SM. INDEPENDENT MARINE SURVEYORS L.L.C. EST.1990

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ISO Dry shipping Container Floor/Under-Carriage Failure

Lately there has been an overwhelming number of off-hire containers with undercarriage failure. Through the termination process Lessors have translated to the repair facilities, via IICL guidelines, the cost of repairs be allocated to the Lessee account as “overload damage”.

Most noticeable issue is a pattern of compression lengthwise along the container floor in a typical fork lift path, accompanied by, failure of ply panels between crossmembers with or without finger cracking at the underside of the ply.
Resulting in crossmembers bowed down with various forklift track patterns and chassis rail to crossmember flange deflections.

The visual conditions noted above can be explained with minimal research, a bit of mechanical and structural knowledge and some reverse engineering.
*IICL: A floor and or undercarriage failure is considered **acceptable by IICL** providing it does not exceed 15 mm. (IICL, container equip- inspections TBL 5.6, page 30 and 5.7, page 31 attached. IICL gray manual, 2nd edition. Page 8-9 attached).*
*However, as the downward trajectory (failure), by virtue of use continues on its inevitable course and exceeds 15 mm breaching the ISO envelope making contact with chassis main rails, it is considered overload damage and deemed **damage at Lessee’s expense**.*

It is my contention that IICL’s determination of damage is solely predicated on face value. No consideration of “new growth” substrates has been factored in or even considered.

Based on my years of experience, having inspected thousands of containers this issue as a pattern presented early on and was obvious. Most if not all under-carriage failures we see today start with typical (**new growth)** Ply floor failure as seen in thousands of containers in-service manufactured from 1990+ onward.

The following is based on my 48 years of corporate and field experience in the container industry which includes; Leasing company operations, equipment control and maintenance as well as repair facility management. Concluding with 36 years owning and operating Independent Marine Surveyors LLC.

To better understand how this series of events culminates into floor failure or complete undercarriage failure, a few key components and their functions need to be clarified:
The undercarriage of a shipping container is a "**composite structure**" which is an engineered assembly combining two or more distinct, separate materials. In this case, 21 ply Marine grade plywood and supporting steal crossmembers which produces a stronger more durable structure with superior properties. Both components bound together provide enhanced strength and weight distribution that neither material could achieve alone. The failure of either of these components compromises the other and devaluates the value of the "**composite structure**".
Additionally, dishing or sagging of plywood floor panels between crossmembers (rolling shear) "**regardless of how minimal**", is a failure of the plywood structure leaving the crossmembers vulnerable and the value of the **composite structure compromised**.

Container Floor board History:

This history is important as it lays out the original floor products used and the lack of issues we experienced.

Dry containers built **prior** to 1980, in part used:

- *6"x1-1/8 Oak or Apitong solid floorboards or,*
- *12"x 1-1/8" laminated oak planks or,*
- *Segmented floor designs incorporating narrow sheets of 1-1/8" 21 ply Marine grade plywood. As well as 48x92 ¾" 21 ply Marine grade plywood.*

All the above species were of "**Old slow growth lumber"**.

Open top containers during this time used 12”x 1-1/8” laminated Oak boards which delaminated due to excessive exposure to environmental conditions.

Pre-1970 manufacturing; Floor failure and undercarriage failure due to substrate failure on cargo containers was unheard of. Undercarriage failures were directly linked to and identified as a result of; inadequate Z-type and C-type crossmembers or, an obscure improper repair.

Post 1970-1980; 21 ply Marine grade plywood started being used more often than other applications e.g., plank flooring as described above. The 21 ply panels used were a different breed, (**OLD slow growth**).
Outside of upper ply delamination and finger cracking from **“Point load impact”.** There were few “**rolling shear**” issues and complete undercarriage **was virtually unheard of.**

Aft 1980-1990 Dry containers and Open top containers incorporated the use of 1-1/8” 21 ply, Marine grade plywood almost exclusively in place of Apitong, Oak and Laminated Oak floor planks. These panels were comprised of the remains of (**OLD slow growth**) lumber which was still in the system. Again, load contributing ply floor and undercarriage failures were rare.
The decision to move toward 21 ply MG plywood was based on favorable weight and cost considerations.

1990-2000 manufactured; Floor failure (rolling shear) undercarriage failure and ply cracking were increasing as we haven’t seen before due to **new growth sustainable lumber**.

