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Comparative Evaluation of the Durability of Two Pallet and Two Packaging Designs Handled using Fork Tines with and without the Sumo Glove

Test Report-No: 2017-0078

Client

Company: Sumo Glove
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Purpose of the Test

Evaluation of the durability of the block strength of a plastic and a wooden pallet design when impacted using fork tines with and without sumo glove.

Evaluation of the durability of two packaging design when impacted using fork tines with and without sumo glove.

Test Program

Custom Incline Impact Block Testing
Custom Pendulum Impact Testing

Test Period

11/01/2017-1/31/2018

Test Performed By

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Executive Summary

Effect of SUMO Glove on the Durability of Wood and Plastic Pallets

The durability of pallet design was evaluated using incline impact test on middle pallet block using a wood and a plastic pallet design. The results are presented in Figures 1-2. The kinetic energy of the individual impacts was measured to get information on the intensity of impacts experienced by the pallets. Once the pallet experienced failure, the cumulative intensity of the impacts was calculated.

The pallets tested with the fork tines protected with the SUMO Glove did not experience any failure. The test was stopped once the equipment capacity was exceeded.

It was found that even if the investigated wood pallets were impacted **13 times harder, the pallets never experienced any structural damage when the fork tine was protected with the SUMO Glove.** Similar results were found for the plastic pallets. Even after **7 times harder impacts, the plastic pallets did not experience any structural damage** when they were impacted with a fork tine protected with the SUMO Glove.

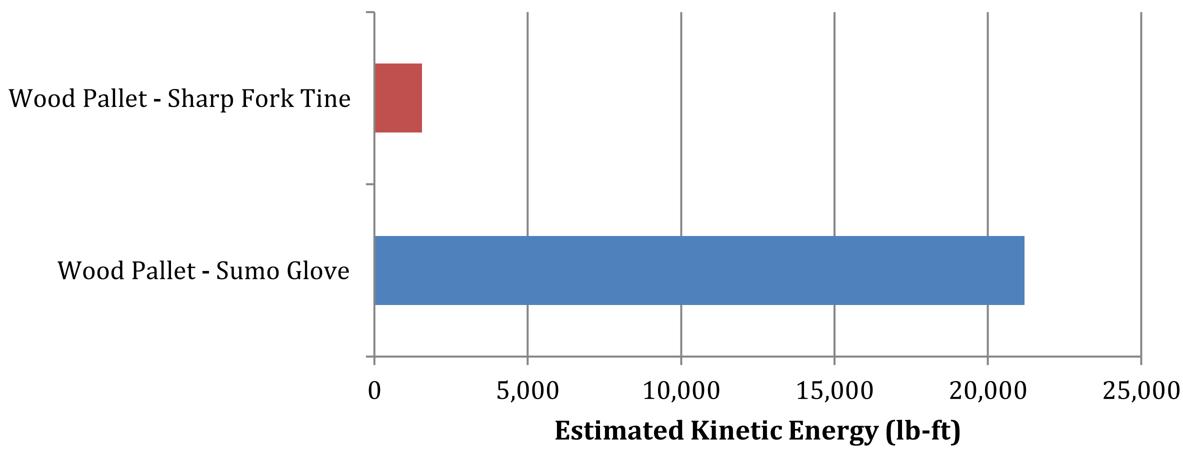

Figure 1 The estimated kinetic energy of the impact that caused the failure of the middle block on the 40 in. side of the investigated wood pallet designs. Note: The pallet did not experience any failure when it was impacted with fork tines protected with the SUMO Glove.

