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COMPARISON OF COMPRESSION CHARACTERISTICS OF FLAT AND SHAPED PLATENS

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Abstract

The effect of flat and shaped compression platens on cotton bale presses on the force required to compress cotton as well as the resilient force exerted by cotton bales and their resulting dimensions was investigated. Eight bales of cotton were compressed with two platen types (four bales on each) on a conventional universal density cotton bale press and evaluated. The test bales were compressed to about 19 inches of platen separation and restrained with 89-inch long bale ties; they averaged 533 pounds at a moisture content of 4.7%. Compression forces were measured initially, and bale tie forces and dimensions were monitored for 61 days. Results indicated that shaped platens require 15% more compression force than flat platens and produce 0.6-inch thicker bales but they reduce bale tie forces 18%.

Introduction

Cotton fiber is difficult to compress and that difficulty increases exponentially as the compressed density increases and as cotton moisture content decreases. Wooden and iron screw presses were used to package cotton fiber in the United States as early as 1799, and wooden screw presses were used as late as 1903 (Bennett, 1962). Prior to that time, cotton fiber was packaged in bags for shipment. Modern bale presses evolved from these early designs. Hydraulically powered bale presses are currently used in the United States to package cotton.

Ginned fiber is rather "fluffy" and has a very low density, thus in order to economically transport fiber, it must be compressed. The Joint Cotton Industry Bale Packaging Committee establishes suggested practices for packaging cotton in terms of density (about 28 lbs/ft^3), bale ties, and bale coverings (Anthony, et al. 1994). To achieve this final density, presses require over 750,000 pounds of compression force in order to compress the cotton to a density of about 40 lbs/ft^3 in a press box with cross-sectional dimensions of about 20 inches by 54 inches. The bale is restrained with six or eight bale ties, wire or steel/plastic straps that are 86 to 89 inches long. These tie lengths and press box dimensions produce bales that are about 21 by 55 by 30 inches when measured at the tie. Since the ties are spaced several inches apart, the unrestrained fiber protrudes above the ties and creates a "hump" between the ties. This dimension is referred to as the "thickness" of the bale. The 30-inch dimension is a function of the tie length as well as the shape of the platen surface that preforms the bale.

The resilient force exerted by cotton is primarily a function of compression density, fiber moisture, and restraint density although the distribution of the fiber in the press can also play a major role (Anthony, 1997). In fact, the force exerted on each of the six or eight ties differs substantially because the amount of cotton restrained by each tie differs. Typically, the cotton is pressed between two rectangular platens that have flat surfaces, or the platens have raised sections on the two longer outside sides to prevent the fiber from interfering with placement of bale ties. These raised sections are used because the platen must move vertically within the press box, thus clearance is required on all sides. If this clearance is excessive, then cotton fiber may overlap the platen and cover the area where the bale tie must be inserted. Excessive clearance is also a problem on older presses that were designed for jute and burlap bagging to be wrapped around the platen before the fiber was added. Currently, bale coverings are applied in the United States after the bale is removed from the press. The raised edges on the shaped platens prevent this fiber overlap problem. The impact of these different platen shapes on bale compressive and resilient characteristics as well as their impact on bale dimensions has not been reported.

In addition, Anthony (1998, 2000) developed an irregularly shaped platen that uses raised sections placed perpendicular to the long sides of the platen which reduced required compression forces about 20% and maintained resilient forces at the same level. For this platen, bales were initially about 0.75 inches larger in the 30-inch direction (compared to bales pressed with a flat platen) but were the same dimension after several days of storage.

As the cotton industry strives to improve the packaged bale for domestic and international shipment and subsequent use, additional knowledge of the complexity of bale packaging is required.

Purpose

The purpose of this research was to determine if 1) additional compression force is required for shaped platens as compared to a flat platen, 2) resilient forces for bales packaged with the two types of platens differed, and 3) the outside thickness of the bales differed.

