears that a belly strop must be able to withstand at least 13 tonnes if it is to contain the load in a bundle in the advent of a wrap-around strop failure. This may be impractical as hammer locks or similar fasteners would be required. Although no tests were performed, it is felt that belly strops would perform their other function extremely well, that of stopping logs from bouncing off the top of the load. In the author's opinion if a safety back up is required in the event of a wrap-around strop failure, then throw-over strops should be used. For vehicles having only fixed stanchions, if these stanchions are adequately designed, strops will only be required to stop the load from bouncing off the top of the vehicle. In this case belly strops (including webbing) or throw-over strops should be adequate. Further discussion and testing is required on this subject before final recommendations are made.

3. The fatigue analysis of the truck fixed stanchion strain gauge indicated that heavy loading of the stanchion occurred many times, and that there was no single peak loading which could cause overload failure. Consequently if failure is to occur it is likely to be due to fatigue. With a fatigue failure, the repeated loading will eventually initiate a crack (normally near

a stress raiser such as a poorly finished weld), and this crack will grow if undetected until failure occurs.

4. Stresses of up to 216 MPa and 286 MPa were calculated from the strain measurements on the stanchions and bolsters respectively. This indicated that these components are highly stressed, and care must be taken with their design, construction and modification.

5. It was noted in the results that for the cornering and figure 8 tests, the strains decreased for an increase in vehicle speed. In these tests the driver was asked to corner as hard as he could within the limit in which he felt safe. The relationship between vehicle speed and side force is noted, for cars, in "Advisory speed signs on curves reduce accidents" by M. Ross Palmer, Traffic Engineering and Control, April 1962. Quoting Mr Palmer:-

"Speed and Side Thrust Relation"

The subjective experiments also indicated that the centrifugal force judged "just comfortable" depended on speed. At lower speeds a greater sideways force was tolerable. Table 4 indicates the relationship.

Table 4

Speed Mile/Hour	Maximum comfortable side thrust, % of gravity
45	17
40	18
35	19
30	21
25	23
20	25
15	27

This relationship was found to agree fairly closely with standards adopted in the United States. Although this side force is greater than that allowed in road design standards, it is still low enough to provide a satisfactory margin of safety, except on ice, and it is in line with the side force actually employed by drivers."

6. In order to assess for cornering the correlation between normal design calculations and the measured strains, a number of calculations were made assuming a side load of 0.3g applied uniformly to the stanchions. The payload was taken as 33 tonne. (Refer to Appendix II.) For the measurement results the net effect due to turning was taken as the zero to peak strain measured during slow speed turns minus the average static strain due to the payload. In summary:

Table 5 : Effect due to Cornering

	Design Calculations Stress (MPa)	Strain $x10^{-6}$	Measurements Strain $x10^{-6}$
Fixed stanchion at gauge position Trailer	95	475	546
Bolster top gauge position	49	243	293
Bolster bottom gauge position	-40	-201	-311

The values compare reasonably well for the stanchion. For the bolster, although the measured quantities are approximately 1½ times those from the calculations, the order of magnitude is similar, i.e. relatively low values. There are a number of factors which could account for the differences:

i) the value of 0.3g is assumed, not measured,

ii) the drawings used for the calculations were not detailed or identical to the unit tested,

iii) during cornering there are forces being generated by the relative positions of the pivot points: bolster centres and drawbeam coupling point, and by the logs trying to hold the truck and trailer bolsters parallel with one another,

iv) the static loading values varied considerably due to nature of the payload,

v) experimental error.

7. The rough loading and unloading tests (refer to Table 3) showed that the log grapple loader tended to produce higher stresses/loads than the Wagner and CAT 966 on the stanchions and wrap-around strop. The Wagner was the most severe on the bolster. The differences however were small.

The forces measured during driving and yard manoeuvring were similar in magnitude to the loading and unloading forces.

8. When the throw-over strops were calibrated, a known force was applied horizontally to the top of the stanchions. All of the gauges were monitored during this calibration, and consequently a sensitivity to point loading could be established:

Table 6 : Sensitivity to Force Applied Inwards To Top of Fixed Stanchion

	Strain Produced in Gauge $x10^{-6}$	Point Load Tonnes
Truck fixed stanchion	1000	3.9
Trailer fixed stanchion	1000	4.9
Trailer bolster bottom	1000	12.7

For comparison purposes Table 7 indicates the equivalent point loading derived from the test results in Table 3 less the average static load values from Table 2.

Table 7 : Equivalent Point Load to Top Of Stanchion (Zero to Peak)

	Truck Fixed Stanchion (Tonnes)	Trailer Fixed Stanchion (Tonnes)	Trailer Bolster Bottom (Tonnes)
Road run	1.93	2.05	4.49
Slow speed turns	2.11	2.68	3.95
Bolster trip	0.98	0.12	1.95
Normal loading with Wagner and CAT 966	0.91	2.61	3.22
Rough loading and unloading CAT 966	1.82	2.47	2.68
Wagner	1.30	3.18	5.22
Grapple	1.94	3.24	3.95

The relationship between the various conditions is not simple. The Wagner tends to push down on the truck more, especially during splitting, than does the CAT 966 or the Grapple log loader. Consequently the Wagner tends to load the bolsters more severely. Bearing this difference in mind, the trailer fixed stanchion and trailer bolster values are similar in magnitude.

By calculation (refer to Appendix I) for a force of 5 tonnes applied inwards horizontally to the top of the stanchion, design stresses at the gauge positions are:

Fixed stanchion	-207 MPa (1036 μ strain)
Top of bolster	-272 MPa (1358 μ strain)
Bottom of bolster	+225 MPa (1125 μ strain)

However this does not include static loading. The effect of the static load will depend on the direction of force onto the stanchions, (inwards or outwards) and also on the amount of load on the vehicle when this side loading occurs.

If a horizontal static loading is to be used in design, for the vehicle loading condition, then it may be safer to use a value of 6 tonnes as the loading experienced during the tests may not be as severe as that which could occur in service. Static load influence could then be ignored for this loading condition.

SUMMARY

1. In the advent of a wrap-around failure, throw-over strop peak tensions are 2.8 tonne.

2. Belly strop tensions of 13 tonne were measured for the release of the wrap-around strops.

3. Wrap-around strop tensions of up to 8.3 tonnes peak were recorded during yard manoeuvres. Loading and unloading produced tensions of 8.1 tonnes peak.

4. If failure does occur, it will probably be due to fatigue rather than a single overload.

5. The tests indicated that peak stresses of up to 209 MPa and 276 MPa are induced into the stanchions and bolsters respectively. This occurred during loading and unloading.

6. The grapple log loader tended to be slightly rougher on the stanchions than the Wagner or CAT 966. The Wagner tended to be rougher on the bolsters. However the differences were not great.

7. Forces imposed during driving and yard manoeuvring were similar in magnitude to the loading and unloading forces.

CONCLUSION

An attempt has been made to fit the experimental results to a simple loading which could be used for design calculations. The following is presented as a basis for discussion only, and may prove to be unsuitable for final inclusion into a code of practice. In any event, further tests should be undertaken on other log securing devices in order to clarify and verify the issue.

It should not be necessary to have a back-up safety system for the bolsters and stanchions provided they are designed with an adequate safety margin. However, if a wrap around strop is needed then it is felt that throw-over strops should also be used, belly strops not being suitable for this function.

Some form of strop is required to hold the top logs from bouncing off. This could be achieved with belly strops or throw-over strops. Webbing type belly strops may be suitable if its only function is holding on the top logs.

The stanchions and bolsters on the vehicle tested seem to be highly stressed. It is felt that a slightly larger margin would be desirable. Consequently the design loads recommended are:

> Loading/unloading - 6.0 tonnes applied horizontally and inward to the top of the stanchions.

Conclusions Cont.

Vertical dynamic loading - 2 times static load.
Cornering - 0.45g applied uniformly to the stanchions.
Wraparound strop - minimum SWL 8.5 tonnes.

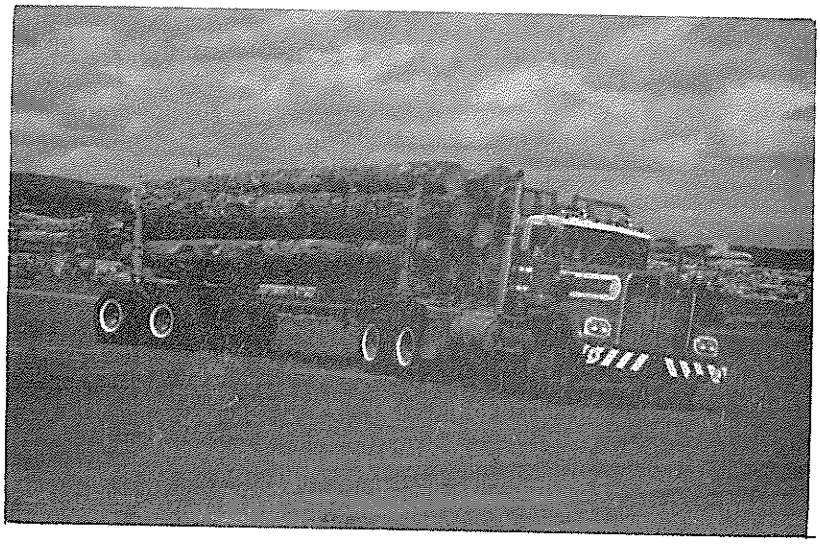


Figure 3 - Test vehicle. Hard cornering test.

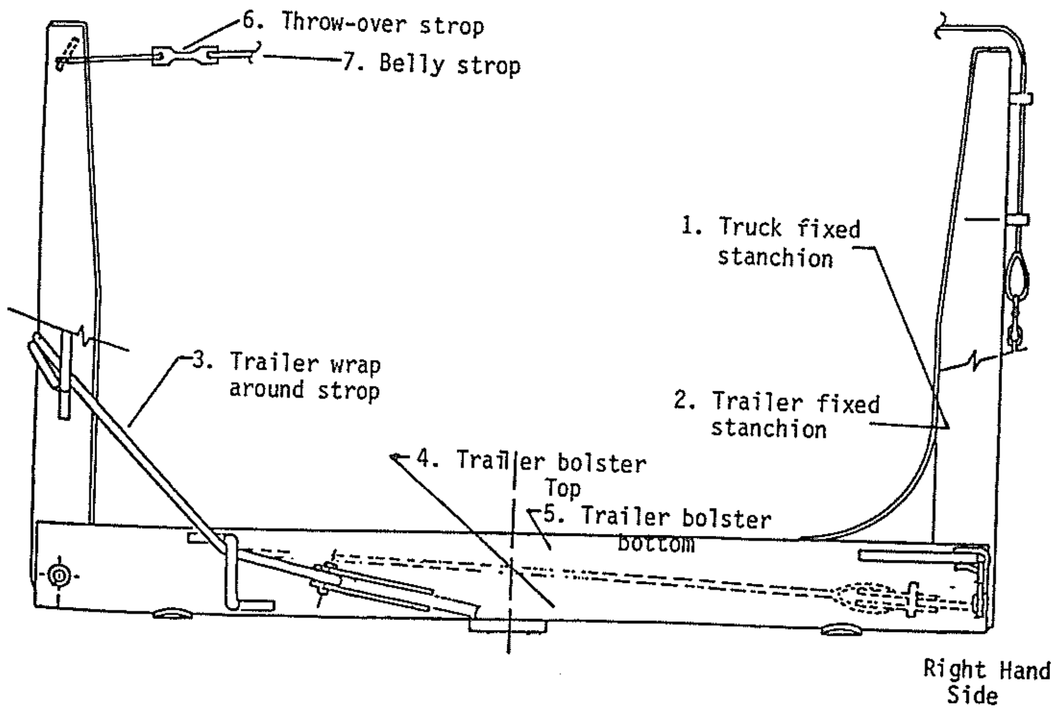


Figure 4 - Measurement positions

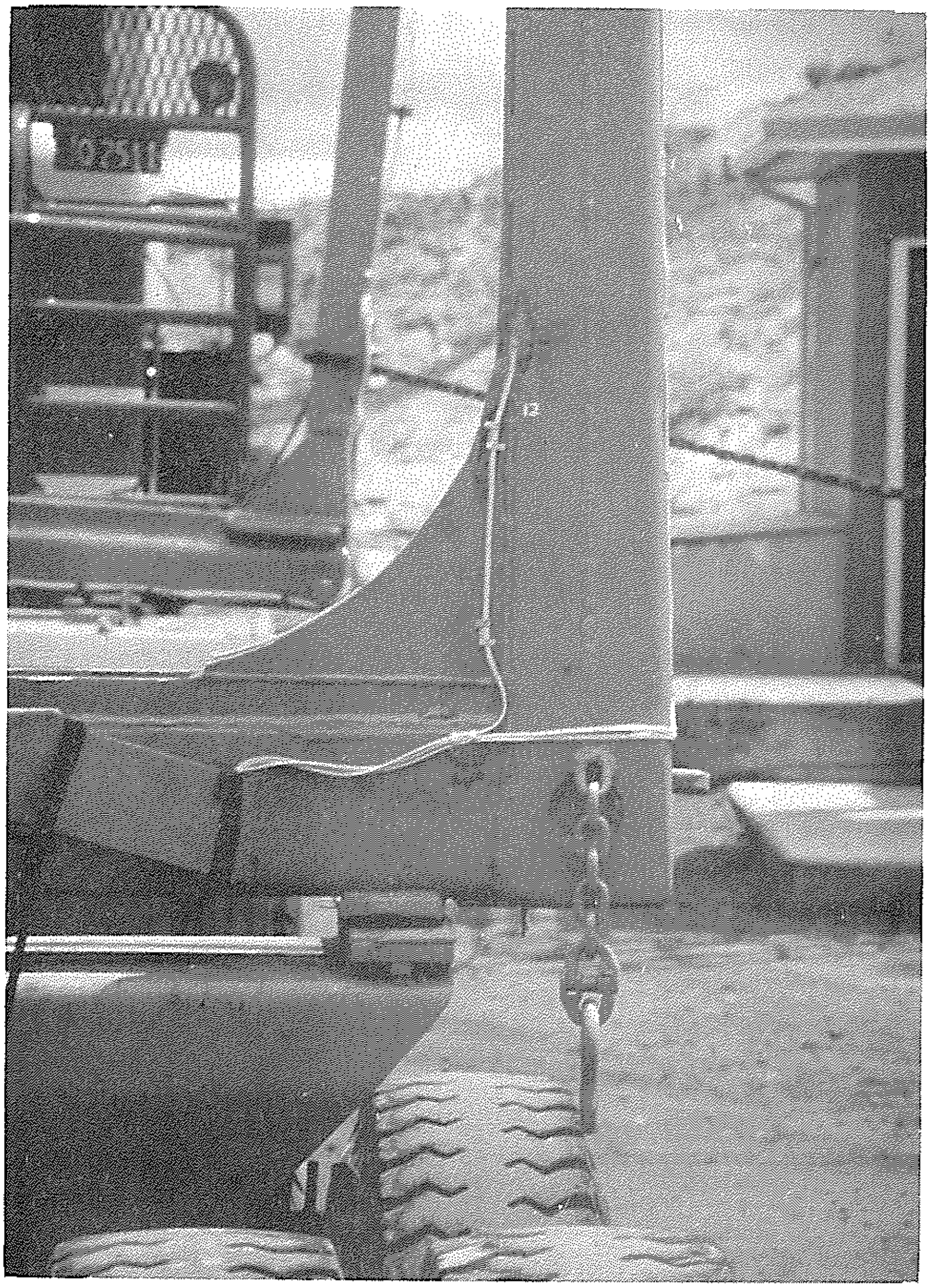


Figure 5 - Strain gauge on trailer fixed stanchion.

