Comparative Performance of Plywood and Timber Pallet Designs for Pallet Pooling.

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1. INTRODUCTION

APA – The Engineered Wood Association contracted with the William H. Sardo Pallet & Container Research Laboratory to conduct a performance evaluation of two plywood deck pallet designs and one timber pallet design. The objectives of the tests were to evaluate the pallet static strength and stiffness during warehouse racking and the bottom deck strength and stiffness supported by conveyors of the plywood pallets. Comparative structural durability was determined using the VPI FasTrack simulated rough handling protocol.

2. MATERIALS

Three pallet designs were tested. The test pallets were manufactured for APA by Quint-C Pallet in Limestone, TN. Table 1 contains a brief description of the test pallets. Detailed pallet specifications (PDS analyses) for each design are found in Appendix A. Figures 1-3 contain photographs of the test pallets.

Figure 1. A photograph of the full panel deck pallets tested.

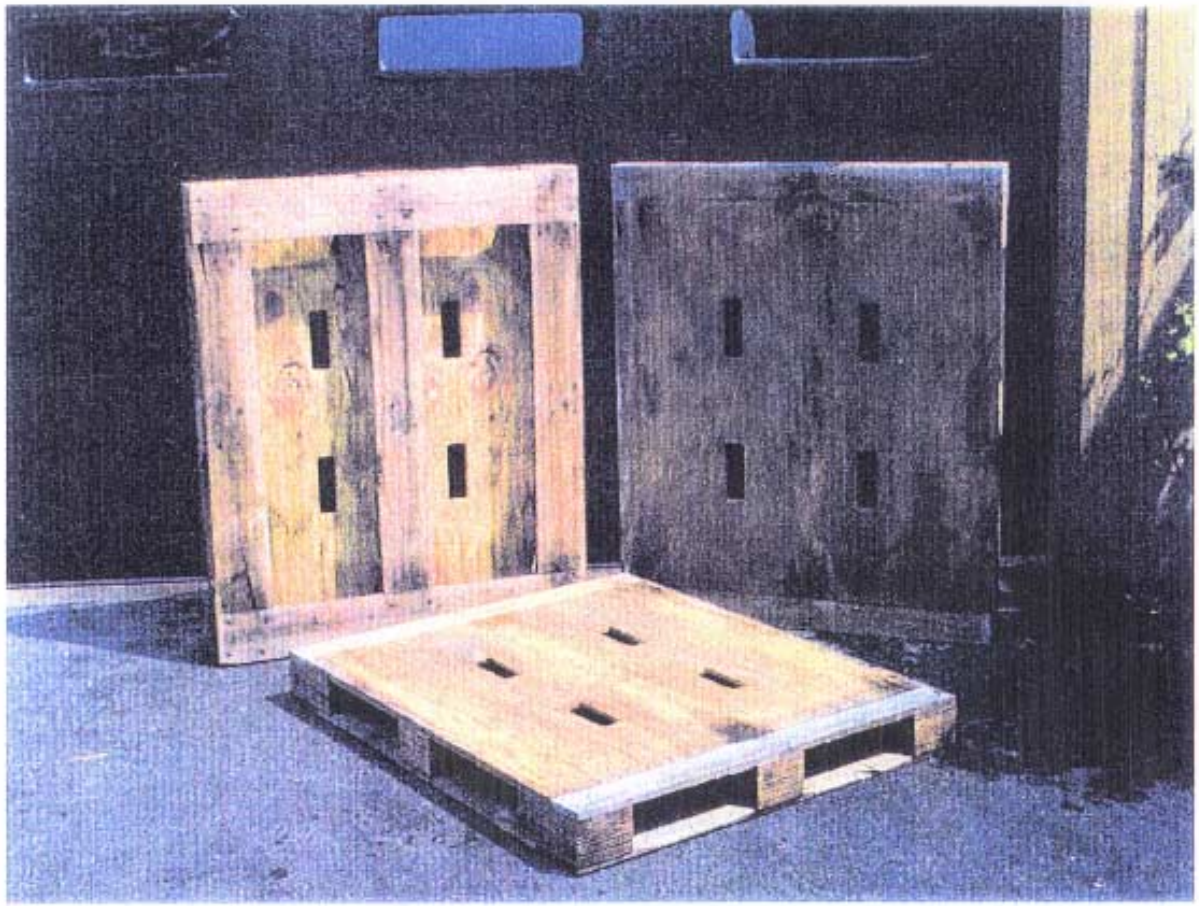


Figure 2. A photograph of the panel deck pallets with hardwood leadboards tested.

Figure 3. A photograph of the lumber/stringer pallets tested.

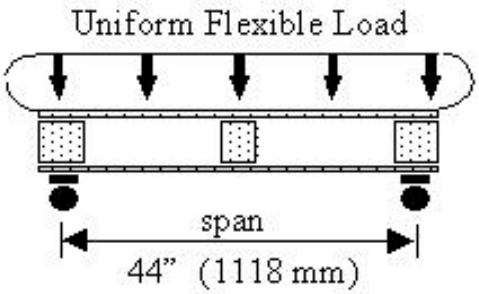
Table 1: A summary of the pallet specifications and fastener sizes.			
Average Values	Full Panel Deck	Panel Deck with Leadboards	Timber/Stringer Pallet
Pallet Weight - pounds	72.4 (4% COV)	70.6 (4% COV)	70.4 (5% COV)
Pallet Length - inches	48	48	48
Pallet Width - inches	40	40	40
Top Deck Construction	5 ply panel, full coverage	5 ply panel, full coverage except hardwood leadboards	Mixed hardwood leadboards approximately 82% coverage
Top Deck Panel/Deckboard Thickness	23/32" (panel)	23/32" (panel) 0.695" (deckboard)	0.668" (deckboard)
Panel Face Grain Direction	Parallel to length	Parallel to length	N/A
Bottom Deck Material/Construction Method	Lumber/Perimeter	Lumber/Perimeter	Lumber/Perpendicular to Stringers
Block Laminating Fastener: Length - Gauge	2.375" - 12-1/2 gauge	2.375" - 12-1/2 gauge	N/A
Panel/Top Deck Fastener: Length - Gauge	2.875" - 10 gauge	2.875" - 10 gauge	2.188" - 10-1/2 gauge

3. TEST METHODS

Static strength and stiffness tests were performed on the plywood deck pallets only. The Pallet Design System (PDS) was used to verify the racking strength of the timber pallet. Rough handling tests were performed on all pallet designs including the timber pallet.

3.1 Bending Test Spanning the Pallet 48-inch Length

Five replicate tests were performed with each panel deck design. The tests were performed in accordance with ASTM D1185, section 8.4. Two semi-rotational 2-inch wide flat stock steel bars support the pallet. The distance between the rotational centers of each support was 44-inches. A 2800-pound uniform flexible load was applied. Deflection measurements were monitored at three points along the centerline of the pallet between supports. The locations were the geometric center of the bottom deck and the center of the pallet sides. Each test included a 2-hour creep period, 1-hour recovery period, and subsequent test to failure. Figure 4 contains a photograph of the test setup.



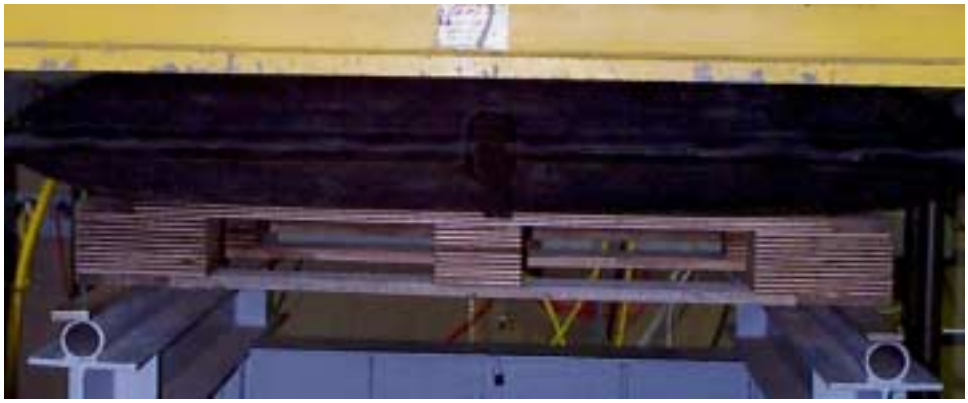


Figure 4. A photograph and schematic view of the racked across length test setup.