Materials and Methods

The dual-box, Continental Bespress® located in Building 21 at the U.S. Cotton Ginning Laboratory was used for this study. The standard press is powered by three 12-inch diameter cylinders that apply force to a platen that compresses the cotton against a stationary platen. The outside edges of the standard platen are turned upward with a 1.625-inch high by 2.25-inch triangular-shaped raised area on each of the longer sides (Figure 1). These "shaped" platens are used to pre-form the bale slightly, and prevent the cotton from interfering with the insertion of the bale ties. This is true for both the upper and lower platens, although the raised sections are smaller for the upper platen. In order to convert the standard shaped platen to a flat platen, wooden inserts were constructed to counter the height of the shaped section of the platen (Figure 2) in one box, and to make the platen appear flat when the wood was installed on the top and bottom platens. By stopping the same at a different point, the final platen separation of the flat platen and shaped platens was held the same for the flat portion of the platens.

Eight bales of cotton of the same variety were randomly ginned and compressed to a platen separation of 19 inches; four for each of the two types of platens. The average bale weight was targeted at 525 pounds rather than 500 pounds in order to ensure that the upper weight limit of the bales being compressed by the ginning industry was considered. As the bales were compressed, the platen separation was measured as well as the hydraulic pressure being exerted by the three 12-inch diameter hydraulic cylinders. The hydraulic pressure was then converted to force and used for the analysis.

In addition, one strain gauge-type transducer was installed on the number 5 bale tie of each bale of cotton immediately before it was taken out of the press. The transducers (Figure 3) were installed in line in the tie by removing a section of the tie of the same length (2.75 inches) that the transducer occupied when installed in the tie. Each transducer was equipped with 0.75-inch diameter bolts on each side that had a hole drilled through the center and parallel to the length of the bolt. The bale tie wire was held in the transducer bolt with setscrews installed in the side of the bolt that had the hole drilled in the center. The transducers were connected to a notebook computer and data collected as soon as the bale was removed from the press. Bales were added to the test about every 15 minutes due to the ginning rate and transducer application time requirements. Unfortunately, the setscrews allowed the tie to slip slightly from the bolts for bales 1 and 2 shortly after the bales were ginned, necessitating replacement of those two bales. Subsequent ties were indented to help the setscrews hold the wire ties in place. Two replacement bales were ginned the following morning using cotton from the same trailer as the day before; however, the humidity was higher than it had been the afternoon before, thus the bale moisture content was higher for those two bales. This was not considered to be a problem because four replications were used.

During storage (which began May 21, 2001 and ended August 3, 2001), the thickness of the bales was measured at each of the seven humps between the ties using the device as shown in Figure 4. Thickness was measured after 3, 8, 16, 24, 37 and 59 days of storage.

The bales were stored without any bagging (naked) in Building 21 (Figure 5). Thus the bales were allowed to adjust to ambient humidity and temperature during the storage period. The bales obviously changed their moisture content during storage but the bales were only weighed before storage and after storage. The bales were not weighed on a daily basis because of concern that movement of the bales might change the bale tie force distribution.

Results

The data collected during the initial bale-packaging phase of the study is shown in Table 1. All of the 10 bales that were ginned for this study are reported in Table 1 because the data is correct up until the wire slipped slightly in the transducers. For the initial eight bales in this study, moisture content averaged about 4.7% and ranged from 4.3% to 4.9%. Moisture content for the two replacement bales was 5.6% and 5.4% (bale numbers 886 and 887). Initial bale weights ranged from 512 to 561 lbs. Initial ram pressures varied from 2150 psi to 2950 psi (maximum available), resulting in compression forces of 728,850 to over 1,000,000 lbs. Compression densities ranged from 45.3 lbs/ft^3 to 47.4 lbs/ft^3. Compression force for the first 8 bales (not shown) was significant for type of platen with the shaped platens requiring considerably more force to compress the bale (995,812 lbs) than the flat platens (864,450 lbs). At the same platen separation in the center of the platen, the volume between the shaped platens is less, thus the density is higher thereby requiring greater compressive force.