Note: Difference in design of the truck stanchion in background.

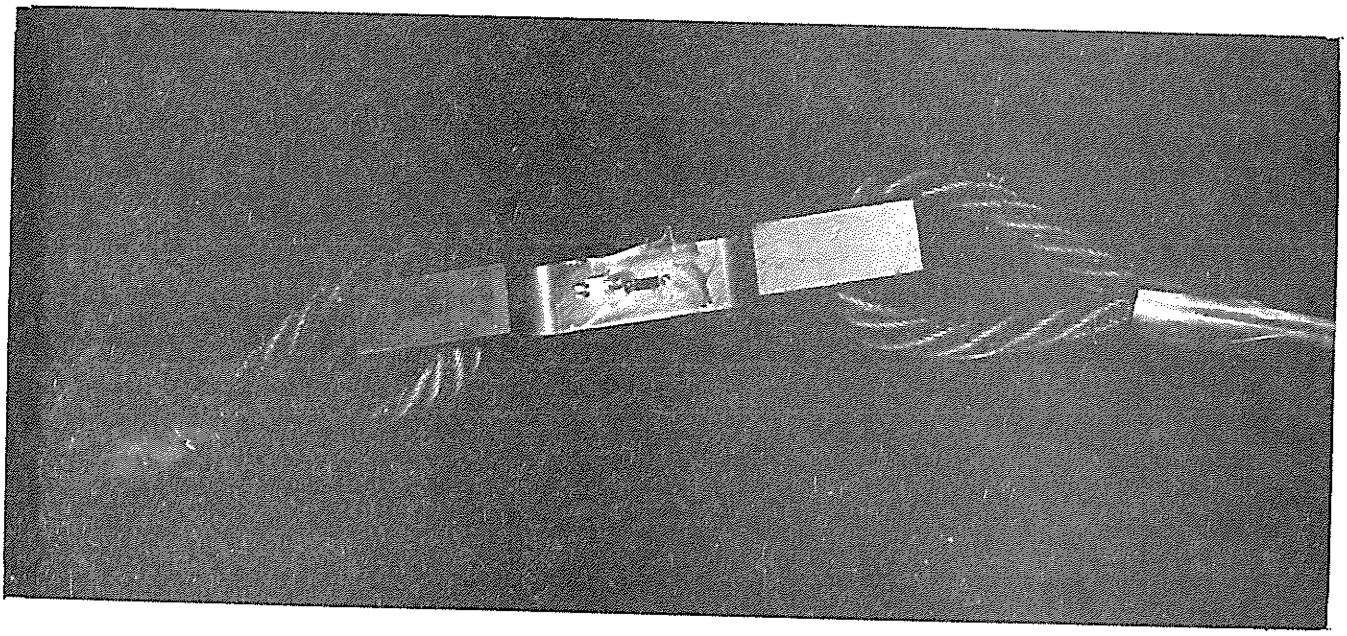


Figure 6 - Strain gauged tension link

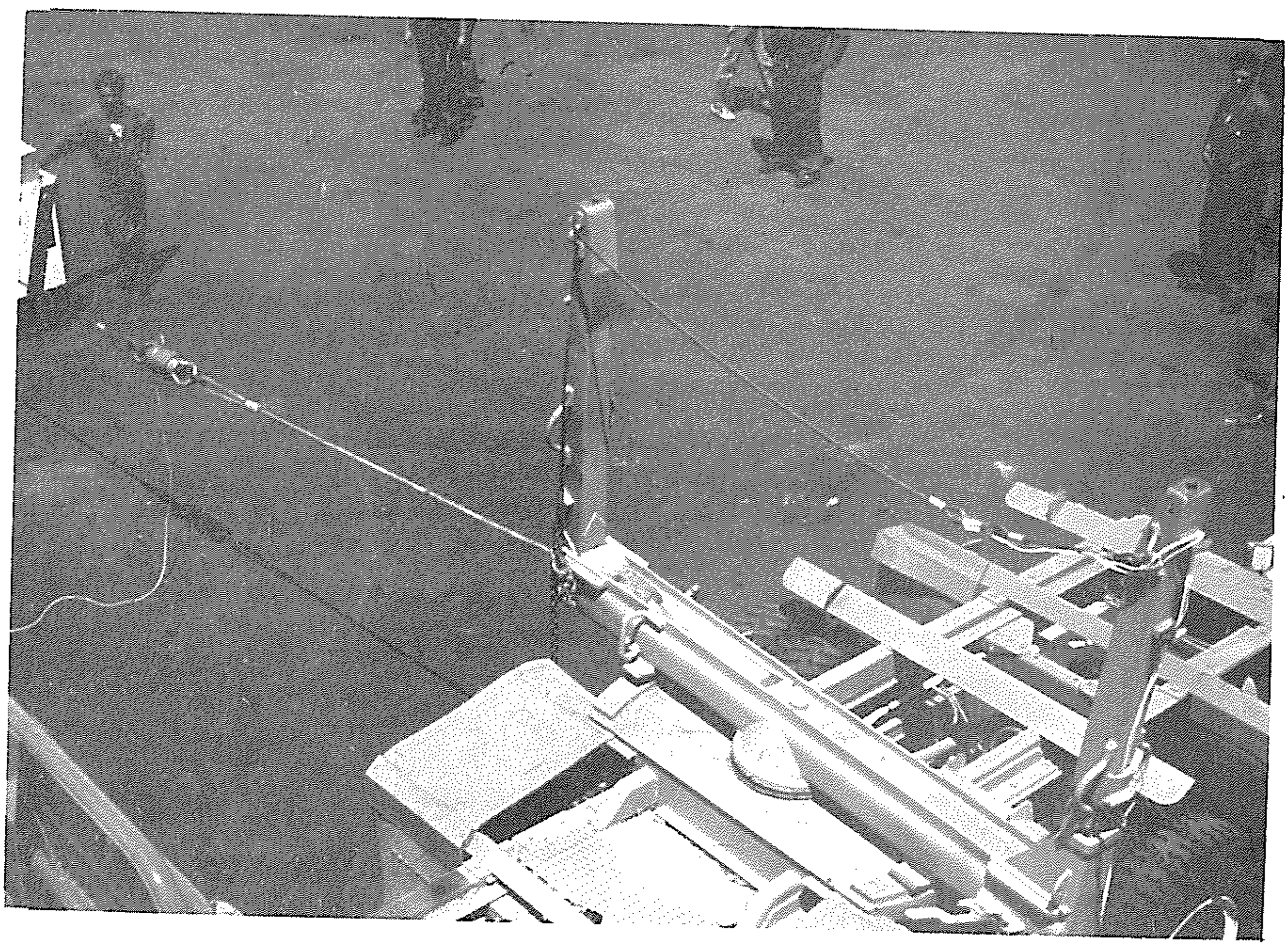


Figure 7 - Calibration of strop tension links with calibrated loadcell and wrecker truck.

Figure 8 - Throw-over strop test

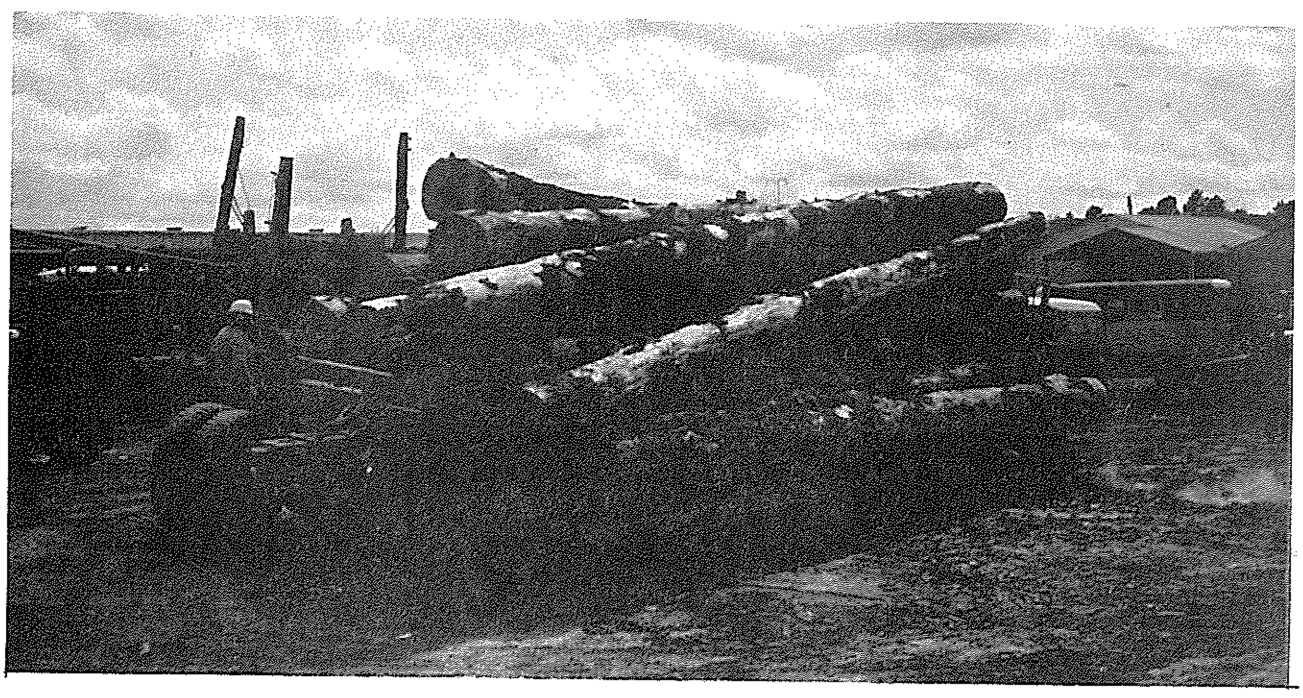


Figure 9 - Belly strop test (KLC webbing)