3.2 Bending Test Spanning the 40-inch Pallet Width.

Five replicate tests were performed with each panel deck design. The tests were performed according to ASTM D1185, section 8.4. Two semi-rotational 2-inch wide flat stock steel bars support the pallet. The distance between the rotational centers of each support was 36-inches. A 2800-pound uniform flexible load was applied. Deflection measurements were monitored at three points along the centerline of the pallet between supports. These were at the geometric center of the bottom deck and the center of the pallet ends. Each test included a 2-hour creep period, 1-hour recovery period, and subsequent test to failure. Figure 5 contains a photograph of the test setup.

Figure 5: A photograph and schematic view of the racked across width test setup.

3.2 Bending Strength and Stiffness of the Pallet Bottom Deck on simulated Conveyor Supports Placed Parallel to the 40-inch Pallet Width.

Five replicate tests were performed with each panel deck design. A test span of 18-1/2 inches was used. The width of the supports was 0.625-inches. A 2800-pound uniform flexible load was applied. Deflection measurements were monitored at three points along the centerline of the pallet between supports. These locations were the center of the pallet sides and the geometric center of the bottom deck. Each test included a 2-hour creep period, 1-hour recovery period, and subsequent test to failure. Figure 6 contains a photograph of the test setup.

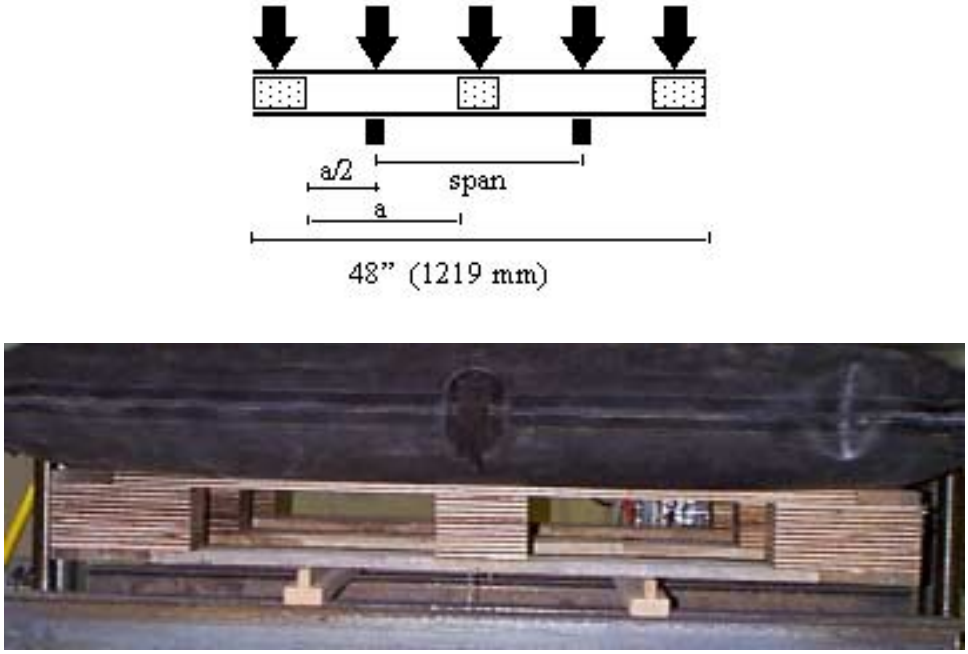


Figure 6: A photograph and schematic view of the conveyor simulation with supports placed parallel to the pallet width.

3.3 Bending Strength and Stiffness of the Pallet Bottom Deck on Simulated Conveyors Supports Placed Parallel to the 48-inch Pallet Length.

Five replicate tests were performed with each panel deck design. A test span of 17-1/2 inches was used. The test support width was 0.625-inches. A 2800-pound uniform flexible load was applied. Deflection measurements were monitored at three points along the centerline of the pallet between supports. The locations were the center of the pallet ends and the geometric center of the pallet bottom deck. Each test included a 2-hour creep period, 1-hour recovery period, and subsequent test to failure. Figure 7 contains a photograph of the test setup.

Figure 7: A photograph and schematic view of the conveyor simulation tests with the supports placed parallel to the pallet length.

3.4 VPI Unit-Load Material Handling FasTrack

Simulated rough handling of palletized unit loads is recommended to assess structural durability and to determine the economics of use of the pallet. This can be achieved by accelerated rough handling using devices employed in material handling. An example of such a test is found in ASTM D1083.[3] To follow is a protocol developed and used at the Pallet and Container Research Laboratory of Virginia Tech. Figure 8 contains a diagram of the FasTrack testing area.

This is a modification of a test protocol developed by the Proctor and Gamble Company to simulate the use of pallets in the grocery dry goods industries. The test simulates idle pallet storage, palletizing, shipping, transport, receiving, and three types of storage: static rack, flow rack, and block staking. The handling devices used in the FasTrack include a 3,000-lb. (1363 Kg) capacity counter-balanced forklift and a 4,000-lb. *(1818 Kg)* capacity electric pallet jack. Fork lift operating speeds are *1 mph (1.6 Km/hr) and 3* mph *(4.8 Km/hr), depending on the mode of handling*. *The electric pallet jack operating speed is 2 mph (3.2 Km/hr).* A dummy load of 1500 lbs. *(682 Kg)* is typically used. However, upon request, other load levels are possible. Fifteen (15) replicates of each design were tested in VPI FasTrack (3 designs, 45 total pallets).

The FasTrack handling modes and sequence:

Handling modes

- Empty pallet storage area: Empty pallets are stacked and stored in this area.
- Staging area: This area is used for sluing and turning pallets so that the forklift can enter the pallet ends and sides and to transfer the pallet via pallet jack. The pallet is staged before and after entering the trailer. This simulates shipping and receiving docks.
- Trailer: This is a simulated 102-in (259 cm) trailer opening with plywood sides. Pallets are moved in and out of one side of the opening to resemble a confined space. Pallets are moved in and out using the pallet sides and ends.
- Transport simulator: Vibration which simulates the moving transport system.
- Static rack storage: This rack simulates warehouse rack storage. The standard free span is 44-inches, but can be adjusted.
- Stack storage: This simulates warehouse block stack storage of loaded pallets. The loaded pallet is placed on an irregular surface of bagged fertilizer.
- Flow rack: This is a gravity feed flow rack which supports pallets on two rows of 5/8-in. wide rollers set 26.25-in. (66.7 cm) apart on center. The pallet rolls on an 8-ft. conveyor. Pallet travel is halted when the bottom leading edge deckboard impacts metal stops placed 26 in. (66 cm) apart. *Roll speeds are adjusted to 80 feet/minute (1.5 Km/hr).*

Handling sequence

The full 4-way entry plywood pallets have on average 17 handlings per FasTrack Cycle.

The partial 4-way entry timber pallets have on average 15 handlings per FasTrack cycle.

