How much load can my pallet carry?

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Load Capacity
Determine the load capacity:

• Physical Testing
  • Laboratory Testing

• Computer Modeling
  • Finite Element Modeling
  • The Pallet Design System - wood only
  • Best Pallet - wood only
Physical Tests

• How will the pallet be supported and handled?

• What kind of load will the pallet support?
Support Conditions

Floor support

Fork tine support

Rack support

Sling support

Conveyor support
Loading Conditions

- Uniformly distributed flexible load
- Uniformly distributed rigid load
- Rigid line load
- Point load
- Discrete load by the actual product
What standard will be used?

- ASTM D1185 - Standard Test Methods for Pallets and Related Structures Employed in Materials Handling and Shipping
- ISO 8611 - Pallets for Materials Handling - Flat Pallets
- AIAG RC9 - Container Performance Test Guidelines
ISO 8611 (2011)

- Newest general pallet testing standard
- Accepted internationally
- Differentiates between nominal and maximum working loads
- Uses rigid beams for nominal load testing
ASTM D1185 (2009)

- This is the oldest general pallet testing standard.
- Only accepted in the U.S.
- It does not differentiate between nominal and maximum working loads.
- Uses a flexible airbag for comparative testing.
AIAG RC9(ed. 3 - 2015)

- Designed specifically for the automotive industry.

- Only offers a **comparative analysis**.

- Does not use realistic loading conditions.
Pallet Tests

- Block or stringer compression testing
- Pallet top or bottom deck bending test
- Pallet bending test using rack support
- Pallet bending test using fork tine support
- Pallet bending test using conveyor support
Block or stringer compression test

- Only representative of rigid loads.
- Does not bend the top deck.
- Could be as much as 30,000 lbs.
Pallet top or bottom deck bending test

- Provides “Static Capacity.”
- Need to test both the top and bottom decks.
- The clearance between the top and bottom deck is important.

Floor Support
Pallet bending test using rack support

- Provides “Rack Capacity”

- Simulates:
  - Load beam.
  - Drive-in and drive-through racks.
Pallet bending test using fork tine support

- Provides “Dynamic Capacity”
- Simulates a pallet supported by 4 inch fork tines.
- Based on the assumption that the fork tines go all the way through the pallet.

Fork Lift Support
Pallet bending test using conveyor support

- Simulates a pallet that is supported by two track chain conveyors.
- ISO 8611 - bottom deck bending test simulates this.
Which tests do I need?

• ASTM D1185
  • General use pallet:
    • All tests are needed.
  • Special purpose pallets:
    • Only need to test for conditions that the pallet will actually experience.

• ISO 8611
  • Handling goods with racking and stacking.
  • Handling goods with stacking (without racking).
  • Handling goods without stacking or racking.
  • Special applications:
    • Conveyor handling.
    • Sling handling.
How to determine load capacity?

The load capacity of the pallet is determined by considering safety and functionality.

It uses a deterministic design procedure using safety factors between 2 - 2.85.
How to determine load capacity?

Phase 1 (Safety):
1. Conduct a strength test.
2. Determine the ultimate load.
3. Divide the ultimate load by the safety factor.
4. Maximum is the safe load value.
How to determine load capacity?

Phase 2 (Functionality):

1. Conduct a stiffness test.
2. Measure the deflection of the pallet under the test load at the end of the creep time.
3. Compare the deflection to the performance limit.
4. Adjust the test load to achieve deflection close to the performance limit.
5. Compare the test load to the maximum safe load.
6. The smallest will be your safe load or load capacity.
High stiffness pallets

\[ \text{Safe load} = \frac{\text{Ultimate Load}}{\text{Safety Factor}} \]

- **Ultimate load**
- **Safe load**
- **Deflection (in.)**
- **Deflection Limit**
- **Load (lbs.)**

A and B points on the graph represent different load-deflection scenarios.
Low stiffness pallets with similar time dependent behavior
Low stiffness pallets with different time dependent behavior
Potential Issues:

- None of the standards define whether to use the average safe load from three replicates or the minimum load.

- Keep in mind that three samples will not be representative to the entire population.
Computer Modeling

- **Wood Pallet Design Software**
  - The "Pallet Design System" by the National Wood Pallet and Container Association.
  - "Best Pallet" and "Best Load" by White and Company.

- **Alternative Pallet Design Software**
  - Finite Element Method.
Wood "Pallet Design Software"

- Can only be used for wood pallets.
- Includes an extensive library of material properties.
- Does not require extensive knowledge of modeling or mechanics.
- Has built-in variation and safety factors.
Load Analysis in Wood Pallet Design Software

Measurement of the Distribution of Pallet Strength

Load to Cause Failure (lbs.)

- 2000 to 2499
- 2500 to 2999
- 3000 to 3499
- 3500 to 3999
- 4000 to 4499
- 4500 to 4999
- 5000 to 5499
- 5500 to 5999
Load Analysis in Wood Pallet Design Software

Measurement of Payload Distribution

Unit Load Weight (lbs.)

