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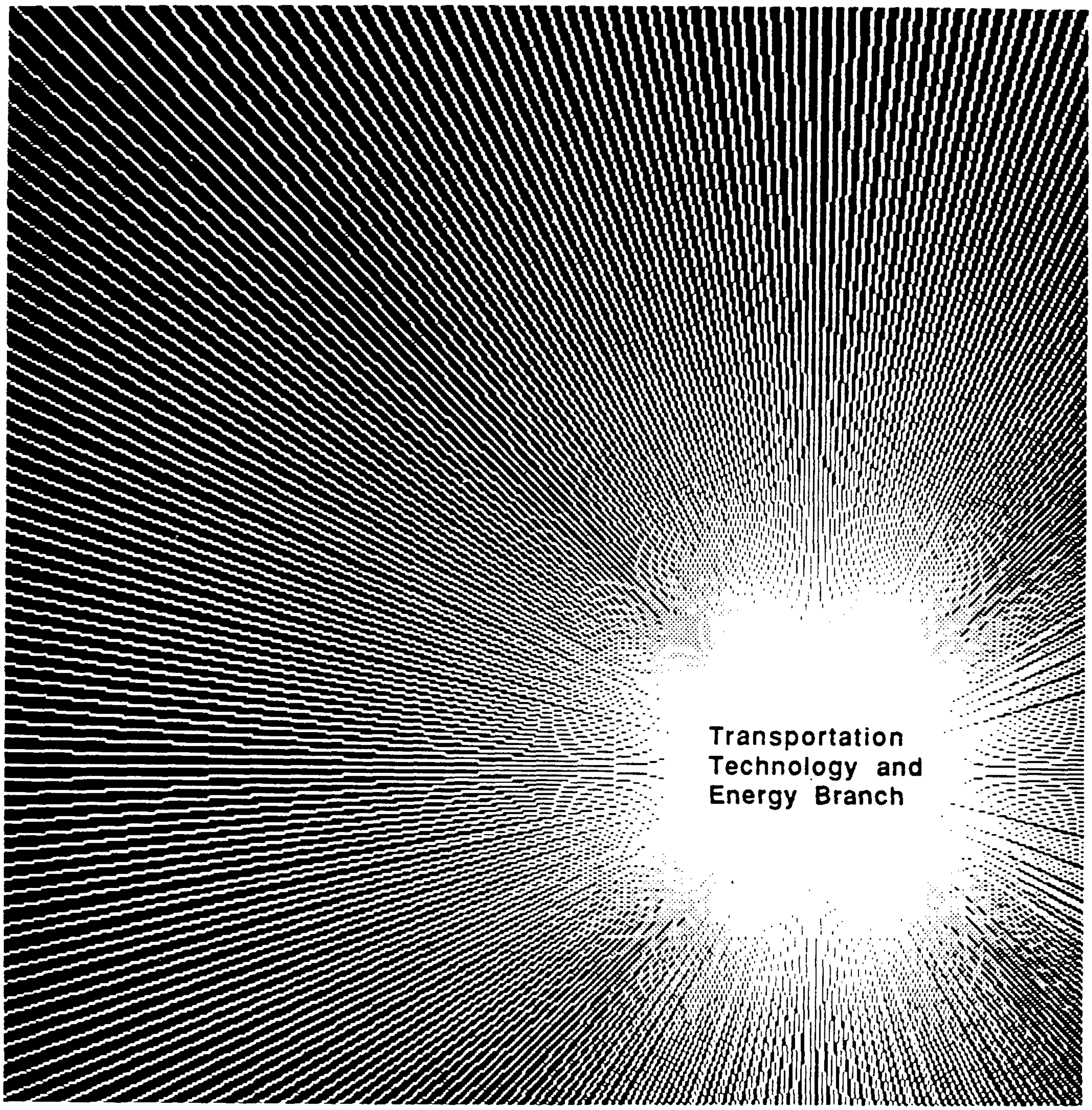

Technical Report Documentation Page

A Proposal for Research to Provide Technical Basis for a Revised National Standard on Load Security for Heavy Trucks

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Abstract:

Ongoing work to draft a National Safety Code Standard for load security for heavy trucks has identified a need for research into the mechanics of load security systems. Extensive consultations found specific needs related to the fundamentals of anchor points for tiedowns, tiedowns, blocking and friction, and related to the specific characteristics of commodities like dressed lumber, metal coils, and a range of others.

This report identifies the load security issues needing research, and describes a program of work to address them, based almost entirely on testing of loads. The results of the tests will be presented in plain language as principles that could be used as a basis for development of the load security standard.

Key words

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PART 1

BACKGROUND

1/ INTRODUCTION

Security of loads on heavy trucks is a matter of public safety, which is why it is subject to a body of industry practice and government regulation. While the majority of professional truckers appear to use appropriate equipment, and often exceed the minimum regulatory requirements for load security, there are sufficient loads lost each year for this issue to remain a concern to the public, highway safety agencies, truckers, and shippers.

Regulation of loads is the responsibility of the provinces in Canada and the states in the U.S. There is no direct federal involvement in Canada. There is federal jurisdiction in the U.S. through a responsibility for inter-state commerce that in fact has resulted in a large measure of regulatory uniformity across the states. With over sixty jurisdictions involved in regulation, it is not surprising that there are differences in requirements, interpretation and enforcement between those jurisdictions. These matters are a real problem to truckers who move loads between jurisdictions. They add to the cost of transportation, and are certainly a hindrance, if not a barrier, to the free movement of goods. While there are broad similarities in requirements across many jurisdictions, there are also some significant differences. Some of the more stringent requirements were often introduced with the best of intentions. However, in general terms, requirements appear to be derived from railway practice, and based more on experience and intuition, or a need to make an obvious improvement, than on engineering analysis.

Trends in freight transportation are providing increasing pressure for uniformity of standards and regulations between jurisdictions. This has led to a range of agreements, like the Canadian Agreement on Vehicle Registration, the Memorandum of Understanding on Heavy Vehicle Weights and Dimensions, and the Commercial Vehicle Safety Alliance (CVSA). Uniformity of load security regulations across Canada has also recently been considered, by a task force of the Committee on Regulatory Affairs and Compliance of the Canadian Council of Motor Transport Administrators (CCMTA). The task force reviewed current regulations and produced a preliminary draft load security standard for the National Safety Code [1]. This draft was unable to resolve significantly different requirements between provinces regarding anchor points and tiedowns, because there was no ready means to evaluate the capacity of load security systems. It therefore identified a number of areas where research was required before all provinces could reach agreement on a national standard for load security.

The Ministry of Transportation of Ontario (MTO) prepared a draft proposal for this research that was circulated to the task force on load security and its parent committee for review. It quickly got wide circulation throughout North America. Each copy of the draft proposal was accompanied by a package that requested review of the content, which elicited helpful comments from many sources. The comments were carefully reviewed and most were accepted as a basis for revision to the proposal. A technical committee was convened, consisting of representatives of governments and governmental agencies and associations, and industry associations representing trailer and equipment manufacturers, shippers and carriers, with approximately equal representation from both Canada and the United States. The committee met in Toronto on August 16 and 17, 1993 to consider a program of research based on a combination of the draft proposal and suggestions for amendment based on the comments received. The committee provided a number of additional suggestions. It agreed that if the draft proposal was revised based on the discussions at the meeting, the research would provide an appropriate basis to develop a revised load security standard for heavy trucks. This final proposal is that revision, and so defines that research. It incorporates all discussions agreed by the technical committee, subject only to further analysis in a few limited areas that do not affect the scope of the program of research.

This proposal addresses the research needs in two parts. The first part presents the background by identifying the issues and discussing some of the principles of load security systems. The second part is the technical proposal that describes a program of work to address the issues. It is based almost entirely on testing of real loads, and includes investigations into the behaviour of elements of load security systems, complete loads, and demonstrations for complete loads. It concentrates on what should be done, and merely outlines in general terms how each test might be done, so the sketches are simply illustrative at this time. The results of the tests will be analyzed and presented in plain language in the form of principles that could be used directly as a basis for development of a load security standard. A video will also be produced to illustrate test findings and results of demonstrations.

2/ OBJECTIVES

The work described in this proposal has three objectives.

1/ To determine how parts of load security systems contribute to the overall capacity of those systems.

2/ To demonstrate the adequacy of parts, and the overall capacity, of load security systems.

3/ To develop principles, based on sound engineering analysis, that could contribute to a revised national standard on load security for heavy trucks.

3/ DEFINITIONS

The following definitions are used to ensure clarity of the proposal. They may differ from definitions used in current regulations, standards, or practice.

Anchor point means part of the structure of a vehicle, or a device that is firmly attached to the structure of a vehicle, that is designed or commonly used for purposes that include attachment of a tiedown assembly.

Dunnage means a device, material, or item of lading that distributes the forces applied by one or more tiedown assemblies over a greater area of the load than would arise from the tiedown assemblies themselves.

Tension device means a device used to produce tension in a tiedown.

Tiedown means a device capable of taking tension loads, including, but not limited to, cable, chain, steel strapping, and webbing.

Tiedown assembly means a combination of a tiedown with one or more tension devices, to secure a load to the vehicle on which it is being carried.

Working load limit, abbreviated as WLL, means the maximum load assigned by a manufacturer that may be applied to a tiedown or component during normal service.

4/ IDENTIFICATION OF ISSUES

The task force report addressing a revised standard on load security under the National Safety Code identified 15 research issues and two areas for development that were considered prerequisite to agreement on a standard [1]. These were presented in essentially a random order, even though there were some clear relationships between some of them. The issues are organized into six groups, each presented in a separate section of this chapter, that will be compatible with the overall structure of this proposal. The issues are presented in their original words [1]. Each is discussed to identify specific aspects of the issue that may be amenable to research.

An additional section in this chapter identifies other issues that have arisen from discussions during development of this proposal, that also seem to be important and warrant research. The final section of this chapter identifies issues that have been raised, but discussion suggests that current practice and procedures are adequate, so research is not necessary at this time.

4.1/ General Requirements

What the performance expectation of the Standard is in terms of safety transporting freight under modern and future highway operations –

It is a responsibility of the client committee to set performance requirements for their standard, and beyond that, to provide means to monitor and assess compliance with the standard, and then to amend the standard as necessary. This item is therefore beyond the scope of this proposal, so will not be addressed further. Aspects of this topic will, however, feature prominently in the discussion of results and will shape development of regulatory principles which will be the principal result offered in the final report.

If the current deceleration rate of 0.6 g is sufficient –

An acceleration of 0.6 g has been selected as representing about the maximum lateral or longitudinal acceleration achievable by a heavy truck under "normal emergency," or non-crash, conditions. It is believed that aspects of current load security requirements and systems are somehow based on this value.

This question, however, is substantially incomplete. It should more properly ask whether load security systems designed using the loads and safety factors specified in the standard provide a sufficiently low probability that actual loads will not exceed the ultimate capacity of the load security system. This should be a statistical problem, whose solution nevertheless appears in deterministic form for design purposes. The acceleration specified for design can in fact be selected quite arbitrarily, provided the other factors in the equation are adjusted to provide an adequate margin of safety to ensure that the load from the restrained object on the vehicle is always less than the real capacity of the load security system. This issue may not be the subject of direct research in this proposal. However, as re-phrased, it is crucial to ensuring the integrity of the load security system, and it will be discussed extensively during the development of the regulatory principles which will be proposed as the basis for revision of the load security standard.

If the current requirement of the working load limit to equal the weight of the load is appropriate –

This issue is directly related to that immediately above and will be dealt with as part of that issue.

4.2/ Anchor points

The working load limits of anchor points –

The load capacity of a tiedown is the lesser of the capacity of the tiedown assembly and the capacity of the anchor points to which it is attached. Anchor points and tiedowns might therefore be considered together as one element of the load security system. However, it is more appropriate to consider them separately. Anchor points are a part of the vehicle, and their load capacity should properly come under the jurisdiction of Transport Canada as a potential new vehicle standard. The tiedown assembly is strictly an operational requirement, so comes under the jurisdiction of the provinces.

Transport Canada is already developing a standard for anchor points on new vehicles, so this aspect of the issue needs no further attention in this proposal.

The strength of the anchor points on existing vehicles, and vehicles not even built yet, will be of concern until all vehicles meet a new vehicle standard. It is critically necessary therefore to assess the load capacity of anchor points on existing vehicles, to be able to provide a load rating for them. Anchor points are of many types and sizes, and a comprehensive assessment would clearly be a major undertaking. It is proposed to evaluate the inherent strength of examples of the following types of anchor point:

1/ Stake pocket;
2/ D-ring;
3/ Chain-in-tube; and
4/ Rub rail.

The trailer side rails, on which the stake pockets are mounted, are not believed to be widely used as anchor points. They are also considered to have adequate strength if they should be so used, so are not considered further. The use of rub rails as anchor points for heavy loads is not recommended [1], and may simply be necessary to demonstrate this.

It is possible that the means by which a chain is hooked to or wrapped around an anchor point may affect the capacity of the anchor point, so these effects will be evaluated for stake pockets and rub rails.

4.3/ Tiedown Assemblies

If the current standard with respect to the tiedown pulley theory is adequate –

Current standards assume that a tiedown chain, webbing, cable, or strap that passes over or through a load, and is anchored at each end, develops equal tension along its length. Current regulations and the proposed standard [1] assume that the tiedown acts as if it were simply passing over a pulley, which allows the tiedown to be rated at a capacity twice its working load limit. It is evident that friction at corners of the load, or the tendency of chains in particular to engage a sharp corner or bite into a soft corner, may prevent equal tension being developed when the tiedown is tensioned only from one side of the vehicle. If tension is not equal in the various spans of a tiedown, it is not clear whether there is any relationship between the rigidity of a load, its tendency to move slightly on the deck of the trailer, or its ability to change shape, which might ensure that accelerations due to roadway roughness do in fact quickly equalize the tensions once the vehicle starts moving. It is therefore necessary to investigate the range of application of the tiedown pulley theory.

If the CVSA calculation method should be adopted –

This is believed simply to be an issue of interpretation, so should properly be addressed by the client committee. It is beyond the scope of this proposal.

4.4/ Blocking

The blocking strength of steel posts, racks, van sides, etc. –

Loads are frequently arranged to bear against stakes, racks, and van sides as part of the load security system. The strength of these parts of the vehicle is not known to be available. Stakes and racks use many materials and are of many designs. It is proposed to test stakes of different types in both shear and bending to allow a working load limit to be assessed for these components.

Trailer manufacturers generally do not design van sides to carry blocking loads, and recommend that they should not be used for this purpose. Loads of closely-packed goods on skids that may lean against trailer walls in a turn are not considered an issue, as in most cases the trailer will roll over before the skid would tip over to demand restraint by the van's walls. In the absence of likely change in van design, the client committee should ensure that loads in vans are secured without relying on the strength of van walls unless those walls are provided by design and construction with anchor points or bearing strength of a specified rating.

It is possible that a need could emerge for a rating for the blocking strength of stakes and racks as part of a new vehicle standard.

The minimum level to which the sides or ends of a vehicle should extend to assure the load will not roll over such sides or ends –

It is a matter of principle that loads within heavy vehicles should be blocked or secured so that they are unable to move or tip. If this principle is followed, then the height of the sides of the vehicle do not become a factor in this. This issue will therefore not be considered further at this stage. It is, however, an issue for loads like refrigerators in such light-duty vehicles as pickup trucks. It is expected that the research proposed here will provide enough information that this issue could be adequately dealt with by analysis.

Develop an appropriate method to secure blocking –

Blocking securement standards –

These two topics are closely related to each other, and to some other specific aspects of blocking that relate to metal coils, discussed in Section 4.6 below. There is clearly a need to assess critically the realistic levels of restraint that can be expected from typical timber blocking nailed to a timber deck.

4.5/ Dressed Lumber

If loads should be secured at intervals of less than the current three metres –

Long loads, which include dressed lumber, must be secured at intervals along their length. The predominant minimum tiedown spacing required is 3 m (10 ft), but other dimensions are used, and in some cases there is a requirement for additional tiedowns at the front of the load. Security of such loads is clearly related to the number, capacity, and tension of tiedowns, and to friction between the load and the vehicle. This issue is crucial to uniformity of provisions between jurisdictions, and will be examined as a function of the various factors identified above. It will also provide some indication of the extent to which trailer headboards or tractor "headache racks" might be considered necessary for certain classes of load.

If each individual level of loads of material like lumber should be secured separately –

This issue is also crucial to uniformity of provisions between jurisdictions. It will also be examined as a function of the various factors identified for the issue above.

4.6/ Metal Coils

If blocking is required to secure coils –

If steel bunks are required to secure coils –

If blocking should be a percentage of the coil size –

These three issues are all closely related and will be treated as a group. Blocking is one element in the load security system for metal coils, and has the potential to provide a portion of the restraint. The objective is to ensure that the entire system provides adequate and reliable load security. As part of this, it is necessary to examine the contribution of various methods of blocking of metal coils to the total capacity of the load security system. If some implementations of the blocking element of the system can assume a greater part of the total capacity, then the total can be satisfied possibly by lesser amounts of the other elements of the system.

The maximum height at which a coil should be transported in a vertical position, i.e., the coil's height shall not exceed 125% of the coil's width –

Loads that arise from a tendency for a metal coil to tip over affect the way in which the load capacity of tiedowns is used. This issue is important for many other loads too, and will be extensively investigated.

If the current tiedown methods are appropriate for securing coils in the lengthwise position, i.e., should the chain angles be limited –

The effectiveness of chains in absorbing horizontal loads as a function of chain angle is important for coils (and other commodities) carried in all positions. This issue will be extensively investigated. The findings should be more broadly applicable for other commodities.

4.7/ Other Issues

This section identifies other issues beyond those identified in the task force report [1] that arose during discussions for preparation of this proposal.

Friction between the load and the vehicle, or between tiedowns and dunnage and the load, is one of the four principal elements of a load security system – the others are blocking, anchor points, and tiedown assemblies. It has been suggested that friction cannot always be relied upon, so should simply be discounted as part of the load security system [2]. However, since friction will unavoidably play a significant role in many of the investigations that are proposed, it will be necessary at least to understand the role it does play when it is present, simply to interpret the results of those investigations. This provides an opportunity to review the above recommendation, though the extent to which it would be prudent to allow for friction remains speculative.

It is evident that some tension devices, like binders and winches, can develop essentially a fixed amount of tension in a tiedown, independent of the rating of the tiedown. This means that a small tiedown could be tensioned to a much greater proportion of its capacity than a larger tiedown, which effectively means it has a much smaller range to absorb tension from the load itself before failure. This raises two issues. First, what are the actual capabilities of the various tension devices to develop tension in tiedowns. Second, to what extent are more tiedowns of a lower capacity effectively different than fewer tiedowns of greater capacity, when both systems would have the same total capacity. It is proposed to investigate both these issues.

It is believed that the load capacity rating of chain is on a straight pull in tension. When one link of a tensioned chain bears directly on a hard surface. that link may be subject to some very high stresses and may yield. It is believed that such factors play a part in the fact that chain has a typical ratio of between 3 and 4 to 1 between its ultimate capacity and its working load limit, a safety factor. However, it is also believed that this safety factor is used by the load security regulations to ensure reliability of load security systems. While these relationships are quite unclear, it is clear that it cannot be used totally in both places. It is proposed, therefore, to investigate to a limited extent any reduction in chain strength as a consequence of the entire tension load being carried by one link in shear or bending.

4.8/ Non-Issues

The following topics were raised as potential issues during discussions in development of this proposal. Discussion of each topic suggested that current practice and procedures were not known to be inadequate, so research was not considered necessary at this time. These non-issues are listed in this section for reference purposes and completeness only.

The manufacturers rating of chain, webbing, and cable tiedowns, and manufacturers standards to identify when damaged tiedowns should be removed from service, are not considered an issue.

The manufacturer's rating of binders and other tension devices, except winches, is also not considered an issue.

The manufacturer's rating of D-rings is also not considered an issue.

The security of 2.44 m (8 ft) long logs loaded cross-wise has already been addressed by industry and is no longer considered an issue [3].

The long-held position of industry that loads of aggregate shift in transit and affect axle loads, which could imply a load security issue, has also been addressed [4]. It was found that the load simply settles vertically, with essentially no longitudinal movement in transit.

The security of heavy equipment and wheeled vehicles was being dealt with by others at the time this proposal was written, so was considered a non-issue and was not included in the proposal. The status of that work is now unclear. Even if it does not proceed, it is expected that standards and procedures recommended by equipment and vehicle manufacturers, perhaps used in conjunction with findings of some of the tests in this proposal, should provide the client committee with an adequate basis to address this issue. For the purposes of this proposal, therefore, it remains a non-issue.

5/ A DISCUSSION OF PRINCIPLES FOR LOAD SECURITY

5.1/ Normal Operating Conditions

Current regulation and practice specifies a number of means of securing loads. There are several provisions that apply to all loads, and schedules for particular classes of load. By and large, performance could be described as adequate, in the sense that loss of load is actually an infrequent occurrence. There are many reasons for this. First, it appears that many truckers secure loads in a conservative manner, to their own standards, that may often exceed the minimum requirements of regulations by a wide margin. Second, though the limiting manoeuvres that would generate the design load for the load restraint system may be within the capability of some vehicles, they are far beyond normal driving, even beyond the occasional moderate emergency manoeuvre that may occur without the vehicle actually being involved in a crash. Third, of course, elements of the load restraint system usually have a significant nominal margin of ultimate strength beyond their rated capacity. Finally, in most cases, loads and load restraint systems provide significantly more than the minimum possible friction between elements. As a consequence of some or all of these factors, there are cases where loads do remain substantially secure even through a crash, even though load restraint in such an extreme condition is not known to be a part of any requirement.

However, the apparent general satisfactory performance of load restraint systems could also be something of an illusion. There are a number of elements that are used quite commonly in restraint systems, like various forms of blocking, anchor points on vehicles, tarps and coverings, and stake and rack assemblies or sidewalls, whose capacities are not truly known. There may also be questions of effectiveness, such as the extent to which tiedowns can develop tension and maintain it during a trip. If some forms or use of these elements do not have adequate capacity, this may be neither evident nor a problem in normal driving because the demand placed on the restraint system is still only a small part of its actual capacity. Any deficiency will not become evident until an infrequent coincidence of adverse factors arises, so that a load is lost.

Shippers may also require truckers to use means to protect the load against damage in transit. Devices used for load protection act in concert with the load security system and could serve either to enhance or degrade the effectiveness of the load security system. Any benefits arising from such devices may be included in the capacity of the load security system. Such devices should not be used where they compromise the integrity of the load security system.

The load security system may be considered to be composed of three parts:

1/ Friction, which acts between the load and the vehicle, and may also act between the load and other elements of the load security system;

2/ Blocking, which prevents movement of the load; and

3/ Tiedown assemblies and anchor points, which together secure the load to the vehicle.

Current load security requirements allow some choice of use of certain combinations of these elements. Requirements address the capacity of the system as a whole, without considering how it will work in practice, and in particular, without direct provision for any redundancy. It appears that there may be some independence between the above three parts of a load restraint system, so there could in practice be some degree of redundancy in many typical restraint systems.

The extent to which each of the above parts of the load restraint system can be relied on individually is not clear. It is known that, used together to share the task of load security, they provide adequate capacity in most cases. It would seem that the capacity of each of these elements of the load restraint system should be identifiable as a rating, when it would be possible to identify the extent to which it contributes to the overall load restraint capacity. From this, it would be a short step to determine requirements so that, if there is a single failure of a component of any of these three parts, the remainder still meet fully the requirement for load security. What, then, might be deemed a failure?

Friction is always available when the load is placed on a clean, dry surface, and is tightly tied down to the vehicle. However, any specific level of friction cannot be guaranteed when the load is placed on an icy or snowy surface, or on dunnage that is frozen; if it is placed on a surface contaminated with oil or grease; if it is placed on un-braked rollers, or would be free to roll; if it is not tightly restrained; or in some other number of possible conditions. All these cases, which exist from the moment of loading, constitute a failure (by absence) of the friction mechanism.

It is important to realize that friction may be enhanced by a positive tiedown that increases the pressure of the load on the vehicle. Tiedowns and friction are therefore not completely independent of each other. However, if it is presumed that any reasonable heavy or bulky load will have at least two tiedowns, then failure of one tiedown will not eliminate all friction between the load and the vehicle.

It is not quite so easy to be specific on the potential modes of failure of blocking. It is almost circular logic to suggest that blocking has failed when it no longer provides its rated restraint capacity, so that the load moves.

A tiedown has failed when it is unable to maintain its own tension. This could be due to mechanical failure of the chain, strap, or cable, the hook or other attachment to the vehicle, the anchor point on the vehicle, or the tension device. A tiedown may lose tension if the load shifts, so the tiedown is therefore somewhat dependent upon both friction and blocking.

Risk analysis considers not just the possibility of failure of a system, but also the consequences of failure. If failure of the load security system for certain classes of load could have much more severe consequences than for other classes, then it could be argued that a greater standard of load security should be applied to the classes with the higher risk. The most obvious case is the metal coil, which can roll away from a truck once it has been dislodged, whereas many other loads simply remain where they fall. The important factor simply is that the load becomes dislodged from the truck, irrespective of whether the truck has been involved in an accident or not. It could be argued that there is no difference whether another vehicle collides with a rolling metal coil or a stationary fallen load of equal mass, either is a serious and random crash, and it is not relevant whether the other vehicle is immediately adjacent to the truck, or even in the separate lanes of a divided highway. Of course, the rolling metal coil may increase the relative velocity at impact with an oncoming vehicle, which might increase the severity of an accident. However, since metal coils typically weigh between 10 to 35 t, any collision with such a mass, whether moving or not, has potentially fatal consequences. Public perception would probably suggest that a rolling coil is more of a hazard than a coil which simply falls, but likely only from the point of view that a vehicle remote from the vehicle that lost the coil is "more innocent" than one close to it. This does raise the question of whether a higher level of security should be considered for a load which can migrate away from the vehicle from which it became dislodged, compared to a load that simply falls inertly to the ground.

5.2/ Crash Conditions

The issue of the role and responsibility of the load security system during a crash needs at least to be discussed. The current regulatory approach is completely silent in this regard. However, it is evident that the load of many vehicles that are involved in crashes is sufficiently well secured that it does remain substantially with the vehicle. From a safety point of view, the load must remain the responsibility of the driver even through a crash, which means it must remain substantially with the vehicle. It will clearly be a difficult problem to set this as a requirement of a load security standard.

It is certainly extremely difficult to estimate the loads involved during a crash, which of course, depend on the circumstances of the crash. It is possible to generate longitudinal loads in excess of 20 g if a truck runs head-on into another truck of similar mass or a bridge abutment. It appears unreasonable to expect a load security system to contain the load in such a case, when the truck itself will be totally destroyed. A crash into a smaller or lighter vehicle, or into a guard rail or barrier wall at a shallow angle, will generate a combination of longitudinal and lateral loads, and the truck may not even suffer serious damage. These loads will be considerably less than for the head-on brick wall collision, perhaps in a range of 3 to 8 g, but are still substantial. A rollover will also generate a combination of longitudinal and lateral loads, and again these are very difficult to estimate.

Current load security standards are based on "normal emergency" load levels, possibly in the 0.6 to 1 g range. It is clear that upgrading load security standards to accommodate a crash would require a substantial upgrade in load security systems which would demand very careful thought and considerable justification. It is not clear whether this would even be achievable. In the interim, it would seem reasonable to consider requiring that anchor points and tiedown assemblies at the side of the vehicle should be protected against damage in a crash, so that the load security system at least stands a chance of continuing to do its job through the crash. It is for this reason, rather than strength, that rub rails should not be considered as an anchor point, even though they may in fact have adequate strength for light loads.

PART 2

TECHNICAL PROPOSAL

6/ METHODOLOGY

The issues identified in the previous section might be approached in a number of ways. The approach should be appropriate to the issue. For example, if the mechanics of a particular issue are well understood and adequate data are available, it might be approached by computer simulation. In contrast, if the mechanics of another issue are not well understood, or are clearly non-linear, or data are difficult to obtain or unreliable, then it would be more appropriate to approach the issue by means of a test program.

Simple load security models have been developed for many generic combinations of load shape and tiedown geometry [2]. Computer simulation models of heavy trucks are available for lateral/directional and rollover dynamics, and braking. It would be possible to combine load security and vehicle dynamics models to compute forces in tiedowns for various types of load as vehicles make specified manoeuvres. Computer simulation models are very useful for ranking the performance of vehicles in comparison with each other. However, they are less useful for assessing the absolute performance of a particular vehicle, as both the model and the data become less reliable as the limit of vehicle stability is approached. These limits are broadly known for many classes of vehicle [2, 5]. It is much easier, and usually conservative, to apply quasi-static limiting accelerations to simple models based on load shape and tiedown geometry.

Beyond this, it is evident that many of the key mechanisms involved in load security, like the pulley effect, the ability to develop tension in tiedowns, the role of friction, and the possible domino effect of multiple small tiedowns, are not well understood. Lacking such basic understanding, and the data needed even for simple load security models, it is necessary to develop both an understanding of the mechanics of the elements of load security and the data needed to use simple models effectively. This means that the issues must be addressed principally by means of a test program. Previous studies have reached the same conclusion [2].

It is proposed therefore to approach the issues identified in Part 1 of this proposal by means of a test program. Subsequent chapters of this section address specific aspects of each of the areas identified in Chapter 4 of Part 1, and propose specific tests to address the issues. Some of the tests, particularly those that simply involve driving a vehicle and monitoring certain vehicle and load responses may be similar to normal driving. Other tests, especially those conducted in a laboratory, are artificial in the sense that test conditions are set up to ensure that the characteristic of interest can be observed reliably without the confounding influence of extraneous or uncontrolled factors. The majority of the tests are designed as laboratory tests in order to be able to determine the capacity of the load security system. Since these systems are based on 0.6 g design load, which is about the limit of the capability of a vehicle, and since the capacity of some systems are likely to exceed this by a wide margin the only way to determine that capacity is by a laboratory test. Some of these tests will be performed using vehicles, but they must necessarily be stationary tests with artificially induced loads in order to develop the magnitude of load necessary. Some tests require large loads that will result in failure of components of the load security system. This introduces significant difficulties as it is necessary to contain the energy that is released when failure occurs, and more than one failure mode may be possible.

