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LX-17-1 Stockpile Returned Material Lot Comparison

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Introduction

Many different lots of LX-17 have been produced over the years. Two varieties of LX-17, LX-17-0 and LX-17-1, have at one point or another been a part of the Livermore stockpile systems. LX-17-0 was made with dry-aminated TATB whereas LX-17-1 was made with wet-aminated TATB. Both versions have the same TATB to Kel-F 800 mass ratio of 92.5%/7.5%. Both kinds of LX-17 were formulated at Holston during the late 1970s or early to mid-1980s and were certified to have met the necessary specifications that cover the purity, particle size range, explosive to binder ratio, etc. In recent years, Trevor Willy and others have performed a detailed evaluation of solid parts made from each of the LX-17 lots manufactured at Holston. Using the Advanced Light Source at LBNL, Willey and his colleagues radiographed many samples from isostatic pressings using the same scanning conditions. In their investigation they identified that even though the bulk composition can be the same, there may exist a large spread in how smoothly the TATB and binder were distributed within the radiographed volume of different lots of material.[1] Overall, the dry-aminated TATB-based material, LX-17-0, had a smooth TATB and binder distribution, whereas the wet-aminated TATB-based LX-17-1 showed a wide range of binder distributions. The results for five different LX-17-1 lots are shown in Figure 1. The wide variation in material distribution has raised the question about whether or not this sort variability will cause significant differences in mechanical behavior.

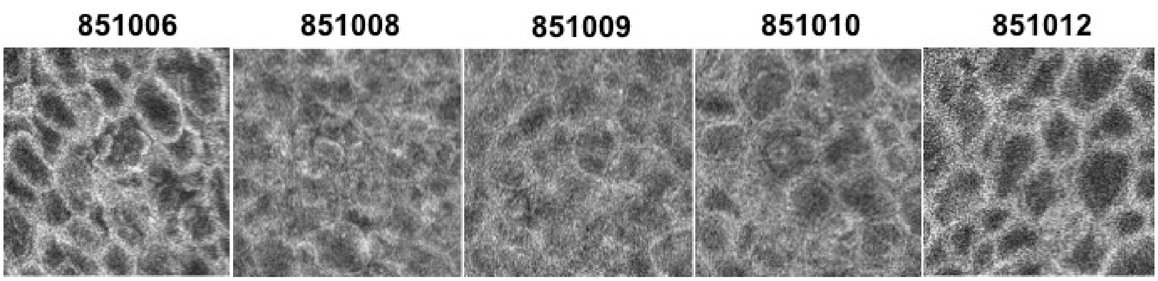

Figure 1. X-ray computed tomography slices (3.6-mm x 3.6-mm) showing the microstructural differences between five Holston lots of LX-17-1. These five lots span the range from the most homogenous (851-008, -009) to the least homogenous (851-006, -012). The lighter color in the images represents regions of binder concentration.

Material Details

To investigate the effect of uneven binder distribution on the mechanical properties of compacted LX-17-1, we obtained two stockpile-returned hemispheres. Each hemi was cored at LLNL into several dozen cylindrical cores to make samples for Disc Acceleration eXperiments (DAX) shots[2] and for mechanical testing. The cores were oriented in the radial direction (through the wall thickness) and were cored axi-symmetrically around the pole in several layers between the waist and the pole. One hemisphere was made from lot 851-006 and the other was made from lot 851-008. There was an obvious distinction in the level of binder uniformity between these two lots, with the binder in lot 851-006 being much less uniformly distributed than the binder was in lot 851-008. The parts that were destined for mechanical testing were finish-machined into

0.5-in diameter x 1.0-in long cylinders. The part densities were all within the WR acceptance limits for both charges, however, the starting density for parts from lot 851-006 were about 0.25% lower than the starting densities of the parts from 851-008.

We recognize that the thermal and stress histories of the parent material charges can affect the behavior of the derivative parts. To mitigate these differences, we employed our binder resetting technique, which allows us to melt the binder in a specimen while minimally affecting the geometry. This process allows us to erase the binder crystallinity effect on behavior and to create samples that are most comparable.

Experimental Details

Samples from each hemisphere had their densities measured using an immersion technique. After the densities were measured, two samples from each group were tested at 50˚C with a constant strain rate of 0.0001/s. The samples were tested until failure using the same protocol as is used in the compression tests for the PBX 9502 stockpile systems. An MTS servo-hydraulic test frame with an environmental chamber was used to control the test conditions. A pair of Shepic, knife-edge extensometers was used to measure the strain during the test and a thermocouple that was attached to the specimen reported the temperature. The stress versus strain behaviors of the two different lots, as received from the stockpile, are shown in Figure 2.