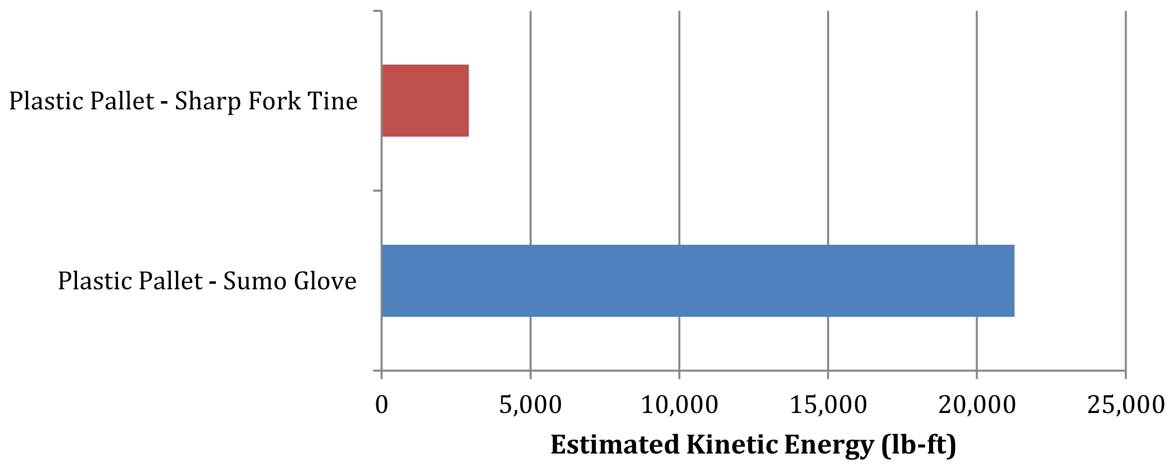

Figure 2 The estimated kinetic energy of the impact that caused the failure of the middle block on the 40 in. side of the investigated plastic pallet design. Note: The pallet did not experience any failure when it was impacted with fork tines protected with the SUMO Glove.

Effect of SUMO Glove on the Durability of Common Packages used in Unit Loads

The durability of two commonly used packaging designs was evaluated using custom pendulum impact test. During the evaluation, regular slotted container (RSC) style corrugated boxes made of single wall corrugated board and plastic bags were evaluated. Both the corrugated boxes and the plastic bags were filled with wood pellets. The results are presented in Figures 3-4. The kinetic energy of the individual impacts was measured to get information on the intensity of impacts experienced by the packages. Once the packages experienced failure, the cumulative intensity of the impacts was calculated. It was found that the corrugated boxes needed to be impacted **almost 5 times harder to cause any major structural damage.** Meanwhile, the investigated plastic pallet needed to be impacted **10 times harder to cause any major structural damage** when the fork tine was protected by Sumo Glove.

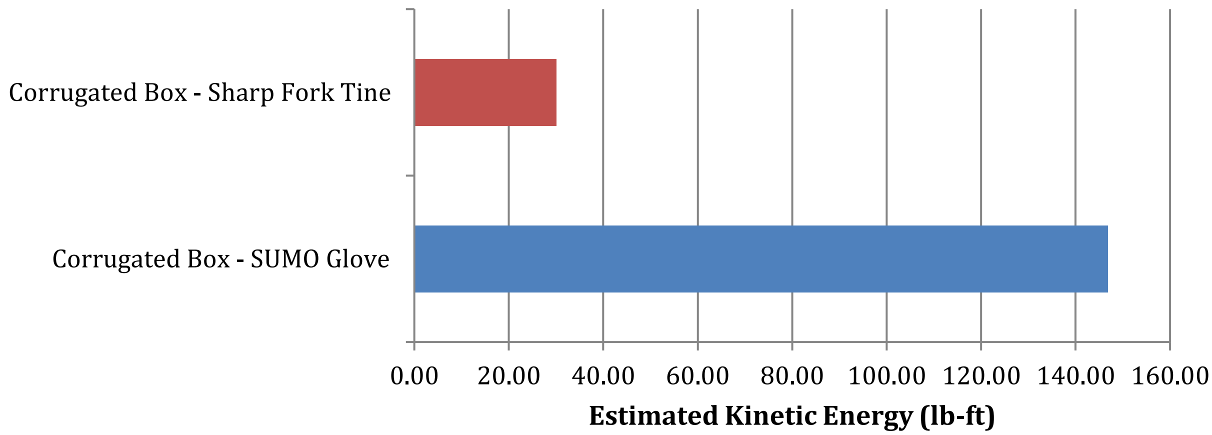

Figure 3 The estimated kinetic energy of the impact that caused the failure of the corrugated boxes stacked on the top of the pallet.