The fact that this proposal is based on a test program does not, of course, preclude the use of simulation and analysis. These tools will be used as necessary, to move from the specific conditions which are tested to the general regulatory principles which will be the principal output from the work.

7/ ANCHOR POINTS

7.1/ The Issues

The load capacities of the anchor point and the tiedown assembly must be assessed separately, and only the lesser of the two can be used as the load capacity of the tiedown. Load ratings of tiedowns are generally available, but review of the load security regulations identified that the load capacity of anchor points was generally unknown [1]. This raised two issues:

1/ New vehicle standards
2/ Rating of existing vehicles.

Setting a new vehicle standard for rating anchor points will solve the issue of the adequacy of anchor points over the long term. It is the responsibility of Transport Canada. A standard is now under development so this issue needs no further attention in this proposal.

Some means of rating the capacity of anchor points on existing vehicles will be required for the foreseeable future, until all vehicles meet a new vehicle standard. Stake pockets, rub rails, and special attachments like D-rings and chain-in-tube assemblies are the most common anchor points. This section proposes tests to determine the inherent strength of typical samples of these anchor points. The means by which a chain is hooked to and wrapped around a stake pocket or a rub rail might affect the strength of the anchor point, so various chain wraps will be investigated for these two particular anchor points.

All these test will be conducted using a laboratory load testing machine, with test articles fabricated to represent typical hardware.

7.2/ Stake Pocket Pull-out Strength

7.2.1/ Purpose

The purpose of this test is to determine the strength and ascertain the mode of failure of typical flatbed trailer stake pockets when pulled in various directions.

7.2.2/ Method

An adapter shall be manufactured for connection to the pocket. The pocket shall be mounted in a load test machine from a jig that is designed such that the pocket only shall fail during the test. The adapter shall be pulled until failure of the pocket occurs. The test shall be conducted with separate pulls in several directions:

a) vertically,
b) forward, parallel to bed,
c) laterally, parallel to bed (inboard),
d) laterally, parallel to bed (outboard), and
e) inboard at 45° to bed.

Three steel pockets, representative of light-, moderate-, and heavy-duty design, and two aluminium pockets representative of light- and heavy-duty design shall be tested.
The test arrangement is shown in Figure 7.2. The test matrix is shown in Test Matrix 7.2.4.

7.2.3/ Results

This test will provide the forces and deflections associated with pocket deformation and subsequent failure for each pull direction, each pocket. This will serve as a means of assessing a working load rating for these stake pockets when used as anchor points for tiedowns.

7.2.4/ Test Matrix – Stake Pocket Pull-out Strength

Test No. 7.2-	Pocket Design Light, Med, or Heavy Duty	Pull Angle Vertical	Long. Fwd.	Lat. (ibd)	Lat. (obd)	45° to bed
1(a)	Light/Steel	X				
1(b)	Light/Steel		X			
1(c)	Light/Steel			X		
1(d)	Light/Steel				X	
1(e)	Light/Steel					X
2(a)	Medium/Steel	X				
2(b)	Medium/Steel		X			
2(c)	Medium/Steel			X		
2(d)	Medium/Steel				X	
2(e)	Medium/Steel					X

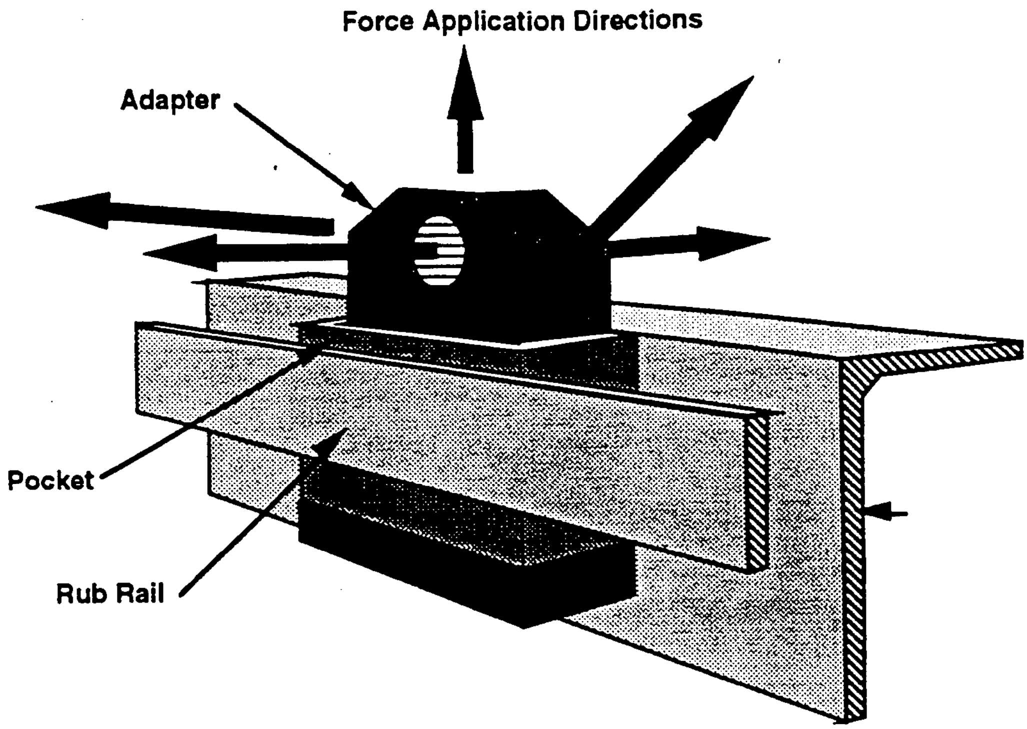


Figure 7.2/ Stake Pocket Pull-out Strength

7.2.4/ Test Matrix – Stake Pocket Pull-out Strength (cont'd)

Test No. 7.2-	Pocket Design Light, Med, or Heavy Duty	Vertical	Pull Angle Long Fwd.	Lat. (ibd)	Lat. (obd)	45° to bed
3(a)	Heavy/Steel	X				
3(b)	Heavy/Steel		X			
3(c)	Heavy/Steel			X		
3(d)	Heavy/Steel				X	
3(e)	Heavy/Steel					X
4(a)	Light/Aluminum	X				
4(b)	Light/Aluminum		X			
4(c)	Light/Aluminum			X		
4(d)	Light/Aluminum				X	
4(e)	Light/Aluminum					X
5(a)	Heavy Aluminum	X				
5(b)	Heavy Aluminum		X			
5(c)	Heavy Aluminum			X		
5(d)	Heavy Aluminum				X	
5(e)	Heavy Aluminum					X

7.3/ D-Ring Pull-out Strength

7.3.1/ Purpose

The purpose of this test is to determine the strength of D-ring welded bracket tiedowns when pulled in various directions, and to ascertain the mode of failure.

7.3.2/ Method

The D-ring assembly shall be mounted in a load test machine from a jig that is designed such that the D-ring assembly only shall fail during the test. The D-ring shall be pulled in seven directions, as shown in Figure 7.3, until failure occurs. The test shall be repeated with three different D-ring assemblies representing, light, medium, and heavy duty.

7.3.3/ Results

This test will provide the force at which failure occurred for each pull direction, which will serve as input in assessing a working load rating for D-ring assemblies when used as anchor points for tiedowns.

7.3.4/ Test Matrix – D-ring Pull-out Strength

Test No. 7.3-	D-ring Design	Pull Angle (refer to Figure 7.3)						
		X	Y	Z	XY	XZ	YZ	XYZ
1(a)	Light Duty	X						
1(b)	Light Duty		X					
1(c)	Light Duty			X				
1(d)	Light Duty				X			
1(e)	Light Duty					X		
1(f)	Light Duty						X	
1(g)	Light Duty							X
2(a)	Medium Duty	X						
2(b)	Medium Duty		X					
2(c)	Medium Duty			X				
2(d)	Medium Duty				X			
2(e)	Medium Duty					X		
2(f)	Medium Duty						X	
2(g)	Medium Duty							X
3(a)	Heavy Duty	X						
3(b)	Heavy Duty		X					
3(c)	Heavy Duty			X				
3(d)	Heavy Duty				X			
3(e)	Heavy Duty					X		
3(f)	Heavy Duty						X	
3(g)	Heavy Duty							X

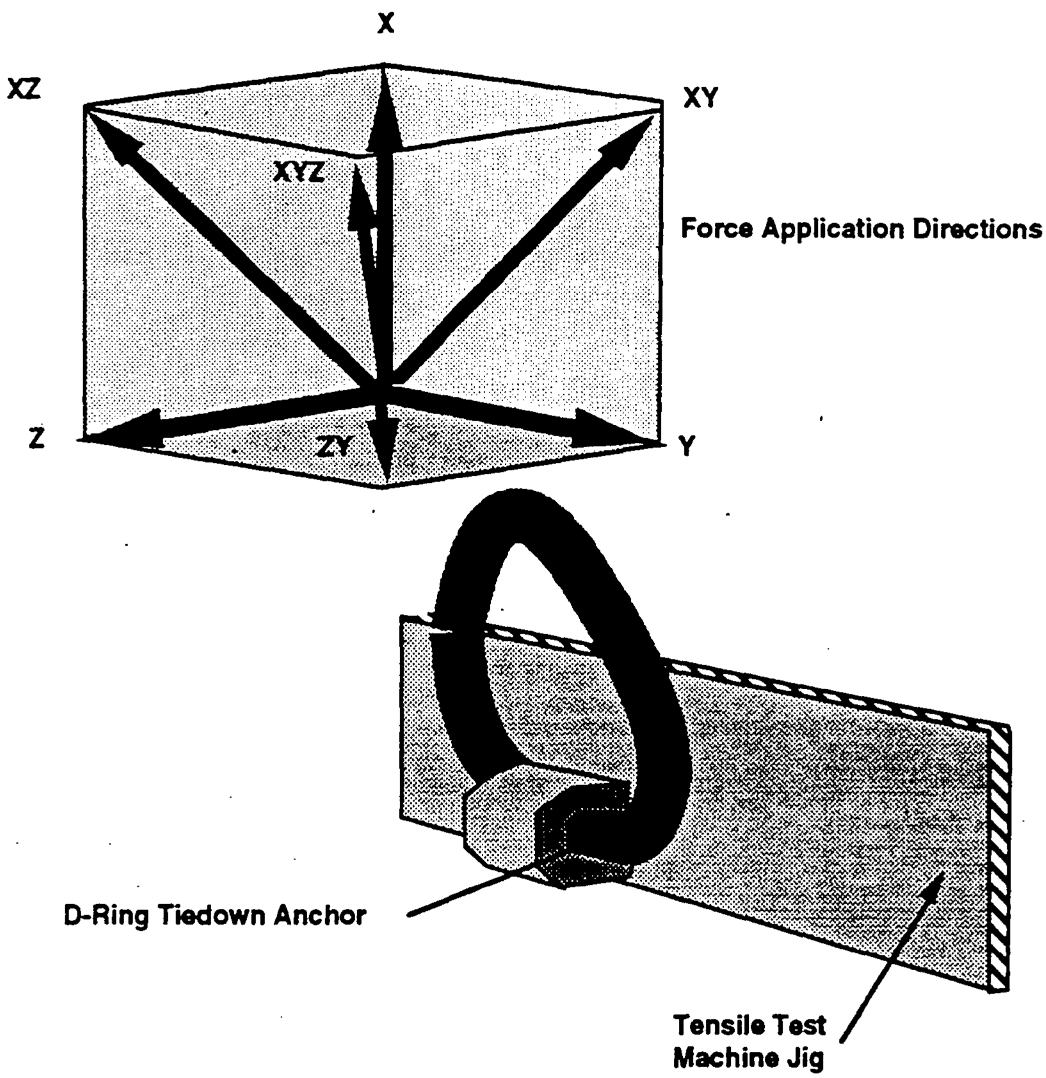


Figure 7.3/ D-Ring Pull-out Strength

7.4/ Web Tensioning Ratchet Strength

7.4.1/ Purpose

The purpose of this test is to determine the strength of web tensioning ratchet assemblies when pulled in various directions, and to ascertain their mode of failure.

7.4.2/ Method

A web ratchet with accompanying webbing shall be installed in a load test machine jig and the webbing shall be pulled until subsequent failure occurs. Three pull directions shall be examined:

(a) vertically,
(b) horizontally outboard, and
(c) at a 45° aft of vertical.

These are shown on Figure 7.4.

Four web ratchets shall be tested. These are:

(a) Heavy Duty (model 1),
(b) Heavy Duty (model 2),
(c) Light Duty (model 1), and
(d) Light Duty (model 2).

Models will be defined at a later date.

Each ratchet shall be secured to the frame using each of the following methods in accordance with its manufacturer's recommendations:

(a) Clip attachment,
(d) Welded attachment, and
(e) Slotted (slider) attachment.

7.4.3/ Results

This test will provide the forces at which failure occurs for each ratchet type, with each connection method, for the given pull direction. This will provide input into evaluating the workload ability of these ratchet assemblies.

7.4.4/ Test Matrix - Web Tensioning Ratchet Strength

Test No. 7.4-	Ratchet Model	Attachment Method	Pull Direction Vert.	Lat.	45° Aft
1(a)	Heavy Duty (Mod 1)	Welded	X		
1(b)	Heavy Duty (Mod 1)	Welded		X	
1(c)	Heavy Duty (Mod 1)	Welded			X
2(a)	Heavy Duty (Mod 2)	Welded	X		
2(b)	Heavy Duty (Mod 2)	Welded		X	
2(c)	Heavy Duty (Mod 2)	Welded			X
3(a)	Heavy Duty (Mod 1)	Slotted	X		
3(b)	Heavy Duty (Mod 1)	Slotted		X	
3(c)	Heavy Duty (Mod 1)	Slotted			X
4(a)	Heavy Duty (Mod 2)	Slotted	X		
4(b)	Heavy Duty (Mod 2)	Slotted		X	
4(c)	Heavy Duty (Mod 2)	Slotted			X

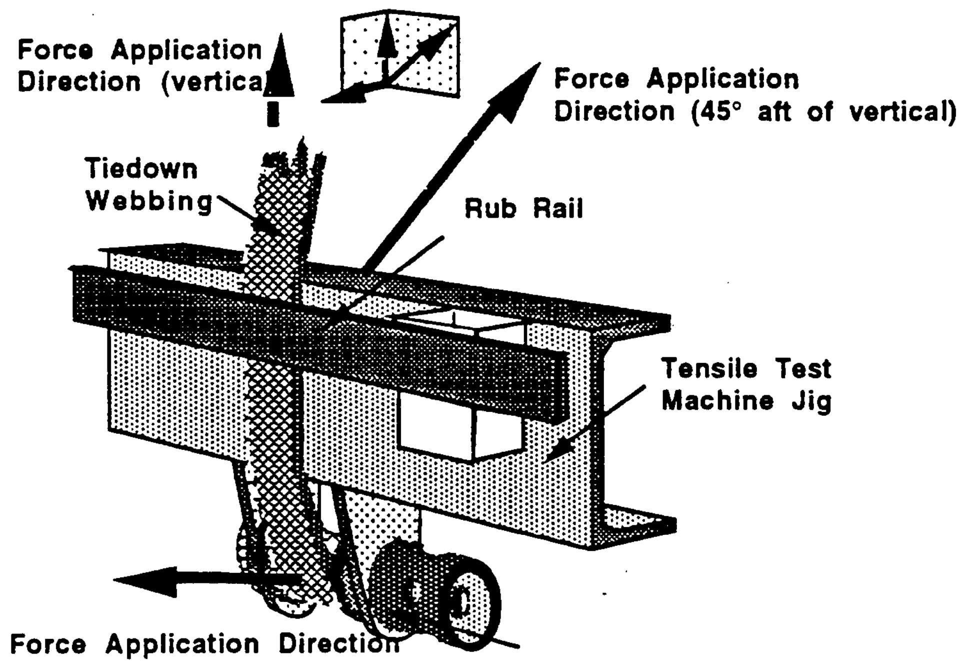


Figure 7.4/ Web Tensioning Ratchet Strength

7.4.4/ Test Matrix - Web Tensioning Ratchet Strength (cont'd)

Test No. 7.4-	Ratchet Model	Attachment Method	Pull Direction Vertical	Lat.	45 ° Aft
5(a)	Heavy Duty (Mod 1)	Clipped	X		
5(b)	Heavy Duty (Mod 1)	Clipped		X	
5(c)	Heavy Duty (Mod 1)	Clipped			X
6(a)	Heavy Duty (Mod 2)	Clipped	X		
6(b)	Heavy Duty (Mod 2)	Clipped		X	
6(c)	Heavy Duty (Mod 2)	Clipped			X
7(a)	Light Duty (Mod 1)	Welded	X		
7(b)	Light Duty (Mod 1)	Welded		X	
7(c)	Light Duty (Mod 1)	Welded			X
8(a)	Light Duty (Mod 2)	Welded	X		
8(b)	Light Duty (Mod 2)	Welded		X	
8(c)	Light Duty (Mod 2)	Welded			X
9(a)	Light Duty (Mod 1)	Slotted	X		
9(b)	Light Duty (Mod 1)	Slotted		X	
9(c)	Light Duty (Mod 1)	Slotted			X
10(a)	Light Duty (Mod 2)	Slotted	X		
10(b)	Light Duty (Mod 2)	Slotted		X	
10(c)	Light Duty (Mod 2)	Slotted			X
11(a)	Light Duty (Mod 1)	Clipped	X		
11(b)	Light Duty (Mod 1)	Clipped		X	
11(c)	Light Duty (Mod 1)	Clipped			X
12(a)	Light Duty (Mod 2)	Clipped	X		
12(b)	Light Duty (Mod 2)	Clipped		X	
12(c)	Light Duty (Mod 2)	Clipped			X

7.5/ Chain-in-Tube Strength

7.5.1/ Purpose

The purpose of this test is to determine the strength of a chain-in-tube anchor when pulled in various directions, and to ascertain the mode of failure.

7.5.2/ Method

A chain-in-tube anchor, as shown in Figure 7.5, shall be mounted in a load test machine from a jig that is designed so that the chain-in-tube assembly only shall fail during the test. Three types of chain-in-tube anchor shall be tested, representing light, medium, and heavy duty recommended application. The chain-in-tube shall be pulled until failure of any of the assembly components occurs. The test shall be conducted with pulls in several directions:

(a) vertical to floor;
(b) parallel to floor, perpendicular to floor joist;
(c) parallel to floor, parallel to floor joist;
(d) 45° vertical from (b);
(e) 45° vertical from (c);
(f) parallel to floor 45° from (b) and (c); and
(g) 45° vertical from (f).

These are shown in Figure 7.5.

7.5.3/ Results

This test will provide the force at which failure occurs in each pull direction, which will serve as input when assessing a working load rating for chain-in-tube attachments when used as anchor points for tiedowns.

7.5.4/ Test Matrix - Chain-in-tube Strength

Test No. 7.5-	Rated Strength	Pull Angle (see text for directions) (a)	(b)	(c)	(d)	(e)	(f)	(g)
1(a)	Light Duty	X						
1(b)	Light Duty		X					
1(c)	Light Duty			X				
1(d)	Light Duty				X			
1(e)	Light Duty					X		
1(f)	Light Duty						X	
1(g)	Light Duty							X

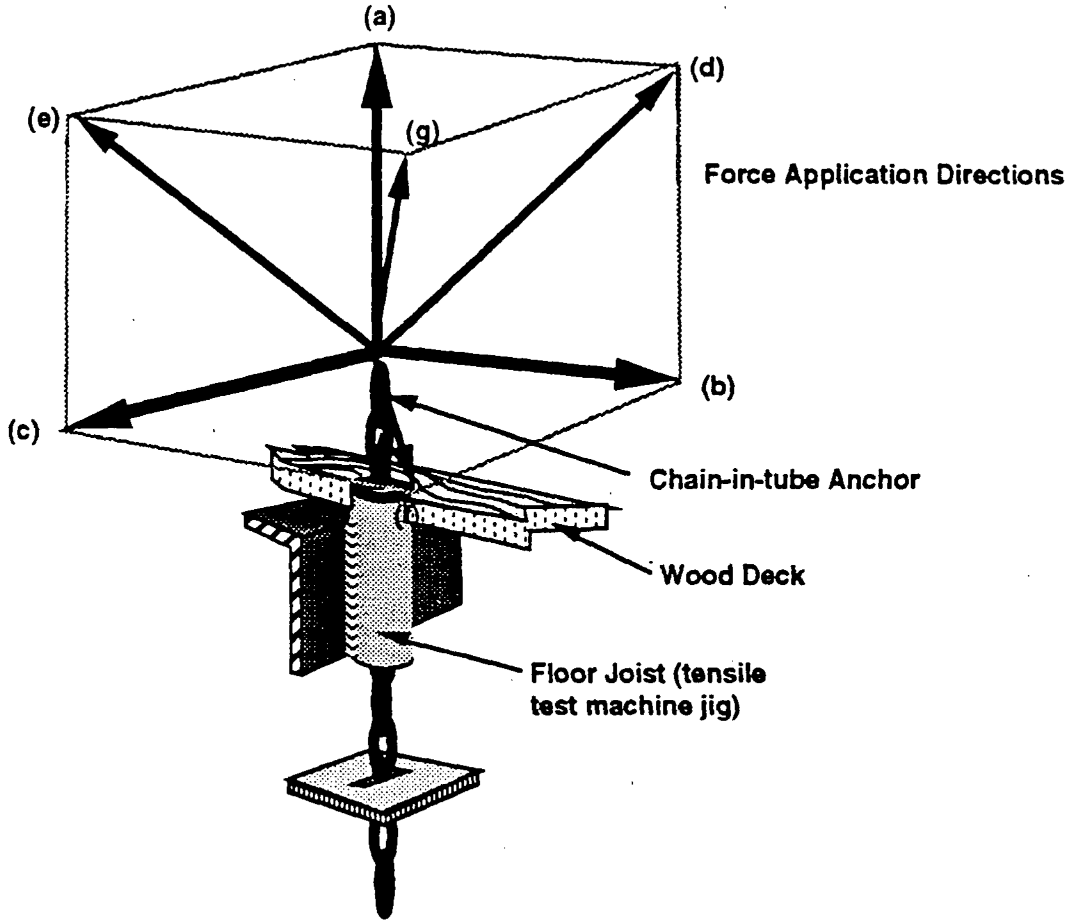


Figure 7.5/ Chain-in-tube Strength

7.5.4/ Test Matrix – Chain-in-tube Strength (cont'd)

Test No. 7.5-	Rated Strength	Pull Angle (see text for directions) (a)	(b)	(c)	(d)	(e)	(f)	(g)
2(a)	Medium Duty	X						
2(b)	Medium Duty		X					
2(c)	Medium Duty			X				
2(d)	Medium Duty				X			
2(e)	Medium Duty					X		
2(f)	Medium Duty						X	
2(g)	Medium Duty							X
3(a)	Heavy Duty	X						
3(b)	Heavy Duty		X					
3(c)	Heavy Duty			X				
3(d)	Heavy Duty				X			
3(e)	Heavy Duty					X		
3(f)	Heavy Duty						X	
3(g)	Heavy Duty							X

7.6/ Welded Rod Anchor Strength

7.6.1/ Purpose

The purpose of this test is to determine the strength of welded rod attached anchor points when pulled in various directions, and to ascertain the mode of failure.

7.6.2/ Method

A welded rod anchor, as shown in Figure 7.6, shall be mounted in a load test machine from a jig that is designed so that the welded rod assembly only shall fail during the test. Three sizes of rod shall be tested, representing light-, medium-, and heavy-duty application. They are:

(a) 1/4 inch mild steel rod with 1/4 x 6 inch continuous fillet weld;
(b) 3/8 inch mild steel rod with 3/8 x 6 inch continuous fillet weld; and
(c) 1/2 inch mild steel rod with 1/2 x 6 inch continuous fillet weld.

The anchor shall be pulled until failure of any of the assembly components occurs. The test shall be conducted with separate pulls in several directions:

(a) vertical to floor;
(b) parallel to floor, perpendicular to anchor eye direction;
(c) parallel to floor, parallel to anchor eye direction;
(d) 45° vertical from (b);
(e) 45° vertical from (c);
(f) parallel to floor 45° from (b) and (c); and
(g) 45° vertical from (f).

These are shown in Figure 7.6.

7.6.3/ Results

This test will provide the force at which failure occurs in each pull direction, which will serve as input when assessing a working load rating for this type of attached anchor.

7.6.4/ Test Matrix – Welded Rod Anchor Strength

Test No. 7.6-	Rod Size	Pull Angle (see text for directions) (a)	(b)	(c)	(d)	(e)	(f)	(g)
1(a)	1/4 "	X						
1(b)	1/4 "		X					
1(c)	1/4 "			X				
1(d)	1/4 "				X			
1(e)	1/4 "					X		
1(f)	1/4 "						X	
1(g)	1/4 "							X

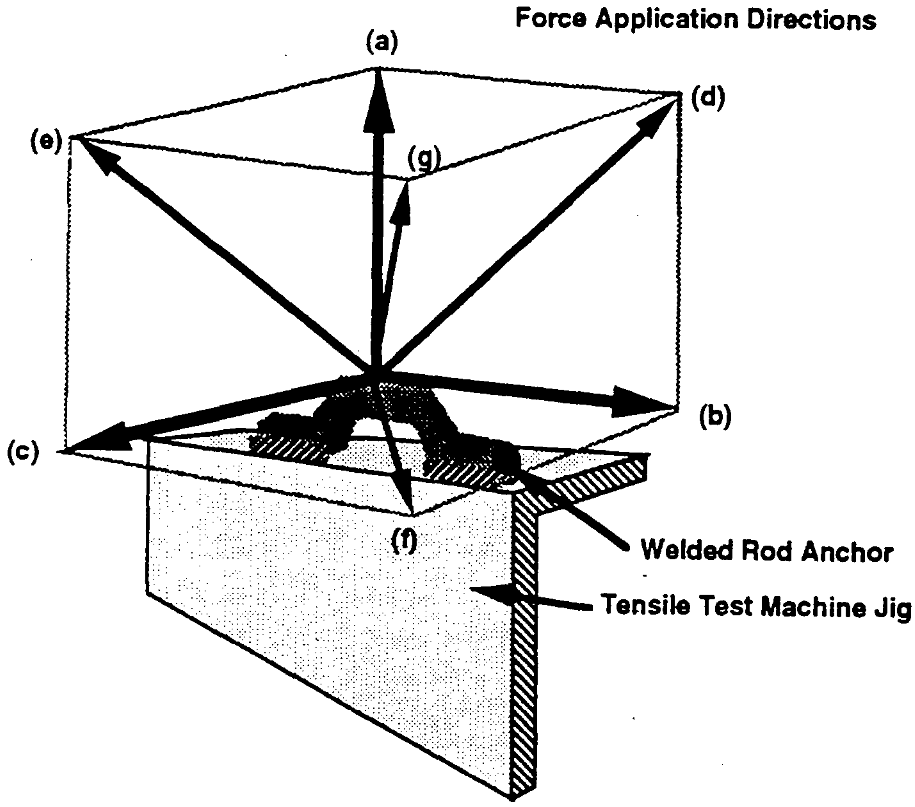


Figure 7.6/ Welded Rod Anchor Strength

7.6.4/ Test Matrix – Welded Rod Anchor Strength (cont'd)

Test No. 7.6-	Rod Size	Pull Angle (see text for directions) (a)	(b)	(c)	(d)	(e)	(f)	(g)
2(a)	3/8 "	X						
2(b)	3/8 "		X					
2(c)	3/8 "			X				
2(d)	3/8 "				X			
2(e)	3/8 "					X		
2(f)	3/8 "						X	
2(g)	3/8 "							X
3(a)	1/2 "	X						
3(b)	1/2 "		X					
3(c)	1/2 "			X				
3(d)	1/2 "				X			
3(e)	1/2 "					X		
3(f)	1/2 "						X	
3(g)	1/2 "							X

7.7/ Effect of Chain Wrap on Stake Pocket Strength

7.7.1/ Purpose

The purpose of this test is to determine whether the method by which a chain is hooked to and wrapped around a stake pocket affects the strength of that pocket.

7.7.2/ Method

A chain with a grab hook shall be wrapped around and hooked to one or more standard stake pockets in the manners shown in Figure 7.7 (a) through (f), individually. The assembly shall be mounted in a tensile load machine and the chain shall be loaded in three directions for Figures 7.7 (a) to (d):

(a) vertical pull,
(b) vertical pull +45° forward, and
(c) vertical pull +45° aft.

The wrap method in Figures 7.7 (e) and (f) will be pulled vertically only. Each wrap will be pulled until failure occurs. A representative common design of steel medium-duty stake pocket, and a heavy-duty aluminum stake pocket as tested in Section 7.2, will be used for this series of tests. A high tensile, instrument quality chain shall be used.

7.7.3/ Results

This test will show the extent to which the method of chain wrap affects the inherent strength of the stake pocket and will illustrate the mechanics of deformation of a stake pocket under such loading.