Bale Tie Force (Tension)
The bale tie force in the one tie that was measured per bale was significantly different for type of platen and day of storage, as well as the interaction between type of platen and day of storage (Table 2). The interaction suggested that the rate of force increased with time differed for the platen types. The average initial bale tie force for the first 8 bales was 1264 lbs and 873 lbs, respectively, for the flat and shaped platens. After 3 days of storage, bale tie forces were 1409 lbs and 1003 lbs, respectively, for the flat and shaped platens (last 8 bales) (Table 3). After 61 days of storage, these numbers increased to 1868 and 1532 lbs, respectively, for the flat and shaped platens. The shaped platen had 29% lower tie forces at day 3 and 18% lower forces at day 61. The study was terminated on day 61 before this decreasing trend was stabilized. The average bale tie force is plotted as a function of time in Figure 6 for both types of platens. During the storage period, the wire slipped from the transducer on three additional bales, with one bale tie slipping 0.75 inches, and the others slipping from 0.03 to 0.09 inches. Apparently the force in the bale tie exceeded the ability of the setscrews to hold the tie for these three bales just as it did for the first two bales. This was likely caused by the flattened wire that was used in the study being considerably harder than the wire used previously, which prevented the setscrew from indenting the wire. Analysis of variance (Table 2) indicated that all sources of variation were significant. Regression analysis of tension (bale tie force) versus day of storage for each bale (Table 4) was significant (0.0001) and the R-square ranged from 0.31 to 0.95.

When data from the bales that were inconsistent due to moisture, weight or slippage problems was disregarded, initial tie force was 876 and 617 pounds for the flat and shaped platens, respectively (a 30% reduction). Similarly for compression force, 839,025 and 991,575 lbs were required for the flat and shaped platens, respectively (an 18% increase). Thus, bale tie force was higher for the flat platens but the compression force was lower.

Bale Thickness
Bale thickness at the hump was significantly different for type of platen and for day of storage, but their interaction was not significant (Table 5). After 59 days of storage, the average bale thickness at the hump was 32.2 and 32.8 inches for the flat and shaped platens, respectively. Bale thickness at the hump increased 0.66 and 0.79 inches, respectively, for the flat and shaped platens over the 59-day storage period. The thickness of each bale at the hump is given in Table 6, and the comparative plot of thickness versus day of storage is shown in Figure 7.

Summary and Conclusions

The purpose of this research was to determine if 1) additional compression force is required for shaped platens as compared to flat platens, 2) resilient forces for bales packaged with the two types of platens differed, and 3) the outside thickness of the bales differed. A Continental BesPress® at the U.S. Cotton Ginning Laboratory equipped with platens that had the outside edges turned upward was used in the study. For comparison, a flat platen was constructed by installing wooden inserts to counter the height of the shaped section of the standard platen. Eight bales of cotton of the same variety were ginned and compressed to a platen separation of 19 inches. As the bales were compressed, the platen separation was measured as well as the hydraulic pressure being exerted by the three 12-inch diameter hydraulic cylinders. Strain gauge-type transducers were installed on the number 5 bale tie of each bale as it was taken out of the press.

During storage, the thickness of the bales was measured at each of the seven humps between the ties. Thickness was measured after 3, 8, 16, 24, 37 and 59 days of storage. The bales were stored without any bagging and allowed to adjust to ambient humidity and temperature during the storage period. The bales were weighed before storage and after storage, and were not weighed on a daily basis to avoid problems with the transducers.

Moisture content averaged about 4.7% and ranged from 4.3% to 4.9%; initial bale weights ranged from 512 to 561 lbs.; compression forces ranged from 728,850 to over 1,000,000 lbs.; and compression densities ranged from 45.3 lbs/ft^3 to 47.4 lbs/ft^3. Compression forces were 995,812 lbs and 864,450 lbs for the shaped and flat platens, respectively. After 3 days of storage, bale tie forces were 1409 lbs and 1003 lbs, respectively, for the flat and shaped platens. After 61 days of storage, these numbers increased to 1868 and 1532 lbs, respectively, for the flat and shaped platens. The shaped platen had 29% lower tie forces at day 3 and 18% lower forces at day 61. Thus, bale tie force is higher for the flat platens but the compression force is lower.

The bale thickness at the hump was significantly different for type of platen and for day of storage and the interaction between those two was not significant. The final bale thickness at the hump was 32.2 and 32.6 inches for the flat and shaped platens, respectively. On average, the bale thickness at the hump increased 0.75 inches during the 61-day storage period.