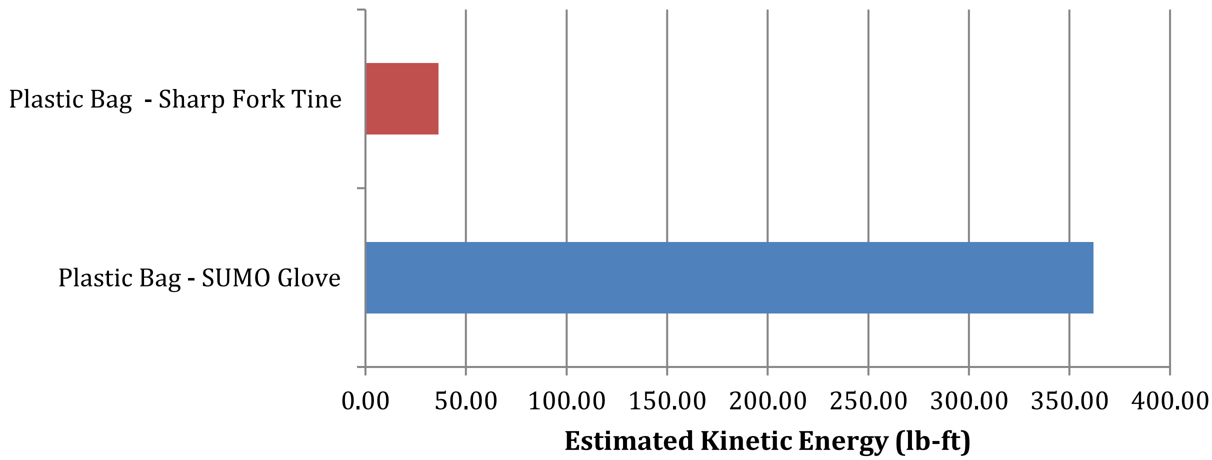

Figure 4 The estimated kinetic energy of the impact that caused the failure of the plastic bags stacked on the top of the pallet.

1. Incline Impact Test on Pallet Blocks

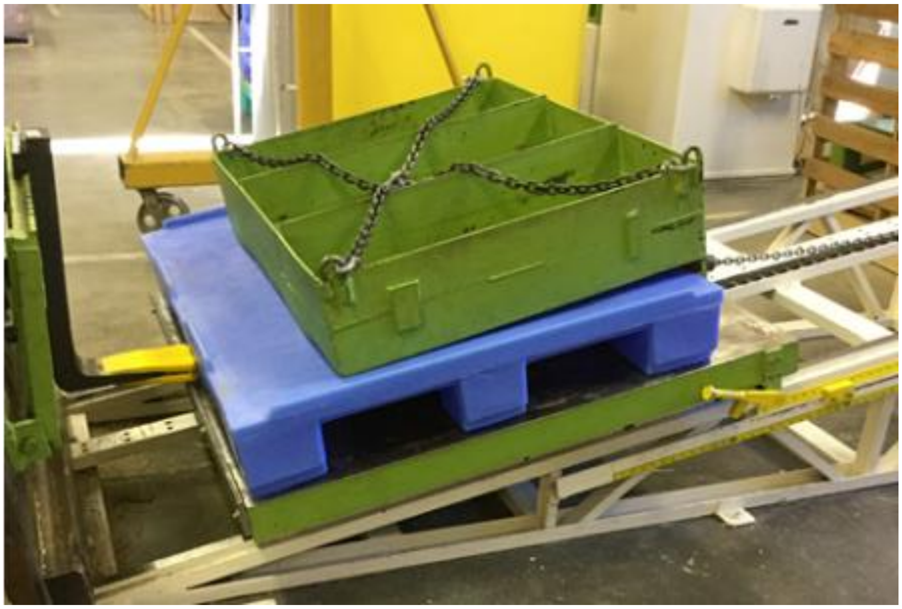

Figure 5 Experimental setup for incline impact test on 40 in. pallet blocks.

The durability of the pallet blocks were tested on the incline impact tester using a modified ISO 8611-2011 standard. The test setup is presented in Figure 5. The impacts start 6- with a 250-pound sled on top of the pallet. After 10 impacts, 450 pounds were added to the sled and another 10 impacts performed. The distance was then increased increments of 6-inches. Ten (10) impacts were repeated until significant strength reduction occurred or the usability of the pallet was compromised. The speed of the pallet was recorded and the potential kinetic energy was calculated. Three (3) samples were tested from each design.

The top and bottom view of the investigated pallet designs are presented in Figures 6-7.