600 to 799
800 to 999
1000 to 1199
1200 to 1399
1400 to 1599
1600 to 1799
1800 to 1999
2000 to 2199
Load Analysis in Wood Pallet Design Software

\[
\beta = \frac{\sqrt{1 + V_s^2} \sqrt{1 + V_r^2}}{\sqrt{\ln(1 + V_s^2) \ln(1 + V_r^2)}}
\]

where:
- \( \beta \) = safety index
- \( R \) = mean resistance (pallet strength)
- \( S \) = mean load effects (stress from unit loads)
- \( V_s \) = coefficient of variation of \( S \)
- \( V_r \) = coefficient of variation of \( R \)
Finite Element Analysis

- Mainly used for plastic pallets.
- Time consuming to build.
- Accuracy depends on material properties and support conditions.
- Only provide one value without a Monte Carlo Simulation.
- Expensive to build.
Load Capacity under Actual Loads

Uniform Loading

Discrete Loading

Airbag
Background

1/6 of the load does not contribute to the bending

1/3 of the load does not contribute to the bending

1/2 of the load does not contribute to the bending
Background

Box Sliding

Box Compression
Load Types

Uniform Loading

a) Cased goods — Column stacked
b) Cased goods — Interlock stacked
c) Sacks — Column stacked
d) Sacks — Interlock stacked
e) Drums
f) Pails
### Load Adjustment in Pallet Design Software

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Stacking Pattern</th>
<th>Load Stabilizers</th>
<th>RAL Support</th>
<th>RAW Support</th>
<th>STACK Support</th>
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<tr>
<td></td>
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<td>Allowable Load</td>
<td>Deflection</td>
<td>Allowable Load</td>
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<td>1.08</td>
<td>0.84</td>
<td>1.08</td>
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<td></td>
<td></td>
<td>Vertical Strapping (1)</td>
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<td>0.92</td>
<td>1.10</td>
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<td>Column</td>
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<td>Vertical Strapping (2)</td>
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<td>Interlock</td>
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<td>Vertical Strapping (2)</td>
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<td>0.80</td>
<td>1.04</td>
</tr>
</tbody>
</table>
Maximum Working Load Test

- **ISO 8611:**
  - Test sequence:
    - Strength test with the loads beams.
    - Stiffness test with actual load.
  - Only modify the load capacity of pallet where the load capacity was determined due to the deflection.

- **ASTM D1185**
  - Test sequence
    - Strength test with actual load.
    - Stiffness test with actual load.
  - Modifies the load capacity of every pallet.
Study on effect of load types on pallet deflection (White 1999)

### Effect of Packaging Types

<table>
<thead>
<tr>
<th></th>
<th>Airbag</th>
<th>Sack</th>
<th>Case</th>
<th>Plastic pail</th>
<th>Steel drum</th>
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<tbody>
<tr>
<td>Effect</td>
<td>1,00</td>
<td>0,87</td>
<td>0,82</td>
<td>0,70</td>
<td>0,54</td>
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</table>

### Effect of Load Securement

<table>
<thead>
<tr>
<th></th>
<th>Column stacked</th>
<th>Interlock stacked</th>
<th>Stretch wrap</th>
<th>Vertical strapping</th>
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</thead>
<tbody>
<tr>
<td>Effect</td>
<td>1,00</td>
<td>0,96</td>
<td>0,87</td>
<td>0,61</td>
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</table>
Study on the effect of package size on pallet deflection (Park 2015)

<table>
<thead>
<tr>
<th>Pallet Stiffness</th>
<th>Box Size (in.)</th>
<th>Average Deflection (in.)</th>
<th>Differences from the Airbag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Airbag</td>
<td>5x10x10</td>
<td>1.05 (8%)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-23%</td>
</tr>
<tr>
<td></td>
<td>10x10x10</td>
<td>0.69 (1%)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-56%</td>
</tr>
<tr>
<td></td>
<td>20x10x10</td>
<td>0.37 (3%)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-76%</td>
</tr>
<tr>
<td>Medium Airbag</td>
<td>5x10x10</td>
<td>0.31 (2%)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-30%</td>
</tr>
<tr>
<td></td>
<td>10x10x10</td>
<td>0.21 (0%)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-52%</td>
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<tr>
<td></td>
<td>20x10x10</td>
<td>0.13 (5%)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-70%</td>
</tr>
<tr>
<td>High Airbag</td>
<td>5x10x10</td>
<td>0.21 (3%)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-22%</td>
</tr>
<tr>
<td></td>
<td>10x10x10</td>
<td>0.15 (4%)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-44%</td>
</tr>
<tr>
<td></td>
<td>20x10x10</td>
<td>0.10 (6%)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-63%</td>
</tr>
</tbody>
</table>

Park (2015)
Study on the effect of package size on pallet strength (unpublished)