7.7.4/ Test Matrix - Effect of Chain Wrap on Stake Pocket Strength

Test No. No. 7.7-	Pocket Design	Wrap	Pull Angle Vertical	45° Fwd	45° Aft
1(a)	Steel	(a)	X		
1(b)	Steel	(a)		X	
1(c)	Steel	(a)			X
2(a)	Steel	(b)	X		
2(b)	Steel	(b)		X	
2(c)	Steel	(b)			X
3(a)	Steel	(c)	X		
3(b)	Steel	(c)		X	
3(c)	Steel	(c)			X
4(a)	Steel	(d)	X		
4(b)	Steel	(d)		X	
4(c)	Steel	(d)			X
5	Steel	(e)	X		
6	Steel	(f)	X		

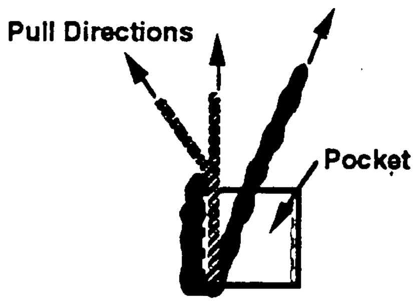


Figure 7.7(a)
Wrap Method (a)

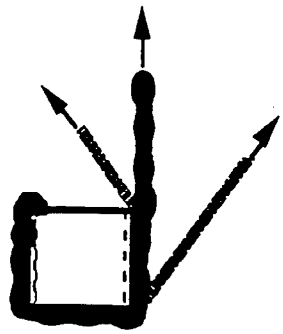


Figure 7.7(b)
Wrap Method (b)

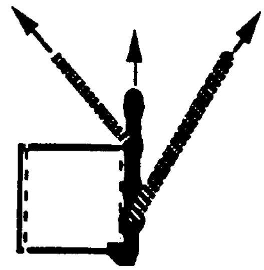


Figure 7.7(c)
Wrap Method (c)

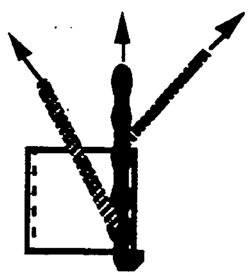


Figure 7.7(d)
Wrap Method (d)

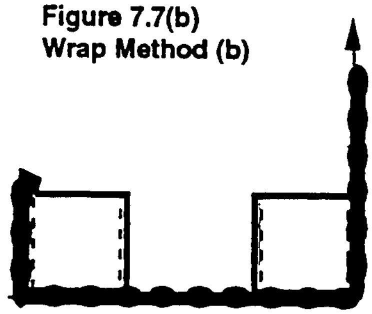


Figure 7.7(e)
Wrap Method (e)

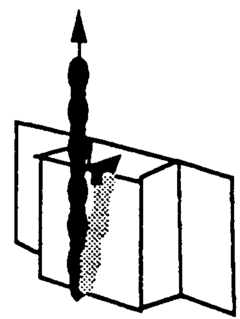


Figure 7.7(f)
Wrap Method (f)

Figure 7.7/ Effect of Chain Wrap on Stake Pocket Strength

7.7.4/ Test Matrix – Effect of Chain Wrap on Stake Pocket Strength (cont'd)

Test No. No. 7.7-	Pocket Design	Wrap	Pull Angle		
			Vertical	45° Fwd	45° Aft
7(a)	Aluminum	(a)	X		
7(b)	Aluminum	(a)		X	
7(c)	Aluminum	(a)			X
8(a)	Aluminum	(b)	X		
8(b)	Aluminum	(b)		X	
8(c)	Aluminum	(b)			X
9(a)	Aluminum	(c)	X		
9(b)	Aluminum	(c)		X	
9(c)	Aluminum	(c)			X
10(a)	Aluminum	(d)	X		
10(b)	Aluminum	(d)		X	
10(c)	Aluminum	(d)			X
11	Aluminum	(e)	X		
12	Aluminum	(f)	X		

7.8/ Rub Rail Strength

7.8.1/ Purpose

The purpose of this test is to determine the strength of rub rails when used as anchor points.

7.8.2/ Method

A chain with a grab hook shall be hooked and wrapped to a rub rail mounted in a load testing machine jig and pulled until failure occurs. The rail shall be pulled:

(a) at the spool midway between two pockets spaced 24" apart;
(b) midway between pocket and spool; and
(c) around the spool.

These are shown in Figure 7.8. Test configuration shown in Figure 7.8 (a) and (b) shall be pulled vertically and 45° inboard of vertical. Test configuration in 7.8(c) shall be pulled vertically only.

Two rub rail materials shall be tested:

(a) steel 3/8 x 3" flat bar on medium duty steel pockets; and
(b) aluminum 3/8 x 2" flat bar on medium duty aluminum pockets.

A high tensile strength instrument quality chain shall be used. It shall be loaded until excessive deformation, unhooking, or a severance failure occurs.

7.8.3/ Results

This series of tests will provide the force at which failure occurred for each test configuration. The data will serve as a means of assessing a working load rating for these rub rails when used as anchor points for tiedowns. It will also show the extent to which the location of chain wrap affects the inherent strength of the rub rail.

7.8.4/ Test Matrix – Rub Rail Strength

Test No 7.8-	Rail Material	Pull Location: between spool & pocket	at spool	over spool	Pull Angle: Vertical	Inboard at 45°
1(a)	3/8 x 3" steel	X			X	
1(b)	3/8 x 3" steel	X				X
2(a)	3/8 x 3" steel		X		X	
2(b)	3/8 x 3" steel		X			X
3	3/8 x 3" steel			X	X	
4(a)	3/8 x 2" aluminum	X			X	
4(b)	3/8 x 2" aluminum	X				X
5(a)	3/8 x 2" aluminum		X		X	
5(b)	3/8 x 2" aluminum		X			X
6	3/8 x 2" aluminum			X	X	

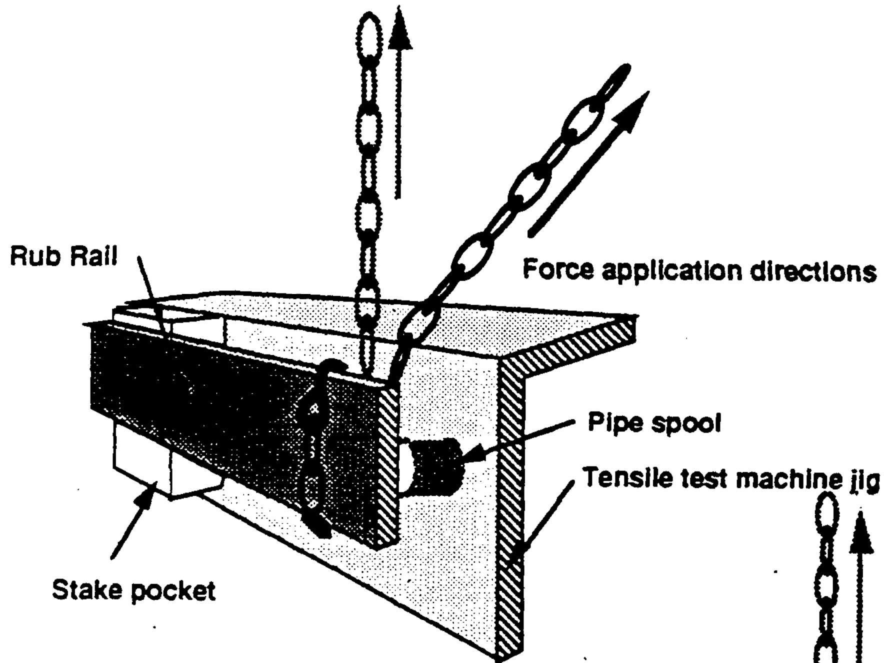


Figure 7.8 (a) Load Applied Midway Between Stake Pockets

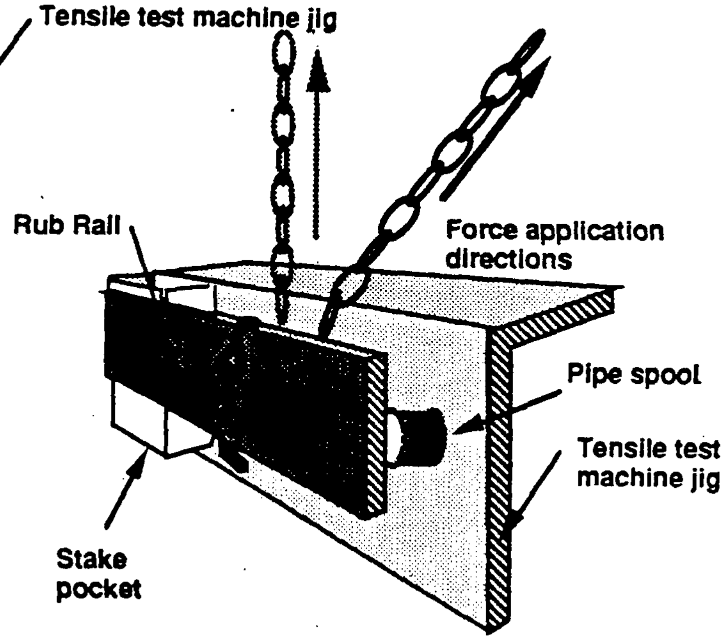


Figure 7.8 (b) Load Applied Midway Between Stake Pocket and Pipe Spool

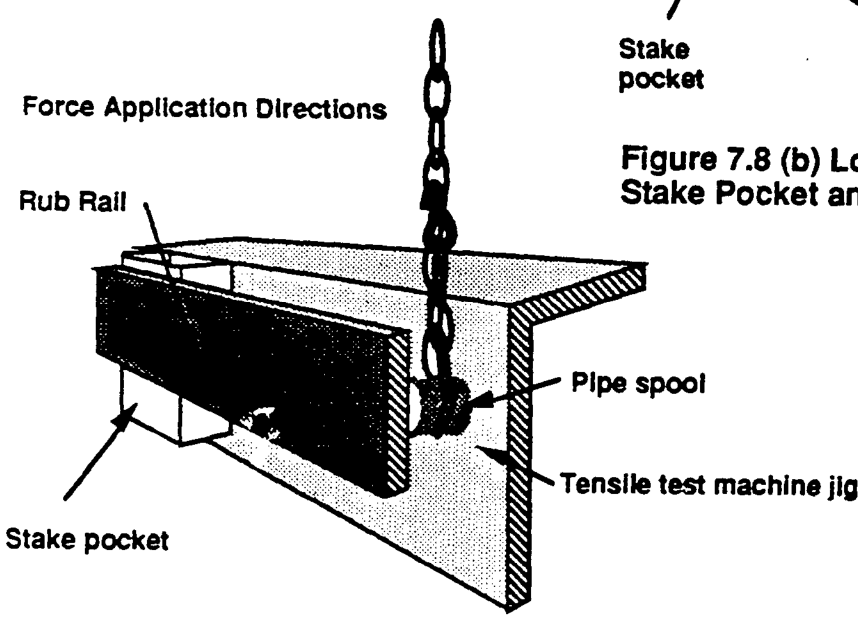


Figure 7.8 (c) Load Applied at Pipe Spool

Figure 7.8/ Rub Rail Strength Test

8/ TIEDOWN ASSEMBLIES

8.1/ The Issues

The tiedown assembly attaches to anchor points on the vehicle to secure the load to the vehicle. This series of tests addresses the following issues of tiedown assemblies:

1/ The effect of binder type, chain size, and chain length on the ability to develop tension in a chain;
2/ The effect on chain strength of links bearing on hard corners;
3/ Equalization of tension in the spans of chain and webbing tiedowns;
4/ The effect of load lateral movement on chain and webbing tiedown tensions; and
5/ The effect of load longitudinal movement on chain and webbing tiedown tensions.

The first two issues relate strictly to the properties of typical tiedown assemblies. It is likely that the information that these tests will reveal has actually already been developed elsewhere, but it is not known to be publicly available.

The other three issues address the pulley effect. Most current regulations in one way or another effectively assume that a tiedown that passes over or through a load, without being attached to the load, achieves equal tension in each span of the tiedown. In effect, the regulation assumes that the tiedown acts as if it is rope passing over a pulley, the load, which is free to rotate. It is clear that a chain passing over or through a rigid load that is tightly restrained to prevent movement might hang up if links get caught on a sharp corner or bite into the load or dunnage. It is therefore necessary to determine the extent to which tension equalizes in the spans of a tiedown, for various types of load and tiedown.

Some of these tests will be conducted using real loads driven on the road. Others are conducted in a laboratory, so that confounding factors are removed from the test and the issue at hand can be isolated and examined in detail.

8.2/ Effect of Binder and Chain Length on Chain Tension

8.2.1/ Purpose

This test determines the effect of binder type, chain size, and chain length on the ability to develop tension in a chain.

8.2.2/ Method

The test set up is illustrated in Figure 8.2. The test shall be perfomed with three different binders, two lever lock (cam over) mechanisms and one ratchet type. The chain length for the lever lock binders shall be adjusted to meet a nominal contact point, and then the lever shall be locked with the assistance of a 0.6 m (24 in) lever bar. The resulting tension in the chain shall be measured. The test shall be done with three nominal binder contact points on the lever binders and at three equal ratchet positions (yet to be determined) for the ratchet binder. The chain span lengths will be 1, 3, and 6 metres (approximately 3, 10, and 20 ft respectively), and three chain sizes, 1/4 inch grade 4, 5/16 inch grade 7, and 3/8 inch grade 4 chain.

8.2.3/ Results

The results of this test will provide an indication of the forces that can be achieved in a chain tiedown system by varying the binder application load. It should show the effect of free chain span on equal binder settings and provide an indication of chain elasticity. The data from this test, coupled with chain specifications, should help develop guidelines to pretension chains effectively without overloading the chain.

8.2.4/ Test Matrix – Effect of Binder and Chain Length on Chain Tension

Test No 8.2-	Binder Type	Binder Set Point	Chain Type 1/4"	5/16"	3/8"	Chain Span 1 m	3 m	6 m
1(a)	Lever 1	1	X			X		
1(b)	Lever 1	2	X			X		
1(c)	Lever 1	3	X			X		
2(a)	Lever 1	1	X				X	
2(b)	Lever 1	2	X				X	
2(c)	Lever 1	3	X				X	
3(a)	Lever 1	1	X					X
3(b)	Lever 1	2	X					X
3(c)	Lever 1	3	X					X
4(a)	Lever 1	1		X		X		
4(b)	Lever 1	2		X		X		
4(c)	Lever 1	3		X		X		
5(a)	Lever 1	1		X			X	
5(b)	Lever 1	2		X			X	
5(c)	Lever 1	3		X			X	

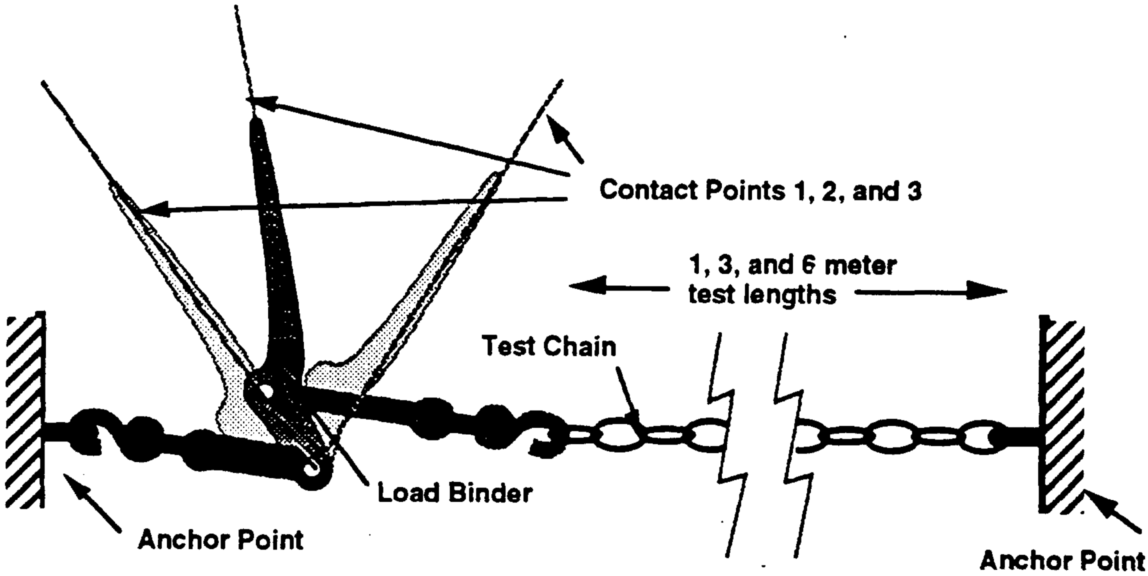


Figure 8.2/ Effect of Binder and Chain Length on Chain Tension

8.2.4/ Test Matrix – Effect of Binder and Chain Length on Chain Tension (cont'd)

Test No 8.2-	Binder Type	Binder Set Point	Chain Type 1/4"	5/16"	3/8"	Chain Span 1 m	3 m	6 m
6(a)	Lever 1	1		X				X
6(b)	Lever 1	2		X				X
6(c)	Lever 1	3		X				X
7(a)	Lever 1	1			X	X		
7(b)	Lever 1	2			X	X		
7(c)	Lever 1	3			X	X		
8(a)	Lever 1	1			X		X	
8(b)	Lever 1	2			X		X	
8(c)	Lever 1	3			X		X	
9(a)	Lever 1	1			X			X
9(b)	Lever 1	2			X			X
9(c)	Lever 1	3			X			X
10(a)	Lever 2	1	X			X		
10(b)	Lever 2	2	X			X		
10(c)	Lever 2	3	X			X		
11(a)	Lever 2	1	X				X	
11(b)	Lever 2	2	X				X	
11(c)	Lever 2	3	X				X	
12(a)	Lever 2	1	X					X
12(b)	Lever 2	2	X					X
12(c)	Lever 2	3	X					X

8.2.4/ Test Matrix – Effect of Binder and Chain Length on Chain Tension (cont'd)

Test No. 8.2-	Binder Type	Binder Set Point	Chain Type 1/4"	Chain Type 5/16"	Chain Type 3/8"	Chain Span 1 m	Chain Span 3 m	Chain Span 6 m
13(a)	Lever 2	1		X		X		
13(b)	Lever 2	2		X		X		
13(c)	Lever 2	3		X		X		
14(a)	Lever 2	1		X			X	
14(b)	Lever 2	2		X			X	
14(c)	Lever 2	3		X			X	
15(a)	Lever 2	1		X				X
15(b)	Lever 2	2		X				X
15(c)	Lever 2	3		X				X
16(a)	Lever 2	1			X	X		
16(b)	Lever 2	2			X	X		
16(c)	Lever 2	3			X	X		
17(a)	Lever 2	1			X		X	
17(b)	Lever 2	2			X		X	
17(c)	Lever 2	3			X		X	
18(a)	Lever 2	1			X			X
18(b)	Lever 2	2			X			X
18(c)	Lever 2	3			X			X
19(a)	Ratchet	1	X			X		
19(b)	Ratchet	2	X			X		
19(c)	Ratchet	3	X			X		
20(a)	Ratchet	1	X				X	
20(b)	Ratchet	2	X				X	
20(c)	Ratchet	3	X				X	
21(a)	Ratchet	1	X					X
21(b)	Ratchet	2	X					X
21(c)	Ratchet	3	X					X
22(a)	Ratchet	1		X		X		
22(b)	Ratchet	2		X		X		
22(c)	Ratchet	3		X		X		
23(a)	Ratchet	1		X			X	
23(b)	Ratchet	2		X			X	
23(c)	Ratchet	3		X			X	
24(a)	Ratchet	1		X				X
24(b)	Ratchet	2		X				X
24(c)	Ratchet	3		X				X
25(a)	Ratchet	1			X	X		
25(b)	Ratchet	2			X	X		
25(c)	Ratchet	3			X	X		
26(a)	Ratchet	1			X		X	
26(b)	Ratchet	2			X		X	
26(c)	Ratchet	3			X		X	
27(a)	Ratchet	1			X			X
27(b)	Ratchet	2			X			X
27(c)	Ratchet	3			X			X

8.3/ Effect of Corner Radius on Chain Tiedown

8.3.1/ Purpose

A chain is rated on the basis of a pure tensile load. It is likely that the chain has lesser strength if all the load is carried by one link in shear or bending. The purpose of this test is to examine the effect on the strength of the chain of a tight chain wrap radius that loads one link in shear or bending.

8.3.2/ Method

The test is shown in Figure 8.3. One link of each chain shall be loaded over a corner until fracture occurs. The tensile strength of each chain shall be determined prior to this test. The test will be repeated using corners of three different radii:

(a) 1/8" radius,
(b) 1" radius, and
(c) 2" radius.

and, with three different orientations of the chain links:

(a) flat link at apex,
(b) upright link at apex, and
(c) link interlock at apex.

Three sizes of chain shall be used for this test:

(a) 1/4" grade 4,
(b) 5/16" grade 7, and
(c) 3/8" grade 4.

The tensile strength of each chain shall be determined prior to this test. All chains tested shall be from the same lot.

8.3.3/ Results

The results should indicate the extent to which severe localized loads on one link of a chain in tension would require the rating of the chain to be diminished.

8.3.4/ Test Matrix – Effect of Corner Radius on Chain Tiedown

Test No. 8.3-	Chain Size	Corner Radius			Link Orientation		
		1/8"	1"	2"	Flat	Upright	Connection
1(a)	1/4"	X			X		
1(b)	1/4"	X				X	
1(c)	1/4"	X					X
2(a)	1/4"		X		X		
2(b)	1/4"		X			X	
2(c)	1/4"		X				X
3(a)	1/4"			X	X		
3(b)	1/4"			X		X	
3(c)	1/4"			X			X

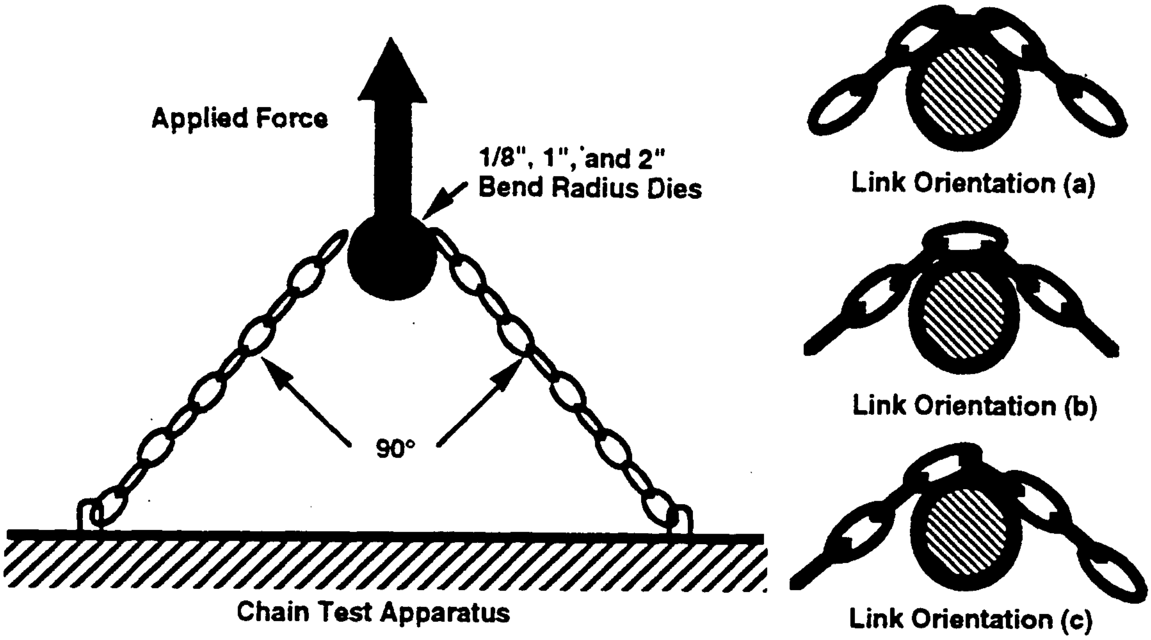


Figure 8.3/ Effect of Corner Radius on Chain Tiedown

8.3.4/ Test Matrix – Effect of Corner Radius on Chain Tiedown (cont'd)

Test No 8.3-	Chain Size	Comer Radius 1/8"	1"	2"	Link Orientation Flat	Upright	Connection
4(a)	5/16"	X			X		
4(b)	5/16"	X				X	
4(c)	5/16"	X					X
5(a)	5/16"		X		X		
5(b)	5/16"		X			X	
5(c)	5/16"		X				X
6(a)	5/16"			X	X		
6(b)	5/16"			X		X	
6(c)	5/16"			X			X
7(a)	3/8"	X			X		
7(b)	3/8"	X				X	
7(c)	3/8"	X					X
8(a)	3/8"		X		X		
8(b)	3/8"		X			X	
8(c)	3/8"		X				X
9(a)	3/8"			X	X		
9(b)	3/8"			X		X	
9(c)	3/8"			X			X

8.4/ Equalization of Tension in the Spans of Tiedowns

8.4.1/ Purpose

The purpose of this test is to examine the effect of load profile and material on tension in the various spans of a tiedown that passes over a load. It examines the extent to which the tiedown behaves as a pulley by equalizing the loads in each of its spans, a key issue on which major assumptions for allowable loads in tiedowns are currently based.

8.4.2/ Method

A load shall be placed on a vehicle and secured as shown in Figure 8.4. Each tiedown shall include a force transducer to measure the tension in each of its vertical spans. The tiedown shall be tensioned from one side and the tensions measured. The test shall be conducted using three different corner configurations:

(a) a rounded polished steel corner,
(b) a rigid sharp corner made of angle iron, and
(c) a sharp corner made of wood.

The tiedown shall be tensioned to three different preloads:

(a) light preload (5% of WLL),
(b) moderate preload (20% of WLL), and
(c) heavy preload (50% of WLL).

Two types of load shall be used:

(a) a rigid structure incapable of motion or deformation and
(b) a softer, more compliant load.

Two types of tiedown shall be used:

(a) 5/16" chain and
(b) 2" nylon webbing.

The vehicle shall be driven on a typical road trip and the tension in the tiedowns shall be monitored to determine the extent to which they equalize during the trip.

8.4.3/ Results

The results will allow assessment of the assumption that a tiedown acts as a pulley and equalizes tension along its length. If some combinations of tiedown and load are unable to achieve equalized tensions, different corner treatments could provide an option.

8.4.4/ Test Matrix – Equalization of Tension in the Spans of Tiedowns

Test No. 8.4-	Tiedown Material	Preload L	M	H	Load Rigid	Compliant	Corner Round	Sharp	Wood
1(a)	5/16" chain	X			X		X		
1(b)	5/16" chain	X			X			X	
1(c)	5/16" chain	X			X				X
2(a)	5/16" chain	X				X	X		
2(b)	5/16" chain	X				X		X	
2(c)	5/16" chain	X				X			X

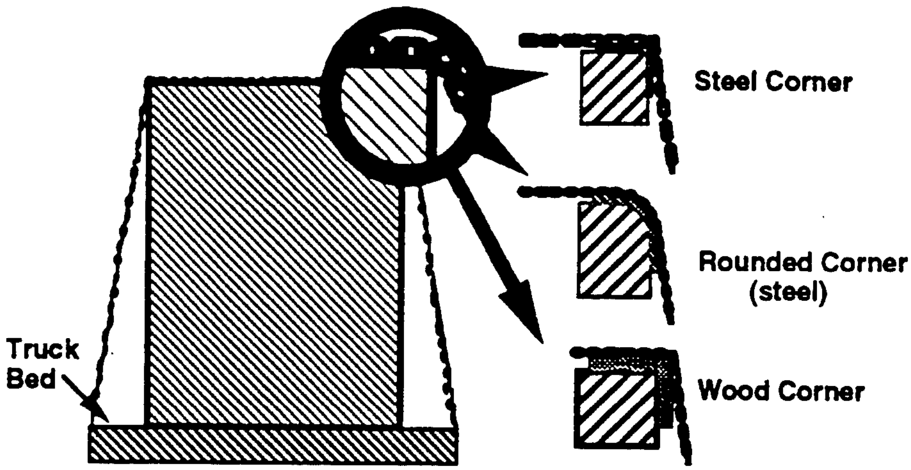


Figure 8.4/ Equalization of Tension in the Spans of Tiedowns

8.4.4/ Test Matrix – Equalization of Tension in the Spans of Tiedowns (cont'd)

Test No. 8.4-	Tiedown Material	Preload L	Preload M	Preload H	Load Rigid	Load Compliant	Corner Round	Corner Sharp	Corner Wood
3(a)	5/16" chain		X		X		X		
3(b)	5/16" chain		X		X			X	
3(c)	5/16" chain		X		X				X
4(a)	5/16" chain		X			X	X		
4(b)	5/16" chain		X			X		X	
4(c)	5/16" chain		X			X			X
5(a)	5/16" chain			X	X		X		
5(b)	5/16" chain			X	X			X	
5(c)	5/16" chain			X	X				X
6(a)	5/16" chain			X		X	X		
6(b)	5/16" chain			X		X		X	
6(c)	5/16" chain			X		X			X
7(a)	2" webbing	X			X		X		
7(b)	2" webbing	X			X			X	
7(c)	2" webbing	X			X				X
8(a)	2" webbing	X				X	X		
8(b)	2" webbing	X				X		X	
8(c)	2" webbing	X				X			X
9(a)	2" webbing		X		X		X		
9(b)	2" webbing		X		X			X	
9(c)	2" webbing		X		X				X
10(a)	2" webbing		X			X	X		
10(b)	2" webbing		X			X		X	
10(c)	2" webbing		X			X			X
11(a)	2" webbing			X	X		X		
11(b)	2" webbing			X	X			X	
11(c)	2" webbing			X	X				X
12(a)	2" webbing			X		X	X		
12(b)	2" webbing			X		X		X	
12(c)	2" webbing			X		X			X

8.5/ Effect of Lateral Motion of the Load on Tiedown Tension

8.5.1/ Purpose

The purpose of this test is to measure the effect of tiedown angle on the tension in the tiedown when the load is allowed to slide laterally under the influence of a horizontal force. As the cargo moves, the tiedown angles and overall length of the tiedown are altered, hence changes in the tension would be expected.

8.5.2/ Method

The load shall be secured and then pulled laterally by a horizontal force, as shown in Figure 8.5. The tiedowns shall be instrumented to measure the tension and the displacement of the load. The test shall be conducted using three different corner configurations:
- (a) a rounded polished steel corner,
- (b) a rigid sharp corner made of angle iron, and
- (c) a sharp corner made of wood.