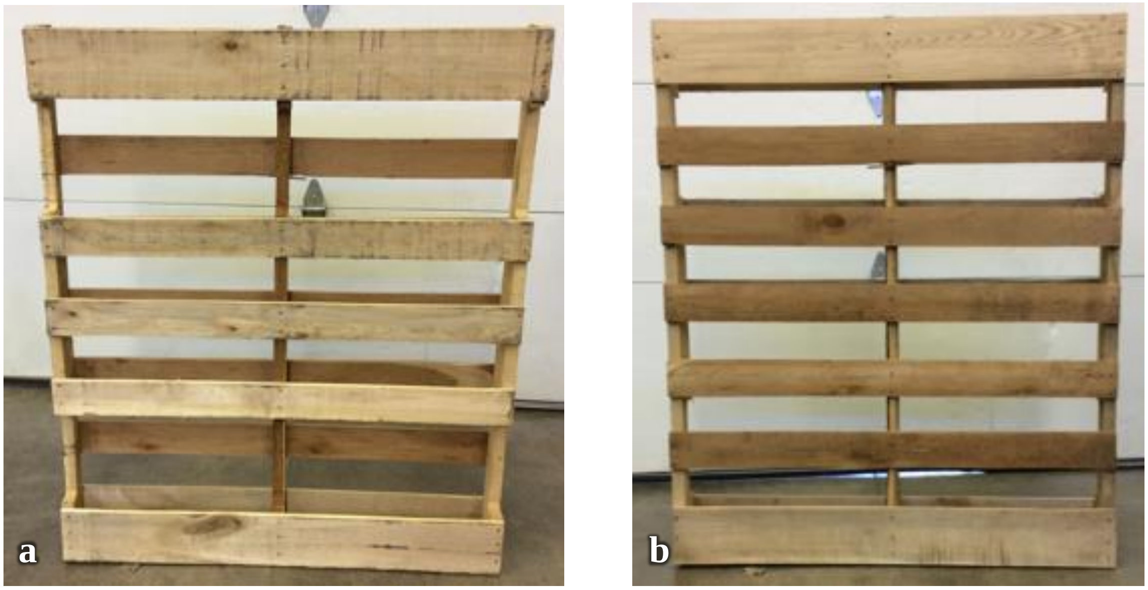

Figure 6 Top (a) and bottom (b) views of the investigated wood pallet design.

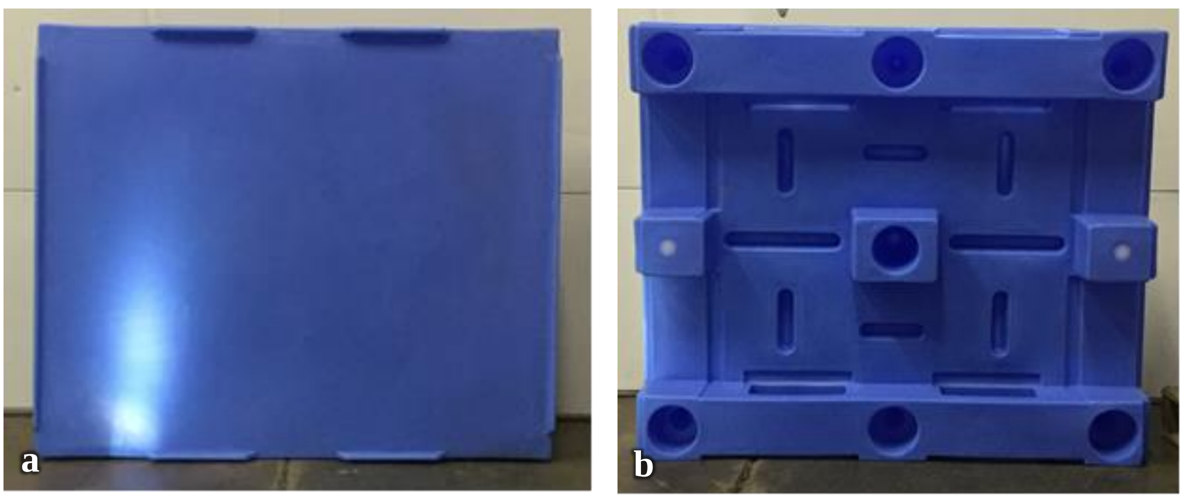

Figure 7 Top (a) and bottom (b) views of the investigated plastic pallet design.

The results for the wood pallet are presented in Table 1-3 while the results for the plastic pallet are presented in Tables 4-6. The representative modes of failure of the wood pallet design are presented in Figure 8-7 while the representative modes of failure of the plastic pallet design are presented in Figures 8-9.

Table 1 Results of incline impact resistance of middle pallet block on the 40 in. end of the wood pallet when impacted using a sharp fork tine. Std. Dev. - Standard Deviation, COV- Coefficient of Variance.