Recommendations

The findings that shaped platens require more compression force, reduce bale tie forces, and produce thicker bales should be used in future decisions concerning cotton bale packaging.

Disclaimer

References

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Bennett, Charles A. 1962. Cotton ginning systems in the United States and auxiliary developments. The Cotton Ginners Journal and the Cotton Gin and Oil Mill Press, Dallas, Texas. pp. 1-18.

Table 1. Initial test conditions for bales ginned May 21, 2001 and stored until August 3, 2001.

		Bale weight (net), lbs		Force, lbs		Platen separation, in.	Hump thickness, in.	Lint moisture, %	Density, lb/ft^3
Bale number	**Platen**	**Initial**	**Final**	**Tie**	**Press**				
878*	Flat	534	534.0	845	830,550	19.00	31.00	4.86	47.2
879*	Flat	530	530.0	906	847,500	19.00	31.00	4.52	46.9
882	Flat	512	525.4	853	779,700	19.00	30.50	4.59	45.3
883*	Flat	561	574.4	1079	1,000,050	19.00	30.50	4.41	49.6
886	Flat	536	543.4	891	779,700	19.00	.	5.58	47.4
887	Flat	527	535.4	919	728,850	19.00	.	5.43	46.6
880*	Shaped	535	546.4	661	1,000,050	19.00	31.00	4.31	47.3
881	Shaped	524	535.4	572	983,100	19.00	31.00	4.72	46.4
884*	Shaped	543	557.4	946	1,000,050	20.00	31.00	4.47	45.6
885	Shaped	532	545.4	700	1,000,050	19.25	30.75	4.35	46.5

*Slipped at transducer connection.

Table 2. Analysis of variance for bale tie force as a function of day of storage[1].

Source of Variation	Mean square for Tension	P>F
Platen	211429380	0.0001
Day	56510851	0.0001
Platen * Day	306545	0.0001
Error	620	

[1] All 10 bales used, including the two that had tie slippage.

Table 3. Summary data for bale tie force as a function of day of storage for two types of platens.

Day of storage	Tension, pounds, for platen type Flat	Shaped
0	1264	873
1	1358	951
2	1394	983
3	1409	1003
4	1429	1016
5	1455	1044
7	1479	1127
8	1470	1151
9	1532	1190
11	1553	1204
16	1662	1334
17	1678	1346
18	1691	1364
19	1699	1372
20	1690	1368
21	1695	1363
22	1714	1375
23	1724	1381
24	1739	1404
25	1744	1413
26	1736	1403
27	1701	1373
28	1690	1362
29	1668	1344
30	1665	1343
31	1700	1367
32	1707	1370
33	1675	1345
34	1673	1344
35	1664	1339
36	1670	1340
37	1701	1364
38	1737	1394
50	1847	1513
57	1877	1527
58	1877	1525
59	1879	1529
60	1885	1536
61	1868	1532

Table 4. Regression analyses of the bale tie force for each bale for all storage times.

Variable[1]	Intercept	Coefficient (slope)	R-square	Root mean square error	P>F
Tension (mean)	1163	0.40	0.31	20.6	0.0001
Tension 878	1152	0.18	0.89	22.7	0.0001
Tension 879	1108	0.21	0.52	71.9	0.0001
Tension 882	1111	0.30	0.94	27.3	0.0001
Tension 883	1372	0.37	0.92	37.4	0.0001
Tension 880	903	0.08	0.31	42.0	0.0001
Tension 881	808	0.37	0.94	31.0	0.0001
Tension 884	1185	0.44	0.95	33.5	0.0001
Tension 885	963	0.42	0.94	37.1	0.0001

[1] Number refers to bale numbers in Table 1.

Table 5. Analysis of variance for thickness at the bale hump.

Source of variation[1]	Mean squares for hump							
	Average	1	2	3	4	5	6	7
Platen	2.94**	4.89**	3.73**	1.23**	1.57**	4.81**	1.71**	3.98**
Day	0.54**	0.34**	0.45**	0.55**	0.67**	0.87**	0.52**	0.48**
Platen * Day	0.05ns	0.071ns	0.040ns	0.02ns	0.014ns	0.004ns	0.009ns	0.03ns
Error	0.017	0.060	0.057	0.040	0.051	0.029	0.057	0.050

[1] Degrees of freedom were 1, 5, 5 and 36, respectively, for Platen, Day, Platen * Day and Error.
** Indicates significance at the 1% level of probability.
ns Indicates lack of significance at the 5% level of probability.