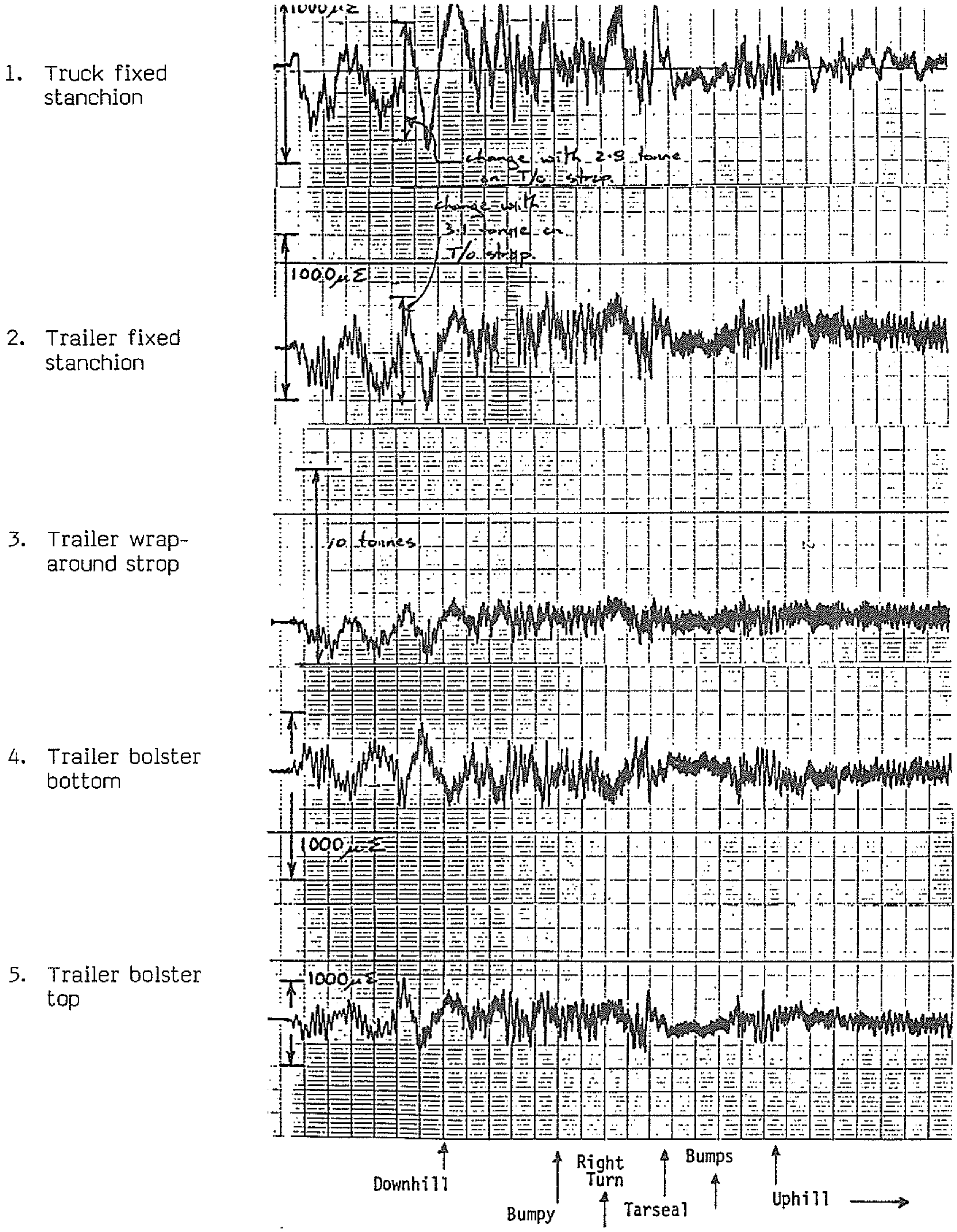


Figure 10 - Sample of road run recording

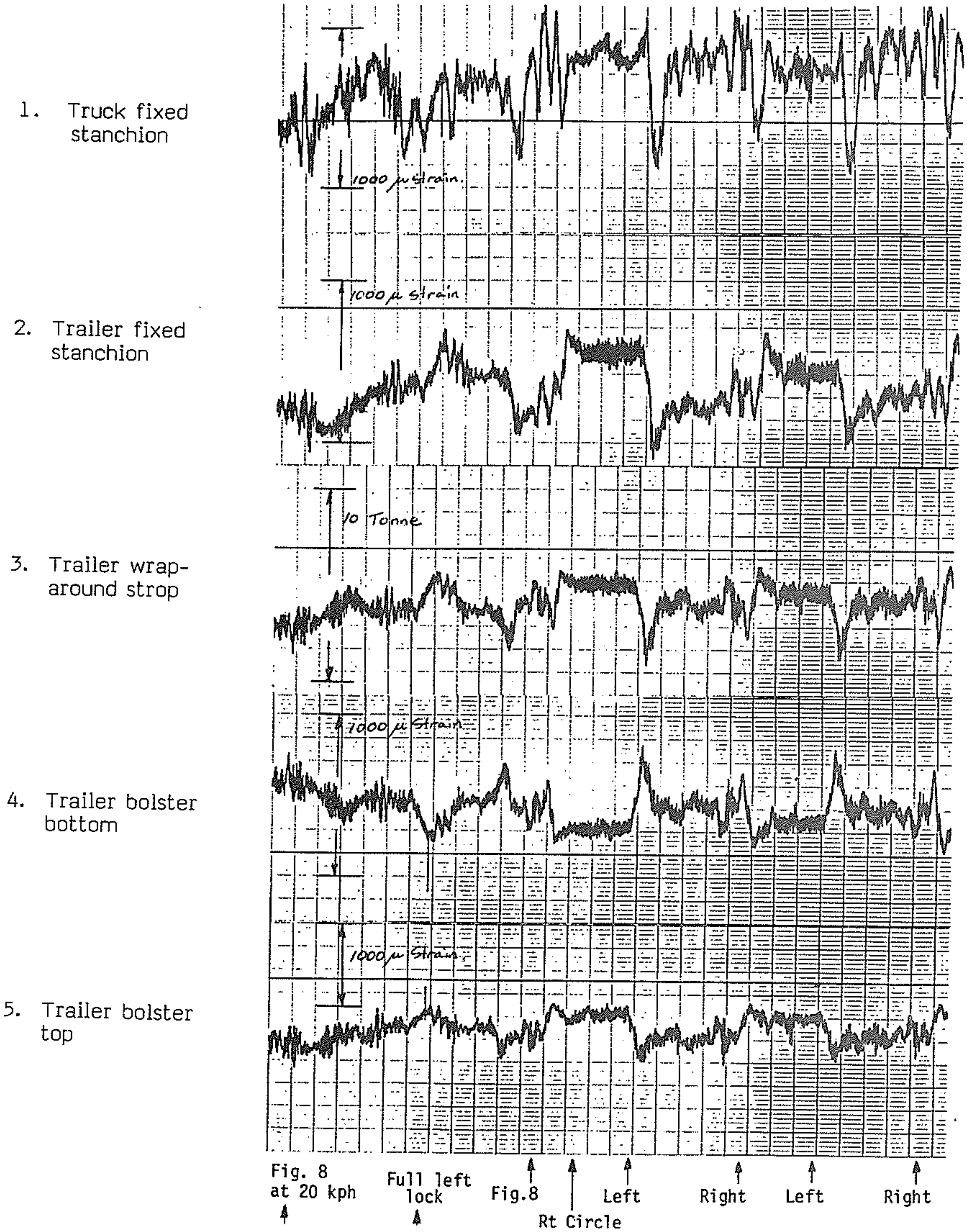


Figure 11 - Sample of turning test recording

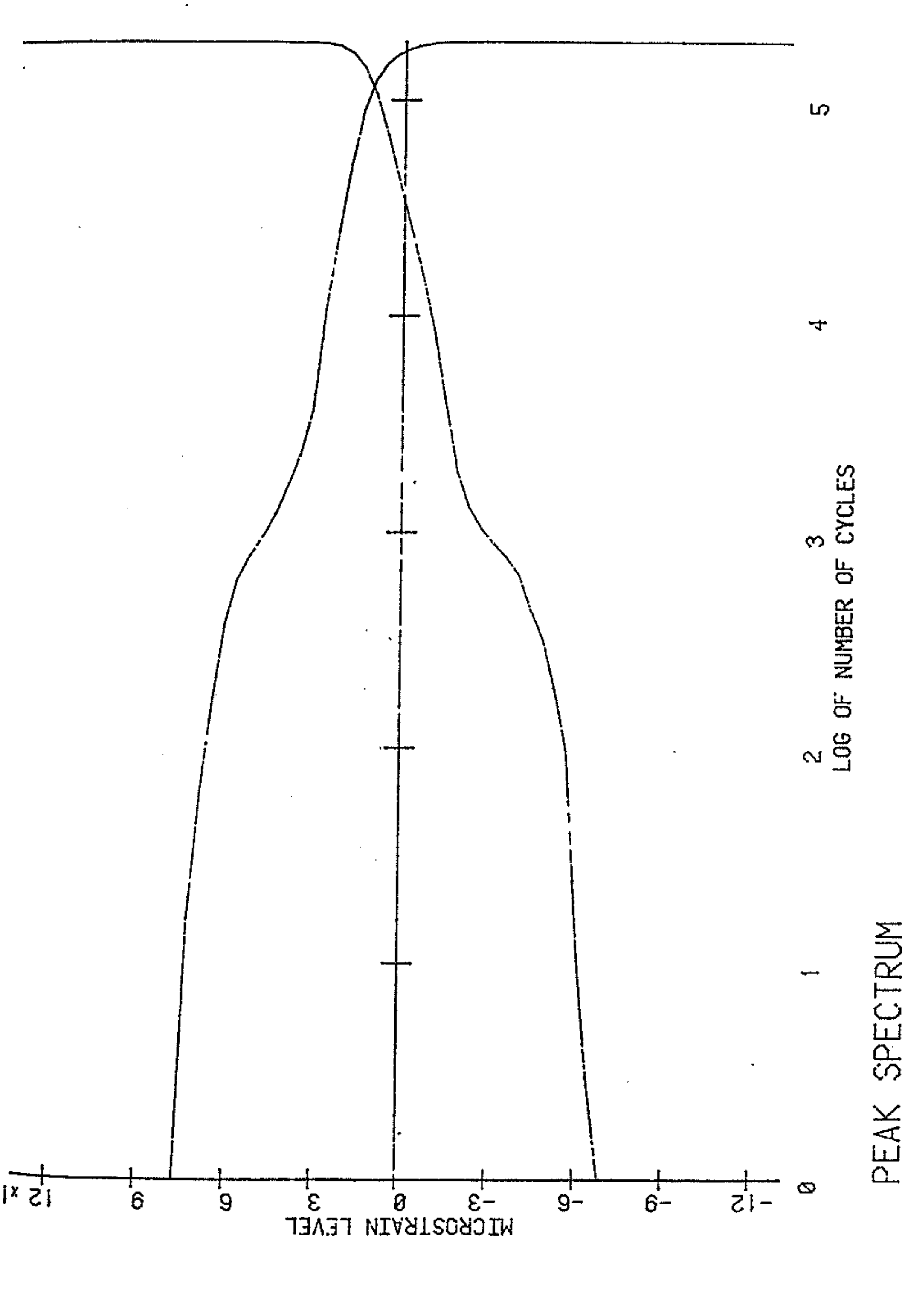


Figure 12 - Truck fixed stanchion. Fatigue analysis on road run on rough and sealed surfaces.

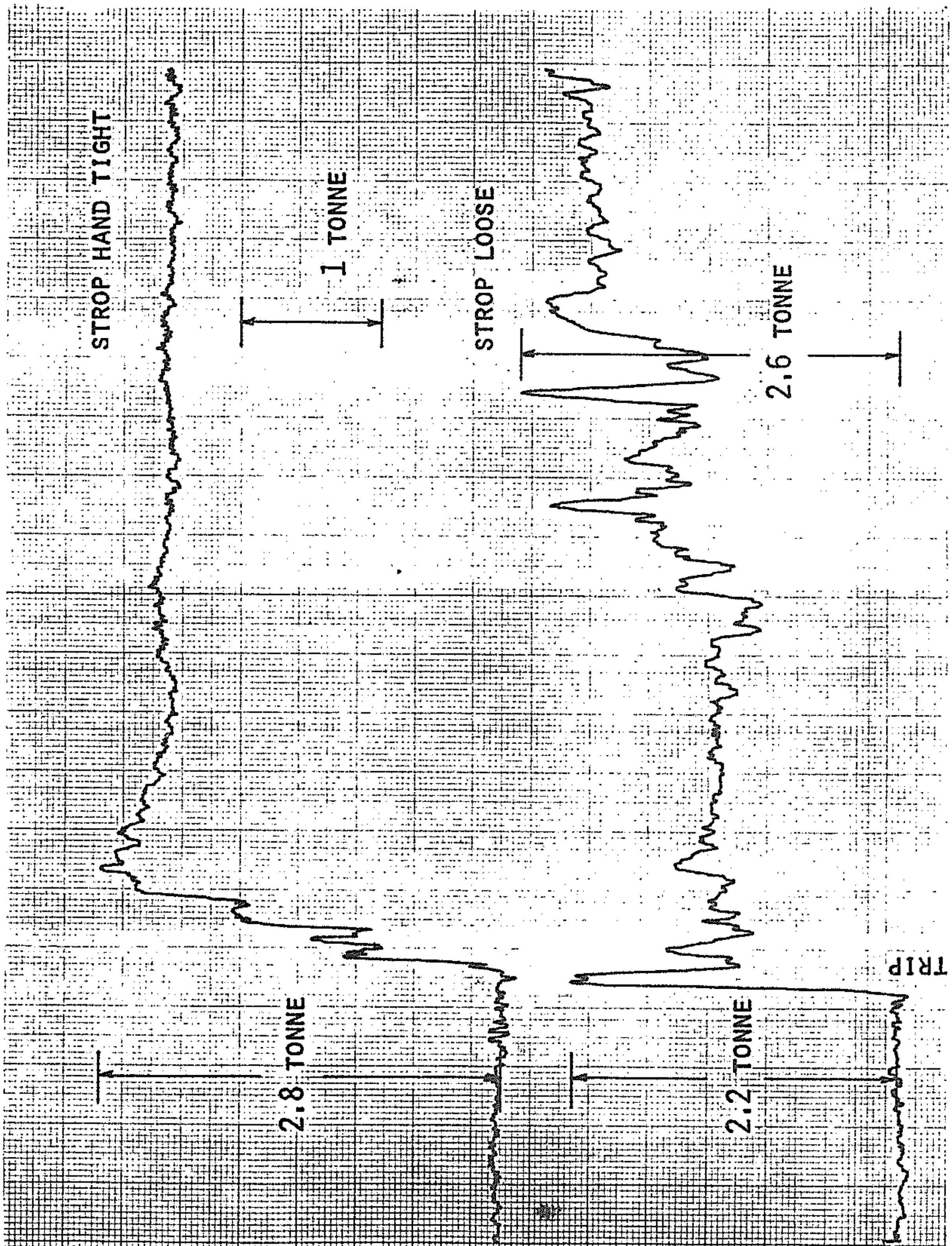


Figure 13 - Truck throw-over strop - Spill test.

2.2 FORCE MEASUREMENT TESTS : SET 2

INTRODUCTION

The committee decided that further tests were required to clarify some of the issues. In particular, the performance of on-highway trucks in comparison to off-highway operation. Tests were undertaken during the week of 13 June 1983 on a vehicle supplied by N.Z. Forest Products Ltd, Kinleith.

EQUIPMENT

The test vehicle was an on-highway Kenworth 8V 71 TT automatic (305 HP at 1950 rpm) logging truck. Two trailers were used; a three axle Mills Tui triple bolster on-highway trailer (865), and a Jack Tidd Ross Todd jinker pole trailer (728). All bunks were 8 ft wide, and wire rope strops of the following diameters were used; a 22 mm wraparound strop, 13 mm throwover strop and a 19 mm belly strop.

Loading and unloading was undertaken with a Wagner stacker, and with a 30RB grapple loader. A GVW of 43 tonnes was used for the tests of vehicle configuration W shown in figure 14 below. A GVW of 36 tonnes was used for the tests of configuration X.

Electrical resistance strain gauges were attached to the structure and strop anchor points at the positions indicated in figures 15 & 16. Three strain gauge type accelerometers were used to measure vehicle movement. All the gauges and accelerometers were wired (as for the off-highway tests) into the recording instrumentation in the vehicle cab. During the tests the signals were amplified and filtered before being recorded, seven at a time on an FM tape recorder (HP 3968A). A voice commentary was recorded on the eighth channel. The system was calibrated as described in section 2.1. "Equipment".

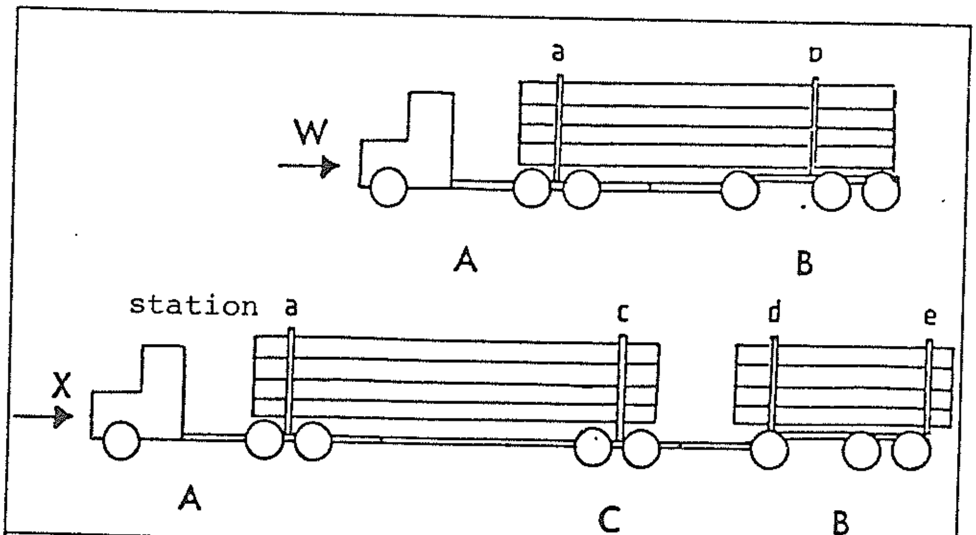


Fig.14 - Test truck and trailer configurations

TEST PROGRAMME

The following tests were repeated three times with different gauge and accelerometer combinations and with different vehicle combinations, once with configuration W and twice with configuration X.

The vehicle was :

1. Loaded by the Wagner stacker taking logs from a 9 ft bunk and forcing into the 8 ft bunk.
2. Driven through slow and fast figure-of-eight turns, and tight circles (hard cornering).
3. Braked hard on a sealed road.
4. Driven over sealed and unsealed roads.
5. Unloaded and reloaded using a grapple log loader.
6. Driven back to the mill, and weighed, and
7. Finally the load was split and removed by the Wagner stacker.

In order to simulate the case where a bundle of logs is dropped off a truck, which may occur if a wraparound strop fails, tests were undertaken using a Wagner stacker. A bundle of logs on a truck was secured by a belly strop which had a strain gauged link in its length. The stacker lifted the bundle out and held the load at approximately truck height above the ground well clear of any obstructions. The stacker then pushed the load off its forks and allowed the bundle to fall on the ground. The strop tensions were recorded during the bundle fall.