A test cycle consists of the following sequential operations:

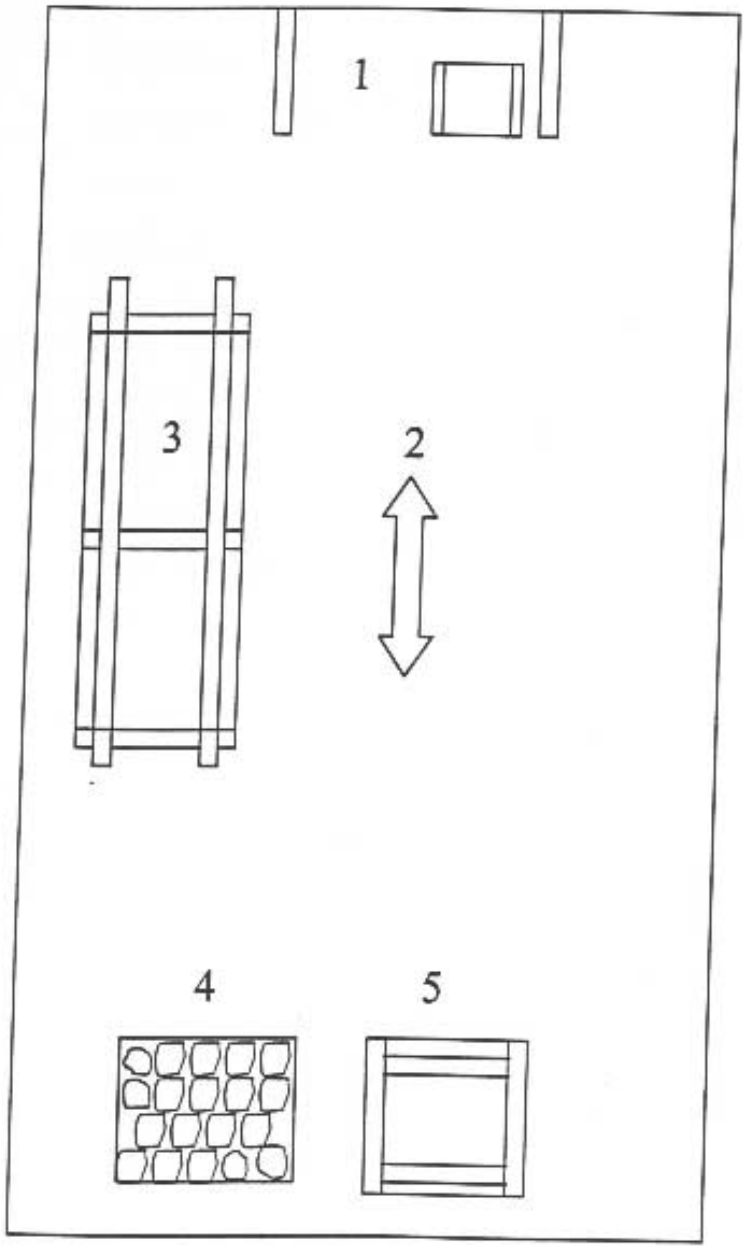
1. *Pallet is visually inspected;*
2. *Transfer the load onto the pallet in the staging area;*
3. Lift the pallet from the 40-in. (101.6 cm) end using the forklift and load into the trailer *at 3 mph (4.8 Km/hr);*

4. Using the forklift, remove from the trailer and return to staging area *at 1 mph (1.6 Km/hr)*;[1]
5. Slue, *at 1 mph* partial 4-way and 4-way pallets in the staging area by forklift so that it is picked up from the side and loaded into a trailer *at 3 mph (4.8 Km/hr)*;
6. Using the forklift, unload the unit-load from the trailer and set it down in the receiving staging area *at 2 mph (1.6 Km/hr)*;
7. Lift the unit load by electric jack and re-load into the trailer *at 2 mph (3.2 Km/hr)*;
8. Unload the unit-load from the trailer and set it own in the receiving staging area using the pallet jack. For the 4-way plywood pallets, step *7 and 8* are repeated using the side entry *at 2 mph (3.2 Km/hr)*;
9. *The unit load is pushed 30 feet (9.14 m) across the concrete floor at 3 mph (4.8 Km/hr) using the fork lift;*
10. The unit-load is lifted by forklift and is set down onto the static rack spanning the length of the pallet. *The operator exits the rack without unit load and re-enters;*
11. Using the forklift, the unit-load is lifted and set on the top of the stacked bags. *The operator exits the stack without unit load and re-enters*;
12. The unit-load is lifted by forklift from stacked storage and set into the gravity *flow conveyor*. The loaded pallet rolls until it impacts the stops *at 80 ft/min (1.5 Km/hr) velocity*;
13. *Using the forklift, the load is removed from the conveyor and set on the floor, and pushed 20 ft (6.1 m) across the floor*;
14. Empty pallets are dropped by pushing off the forks from a 5-ft. (1.52 m) height after every *10* cycles;
15. *After every 5 cycles, the pallet operator impacts bottom deck components with the tine tips of the forklift on the floor and entering the pallet at 1 mph (1.6 Kg/hr) velocity;*
16. *The load is removed from the pallet and inspected for damage at a suitable frequency to monitor pallet durability.*

[1] After each placement of the unit load, the forklift tines are raised and lowered.

VPI UNIT LOAD MATERIAL HANDLING "FASTRACK"

William H. Sardo Jr. Pallet and Container Research Laboratory



Station	Description
1	Trailer
2	Staging Area
3	Gravity-feed conveyor
4	Stack Storage
5	Static Rack Storage

Figure 8: A schematic view of the VPI FasTrack.

4. RESULTS

4.1 Bending Test Spanning the Pallet 48-inch Length

Tables 2 & 3 contain summaries of the pallet static strength and stiffness test spanning the pallet length. Addition of the end board reduces the pallet stiffness spanning pallet length by an average of 10%. All pallets tested had a maximum load or load at failure exceeding 11,000 pounds. These pallet designs can safely support the 2800-pound uniformly distributed load.

Table 2: A summary of the racking tests of the full panel deck pallets. Racked across the length at a 44-inch free span, supporting a 2800 pound uniformly distributed flexible load.

Replicate	Initial deflection @ 2800 pounds			Deflection after 2 hours @ 2800 pounds			1-hr pallet recovery			Maximum Load (pounds)
	end	center	end	end	center	end	end	center	end	
1	0.325	0.401	0.333	0.338	0.511	0.339	0.128	0.149	0.137	11,000+ [1]
2	0.361	0.429	0.36	0.445	0.539	0.447	0.159	0.209	0.207	11,000+ [1]
3	0.285	0.372	0.292	0.371	0.488	0.379	0.155	0.162	0.171	11,000+ [1]
4	0.363	0.422	0.385	0.423	0.508	0.455	0.127	0.129	0.124	11,000+ [1]
5	0.235	0.35	0.353	0.342	0.504	0.476	0.105	0.131	0.166	11,000+ [1]
AVG	0.314	0.395	0.345	0.384	0.510	0.419	0.135	0.156	0.161	-------
Std Dev.	0.054	0.033	0.035	0.048	0.018	0.058	0.022	0.033	0.032	-------
COV	17	8	10	13	4	14	17	21	20	-------

[1] The pallet reached machine capacity and did not fail.

Table 3: A summary of the racking tests of the panel deck with hardwood leadboards pallets. Racked across the length at a 44-inch free span, supporting a 2800 pound uniformly distributed flexible load.

Replicate	Initial deflection @ 2800 pounds			Deflection after 2 hours @ 2800 pounds			1-hr pallet recovery			Maximum Load (pounds)
	end	center	end	end	center	end	end	center	end	
1	0.368	0.418	0.317	0.462	0.538	0.423	0.129	0.132	0.111	11,000+ [1]
2	0.337	0.406	0.295	0.434	0.525	0.383	0.148	0.129	0.077	11,000+ [1]
3	0.389	0.447	0.325	0.499	0.589	0.438	0.142	0.158	0.147	11,000+ [1]
4	0.444	0.423	0.349	0.538	0.541	0.477	0.145	0.146	0.168	11,000+ [1]
5	0.328	0.399	0.315	0.421	0.514	0.408	0.103	0.097	0.093	11,000+ [1]
AVG	0.373	0.419	0.320	0.471	0.541	0.426	0.133	0.132	0.119	------
Std Dev.	0.046	0.019	0.020	0.048	0.029	0.035	0.018	0.023	0.038	------
COV	12	4	6	10	5	8	14	17	32	------

[1] The pallet reached machine capacity and did not fail.

