Unit Load Design & Analysis for Boxes

Kristen DeLack, PE

National Wooden Pallet & Container Association

Pallets Move the World®

Unit Load for Boxes
Crash Course

Agenda

1. General
    1. PDS capabilities
    2. Workflow
2. Stretch wrap
    1. Types, grades
    2. Wrapping recipe
    3. Containment force
    4. Considerations, effects
3. Box support
    1. Box corners
    2. Deckboard gaps
    3. Overhang
4. Running PDS
    1. Walk through
    2. Tutorial
    3. Optimization
5. Case study

Current PDS Analysis Capabilities

- PDS limitations
  - Regular Slotted Containers (RSC)’s
  - Column stacked (Interlocked stacked will be available later in 2020)
  - Symmetrical layouts in two planes
  - 80% pallet coverage
  - No overhang
  - Up to 5 boxes across length or width
  - Unlimited number of box layers/height

- Support conditions
  - Racked across length
  - Racked across width
  - Stacked 3 high

- Stretch wrap containment required. Strapping, edge protection can be added, but won’t be considered in the analysis.

Unit Load Design Workflow

01 Input basic details

Pallet style, length/width, analysis options.

02 Input cargo details

Box size, stacking pattern, containment, weight. Use initial box material.

03 Design initial pallet

Following familiar method in PDS

04 Perform analysis

RAL, RAW and stacked analysis.

05 Review results

06 Optimize

Minimize costs for either the packaging or pallet.

Notes on Stretch Wrap

- Stretch wrap containment force is an important factor in unit load performance.

- The containment force depends on:
  - Number of wraps, wrap pattern
  - Material and gauge of the stretch wrap.
  - Total pre-stretch and pre-tension.
  - Temperature of storage – especially for “high performance” films.

- As unit load performance depends on the stretch wrap, it is essential that the end-user has established a reasonable process for applying the stretch wrap and a qualified quality assurance & control program.