<table>
<thead>
<tr>
<th>Pallet Stiffness</th>
<th>Package Size</th>
<th>Deflection Mean (in.)</th>
<th>CoV (%)</th>
<th>Strength Mean (lbs.)</th>
<th>CoV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Airbag</td>
<td>2.1</td>
<td>3</td>
<td>218</td>
<td>3</td>
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</tr>
<tr>
<td>5 in. box</td>
<td>2.1</td>
<td>7</td>
<td>1,006</td>
<td>19</td>
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<tr>
<td>10 in. box</td>
<td>1.3</td>
<td>8</td>
<td>3,000</td>
<td>0.1</td>
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<tr>
<td>20 in. box</td>
<td>0.5</td>
<td>3</td>
<td>3,009</td>
<td>0.4</td>
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<tr>
<td>Medium Airbag</td>
<td>2.1</td>
<td>3</td>
<td>899</td>
<td>4</td>
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<tr>
<td>5 in. box</td>
<td>2.1</td>
<td>1</td>
<td>2,046</td>
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<tr>
<td>10 in. box</td>
<td>1.1</td>
<td>4</td>
<td>3,000</td>
<td>0.3</td>
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<tr>
<td>20 in. box</td>
<td>0.5</td>
<td>4</td>
<td>3,018</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>
Big Box Stores Pallet Requirement

- **BJ’s Wholesale:** Each pallet must be capable of supporting its own weight to allow double-stacking. A typical pallet build would be 47” high (including the pallet) with a maximum weight no more than 2500 pounds (though this can vary based on product categories and merchandising methods). The purchase order and/or BJ’s Buyer will determine the specific pallet configuration and pallet height for each product. (2013 PackagingSpec)

- **Walmart:** Walmart requires that all pallets shipped into Walmart DCs meet or exceed the Grocery Manufacturers Association (GMA) Grade “A” pallet standards. Product may be stored in a standard rack on a supplier’s pallet for an extended period of time. **Pallets must support the weight of the product shipped on them.**
Big Box Stores Pallet Requirement

- Costco: If pallets will be manufactured by different companies, or using different materials at different times, each unique pallet must be represented by its own PDS™ Report, and each Report must be approved. (2011 Pallet Spec)

PDS™ STRUCTURAL SPECIFICATIONS
- A Unit Load Type: Uniformly Distributed – Full Pallet Coverage
- B Unit Load Weight Variability: 49.5% Load Weight Coefficient of Variation and 2.15 Max to Avg Load Ratio
- C Support Condition:
  - Racked Across Width (deckboards), 2 Beam Support
  - 34” span
  - USER SPECIFIED Deflection Limit of .65”
  - Maximum Load FOR DEFLECTION LIMIT no less than 3,250 lbs

PDS™ REPORTS must include USER SPECIFIED DEFLECTION LIMIT and MAXIMUM LOAD for DEFLECTION LIMIT
## Requirements of Automated Material Handling (ANSI MH1 - 2005)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pallet size and shape variation</td>
<td></td>
</tr>
<tr>
<td>length</td>
<td>+0.13/-0.25 in. (+3.3/-6 mm)</td>
</tr>
<tr>
<td>width</td>
<td>+0.13/-0.25 in. (+3.3/-6 mm)</td>
</tr>
<tr>
<td>height</td>
<td>+0.13/-0.38 in. (+3.3/-9.5 mm)</td>
</tr>
<tr>
<td>squareness</td>
<td>Diagonals shall be within 0.50 in. (25 mm)</td>
</tr>
<tr>
<td>Flatness of decks (supporting no load)</td>
<td>Within 0.25 in. (6 mm) of target level [Note (1)]</td>
</tr>
<tr>
<td>Minimum static coefficient of surface friction: Top and bottom surface of top deck and bottom surface of bottom deck</td>
<td>0.15</td>
</tr>
<tr>
<td>Component placement variation</td>
<td>Within 0.25 in. (6 mm) of target location</td>
</tr>
<tr>
<td>Maximum deflection of the pallet under load</td>
<td>0.50 in. (13 mm)</td>
</tr>
<tr>
<td>Minimum clearance between pallet under load and handling equipment</td>
<td>0.50 in. (13 mm)</td>
</tr>
<tr>
<td>Maximum deflection of pallet components under load</td>
<td>0.25 in. (6 mm)</td>
</tr>
</tbody>
</table>
Conclusion

- Not all pallet testing standards provide the same information
- The load capacity of a pallet highly dependent on the type of payload
- Pallet design software has more reliable safety factors
- The stiffness of the pallet is crucial in automated materials handling
Thank you for your time and attention!

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Phone: (540) 231-7673
Website: www.unitload vt.edu
References

- ISO 8611(2011) - Pallets for Materials Handling - Flat Pallets
- WHITE, M.S., WILBUR, D., RUPERT, R. and MC LEOD, J. 1999 Determination of pallet maximum working loads from nominal load measurements. Center for Unit Load Design, Virginia Tech., Blacksburg, VA, USA,
- PARK J. 2015 Investigation of Effects of Physical Interactions and Refurbishment of Logistical Packaging Components in Unit Loads from a Sustainability Perspective, Ph.D Dissertation, Virginia Tech, Blacksburg, VA, USA.