4.2 Bending Test Spanning the 40-inch Pallet Width.

Tables 4 & 5 contain summaries of the pallet static strength and stiffness tests spanning the pallet width test of the full panel deck and the panel deck with hardwood leadboards pallets. The pallets with hardwood endboards are somewhat stronger and stiffer spanning the pallet width. The hardwood endboard appears to stiffen and strengthen the pallet in this support mode. The pallet can safely support a 2800-pound uniformly distributed load spanning the pallet width. Table 6 contains average initial deflections of the panel deck pallets and predicted values of the stringer pallet using PDS. These values were used to substantiate the difference in stiffness between the designs.

Table 4: A summary of the racking tests of the full panel deck pallets. Racked across the width at a 36-inch free span, supporting a 2800 pound uniformly distributed flexible load.

Replicate	Initial deflection @ 2800 pounds			Deflection after 2 hours @ 2800 pounds			1-hr pallet recovery			Maximum Load (pounds)
	end	center	end	end	center	end	end	center	end	
1	0.285	0.515	N/A	0.379	0.645	N/A	0.095	0.091	N/A	9958
2	0.372	0.557	N/A	0.464	0.694	N/A	0.151	0.131	N/A	10815 [1]
3	0.451	0.690	N/A	0.563	0.834	N/A	0.217	0.178	N/A	8417
4	0.509	0.624	0.428	0.606	0.751	0.549	0.187	0.155	0.161	10432 [1]
5	0.489	0.681	0.577	0.594	0.806	0.692	0.183	0.166	0.172	8290
AVG	0.421	0.613	0.503	0.521	0.746	0.621	0.167	0.144	0.167	-------
Std Dev.	0.092	0.077	0.105	0.097	0.078	0.101	0.046	0.034	0.008	-------
COV	22	12	21	19	10	16	28	24	5	-------

[1] The pallet reached machine capacity and did not fail.

Table 5: A summary of the racking tests of the panel deck with hardwood leadboards pallets. Racked across the width at a 36-inch free span, supporting a 2800 pound uniformly distributed flexible load.

Replicate	Initial deflection @ 2800 pounds			Deflection after 2 hours @ 2800 pounds			1-hr pallet recovery			Maximum Load (pounds)
	end	center	end	end	center	end	end	center	end	
1	0.386	0.574	0.448	0.498	0.700	0.551	0.131	0.128	0.118	8687
2	0.416	0.614	0.454	0.528	0.757	0.569	0.166	0.167	0.155	10,742 [1]
3	0.436	0.633	0.465	0.513	0.753	0.556	0.156	0.157	0.127	11,221 [1]
4	0.343	0.486	0.325	0.432	0.584	0.407	0.210	0.159	0.208	11,574 [1]
5	0.356	0.591	0.338	0.462	0.732	0.429	0.121	0.175	0.142	10,253 [1]
AVG	0.387	0.580	0.406	0.487	0.705	0.502	0.157	0.157	0.150	-------
Std Dev.	0.039	0.057	0.068	0.039	0.071	0.078	0.035	0.018	0.035	-------
COV	10	10	17	8	10	15	22	11	24	-------

[1] The pallet reached machine capacity and did not fail.

Table 6: A summary of the average initial deflection of the panel deck pallet designs compared to a PDS predicted deflection of the lumber/stringer pallet design supporting a 2800-pound load.			
Test Method	Average Initial Deflection with a 2800-pound load (inches)		
	Full panel deck pallets [1]	Panel deck pallets with hardwood leadboards [1]	Lumber/stringer pallets [2]
Racked across length, 44-inch free span	0.395	0.419	0.208
Racked across width, 36-inch free span	0.613	0.580	0.426

[1] The values noted are average measured values from laboratory tests.

[2] The values reported were predicted using the Pallet Design System.

4.3 Bending Strength and Stiffness of the Pallet Bottom Deck on Conveyors with Supports Placed Parallel to the 40-inch Pallet Width.

Tables 7 & 8 contain summaries of the results of flexural strength and stiffness tests of the full panel deck and panel deck with hardwood leadboards pallets tested on conveyor supports placed parallel to the pallet width. There is no significant difference in the end maximum deflection. The designs are similar in stiffness. Both designs can safely support a 2800-pound uniformly distributed load in conveyor support.

Table 7: A summary of the conveyor simulation tests of the full panel deck pallet with supports placed parallel to the 40-inch pallet width. A 2800 pound uniformly distributed flexible load was applied.										
Replicate	Initial deflection @ 2800 pounds			Deflection after 2 hours @ 2800 pounds			1-hr pallet recovery			Maximum Load (pounds)
	end	center	end	end	center	end	end	center	end	
1	0.301	0.176	0.284	0.378	0.191	0.358	0.114	0.026	0.107	8912
2	0.293	0.108	0.308	0.341	0.117	0.362	0.111	0.026	0.113	10,913 [1]
3	0.313	0.094	0.298	0.358	0.105	0.359	0.070	0.021	0.077	9284
4	0.279	0.153	0.198	0.357	0.184	0.28	0.134	0.037	0.061	10,988 [1]
5	0.229	0.100	0.227	0.306	0.106	0.294	0.112	0	0.102	10,477 [1]
AVG	0.283	0.126	0.263	0.348	0.141	0.331	0.108	0.022	0.092	-------
Std Dev.	0.033	0.036	0.048	0.027	0.043	0.040	0.023	0.014	0.022	-------
COV	12	29	18	8	31	12	22	62	24	-------

[1] The pallet reached machine capacity and did not fail.

Table 8: A summary of the conveyor simulation tests of the panel deck pallets with hardwood leadboards. The conveyor supports were placed parallel to the 40-inch pallet width. A 2800 pound uniformly distributed load was applied.

Replicate	Initial deflection @ 2800 pounds			Deflection after 2 hours @ 2800 pounds			1-hr pallet recovery			Maximum Load (pounds)
	end	center	end	end	center	end	end	center	end	
1	0.277	0.152	0.227	0.344	0.173	0.314	0.137	0.046	0.081	7779
2	0.184	0.147	0.294	0.262	0.168	0.391	0.069	0.046	0.138	7301
3	0.188	0.138	0.330	0.245	0.159	0.380	0.068	0.038	0.127	10,261 [1]
4	0.324	0.140	0.212	0.378	0.151	0.251	0.176	0.036	0.041	9975
5	0.288	0.130	0.206	0.354	0.143	0.262	0.109	0.028	0.058	9017
AVG	0.252	0.141	0.254	0.317	0.159	0.320	0.112	0.039	0.089	-------
Std Dev.	0.063	0.008	0.055	0.059	0.012	0.065	0.046	0.008	0.042	-------
COV	25	6	22	19	8	20	41	19	48	-------

[1] The machine capacity was reached and the pallet did not fail.

4.4 Bending Strength and Stiffness of the Pallet Bottom Deck on Conveyors with Supports Placed Parallel to the 48-inch Pallet Length.

Summaries of the conveyor simulation support tests with supports placed parallel to the pallet length are in Tables 9 & 10. The full panel deck pallet was stiffer than the panel deck with hardwood leadboards pallet. The difference in deflection is the result of the decreased stiffness of the panel/corner block joints. The nailing area of the panel/corner block interface was decreased by the addition of a hardwood leadboard. The decreased nailing area results in a less stiff connection and pallet when the pallet is supported in this manner. Both pallet designs are strong and stiff enough to support a 2800-pound uniformly distributed load on conveyor supports placed parallel to the pallet length.

Table 11 contains a summary of the average maximum deflections from all tests. Noted are the average maximum deflections. Both panel deck designs have similar stiffness values and will safely support 2800-pounds in all support modes tested.