Pallet ID	Number of Impacts to Failure								
	6 in. 250lbs	**6 in. 700lbs**	**12 in. 700lbs**	**18 in. 700lbs**	**24 in. 700lbs**	**30 in. 700lbs**	**36 in. 700lbs**	**42 in. 700lbs**	**48 in. 700lbs**
Pallet 1	10	10	10	1					
Pallet 2	10	10	3	0					
Pallet 3	10	10	3	0					
Average	**10**	**10**	**5.3**	**0.3**					
Std. Dev.	**0**	**0**	**4.0**	**0.6**					
COV (%)	**0**	**0**	**76**	**173**					

Table 2 Results of incline impact resistance of middle pallet block on the 40 in. end of the wood pallet when impacted using a SUMO Glove protected fork tine. Std. Dev. - Standard Deviation, COV- Coefficient of Variance.

Pallet ID	Number of Impacts to Failure								
	6 in. 250lbs	**6 in. 700lbs**	**12 in. 700lbs**	**18 in. 700lbs**	**24 in. 700lbs**	**30 in. 700lbs**	**36 in. 700lbs**	**42 in. 700lbs**	**48 in. 700lbs**
Pallet 1	10	10	10	10	10	10	10	10	10
Pallet 2	10	10	10	10	10	10	10	10	10
Pallet 3	10	10	10	10	10	10	10	10	10
Average	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Std. Dev.	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
COV (%)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Table 3 Average estimated kinetic energy caused by the impact of the middle pallet block on the 40 in. end of the investigated wood pallet designs.

	Average Estimated Kinetic Energy (lb-ft)	**COV (%)**
Wood pallet design tested using a sharp fork tine	1,540	40
Wood pallet design tested using a SUMO Glove protected fork tine	21,186+	3

Note: The pallets impacted with the SUMO Glove did not experience any failure.

Figure 8 Representative mode of failure of the middle pallet block on the 40 in. end of the investigated wood pallet design when impacted by during sharp fork tines.

Figure 9 Representative mode of failure of the middle pallet block on the 40 in. end of the investigated wood pallet design when impacted by during SUMO Glove protected fork tines.

Table 4 Results of incline impact resistance of middle pallet block on the 40 in. end of the plastic pallet when impacted using a sharp fork tine. Std. Dev. - Standard Deviation, COV- Coefficient of Variance.

Pallet ID	Number of Impacts to Failure								
	6 in. 250lbs	**6 in. 700lbs**	**12 in. 700lbs**	**18 in. 700lbs**	**24 in. 700lbs**	**30 in. 700lbs**	**36 in. 700lbs**	**42 in. 700lbs**	**48 in. 700lbs**
Pallet 1	10	10	10	2					
Pallet 2	10	10	10	3					
Pallet 3	10	10	10	8					
Average	**10**	**10**	**10**	**4.3**					
Std. Dev.	**0**	**0**	**0**	**3.2**					
COV (%)	**0**	**0**	**0**	**74**					

Table 5 Results of incline impact resistance of middle pallet block on the 40 in. end of the plastic pallet when impacted using a SUMO Glove protected fork tine. Std. Dev. - Standard Deviation, COV- Coefficient of Variance.

Pallet ID	Number of Impacts to Failure								
	6 in. 250lbs	**6 in. 700lbs**	**12 in. 700lbs**	**18 in. 700lbs**	**24 in. 700lbs**	**30 in. 700lbs**	**36 in. 700lbs**	**42 in. 700lbs**	**48 in. 700lbs**
Pallet 1	10	10	10	10	10	10	10	10	10
Pallet 2	10	10	10	10	10	10	10	10	10
Pallet 3	10	10	10	10	10	10	10	10	10
Average	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Std. Dev.	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
COV (%)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Table 6 Average estimated kinetic energy caused by the impact of the middle pallet block on the 40 in. end of the investigated plastic pallet design.

	Average Estimated Kinetic Energy (lb-ft)	**COV (%)**
Plastic pallet design tested using a sharp fork tine	2,925	20
Plastic pallet design tested using a SUMO Glove protected fork tine	21,263+	6

Note: The pallets impacted with the SUMO Glove did not experience any failure.