Table 6. Thickness of the bale at each hump as a function of day of storage.

		Thickness at hump, inches							
Treatment	Day	Average	1	2	3	4	5	6	7
Flat	3	31.54	31.78	31.58	31.58	31.63	31.08	31.56	31.56
Flat	8	31.77	31.80	31.64	31.77	31.91	31.48	31.86	31.97
Flat	16	31.98	32.09	31.88	32.00	32.06	31.69	32.06	32.11
Flat	24	32.05	32.06	31.94	32.08	32.30	31.77	32.06	32.17
Flat	37	32.12	32.22	32.03	32.19	32.28	31.83	32.09	32.22
Flat	59	32.20	32.25	32.02	32.16	32.33	32.05	32.22	32.38
Shaped	3	31.98	32.19	31.92	31.81	31.89	31.73	31.91	32.41
Shaped	8	32.29	32.73	32.23	32.11	32.31	32.09	32.19	32.38
Shaped	16	32.48	32.67	32.47	32.34	32.53	32.33	32.38	32.63
Shaped	24	32.56	32.83	32.55	32.31	32.63	32.47	32.45	32.72
Shaped	37	32.56	32.73	32.48	32.48	32.56	32.41	32.48	32.75
Shaped	59	32.77	32.88	32.77	32.63	32.75	32.66	32.72	32.98