Table 9: A summary of the conveyor simulation tests on the full panel deck pallets with supports placed parallel to the 48-inch pallet length. A 2800 pound uniformly flexible load was applied.										
Replicate	Initial deflection @ 2800 pounds			Deflection after 2 hours @ 2800 pounds			1-hr pallet recovery			Maximum Load (pounds)
	end	center	end	end	center	end	end	center	end	
1	0.462	0.406	0.470	0.618	0.544	0.642	0.235	0.186	0.269	6388
2	0.558	0.466	0.436	0.703	0.580	0.573	0.248	0.168	0.186	6896
3	0.365	0.438	0.511	0.510	0.566	0.649	0.144	0.170	0.224	7054
4	0.512	0.479	0.541	0.666	0.621	0.703	0.282	0.238	0.286	6932
5	0.449	0.427	0.521	0.556	0.514	0.633	0.150	0.144	0.212	6727
AVG	0.469	0.443	0.496	0.611	0.565	0.640	0.212	0.181	0.235	6799
Std Dev.	0.073	0.029	0.042	0.079	0.040	0.046	0.062	0.035	0.041	258
COV	15	7	9	13	7	7	29	19	18	4

Table 10: A summary of the conveyor simulation tests of the panel deck pallets with hardwood leadboards. The pallet was tested with supports parallel to the 48-inch length. A 2800 pound uniformly distributed flexible load was applied.										
Replicate	Initial deflection @ 2800 pounds			Deflection after 2 hours @ 2800 pounds			1-hr pallet recovery			Maximum Load (pounds)
	end	center	end	end	center	end	end	center	end	
1	0.542	0.524	0.499	0.601	0.572	0.533	0.081	0.062	0.097	8088
2	0.664	0.678	0.667	0.763	0.774	0.780	0.231	0.198	0.221	6581
3	0.593	0.578	0.735	0.688	0.674	0.863	0.187	0.171	0.343	5125
4	0.615	0.704	0.684	0.723	0.809	0.807	0.214	0.255	0.247	7386
5	0.560	0.538	0.549	0.649	0.620	0.656	0.195	0.142	0.162	6774
AVG	0.595	0.604	0.627	0.685	0.690	0.728	0.182	0.166	0.214	6791
Std Dev.	0.048	0.082	0.099	0.063	0.100	0.133	0.059	0.071	0.092	986
COV	8	14	16	9	15	18	32	43	43	15

Table 11: A summary of the racking and conveyor tests of the full panel deck and panel deck pallets with hardwood leadboards.		
Test Method	Average Maximum Deflection (inches) [1]	
	Full panel deck pallets (inches)	Panel deck pallets with hardwood leadboards (inches)
Racked across length 44" free span	*0.510*	*0.541*
Racked across width 36" free span	*0.746*	*0.705*
Conveyor simulation with supports parallel to 40" pallet width	*0.348*	*0.320*
Conveyor simulation with supports parallel to 48" pallet length	*0.640*	*0.728*

[1] The average maximum deflection was taken after 2-hrs with a 2800 pound sustained load.

4.5 Pallet, Comparative Resistance to Accelerated Rough Handling in the VPI FasTrack

Tables 12, 13, and 14 contain the results of the rough handling tests of the plywood and timber pallet designs. Table 15 contains a summary of all FasTrack results. The number of FasTrack cycles and handlings until failure is noted. The failure location is also noted. Because the number of handlings per cycle was different, the best comparison is the number of handlings. The tests were stopped when pallets were no longer functional and would require repair.

The most common failure of the timber pallet was the splitting of the stringer foot during slewing. Some end board damage also occurred. The most prevalent form of damage causing pallet failure on the panel deck pallets was block splitting. The panel deck pallets contained nail laminated blocks. Through further laboratory investigations, the Pallet & Container Research Laboratory discovered that the blocks were poorly manufactured. The length of the block and laminating fasteners were too short. The block fasteners from the top and bottom deck should overlap by at least one inch in the block. The laminating fasteners should pass almost completely through the block just shy of puncturing the outer ply of the block.

Because of a typical large level of test variation there is no significant difference in the average resistance to rough handling of the two plywood deck pallet designs. At the point of pallet failure there was no difference in performance between the full panel deck pallets and panel deck pallets with hardwood leadboards. However, the plywood designs exhibit about 3 times the resistance to rough handling of the timber pallets. It seems that the same plywood pallet designs with properly assembled blocks would last significantly longer than those tested because block failure limited the plywood pallet durability in 29 of 30 tests.

Pallets tested in the FasTrack were stored outside and subjected to weathering. The weathering could have influenced the block failures.

Proper block assembly is critical to the panel deck designs resistance to rough handling. Clearly, the splitting blocks were the largest cause of pallet failure in the FasTrack. Experience in the field will determine whether the block splitting is a major form of damage to pallets in use. As a minimum guide, the National Wooden Pallet and Container Association's *Uniform Standard for Wood Pallets, September 1, 1996* section 5.2.3.3, figure 5 should be considered for block assembly. The nail-laminated block in figure 5 contains 2 nails, which are driven through the block only and penetrate the entire depth. Through further testing, nail laminated, glue laminated, or other types of blocks may prove to have greater impact resistance than the minimum standard. A block of increased impact resistance will increase the overall durability of the pallet designs tremendously.

Table 12: A summary of the VPI FasTrack Accelerated Material Handling tests of the full panel deck pallets.			
Replicate	Number of FasTrack Cycles until failure.	Number of handlings until failure	Failure location
1	116	1972	Butted board
2	125	2125	block
3	153	2601	block
4	34	578	block
5	32	544	block
6	65	1105	block
7	95	1615	block
8	73	1241	block
9	13	221	block
10	19	323	block
11	25	425	block
12	32	544	block
13	55	935	block
14	94	1598	block
15	45	765	block
Average	***65***	***1106***	

Table 13: A summary of the VPI FasTrack Accelerated Material Handling tests of the panel deck pallets with hardwood leadboards.			
Replicate	Number of FasTrack Cycles until failure.	Number of handlings until failure	Failure location
1	134	2278	block
2	65	1105	block
3	157	2669	block
4	20	340	block
5	27	459	block
6	29	493	block
7	26	442	block
8	22	374	block
9	43	731	block
10	34	578	block
11	15	255	block
12	38	646	block
13	208	3536	block
14	13	221	block
15	19	323	block
Average	***57***	***963***	

Table 14: A summary of the VPI FasTrack Accelerated Material Handling tests of the timber pallets.			
Replicate	Number of FasTrack Cycles until failure.	Number of handlings until failure	Failure location
1	4	60	stringer
2	45	675	bottom leadboard
3	5	75	stringer
4	105	1575	stringer
5	10	150	stringer
6	45	675	stringer/leadboard joint
7	8	120	stringer
8	7	105	stringer
9	2	30	stringer
10	11	165	stringer
11	19	285	stringer
12	17	255	stringer
13	5	75	stringer
14	13	195	stringer
15	32	480	stringer
Average	***22***	***328***	

Table 15: A summary of the number of cycles and handlings received in the VPI FasTrack.		
Pallet Design Type	Average Number of Cycles	Average Number of Handlings
Full Panel Deck	*65*	*1105*
Panel Deck with hardwood leadboards	*57*	*969*
Stringer	*22*	*330*

5. Conclusion

The purpose of the testing was to compare the relative resistance to rough handling and the relative strength and stiffness of the pallet designs in warehouse racking and conveyor usage.

5.1 The strength and stiffness of both panel deck and timber pallet designs in warehouse racking and conveyor support are adequate for supporting a 2800-pound uniformly distributed load during unit load material handling.

5.2 The plywood deck design is 53% less stiff than the 3-stringer partial 4-way, non-reversible lumber pallet spanning the pallet length in warehouse racking. The 3-stringer partial 4-way, non-reversible lumber pallet is 36% stiffer than the plywood design spanning the pallet width in simulated warehouse racking.

5.3 The perimeter base plywood deck pallets tested were approximately three times as durable and resistant to rough handling as the timber pallet design.