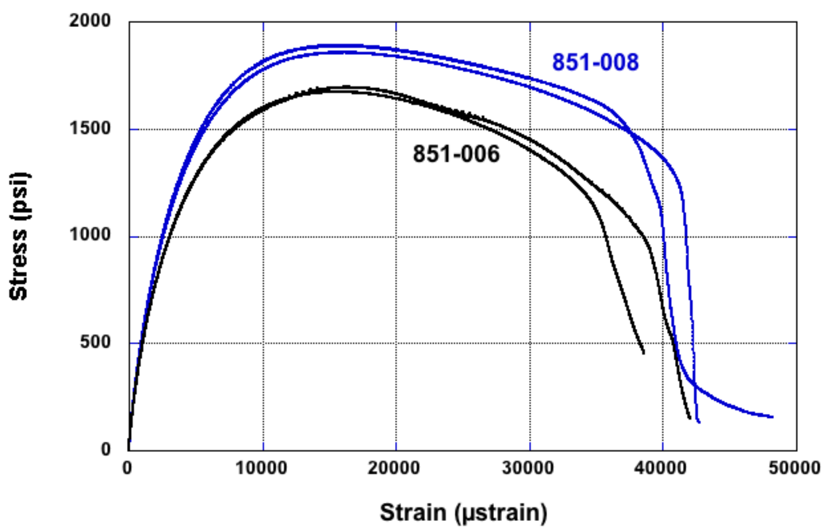

Figure 2. Stress versus strain curve for two samples taken from each hemisphere and compression tested at 50˚C until failure with strain rate control of 0.0001/s. The samples from lot 851-008 had greater strength (~11%) and a greater initial modulus (~12%). The Strain-at-Peak Stress was about the same for the two materials.

After the original two sets of parts were tested we took two additional parts from each lot and reset the binder.[3] The pairs were put into a pressure chamber and then pressurized up to 950-psi. The pressurization is needed to counteract the effect of thermally induced ratchet growth. After the desired pressure was achieved, a thermal ramp up to 110˚C was initiated. A two-hour dwell at 110˚C took place and then the chamber was ramped down to room temperature, with the pressure still applied. Once the chamber and its contents had reached thermal equilibrium at about 23˚C the pressure was removed. The samples were taken out of the pressure vessel and once again had their densities measured. Soon after the densities were taken the samples were subjected to compression tests at 50˚C and a constant strain rate of 0.0001/s. The results for redundant tests of both lots before and after reset are shown in Figure 3.

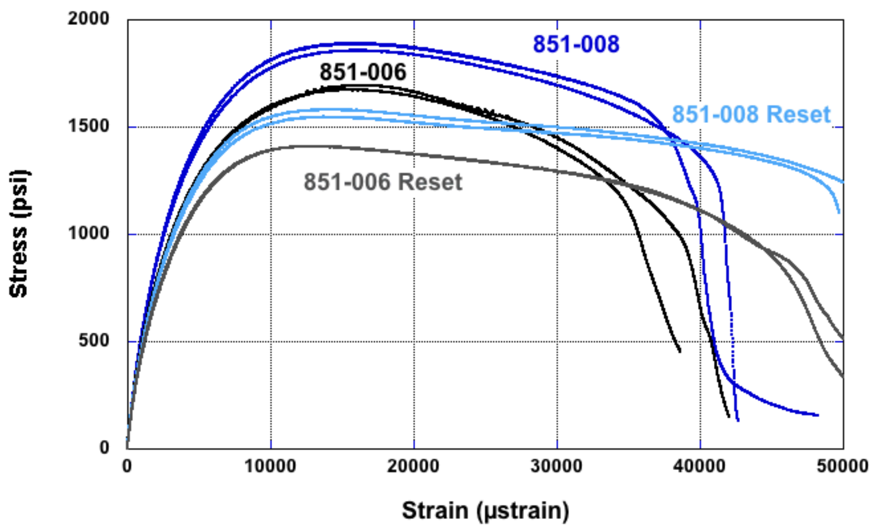

Figure 3. Stress versus strain curves for two groups of two samples taken from each hemisphere before and after the binder was reset. All samples were compression tested at 50˚C until failure with strain rate control of 0.0001/s.