RESULTS (1-3)

The results were analysed as described in section 2.1 "off-highway vehicle tests". All tensile strains and tensions have been marked positive, comprehensive strains are marked negative. Unless otherwise stated, zero values are from a truck empty state. The degree of uncertainty in the measurement of the strains and tensions is estimated to be ±10%. The following is a summary of the results.

1.	Vertical acceleration	2.2 g ($22 m/s^2$) bumps.
2.	For and aft acceleration	0.78 g hard braking, logs moved, cab guard broken
3.	Sideways acceleration	0.45 g slow speed hard cornering

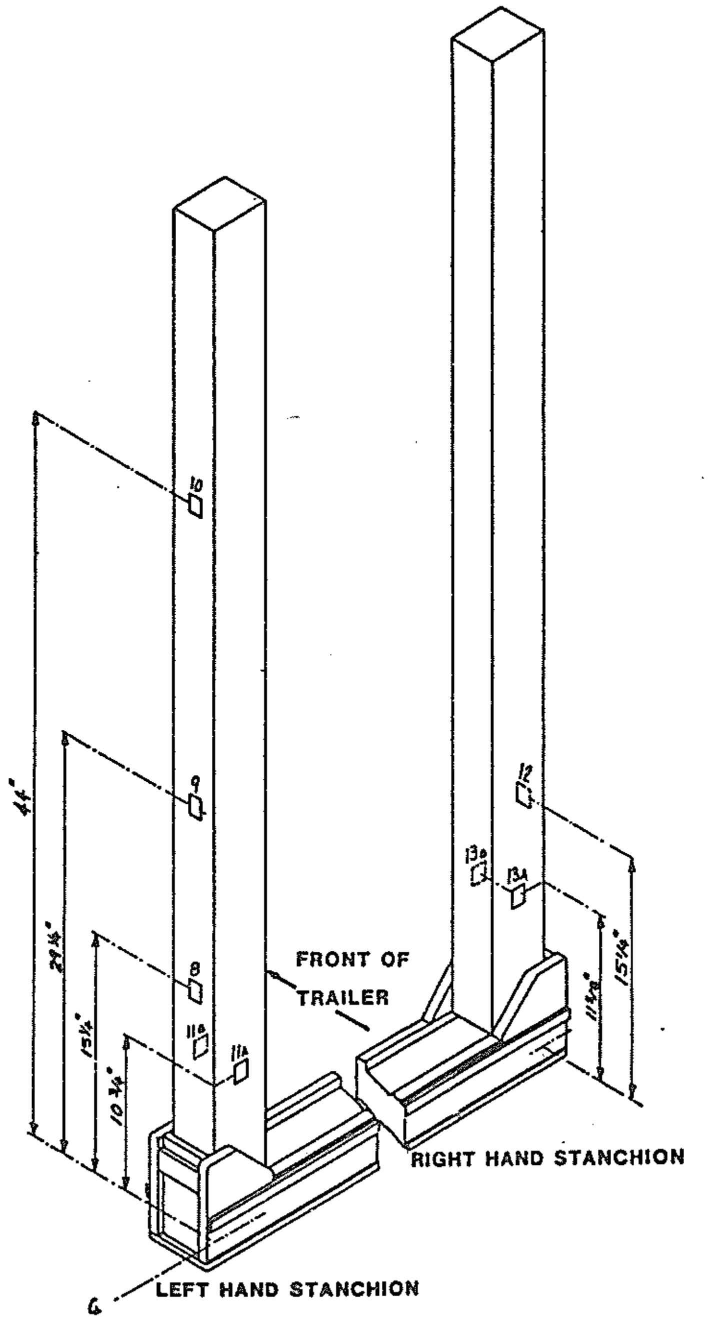


Fig.15 - Strain gauges - station d

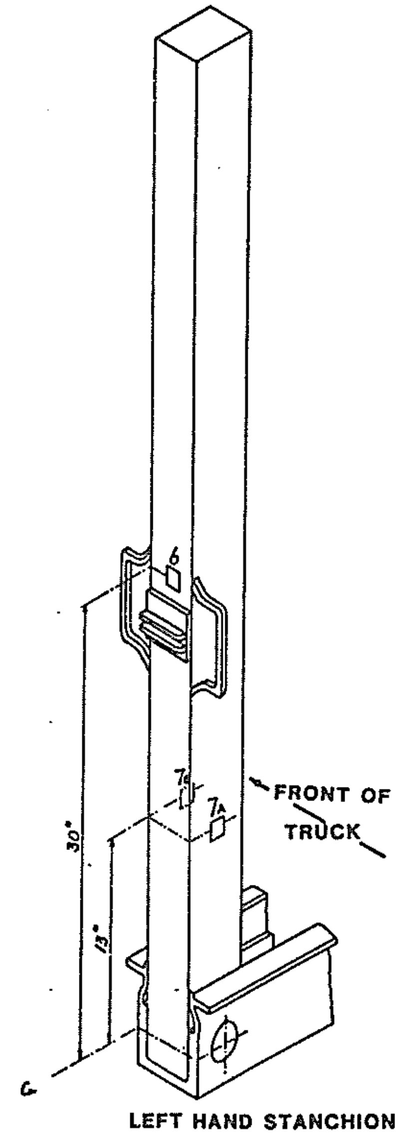


Fig.16 - Strain gauges - station a

RESULTS (4-13)

	4. Left hand wraparound strop Station a	5. Right Hand wraparound strop Station a	6. Left hand stanchion Station a	7. Left hand stanchion Station a
	(tonne)	(tonne)	(strain x10^{-6})	(strain x10^{-6})
Road run, gravel tarseal and yard manoeuvres	2.0	1.8	+ 409 - 656	+ 297 - 406
Cornering	2.4	2.1	125	82
Hard braking	2.0	1.8	+ 556 - 563	+ 594 - 312
Bumps	2.5	2.9	+ 250 - 250	+ 172 - 187

	8. Left hand stanchion side load Station d	9. Left hand stanchion side load Station d	10. Left hand stanchion side load Station d	11. Left hand stanchion fore and aft Station d	12. Left hand stanchion side load Station d	13. Left har stanchion fore and aft Station d
	(strain x10^{-6})	(strain x10^{-6})	(strain x10^{-6})	(strain x10^{-6})	(strain x10^{-6})	(strain x10⁻
Calibration 3 tonne pull at eye	- 1250	- 1000	- 436	-	- 1350	
Loading (rough unloading, Wagner)	- 750	- 560	- 150	+ 210 - 120	- 746	+ 310
Road run	- 180	- 180	± 70	± 140	- 230	+ 90
Cornering and bump	+ 440	+ 1430	+ 560	-		
Cornering					- 404	- 140
Braking (hard)					- 468	- 750

RESULTS (14)

Belly Strop Test

Load dropped from Wagner stacker forks positioned at truck deck height. Peak tension measured in belly strop was 14.2 tonne.

2.3 TRAILER TILT TESTS

The following is a description of tests which were carried out by the Kaingaroa Logging Co Ltd, June 8-14, 1983. The tests were supervised by Mechanical Superintendant, John Britton.

PURPOSE

To investigate aspects of sliding log behaviour and the effect of securing devices by simulating a condition where the horizontal force on the load is equal to the vertical force (such a condition occurs in an emergency situation where a loaded logging truck undergoes a 1.0 g deceleration).

SCOPE

Loads:

1. Radiata export short pulp. 14.94 tonnes total mass, felled 3-4 weeks previously.

2. Eucalyptus shorts. 18.58 tonnes total mass, unknown age but estimated at 6-8 weeks. Eucalyptus logs were watered every 3-4 hours when testing to simulate slippery or icy logs.

Equipment:

- Off-highway pup type trailer (KLC plant No. 122)
- Stanchion height 1.83m
- Bunk width 2.64m
- Various load securing devices
- Tilt angle measuring device.

Securing Devices Tested:

Throwover strops : 6 and 8 mm wire rope. Fixed end anchored either

(a) at top of stanchion

(b) half way down stanchion.

Belly strops : 6, 8 and 13 mm.

Strop Specification:

6 mm : 6 x 19 180 grade fibre core
8 mm : 6 x 19 180 grade fibre core
13 mm : 6 x 32 180 grade I.W.R.C.
Chain : 6 mm long link mild steel galvanised.

THEORY

Tilting a load of logs on a trailer at 45° gives a longitudinal component of force equal to the component normal to the logs (diagram (i)). The ratio is the same as a level load subject to a 1.0 g deceleration or acceleration (diagram (ii)). The overall behaviour of the logs is assumed to be the same in either case, with the exception that in the tilted case the longitudinal and normal forces are 0.7071 of the level case.

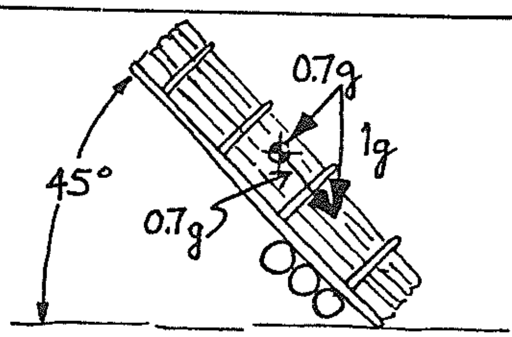


Figure 17

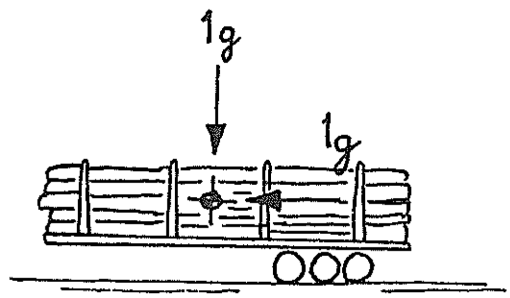


Figure 18

METHOD

1. Load a single load of shorts onto the two rear bunks of the trailer.

2. Attach securing devices to be tested.

3. Lift up front end of trailer until load begins to shift (or limit of lift is reached).

4. Observe way in which load shifted and operation of load securing devices.

5. Measure inclination angle of trailer.

EXPERIMENTAL ERROR

Angles were measured with a relatively crude indicator with an accuracy of about ± 1½%.

TEST RESULTS

There was a significant amount of variability when tests were repeated. Performance of some arrangements for securing loads was often contrary to that expected or indicated by previous tests.

The test results are presented in three groups :

1. No securing devices fitted.
2. Throwover strops/chains fitted.
3. Belly strops used.

Some possible types of securing device (e.g. belly chain) were not used due to lack of time.

In all cases, the angles listed are from the horizontal.

1. <u>No Securing Devices Were Fitted</u>:

Trailer was tipped until one or more logs in the load slid down.

Typical values : Radiata 37° ± 3°
Wet Eucalyptus 35° ∓ 3°

Logs did slide at angles outside the above ranges - the variability extended from about 30° to 45° for both species.

2. <u>Throwover Strops/Chains Fitted</u>:

(a) Configuration:

Two of 6 mm strops, fixed and anchored at top of each stanchion, pulled hand tight, free end anchored in keyhole at bottom of opposite stanchions:

i) Radiata - slid at 47° both strops failed in tension at a stress raiser at the fixed end. (This stress raiser was eliminated in later tests).

ii) Radiata - slid at 38°. Logs slid out from under strops.

iii) Radiata - held at 50°. No failure.

iv) Eucalyptus - Slid at 36°. Logs slid out from under the strops.

(b) Configuration:

Two of 6 mm strops, fixed end anchored halfway down each stanchion, pulled hand tight. Free end anchored as in (a).

i) Radiata - held in 50°. No failure.

ii) Eucalyptus - Slid at 36°. Logs slippd out from under strops.

iii) Eucalyptus - Slid at 36°. Both strops failed in tension.

(c) Configuration:

Two of 6 mm chain fastened as in (a).

i) Radiata - held to 50°. No failure.

ii) Eucalyptus - Slid at 43°. Logs slipped out from under chain.

(d) Configuration:

Two of 8 mm strops anchored as in (a).

i) Radiata - held to 50°. No failure.

ii) Eucalyptus - Slid at 35°. Logs slipped out from under strops.

3. Belly Strops

(a) Configuration:

Belly strop twitched tight (C & R twitch)

i) Radiata - held to 50° - using 8 mm strop.

ii) Eucalyptus - held to 50° - using 13 mm strop.

iii) Eucalyptus - slid at 40° - using 8mm strop. Most logs slid out from under stop.

(b) Configuration:

Belly strop hand tight, i.e. not twitched.

i) Radiata - held to 50° - using 8 mm strop (did this test two times).

RESULTS

1. The manner in which the logs slid when the load was unsecured was variable - usually one or two logs from the top layer of the load would start sliding which would start other logs (beside or underneath) sliding.

Sometimes one or two logs would slide right off the load without disturbing others.

In all cases, the bottom row of logs remained in position on the bunk and did not slide.

2. None of the securing devices used were able to consistently restrain the logs in a compact group, even when a tightly twitched belly strop was used. This was found to be the case for both radiata and eucalyptus log loads, even when all top logs were in contact with the securing strop or chain.

3. Wet Eucalyptus logs were consistently harder to restrain than radiata. Contributing factors could have been:

(a) Increased density (18.58 tonnes/load versus 14.94 tonnes/load radiata).

(b) Harder, smoother wet surface, giving rise to lower friction and making it more resistant to strops or chains digging in and gripping the log.

4. Throwover strops or chains with the fixed end anchored at the top of the stanchion extended above the stanchion.

   Placing the anchor point lower down the stanchion allows the strops/chain to clamp down on the top logs beside the stanchion, restraining them more effectively.

5. Twitching a belly strop tight appeared to prevent the upper portion of the load moving as far as it would have, had the strop been hand tight. However, it is possible that the increased tensile stress on a strop after twitching could lead to failure under less load than a non-twitched strop. Non-twitched belly strops appeared to provide equal performance - without the reliability problem incurred by the inclusion of the twitch.

6. Strop failure always occurred when the strop tightened on the moving logs, i.e. it was absorbing the momentum of the moving logs.

7. Note that all strops/chains experienced a static load of only 0.7071 g. The impact load could have been twice this figure. The static load in the hypothetical accident situation would be 1.0 g, with a correspondingly higher impact figure.

CONCLUSIONS

1. Belly strops and throwover strops or chains appear to be equally effective, providing the fixed end of the throwover strops or chains are mounted (say) about halfway down the stanchion.

2. The possibility of dispensing with twitches could bear investigation. Using a twitch introduces an area of unreliability with possibly no overall improvement in securing the load - other than to reduce the movement of the load. The movement of the top logs in the load when using untwitched strops appeared insignificant in terms of vehicle safety.

   An alternative to a twitch could be a device that takes up any slack on the rope and locks if the rope comes under tension. This could be safer from the operators viewpoint because it reduces the effort of twitching and automatically compensates for the load settling, which reduces the effect of twitching in normal circumstances.