The tiedown shall be tensioned to three different preloads:
- (a) low preload (5% of WLL),
- (b) moderate preload (20% of WLL), and
- (c) high preload (50% of WLL).

Three different wrap angles shall be used:
- (a) 45° to the floor,
- (b) 60° to the floor, and
- (c) 80° to the floor.

Two types of tiedown shall be used:
- (a) 5/16" chain and
- (b) 2" nylon webbing.

A dolly is used to eliminate the effect of friction on the truck bed. A preliminary test of the unsecured load will determine the friction in the test rig itself.

8.5.3/ Results

This test will show the effect of lateral motion of the load on the tension in the spans of a tiedown, and will show the tiedown's ability to contain lateral motion of the load.

8.5.4/ Test Matrix – Effect of Lateral Motion of the Load on Tiedown Tension

Test No. 8.5-	Tiedown Material	Preload			Tiedown Angle			Corner		
		L	M	H	45°	60°	80°	Round	Sharp	Wood
1(a)	5/16" chain	X			X			X		
1(b)	5/16" chain	X			X				X	
1(c)	5/16" chain	X			X					X
2(a)	5/16" chain	X					X	X		
2(b)	5/16" chain	X					X		X	
2(c)	5/16" chain	X					X			X

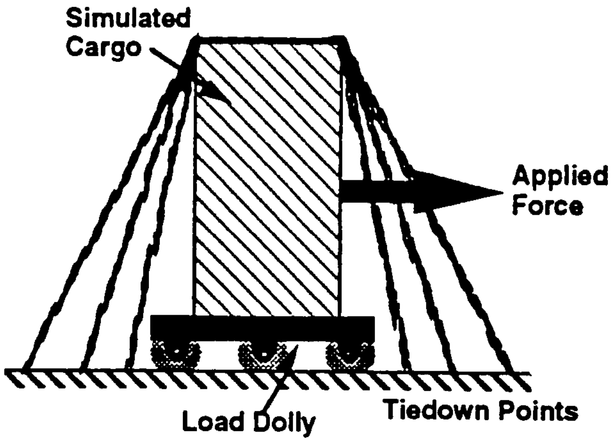


Figure 8.5/ Effect of Lateral Motion of the Load on Tiedown Tension

8.5.4/ Test Matrix – Effect of Lateral Motion of the Load on Tiedown Tension (cont'd)

Test No. 8.5-	Tiedown Material	Preload			Tiedown Angle			Corner		
		L	M	H	45°	60°	80°	Round	Sharp	Wood
3(a)	5/16" chain	X					X	X		
3(b)	5/16" chain	X					X		X	
3(c)	5/16" chain	X					X			X
4(a)	5/16" chain		X		X			X		
4(b)	5/16" chain		X		X				X	
4(c)	5/16" chain		X		X					X
5(a)	5/16" chain		X			X		X		
5(b)	5/16" chain		X			X			X	
5(c)	5/16" chain		X			X				X
6(a)	5/16" chain		X				X	X		
6(b)	5/16" chain		X				X		X	
6(c)	5/16" chain		X				X			X
7(a)	5/16" chain			X	X			X		
7(b)	5/16" chain			X	X				X	
7(c)	5/16" chain			X	X					X
8(a)	5/16" chain			X		X		X		
8(b)	5/16" chain			X		X			X	
8(c)	5/16" chain			X		X				X
9(a)	5/16" chain			X			X	X		
9(b)	5/16" chain			X			X		X	
9(c)	5/16" chain			X			X			X

8.5.4/ **Test Matrix – Effect of Lateral Motion of the Load on Tiedown Tension (cont'd)**

Test No. 8.5-	Tiedown Material	Preload			Tiedown Angle			Corner		
		L	M	H	45°	60°	80°	Round	Sharp	Wood
10(a)	2" webbing	X			X			X		
10(b)	2" webbing	X			X				X	
10(c)	2" webbing	X			X					X
11(a)	2" webbing	X				X		X		
11(b)	2" webbing	X				X			X	
11(c)	2" webbing	X				X				X
12(a)	2" webbing	X					X	X		
12(b)	2" webbing	X					X		X	
12(c)	2" webbing	X					X			X
13(a)	2" webbing		X		X			X		
13(b)	2" webbing		X		X				X	
13(c)	2" webbing		X		X					X
14(a)	2" webbing		X			X		X		
14(b)	2" webbing		X			X			X	
14(c)	2" webbing		X			X				X
15(a)	2" webbing		X				X	X		
15(b)	2" webbing		X				X		X	
15(c)	2" webbing		X				X			X
16(a)	2" webbing			X	X			X		
16(b)	2" webbing			X	X				X	
16(c)	2" webbing			X	X					X
17(a)	2" webbing			X		X		X		
17(b)	2" webbing			X		X			X	
17(c)	2"webbing			X		X				X
18(a)	2"webbing			X			X	X		
18(b)	2"webbing			X			X		X	
18(c)	2"webbing			X			X			X

8.6/ Effect of Longitudinal Motion of the Load on Tiedown Tension

8.6.1/ Purpose

The purpose of this test is to measure the effect of tiedown angle on the tension in the tiedown when the load is allowed to slide longitudinally under the influence of a horizontal force. As the cargo moves, the tiedown angles and overall length of the tiedown are altered, hence changes in the tension would be expected.

8.6.2/ Method

The load shall be secured and then pulled longitudinally by a horizontal force, as shown in Figure 8.6. The tiedowns shall be instrumented to measure the tension and the displacement of the load. The test shall be conducted using three different corner configurations:
- (a) a rounded polished steel corner,
- (b) a rigid sharp corner made of angle iron, and
- (c) a sharp corner made of wood.

The tiedown shall be tensioned to three different preloads:
- (a) low preload (5% of WLL),
- (b) moderate preload (20% of WLL), and
- (c) high preload (50% of WLL).

Three different wrap angles shall be used:
- (a) 45° to the floor,
- (b) 60° to the floor, and
- (c) 80° to the floor.

Two types of tiedown shall be used:
- (a) 5/16" chain and
- (b) 2" nylon webbing.

A dolly is used to eliminate the effect of friction on the truck bed. A preliminary test of the unsecured load will determine the friction in the test rig itself.

8.6.3/ Results

This test will show the effect of lateral motion of the load on the tension in the spans of a tiedown and will show the tiedown's ability to contain lateral motion of the load.

8.6.4/ Test Matrix – Effect of Longitudinal Motion of the Load on Tiedown Tension

Test No. 8.6-	Tiedown Material	Preload L	Preload M	Preload H	Tiedown Angle 45°	Tiedown Angle 60°	Tiedown Angle 80°	Corner Round	Corner Sharp	Corner Wood
1(a)	5/16" chain	X			X			X		
1(b)	5/16" chain	X			X				X	
1(c)	5/16" chain	X			X					X
2(a)	5/16" chain	X				X		X		
2(b)	5/16" chain	X				X			X	
2(c)	5/16" chain	X				X				X

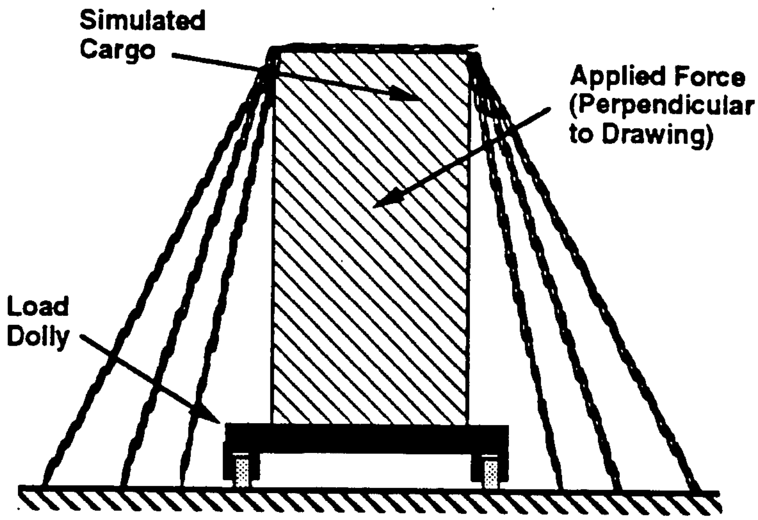


Figure 8.6/ Effect of Longitudinal Motion of the Load on Tiedown Tension

8.6.4/ Test Matrix – Effect of Longitudinal Motion of the Load on Tiedown Tension (cont'd)

Test No. 8.6-	Tiedown Material	Preload L	Preload M	Preload H	Tiedown Angle 45°	Tiedown Angle 60°	Tiedown Angle 80°	Corner Round	Corner Sharp	Corner Wood
3(a)	5/16" chain	X					X	X		
3(b)	5/16" chain	X					X		X	
3(c)	5/16" chain	X					X			X
4(a)	5/16" chain		X		X			X		
4(b)	5/16" chain		X		X				X	
4(c)	5/16" chain		X		X					X
5(a)	5/16" chain		X			X		X		
5(b)	5/16" chain		X			X			X	
5(c)	5/16" chain		X			X				X
6(a)	5/16" chain		X				X	X		
6(b)	5/16" chain		X				X		X	
6(c)	5/16" chain		X				X			X
7(a)	5/16" chain			X	X			X		
7(b)	5/16" chain			X	X				X	
7(c)	5/16" chain			X	X					X
8(a)	5/16" chain			X		X		X		
8(b)	5/16" chain			X		X			X	
8(c)	5/16" chain			X		X				X
9(a)	5/16" chain			X			X	X		
9(b)	5/16" chain			X			X		X	
9(c)	5/16" chain			X			X			X

8.6.4/ Test Matrix – Effect of Longitudinal Motion of the Load on Tiedown Tension (cont'd)

Test No. 8.6-	Tiedown	Preload			Tiedown Angle				Corner	
	Material	L	M	H	45°	60°	80°	Round	Sharp	Wood
10(a)	2" webbing	X			X			X		
10(b)	2" webbing	X			X				X	
10(c)	2" webbing	X			X					X
11(a)	2" webbing	X				X		X		
11(b)	2" webbing	X				X			X	
11(c)	2" webbing	X				X				X
12(a)	2" webbing	X					X	X		
12(b)	2" webbing	X					X		X	
12(c)	2" webbing	X					X			X
13(a)	2" webbing		X		X			X		
13(b)	2" webbing		X		X				X	
13(c)	2" webbing		X		X					X
14(a)	2" webbing		X			X		X		
14(b)	2" webbing		X			X			X	
14(c)	2" webbing		X			X				X
15(a)	2" webbing		X				X	X		
15(b)	2" webbing		X				X		X	
15(c)	2" webbing		X				X			X
16(a)	2" webbing			X	X			X		
16(b)	2" webbing			X	X				X	
16(c)	2" webbing			X	X					X
17(a)	2" webbing			X		X		X		
17(b)	2" webbing			X		X			X	
17(c)	2" webbing			X		X				X
18(a)	2" webbing			X			X	X		
18(b)	2" webbing			X			X		X	
18(c)	2" webbing			X			X			X

9/ BLOCKING

9.1/ The Issues

Blocking is used to transmit forces from the load to components that can resist the forces. It takes the form of wooden blocks, which may be wedged between a truck bed and the load, or usually secured to the truck bed by means of nailing or clamping, thus serving to restrict the motion of the load. Since blocking may serve as a securement system by itself, or in conjunction with other systems, it is necessary to investigate the degree of restraint it offers. This series of tests examines the load retention ability of various blocking mechanisms to aid in understanding its ability to accept and transmit loads.

This series of tests examines the horizontal load capacity of various configurations of wood blocking nailed to the deck, the shear and bending strength of various stakes.

Wooden blocks are often used as dunnage when chain or cable are used to secure a load. The extent to which these tiedowns cause deformation of the wood will have an affect on the pulley effect, as outlined in the previous chapter.

All of the tests in this series will be done in a laboratory, to isolate the factors of interest from confounding effects that may arise with real loads on the highway.

9.2/ Load Capacity of Nailed Wood Blocking

9.2.1/ Purpose

The purpose of this test is to examine the ability of 10 x 10 cm (4 x 4 in) wood blocks nailed to a truck deck to resist break-out forces parallel to the truck bed.

9.2.2/ Method

The general test arrangement is shown in Figure 9.2. A block, 10 cm x 10 cm, shall be nailed to the truck bed. Two typical truck bed materials shall be used:

(a) oak (hardwood) and
(b) pine (softwood).

The force shall be applied above and parallel to the floor, perpendicular to the surface of the block, over the full length of the block. Two force locations shall be used:

(a) 2.5 cm above the floor and
(b) 7.5 cm above the floor.

There shall be three blocking materials tested:

(a) birch,
(b) pine, and
(c) spruce.

The blocks shall be secured with 8.9 cm (3-1/2") nails. Failure shall be defined as the block separating completely from the bed. Application load, deformation, and nature of failure shall be recorded. The test shall be repeated with each of the nailing arrangements shown in Figure 9.2(a).

9.2.3/ Results

These tests will show the relative restraining effects of the various blocks and nailing arrangements and may help assess a working load capacity for blocking.

9.2.4/ Test Matrix – Load Capacity of Nailed Wood Blocking

Test No. 9.2-	Bed Material	Block Material	Nailing Arrangement (a)	(b)	(c)	(d)	Force Low	High
1(a)	Oak	Pine	X				X	
1(b)	Oak	Pine	X					X
1(c)	Oak	Pine		X			X	
1(d)	Oak	Pine		X				X
1(e)	Oak	Pine			X		X	
1(f)	Oak	Pine			X			X
1(g)	Oak	Pine				X	X	
1(h)	Oak	Pine				X		X
2(a)	Oak	Birch	X				X	
2(b)	Oak	Birch	X					X
2(c)	Oak	Birch		X			X	
2(d)	Oak	Birch		X				X

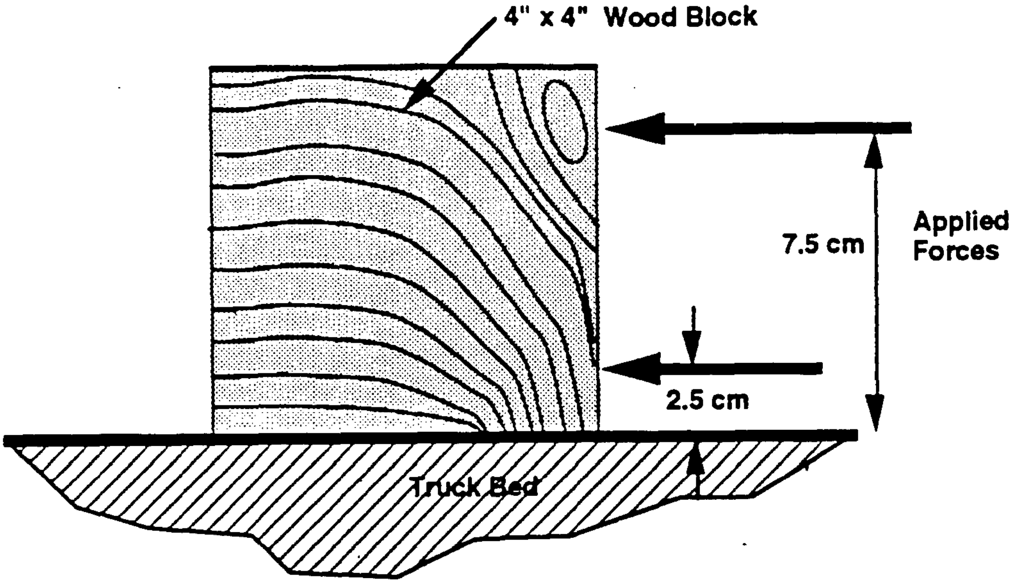


Figure 9.2/ Test to Determine "Break-out" Force on Block

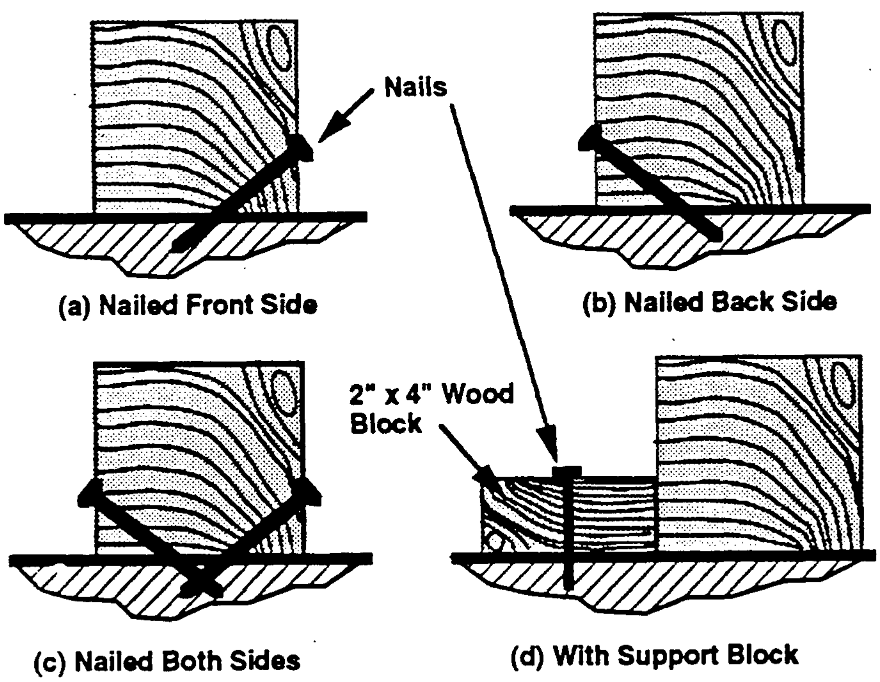


Figure 9.2 (a) Test to Measure Effect of Nailing

9.2.4/ Test Matrix – Load Capacity of Nailed Wood Blocking (cont'd)

Test No. 9.2-	Bed Material	Block Material	Nailing Arrangement (a)	(b)	(c)	(d)	Force Low	High
2(e)	Oak	Birch			X		X	
2(f)	Oak	Birch			X			X
2(g)	Oak	Birch				X	X	
2(h)	Oak	Birch				X		X
3(a)	Oak	Spruce	X				X	
3(b)	Oak	Spruce	X					X
3(c)	Oak	Spruce		X			X	
3(d)	Oak	Spruce		X				X
3(e)	Oak	Spruce			X		X	
3(f)	Oak	Spruce			X			X
3(g)	Oak	Spruce				X	X	
3(h)	Oak	Spruce				X		X
4(a)	Pine	Pine	X				X	
4(b)	Pine	Pine	X					X
4(c)	Pine	Pine		X			X	
4(d)	Pine	Pine		X				X
4(e)	Pine	Pine			X		X	
4(f)	Pine	Pine			X			X
4(g)	Pine	Pine				X	X	
4(h)	Pine	Pine				X		X
5(a)	Pine	Birch	X				X	
5(b)	Pine	Birch	X					X
5(c)	Pine	Birch		X			X	
5(d)	Pine	Birch		X				X
5(e)	Pine	Birch			X		X	
5(f)	Pine	Birch			X			X
5(g)	Pine	Birch				X	X	
5(h)	Pine	Birch				X		X
6(a)	Pine	Spruce	X				X	
6(b)	Pine	Spruce	X					X
6(c)	Pine	Spruce		X			X	
6(d)	Pine	Spruce		X				X
6(e)	Pine	Spruce			X		X	
6(f)	Pine	Spruce			X			X
6(g)	Pine	Spruce				X	X	
6(h)	Pine	Spruce				X		X

9.3/ Effect of Nail Spacing on Load Capacity of Nailed Wood Blocking

9.3.1/ Purpose

The purpose of this test is to examine the ability of 10 x 10 cm (4 x 4 in) wood blocks, (comprised of two 2 x 4 in blocks nailed together) nailed to a truck deck with 15 cm (6 in) spikes to resist break-out forces parallel to the truck bed. The test examines the effect of nail spacing on break-out load.

9.3.2/ Method

The general test arrangement is shown in Figure 9.3. The block shall be nailed to the truck bed and pushed laterally until failure occurs. Two typical truck bed materials shall be used:
- (a) oak (hardwood) and
- (b) pine (softwood).

The force shall be applied above and parallel to the floor, perpendicular to the surface of the block, and over the full length of the block. Two force locations shall be used:
- (a) 2.5 cm above the floor and
- (b) 7.5 cm above the floor.

There shall be three blocking materials tested:
- (a) birch,
- (b) pine, and
- (c) spruce.

Failure shall be defined as the block separating completely from the bed. Application load, deformation, and nature of failure shall be recorded. The test shall be repeated for each of the nail spacings shown in Figure 9.3.

9.3.3/ Results

These tests will show the relative restraining effects of the various nailing arrangements of blocking, and may help assess a working load capacity for blocking.

9.3.4/ Test Matrix – Effect of Nail Spacing on Load Capacity of Nailed Wood Blocking

Test No. 9.3-	Bed Material	Block Material	Nailing Arrangement (a)	(b)	(c)	Force Low	High
1(a)	Oak	Pine	X			X	
1(b)	Oak	Pine	X				X
1(c)	Oak	Pine		X		X	
1(d)	Oak	Pine		X			X
1(e)	Oak	Pine			X	X	
1(f)	Oak	Pine			X		X
2(a)	Oak	Birch	X			X	
2(b)	Oak	Birch	X				X
2(c)	Oak	Birch		X		X	
2(d)	Oak	Birch		X			X

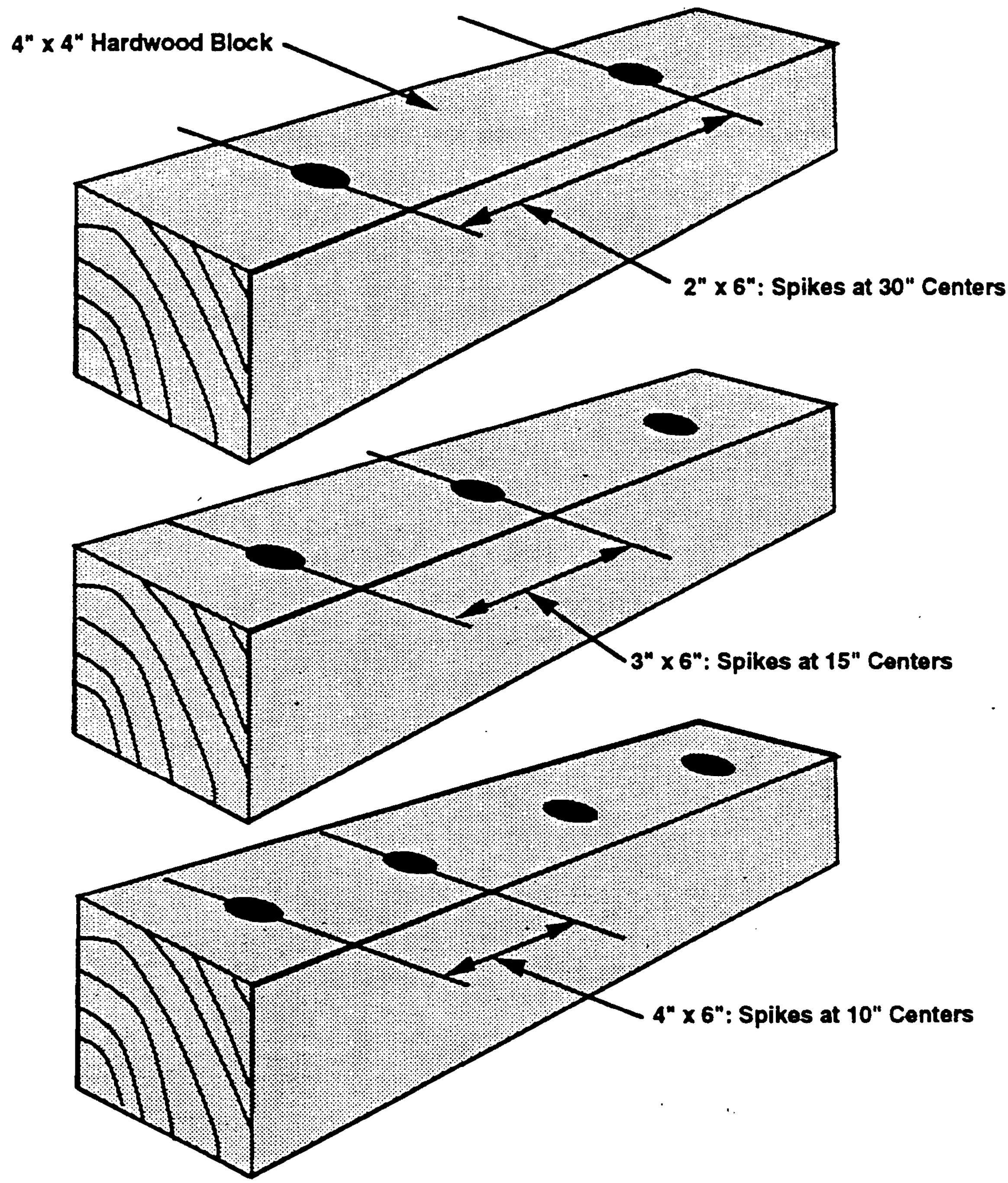


Figure 9.3/ Effect of Nail Spacing on Load Capacity of Nailed Wood Blocking

9.2.4/ Test Matrix – Effect of Nail Spacing on Load Capacity of Nailed Wood Blocking (cont'd)

Test No. 9.2-	Bed Material	Block Material	Nailing Arrangement (a)	(b)	(c)	Force Low	High
2(e)	Oak	Birch			X	X	
2(f)	Oak	Birch			X		X
3(a)	Oak	Spruce	X			X	
3(b)	Oak	Spruce	X				X
3(c)	Oak	Spruce		X		X	
3(d)	Oak	Spruce		X			X
3(e)	Oak	Spruce			X	X	
3(f)	Oak	Spruce			X		X
4(a)	Pine	Pine	X			X	
4(b)	Pine	Pine	X				X
4(c)	Pine	Pine		X		X	
4(d)	Pine	Pine		X			X
4(e)	Pine	Pine			X	X	
4(f)	Pine	Pine			X		X
5(a)	Pine	Birch	X			X	
5(b)	Pine	Birch	X				X
5(c)	Pine	Birch		X		X	
5(d)	Pine	Birch		X			X
5(e)	Pine	Birch			X	X	
5(f)	Pine	Birch			X		X
6(a)	Pine	Spruce	X			X	
6(b)	Pine	Spruce	X				X
6(c)	Pine	Spruce		X		X	
6(d)	Pine	Spruce		X			X
6(e)	Pine	Spruce			X	X	
6(f)	Pine	Spruce			X		X

9.4/ Bending Strength of Stakes

9.4.1/ Purpose

The purpose of this test is to determine the ability of typical stakes to withstand a bending load parallel to the truck bed. This load would arise when the stakes are used as blocking against a load.

9.4.2/ Method

The stake shall be secured in a test jig and loaded as shown in Figure 9.4 at a point 1 m (39.5 in) above the truck deck until the stake fails. Four stake materials shall be tested:

(a) oak,
(b) spruce,
(c) aluminum (10 GA. wall), and
(d) steel (10 GA. wall).

The forces, deformation, and nature of failure shall be recorded.

9.4.3/ Results

The results will show the relative ability of the stakes to withstand bending and should help to assess a working load rating for stakes when used as blocking for a load.

9.4.4/ Test Matrix - Bending Strength of Stakes

Test No. 9.4-	Stake Material
1	Oak
2	Spruce
3	Aluminum
4	Steel

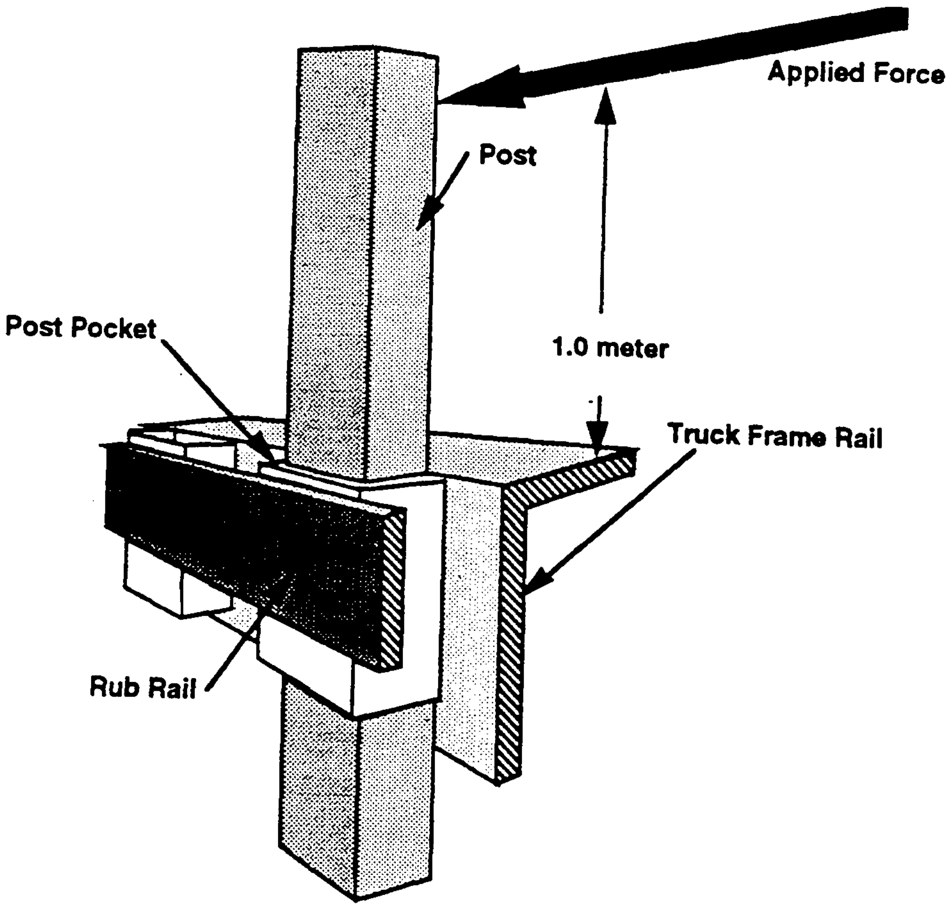


Figure 9.4/ Bending Strength of Stakes

9.5/ Effect of Tiedown on Wood Blocks Used as Dunnage

9.5.1/ Purpose

The purpose of this test is to examine the ability of the blocking material to withstand corner loading by chains and cable. It is to study the effect of the deformation in the wood to ascertain how it would affect the tensioning of the tiedown and possible fracturing of the wooden corner.