The Peak Stress values, the Strain-at-Peak Stress and the Initial Modulus for each test were extracted. The Initial Modulus was found by taking the stress versus strain data over the first 500-µstrain and fitting the data with a line. These three values were averaged for the two redundant tests per test group: 851-008 (before reset), 851-008 (after reset), 851-006 (before reset) and 851-006 (after reset). The individual test values and the averages are shown in Table 1.

Table 1. Summary of the compression stress versus strain data for two lots showing the behavior before and after the binder was reset. Repeated tests were run for both lots (851-008 and 851-006) under both conditions (with and without binder reset). The average from the repeated tests are shown in red.

	Peak Stress (psi)	Strain-at-Peak Stress (µstrain)	Initial Modulus (psi)

851008	A	1888	15900	624480
	B	1856	16190	622960
	Average	**1872**	**16045**	**623720**
	C-R	1580	14100	573510
	D-R	1545	14020	573660
	Average	**1562.5**	**14060**	**573585**

851006	A	1693	16430	555020
	B	1672	15674	556140
	Average	**1682.5**	**16052**	**555580**
	C-R	1410	13100	524730
	D-R	1409	12910	530190
	Average	**1409.5**	**13005**	**527460**

The average values for each test group were compared to the others. When comparing the samples from lot 851-008, the reset strength was about 20% lower, the Strain-at-Peak Stress was 14% lower and the Initial Modulus was around 9% lower. For samples from lot 851-006 the Peak Stress was also about 20% lower for the reset specimens as it was for the baseline samples. The Strain-at-Peak Stress was about 23% lower and the Initial Modulus was about 5% lower for 851-006 after reset. The Peak Stress of lot 851-008 was about 11% higher than lot 851-006. The Strains-at-Peak Stress were about the same and the Initial Modulus was about 12% higher before reset. After both materials were reset, lot 851-008 was still about 11% stronger than lot 851-006. The Strain-at-Peak Stress was about 8% higher and the Initial Modulus was about 9% higher for 851-008. The comparison results are shown in Table 2.

Table 2. Comparison of the lots with themselves before and after the binder reset and also a comparison between the lots before and after reset.

	Peak Stress	**Strain at Peak Stress**	**Initial Modulus**
851008 - Before and After Reset			
Ratio	1.20	1.14	1.09

851006 - Before and After Reset			
Ratio	1.19	1.23	1.05

851-008 to 851-006			
Ratio	1.11	1.00	1.12

Reset 851-008 to Reset 851-006			
Ratio	1.11	1.08	1.09

Conclusion

Quasi-static compression tests of two different LX-17-1 lots tested at 50˚C and a constant strain rate of 0.0001/s were compared to the uniformity of explosive/binder distribution as seen with x-ray computed tomography. Samples retrieved from the stockpile-returned hemisphere lot 851-008, a more uniform lot, exhibited greater strength and greater stiffness when compared to lot 851-006, a lot with less uniform binder distribution. Because we know that binder crystallinity can play a major time-dependent role in causing material variability, we performed a binder resetting operation through which we are able to remove the binder crystallinity and its effect on the mechanical performance. The resulting data showed that while each material's strength was lowered by about 20% following the binder reset, the strength ratio of 1.11 for lot 851-008/851-006 stayed the same before and after reset. The stiffness was also around 10% higher, whereas it was 12% higher before. The Strain-at-Peak Stress values were mixed with an increase in the ratio from 1 to 1.08 after reset. In post-test inspection we noted that the samples from lot 851-008 barreled higher than normal, which would affect the average strain reading captured by the extensometers. Given that these samples were cored through the wall of the main charge in a region where we see higher densities towards the inner contour we would hypothesize that a density gradient in the part contributed to this effect. Follow-on work to this effort will include compressive creep tests to assess how the material behaves over much slower strain rates.

References

1. Trevor's ESC FY13 report
2. K. T. Lorenz, et al., "Development of the Next-Generation Age-Aware Performance Test" in *Enhanced Surveillance Campaign FY2014 Annual Report (U)* (Lawrence Livermore National Laboratory, 2014).
3. Gagliardi, F. J., Cunningham, B. J., Souers P. C., and Pease, S. T., "Strain Response of Insensitive High Explosives to the Combined Effects of Confinement and Temperature Change" LLNL-CONF-656302, *Proceedings of the 15th Detonation Symposium*, San Francisco CA, July 2014.