3. Belly and throwover strop strengths could be calculated on the basis of the tension induced by a 1.0 g acceleration shifting the strop from the vertical. The angle from the vertical could be determined by establishing the safe distance through which a log could travel before hitting the cabguard of the truck.

2.4 FORWARD DECELERATION TESTS

INTRODUCTION

Earlier work of the working group had established the overall design requirements for the securing of logs during road transport. However, the specific sizes and configurations of chains/strops normally used on logging trucks still had to be established and incorporated into the proposed code as "standard design". The particular concern regarding the throw over strops and belly strops was their effectiveness during emergency braking, i.e. whether they would meet the requirement that:

"The load restraining system must be capable of containing the load under ... a) forward deceleration under emergency braking conditions when the combined restraining forces must be at least equal to the pay load masses (i.e. force of 1.0 g)".

This report will summarise the test work which was undertaken with various throw over and belly chain configurations during emergency braking trials undertaken on 11 and 16 January 1984. The tests were undertaken in conjunction with the Kaingaroa Logging Company Ltd, Murupara.

TEST METHOD AND EQUIPMENT

A four axle off-highway trailer was used for the tests. The brakes on the trailer were modified in order to simulate extreme braking. The trailer was pushed by a logging truck tractor unit up to a speed of approximately 25km/hr. When a few metres separated the tractor from the trailer, the emergency brakes on the trailer were applied. The test loads carried by the trailer were 9.6 tonnes of debarked short (4.7 metre) logs and 26.4 tonnes of long (12.1 metre) logs. The logs were hosed down with water before each group of tests in order to increase their "slipperyness". The logs were all placed in the centre of the trailer.

The trailer decelerations were measured by a tapley meter, and as a cross check an accelerometer was also employed during some of the tests.

The tensions in the chains were measured by inserting specially constructed tension links into the chain lengths. The signals from these links were amplified and recorded on chart in the cab of a chase vehicle. The measurement system was capable of measuring changes well in excess of the expected dynamic response of the trailer-load securing system. The uncertainty in the measured loads is estimated to be ± 5%.

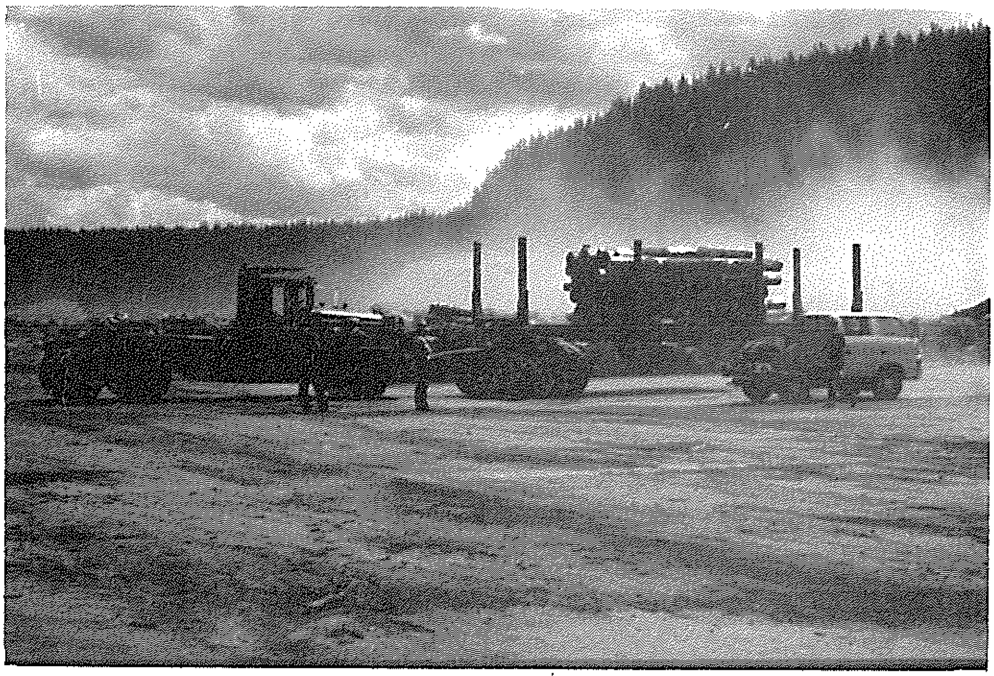


Figure 19 - Test equiment setup

RESULTS

The following tables summarise the results. Tensions are in tonnes. Decelerations are in "g" (gravitational acceleration).

TABLE 8 : BELLY STROP TEST

Short Logs

Test	Deceleration	Initial Tension (Tonne)	Peak Tension (Tonne)	Final Tension (Tonne)	Comment
1	1.0	0.49	1.67	1.18	Tight twitching, logs slid forward Top 1.5m Bot. 0.5m
2	1.0	0.53	1.1	0.86	Tight twitching, logs. Top logs moved 0.3m.
3	1.0	0.08	1.06	0.73	Minimal twitching. All logs moved. Top logs 1m.
4	0.75	0.04	0.16	0.08	Minimal twitching. Top logs moved 0.1m
5	1.0	0	1.06	0.61	No twitching. All logs moved. Bot. 0.2m Top 1m One log on top 2m

TABLE 9 : THROW OVER STROP TEST

Short Logs

Test	Deceleration	Initial Tension Rear	Initial Tension Front	Peak Tension Rear	Peak Tension Front	Final Tension Rear	Final Tension Front	Comment
6	0.95	0	0	0.86	2.81	0	0.34	No twitching. All logs moved. Bot. 0.1m Top 2.5m to 3m
7	0.95	0	0	1.75	1.20	1.02	0.36	No twitching (hand tight). Top logs 1.5m Bot. logs 0.
8	0.82	0.20	0.20	0.98	3.08	0.49	2.24	Twitched Top logs 0.2m
9	0.64	0.16	0.12	0.24	0.20	0.08	0.12	Twitched. One log only moved 1.3m.
10	0.65	0.12	0.16	0.18	0.16	0.08	0.08	Twitched. No logs moved.
11	0.7	0.08	0.08	1.26	2.12	0.86	1.92	Minimal twitching. Top half of logs moved 0.5m. One log moved 2m.
12	0.8		0.40		0.84		0.60	One log only moved 1.5m.
13	0.7		No Strops					All logs moved. 1 log on road
14	0.85		No Strops					All logs moved 3 logs on road.

LONG LOGS

Tests were undertaken with a belly strop and also no strops on a long log, 26.4 tonne load. Unfortunately the maximum deceleration which could be obtained was 0.46g. There was no movement of the logs relative to the trailer.

DISCUSSION

1. The logs were not contained on the trailer when no strops were used during the emergency stops.

2. Maximum strop tension which was achieved during twitching, using a standard twitch, was 0.53 tonne. The twitch was very difficult to operate at this tension.

3. Peak strop tension for the belly strop was 1.67 tonne.

4. Peak strop tension for the throw over strops was 3.08 tonne.

5. The tests did not indicate any direct advantage or disadvantage of tight twitching versus minimal twitching. With no twitching, however, the top logs moved more freely and further. Very loose strops would probably act very much like the no strop situation under fore and aft decelerations.

6. Sometimes, even with the load tightly twitched, one log on the top of the load slid freely. This occurred when the log was not in contact with the strop, and only resting on the logs underneath.

7. The force which must be constrained by the strops will be proportional to the weight of the load and the "slipperyness" of the logs.

$$F_R = M(\alpha - \mu g)$$

F_R = restraining force
M = mass of load
α = deceleration
μ = frictional coefficient
g = gravitation acceleration

Consequently the long logs would have produced proportionately greater strop tensions if a 1.0g stop could have been obtained.

8. Throw over strops were in general more effective in containing the total load, this shows up particularly with the movement of the bottom logs. This effectiveness was reflected by the higher peak tensions in the throw over strops. On one occasion, during a belly strop test, the bottom logs moved 0.5m.

9. Vehicle speed was approximately 25km/hr. The movement of logs will be considerably greater for the same decelerations at higher speeds.

3. DISCUSSION

3.1 SUMMARY OF COMMITTEE MEETINGS

Meetings were held on :

(1) 7 February, 1983
(2) 10 May, 1983
(3) 31 May, 1983
(4) 20 June, 1983
(5) 20 July, 1983
(6) 7 September, 1983
(7) 7 December, 1983
(8) 27 February, 1984

The main points of discussion and action of each meeting's agenda are listed below in point form. After each meeting summary is a paragraph on the action which took place between meetings.

1.
- define objectives of working group
- submittal of background information by group members
- presentation of more results from November tests
- discussion on lack of accident information available
- discussion on terminology which applies to load securing devices and methods required to clarify all the terms used before getting into the details.

Between meetings a draft of terms used to describe load securing devices was written. A search to find details of overseas transport regulations was undertaken.

2.
- corrections/additions to draft of term definitions
- discussion on use of synthetic webbing
- summary presented of DSIR report on tests done in November
- discussion of test results and their implications
- recommendations for further testing - possible braking tests to check load restraint of various devices for horizontal motion.

After meeting 2 a sub-group meeting was held to discuss details of further tests. Tilt tests were organised and carried out at KLC and following that brake tests were run. At the same time details were finalised for more force measurement tests to be run in June 1983.

3. - alterations were made to the terminology draft
   - test results from tilt and braking tests were presented and discussed
   - the functional definitions of belly strops vs throwover strops were discussed.

   Two members were assigned to summarise the functions of each for on and off highway separately.

In this period a second set of force measurement tests was carried out using the DSIR team. The summaries of strop functions were completed and a force analysis of each type of strop (belly and throwover) was completed. A submittal was received from DSIR on a suggested format for a revised Bush Code.

4. - preliminary test results from the second set (June/83) of force monitoring tests were presented and discussed
   - the submittals on functions were discussed
   - the suggested format revision for the code was accepted
   - design requirements for possible configurations of headboards/bulkheads/cab safety frames were discussed.

5. - final results from force monitoring and tilt tests were presented and discussed
   - discussions about functions of on/off highway requirements of load securing devices
   - action was proposed that Baas and Stulen put together a draft of recommendations for code revision
   - details of a court case in Nelson were discussed (where the DSIR will be acting as expert witness for the D.O.L.)

Between meetings Stulen and Baas organised a first draft of recommendations for bush code revision. A copy of the draft was sent to each member of the working group for comment.

6. - details to be contained in recommendations report were discussed
   - format of draft accepted
   - scope of report was limited to include all special equipment used to secure logs on heavy road transport vehicles

Between meetings a cost and specifications comparison was done between chain and wire rope for making throw over strops.

7. - A comparison of chain and wire rope was discussed in meeting the requirements of the throw over strop

- The committee agreed that chain would be recommended over wire rope for strops because of distinct advantages in inspection, handling and cost

- The differences in strength requirements required for fixed as opposed to drop stanchion units was discussed.

- The committee decided that the draft should specify equal strength requirements for either fixed or drop stanchion type units.

- The need for work on securing timber loads on trucks was discussed.

Between meetings tests were organised and carried out on the forward deceleration of a loaded log trailer. (The results of these tests are contained in Section 2.4)

8 - The results of the forward deceleration tests were discussed.

- A film was shown of the forward deceleration tests.

- Section 3.1 of the recommendations draft was rewritten in accordance with the results of the deceleration tests. The revised Section 3.1 was accepted as part of the recommendations report.

- The committee agreed on a recommendation for the location of anchor points on stanchions.

- It was decided that the work on standard designs be carried out under the direction of LIRA but using the expertise of the DSIR.

- The subject of funding for the timber securing devices was discussed and it was decided that a number of organisations would approach the Accident Compensation Commission.

- It was decided that LIRA would inform the industry of the work of the committee.

- The final changes were decided for the recommendations report.

As a result of the work of this committee, a report was sent to the Department of Labour recommending changes to the Transportation Section of its Bush Safety Code, on behalf of the Institute of Road Transport Engineers, in April 1984.

3.2 DEVELOPING THE RECOMMENDATIONS REPORT

During the test work and as a result of discussions between committee members it was decided that the code requirements for inspection, operation and maintenance should be separated into distinct sections within the transportation section of the bush code. This was found to be done in the Australian Truck Loading Code. Separate sections were contained with the requirements listed in each being directed at specific audiences.

It was proposed that the recommendations being made as a result of the committee work be laid out in a format similar to the Australian code but specifically tailored to the needs of the log transport industry. The format which was proposed for the revised code was as follows :

Part I - Design Requirements

Audience : Equipment designers and manufacturers.

Content : This would stipulate the basic requirements which must be met in designing log load securing devices; for example the device must be able to restrain the load under emergency braking (probably equivalent to the weight of the load, 1.0 g). It would be the designer's and manufacturer's responsibility to produce a rig capable of meeting these requirements.

Part II - Operation and Inspection

Audience : Transport management staff, truck drivers, mechanics and inspection people.

Content : Practical requirements and guidelines for everyday operation and maintenance of equipment. Examples from the bush code are :

6.18 Chains shall not be built up by welding after wear ...

6.19 All logging trucks should be loaded so that the load does not extend backwards more than 4 metres from the rear axle.

Part III - Standard Designs

Audience : Any intending builder of log transport equipment.

Content : Detail designs of equipment commonly used in log transport and securing devices.

All designs specified in this part would meet the requirements of Parts I and II.

It was the intention in developing these separate parts that in future the manufacturer of any log transport equipment be responsible for ensuring that it met the requirements of either Part I or Part III before being used for log transport.

3.3 THE USE OF SYNTHETIC WEBBING FOR LOG LOAD SECURING

During the force measurement tests a set of two web straps were put forward by a user to test their ability to retain a log load in event of a wraparound strop failure on a drop stanchion-type vehicle (as per test programme item 8, section 2.1). Their failure in the above test did not provide any information for or against their use in securing log loads.

However, the low resistance to abrasion by logs was seen as a major problem and it was felt that webbing presently available was unsuitable for this application.

4. RECOMMENDATIONS

4.1 RECOMMENDATIONS OF THE WORKING COMMITTEE ON ROAD TRANSPORTATION OF LOGS

PART I : DESIGN REQUIREMENTS

This part stipulates the basic requirements which must be met in designing log load securing devices. It is the designer's and manufacturer's responsibility to produce a vehicle capable of meeting these requirements.

1.1 The load restraining system must be capable of containing the load under three particular conditions:

(a) Forward deceleration under emergency braking conditions when the combined restraining forces must be at least equal to the payload masses (i.e. a force of 1.0 g).

(b) Rearward deceleration when braking during reversing when the combined restraining forces must be at least 50% of the payload masses, (i.e. 0.5 g)

(c) Sideways or lateral acceleration when cornering when the combined restraining forces must be 50% of payload masses (0.5 g).

1.2 The restraining system must be able to withstand the forces which are imposed during loading/unloading.

1.3 Due consideration must be given to the probability that fatigue loading will be the mechanism of failure.

1.4 All logging trucks and trailers operating off highway must meet all the practical safety requirements of the Ministry of Transport.