PALLET DESIGN SYSTEM Version 3.2

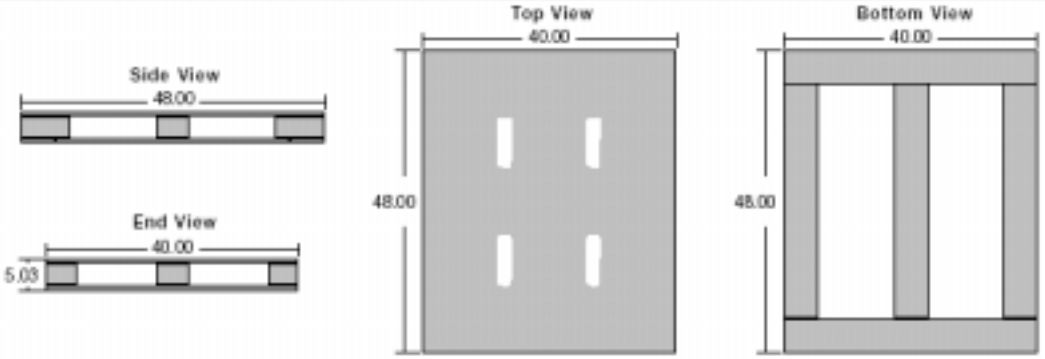
Pallet Specification Sheet

All dimensions in inches

Customer:
APA - The Engineered Wood Association
7011 S. 19th St.
Tacoma, WA 98411-0700
Ph: (206) 565-6600
Fx: (206) 565-7265

Prepared by:
Sardo Pallet and Container Research Laboratory
Virginia Polytechnic Institute and State University
1650 Ramble Road Ph: 540-231-3043
Blacksburg, VA 24060 Fx: 540-231-8868
Analysis by: Peter C. Hammer email: phammer@vt.edu
PDS License: 100 Date: April 17, 2003

Pallet ID: 48x40 full panel deck
Classification 48.00 x 40.00, Block-Class, Double-Face Non-Reversible, Full 4-Way, Multiple-Use, New Manufacture



Components

Top Deck:
Style: Panel
Thickness: 0.719 Width: 40.00 Length: 48.00
Panel Strong Axis Parallel to Pallet Length
Hand Holes: (4)
Length: 8.00 Width: 2.00 Radius: 0.75
Panel Area: 13.3 sq ft

Bottom Deck:
Style: Perimeter Base Type: New Lumber
Thickness: 0.688
Outer Board Length: 40.00 Outer Board Width: 5.500
Butted Board Length: 37.00
Total Number of Butted Boards 3

Number	Width
3	5.500

Butted Boards Parallel to Pallet Length
Volume: 5.0 bd ft

Blocks:
Type: New Lumber Grain Orientation: Sidegrain Nailing
Height: 3.625
Total Number of Blocks: 9
End Block Length: 8.00 Center Block Length: 5.00
Block Width: 5.000
Volume: 5.9 bd ft

Materials

Fasteners:
Fastener ID:
Fastener Type: Annularly Threaded Nail
Fastener Length: 3.00
Thread Length: 2.00
Thread Diameter: 0.142
Wire Diameter: 0.135
Head Diameter: 0.296
Rings: 40
MIBANT Angle: 23
FWI: 59
FSI: 120
Total Number: 102

Panel:
Panel Product: Plywood
Panel Grade: Rated Sheathing
Thickness: 23/32
Number of Plies: 4 Ply
Exposure Class: Exterior

New Lumber:
Lumber ID:

Species Class	Grade	Lumber Mix
Eastern Oaks	Multiple-Use & BTR	100 %

Moisture Content: Green

Total New Lumber Volume: 10.9 bd ft

Custom Notes and Information:

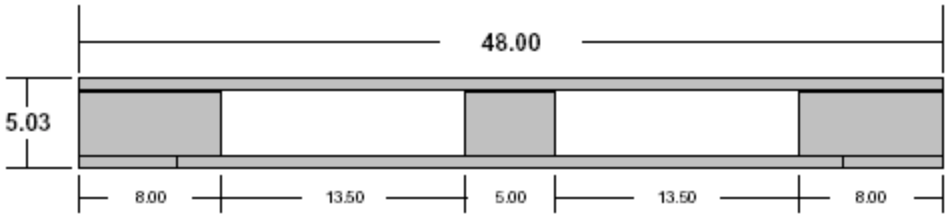
PALLET DESIGN SYSTEM Version 3.2

Pallet Drawing - Side and End View

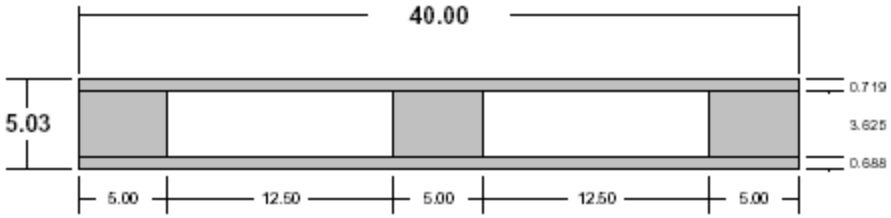
All dimensions in inches

Pallet ID: 48x40 full panel deck
Classification 48.00 x 40.00, Block-Class, Double-Face Non-Reversible, Full 4-Way, Multiple-Use, New Manufacture

Side View



End View



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PALLET DESIGN SYSTEM Version 3.2

Pallet Drawing - Top View

All dimensions in inches

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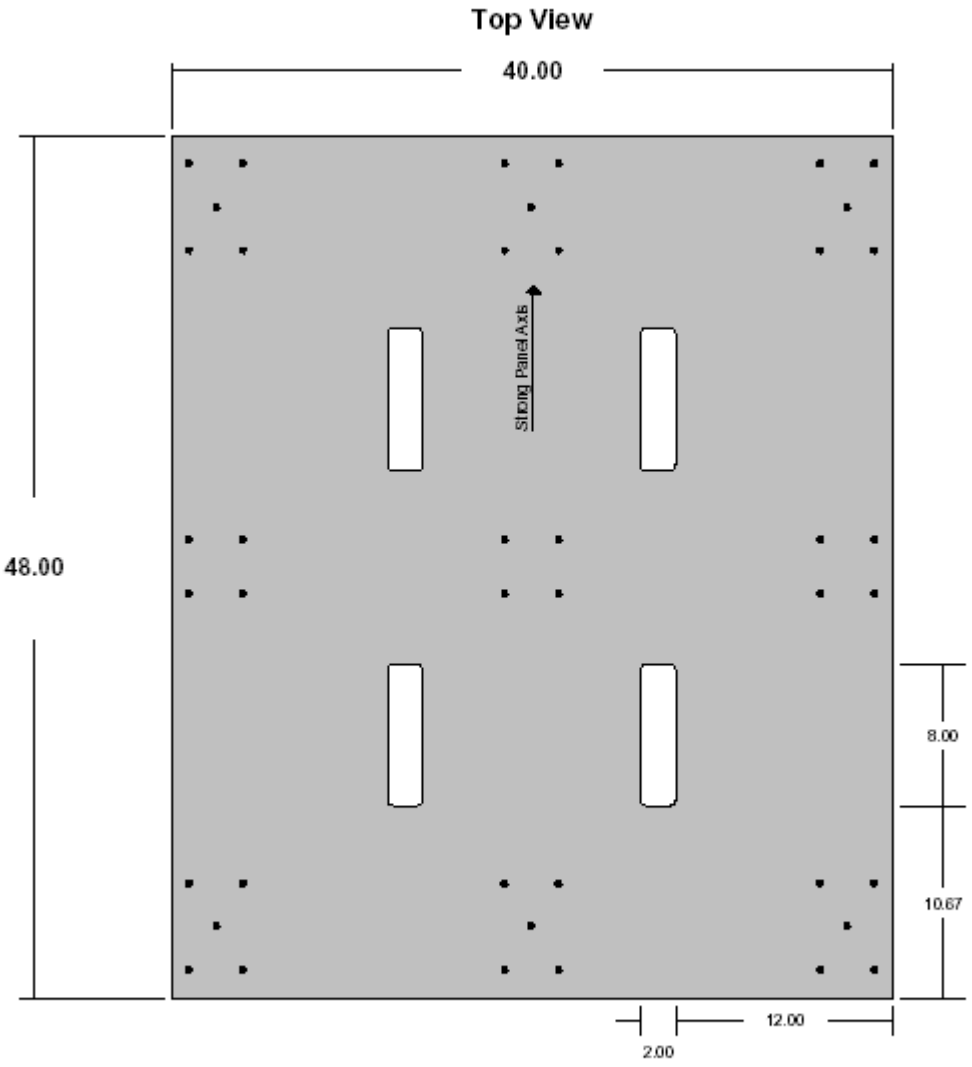