In come the 2000s: In regards to 21 ply flooring, there was a drastic noticeable change in product consistency and reliability. Most all dry cargo containers and Open tops used some form of 1-1/8” 19 or 21 (**new growth**) Plywood and or Bamboo combination flooring.
The first and most noticeable issue was the dishing or sagging (rolling shear) of ply panels between crossmembers (supported @ 11 ¾ centers). And finger cracking to underside ply, void of impact.
As well as, top ply delamination consisting of different markers then seen in previous delamination.

2000-2015 manufactured; Floor failure, ply cracking and undercarriage failure **with exception to traditional delamination** are extremely common in one form or another or in combination. **The markers of delamination as we knew them have changed**. Prior to 2000+/- whole laminates would separate and can be pulled up in sheets as **adhesive bond failed**. With the implementation of new adhesion products, ply layers did not separate as consistently due to adhesive

failure. Rather, **the new growth weaker ply fibers failed. The adhesive did not break down as seen in old growth panels. Instead, the new growth panel fibers broke loose under stress**. **The markers are visibly different.**

Differences at a Glance

Feature	Pre-2000s (Common)	Post-2000s (Standard)
Glue Type	Mixed or lower-grade resins	**Phenolic WBP** (Water & Boil Proof)
Veneer Quality	More internal voids/knots	**Void-free** hardwood cores
Chemical Treatment	Basic fungicides	Heavy impregnation for AQIS compliance

Source of the Statistics

The "Differences at a Glance" table originates from **technical product specifications** or **industry guides** provided by specialized timber importers and marine plywood manufacturers (such as those in Australia, hence the **AQIS nce** reference).

In regards to undercarriage failure as a result of inadequate substrate (**new growth lumber**) the steps are as follows:

1. 21 Ply flooring failure during loading due to inadequate structural composition of substrate.
2. Understructure (crossmembers) structural value compromised by failed key component (structural ply substrate).
3. Undercarriage (crossmembers) failure due to structurally compromised substrate.

There is significant reference material, including industry articles, government documents, and studies, that discusses the shift from old-growth to fast-growth wood sources and the resulting difference in wood and plywood properties, particularly starting around the **1980s and early 1990s**.

Research and Reference Material:

Widely circulated opinion or general understanding within construction and building fields are:
Plywood panels from the 1980s are considered stronger due to the **higher quality of the source lumber** used at the time, which primarily came from slow-growing, dense **old-growth forests**. Modern lumber, used for today's plywood, generally comes from fast-growing, sustainably farmed trees that produce a less dense wood.

While there is no single standardized "density multiplier" for marine-grade plywood across decades, modern new-growth wood is typically **15% to 30% less dense** than pre-1980s old-growth wood. *To match the performance of a vintage 21-ply old-growth sheet, a modern equivalent would need a significant increase in both raw density and structural reinforcement to compensate for wider growth rings and higher sapwood content.*

Density and Structural Differences

Old-growth wood, harvested from trees that grew slowly in competitive environments, naturally possesses tighter growth rings and a higher proportion of latewood (the denser, stronger part of the wood).

- **Ring Density**: Pre-1980s old-growth wood samples often show roughly **60 growth rings** per inch, whereas modern plantation-grown (new-growth) wood often has as few as **14 to 16 rings** in the same space.
- **Mass Comparison**: Modern marine-grade plywood typically ranges between **430 kg/m³ and 750 kg/m³**. According to some experts, old-growth wood is so much denser and stronger that **the difference has been compared to the gap between "paper and marble".**

Key Reference Material Types

- **Industry and Trade Articles**: Many articles from lumber and construction industry sources (like The Craftsman Blog, Russell Rowland, Inc., and Sherwood Lumber) highlight the differences in wood quality, often providing visual comparisons of growth rings and discussing practical implications for building and restoration. These sources date the shift to the near-depletion of old-growth timber in the 1980s.
- **Government/Research Documents**: The U.S. Department of Agriculture (USDA) Forest Products Laboratory has produced technical papers and reports that scientifically analyze the properties of different wood types.
    - A 1985 document titled **Weak Wood Fast-grown Trees make Problem Lumber** specifically addresses concerns that rapid growth in softwoods leads to more juvenile wood and lower density, impacting strength and quality. This document discusses forest management implications for strength requirements.
    - Other USDA documents, such as the **Mechanical Properties of Wood** chapter from the Forest Products Laboratory, provide detailed, average mechanical properties of various species based on extensive testing, which forms the basis for building codes and engineering standards.
- **Academic Studies & Conference Papers**: Research papers, often found on platforms like ResearchGate, analyze specific performance characteristics of plywood made from various species or with different manufacturing techniques. For example, some studies discuss the "deflection characteristics of plywood" and how different veneer compositions (which vary by wood source) affect mechanical properties.
- **Product Standards**: U.S. building codes require structural panels to comply with Voluntary (**Product Standards) PS 1** (Structural Plywood) and **PS 2** (Performance Standard for Wood-Based Structural-Use Panels), developed under the Department of Commerce. These standards ensure a minimum level of structural performance, which means that while the raw material has changed, modern engineered designs account for the