1.5 There shall be fitted between the cab and the forward end of the log load of every truck used for transporting logs, a cab protection frame of sound construction. It shall be suitably fastened and stayed so as to protect the cab during loading, and the driver in event of sudden movement of the logs during an emergency stop and for rollover protection.

1.6 All vehicles and equipment used for log cartage must be built to a Department of Labour approved standard design or to a design certified by a registered engineer.

PART 2 : OPERATION AND INSPECTION

SECTION 1 : GENERAL SAFETY RULES

2.1.1 Where applicable, these rules are to be observed by all persons employed, engaged, or visiting any bush undertaking.

2.1.2 Where the term "bush worker" is used it applies to any person engaged whether on his own account, as a contractor, employee, or visitor and where applicable all sections of this Code shall apply to that person. "Bush undertakings" means any tree-felling or logging undertaken, conducted for commercial purposes, in which any person is engaged in felling trees by any means or logging operations; and, whether or not conducted for commercial purposes, includes:

- Transportation of logs, flitches, sawn timber, or waste products on other than a public road or street or a Government railway.

2.1.3 Every employer shall nominate a competent person to be in charge of each operation and that person shall exercise such supervision as will ensure that the work is performed in a safe manner at all times.

2.1.4 Employers shall also ensure that all workers are properly instructed and trained in the work they are required to perform and in the dangers and hazards involved in each operation.

2.1.5 All workers shall acquaint themselves with the relevant safety provisions of this Code for each operation and shall take all necessary precautions to ensure their own safety and the safety of others engaged in each particular operation.

2.1.6 The driver of any truck shall have the final responsibility to ensure that his truck is loaded correctly.

2.1.7 The driver of any truck shall be responsible for the correct securing of his load in accordance with this Code.

2.1.8 Every employer or owner of any vehicle used in a bush undertaking must provide himself or his driver with the necessary requisites to enable him to comply with Section 2.1.7 above.

2.1.9 All workers engaged in bush operations shall wear steel toe capped footwear, and shall make proper use of all safeguards; safety devices, and protective equipment furnished for their own use and for protection of others.

2.1.10 Safety helmets must be worn at all times by all persons in and about a bush undertaking; this also includes the unloading of logging trucks wherever their final destination.

2.1.11 All chains and strops used to secure the load must be tensioned.

2.1.12 Where stanchions are used on logging trucks the load shall not extend above the top of the stanchion or the stanchion extension where fitted (see figure 20).

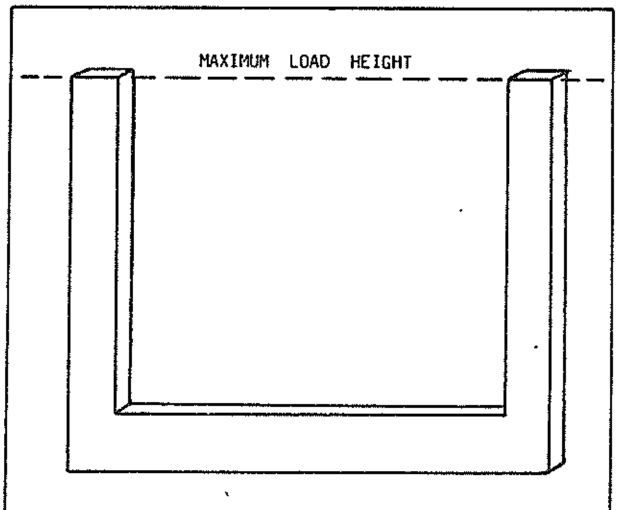


Fig. 20 Logs not to be above stanchion or stanchion extension

2.1.13 Chains, load binder attachments and anchor points should be maintained in good condition. Under any of the following conditions, the chain or other components should be condemned and replaced:

i) Cracked welds or links in chains or load binder attachments;

ii) Bent, twisted, stretched or collapsed links;

iii) Links weakened by gouges or pits reducing the diameter by 10%;

iv) Chains repaired or joined by repair links of a type other than those designed for the purpose;

v) Links obviously worn or showing other visible evidence of loss of strength. (Wear 10% or more).

vi) Knots in any portion of the chain;

vii) Spread or distorted hooks;

viii) An anchor point used in the securement of the load, which is in a weakened condition or shows evidence of loss of strength because of cracks, breaks, distortion or other deterioration.

ix) Repair of the above items, except for item viii), by welding is not permitted.

SECTION 2 : LOGGING TRUCK SAFETY RULES

2.2.1 All motor vehicles, logging trucks and trailers subject to the Transport Act shall carry a current certificate of fitness. Vehicles not subject to the Transport Act shall be inspected every six months by a competent person and a record to this effect is to be displayed in the vehicle.

2.2.2 Drivers of logging trucks shall have a current driving licence applicable to the vehicle being driven. Drivers must have a thorough knowledge of the regulations for operating the particular type of vehicle.

2.2.3 The driver must check all devices used to secure the load and check the truck and trailer operation before leaving the loading site. Brake testing shall be undertaken before descending steep gradients and also in cases where the brakes are likely to be affected by surface water.

If any defect is found which will prevent the safe operation of the equipment, all necessary repairs or adjustments shall be made before the equipment is used.

2.2.4 <u>Vehicle Inspection</u>

(a) Inspection and maintenance records should be maintained to ensure maintenance is performed properly.

(b) Compressed air tanks should be drained at least daily.

(c) Each truck should be equipped with a functional fire extinguisher. The extinguisher must be maintained full, in operating condition, mounted securely, and readily available. The vehicle should be equipped with a first aid kit.

(d) Wheels shall be checked for cracks and loose or missing lug bolts. Remove rocks, wood chunks, and other debris from between tyres and tread.

2.2.5 All trucks shall be driven in gear at all times.

2.2.6 Logging trucks shall be operated in accordance with the Ministry of Transport Road Code. Lights should be operated at all times. The driver shall drive safely at all times and shall not exceed any speed restrictions laid down.

2.2.7 Where a bridge or other structure is posted with a load limit sign, drivers shall not drive a vehicle carrying a load in excess of the posted limit over such a structure.

2.2.8 All road sign instructions and signals must be obeyed.

2.2.9 No person shall be permitted to ride on the back of any logging truck or on the load while the truck is in motion.

2.2.10 Only authorised persons shall travel in logging trucks or operate machines.

2.2.11 To prevent a load of logs sliding off a bolster all logs shall overhang the bolster and stanchion edge by at least 300 mm.

2.2.12 No log shall be swung or lifted over the truck cab during loading or unloading operations.

2.2.13 When logs are stockpiled at the skids they shall be correctly placed and chocked where necessary so as not to create a hazard. No person shall stand on or near a stockpile while logs are being stacked or extracted from the pile.

2.2.14 A satisfactory system of clear signalling shall be arranged before loading or unloading commences. Only one person shall give the signals, except that any person may give a stop signal in an emergency.

2.2.15 When bolsters show signs of significant yield they must be replaced.

SECTION 3 : LOGGING TRUCKS - BOLSTER AND CHOCK BLOCKS

2.3.1 Trucks and trailers using chock blocks shall be loaded so that the outer logs of each succeeding tier are stable and shall be well balanced over the centre of the bolster.

2.3.2 The load is to be secured to each bolster with a binder chain and two chock blocks with chain fastenings on trucks with chock blocks. Where a jockey log is not held by the binder chains such log is to be secured to the load by two belly chains on trucks with chock blocks.

2.3.3 Belly chains and binder chains shall have their twitches so placed that they can be released from the opposite side to unloading.

2.3.4 The load shall be completed and the strops or chains secured before the truck is started. They shall not be released until the load is ready to be removed, except that where necessary, they may be released singly to tighten or relocate. Any branding or measuring shall be completed before binder and belly chains are released.

SECTION 4 : LOGGING TRUCKS - FIXED AND DROP STANCHIONS

2.4.1 Wraparound strops, belly chains/strops, stanchion chains/strops, and safety plates, including fastening of each, shall be inspected daily or at the end of each shift by the truck driver and thoroughly examined by a competent person nominated by the employer, at least once in every four weeks to ensure that all such equipment is maintained in a safe condition.

2.4.2 All parts such as strops, chains and twitches shall comply with Section 1.1. of this Code.

2.4.3 If possible, only logs of length capable of being supported at either end by a stanchion should be loaded on logging trucks or trailers. In cases where it becomes necessary to load logs having a length shorter than the distance between the stanchions, then such logs shall be nestled between the lower rows, or if placed on top of the load, the end of the log not supported by the stanchion shall be secured by a belly chain.

2.4.4 Round the top of the load for effective binding. Refer to Figure 21 below.

SECTION 5 : LOGGING TRUCKS - ACROSS THE DECK LOADING OF ROUNDWOOD

2.5.1 The load on the truck or trailer unit is to be secured by two chains for each unit which are to be twitched tight. The chain and components are to comply with Section 1.1 of this Code.

2.5.2 Prevent logs from crossing, because those on top will have no contact with the binder, and the wood may fall off in transit. Refer to figure 22.

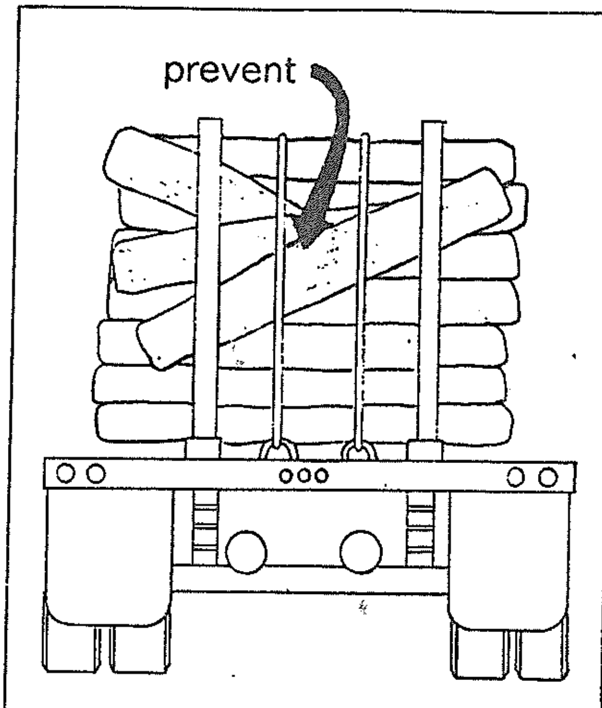


Fig 22

2.5.3 Round the top of the load slightly so the binder will contact and exert pressure on as many logs as possible. Refer to figure 23.

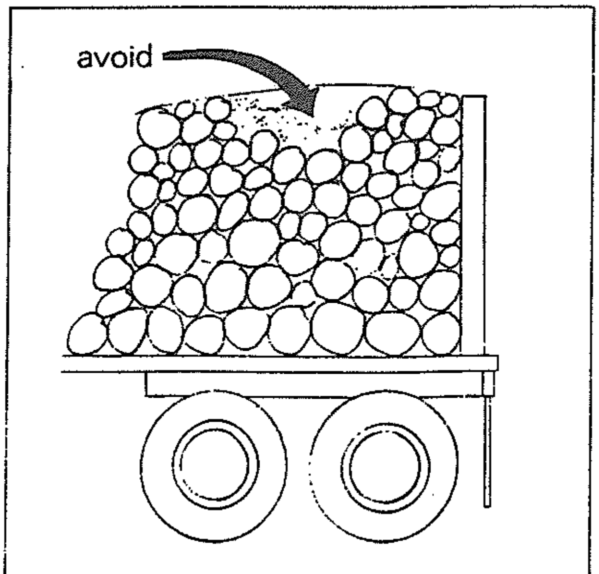


Fig. 23

2.5.4 Extreme care is necessary when the binder chains are released for unloading. When rear uprights are removed, chock blocks or other means may be necessary to prevent the load moving.

SECTION 6 : LOG TRAIN TRUCKS AND MULTIPLE BUNK TRUCKS

2.6.1 Log train trucks with multiple trailers or bunks are to have their loads secured in accordance with Section 1.1 of this Code.

PART 3 : STANDARD DESIGNS

This part details normally used methods of securing loads. It contains information on the function, recommended sizes and types of various components such as belly chains/strops, throw-over chains/strops and stanchions, headboard and cabguard.

3.1 GENERAL

3.1.1 Belly chains, throw-over chains or any other chains or steel wire ropes used to secure a load in accordance with this Code (not including those used for wraparound strops/chains), must have a safe working load (SWL) equal to or greater than 2.0 tonne. This SWL is based on a safety factor of 4:1 with respect to the minimum breaking load. A SWL of 2.5 tonne is preferred.

3.1.2 All chains must comply with BS 4941:1981 or must be specifically approved by the Department of Labour or M.O.T. Steel wire ropes must comply with NZS 5231:1980 and BS 302:1968. Chains are preferred to steel wire ropes for log load securing.

3.1.3 All chains and strops must be tensioned up to but not exceeding their SWL. This pretension reduces the risk of chain/strop fatigue failure.

3.1.4 Stanchion chains/strops are preferred to belly chains/strops for on-highway log transportation.

3.1.5 The designer or manufacturer must produce a list of the parts which will be replaced by the operator. This includes items such as strops, chains and twitches.

3.1.6 Synthetic materials for straps or strops must not be used as load securing devices unless specifically approved by the Department of Labour.

3.1.7 To prevent a load of logs sliding off a bolster, all logs should overhang the bolster and stanchion edge by at least 300 mm.

3.2 LOGGING TRUCKS - BOLSTER AND CHOCK BLOCKS

3.2.1 Each bolster should be made up of a heavy duty channel steel with webbs facing upwards.

3.2.2 Steel chock blocks are to fit firmly into the channel so as to prevent sideways movement of the chock bolsters.

3.2.3 Bolster pivot pins are to be secured at the bottom by a pin or other locking device.

3.2.4 Bolster chock blocks should have a minimum height of 200 mm (8") above the upper edge of the bolster.

3.2.5 An adequate safety bolt, pin, or other effective stop is to be fitted to the end of the trailer pole.

3.2.6 The load is to be secured to each bolster with a binder chain and two chock blocks with chain fastenings.

3.2.7 Belly chains, throw-over chains and any other chains used to secure the load must have their twitches so placed that they can be released from the opposite side to unloading.

3.3 LOGGING TRUCKS - DROP STANCHION

3.3.1 Wraparound strops when used with drop stanchions shall be at least 19 mm (3/4") diameter wire rope.

3.3.2 Drop stanchions shall have the control for the release pin so placed that it can be released on the side opposite to that from which the load is to be removed.

3.3.3 A throw-over chain/strop is to be fitted to each set of drop stanchions. All fittings and components must be capable of holding the stanchions in an upright position should the wraparound strop fail. It is recommended that fixed end of the chain/strop be anchored 300 mm from the top of the stanchion. The chain/strop should then pass through a guide also located 300 mm from the top of the opposite stanchion before passing down to the anchor point.