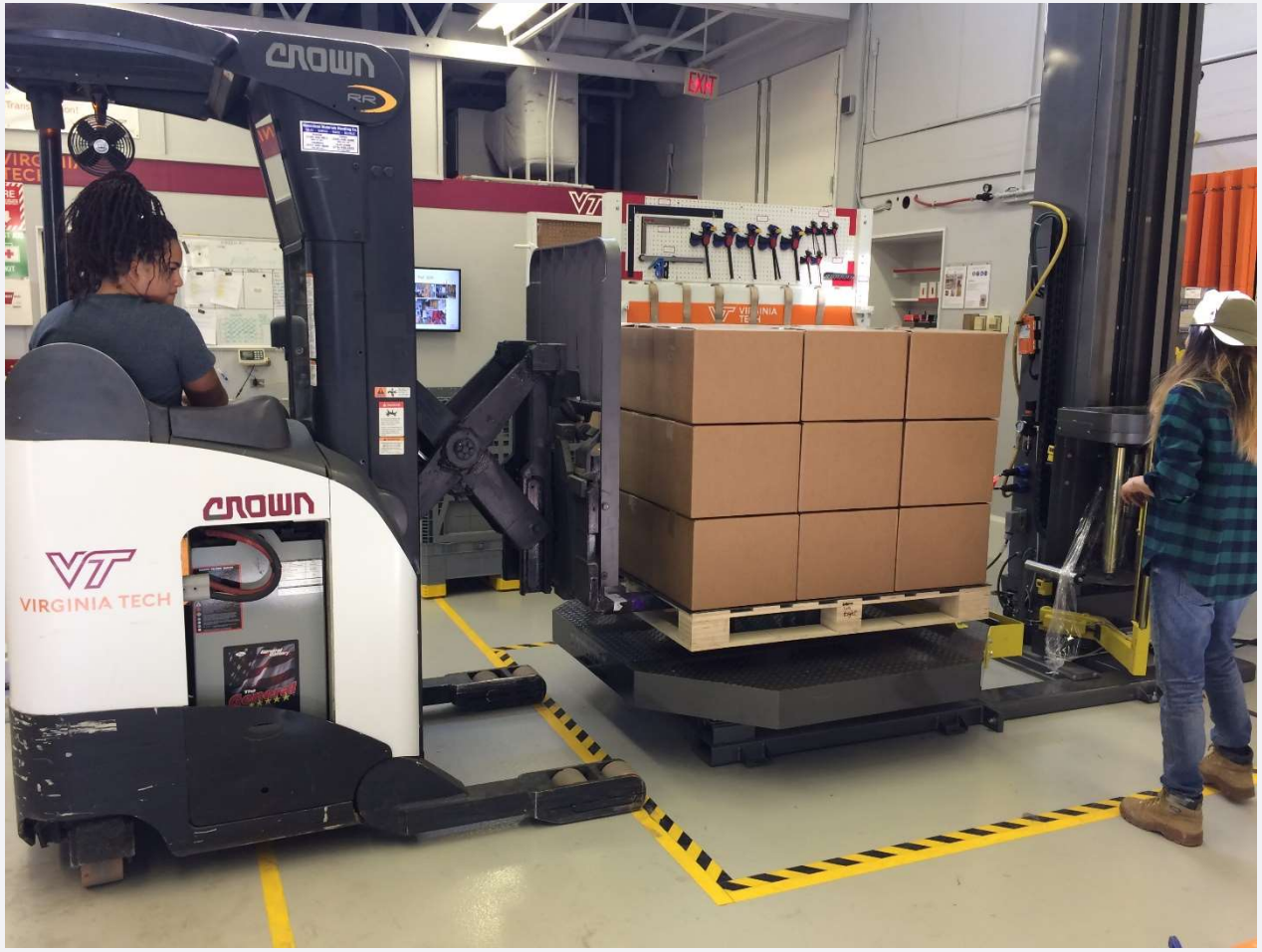
Containment Force

PDS assumes a containment force of 75 lbs per corner. This corresponds approximately to an ASTM D4649 pull-plate test result of 15 lbs. This is thought to be the minimum likely to be encountered in the industry.

Automated Vs. Hand Wrap

Hand wrapping is inconsistent and should not be relied upon for unit load design. Automated wrapping machines are essential.