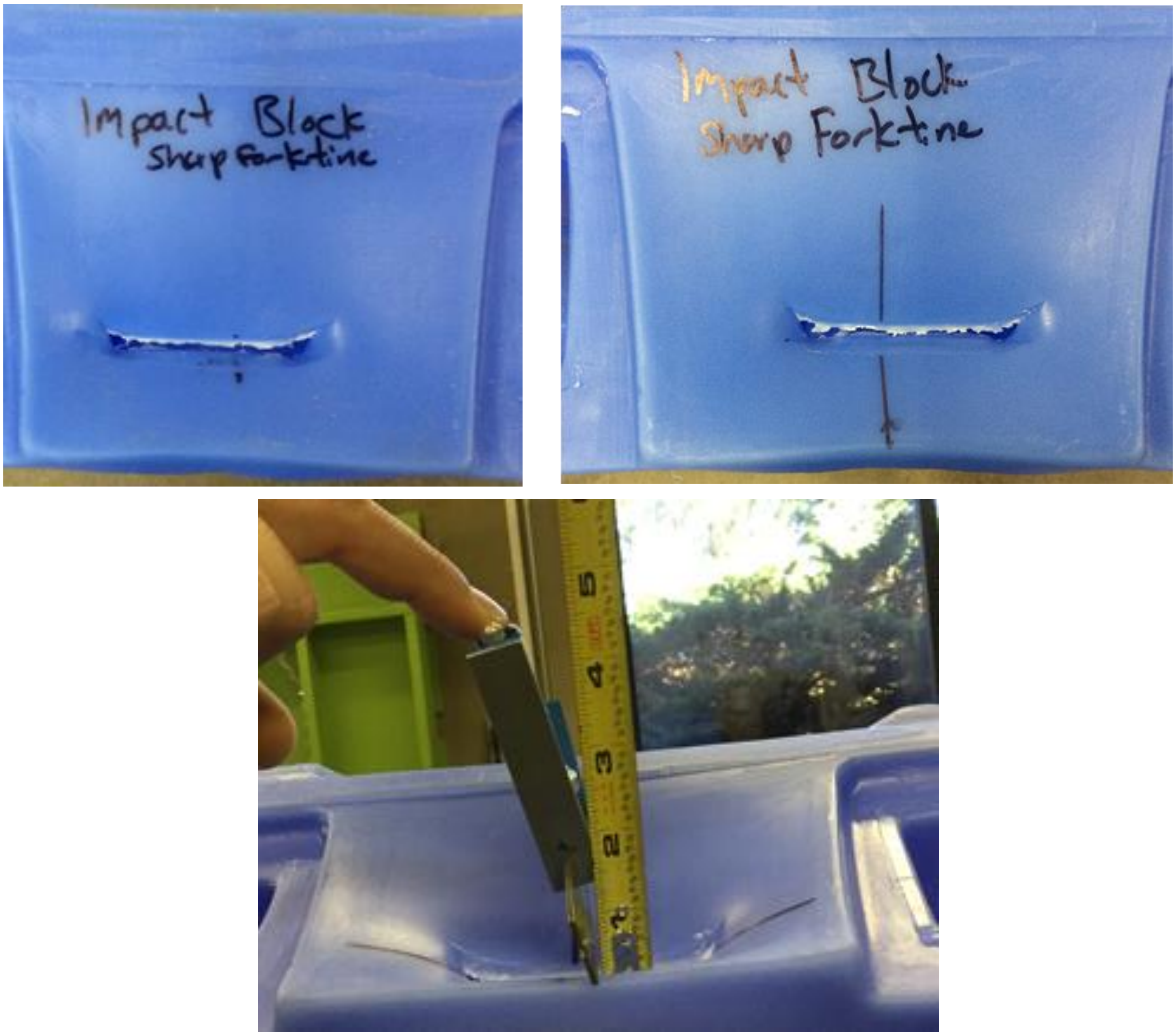

Figure 10 Representative mode of failure of the middle pallet blocks on the 40 in. end of the investigated plastic pallet design when impacted by during sharp fork tines.