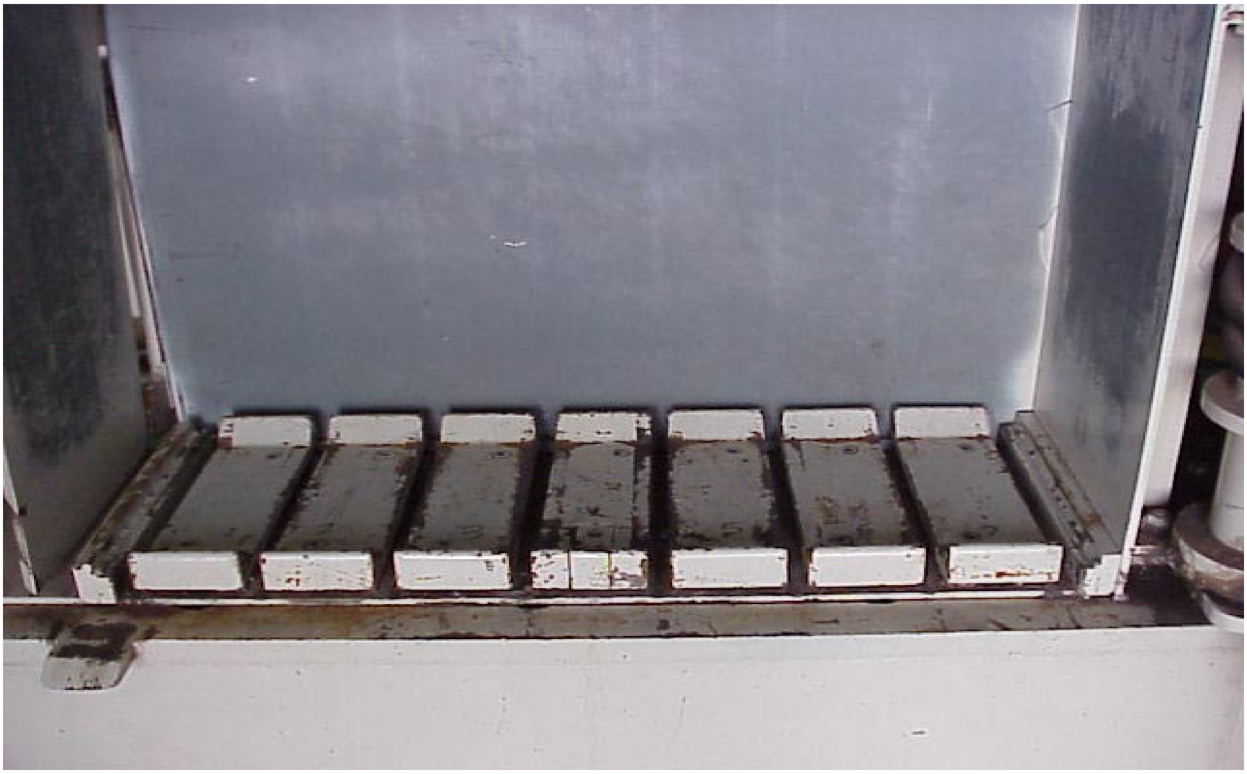

Figure 1. Standard (shaped) bottom platen for Continental Bespress®. Note the "raised area" (1.625 by 2.25 inches) on each side that pre-form bales to make it easier to install bale ties.

Figure 2. Wooden inserts installed on the shaped platen to make it flat.

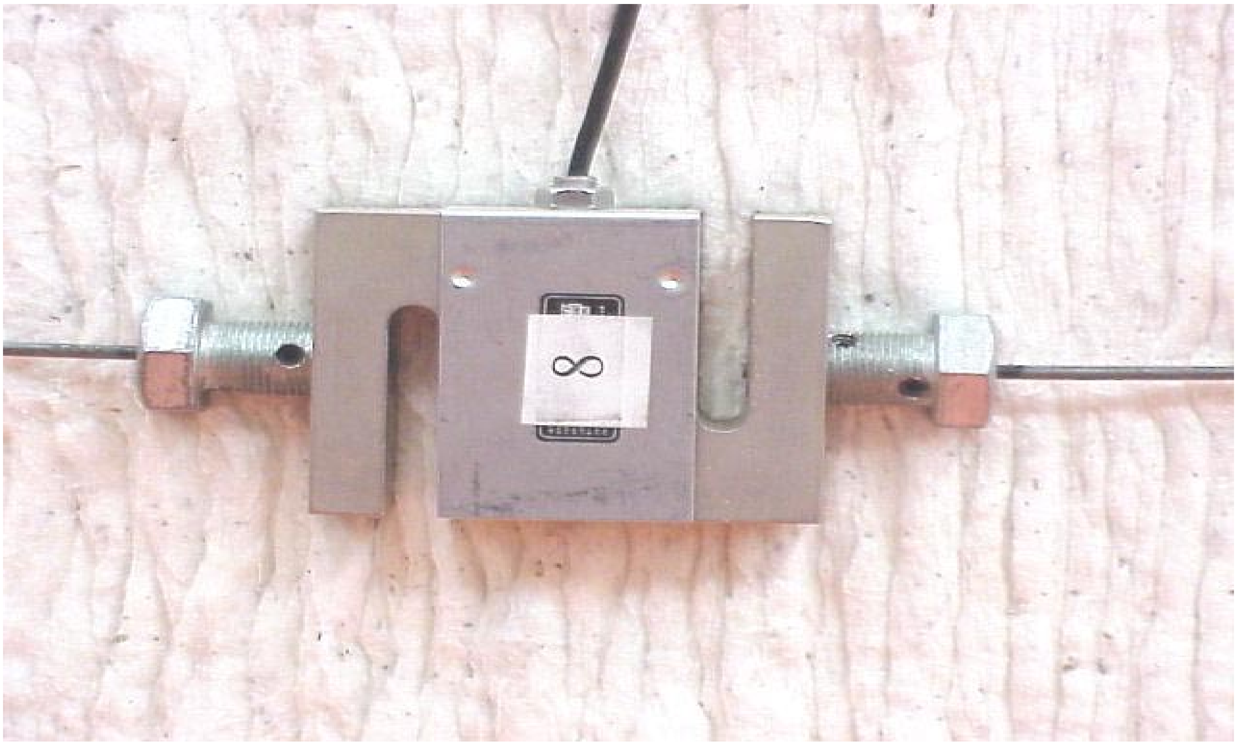

Figure 3. Transducer installed in tie number 5.