3.3.4 The minimum size of the pivot pin on drop stanchions, if made of mild steel, should be 32 mm (1¼") diameter.

3.3.5 Stanchion extension pins should be made of steel bar and shall extend above the stanchion a maximum distance of:

(a) 155 mm (6") where made of 38 mm (1½") diameter bar.

(b) 305 mm (12") where made of 45 mm (1 3/4") diameter bar.

(c) 457 mm (18") where made of 50 mm (2") diameter bar.

3.3.6 Stanchion extension pins shall extend into the stanchion a distance of at least equal to half the length extending above the top of the stanchion.

3.3.7 Provisions shall be made to retain the extension pin in the stanchion. The extension pin may be carried long end downwards in the stanchion or in a separate rack.

3.4 LOGGING TRUCKS - FIXED STANCHIONS

3.4.1 Where stanchion extension pins are used such pins are to comply with Section 3.3.5, 3.3.6 and 3.3.7 of this Code.

3.4.2 Where throw-over chains/strops are used to secure a load there must be one at each stanchion twitched tight. Alternatively, a single belly chain/strop, which must be twitched tight, in the centre of each load can be used.

3.5 FLAT DECK TRUCKS TRANSPORTING LOGS

3.5.1 Each flat deck truck or flat deck trailer transporting logs shall be equipped with steel bolsters securely attached to the deck.

3.5.2 Should the bolsters be equipped with chock blocks, such blocks shall comply with Section 2.3 and 3.2 of this Code.

3.5.3 Should the bolsters be equipped with drop or fixed stanchions then such stanchions shall comply with Sections 2.4, 3.3. and 3.4 of this Code.

3.5.4 Where flat deck trucks are fitted with hoists the deck shall be pinned to the chassis.

NOTE: This can be achieved by drilling and pinning through the chassis guides.

3.5.5 Each load on a flat deck truck or trailer shall be secured in accordance with Section 3.1 by two chains/strops.

3.6 ACROSS THE DECK LOADING OF ROUNDWOOD

3.6.1 For transporting across the deck roundwood the frontal end of the truck deck should be fitted with a headboard or cab guard.

3.6.2 On the rear end of the truck or trailer unit steel uprights or chock blocks of sufficient height and strength to retain the load are to be provided.

3.6.3 The load on the truck or trailer unit is to be secured by two chains/strops in accordance with Section 3.1 for each unit.

3.7 SELF LOADING TRUCKS

3.7.1 Self loading trucks are to be equipped with out-riggers and stabilisers that will firmly stabilise the unit while loading and unloading operations are carried out. If the lifting moment of the crane is less than the tipping moment of the vehicle then no stabilisiers are required.

3.7.2 A safe and adequate means of access and egress from the loading work station is to be provided.

3.7.3 Positive means is to be provided so as to prevent a free fall of the boom in the event of a malfunction.

3.7.4 Each set of controls for the operation of the self loading unit is to be of the deadman operation type.

3.8 LOG TRAIN TRUCKS AND MULTIPLE BUNK TRUCKS

3.8.1 The chains/strops and components used for securing a load must comply with Sections 1.1 and 3.1 of this Code.

3.8.2 Where the load is contained within more than two stanchions and if throw-over chains/strops are used then a minimum of two chains/strops are required to be used.

3.9 DETAIL DESIGN : HEADBOARD

3.9.1 This section contains a detail design for a headboard for a logging truck or trailer. This design meets the code requirements. (See Fig. 24).

3.9.2 Headboard design for across the deck loading of roundwood.

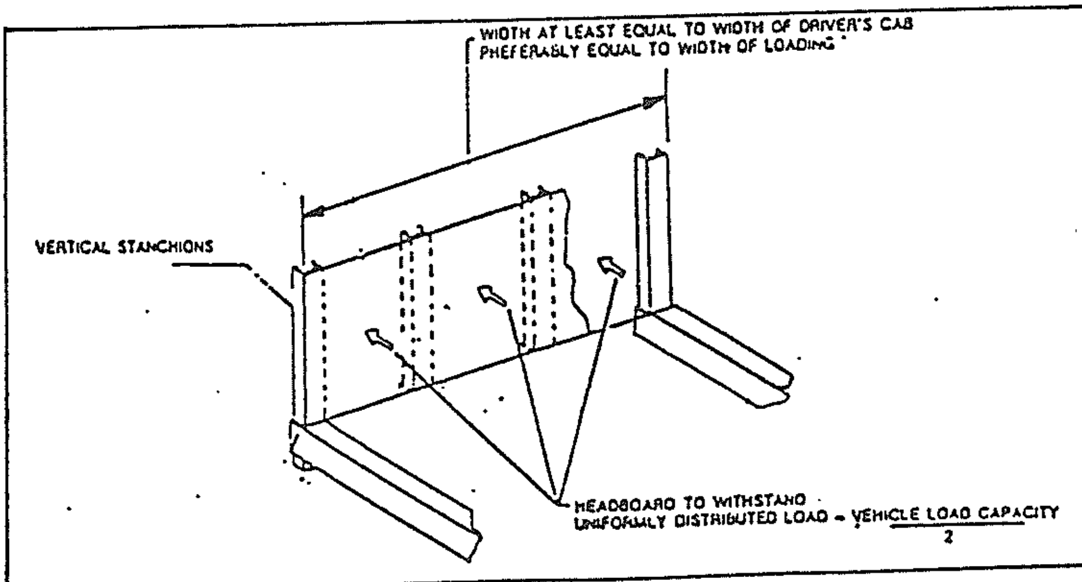


Figure 24: Headboard Design

3.10 DETAIL DESIGN : CAB GUARD

The principles of the general construction shown in figure 23 are as follows:

3.10.1 The centre uprights shall be at least 126 mm x 64 mm (5 in x 2½ in) channel or other sections of equivalent strength and shall project at least 150 mm (6 in) above the cab height.

3.10.2 The outer frame of the cab protection frame shall be of 50 mm (2 in) pipe (wall thickness of 4 mm) and to a width of at least 2440 mm (8 ft) overall.

3.10.3 The intermediate cross members to be at least 38 mm pipe passing through the main two channel uprights and being a maximum of 380 mm (15 in) centre. These shall not be welded around the point where they pass through the upright channels, but attached with a 45° angle cut gussets to the main upright.

3.10.4 The two main uprights shall be mounted to an angle or RHS sub-frame which is bolted down the side of the chassis.

3.10.5 The stay holding the main frame upright to the chassis shall be at least 50 mm (2 in) pipe (wall thickness of 4 mm) and straight anchored to the highest point of the frame and back as far as possible, either ahead or behind the frame. These stays shall also be gussetted to the frame and to the chassis mounting bracket. If pipe gussets are constructed from hollow section of pipe they are more effective when welded to the side of the hollow section.

3.10.6 To receive added protection from a frame when carting small short logs a 3 mm (1/8") steel plate may be welded to the pipes and covering the complete area of the frame but allowing for a rear vision window.

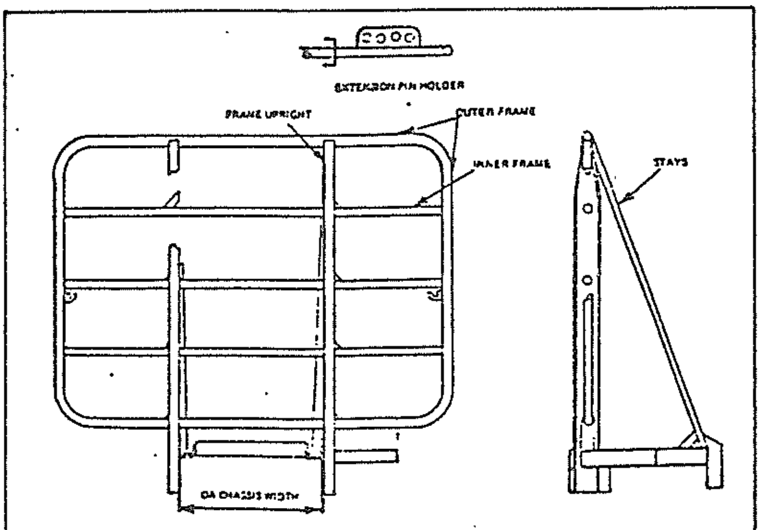


Figure 25: Cab Guard Design

4.2 IMPLEMENTING THE STANDARD DESIGNS

In forming the recommendations report into bush code, some minor modifications were made to the original recommendations to simplify their understanding and implementation.

From overall test results it was decided that throwover strops should be used rather than belly strops. The exception is for operations on very hilly, off-highway terrain where the risk of a roll-over is more likely than an emergency stop and where very few other people are likely to be in the area. In this situation it is important that the load separates from the truck or trailer during the roll-over.

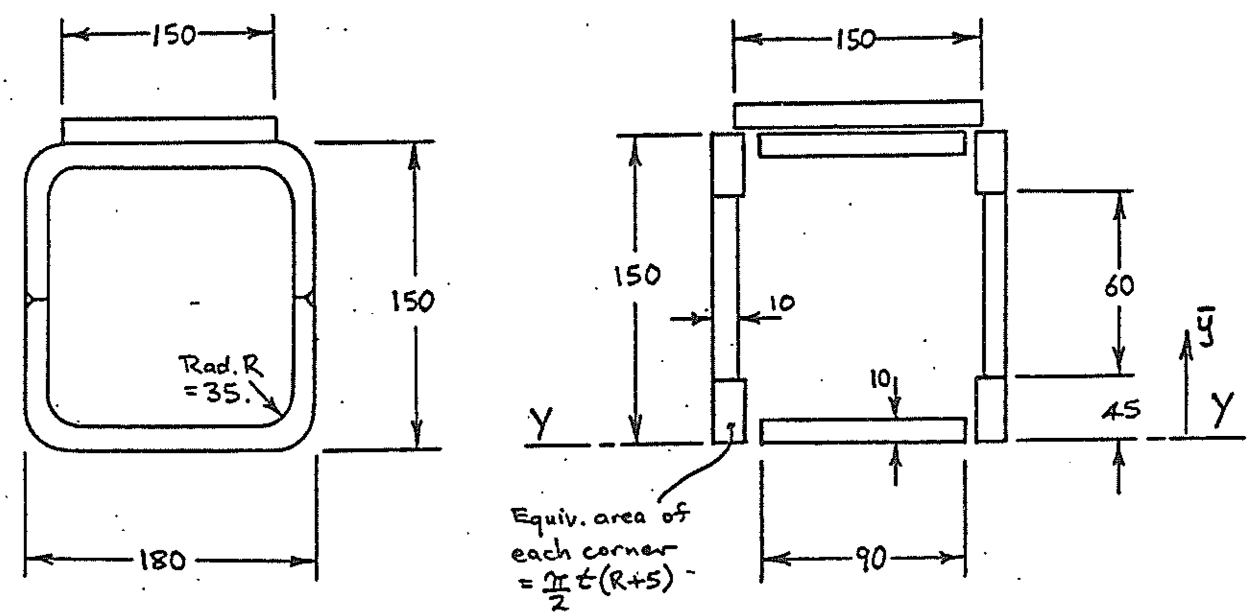
By using the previous test results it was determined (refer to Appendix VI) that the aggregate strength of the throwover strops should be half of the payload mass (e.g. - a 20 tonne payload mass required two 5 tonne minimum breaking strength chains). For most operations on highway, throwover chains would consequently be of 7.0 tonne minimum breaking strength (for up to 28 tonne payload, two chains would be necessary). A good quality, alloy, 10 mm chain has a strength greater than 7.0 tonne.

APPENDIX I

Typical calculation of stresses in stanchion and bolster for a horizontal point loading applied to top of stanchion.

Fixed Stanchion

Cross section 1500mm from top: Equivalent for calculations:



Moment of inertia   Iyy = 24,105,571mm^4
Centroid   y = 92.1mm
Area   A = 7013mm^2

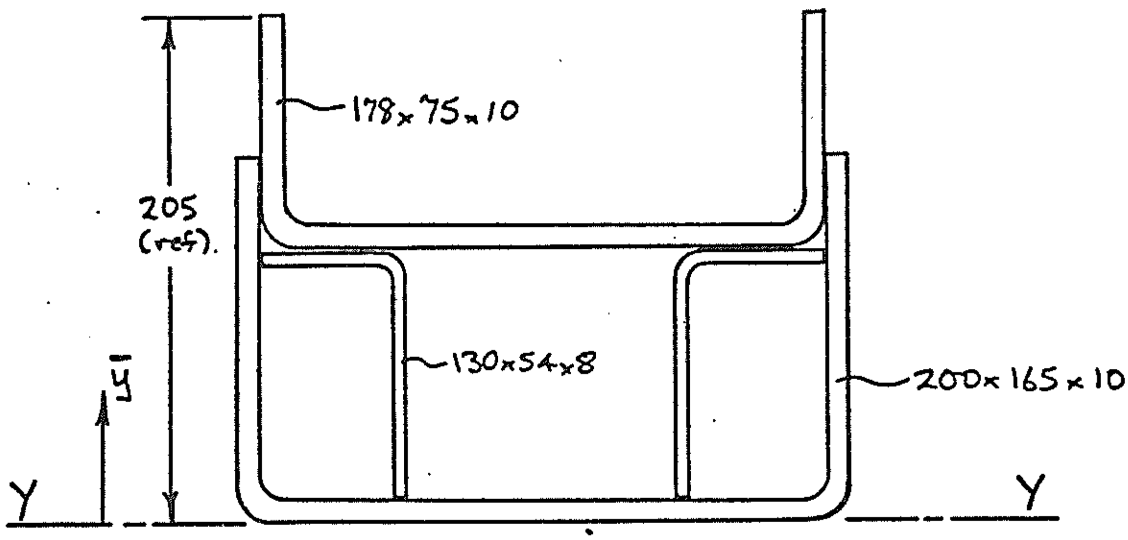
For 5 tonne side load inwards at the top of the stanchion,

Bending moment = 5000 x 9.807 x 1500
(1500mm from top) = 73.55 x 10^6 N-mm

$$\text{Bending stress} = \frac{73.55 \times 10^6 \times \begin{matrix}(67.9)\\(92.1)\end{matrix}}{24,105,577}$$

= 207 MPa, C (1036 με) inside
281 MPa, T (1405 με) outside

Bolster



Moment of inertia	Ivy	= 37,944,495mm^4
Centroid	y	= 92.88mm
Area	A	= 10,468 mm^2

For a 5 tonne load inwards at the top of the stanchion,

Bending moment = 5,000 x 9.807 x 1875

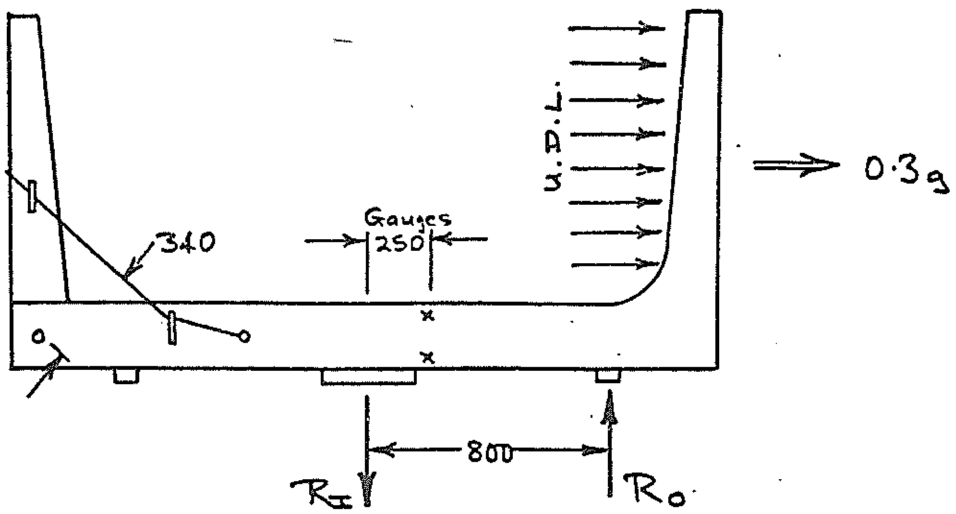
= 91.9 x 10^6 N-mm

$$\text{Bending Stress} = \frac{91.9 \times 10^6 \times \begin{pmatrix}92.88\\112.12\end{pmatrix}}{37{,}944{,}495}$$

= 225 MPa, T (1125 με) bottom
272 MPa, C (1358 με) top

APPENDIX II

Calculation of stanchion and bolster stresses for cornering



Assumptions : 33 tonnes of logs

0.33g corner

side load is uniformly distributed on two side arms

UDL = 11,00 kg x 9.807/(1800mm x 2)
= 30.0 N/mm

Moments of inertia etc from Appendix I.

