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The Effect of Reflected Blast Waves in HDPE Mortars

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A recent article discussed a problem with some comet shells exploding as they were being fired, and thus seriously damaging the HDPE mortars being used.[1] Included in the article were photographs of the two mortars that had been damaged. In these photos, it was clear that, while both ends of the mortars received serious damage, the middle section of the mortars received less damage in one case and no damage in the other. This raised a question in the minds of some readers, how could a single explosion damage both ends of a mortar while leaving the middle of the mortar essentially undamaged? The purpose of this article is to address that question.

During the course of conducting initial studies of the overall suitability of HDPE pipe for use as fireworks mortars,[2-5] many explosions were caused to occur inside HDPE pipes. However, as it turned out, these explosions were all made to occur in the lower portion of the mortars and never near the top (muzzle) of the mortar. As a result, the damage was always observed to only occur in the lower portion of the test mortars. Accordingly, upon first observing a mortar damaged by a single explosion occurring near the open end, and with the resulting damage concentrated at both its ends, it was necessary to contemplate why this would happen.

When a powerful explosion occurs near the top of a mortar, the top of the HDPE mortar will be damaged by the blast as the blast wave radiates outward. However, the blast wave must also propagate down the bore of the mortar where it will be reflected upon meeting the mortar plug (at least so long as the plug remains in place). During the time that the incident and reflected blast waves overlap in the area just above the mortar plug, their pressures will add constructively to produce a greater blast pressure. Therefore, if the incident blast wave pressure is sufficient, when it adds to the pressure of the reflected blast wave, it is possible to explode the bottom of the mortar (as well as the top of the mortar) from a single explosion. This seemed simple enough, but did it really work that way in actuality? Accordingly, some testing was performed.

In the first series of tests, a starter pistol (firing blanks) was discharged into the muzzle of a 3-inch mortar, after having installed a quartz (piezoelectric) pressure sensor at various points near the bottom of the mortar. Figure 1 is a sketch of the bottom portion of the test mortar that includes the location of the lowest two positions for the pressure transducer. Pressure data was collected at four locations, 16.0, 8.0, 4.0 and 0.5 inches above the mortar plug. The data from the lowest three positions in the mortar are shown in Figure 2. For each location, the data from four separate measurements were averaged and then smoothed for

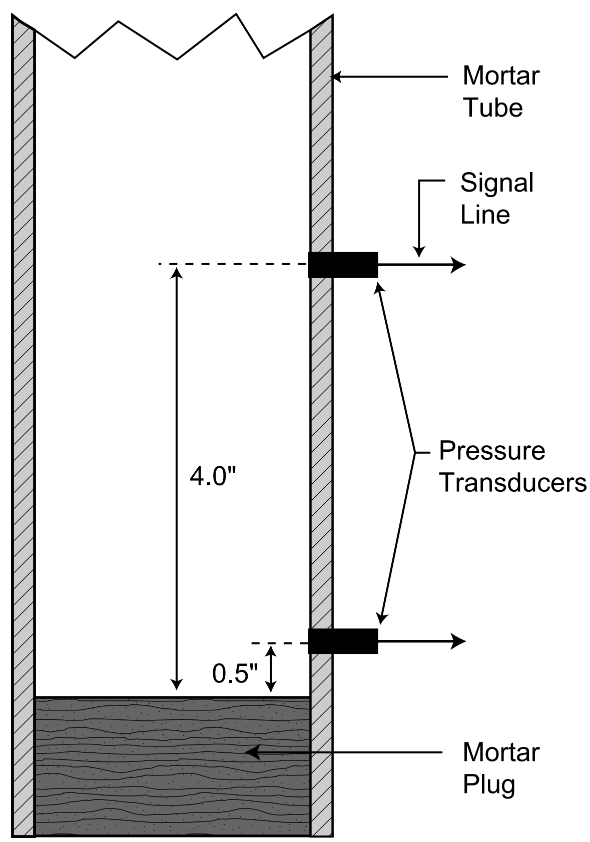

Figure 1. Sketch of the set-up for the first series of mortar tests. (Not to scale.)

presentation, using a simple running average filter.