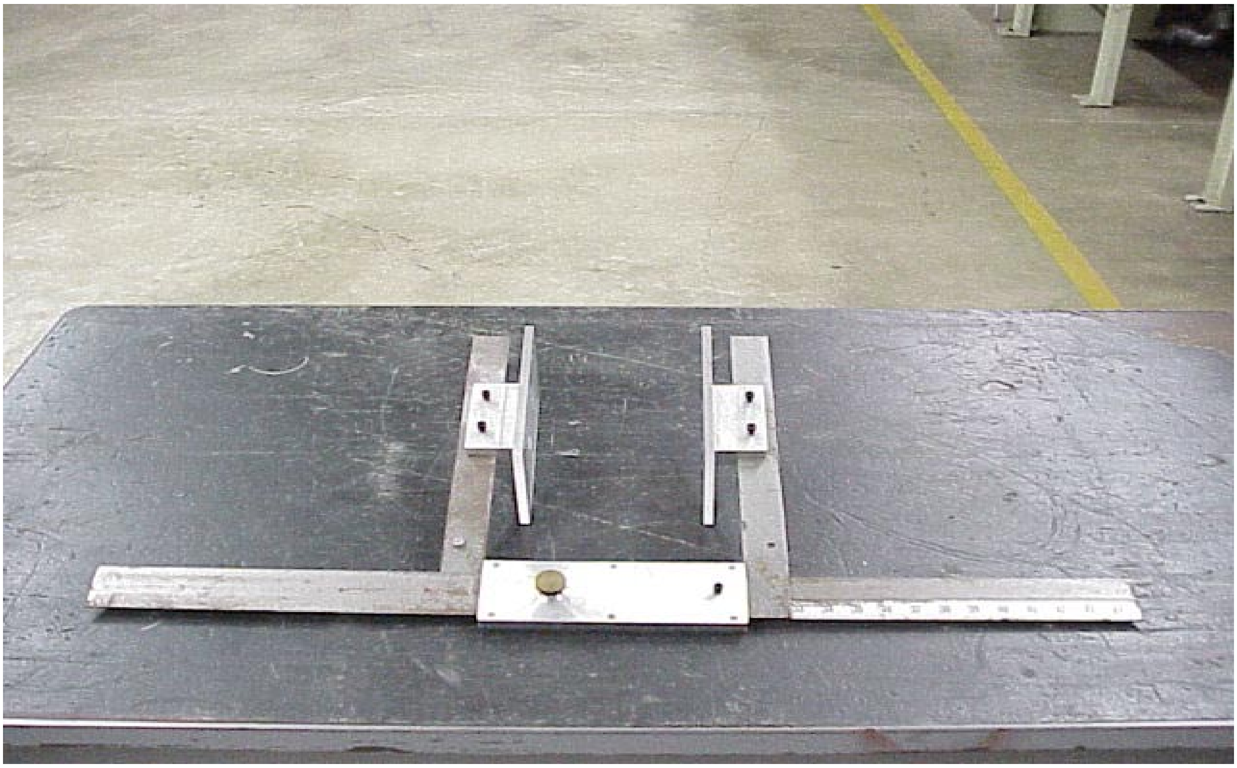

Figure 4. Two carpenters squares were joined together using a sliding mechanism with setscrews and wide flanges were added to help measure the thickness at the hump.

Figure 5. Bales stored in Building 21.