9.5.2/ Method

The test set-up is illustrated in Figure 9.5. A block of wood shall be set-up in a test rig and the securement shall be wrapped over it and tightened until the block fails totally (severance). Two block (15 x 15 cm, 6"x6") materials shall be tested:

- (a) oak and
- (b) pine.

The test shall be done with the tiedown wrapped at three different angles:

- (a) 45°,
- (b) 60°, and
- (c) 90°.

Five tiedowns shall be tested:

- (a) 1/4" chain,
- (b) 3/8" chain,
- (c) 1/4" steel cable,
- (d) 1/2" steel cable, and
- (e) 2" nylon webbing.

Tiedown tension loads and deformation of the block shall be measured.

9.5.3/ Results

The results of this test are expected to show the ability of blocking material to withstand the abrading and cutting effect of a tiedown and to measure the block's ability to maintain tension of the tiedown.

9.5.4/ Test Matrix – Effect of Tiedown on Wood Blocks Used as Dunnage

Test No. 9.5-	Block Material	Tiedown Material	Wrap Angle 45°	60°	90°
1(a)	Oak	1/4" chain	X		
1(b)	Oak	1/4" chain		X	
1(c)	Oak	1/4" chain			X
2(a)	Oak	3/8" chain	X		
2(b)	Oak	3/8" chain		X	
2(c)	Oak	3/8" chain			X
3(a)	Oak	1/4" cable	X		
3(b)	Oak	1/4" cable		X	
3(c)	Oak	1/4" cable			X

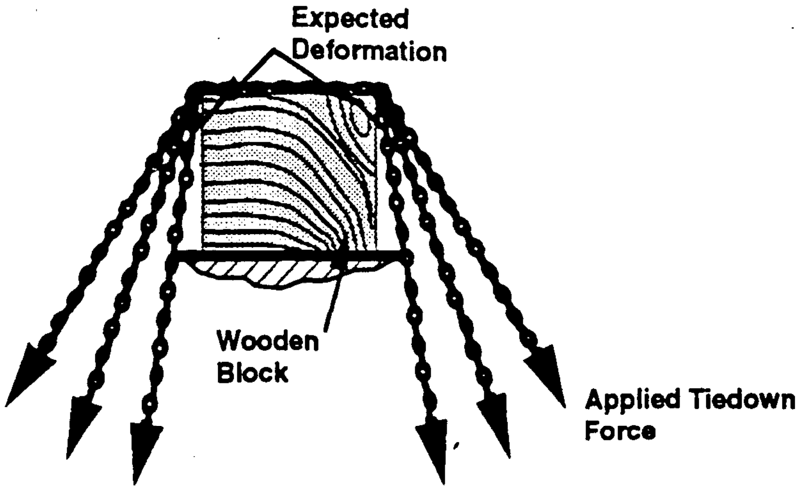


Figure 9.5/ Effect of Tiedown on Wood Blocks Used as Dunnage

9.5.4/ Test Matrix – Effect of Tiedown on Wood Blocks Used as Dunnage (cont'd)

Test No. 9.5-	Block Material	Tiedown Material	Wrap Angle 45°	60°	90°
4(a)	Oak	1/2" cable	X		
4(b)	Oak	1/2" cable		X	
4(c)	Oak	1/2" cable			X
5(a)	Oak	2" webbing	X		
5(b)	Oak	2" webbing		X	
5(c)	Oak	2" webbing			X
6(a)	Pine	1/4" chain	X		
6(b)	Pine	1/4" chain		X	
6(c)	Pine	1/4" chain			X
7(a)	Pine	3/8" chain	X		
7(b)	Pine	3/8" chain		X	
7(c)	Pine	3/8" chain			X
8(a)	Pine	1/4" cable	X		
8(b)	Pine	1/4" cable		X	
8(c)	Pine	1/4" cable			X
9(a)	Pine	1/2" cable	X		
9(b)	Pine	1/2" cable		X	
9(c)	Pine	1/2" cable			X
10(a)	Pine	2" webbing	X		
10(b)	Pine	2" webbing		X	
10(c)	Pine	2" webbing			X

10/ FRICTION

10.1/ Issues

Friction is always present between tiedowns and load, and between the load and the truck deck. It is not considered reliable [2], but in most cases it is an added bonus. Friction may be enhanced by tension in the tiedown system. This series of tests investigates the friction between some surfaces that are commonly in use in the trucking industry, including the effects of dirt, oil, water, and roughness on the surfaces.

10.2/ Static and Sliding Coefficients of Friction

10.2.1/ Purpose

The purpose of this test is to determine the coefficients of static and sliding friction between typical truck decks and typical load materials for various deck conditions with the deck static and in motion (vibratory).

10.2.2/ Method

A skid test rig shall be set-up as shown in Figure 10.2. Combinations of floor material, skid material, and surface condition shall be examined at moderate floor pressure. Four coefficients of friction shall be measured:

(a) break-out coefficient (non-vibration);
(b) sliding coefficient (non-vibration);
(c) break-out coefficient (vibration); and
(d) sliding coefficient (vibration).

For the vibrated load coefficient, the test bed shall be shaken in the vertical mode in a manner identical to a truck bed travelling a roadway. The slider shall be pulled until constant sliding velocity is achieved. Force and load displacement will be measured.

The friction test shall encompass the following:

Truck Floors:

1/ Coarse solid hardwood;
2/ Smooth solid (sealed) hardwood;
3/ Smooth steel;
4/ Grooved aluminum (x direction, along grooves);
5/ Grooved aluminum (y direction, across grooves); and
6/ Transdeck.

Skidder Material:

1/ Oak;
2/ Spruce;
3/ Smooth steel;
4/ Machine feet;
5/ Steel pads;
6/ Plastic skid;
7/ Concrete;
8/ Rubber; and
9/ Paper.

Floor Surface Condition:

1/ Clean and dry;
2/ Wet;
3/ Oily; and
4/ Sandy.

It will be very onerous, and not necessarily entirely useful, to test all combinations of floor, skidder, and surface condition. A selection of combinations was made to best represent the range of conditions most likely to be found in daily practice.

10.2.3/ Results

The results will help assess the role that friction plays in load security. This series of tests will also help in interpretation of the results from other tests in this proposal.

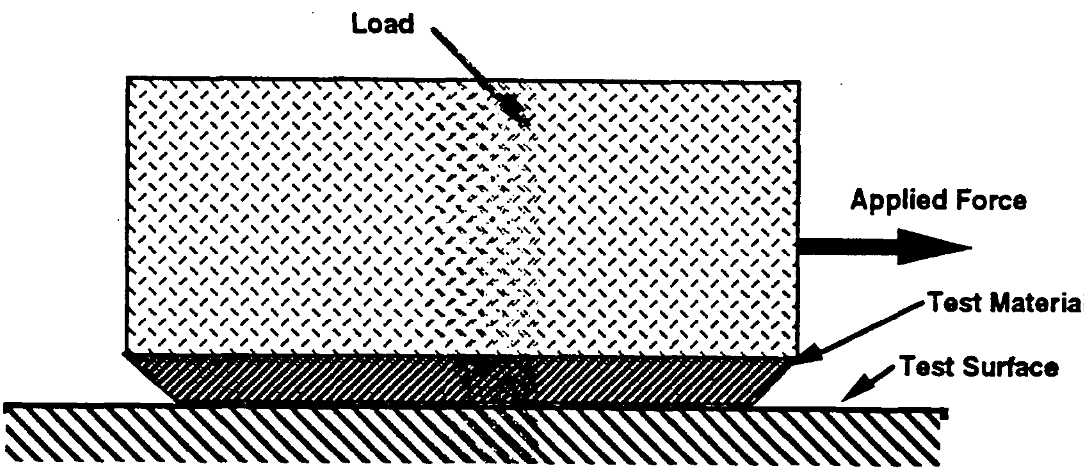
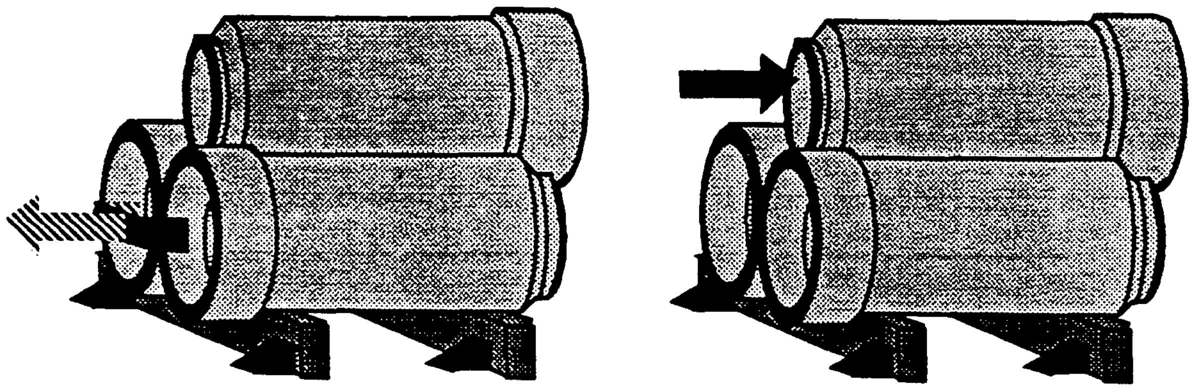


Figure 10.2/ Static and Sliding Coefficients of Friction

10.2.4/ Test Matrix – Static and Sliding Coefficients of Friction

Test No.10.2-	Floor Material	Skidder Material	Clean	Interface Dry	Oily	Wet
1(a)	coarse	spruce	X			
1(b)	hardwood	oak	X		X	
1(c)		machine feet	X			X
1(d)		steel pads	X			X
1(e)		plastic skid	X		X	
1(f)		concrete	X			X
1(g)		rubber	X		X	
2(a)	smooth	oak	X			
2(b)	hardwood	smooth steel	X		X	
2(c)		plastic skid	X		X	
2(d)		concrete	X		X	
2(e)		rubber	X		X	
2(f)		paper	X		X	
3(a)	smooth steel	spruce	X	X		
3(b)		machine feet	X		X	
3(c)		plastic skid	X	X		
3(d)		concrete	X			X
3(e)		rubber	X		X	
3(f)		paper	X	X	X	



Test 10.2.-7(a)/ Concrete Pipe on Hardwood **Test 10.2.-7(b)/ Concrete Pipe on Concrete Pipe**

Figure 10.3/ Friction of Concrete Pipes

10.2.4/ Test Matrix – Static and Sliding Coefficients of Friction (cont'd)

Test No.10.2-	Floor Material	Skidder Material	Interface Clean	Dry	Oily	Wet
4(a)	grooved	spruce	X			X
4(b)	aluminum	machine feet	X		X	
4(c)	(x direction)	plastic skid	X			X
4(d)		concrete	X			
4(e)		rubber	X		X	
5(a)	grooved	spruce	X			X
5(b)	aluminum	machine feet	X		X	
5(c)	(y direction)	plastic skid	X			X
5(d)		concrete	X			
5(e)		rubber	X		X	
6(a)	Transdeck	oak	X	X		
6(b)		machine feet	X		X	
6(c)		steel pads	X		X	
6(d)		plastic skid	X			X
6(e)		concrete	X			
6(f)		rubber	X			X
6(g)		paper	X	X		
7(a)	Hardwood	Concrete Pipe			X ***	
7(b)	Concrete Pipe	Concrete Pipe			X ***	

*** See Figure 10.3

11/ DRESSED LUMBER

11.1/ Issues

Dressed lumber is an example of a long load for which special load security considerations are necessary. There are significant differences in the numbers and spacing of tiedowns required by different jurisdictions, and it is necessary to conduct some objective tests to assess the actual load capacity of the various requirements. This series of tests will investigate the effect of the number and spacing of tiedowns, and for loads consisting of more than one tier of lumber the difference between tiedowns over every tier and tiedowns simply over all tiers.

11.2/ Dressed Lumber Test Series, 1 through 6

11.2.1 Purpose

This test investigates the effect of tying down combinations of bundles of dressed lumber. The purpose is to investigate the effect of tiering and tiedown method on the security of the bundles when subjected to static and dynamic loading.

11.2.2/ Method

Six test series as shown in Figure 11.2(a), (b), (c), (d), (e), and (f) respectively shall be subjected to various tests:

(a) lateral tilting,
(b) longitudinal tilting, and
(c) dynamic manoeuvres in the lateral plane.

The tiedowns shall be instrumented to measure tension. Three preload tensions shall be used in the webbing tiedowns:

(a) low tension (5% of WLL),
(b) medium tension (20% of WLL), and
(b) high tension (50% of WLL).

The bundles shall be 8 feet in length and consist of boards of dressed lumber. Two types of truck floor decking shall be tested:

(a) wood deck and
(b) a teflon low-friction sheet between the load and the deck.

Specific tests shall also be done with a sheet of low-friction material between the tiers to assess the likelihood of slippage. Changes in tiedown tension and tier deflection shall be measured.

11.2.3/ Results

The results of this test should determine the load capacity of the various tiedown methods and should illustrate the consequences of load movement.

Note: Actual number of test runs in test matrices may be shortened due to requirements becoming obvious during testing and thus eliminating a number of test configurations.

11.2.4 (a)/ Test Matrix – One Bundle 8' Dressed Lumber (Refer to Figure 11.2(a))

Test No. 11.2(a)	Number of Tiedowns	Tension L	M	H	Deck Material	Tilt Direction Lat.	Long.	Dynamic Test Yes	No
1(a)	1	X			Wood	X			X
1(b)	1	X			Wood		X		X
1(c)	1		X		Wood	X			X
1(d)	1		X		Wood		X		X
1(e)	1			X	Wood	X			X
1(f)	1			X	Wood		X		X

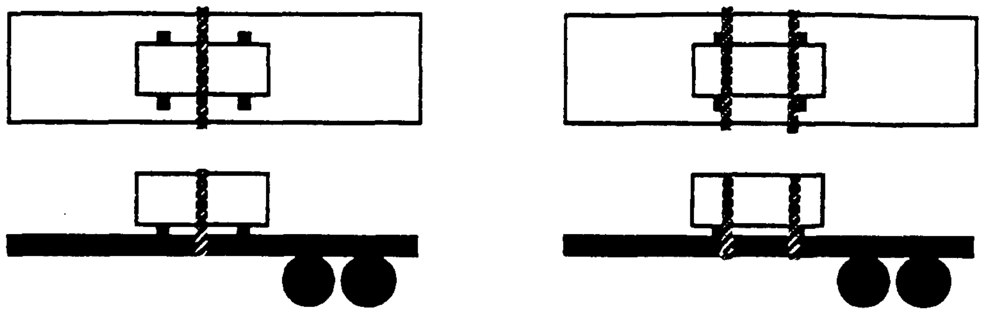


Figure 11.2(a)/ One Bundle 8' Dressed Lumber

11.2.4 (a)/ Test Matrix – One Bundle 8' Dressed Lumber (Refer to Figure 11.2(a))

Test No. 11.2(a)	Number of Tiedowns	Tension L	M	H	Deck Material	Tilt Direction Lat.	Long.	Dynamic Test Yes	No
2(a)	2	X			Wood	X			X
2(b)	2	X			Wood		X		X
2(c)	2		X		Wood	X			X
2(d)	2		X		Wood		X		X
2(e)	2			X	Wood	X			X
2(f)	2			X	Wood		X		X
3(a)	1	X			Teflon	X			X
3(b)	1	X			Teflon		X		X
3(c)	1		X		Teflon	X			X
3(d)	1		X		Teflon		X		X
3(e)	1			X	Teflon	X			X
3(f)	1			X	Teflon		X		X
4(a)	2	X			Teflon	X			X
4(b)	2	X			Teflon		X		X
4(c)	2		X		Teflon	X			X
4(d)	2		X		Teflon		X		X
4(e)	2			X	Teflon	X			X
4(f)	2			X	Teflon		X		X

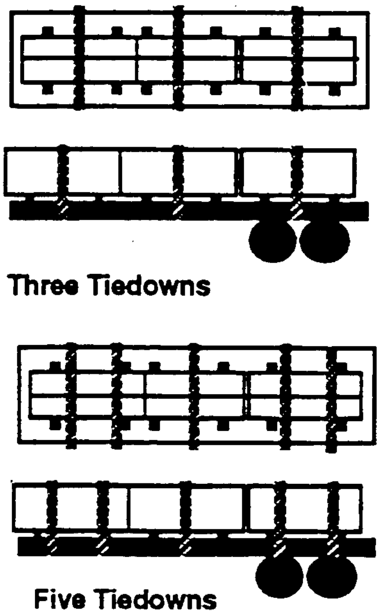


Figure 11.2(b)/ Six Bundles 8' Dressed Lumber

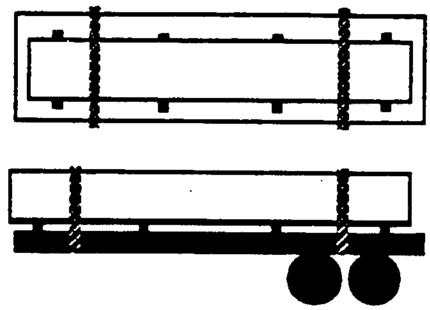


Figure 11.2(c)/ One Bundle 16' Dressed Lumber

11.2.4 (b)/ Test Matrix - Six Bundles 8' Dressed Lumber (Refer to Figure 11.2(b))

Test No. 11.2(b)	Number of Tiedowns	Tension determined in (a)	Deck Material	Tilt Direction Lat.	Tilt Direction Long.	Dynamic Test Yes	Dynamic Test No
1	3	X	Wood	X		X	
1(a)	3	X	Wood		X	X	
2	5	X	Wood	X		X	
2(a)	5	X	Wood		X	X	

11.2.4 (c)/ Test Matrix - One Bundle 16' Dressed Lumber (Refer to Figure 11.2(c))

Test No. 11.2(c)	Number of Tiedowns	Tension L	Tension M	Tension H	Deck Material	Tilt Direction Lat.	Tilt Direction Long.	Dynamic Test Yes	Dynamic Test No
1(a)	2	X			Wood	X			X
1(b)	2	X			Wood		X		X
1(c)	2		X		Wood	X			X
1(d)	2		X		Wood		X		X
1(e)	2			X	Wood	X			X
1(f)	2			X	Wood		X		X
2(a)	2	X			Teflon	X			X
2(b)	2	X			Teflon		X		X
2(c)	2		X		Teflon	X			X
2(d)	2		X		Teflon		X		X
2(e)	2			X	Teflon	X			X
2(f)	2			X	Teflon		X		X

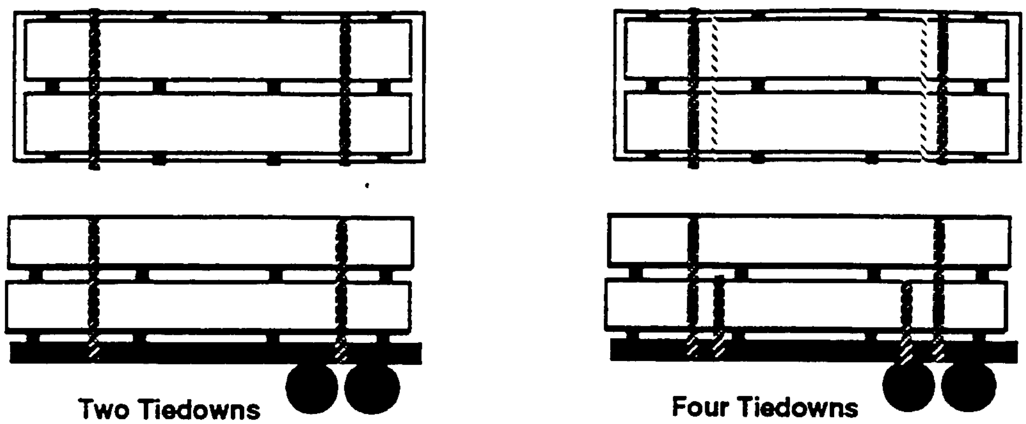


Figure 11.2(d)/ Four Bundles 16' (Tiered) Dressed Lumber

11.2.4 (d)/ Test Matrix – Four Bundles 16' (Tiered) Dressed Lumber (Refer to Figure 11.2(d))

Test No. 11.2(d)	Number of Tiedowns	Tension L	M	H	Deck Material	Tilt Direction Lat.	Long.	Dynamic Test Yes	No
1(a)	2	X			Wood	X			X
1(b)	2	X			Wood		X		X
1(c)	2		X		Wood	X			X
1(d)	2		X		Wood		X		X
1(e)	2			X	Wood	X			X
1(f)	2			X	Wood		X		X
2(a)	2	X			Teflon	X			X
2(b)	2	X			Teflon		X		X
2(c)	2		X		Teflon	X			X
2(d)	2		X		Teflon		X		X
2(e)	2			X	Teflon	X			X
2(f)	2			X	Teflon		X		X
3(a)	4	X			Wood	X			X
3(b)	4	X			Wood		X		X
3(c)	4		X		Wood	X			X
3(d)	4		X		Wood		X		X
3(e)	4			X	Wood	X			X
3(f)	4			X	Wood		X		X
4(a)	4	X			Teflon	X			X
4(b)	4	X			Teflon		X		X
4(c)	4		X		Teflon	X			X
4(d)	4		X		Teflon		X		X
4(e)	4			X	Teflon	X			X
4(f)	4			X	Teflon		X		X
5	as required				Wood			X	

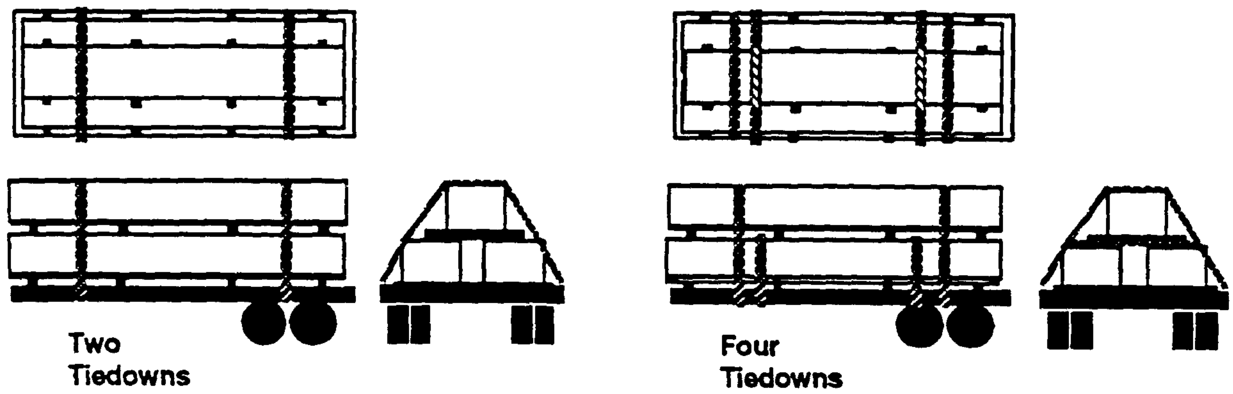


Figure 11.2(e)/ Three Bundles 16' (Tiered) Dressed Lumber

11.2.4 (e)/ Test Matrix – Three Bundles 16' (Tiered) Dressed Lumber (Refer to Figure 11.2(e))

Test No. 11.2(e)	Number of Tiedowns	Tension determined in (d)	Deck Material	Tilt Direction Lat.	Tilt Direction Long.	Dynamic Test Yes	Dynamic Test No
1	2	X	Wood	X			X
2	as required	X	Wood	X			X

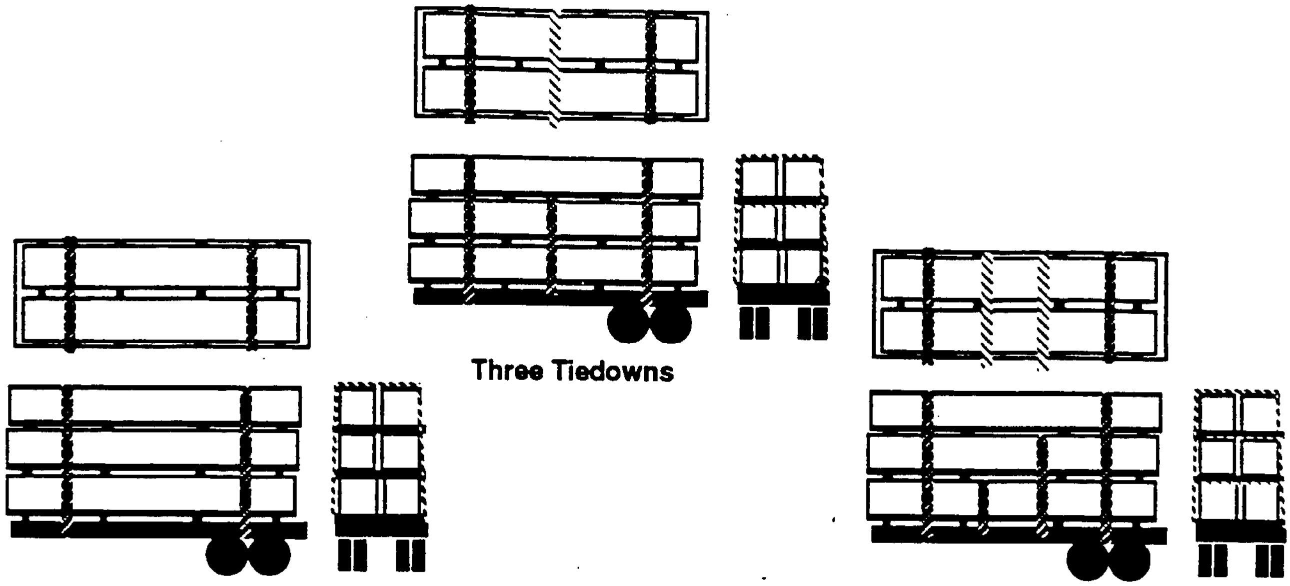


Figure 11.2(f)/ Six Bundles 16' (Tiered) Dressed Lumber

11.2.4 (f)/ Test Matrix – Six Bundles 16' (Tiered) Dressed Lumber (Refer to Figure 11.2(f))

Test No. 11.2(f)	Number of Tiedowns	Tension L	M	H	Deck Material	Tilt Direction Lat.	Long.	Dynamic Test Yes	No
1(a)	2	X			Wood	X			X
1(b)	2	X			Wood		X		X
1(c)	2		X		Wood	X			X
1(d)	2		X		Wood		X		X
1(e)	2			X	Wood	X			X
1(f)	2			X	Wood		X		X

11.2.4 (f)/ Test Matrix – Six Bundles 16' (Tiered) Dressed Lumber (Refer to Figure 11.2(f))

Test No. 11.2(f)	Number of Tiedowns	Tension L	M	H	Deck Material	Tilt Direction Lat.	Long.	Dynamic Test Yes	No
2(a)	2	X			Teflon	X			X
2(b)	2	X			Teflon		X		X
2(c)	2		X		Teflon	X			X
2(d)	2		X		Teflon		X		X
2(e)	2			X	Teflon	X			X
2(f)	2			X	Teflon		X		X
3(a)	3	X			Wood	X			X
3(b)	3	X			Wood		X		X
3(c)	3		X		Wood	X			X
3(d)	3		X		Wood		X		X
3(e)	3			X	Wood	X			X
3(f)	3			X	Wood		X		X
4(a)	3	X			Teflon	X			X
4(b)	3	X			Teflon		X		X
4(c)	3		X		Teflon	X			X
4(d)	3		X		Teflon		X		X
4(e)	3			X	Teflon	X			X
4(f)	3			X	Teflon		X		X
5(a)	4	X			Wood	X			X
5(b)	4	X			Wood		X		X
5(c)	4		X		Wood	X			X
5(d)	4		X		Wood		X		X
5(e)	4			X	Wood	X			X
5(f)	4			X	Wood		X		X
6(a)	4	X			Teflon	X			X
6(b)	4	X			Teflon		X		X
6(c)	4		X		Teflon	X			X
6(d)	4		X		Teflon		X		X
6(e)	4			X	Teflon	X			X
6(f)	4			X	Teflon		X		X

12/ METAL COILS

12.1/ Issues

Because of their shape and weight, metal coils are a particular challenge for load security restraint systems. The geometric shape of a coil is such that it offers different resistance to motion depending on the way that it is oriented. Its inherent tendency to roll away when placed with the eye of the coil horizontal means that blocking and tiedowns together must provide all the restraint. This series of tests examines the separate effects of friction, blocking, and tiedown on coils, and the combined effect of all three of these components of the load security system.

This series of tests includes the following:

1/ Effect of Friction;
2/ Effect of Blocking;
3/ Chain Securement, Eye Lateral;
4/ Chain Securement, Eye Longitudinal;
5/ Coil with Eye Lateral in Cradle, Cradle Secured;
6/ Coil with Eye Lateral in Cradle, Cradle Unsecured;
7/ Coil with Eye Lateral in Cradle, with Chains, Cradle Unsecured;
8/ Effect of Blocking Length for a Coil with Eye Longitudinal;
9/ Coil with Eye Longitudinal, in Cradle, Various Securement Combinations;
10/ Coil with Eye Longitudinal, in Cradle, Steep Angle Chains;
11/ Coil with Eye Longitudinal, in Cradle Test, Shallow Angle Chains;
12/ Coil with Overwrap Chains and Webbing, Combination Block and Chain; and
13/ Coil with Overwrap Chains and Two Way Blocking.

12.2/ Effect of Friction

12.2.1/ Purpose

The purpose of this test is to determine the extent to which friction plays a part in the load security system for metal coils.