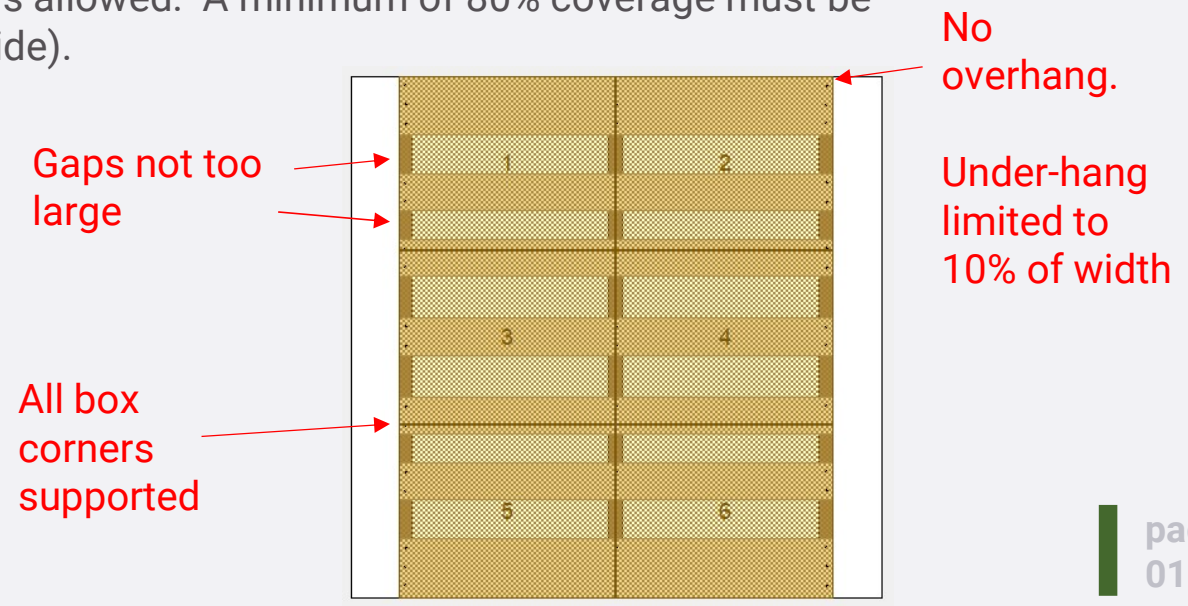
Research-grade automated wrapping



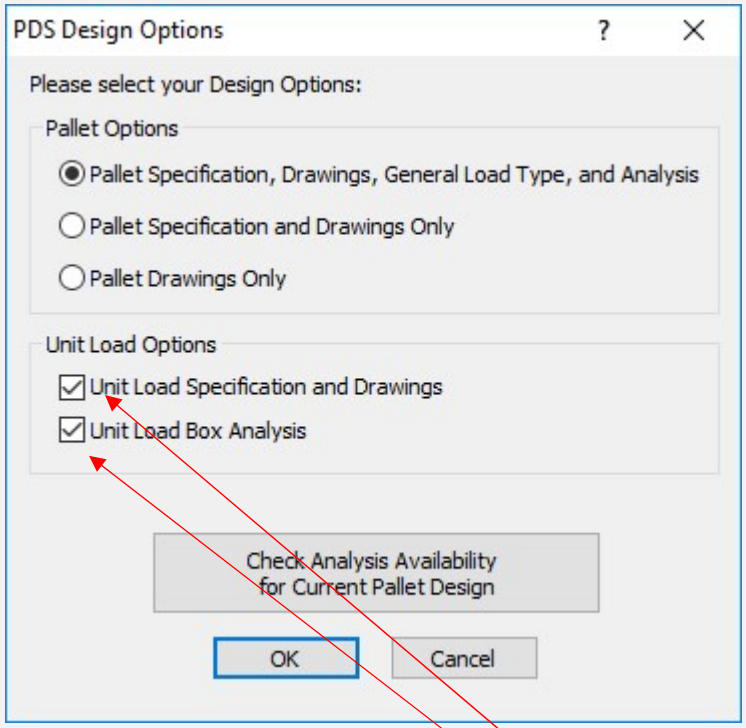
Stretch Wrap

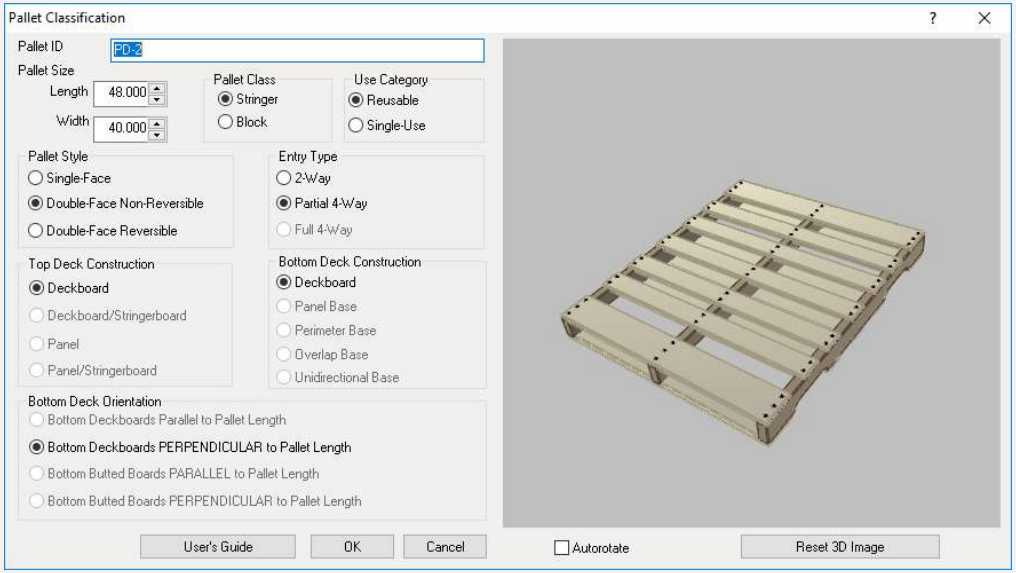
Best practices
Stacking pattern

- PDS generally assumes that best practices are followed in the layout of the deckboards to support the boxes. Results for poor designs will be provided, but have a higher uncertainty level.
- All box corners should be sufficiently supported. This precludes both internal and external overhang.
- Deckboard gaps should not be too large. Support at least 50% of the box length spanning the deckboards.
- Limited under-hang is allowed. A minimum of 80% coverage must be achieved (10% per side).