Stanchion 1500mm from top

Bending moment = $30 \times 1500^2/2$
= 33.75×10^6 N-mm

Additional bending stress during left cornering $= \dfrac{33.75 \times 10^6 \times \frac{(67.9)}{(92.1)}}{24{,}105{,}577}$

= 95 MPa, T (475 $\mu\varepsilon$) inside
129MPa, C (645 $\mu\varepsilon$) outside

Bolster

Bending moment at bottom of each stanchion

= 11,000 kg x 9.807 x 975mm/2

= 52.6×10^6 N-mm

This is reacted by $R_I = R_O = 65.74 \times 10^3$N

Bending moment at gauges = $R_I \times 250$mm

= 16.43×10^6 N-mm

Additional bending stress during left cornering = $\dfrac{16.43 \times 10^6 \times \begin{matrix}(92.88)\\(112.12)\end{matrix}}{37,944,495}$

= 40 MPa, C (201 $\mu\varepsilon$) bottom

= 49 MPa, T (243 $\mu\varepsilon$) top

Wraparound Strop

For right turn, tension = $\dfrac{11,000 \text{ kg} \times 950\text{mm}}{340\text{mm} \times 2 \text{ arms} \times 2 \text{ cables}}$

= 7.7 tonnes

(cf. measured 5.7 tonnes)

APPENDIX III

DEFINITIONS AND FUNCTIONS

1. **Definition of "Off-Highway/On-Highway"**

Roads within areas of land to which the public have restricted (e.g. by means of a permit) access. In some exceptional circumstances it can include roads where there are low traffic volumes and/or few bystanders.

All public roads are classified as "on-highway".

Experience indicates that "off-highway" most accidents always involve the driver, sometimes involve other road users and rarely involve the bystanders.

This is in contrast to "on-highway" accidents, where the risk of involving bystanders and other road users is significantly higher.

2. **General Function of Load Securing Devices**

Off Highway:

(a) Primarily to reduce injury risk to the driver of the vehicle.
(b) Secondly to reduce injury risk to other road users.
(c) Thirdly to reduce injury risk to bystanders.

On-Highway:

(a) Primarily to reduce risk of injury to other road users and bystanders.
(b) Secondly to reduce risk of injury to the driver of the vehicle.

3. **Functional Definitions**

Belly chains/strops and throw-over chains/strops:

(1) To reduce risk of logs sliding forward and hitting or sliding over the cab.
(2) To reduce risk of logs sliding off the back of the load.
(3) To reduce risk of logs jumping over the stanchions.

In addition, throw-over chains/strops:

(4) Restrain the drop stanchion in the event of a wraparound strop failure.
(5) Retain the load on the vehicle in the event of a vehicle upset.

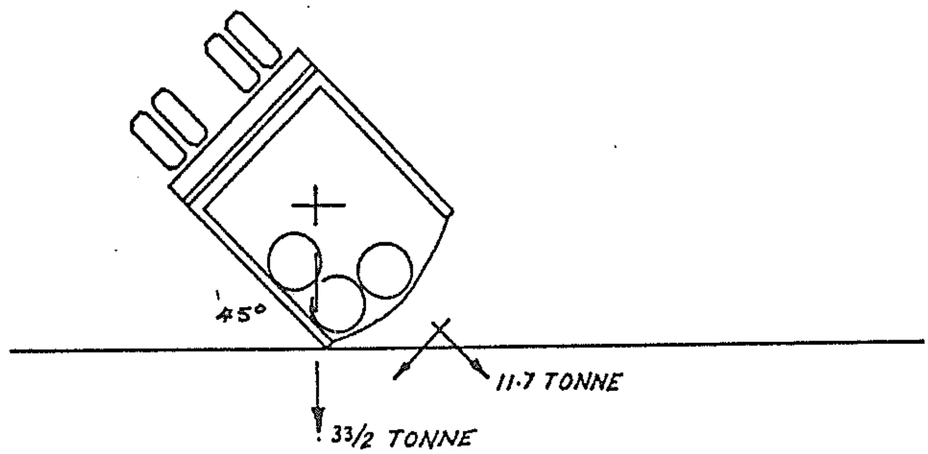
APPENDIX IV

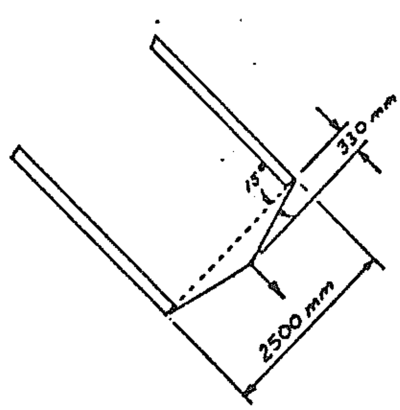
LOG LOAD SECURING DEVICES
THROW OVER STROP AND BELLY STROP LOADS

At the committee meeting on 31 May there was considerable discussion as to whether the load securing devices should be able to contain the load in the event of an accident. In order to establish whether this was feasible, we calculated what the strop tensions would be for two simple cases:

1. Vehicle in Roll Situation with Throw Over Strops

If we take the case when the vehicle is at a 45° position





Tension in throw-over strop will be $T = \frac{11.7}{2} \times \frac{1}{\sin 15°}$

$= 26.6$ Tonne

This will increase as the angle of tip increases.

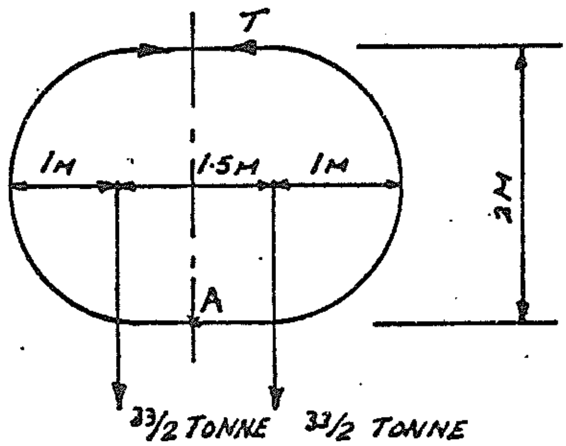
For the case where the load is overfull, and strop loose, if we take a strop deflection of 1000 mm the angle of strop will be 38° and the resulting strop tension will be 9.36 tonne.

Added to this will be the effect due to the dynamics of the situation.

It is normal design practice to assure 2 g dynamic loading. Throw over strop tensions will, consequently, be in excess of 18 tonnes.

2. <u>Logs Separate From the Vehicle, but Held in a Bundle by the Belly Strop</u>

Belly strop length on a log truck is approximately 9 m. If we assume that the log bundle's shape is oval when it sits on the ground after the accident,



Taking moments about A

$$T \times 2 = \frac{33}{2} \times \frac{1.5}{2}$$

$$T = 6.19 \text{ tonne}$$

For the instant when the load hits the ground if we assume a loading of 2 g, the strop tension will be

$$T_{dynamic} = 12.4 \text{ tonne}$$

The measured tension during the November trials was approximately 13 tonnes.

On 14 June a bundle of logs held together with a special belly strop was dropped off a stacker from a height of 1.73 m. Tensions of 14.2 tonnes were recorded at impact.

APPENDIX V

In considering the choice between chain and wire rope for load securing devices there are a number of factors which must be taken into account.

Item	Chain	Wire Rope
Size (mm)	8.5	11 (6 x 31)
Grade	70	180
Type	-	steel core
Minimum breaking strength (tonnes)	8.08	7.75
Weight (kg/m)	1.6	0.5
Length/strop (m)	8.0	6.0 wire rope 2.0 chain
Weight/strop (kg)	12.8	6.2
Cost ($/m)	11.02	3.26
Fittings necessary	A - chain engaging link B - binder	A - chain engaging link B - binder C - wire rope eyes (2) D - chain to eye connectors (2)
Cost/strop ($)	88.16 + (A + B)	19.56 + 22.04 + 11.50 + 24.00 + (A + B) = 77.10 + (A + B)
Repair cost ($)	12.00	19.56
Corrosion	Little, easily visible	- more vulnerable - may not be visible
Handling	- Heavy but flexible - no gloves reqd.	- light but stiff - sprags, require gloves
Ease of throwing	Equal	Equal
Damage problems	- repairable with hammerlock - takes a lot of abuse	- must throw away - problems with kinking on sharp corners

APPENDIX VI

LASHING REQUIREMENTS FOR LOG LOAD SECURING

The Swedish regulation F44-1975 states that the forces involved in load securing can be calculated with satisfactory accuracy according to the simplified formula :

$$P + (10\ Q + S)\ \mu = Qa \qquad (1)$$

P = force acting on retaining devices (head boards etc) (N, newtons)

Q = the mass of the load (kg)

a = design acceleration (m/s^2)
[$1g \approx 10\ m/s^2$]
[$\frac{1}{2}g \approx 5\ m/s^2$]

s = the sum of the tensile forces exerted by the vertical parts of the lashing (N)

μ = friction coefficient.

In other words, the total force produced by the acceleration is Qa. This is resisted by the force P onto restraints such as headboards plus the sum of the frictional restraint due to the load mass and the frictional restraint generated by the downward force onto the load produced by the vertical parts of the lashings.

For normal logging trucks, the restraining force P is zero for the for-and-aft deceleration situation as the vehicles have no items such as headboards.

The effective coefficient of friction of the logs within the stanchion bolster assembly is greater than if the logs were resting on a flat deck. This increase is due to the support provided by the stanchions, and also by the grip provided by the design of the stanchions and bolsters, in particular the knife-edge type surface onto which the logs rest.

In order to estimate a coefficient of friction in this situation some of the earlier test results will be used.

The tests undertaken by KLC during 8-14 June 1983 a trailer was tilted with no strops until the logs started to move.

Radiata logs	37° ± 3° tilt angle
Wet eucalyptus	35° ± 3° tilt angle

If we use a conservative value of 30° and use this in accordance with the Swedish regulations, part 1.2.2.3 "practical experiments - determination of friction coefficient" then the coefficient of friction is estimated to be 0.58.

During 12 and 16 January 1984, hard braking tests were undertaken at KLC. One test with no lashings securing the logs indicated that the load moved during a 0.7g stop. During another test the load did not move during a 0.46g stop, again there was no lashings. If we assume that the deceleration at which unlashed logs begin to move is 0.5g (i.e. a conservative estimate between 0.46, and 0.7) it is possible to calculate the equivalent coefficient of friction by using equation 1 above. In the calculation P=O, S=O (no lashing) $a = 5\ m/s^2$,

$$\text{hence} \quad 0 + (10\ Q + 0) = Q \times 5$$
$$\text{hence} \quad 10\ Q\mu = Q \times 5$$
$$\therefore \quad \mu = 0.5$$

From the above results then, a conservative value for the effective coefficient of friction is 0.5.

It has been proposed that the aggregate strength of the lashings should be at least equivalent to 0.5 times the payload mass. This would mean that the vertical parts of the lashings would have a strength equivalent to the payload mass. If we use this criteria in equation (1), and calculate the deceleration, then

$$(10 \times Q + Q \times 10)\ 0.5 = Qa$$

$$a = \frac{(10 + 10)\ Q \times 0.5}{Q}$$

$$= 10\ m/s^2 \simeq 1.0\ g$$

In the IRTE draft bush code a safe working load (SWL) of 2.0 tonne was proposed. In a subsequent submission to Department of Labour, we recommended a departure from this method of specifying lashing criteria, namely, we suggested a change to minimum breaking strength (MBS) rather than safe working load. The corresponding figure to the 2 tonne SWL was chosen to be 7 tonne MBS as this allowed good quality 10 mm chain to be used (e.g. Hi - 65 or grade P). It was also recommended that for on-highway use throw-over strops be used.

For a vehicle fitted with two 7 tonne chains, S is 7 tonnes x 2 (chains) x 2 (vertical lengths/chain) = 28 tonne. For a 1g stop the maximum payload restrained will be

$$(10\ Q + 28 \times 10^3 \times 10)\ 0.5 = Q \times 10$$

$$Q = 28 \text{ tonne.}$$

A typical maximum payload on highway is 25.5 tonne.

The most significant assumption which has been made is that the effective coefficient of friction of the logs to the stanchion/bolster assembly is 0.5. This is a conservative value, based on test results. It is possible that with very slippery logs this value may be lower. We have, however, the cab guard as a backup. A good cab guard can be relied upon to absorb approximately 0.1g if the gap between the logs and guard is less than 2 m. Consequently, for a 25.5 tonne load, μ could drop to 0.43 and the 7 tonne lashings would still retain adequate load securing.

In Summary

The proposal to change the lashing criteria to be such that its aggregate strength is equivalent to half of the payload is adequate to retain the load. For on-highway use, the draft proposal of two 7 tonne lashings is also adequate for loads up to 28 tonnes, which is in excess of the legal limits when vehicle tare is taken into consideration. The choice therefore between the two criteria must be made on other factors such as :

(i) will an on-highway payload mass exceed 28 tonne?

(ii) the 7 tonne lashing criteria is severe for the small payloads (such as 10 tonnes). Against this is the advantage of policing and uniformity of equipment in the industry.

Note, however, for off-highway use the risk of roll over is probably greater than emergency braking and, consequently, it is preferable, particularly in sparsely populated, hilly country, to shed the load rather than restrain it during emergency braking. Consequently, the option of one 7 tonne belly strop would be good for these situations.

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