12.2.2/ Method

For this series of tests the coil(s) shall be pulled across the deck of a trailer. Two trailer decks shall be tested:
- (a) rough oak and
- (b) steel (smooth).

The test shall be conducted for two coil orientations:
- (a) eye vertical and
- (b) eye horizontal.

The interface for sliding shall be:
- (a) coil on wood;
- (b) coil on steel;
- (c) paper on wood;
- (d) paper on steel; and
- (e) plastic on wood.

In certain applications the coil shall be placed on a skid and pulled across the skid (with the skid secured to the floor), and the coil shall be banded to a skid and the skid pulled across the floor. Two coil materials shall be tested:
- (a) aluminum and
- (b) steel.

Two pull heights shall be used:
- (a) 1" off deck and
- (b) coil radius off deck, pulled through the center of the coil.

A further specific test includes pulling a coil banded to a secured skid to fail the banding. General layouts for these tests are shown in Figure 12.2.

12.2.3/ Results

The results of this test will help determine the contribution of friction to the overall restraint of a load security system.

12.2.4/ Test Matrix – Effect of Friction

Test No. 12.2-	Coil Material	Eye Position		Interface	Pull Position	
	Mat'l & wt.	Vert.	Hor.	Condition	High	Low
1(a)	Steel 17K	X		Steel on wood	X	
1(b)	Steel 17K	X		Steel on wood		X
1(c)	Steel 17K		X	Steel on wood	X	

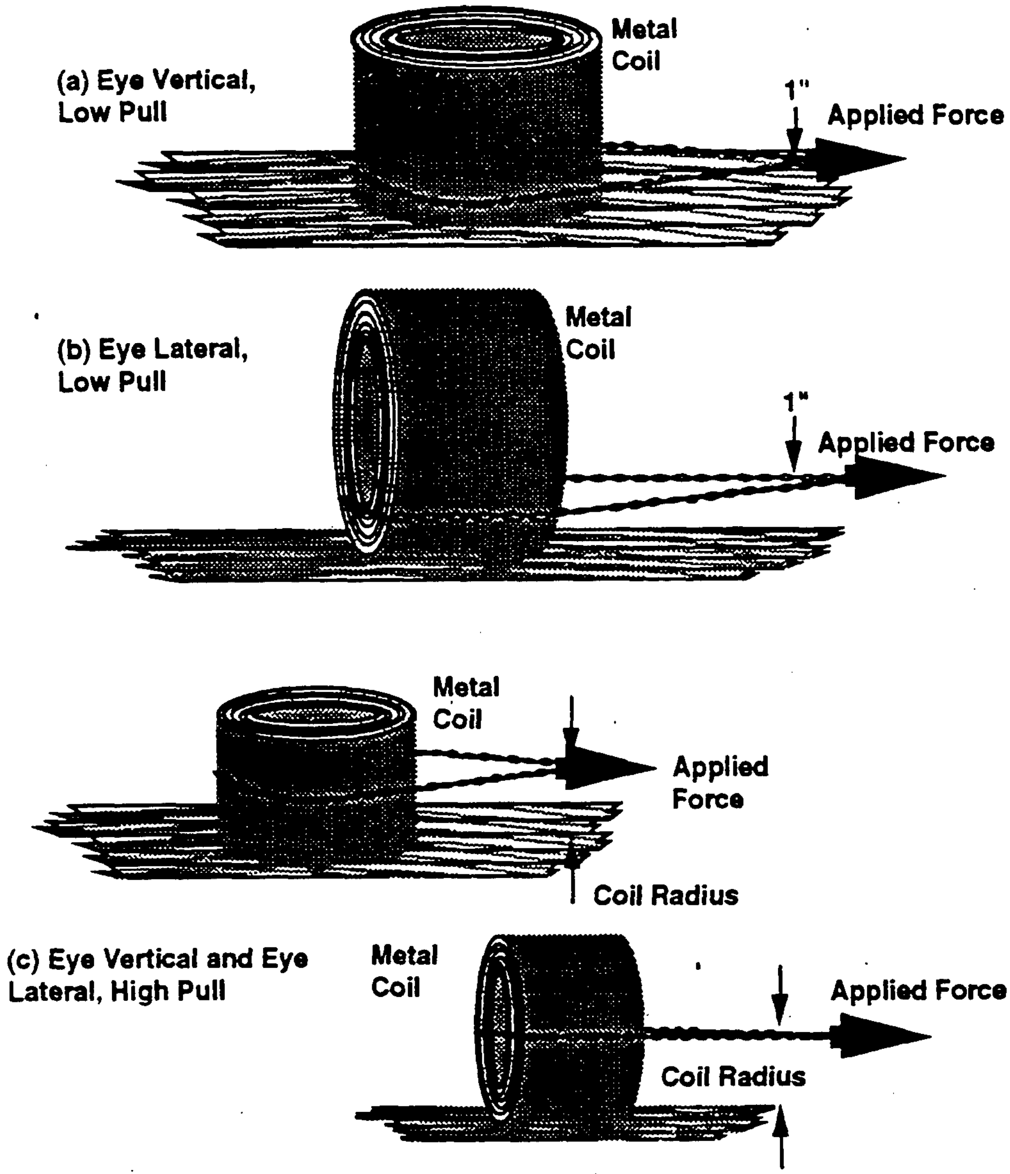


Figure 12.2/ Effect of Friction

12.2.4/ Test Matrix - Effect of Friction

Test No. 12.2-	Coil Material Mat'l & wt.	Eye Position Vert.	Eye Position Hor.	Interface Condition	Pull Position High	Pull Position Low
1(d)	Steel 17K		X	Steel on wood		X
1(e)	Steel 17K	X		Steel on steel	X	
1(f)	Steel 17K	X		Steel on steel		X
1(g)	Steel 17K		X	Steel on steel	X	
1(h)	Steel 17K		X	Steel on steel		X

12.2.4/ Test Matrix – Effect of Friction (cont'd)

Test No. 12.2-	Coil Material Mat'l & wt.	Eye Position Vert.	Eye Position Hor.	Interface Condition	Pull Position High	Pull Position Low
1(i)	Steel 17K	X		Steel/paper on wood	X	
1(j)	Steel 17K	X		Steel/paper on wood		X
1(k)	Steel 17K		X	Steel/paper on wood	X	
1(l)	Steel 17K		X	Steel/paper on wood		X
1(m)	Steel 17K	X		Steel on aluminum	X	
1(n)	Steel 17K	X		Steel on aluminum		X
1(o)	Steel 17K		X	Steel on aluminum	X	
1(p)	Steel 17K		X	Steel on aluminum		X
1(q)	Steel 17K	X		Steel/plastic on wood	X	
1(r)	Steel17K	X		Steel/plastic on wood		X
1(s)	Steel17K		X	Steel/plastic on wood	X	
1(t)	Steel17K		X	Steel/plastic on wood		X
2(a)	Steel 25K	X		Steel on wood	X	
2(b)	Steel 25K	X		Steel on wood		X
2(c)	Steel 25K		X	Steel on wood	X	
2(d)	Steel 25K		X	Steel on wood		X
3(a)	Aluminum 10K	X		Aluminum on wood	X	
3(b)	Aluminum 10K	X		Aluminum on wood		X
3(c)	Aluminum 10K		X	Aluminum on wood	X	
3(d)	Aluminum 10K		X	Aluminum on wood		X
4(a)	Aluminum 10K	X		Aluminum banded to skid, aluminum pulled until banding fails		
4(b)	Aluminum 10K	X		Aluminum banded to skid, skid pulled		

12.3/ Effect of Blocking

12.3.1/ Purpose

The purpose of this test is to examine the effect of blocking on the motion of an unsecured metal coil.

12.3.2/ Method

Three separate tests are identified.

A metal coil shall be tested in the orientations shown in Figure 12.3, broken down as follows:
- (a) eye lateral, 1" over floor and
- (b) eye lateral, touching floor.

In the following manners:
- (a) blocking not secured and
- (b) blocking secured.

The test blocks in Figures 12.3 (b) and (c) shall be instrumented to measure force and displacement. These tests shall be conducted using the following blocking:
- (a) 10 cm x 10 cm square;
- (b) 10 cm x 10 cm 22° bevel on one side;
- (c) 15 cm x 15 cm square; and
- (d) 15 cm x 15 cm 22° bevel on one side.

Two coil sizes shall be used:
- (a) 1.27 m diameter steel and
- (b) 1.83 m diameter steel.

In addition, one test will be conducted with secured blocking for the 1.27 m diameter coil with its eye vertical.

The forces required to move the coil and the resulting reactions and displacements of the coil and blocks shall be measured.

12.3.3/ Results

The results of this test will help determine the contribution of blocking to the restraint of a load security system.

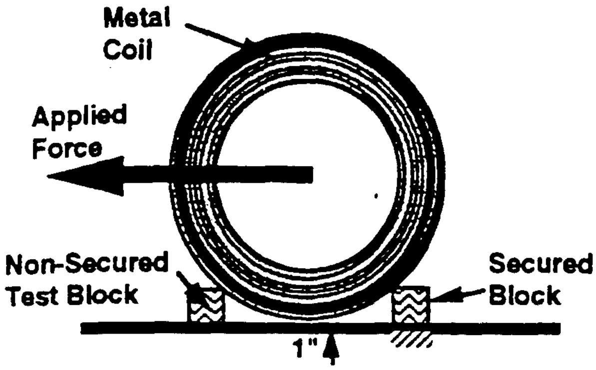


Figure 12.3(a) / Non-Secured Blocking

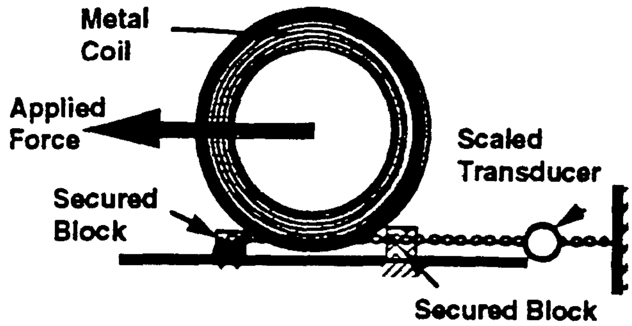


Figure 12.3(b)/ Secured Blocking, Eye Lateral

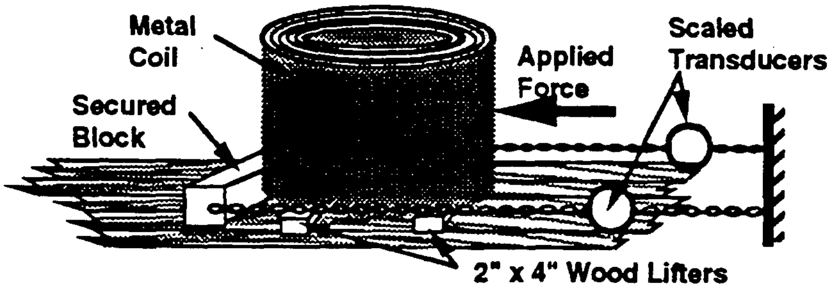


Figure 12.3(c) /Secured Blocking, Eye Vertical

12.3.4/ Test Matrix – Effect of Blocking

Test No. 12.3-	Coil Diameter		Blocking		Bevelled		Floor/Coil	Eye	
	1.27 m	1.83 m	10 cm	15 cm	Yes	No	Clearance	V	H
1(a)	X		X			X	1"		X
1(b)	X		X			X	0"		X
1(c)	X		X		X		1"		X
1(d)	X		X		X		0"		X
1(e)	X			X		X	1"		X
1(f)	X			X		X	0"		X
1(g)	X			X	X		1"		X
1(h)	X			X	X		0"		X
2(a)		X	X			X	1"		X
2(b)		X	X			X	0"		X
2(c)		X	X		X		1"		X
2(d)		X	X		X		0"		X
2(e)		X		X		X	1"		X
2(f)		X		X		X	0"		X
2(g)		X		X	X		1"		X
2(h)		X		X	X		0"		X
3	X		X			X	0"	X	

12.4/ Chain Securement, Eye Lateral

12.4.1/ Purpose

The purpose of this series of tests is to determine how chains contribute to the restraint of a metal coil under load in the direction of rolling. It also evaluates the difference between a larger number of smaller chains and a smaller number of larger chains.

12.4.2/ Method

Two separate tests are proposed.

The first test shall measure chain tension under longitudinal loading for a coil with its eye horizontal and the load applied in the direction of rolling of the coil, as shown in Figure 12.4(a). It shall measure how chains share loads in reacting to the applied force. The load shall be applied for all combinations of up to four chains at the following angles:

(a) 45°,
(b) 60°,
(c) 75°, and
(d) 90°,

All chains shall be instrumented to measure tension and the coil instrumented to measure displacement (1/4" grade 70 chain shall be used).

The second test shall measure chain tension under longitudinal loading for a coil with its eye horizontal and the load applied in the direction of rolling of the coil, as shown in Figure 12.4(b). This test also measures how chains share loads in reacting. The applied force. However, the load shall be applied up to the point where chains break, for two combinations of chains. The chains tested shall be:

(a) up to 4 1/4" grade 70 and
(b) up to 2 3/8" grade 70.

Each set of chains shall be preloaded to:

(a) low (5% of WLL),
(b) medium (20% of WLL), and
(c) high (50% of WLL).

Two chain angles shall be used for this test series:

(a) 45° to bed and
(b) 75° to be.

All tests shall be performed on a 25,000 lb coil of steel.

12.4.3/ Results

The results of these tests will show how different numbers of chains share in reacting to an applied load. The test should also evaluate whether there is any tendency to a "domino effect" failure of sets of chains.

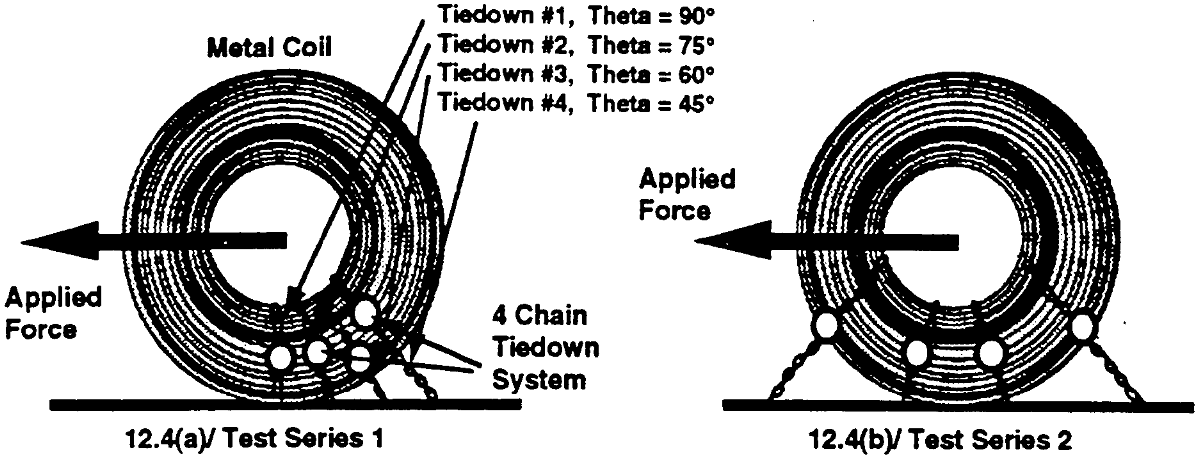


Figure 12.4/ Chain Securement, Eye Lateral

12.4.4/ Test Matrix – Chain Securement, Eye Lateral

Test No. 12.4-1-	Chain Secured (a)	(b)	(c)	d)
1(a)	X			
1(b)		X		
1(c)			X	
1(d)				X
2(a)	X	X		
2(b)	X		X	
2(c)	X			X
2(d)		X	X	
2(e)		X		X
2(f)			X	X
3(a)	X	X	X	
3(b)	X	X		X
3(c)	X		X	X
3(d)		X	X	X
4	X	X	X	X

Test No.12.4-2-	Number of Chains	Chain Size 1/4"	3/8"	Preload Low	Med	High	Chain Angle
1(a)	4	X		X			75° and 45°
1(b)	4	X			X		75° and 45°
1(c)	4	X				X	75° and 45°
2(a)	2		X	X			75°
2(b)	2		X		X		75°
2(c)	2		X			X	75°
3(a)	2		X	X			45°
3(b)	2		X		X		45°
3(c)	2		X			X	45°

12.5/ Chain Securement, Eye Longitudinal

12.5.1/ Purpose

The purpose of this test is to examine the effect of chain angle on a coil with its eye horizontal loaded along the axis of the eye.

12.5.2/ Method

The coil shall be set-up as shown in Figure 12.5. The load shall be applied and the tension in the tiedowns and motion of the coil shall be measured. The chain angles to be tested, in plan view, are:

(a) 45° to trailer edge,
(b) 65° to trailer edge,
(c) 85° to trailer edge, and
(d) -45° to trailer edge.

Inside the coil, the tiedowns shall be:

(a) straight through and
(b) crossed.

A 50,000 lb steel coil and 3/8" chain, adjusted to medium tension (20% of WLL), shall be used for all tests.

12.5.3/ Results

The results of this test will show the effect of longitudinal chain angle on load security.

12.5.4/ Test Matrix – Chain Securement, Eye Longitudinal

Test No. 12.5-	Tiedown Angle				Inside Eye Orientation	
	45°	65°	85°	-45°	Straight	Crossed
1(a)	X				X	
1(b)	X					X
2(a)		X			X	
2(b)		X				X
3(a)			X		X	
3(b)			X			X
4(a)				X	X	
4(b)				X		X

Plan View

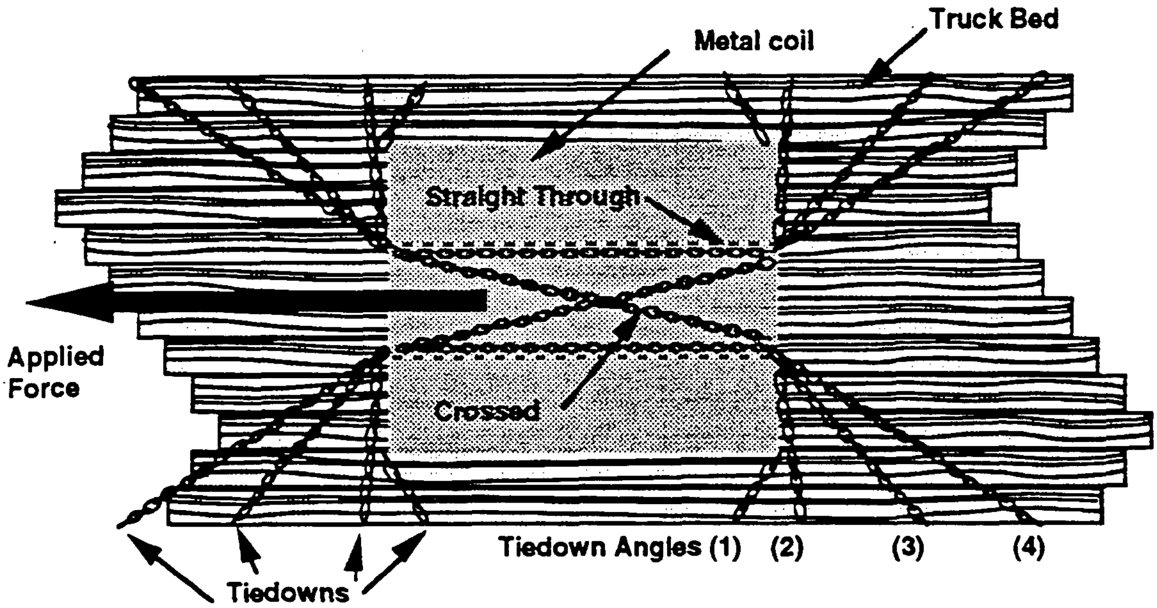


Figure 12. 5 Chain Securement - Eye Longitudinal

12.6/ Coil with Eye Lateral in Cradle, Cradle Secured

12.6.1/ Purpose

The purpose of this test is to roll a coil over one of the support blocks in a test cradle. The test is to ascertain the magnitude of the load required for such a manoeuvre and to examine the effects on the cradle and blocks.

12.6.2/ Method

The test set-up is shown in Figure 12.6. An aluminum, 10,000 lb, 1.27 m diameter coil is loaded until the coil lifts off the rear block and rolls across the forward block. The block/block configurations to be tested are:

(a) 10 cm x 10 cm square;
(b) 10 cm x 10 cm bevelled;
(c) 10 cm x 10 cm bevelled with rubber mat;
(d) 15 cm x 15 cm square; and
(e) 15 cm x 15 cm bevelled.

The forces in the system and displacements shall be measured and recorded.

12.6.3/ Results

The results of this test will show the inherent restraining effect of blocking where the blocking is restrained by a cradle.

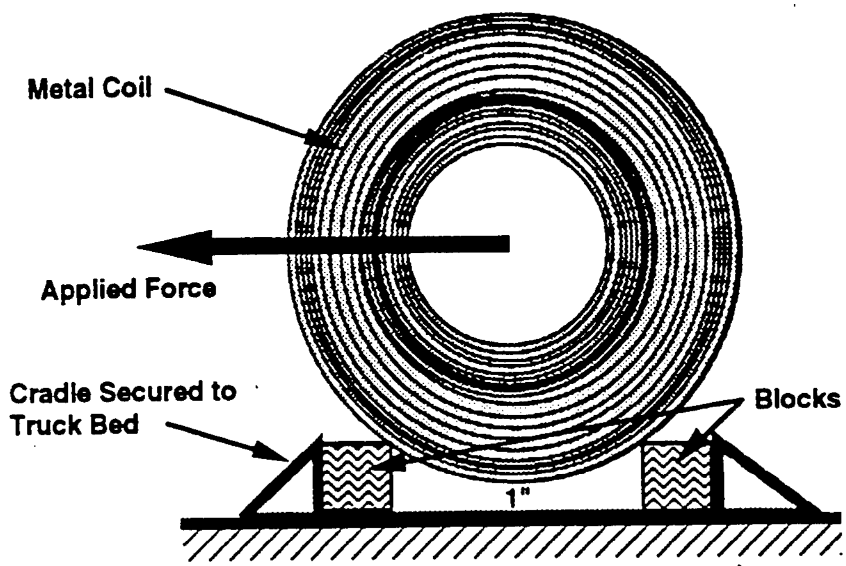


Figure 12.6/ Coil with Eye Lateral in Cradle, Cradle Secured

12.6.4/ Test Matrix - Coil with Eye Lateral in Cradle, Cradle Secured

Test No. 12.6-	Block Size 10 x 10	Block Size 15 x 15	Block Shape Square	Block Shape Bevelled	Friction Interface
1(a)	X		X		Aluminum on wood
1(b)	X			X	Aluminum on wood
1(c)	X			X	Aluminum on rubber
2(a)		X	X		Aluminum on wood
2(b)		X	X		Aluminum on wood

12.7/ Coil with Eye Lateral In Cradle, Cradle Unsecured

12.7.1/ Purpose

The purpose of this test is to attempt to roll a coil over one of the support blocks in a test cradle. The test is to ascertain the magnitude of the load required for such a manoeuvre and to examine the effects on the cradle and blocks, and determine if the cradle moves under such loading.

12.7.2/ Method

The test set-up is shown in Figure 12.7. The coil is loaded until the coil lifts off the rear block and rolls across the forward block, or the cradle slides. The block sizes and shapes to be tested are:

- (a) 10 cm x 10 cm square;
- (b) 10 cm x 10 cm bevelled;
- (c) 10 cm x 10 cm bevelled with rubber mat;
- (d) 15 cm x 15 cm square; and
- (e) 15 cm x 15 cm bevelled.

The interfaces between the cradle and truck bed are:

- (a) steel cradle on dry wood;
- (b) steel cradle on wet wood;
- (c) steel cradle on dry steel;
- (d) steel cradle on wet steel; and
- (e) steel cradle on rubber pad on dry wood.

The forces and displacements within the system shall be measured. The tests shall be performed with a 25,000 lb steel coil.

12.7.3/ Results

The results of this test will show the restraining effect of a cradle resting on a truck bed.

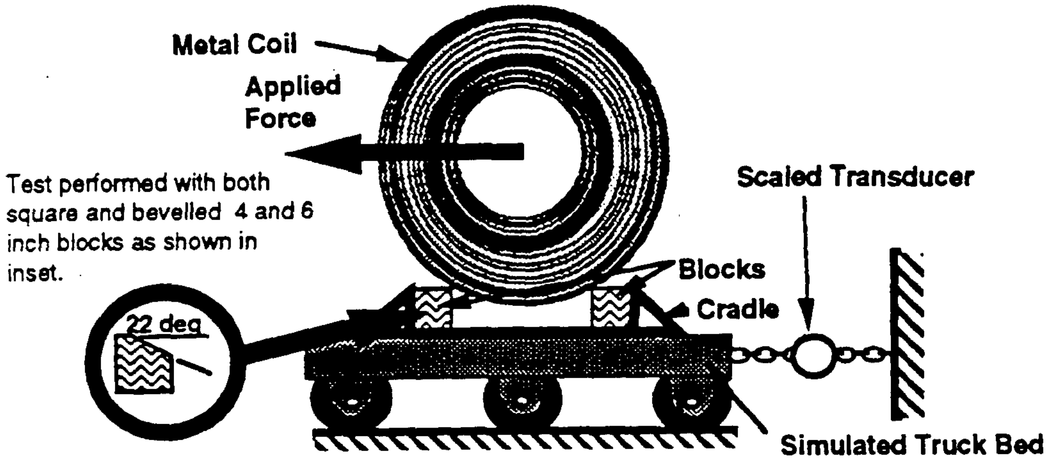


Figure 12.7/ Coil with Eye Lateral in Cradle, Cradle Unsecured

12.7.4/ Test Matrix – Coil with Eye Lateral in Cradle, Cradle Unsecured

Test No. 12.7-	Block Size 10 x 10	Block Size 15 x 15	Block Shape Square	Block Shape Bevel	Coil Interface	Floor Interface
1(a)	X		X		Coil on wood	Cradle/dry wood
1(b)	X		X		Coil on wood	Cradle/wet wood
1(c)	X		X		Coil on wood	Cradle/dry steel
1(d)	X		X		Coil on wood	Cradle/wet steel
1(e)	X		X		Coil on wood	Rubber mat/wood
2(a)	X			X	Coil on wood	Cradle/dry wood
2(b)	X			X	Coil on wood	Cradle/wet wood
2(c)	X			X	Coil on wood	Cradle/dry steel
2(d)	X			X	Coil on wood	Cradle/wet steel
2(e)	X			X	Coil on wood	Rubber mat/wood
3(a)		X	X		Coil on wood	Cradle/dry wood
3(b)		X	X		Coil on wood	Cradle/wet wood
3(c)		X	X		Coil on wood	Cradle/dry steel
3(d)		X	X		Coil on wood	Cradle/wet steel
3(e)		X	X		Coil on wood	Rubber mat/wood
4(a)		X		X	Coil on wood	Cradle/dry wood
4(b)		X		X	Coil on wood	Cradle/wet wood
4(c)		X		X	Coil on wood	Cradle/dry steel
4(d)		X		X	Coil on wood	Cradle/wet steel
4(e)		X		X	Coil on wood	Rubber mat/wood
5(a)	X			X	Coil on rubber	Cradle/dry wood
5(b)	X			X	Coil on rubber	Cradle/wet wood
5(c)	X			X	Coil on rubber	Cradle/dry steel
5(d)	X			X	Coil on rubber	Cradle/wet steel
5(e)	X			X	Coil on rubber	Rubber mat/wood

12.8/ Coil with Eye Lateral in Cradle, with Chains, Cradle Unsecured

12.8.1/ Purpose

This test examines the effect of chain configuration on restraint of a coil mounted in an unsecured cradle.

12.8.2/ Method

The test set-ups are shown in Figure 12.8. The coil shall be secured and then loaded to cause failure of the tiedown chains, while measuring the tension in the chains and motion of the coil. The securement methods examined are:

(a) 1 x 1/4" chain at 90°,
(b) 1 x 3/8" chain at 90°,
(c) 1 x 1/4" chain at 45°,
(d) 1 x 3/8" chain at 45°,
(e) 4 x 1/4" chain at 75 and 45°, and
(f) 2 x 3/8" chain at 45°.

The block/coil interfaces to be examined are:

(a) coil on wood, block 3/4 of coil width; and
(b) coil on rubber on wood, block 3/4 of coil width.

Two preload tensions shall be used:

(a) medium preload (20% of WLL)and
(b) high preload (50% of WLL).

The coil tested shall be a 50,000 lb steel coil.

12.8.3/ Results

The test results will show the influence of various chaining methods on coil restraint.