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PALLET DESIGN SYSTEM Version 3.2

Pallet Drawing - Bottom View

All dimensions in inches

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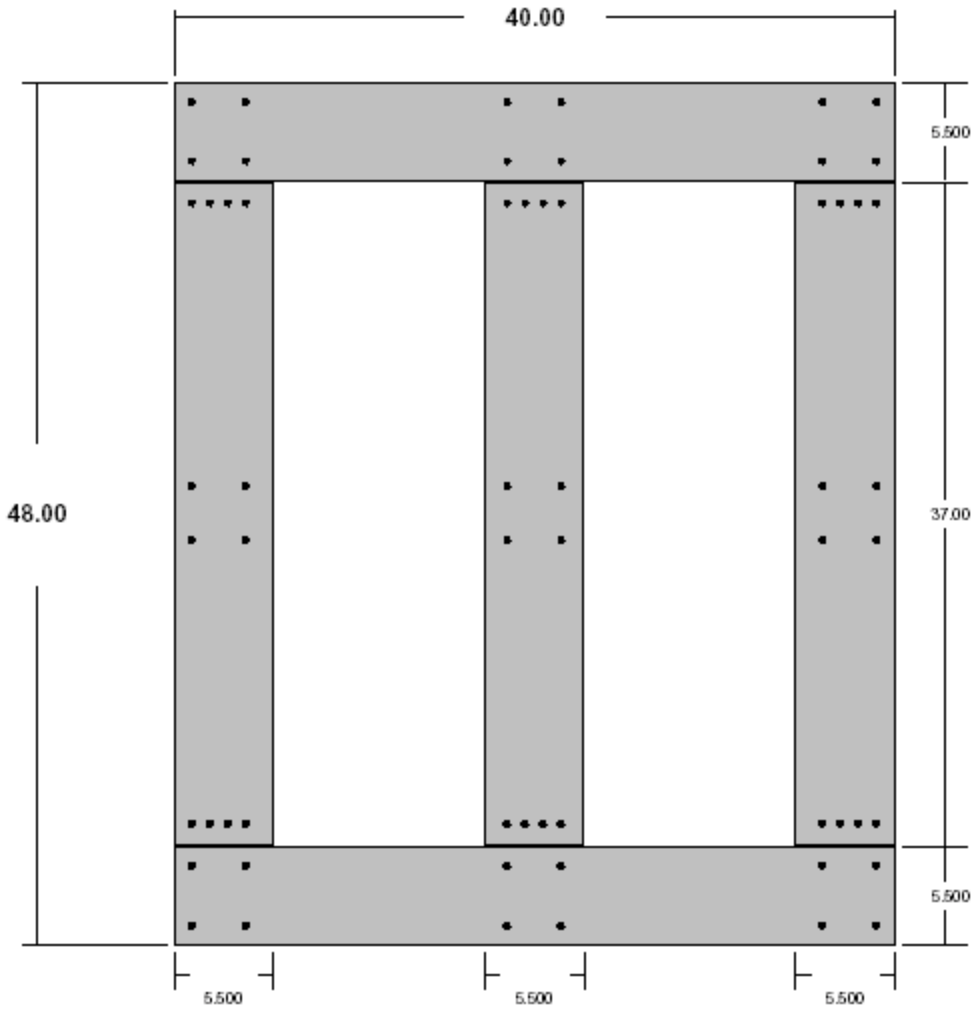
Classification: 48.00 x 40.00, Block-Class, Double-Face Non-Reversible, Full 4-Way, Multiple-Use, New Manufacture

Bottom View



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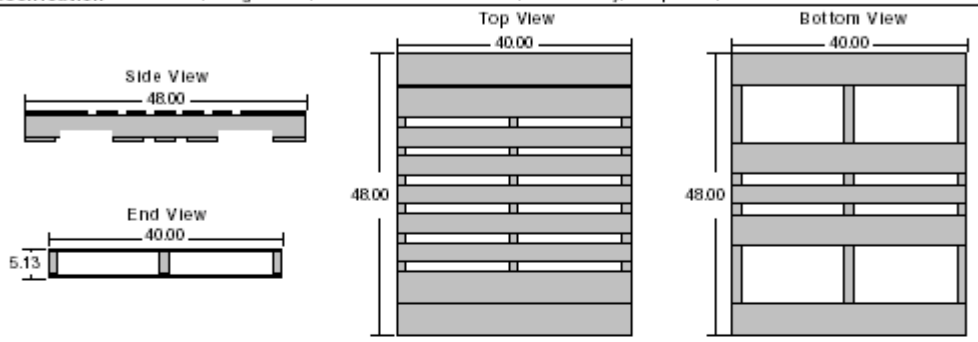
Pallet ID: Lumber/Stringer 48x40 Pallet Design
Classification 48.00 x 40.00, Stringer-Class, Double-Face Non-Reversible, Partial 4-Way, Multiple-Use, New Manufacture



Components

Top Deck:

Style: Deckboard Type: New Lumber
Thickness: 0.688 Length: 40.00 Wing: 0.00
Total Number of Deckboards 9

Number	Width	Fasteners Per Connection
4	5.500	3
5	3.500	2

Endboards Flush, Endboards Butted, Interior boards Equally Spaced
Volume: 7.5 bd ft

Bottom Deck:

Style: Deckboard Type: New Lumber
Thickness: 0.688 Length: 40.00 Wing: 0.00
Total Number of Deckboards 5

Number	Width	Fasteners Per Connection
4	5.500	3
1	3.500	2

Endboards Flush, Interior Cluster Equally Spaced
Select Bottom Deck Endboards
Volume: 4.9 bd ft

Stringers:

Type: New Lumber
Height: 3.750 Length: 48.00
Total Number of Stringers: 3

Number	Width
3	1.750

Partial 4-way Entry Notch:
Depth: 1.250 Length: 9.00 Location: 6.00 Radius: 0.50
Volume: 6.6 bd ft

Materials

Fasteners:

Fastener ID:
Fastener Type: Helically Threaded Nail
Fastener Length: 2.25
Thread Length: 1.50
Thread Diameter: 0.125
Wire Diameter: 0.113
Head Diameter: 0.281
Helixes: 8.3
Flutes: 4
Thread Angle: 61
MIBANT Angle: 21
FWI: 70
FSI: 97
Total Number: 108

New Lumber:

Select Components

Lumber ID:

Species Class	Grade	Lumber Mix
Southern Yellow Pine	Multiple-Use & BTR	100 %

Moisture Content: Kiln Dry - 19%

Standard Components

Lumber ID:

Species Class	Grade	Lumber Mix
Eastern Oaks	Multiple-Use & BTR	100 %

Moisture Content: Green

Total New Lumber Volume: 19.0 bd ft

Custom Notes and Information:

PALLET DESIGN SYSTEM Version 3.2

Pallet Drawing - Side and End View

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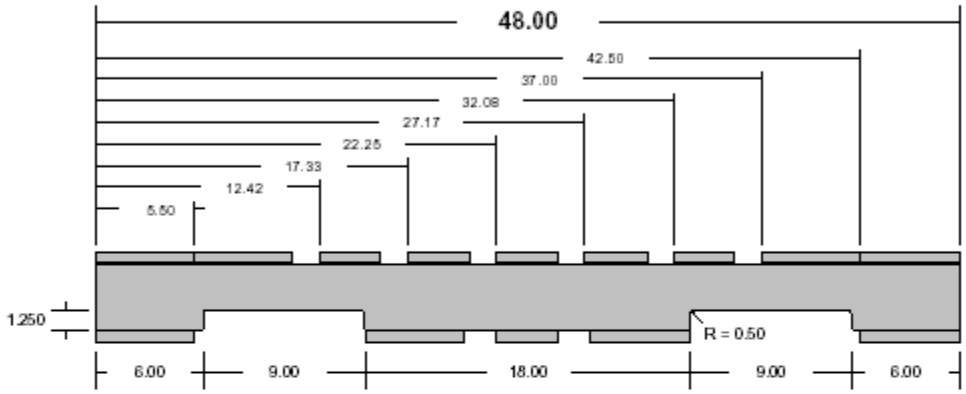
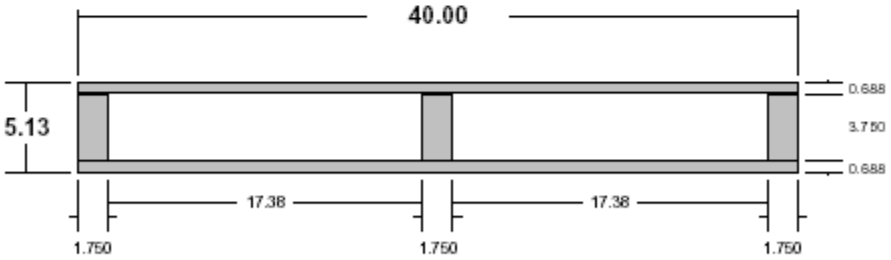
Side View



End View



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Pallet Drawing - Top View

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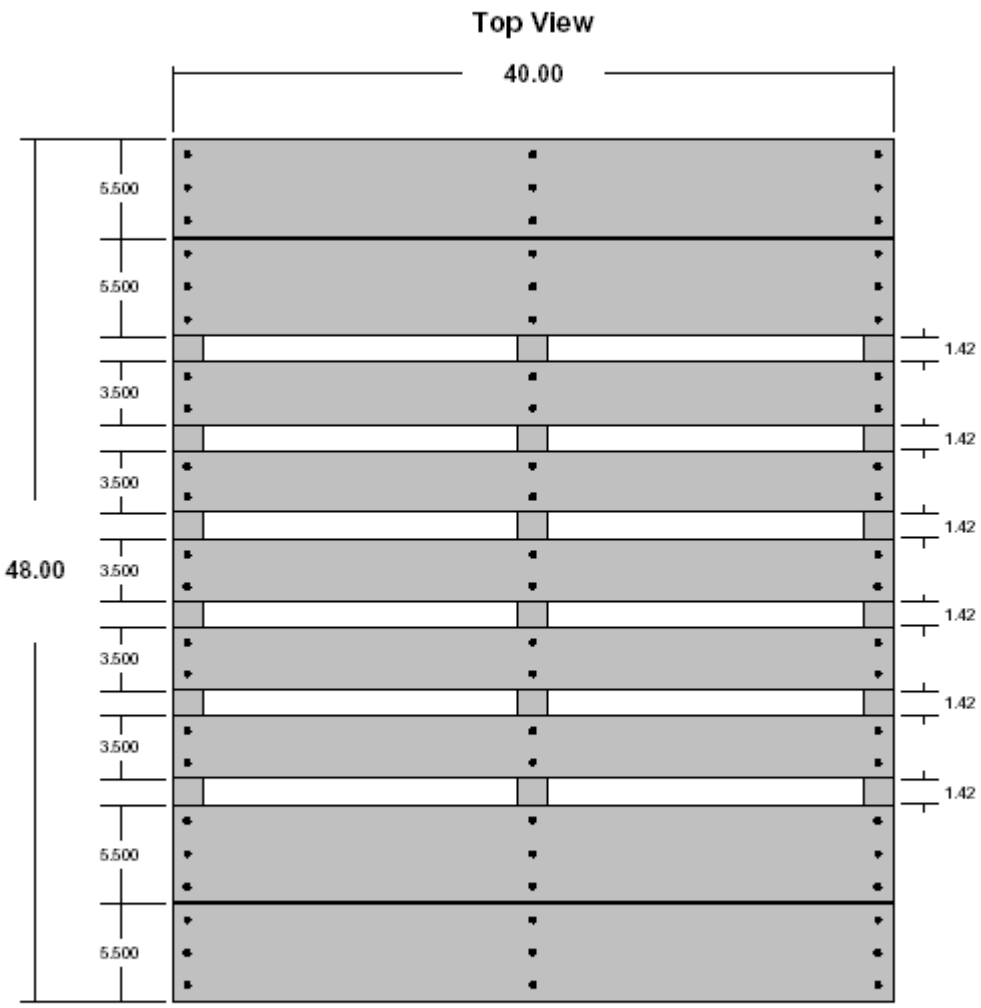

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Pallet Drawing - Bottom View

All dimensions in inches

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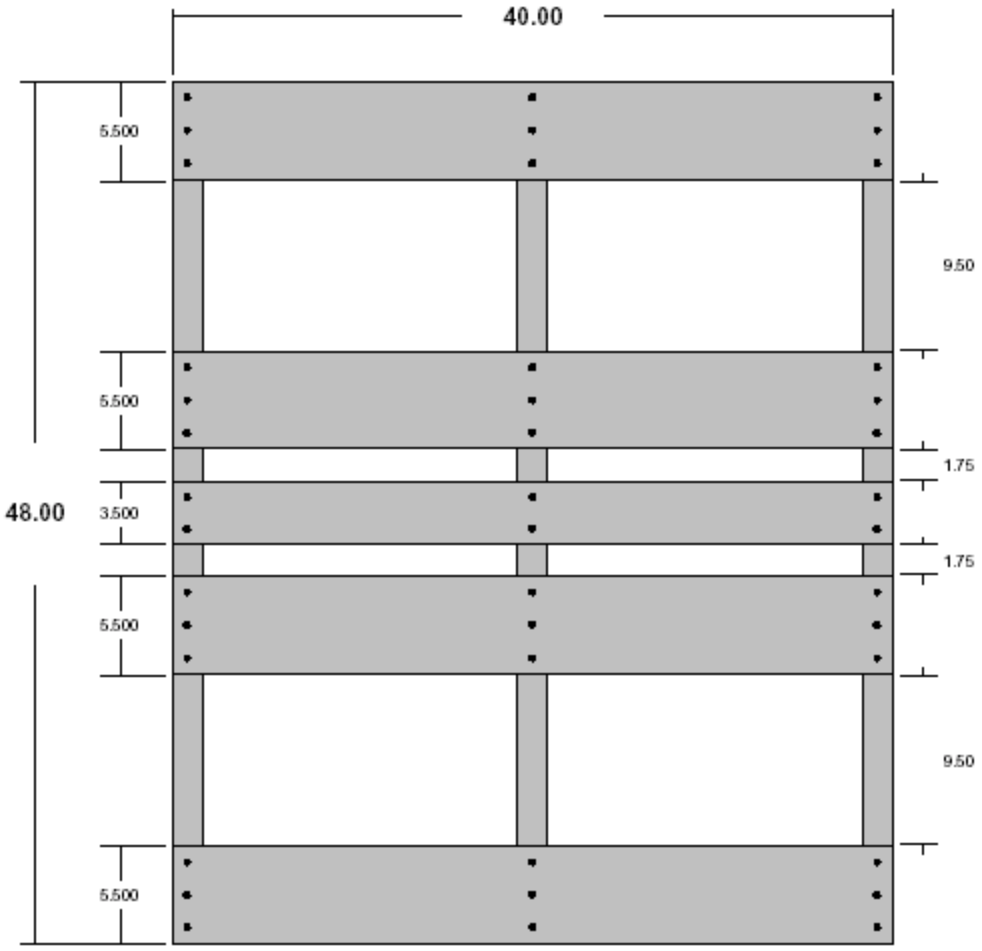
Bottom View



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