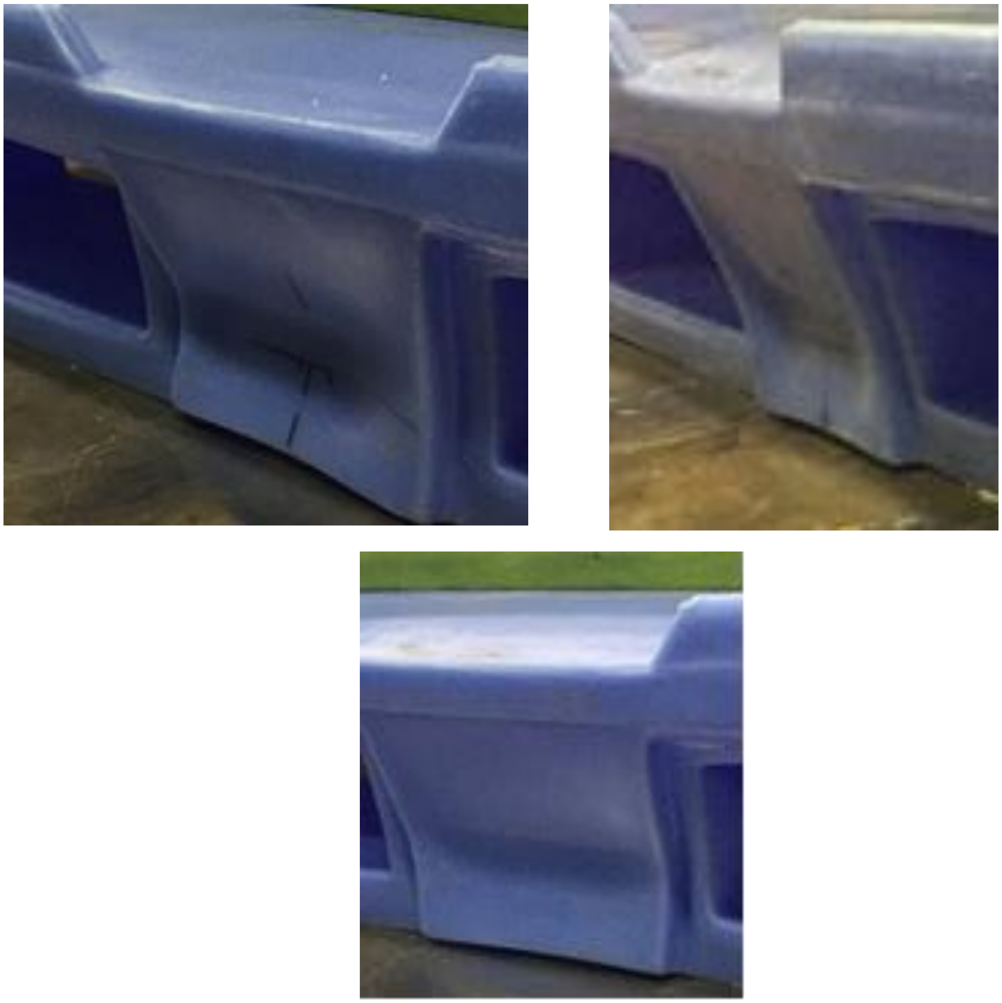

Figure 11 Representative mode of failure of the middle pallet blocks on the 40 in. end of the investigated plastic pallet design when impacted by during SUMO Glove protected fork tines.