Input Basic Design Options



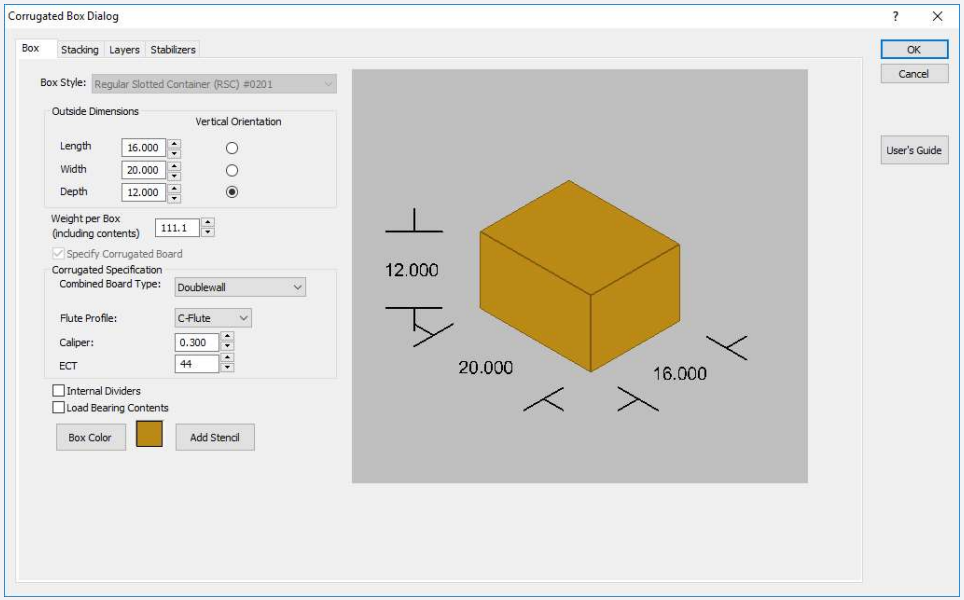


Fill out Pallet Classification dialog. Note: Only stringer pallets are currently available. Blocks will follow in the next few weeks.

Check boxes

Input Cargo Details

Select Box icon



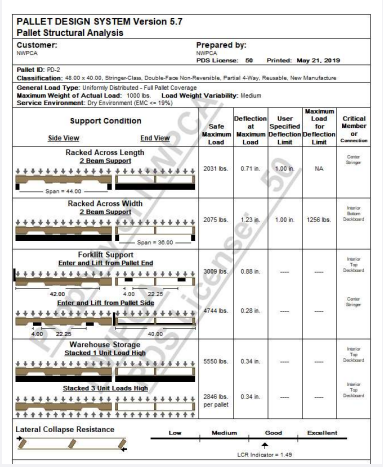
Complete all tabs in Corrugated Box Dialog.
Some choices are not yet available, such as non-symmetrical stacking patterns.
Box Caliper and ECT are the initial values which may be optimized during the design process.

Design Initial Pallet
Perform Initial Analysis

- Design a pallet following your regular practices in PDS.
  - Specify a uniformly distributed load.
  - A custom load specification may also be used. This will affect the UDL results, but not the full unit load analysis which will use a more detailed loading pattern.
  - Specify racking layout and check boxes to perform Racked Across Width (RAW), Racked Across Length (RAL) analysis

- Perform ***Complete Analysis*** for RAL, RAW, and Stacked conditions. Additional analyses may be performed, but aren't necessary for the unit load analysis.

- Review the results for UDL loading, as usual.
  - Load capacity and displacement may be slightly lower than required. Load sharing between the pallet and cargo potentially will make up the difference.