different properties of new-growth wood by **requiring larger sizes or specific engineering**.

Summary of Noted Differences

The consensus across these materials is that pre-1990s old-growth wood is typically denser and stronger due to its slow growth rate and higher heartwood content, while modern fast-growth wood (used in post-1990s plywood) is less dense, contains more sapwood/juvenile wood, and is comparatively softer. This is primarily due to:

- **Density and Growth Rings**: Older trees that grow slowly in natural forests develop tighter growth rings, resulting in denser, more stable, and stronger wood. Fast-grown plantation wood has fewer growth rings per inch.
- **Heartwood vs. Sapwood**: Old-growth lumber has a higher proportion of durable, rot-resistant heartwood. New-growth wood is largely sapwood, which is softer and more susceptible to rot and termites.
- **Structural Properties**:
- The density difference directly affects mechanical properties, such as compressive strength and stiffness. **This necessitates larger dimensions or different engineered solutions today to achieve the same structural performance as older materials.** The American

Lumber Standard Committee and related bodies periodically update official design values (strength ratings) to reflect these changes in the available timber supply.

Question: **what would be the density difference in new growth 21 marine grade plywood compared to pre 1980 old growth 21 ply plywood to achieve the same structural performance**?

Answer: **To achieve the same structural performance as pre-1980 old growth 21-ply plywood, new growth 21-ply marine grade plywood would need to be significantly denser, or a larger dimension (thicker or wider pieces would be needed if using solid lumber) to compensate for the difference in wood quality.**

Density Differences

The primary reason for the difference is the growth rate of the trees.

- **Old Growth Wood** (pre-1980): Characterized by slow, natural growth in dense forests, resulting in very tight growth rings and a higher proportion of dense latewood and rot-resistant heartwood. This makes the wood naturally harder, denser, and stronger.
- **New Growth Wood** (modern, plantation-farmed): Grown rapidly for quick production, leading to fewer growth rings per inch, lower density, more sapwood (which is softer and weaker), and less natural resistance to rot and insects.

The exact density difference in a 21-ply plywood is highly dependent on the specific species used for both the core and face veneers. However, generally:

- **Modern marine plywood** (e.g., Okoume) often has a density in the range of 450 to 500 kg/m³. Other hardwood marine options (e.g., Meranti, Birch) can range from 600 kg/m³ to over 750 kg/m³.
- **Old growth wood** of the same species would typically have a density in the upper end or exceeding the range for modern lumber due to its tighter grain structure.

Achieving Same Structural Performance

Because modern new-growth wood is inherently less dense and weaker pound-for-pound than old-growth wood, achieving the same performance in new plywood requires design and material compensation.

- **Material Selection:** Using a naturally denser species (like high-quality birch or meranti instead of lightweight Okoume) can help bridge the gap in density and strength.
- **Engineering/Design:** If the species cannot match the density of the original material, the engineered product must compensate. This might involve using more plies (though both are 21-ply), ensuring void-free construction (a requirement for quality marine ply, but especially critical now), or potentially increasing the overall thickness of the panel to meet specific load requirements.

In practice, the modern equivalent of an old-growth panel will likely be slightly heavier (if using a denser modern species) or a thicker panel would be specified to meet the same engineering strength and stiffness ratings.