12.8.4/ Test Matrix – Coil with Eye Lateral in Cradle, with Chains, Cradle Unsecured

Test No. 12.8-	Chains and Orientation	Preload M	Preload H	Coil Interface Coil/wood	Coil Interface Rubber/wood
1(a)	1 x 1/4" at 90°	X		X	
1(b)	1 x 1/4" at 90°	X			X
1(c)	1 x 1/4" at 90°		X	X	
1(d)	1 x 1/4" at 90°		X		X
2(a)	1 x 3/8" at 90°	X		X	
2(b)	1 x 3/8" at 90°	X			X
2(c)	1 x 3/8" at 90°		X	X	
2(d)	1 x 3/8" at 90°		X		X

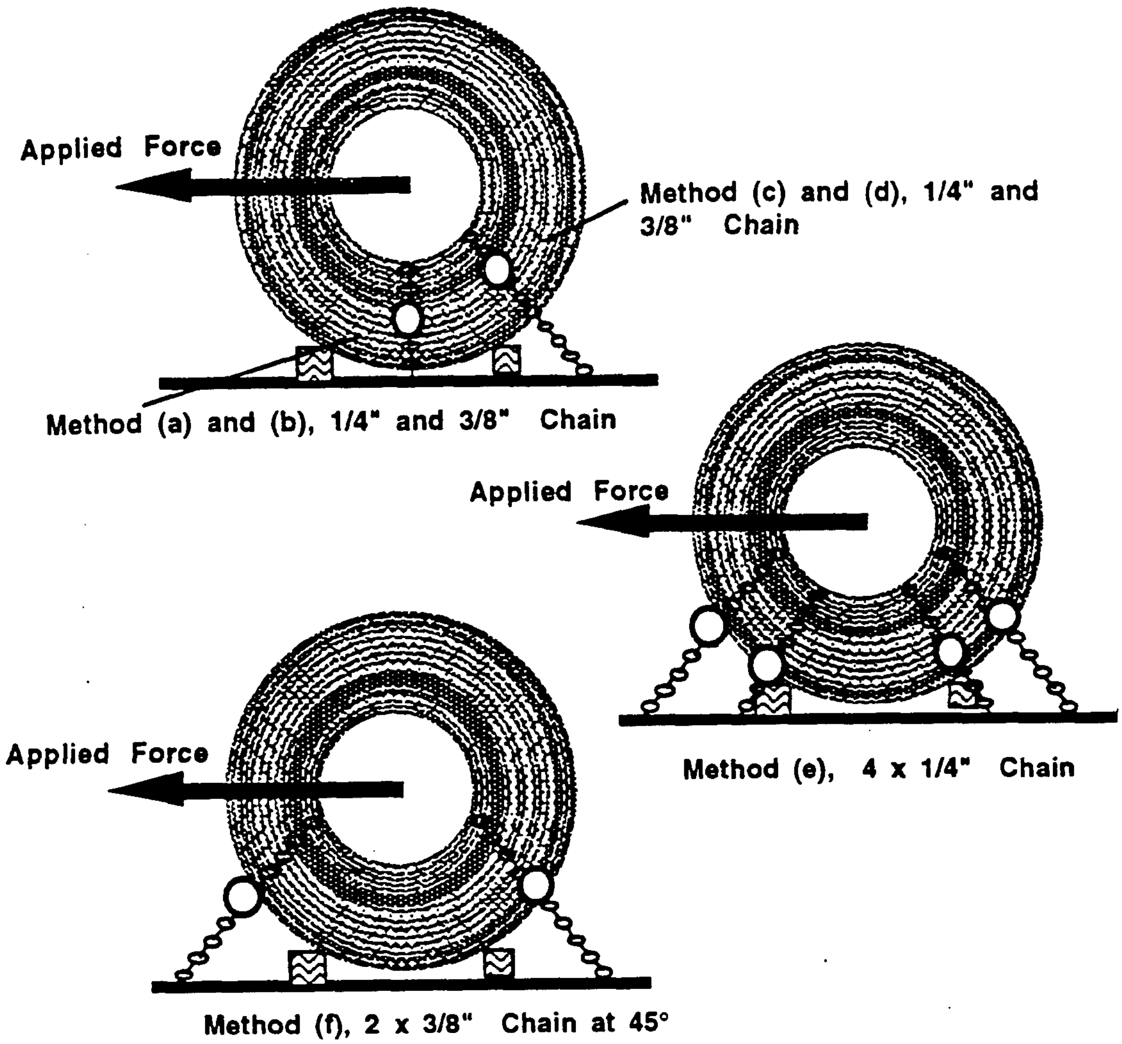


Figure 12.8/ Coil with Eye Lateral in Cradle, with Chains, Cradle Unsecured

12.8.4/ Test Matrix – Coil with Eye Lateral in Cradle, with Chains, Cradle Unsecured (Cont'd)

Test No. 12.8-	Chain and Orientation	Preload M	Preload H	Coil Interface Coil/wood	Rubber/wood
3(a)	1 x 1/4" at 45°	n/a		X	
3(b)	1 x 1/4" at 45°	n/a			X
4(a)	1 x 3/8" at 45°	n/a		X	
4(b)	1 x 3/8" at 45°	n/a			X
5(a)	4 x 1/4" at 45° & 75°	X		X	
5(b)	4 x 1/4"at 45° & 75	X			X
5(c)	4 x 1/4"at 45° & 75		X	X	
5(d)	4 x 1/4"at 45° & 75		X		X
6(a)	2 x 3/8" at 45°	X		X	
6(b)	2 x 3/8" at 45°	X			X
6(c)	2 x 3/8" at 45°		X	X	
6(d)	2 x 3/8" at 45°		X		X

12.9/ Effect of Blocking Length for a Coil with Eye Longitudinal

12.9.1/ Purpose

This test examines the effect of an unrestrained coil sliding out on its blocking under the influence of a force through the eye.

12.9.2/ Method

The test set-up is shown in Figure 12.9, where both the cradle and the blocking are secured so that they will not move relative to the truck bed. The coil shall be pulled until it slides on the blocking. The forces required to cause motion and relative displacement shall be measured. The coil shall be tested with the following interfaces:

(a) coil on wood block and
(b) coil on rubber mat on wood block.

The block conditions shall be:

(a) dry wood,
(b) oily wood,
(c) dry rubber, and
(d) oily rubber.

The block lengths shall be:

(a) 75% of coil width,
(b) 100% of coil width, and
(c) 125% of coil width.

The coil examined shall be a 50,000 lb steel coil, the blocks shall be 10 cm x 10 cm, bevelled.

12.9.3/ Results

The results from this test will show the friction resistance offered by the blocking material, and the extent to which blocking longer than the coil might provide additional resistance due to the coil biting into the wood.

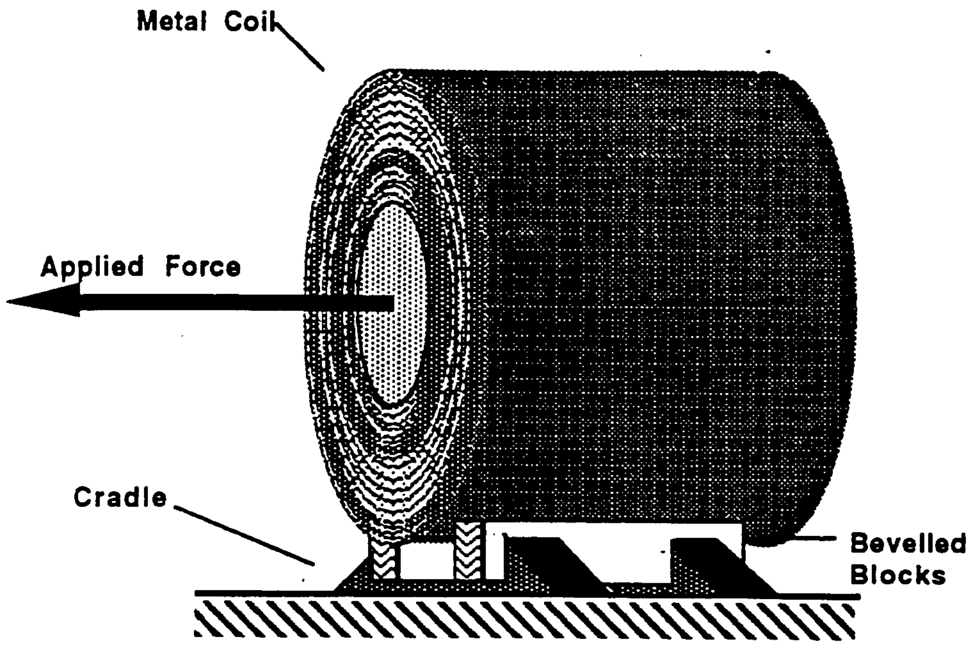


Figure 12.9/ Effect of Blocking Length for a Coil with Eye Longitudinal

12.9.4/ Test Matrix - Effect of Blocking Length for a Coil with Eye Longitudinal

Test No. 12.9-	Coil/Block Interface	Interface Condition	Block Length 75%	100%	125%
1(a)	Coil on wood	Dry wood	X		
1(b)	Coil on wood	Dry wood		X	
1(c)	Coil on wood	Dry wood			X
2(a)	Coil on wood	Wet wood	X		
2(b)	Coil on wood	Wet wood		X	
2(c)	Coil on wood	Wet wood			X
3(a)	Coil on rubber	Dry rubber	X		
3(b)	Coil on rubber	Dry rubber		X	
3(c)	Coil on rubber	Dry rubber			X
4(a)	Coil on rubber	Wet rubber	X		
4(b)	Coil on rubber	Wet rubber		X	
4(c)	Coil on rubber	Wet rubber			X

12.10/ Coil with Eye Longitudinal, in Cradle, Various Securement Combinations

12.10.1/ Purpose

The purpose of this test is to examine the effect of a coil sliding on its blocking, or the coil and cradle sliding as one, on the truck bed. The test examines the effect of various blocking materials and conditions and various bed materials and conditions, with no restraint other than friction between the surfaces.

12.10.2/ Method

The test set-up is shown in Figure 12.10. For this test either the cradle and/or the blocking is secured to the truck bed. The blocking material, coil, and cradle shall be secured together and pulled to measure the friction at the cradle/bed interface. The cradle shall then be secured to the bed and the coil shall be secured to the blocks to measure the friction at the block/cradle interface. The blocking and cradle shall then be secured to the bed and the coil pulled to measure the friction at the coil/blocking interface, except for those combinations already tested in Section 12.9 above. The forces required to cause motion, and relative displacement, shall be measured. The cradle/bed conditions examined are:

(a) dry wood bed;
(b) wet wood bed;
(c) dry metal bed;
(d) wet metal bed;
(e) dry rubber between wood bed and cradle; and
(d) oily rubber between wood bed and cradle.

The interface between the blocks and cradle shall be:

(a) dry and
(b) wet.

The coil and block interfaces to be tested are:

(a) oily wood and
(b) oily rubber.

The securement shall be set to measure the forces and motions at the following interfaces:

(a) cradle and bed,
(b) cradle and blocks, and
(c) coil and blocks.

The blocking shall extend 75% of the coil width and a 25,000 lb steel coil shall be used.

All blocking shall be 10 cm x 10 cm bevelled wood block.

12.10.3/ Results

The results of this test will show the friction offered by all of the components of the cradle, blocks, and coil for most conditions encountered.

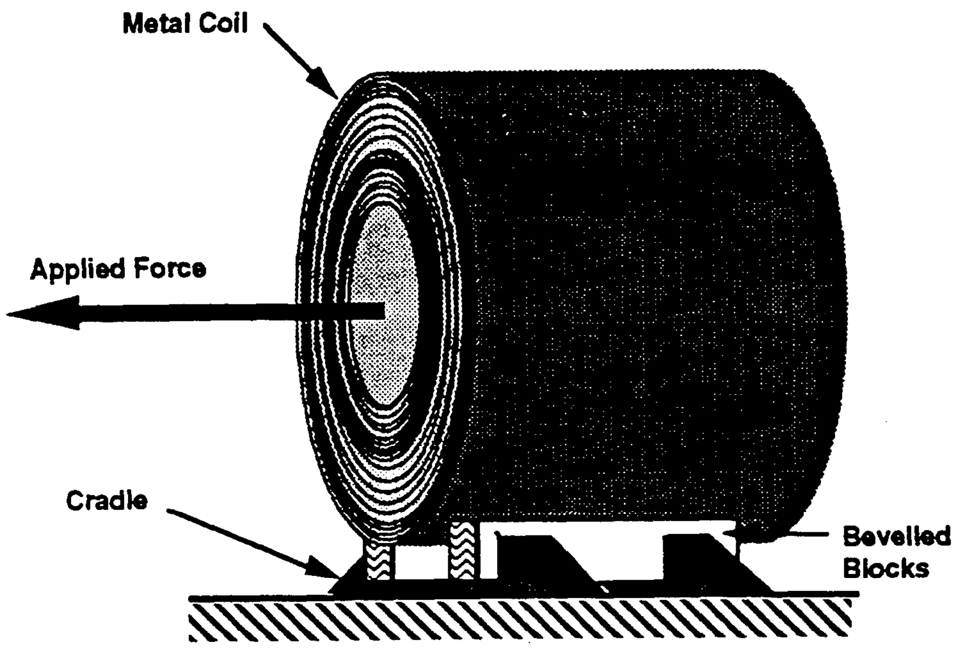


Figure 12.10/ Coil With Eye Longitudinal in Cradle, Various Securement Combinations

12.10.4/ Test Matrix - Coil with Eye Longitudinal, in Cradle, Various Securement Combinations

Test No. 12.10-	Interface Examined			Interface Condition			Interface Material		
	Coil/Block	Block/Cradle	Cradle/Bed	Dry	Wet	Oily	Wood	Steel	Rubber
1(a)	X					X	X		
1(b)	X					X			X
2(a)		X		X			X		
2(b)		X			X		X		
3(a)			X	X			X		
3(b)			X	X				X	
3(c)			X	X					X
4(a)			X		X		X		
4(b)			X		X			X	
4(c)			X			X			X

12.11/ Coil with Eye Longitudinal, in Cradle, Steep Angle Chains

12.11.1/ Purpose

This test examines the combination of cradle and chains as a securement system. The cradle is unsecured and the coil is secured by chains at the steepest angle obtainable, approximately 85° in plan view.

12.11.2/ Method

The coil shall be set up and secured as shown in Figure 12.11, and loaded through the eye. The cradle/bed interfaces tested shall be:
- (a) dry wood and
- (b) dry steel.

The coil and block interfaces tested shall be:
- (a) steel coil on dry wood,
- (b) steel coil on wet wood,
- (c) steel coil on dry rubber, and
- (d) steel coil on wet rubber.

The chains through the eye shall be:
- (a) straight through and
- (b) crossed.

Three preloads shall be examined:
- (a) low (5% of WLL),
- (b) medium (20% of WLL), and
- (c) high (50% of WLL).

Two chain tiedown systems shall be examined:
- (a) 4 x 1/4" chains and
- (b) 2 x 3/8" grade chains.

A 25,000 lb steel coil shall be tested with 10 cm x 10 cm bevelled wood blocks. Measurements shall be made of the applied force, chain tension, and coil displacement.

12.11.3/ Results

The results will provide the capacity of the entire load security system as tested.

12.11.4/ Test Matrix – Coil with Eye Longitudinal, in Cradle, Steep Angle Chains

Test No. 12.11-	Chains size and quantity	Preload L	Preload M	Preload H	Orientation Str.	Orientation Cross	Bed Interface	Block Interface
1(a)	4 x 1/4"	X			X		Dry wood	Dry wood
1(b)	4 x 1/4"	X			X		Dry wood	Wet wood
1(c)	4 x 1/4"	X			X		Dry wood	Dry rubber
1(d)	4 x 1/4"	X			X		Dry wood	Wet rubber

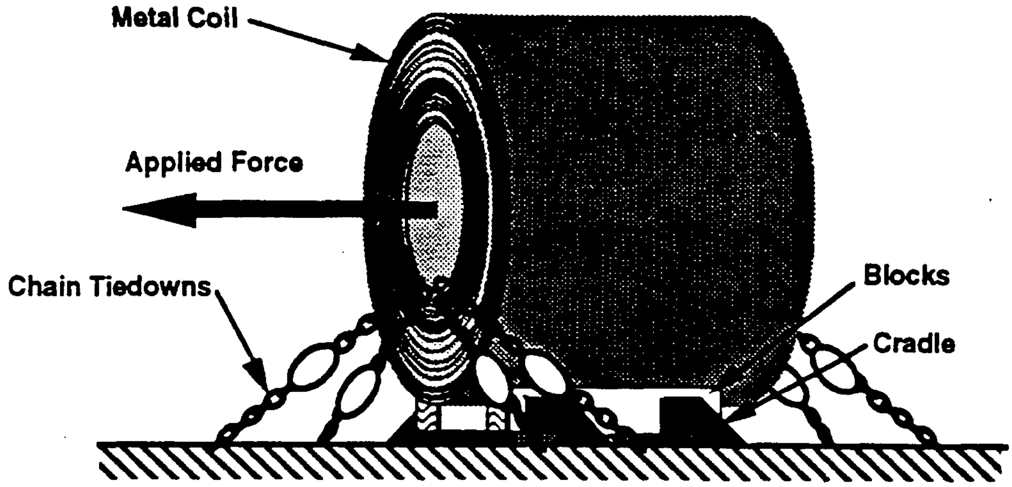


Figure 12.11/ Coil with Eye Longitudinal, in Cradle, Steep Angle Chains

12.11.4/ Test Matrix – Coil with Eye Longitudinal, in Cradle, Steep Angle Chains

Test No. 12.11-	Chains size and qty	Preload L	Preload M	Preload Hvy	Orientation Str.	Orientation Cross	Bed Interface	Blk Interface
2(a)	4 x 1/4"	X				X	Dry wood	Dry wood
2(b)	4 x 1/4"	X				X	Dry wood	Wet wood
2(c)	4 x 1/4"	X				X	Dry wood	Dry rubber
2(d)	4 x 1/4"	X				X	Dry wood	Wet rubber
3(a)	4 x 1/4"		X		X		Dry wood	Dry wood
3(b)	4 x 1/4"		X		X		Dry wood	Wet wood
3(c)	4 x 1/4"		X		X		Dry wood	Dry rubber
3(d)	4 x 1/4"		X		X		Dry wood	Wet rubber
4(a)	4 x 1/4"		X			X	Dry wood	Dry wood
4(b)	4 x 1/4"		X			X	Dry wood	Wet wood
4(c)	4 x 1/4"		X			X	Dry wood	Dry rubber
4(d)	4 x 1/4"		X			X	Dry wood	Wet rubber
5(a)	4 x 1/4"			X	X		Dry wood	Dry wood
5(b)	4 x 1/4"			X	X		Dry wood	Wet wood
5(c)	4 x 1/4"			X	X		Dry wood	Dry rubber
5(d)	4 x 1/4"			X	X		Dry wood	Wet rubber

12.11.4/ Test Matrix – Coil with Eye Longitudinal, in Cradle, Steep Angle Chains(cont'd)

Test No. 12.11-	Chains size and qty	Preload L	Preload M	Preload H	Orientation Str.	Orientation Cross	Bed Interface	Block Interface
6(a)	4 x 1/4"			X		X	Dry wood	Dry wood
6(b)	4 x 1/4"			X		X	Dry wood	Wet wood
6(c)	4 x 1/4"			X		X	Dry wood	Dry rubber
6(d)	4 x 1/4"			X		X	Dry wood	Wet rubber
7(a)	4 x 1/4"	X			X		Dry steel	Dry wood
7(b)	4 x 1/4"	X			X		Dry steel	Wet wood
7(c)	4 x 1/4"	X			X		Dry steel	Dry rubber
7(d)	4 x 1/4"	X			X		Dry steel	Wet rubber
8(a)	4 x 1/4"	X				X	Dry steel	Dry wood
8(b)	4 x 1/4"	X				X	Dry steel	Wet wood
8(c)	4 x 1/4"	X				X	Dry steel	Dry rubber
8(d)	4 x 1/4"	X				X	Dry steel	Wet rubber
9(a)	4 x 1/4"		X		X		Dry steel	Dry wood
9(b)	4 x 1/4"		X		X		Dry steel	Wet wood
9(c)	4 x 1/4"		X		X		Dry steel	Dry rubber
9(d)	4 x 1/4"		X		X		Dry steel	Wet rubber
10(a)	4 x 1/4"		X			X	Dry steel	Dry wood
10(b)	4 x 1/4"		X			X	Dry steel	Wet wood
10(c)	4 x 1/4"		X			X	Dry steel	Dry rubber
10(d)	4 x 1/4"		X			X	Dry steel	Wet rubber
11(a)	4 x 1/4"			X	X		Dry steel	Dry wood
11(b)	4 x 1/4"			X	X		Dry steel	Wet wood
11(c)	4 x 1/4"			X	X		Dry steel	Dry rubber
11(d)	4 x 1/4"			X	X		Dry steel	Wet rubber
12(a)	4 x 1/4"			X		X	Dry steel	Dry wood
12(b)	4 x 1/4"			X		X	Dry steel	Wet wood
12(c)	4 x 1/4"			X		X	Dry steel	Dry rubber
12(d)	4 x 1/4"			X		X	Dry steel	Wet rubber
13(a)	2 x 3/8"	X			X		Dry wood	Dry wood
13(b)	2 x 3/8"	X			X		Dry wood	Wet wood
13(c)	2 x 3/8"	X			X		Dry wood	Dry rubber
13(d)	2 x 3/8"	X			X		Dry wood	Wet rubber

12.11.4/ Test Matrix – Coil with Eye Longitudinal, in Cradle, Steep Angle Chains (cont'd)

Test No. 12.11-	Chains size and qty	Preload L	M	H	Orientation Str.	Cross	Bed Interface	Block Interface
14(a)	2 x 3/8"	X			X		Dry wood	Dry wood
14(b)	2 x 3/8"	X			X		Dry wood	Wet wood
14(c)	2 x 3/8"	X			X		Dry wood	Dry rubber
14(d)	2 x 3/8"	X			X		Dry wood	Wet rubber
15(a)	2 x 3/8"		X		X		Dry wood	Dry wood
15(b)	2 x 3/8"		X		X		Dry wood	Wet wood
15(c)	2 x 3/8"		X		X		Dry wood	Dry rubber
15(d)	2 x 3/8"		X		X		Dry wood	Wet rubber
16(a)	2 x 3/8"		X			X	Dry wood	Dry wood
16(b)	2 x 3/8"		X			X	Dry wood	Wet wood
16(c)	2 x 3/8"		X			X	Dry wood	Dry rubber
16(d)	2 x 3/8"		X			X	Dry wood	Wet rubber
17(a)	2 x 3/8"			X	X		Dry wood	Dry wood
17(b)	2 x 3/8"			X	X		Dry wood	Wet wood
17(c)	2 x 3/8"			X	X		Dry wood	Dry rubber
17(d)	2 x 3/8"			X	X		Dry wood	Wet rubber
18(a)	2 x 3/8"			X		X	Dry wood	Dry wood
18(b)	2 x 3/8"			X		X	Dry wood	Wet wood
18(c)	2 x 3/8"			X		X	Dry wood	Dry rubber
18(d)	2 x 3/8"			X		X	Dry wood	Wet rubber
19(a)	2 x 3/8"	X			X		Dry steel	Dry wood
19(b)	2 x 3/8"	X			X		Dry steel	Wet wood
19(c)	2 x 3/8"	X			X		Dry steel	Dry rubber
19(d)	2 x 3/8"	X			X		Dry steel	Wet rubber
20(a)	2 x 3/8"	X				X	Dry steel	Dry wood
20(b)	2 x 3/8"	X				X	Dry steel	Wet wood
20(c)	2 x 3/8"	X				X	Dry steel	Dry rubber
20(d)	2 x 3/8"	X				X	Dry steel	Wet rubber
21(a)	2 x 3/8"		X		X		Dry steel	Dry wood
21(b)	2 x 3/8"		X		X		Dry steel	Wet wood
21(c)	2 x 3/8"		X		X		Dry steel	Dry rubber
21(d)	2 x 3/8"		X		X		Dry steel	Wet rubber

12.11.4/ Test Matrix – Coil with Eye Longitudinal, in Cradle, Steep Angle Chains (cont'd)

Test No. 12.11-	Chains size and qty	Preload L	Preload M	Preload H	Orientation Str.	Orientation Cross	Bed Interface	Block Interface
22(a)	2 x 3/8"	X				X	Dry steel	Dry wood
22(b)	2 x 3/8"	X				X	Dry steel	Wet wood
22(c)	2 x 3/8"	X				X	Dry steel	Dry rubber
22(d)	2 x 3/8"	X				X	Dry steel	Wet rubber
23(a)	2 x 3/8"			X	X		Dry steel	Dry wood
23(b)	2 x 3/8"			X	X		Dry steel	Wet wood
23(c)	2 x 3/8"			X	X		Dry steel	Dry rubber
23(d)	2 x 3/8"			X	X		Dry steel	Wet rubber
24(a)	2 x 3/8"			X		X	Dry steel	Dry wood
24(b)	2 x 3/8"			X		X	Dry steel	Wet wood
24(c)	2 x 3/8"			X		X	Dry steel	Dry rubber
24(d)	2 x 3/8"			X		X	Dry steel	Wet rubber

12.12/ Coil with Eye Longitudinal, in Cradle, Shallow Angle Chains

12.12.1/ Purpose

This test examines the combination of cradle and chains as a securement system. The cradle is unsecured and the coil is secured by chains at a shallow angle.

12.12.2/ Method

The securement system shall be set up as shown in Figure 12.12. The cradle/bed conditions shall be:
- (a) wet wood,
- (b) dry wood,
- (c) wet rubber, and
- (d) oily rubber.

The chains used shall be 3/8" grade 70 and the in the eye shall be:
- (a) straight through and
- (b) crossed.

Three preload tensions on the chain shall be used:
- (a) low (5% of WLL),
- (b) medium (20% of WLL), and
- (c) high (50% of WLL).

The chain angles tested shall be:
- (a) 60°,
- (b) 45°, and
- (c) 85°.

The coil used for this test shall be a 17,000 lb steel coil, the blocking shall be 10 cm x 10 cm bevelled wood, and the chain shall be 3/8" grade 70. Measurements shall be made of the applied force, chain tension, and coil displacement.

12.12.3/ Results

The results will provide the capacity of the entire load security system for the combinations tested.

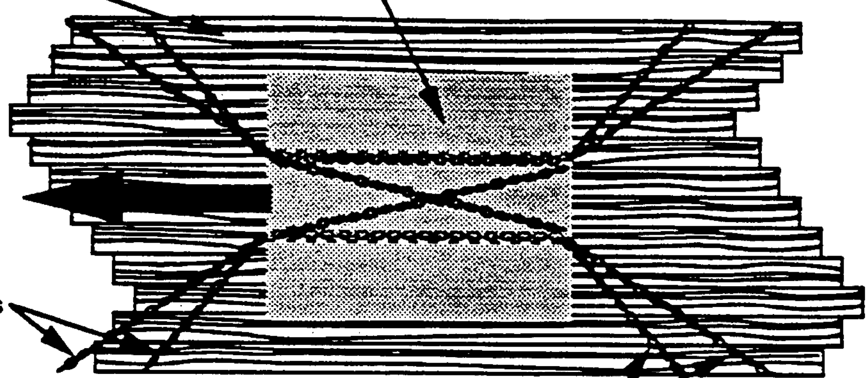


Figure 12.12/ Coil with Eye Longitudinal, in Cradle, Shallow Angle Chains

12.12.4/ Test Matrix – Coil with Eye Longitudinal, in Cradle, Shallow Angle Chains

Test No. 12.12-	Chain Tension L	M	H	Chain Orientation	Angle(°) Front	Rear	Interface
1(a)	X			Straight	45	45	Dry wood
1(b)	X			Straight	45	45	Wet wood
1(c)	X			Straight	45	45	Dry rubber
1(d)	X			Straight	45	45	Oily rubber
1(e)		X		Straight	45	45	Dry wood
1(f)		X		Straight	45	45	Wet wood
1(g)		X		Straight	45	45	Dry rubber
1(h)		X		Straight	45	45	Oily rubber
1(i)			X	Straight	45	45	Dry wood

12.12.4/ Test Matrix – Coil with Eye Longitudinal, in Cradle, Shallow Angle Chains (cont'd)

Test No. 12.12-	Chain Tension L	M	H	Chain Orientation	Angle(°) Front	Rear	Interface
1(j)			X	Straight	45	45	Wet wood
1(k)			X	Straight	45	45	Dry rubber
1(l)			X	Straight	45	45	Oily rubber
2(a)	X			Crossed	45	45	Dry wood
2(b)	X			Crossed	45	45	Wet wood
2(c)	X			Crossed	45	45	Dry rubber
2(d)	X			Crossed	45	45	Oily rubber
2(e)		X		Crossed	45	45	Dry wood
2(f)		X		Crossed	45	45	Wet wood
2(g)		X		Crossed	45	45	Dry rubber
2(h)		X		Crossed	45	45	Oily rubber
2(i)			X	Crossed	45	45	Dry wood
2(j)			X	Crossed	45	45	Wet wood
2(k)			X	Crossed	45	45	Dry rubber
2(l)			X	Crossed	45	45	Oily rubber
3(a)	X			Straight	60	60	Dry wood
3(b)	X			Straight	60	60	Wet wood
3(c)	X			Straight	60	60	Dry rubber
3(d)	X			Straight	60	60	Oily rubber
3(e)		X		Straight	60	60	Dry wood
3(f)		X		Straight	60	60	Wet wood
3(g)		X		Straight	60	60	Dry rubber
3(h)		X		Straight	60	60	Oily rubber
3(i)			X	Straight	60	60	Dry wood
3(j)			X	Straight	60	60	Wet wood
3(k)			X	Straight	60	60	Dry rubber
3(l)			X	Straight	60	60	Oily rubber

12.12.4/ Test Matrix – Coil with Eye Longitudinal, in Cradle, Shallow Angle Chains (cont'd)

Test No. 12.12-	Chain Tension L	M	H	Chain Orientation	Angle(°) Front	Rear	Interface
4(a)	X			Crossed	60	60	Dry wood
4(b)	X			Crossed	60	60	Wet wood
4(c)	X			Crossed	60	60	Dry rubber
4(d)	X			Crossed	60	60	Oily rubber
4(e)		X		Crossed	60	60	Dry wood
4(f)		X		Crossed	60	60	Wet wood
4(g)		X		Crossed	60	60	Dry rubber
4(h)		X		Crossed	60	60	Oily rubber
4(i)			X	Crossed	60	60	Dry wood
4(j)			X	Crossed	60	60	Wet wood
4(k)			X	Crossed	60	60	Dry rubber
4(l)			X	Crossed	60	60	Oily rubber
5(a)	X			Straight	85	45	Dry wood
5(b)	X			Straight	85	45	Wet wood
5(c)	X			Straight	85	45	Dry rubber
5(d)	X			Straight	85	45	Oily rubber
5(e)		X		Straight	85	45	Dry wood
5(f)		X		Straight	85	45	Wet wood
5(g)		X		Straight	85	45	Dry rubber
5(h)		X		Straight	85	45	Oily rubber
5(i)			X	Straight	85	45	Dry wood
5(j)			X	Straight	85	45	Wet wood
5(k)			X	Straight	85	45	Dry rubber
5(l)				Straight	85	45	Oily rubber

12.13/ Coil with Overwrap Chains and Webbing, Combination Block and Chains

12.13.1/ Purpose

This test measures the restraint provided by chains or webbing that overwraps a coil mounted on secured blocks.