PALLET DESIGN SYSTEM Version 5.7
Pallet Structural Analysis

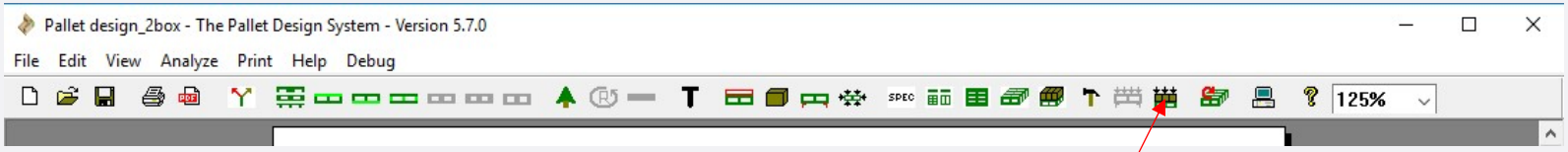
Customer:
NWPCA

Prepared by:
NWPCA
PDS License: 00 Printed: May 21, 2019

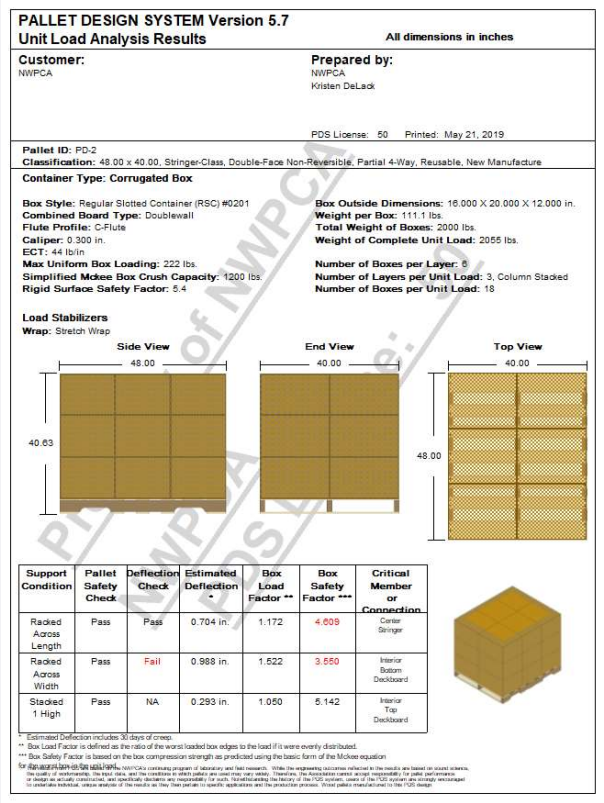
Pallet ID: PD-2
Classification: 48.00 x 40.00, Stringer-Class, Double-Face Non-Reversible, Partial 4-Way, Reusable, New Manufacture
General Load Type: Uniformly Distributed - Full Pallet Coverage
Maximum Weight of Actual Load: 1000 lbs. Load Weight Variability: Medium
Service Environment: Dry Environment (EMC <= 19%)

Support Condition (Side View / End View)	Safe Maximum Load	Deflection at Maximum Load	User Specified Deflection Limit	Maximum Load for Deflection Limit	Critical Member or Connection
Racked Across Length 2 Beam Support Span = 44.00	2031 lbs.	0.71 in.	1.00 in.	NA	Center Stringer
Racked Across Width 2 Beam Support Span = 36.00	2075 lbs.	1.23 in.	1.00 in.	1256 lbs.	Interior Bottom Deckboard
Forklift Support Enter and Lift from Pallet End 42.00 4.00 22.25	3089 lbs.	0.88 in.	-----	-----	Interior Top Deckboard
Enter and Lift from Pallet Side 4.00 22.25 40.00	4744 lbs.	0.28 in.	-----	-----	Center Stringer
Warehouse Storage Stacked 1 Unit Load High	5550 lbs.	0.34 in.	-----	-----	Interior Top Deckboard
Stacked 3 Unit Loads High	2046 lbs. per pallet	0.34 in.	-----	-----	Interior Top Deckboard
Lateral Collapse Resistance Low / Medium / Good / Excellent LCR Indicator = 1.49					

Review Unit Load Analysis Results



Unit Load Analysis Results



PALLET DESIGN SYSTEM Version 5.7
Unit Load Analysis Results

All dimensions in inches

Customer:
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Pallet ID: PD-2
Classification: 48.00 x 40.00, Stringer-Class, Double-Face Non-Reversible, Partial 4-Way, Reusable, New Manufacture