Key Takeaway:

*Modern new-growth wood is typically **15% to 30% less dense** than pre-1980s old-growth wood. To match the performance of a vintage 21-ply old-growth sheet, a modern equivalent would need a significant increase in both raw density and structural reinforcement to compensate for wider growth rings and higher sapwood content.*

(no additional structural compensation has been affected to ply substrates since the curve)

***Mass Comparison**: Modern marine-grade plywood typically ranges between **430 kg/m³ and 750 kg/m³**. According to some experts, old-growth wood is so much*

denser and stronger that ***the difference has been compared to the gap between "paper and marble".***

Performance Standard for Wood-Based Structural-Use Panels), developed under the Department of Commerce. These standards ensure a minimum level of structural performance, which means that while the raw material has changed, modern engineered designs account for the different properties of new-growth wood by ***requiring larger sizes or specific engineering****.*

Structural Properties*: The density difference directly affects mechanical properties, such as compressive strength and stiffness.* ***This necessitates larger dimensions or different engineered solutions today to achieve the same structural performance as older materials.*** *The American Lumber Standard Committee and related bodies periodically update official design values (strength ratings) to reflect these changes in the available timber supply.*

To achieve the same structural performance as pre-1980 old growth 21-ply plywood, new growth 21-ply marine grade plywood would need to be significantly denser, or a larger dimension (thicker or wider pieces would be needed if using solid lumber) to compensate for the difference in wood quality.

Modern marine plywood *(e.g., Okoume) often has a density in the range of 450 to 500 kg/m³. Other hardwood marine options (e.g., Meranti, Birch) can range from 600 kg/m³ to over 750 kg/m³.*

Old growth wood *of the same species would typically have a density in the upper end or exceeding the range for modern lumber due to its tighter grain structure.*

In light of all the above information and the outstanding information available on this subject, there are a couple of good questions that have been asked many times. I would like to address them.

Question: *Why don't we see all container floors showing signs of floor failure or undercarriage failure?*

Answer: *If you have a unit early on with floor failure and it lives out its remaining days moving Wheaties or garments, the likelihood of having undercarriage failure is unlikely.*

Question: *Why are we seeing more floor panel failures and undercarriage failures on 20'dry containers appose to 40' containers?*

Answer: *Same load weight restrictions in half the containment center.*
Operating and maneuverability restrictions.
Heavier and denser cargo.
Under much more structural stress. 20' containers at half the size move near the weight of a 40' container and are subject to possibly twice the Racking, translating into much more stress, wear and deterioration structurally and mechanical.

Summary Table of Differences

Feature	***20-foot Container***	***40-foot Container***
Cargo Density	*High (Heavy)*	*Low/Moderate (Voluminous)*
Common Cargo	*Heavy, dense items*	*Light, bulky goods*
Primary Damage	*Floor/Structural failure*	*External scratches/dents*
Typical Usage	*Harsh, industrial*	*General cargo*

Conclusion:

The amount of detailed information on this subject that exists outside the shipping industry, and has not filtered into out learned publications is both astonishing and worrisome.
To argue this issue in face of the facts would be illogical.

Facts are:

- *We are currently utilizing new growth lumber.*
- *This problem did not exist utilizing old growth lumber.*
- *New growth lumber pound for pound does not mechanically or structurally support the standards of tested old growth lumber.*
- *No structural compensation has been made for new growth deficit.*
- *Current structural panels in their existing form are not compliant with long term design requirements associated with original structural standards.*
- *We have all the visible and physical signs of ply panel failure prior to damage or undercarriage failure as well as a point of reference and long-term in-service test results.*
- *There is zero failed structural tolerance allowance for a ply panel.*
- *Ply panel failure compromises the composite structure.*
- *Composite structure failure can only progress due to panel failure; it is not self-healing.*
- *A compromised composite structure used to its design potential or over time will create an environment for catastrophic failure.*
- *All these undercarriage failures are accompanied by floor failure or replacement due to previous floor failure.*

Lessors have chosen to overlooked the fact that the most vulnerable part of a container, the floor, which currently is inherently structurally inadequate, is subject to normal or age-related wear and deterioration. And, that it's compromised condition leads to levels of undercarriage failure, eventually leading to catastrophic failure.

Lessors by virtue of a face value diagnosis has formulated a result. Uncontested that result has become the accepted hypothesis to the problem.
Further, by not addressing the rolling shear issue they are imposing the notion that a recognized failure (rolling shear) will lead no further. And, a container "regardless of age" operates within a vacuum where the laws of physics and materials science do not apply.

Closing:

It is my hope this information finds its way to a responsible knowledgeable actor within our education-based community who will unbiasedly move forward effecting common sense change and addressing safety concerns as well as proper liability allocations.

If there are any questions I could resolve regarding this matter, please do not hesitate to ask.

Pictures representing floor failures are attached.

Regards,
John D. Citarella
Independent Marine Surveyors LLC.