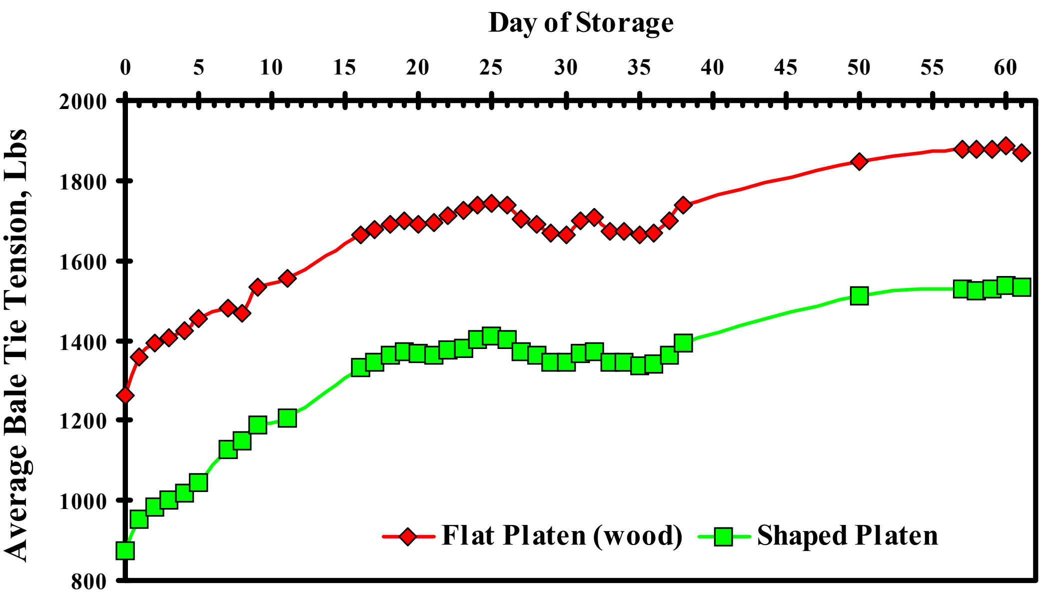

Figure 6. Average bale tie tension for all bales by platen type and day of storage.

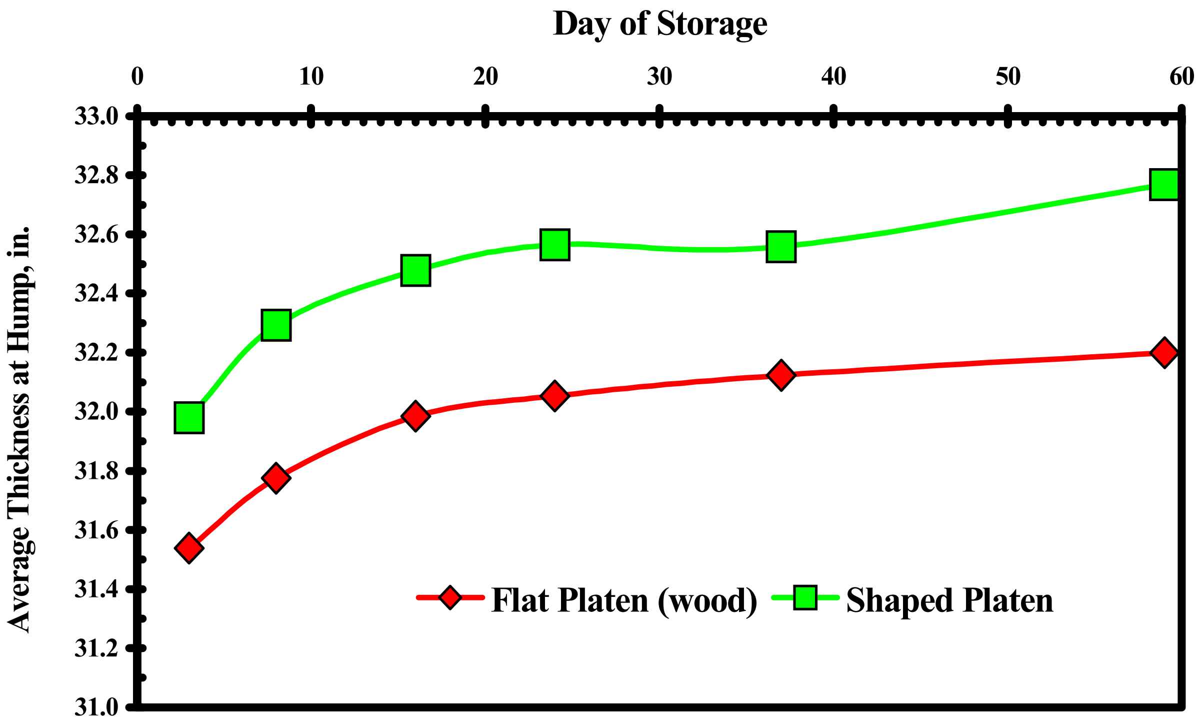

Figure 7. Thickness at the hump as a function of day of storage.