Container Type: Corrugated Box

Box Style: Regular Slotted Container (RSC) #0201
Combined Board Type: Doublewall
Flute Profile: C-Flute
Caliper: 0.300 in.
ECT: 44 lb/in
Max Uniform Box Loading: 222 lbs.
Simplified Mckee Box Crush Capacity: 1200 lbs.
Rigid Surface Safety Factor: 5.4

Box Outside Dimensions: 16.000 X 20.000 X 12.000 in.
Weight per Box: 111.1 lbs.
Total Weight of Boxes: 2000 lbs.
Weight of Complete Unit Load: 2055 lbs.

Number of Boxes per Layer: 6
Number of Layers per Unit Load: 3, Column Stacked
Number of Boxes per Unit Load: 18

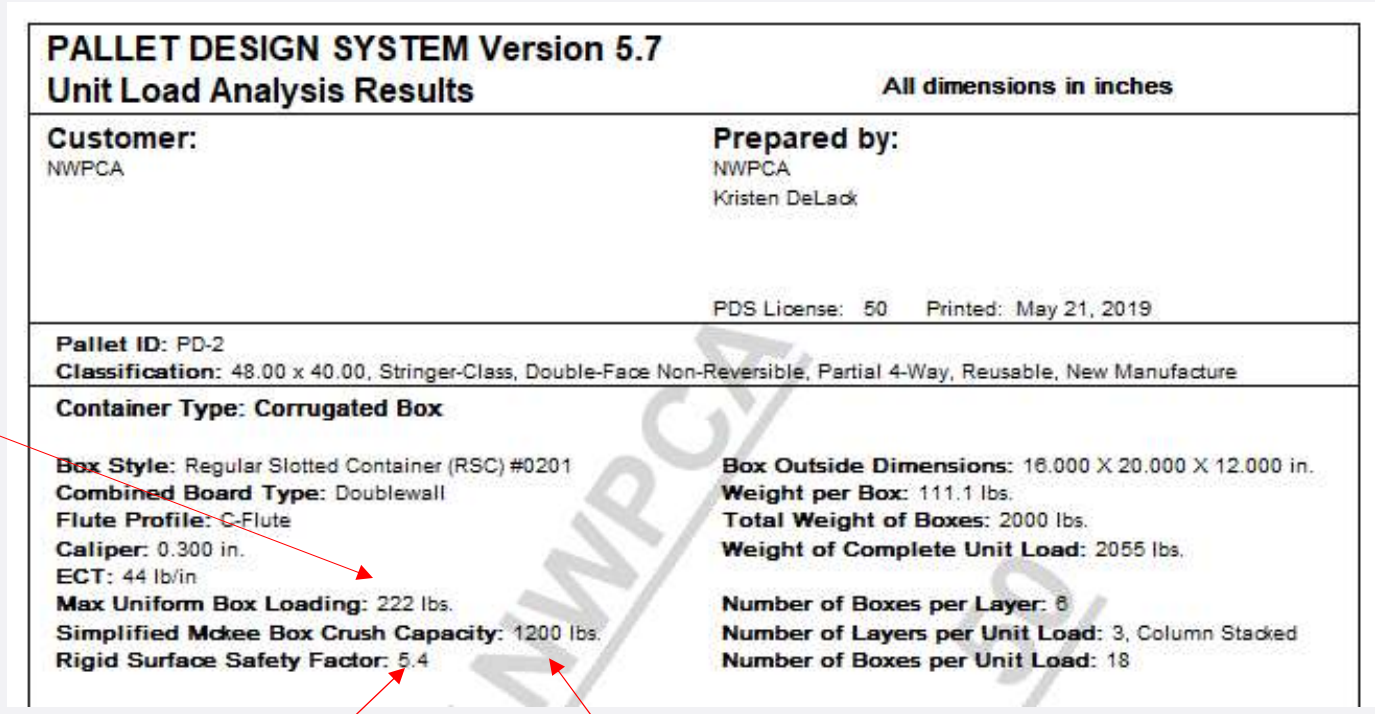
Load Stabilizers
Wrap: Stretch Wrap

Side View **End View** **Top View**

Support Condition	Pallet Safety Check	Deflection Check	Estimated Deflection *	Box Load Factor **	Box Safety Factor ***	Critical Member or Connection
Racked Across Length	Pass	Pass	0.704 in.	1.172	4.609	Center Stringer
Racked Across Width	Pass	Fail	0.988 in.	1.522	3.550	Interior Bottom Deckboard
Stacked 1 High	Pass	NA	0.293 in.	1.050	5.142	Interior Top Deckboard