12.13.2/ Method

The coil shall be secured as shown in Figure 12.13. The tiedowns used shall be:
- (a) 3/8" grade 70 chain and
- (b) 2" nylon webbing.

The tiedowns shall be preloaded to:
- (a) low (5% of WLL),
- (b) medium (20% of WLL), and
- (c) heavy (50% of WLL).

The test shall be conducted to pull the coil laterally and longitudinally until relative motion occurs between the coil and bed, i.e.:
- (a) eye lateral and
- (b) eye longitudinal.

The tension in the chains and the displacement of the coil shall be measured. A 17,000 lb steel coil and 10 cm x 10 cm bevelled blocks shall be used for this test.

12.13.3/ Results

The results will assess the capacity of this load security system.

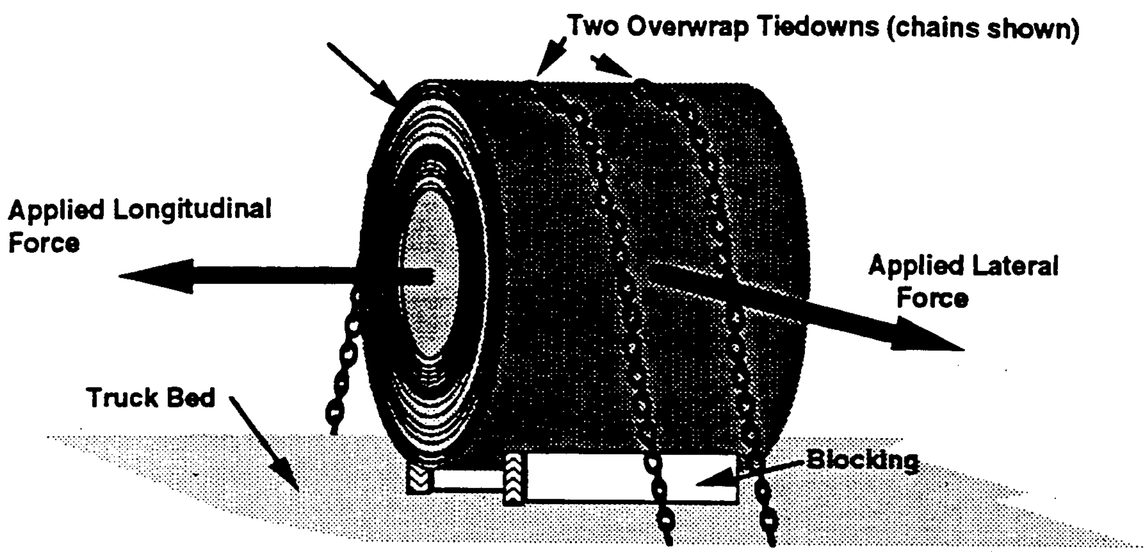


Figure 12.13/ Coil with Overwrap Chains and Webbing, Combination Block and Chains

12.13.4/ Test Matrix – Coil with Overwrap Chains and Webbing, Combination Block and Chains

Test No. 12.13-	Tiedown		Preload			Pull Direction	
	Chain	Webbing	L	M	H	Lat.	Long.
1(a)	X		X			X	
1(b)	X		X				X
1(c)	X			X		X	
1(d)	X			X			X
1(e)	X				X	X	
1(f)	X				X		X
2(a)		X	X			X	
2(b)		X	X				X
2(c)		X		X		X	
2(d)		X		X			X
2(e)		X			X	X	
2(f)		X			X		X

12.14/ Coil with Overwrap Chains and Two-Way Blocking

12.14.1/ Purpose

This test measures the restraint provided chains that overwrap a coil that is also contained by blocking both laterally and longitudinally.

12.14.2/ Method

The coil shall be secured with a single 3/8 in chain on 10 cm x 10 cm bevelled blocking, with secured lateral blocking, as shown in Figure 12.14. The test shall be conducted to pull the coil laterally and longitudinally until relative motion occurs between the coil and bed, and the tension in the chains and the displacement of the coil shall be measured. The chain shall be tightened to three pretensions:

(a) low (5% of WLL),
(b) medium (20% of WLL), and
(c) high (50% of WLL).

The test shall be conducted to pull the coil laterally and longitudinally until relative motion occurs between the coil and bed, i.e.:

(a) eye lateral and
(b) eye longitudinal.

The test shall be done with a 17,000 lb steel coil. The tension in the chains and the displacement of the coil shall be measured.

12.14.3/ Results

The results will assess the capacity of this load security system.

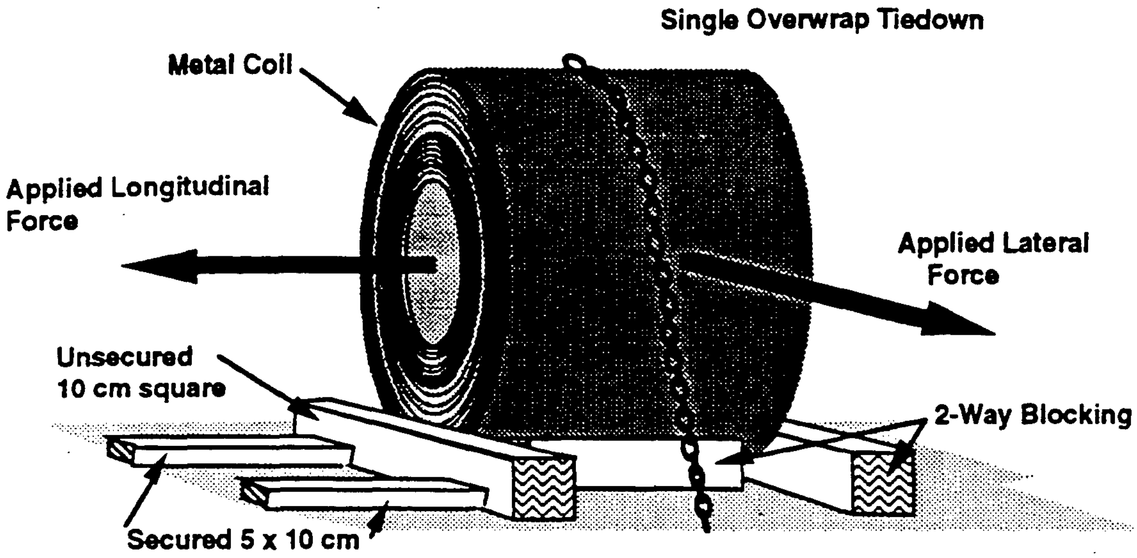


Figure 12.14/ Coil with Overwrap Chains and Two-Way Blocking

12.14.4/ Test Matrix – Coil with Overwrap Chains and Two-Way Blocking

Test No. 12.14-	Chain Preload			Pull Direction	
	L	M	H	Lat.	Long.
1(a)	X			X	
1(a)	X				X
2(a)		X		X	
2(b)		X			X
3(a)			X	X	
3(b)			X		X

13/ OTHER COMMODITIES

13.1/ Issues

The size, shape, weight, stackability, and packability of the myriad of commodities that are shipped by truck, each provide their own particular problems for load security with tiedowns. This series of tests examines the ability of tiedowns to restrain a number of types of commodity that are recognized to have particular problems. It addresses the following specific commodities:

1/ Palletized Loads
2/ Heavy Steel Plate
3/ Large Boulders
4/ Coiled Wire
5/ One-Foot Diameter Pipe
6/ ISO Modular Containers

13.2/ Palletized Loads

13.2.1/ Purpose

The purpose of this test is to ascertain the ability of the tiedown system to contain the material on the pallet, and the pallet on the truck bed, under various loading conditions.

13.2.2/ Method

The palletized product shall be secured to the truck bed in the manner recommended by regulation, or common practice. Typical tiedown corners shall be used where the tiedown contacts the cargo, and there shall be no side or end face protection on the cargo. The tiedowns shall be tightened to a moderate preload, 20% of WLL. The tiedowns shall be instrumented and the tiedown tension and load displacement shall be measured. The specific case of an aluminum coil on a skid is shown in Figure 13.2, a 20,000 lb aluminum coil shall be used. The truck shall be tilted both laterally and longitudinally, until either the load moves or the tilt table reaches its maximum angle. The commodities and tiedowns used are as follows:

Commodity	Tiedown
(a) Bricks	Webbing
(b) Concrete Block	Webbing
(c) Masonry Stone	Webbing
(d) Bagged Cement	Webbing
(e) Sod	(a) No tiedown
	(b) Webbing
	(c) Net
(f) Banded Aluminum Coil	(a) X band – skid blocked
	(b) XX Webbing Tiedown (Figure 13.2(a))
	(c) Offset webbing tiedown (Figure 13.2(b))
	(d) Chain cross wrap (Figure 13.2(c))

13.2.3/ Results

This test will show the effectiveness of tiedowns for each of the commodities tested.

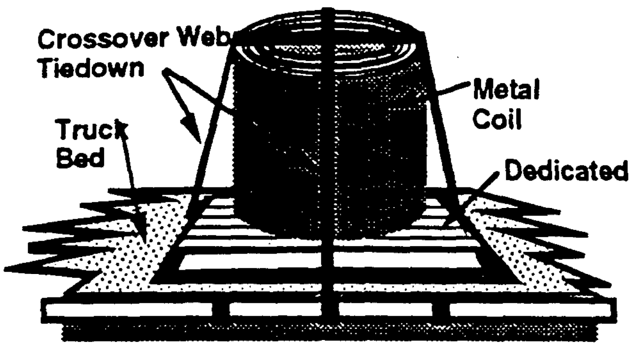
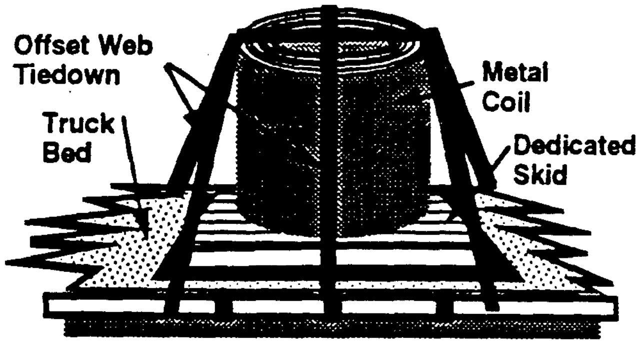
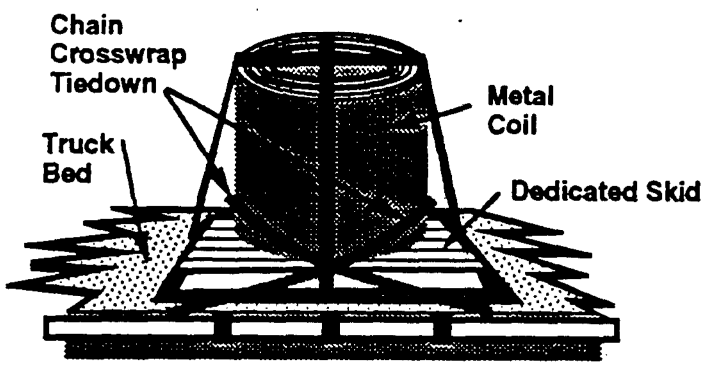


Figure 13.2(a)/ Crossover Web Tiedown



13.2(b)/ Offset Web Tiedown



13.2(c)/ Chain Crosswrap Tiedown

Figure 13.2/ Palletized Loads

13.2.4/ Test Matrix – Palletized Loads

Test No. 13.2-	Commodity	Tiedown	Tiedown Orientation
1	Bricks	2" webbing	Overtop
2	Concrete Block	2" webbing	Overtop
3	Masonry Stone	2" webbing	Overtop
4	Bagged Cement	2" webbing	Overtop
5(a)	Sod	no tiedown	
5(b)	Sod	2" webbing	Overtop
5(c)	Sod	Net	Overtop
6(a)	Banded Coil	Skid blocked	Truck deck
6(b)	Banded Coil	X webbing	Overtop
6(c)	Banded Coil	Interlock web	Overtop
6(d)	Banded Coil	Chain loop	Front/top

13.3/ Heavy Steel Plate

13.3.1/ Purpose

The purpose of this test is to determine the effectiveness of overwrapped tiedowns on various width heavy steel plates under various loading conditions.

13.3.2/ Method

Three different widths of 1-1/4 in thick steel plate shall be tested as shown in Figure 13.3. Each plate shall be secured with moderate preload, 20% WLL using:

(a) 1/4" steel chain

(b) 2" nylon webbing

and then pulled laterally and longitudinally. The forces in the tiedowns and displacements of the steel plates shall be measured. The tiedown shall contact the plate on the sharpest kerf (burred or cut edge upward).

13.3.3/ Results

This test will demonstrate the effectiveness of chain and nylon webbing tiedowns on various widths of steel plate.

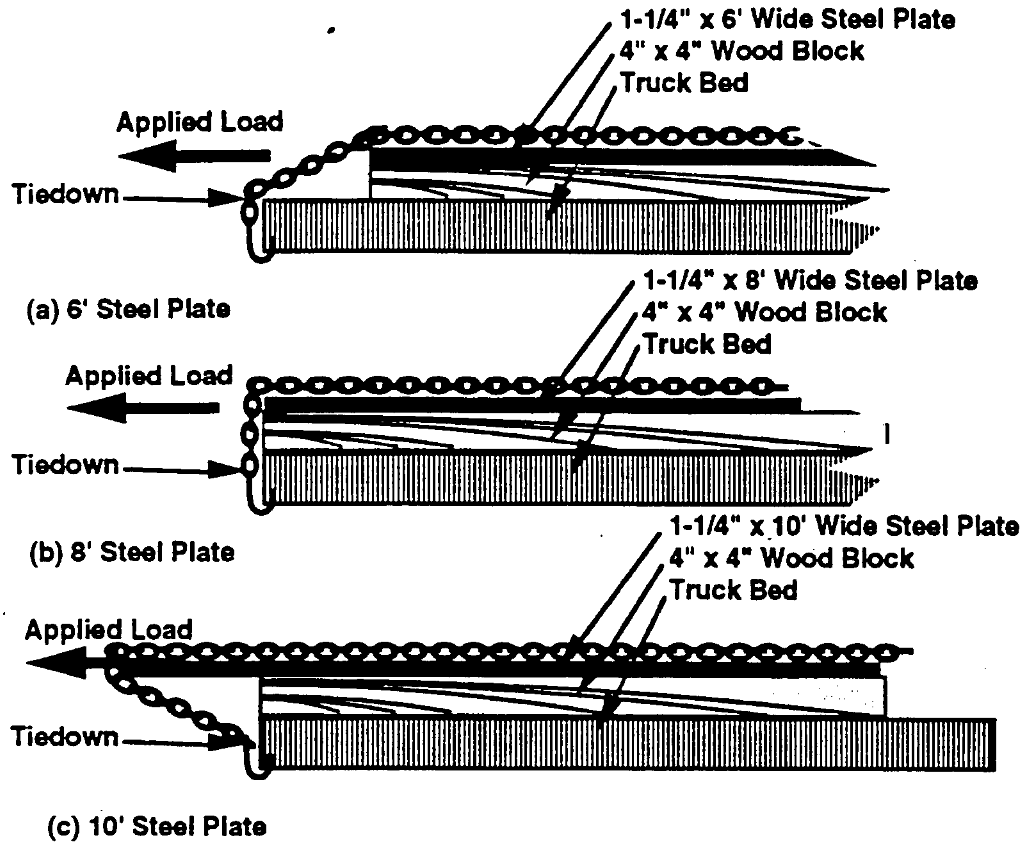


Figure 13.3/ Heavy Steel Plate

13.3.4/ Test Matrix - Heavy Steel Plate

Test No. 13.2-	Tiedown		Plate Width			Pull Direction	
	Chain	Web	6'	8'	10'	Lat.	Long.
1(a)	X		X			X	
1(b)	X		X				X
2(a)	X			X		X	
2(b)	X			X			X
3(a)	X				X	X	
3(b)	X				X		X
4(a)		X	X			X	
4(b)		X	X				X
5(a)		X		X		X	
5(b)		X		X			X
6(a)		X			X	X	
6(b)		X			X		X

13.4/ Large Boulders

13.4.1/ Purpose

The purpose of this test is to determine the effectiveness of three tiedown methods for restraining the movement of a boulder in the longitudinal direction.

13.4.2/ Method

A boulder shall be secured on a flatdeck trailer and tested using three different tiedown methods:

(a) single overwrapped chain,
(b) not yet determined, and
(c) not yet determined.

The tiedowns shall be loaded to a high pretension load, 50% WLL. The general layout of method (a) is shown in Figure 13.4. The boulder shall be pulled in an effort to slip it out from under the tiedown. The force applied and the displacement of the boulder shall be measured. The test shall be repeated without the restraint. Three different shaped boulders, one near spherical, another near cubic, and the other irregular, shall be tested.

13.4.3/ Results

This test will determine the effectiveness of these tiedowns on boulders.

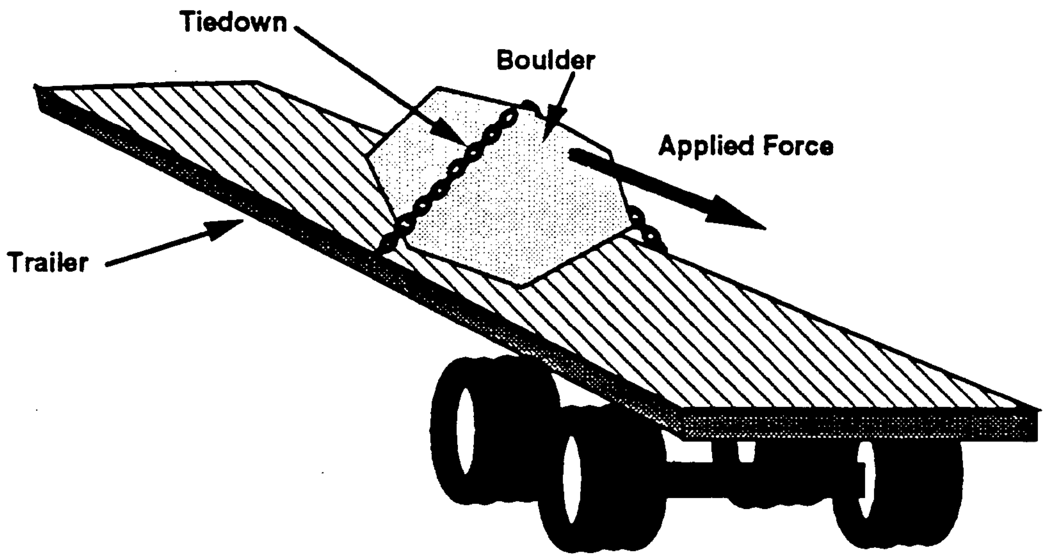


Figure 13.4/ Large Boulders

13.4.4/ Test Matrix – Large Boulders

Test No. 13.4-	Tiedown Method				Boulder Shape		
	(a)	(b)	(c)	None	Round	Cubic	Irregular
1(a)				X		X	
1(b)	X				X		
1(c)		X			X		
1(d)			X		X		
2(a)				X		X	
2(b)	X					X	
2(c)		X				X	
2(d)			X			X	
3(a)				X			X
3(b)	X						X
3(c)		X					X
3(d)			X				X

13.5/ Coiled Wire/Steel Rods

13.5.1/ Purpose

The purpose of this test is to determine the effectiveness of five tiedown methods/loading situations, for restraining the movement of steel rods and steel wire in coils.

13.5.2/ Method

The loads shall be tied down in each of the methods selected:

(a) method a,
(b) method b,
(c) method c,
(d) method d, and
(e) method e.

The tiedowns shall be secured to moderate tension (20% WLL) and the vehicle tilted laterally. The tiedowns shall be re-evaluated for tension. A similar test shall be done in the longitudinal direction.

13.5.3/ Results

This test will determine the effectiveness of the tiedown methods tested.

13.5.4/ Test Matrix – Coiled Wire/Steel Rods

Test No. 13.5-	Tiedown/Load Method					Tilt	
	(a)	(b)	(c)	(d)	(e)	Lat.	Long.
1(a)	X					X	
1(b)	X						X
2(a)		X				X	
2(b)		X					X
3(a)			X			X	
3(b)			X				X
4(a)				X		X	
4(b)				X			X
5(a)					X	X	
5(b)					X		X

13.6/ One-Foot Diameter Pipe

13.6.1/ Purpose

The purpose of this test is to determine the load retention characteristics of tiedowns securing one-foot diameter pipe.

13.6.2/ Method

Thirty pieces of 0.3 m (1 ft) diameter pipe, 3 m (10 ft) long shall be loaded as shown in Figure 13:

(a) nested and
(b) stacked with spacers.

The pipe shall be secured with:

(a) two 2" nylon web tiedowns and
(b) three 2" nylon web tiedowns.

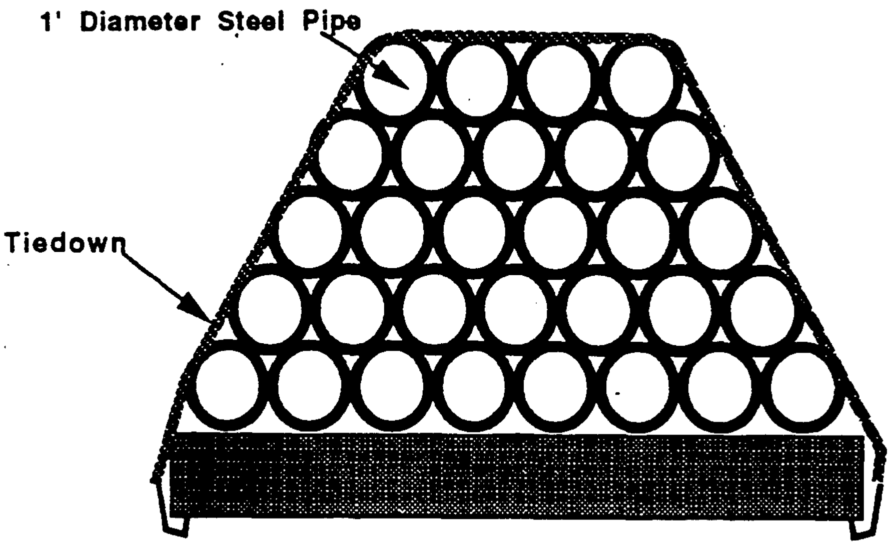
at moderate tension, 20% WLL. The vehicle shall be tilted both laterally and longitudinally. The tension in the webbing shall be monitored, together with any movement of any pipe. After the test, the cargo shall be reloaded, pretensioned, and driven over rough road to allow the cargo to settle. The vehicle shall then be tilted again in both directions.

13.6.3/ Results

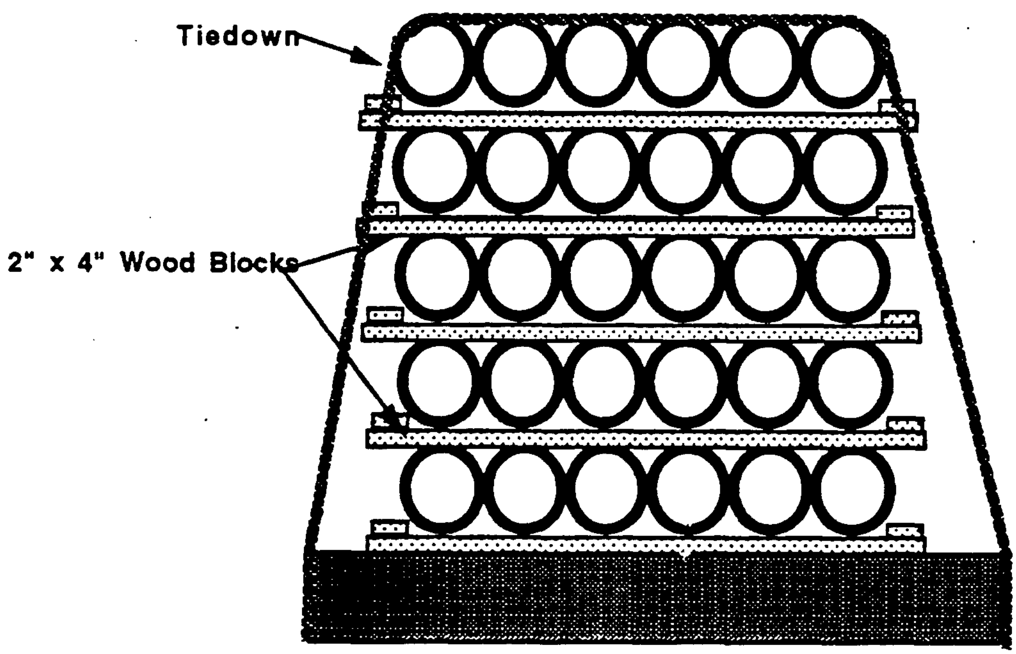
This test shall determine the effectiveness of the tiedown method on the two load configurations and the effect of a third tiedown on load security.

13.6.4/ Test Matrix – One-Foot Diameter Pipe

Test No. 13.6-	Load Arrangement Nested	Load Arrangement Stacked	No. of Tiedowns	Tilt 1 Lat.	Tilt 1 Long.	Tilt 2 Lat.	Tilt 2 Long.
1(a)	X		2	X			
1(b)	X		2		X		
1(c)	X		2			X	
1(d)	X		2				X
2(a)	X		3	X			
2(b)	X		3		X		
2(c)	X		3			X	
2(d)	X		3				X
3(a)		X	2	X			
3(b)		X	2		X		
3(c)		X	2			X	
3(d)		X	2				X
4(a)		X	3	X			
4(b)		X	3		X		
4(c)		X	3			X	
4(d)		X	3				X



(a) Nested Configuration



(b) Stacked Configuration

Figure 13.6/ One-Foot Diameter Pipe

13.7/ ISO Modular Container

13.7.1/ Purpose

This test shall determine the effectiveness of overwrapped tiedowns in securing a 20 ft ISO modular container.

13.7.2/ Method

An ISO modular container loaded to its maximum load shall be secured to a wooden truck bed with nylon webbing. The bed condition shall be:

(a) dry and
(b) wet.

The tiedowns shall be tensioned to:

(a) low (5% WWL),
(b) moderate (20% WWL), and
(c) high (50% WWL).

The trailer shall be tilted:

(a) laterally and
(b) longitudinally

up to the tilt table maximum or slippage occurs. The tiedowns shall be instrumented to measure tension.

13.7.3/ Results

This test shall determine the effect of tiedown tension on containment of the cargo and the effect of truck bed condition on the security of the load.

13.7.4/ Test Matrix – ISO Modular Container

Test No. 13.7-	Bed Condition		Pretension			Tilt Direction	
	Dry	Wet	L	M	H	Lat.	Long.
1(a)	X		X			X	
1(b)	X		X				X
2(a)	X			X		X	
2(b)	X			X			X
3(a)	X				X	X	
3(b)	X				X		X
4(a)		X	X			X	
4(b)		X	X				X
5(a)		X		X		X	
5(b)		X		X			X
6(a)		X			X	X	
6(b)		X			X		X

14/ DEVELOPMENT OF REGULATORY PRINCIPLES

Research is necessarily technical, and it is not always possible to address the range of topics of interest to the client in a direct manner. A technical research report therefore may not necessarily be of direct benefit to a client with a plain language question when the results may require some, often considerable, interpretation and judgement if they are to be useful for regulatory or operational purposes. While the work proposed here must be reported in technical terms, it is necessary to go further than that and provide the necessary interpretations so that, in this case, the results do help address the regulatory needs.

It is therefore proposed to take the findings of the research, which represent the principles of mechanics, discuss and analyze them in the context of current industry practice in load security, and propose a set of principles that might serve as a technical basis for a national standard on load security. This step is intended to provide, in plain language, those charged with regulatory development with the essentials necessary to draft a standard. The discussion is likely to be quite lengthy, as there are a considerable number of closely-related policy issues. It will also involve some analysis, and possibly some computer simulation, to generalize results from the specific conditions of tests conducted during the work. It is expected that the discussion will identify a number of areas where choices are available in approach, format, or other aspects of a standard. It is intended that these will be clearly identified and discussed, so that the consequences of choices are clear for subsequent development of a standard. It is also expected that certain elements of the work will identify practices, procedures, or methods that may have considerable merit, or are without merit and should be discouraged.

The regulatory principles will not be a finished standard, for two reasons. First, not all aspects of the standard are covered by this research, so regulatory principles for the part that has been researched will need to be blended with the rest of the standard and other current practice. Second, it is often considered necessary to simplify or adapt purely technical recommendations to the level and practices of both industry and enforcement staff.

15/ DELIVERABLES

The Ministry of Transportation of Ontario will publish, and keep in print, a detailed technical report that summarizes the results of the work. It will basically follow the structure and format of this proposal, and a suggested table of contents is presented. This report will describe the methods used, and present the findings, for all tests in each area of investigation. It will then take these findings, and will discuss and analyze them in the context of current industry practice in load security, to propose a set of regulatory principles that might serve as the basis for a national standard on load security. This step is intended to provide, in plain language, those charged with regulatory development with the essentials necessary to draft a standard. Clear recommendations will therefore be made, with respect to aspects of a standard, and areas for further work.

All tests are documented on video as a matter of procedure. The work will also be summarized in a comprehensive video, with script and music, that will illustrate the principal findings and conclusions from actual tests or demonstrations. It will also create a stock of material that would be available for a training video on the final standard.

PROPOSED TABLE OF CONTENTS FOR FINAL REPORT

ABSTRACT

EXECUTIVE SUMMARY

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7/ FRICTION

8/ DRESSED LUMBER

9/ METAL COILS

10/ OTHER COMMODITIES

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12/ CONCLUSIONS

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