2. Pendulum Impact Test

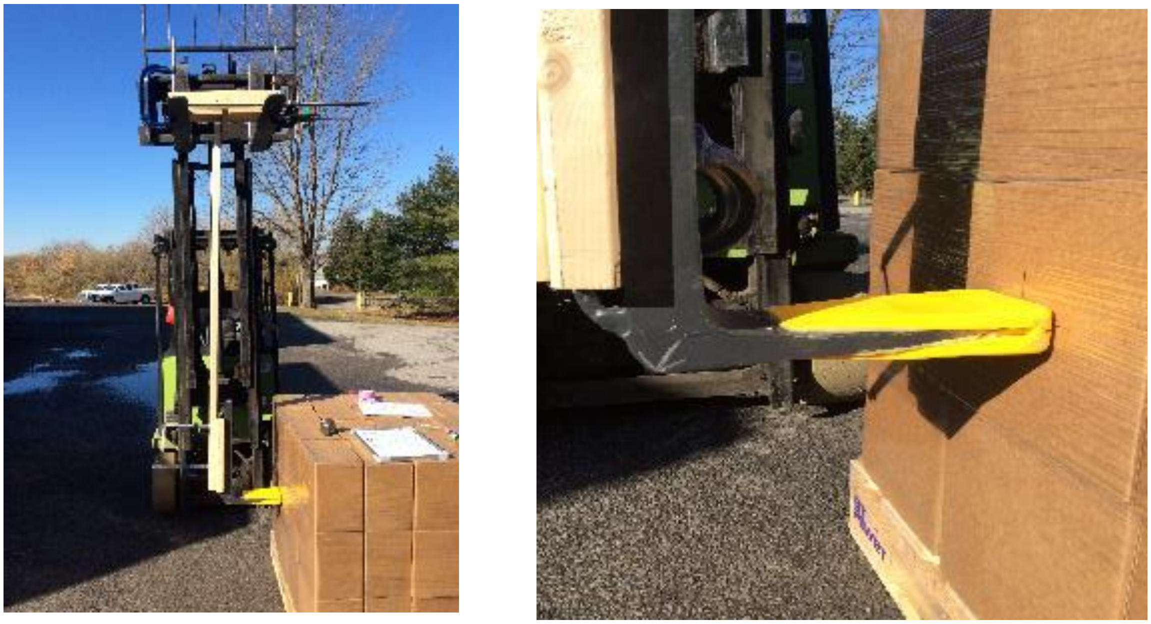

Figure 12 Experimental setup for pendulum impact test of corrugated boxes with the SUMO Glove.

The impact resistance of different packages were evaluated using a custom pendulum impact test using fork tines with and without the SUMO glove. During the test, three layers of packages were stacked on a pallet and were stretch wrapped. The center of the packages on the second layer were impacted by the fork tines. The packages evaluated included a corrugated box and a plastic bag. The corrugated box was a regular slotted container (RSC) made of 44 ECT C-flute corrugated board. The size of the box was 11.5 in. x 7.75 in. x 11.25 in. The corrugated boxes were filled with 18 lbs. of wooden pellets. Twenty corrugated boxes were included in a layer and four layers were placed on the top of each other. The overall weight of the unit load was 1,440 lbs.

The plastic bags had a 28 in. x 15.75 in. x 4 in. dimension and they were filled with 40 lbs of wooden pellets. Two plastic bags were stacked next to each other to form a layer. Overall, three layers of bags were stacked on the top of each other. The rest of the unit load was composed on nine additional 11.5 in. x 7.75 in. x 12.25 in. corrugated boxes. A 1,400 lbs rubber unit load was placed on the top of the unit load increase the overall weight of the unit load 1,802 lbs.

The kinetic energy of the impact was gradually increased until damage of the packages was observed. The following impacts sequence was conducted: 0.5 in., 1 in., 2 in., 2.5 in., 3 in., 3.5 in., 4 in., 4.5 in., 5 in., 7.5 in., 10 in., 15 in., 20 in. Three replicate tests were conducted. The effect of the SUMO glove was evaluated by comparing average kinetic energy causing failure of the package using a fork tine with and without the SUMO glove.

The results for the wood pallet are presented in 7.The representative modes of failure of the corrugated boxes are presented in Figure 13-14 while the representative modes of failure of the plastic bags are presented in Figures 15-16.

Table 7 Summary table of the pendulum impact test of the two investigated package types with and without the SUMO glove.

Package Type	Fork Tine	Average Cumulative Kinetic Energy (lb-ft)	Average Number of Impacts Until Failure
Corrugated Box	Sharp Fork Tine	30.13	4.67
	SUMO Glove	146.90	10.67
Plastic Bag	Sharp Fork Tine	36.17	5.00
	SUMO Glove	361.70	14.00

Figure 13 Representative damages of the corrugated boxes after the pendulum impact test with the sharp fork tine. The average kinetic energy causing failure was 30.13 lb-ft.

Figure 14 Representative damages of the corrugated boxes after the pendulum impact test with the SUMO Glove protected fork tine. The average kinetic energy causing failure was 140.90 lb-ft.

Figure 15 Representative damages of the plastic bags after the pendulum impact test with the sharp fork tine. The average kinetic energy causing failure was 36.17 lb-ft.

Figure 16 Representative damages of the plastic bags after the pendulum impact test with the SUMO Glove protected fork tine. The average kinetic energy causing failure was 361.70 lb-ft.

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Timing of Deliverables: Client is advised that testing cannot begin until the Scope of Statement is signed and delivered to CPULD, the required fee or down payment must be paid, and all materials to be provided by the Client are actually received at CPULD. If materials are not provided in a timely manner, the deliverables may not be completed in accordance with the time estimates provided in the Scope of Statement. From time to time, additional testing materials to be provided by the Client may be required to complete the testing, in which case completion of deliverables may be affected. As an academic research center, the demands of the academic calendar at Virginia Tech may also affect the availability of test equipment and testing personnel, which may impact delivery timetables.

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