* Estimated Deflection includes 30 days of creep.
** Box Load Factor is defined as the ratio of the worst loaded box edges to the load if it were evenly distributed.
*** Box Safety Factor is based on the box compression strength as predicted using the basic form of the Mckee equation

Interpreting the Results
Basic Results



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Container Type: Corrugated Box

Box Style: Regular Slotted Container (RSC) #0201
Combined Board Type: Doublewall
Flute Profile: C-Flute
Caliper: 0.300 in.
ECT: 44 lb/in
Max Uniform Box Loading: 222 lbs.
Simplified Mckee Box Crush Capacity: 1200 lbs.
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Box Outside Dimensions: 16.000 X 20.000 X 12.000 in.
Weight per Box: 111.1 lbs.
Total Weight of Boxes: 2000 lbs.
Weight of Complete Unit Load: 2055 lbs.

Number of Boxes per Layer: 6
Number of Layers per Unit Load: 3, Column Stacked
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Capacity as if box loading is completely uniform.

Traditional box safety factor

Max load acting on top of the bottom box in column. Currently, this assumes stacked only 1 high.

Interpreting the Results
Basic Results

Deflection check - if deflection limit is specified. Includes safety factor.

Pallet Structural capacity check. Based on input cargo weight (Weight of boxes X number of boxes)

Support Condition	Pallet Safety Check	Deflection Check	Estimated Deflection *	Box Load Factor **	Box Safety Factor ***	Critical Member or Connection
Racked Across Length	Pass	Pass	0.704 in.	1.172	4.609	Center Stringer
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*** Box Safety Factor is based on the box compression strength as predicted using the basic form of the Mckee equation for the worst box in the unit load.

Factor indicating how much the worst box is loaded on the flexible pallet versus how much it would be loaded on an idealized rigid pallet.

Modified safety factor which considers the flexible pallet.

Notes on Box Safety Factors

ASTM D4169: Standard Practice for Performance Testing of Shipping Containers and Systems

	Shipping Unit Construction	Assurance Level					
		Warehouse			Vehicle		
		I	II	III	I	II	III
1	No internal support	8.0	4.5	3.0	10.0	7.0	5.0
2	Load bearing internal supports	4.5	3.0	2.0	6.0	4.5	3.0
3	Insensitive containers (i.e. plastic boxes)	3.0	2.0	1.5	4.0	3.0	2.0

Determine box safety factor requirements through discussions/input from end user. Currently, 5.0 is hard coded into PDS. In the future, we will likely include a way to select or specify this number.

Optimization

Design optimization can proceed along the following two routes

1. Save packaging costs: Increase pallet stiffness by:
   - RAW - Make deckboards thicker (preferred), wider or add additional. Also can change species and moisture content.
   - RAL - Make stringers taller (preferred), wider or add additional. Also can change species and moisture content.
   - Stacked – Same as RAW.

2. Reduce pallet cost: Reduce wood material in pallet:
   - Make components thinner or narrower, as desired.
   - Possibly, this requires the corrugated box material strength to be raised (for example, changing ECT to 44 from 32) to meet desired box safety factor.
   - The pallet will effectively have two ***Safe Load*** ratings. One for a generic UDL loading. A second one as a complete, fully specified, unit load. The second rating will be higher. Unit Load for Boxes only verifies that the specified cargo weight is acceptable as the "system" will only be rated as a complete set of unit load specifications. If the stretch wrap or a few boxes are removed, the load rating will be reduced back to the generic ULD rating.

Open the example file in PDS

Contact Information

name	address	phone	email
Kristen DeLack, PE	2020 Kraft Drive, Suite 3030 Blacksburg, VA 24060	(281) 794-5430	kdelack@palletcentral.com

Q & A