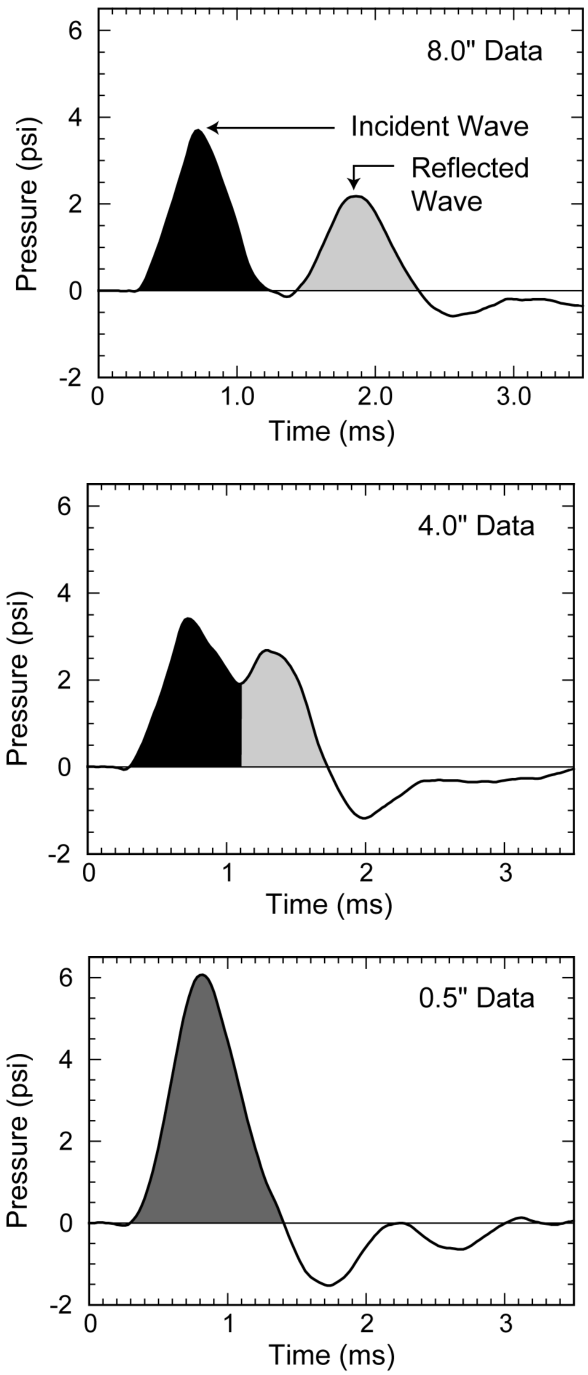

Figure 2. Internal mortar pressure data from the first series of tests.

In the data taken at 8.0 inches above the mortar plug, the incident pressure wave is shown as black and the reflected pressure wave, with its somewhat reduced magnitude, is shown as lightly shaded. The incident and reflected waves are clearly resolved and are separated in time by approximately 1.14 ms (milliseconds). The pressure wave needed to travel a total of 16.0 inches (8 inches down to the plug and 8 inches back up to the transducer) or 1.33 feet, during the interval between the arrival times at the transducer. At the temperature in the lab, and the initial temperature of the air in the bore of the mortar, the speed of sound would have been approximately 1130 feet per second. This computes to a time interval between incident and reflected pressure waves of slightly less than 1.18 ms, or about 3 percent longer than was measured. That the pressure wave traveled slightly faster than the speed of sound is consistent with its being a weak blast wave. (This was confirmed by examining details of the shape of the pressure event as seen in the raw, non-smoothed, data.)

In the data taken at 4.0 inches above the mortar plug, the incident and reflected pressure waves are less separated in time, and have started to merge together. In the data taken at 0.5 inch above the mortar plug, the incident and reflected pressure waves are seen to have merged into one. It can be seen that the amplitude of the combined pressure wave is approximately equal to the sum of the incident and reflected waves seen in the data taken higher in the mortar. Thus it seemed clear that the theory was being borne out in practice, but how would an actual mortar react to a pressure pulse sufficiently strong to damage it?

In the next pair of tests, 2-inch HDPE mortars were subjected to explosive blasts. During the course of a fireworks display a powerful explosive blast inside a mortar might potentially originate from a premature functioning of a star shell or a salute. In these tests, the pressure events were produced using flash powder charges contained in thin-walled polyethylene bottles that were of only slightly smaller diameter than the inside diameter of the mortars. Each test charge was suspended just inside the mortar near its muzzle. The results of the two tests are shown in Figure 3. In one test a charge mass of only 25 grams of flash powder was used (upper mortar in Figure 3), and in another test a charge of 50 grams was used (lower mortar in Figure 3). With the smaller flash powder charge most of the mortar is undamaged, except for its two ends, which are damaged almost equally. In the photograph, the left end of the mortar is the muzzle of the mortar (nearest the explosive charge) and the right end is where the plug had been. With the larger explosive charge, the damage is more extreme but is still concentrated at the two ends of the mortar. Thus the reflected blast wave prediction was fully borne out in these tests.

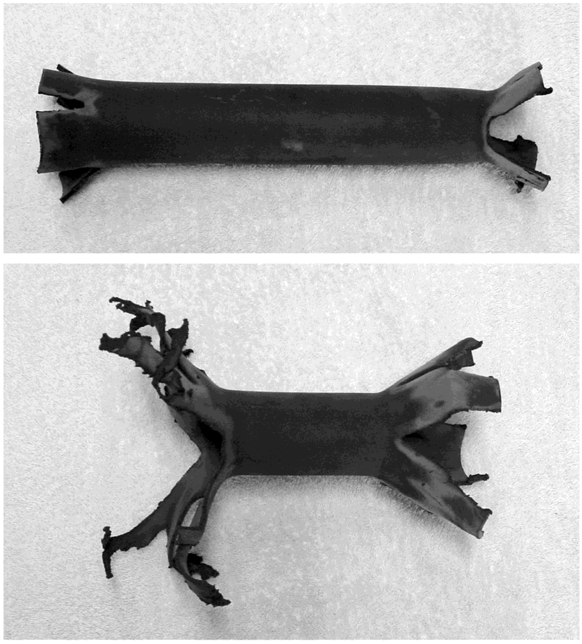

Figure 3. Photographs of the two mortars tested using small explosive charges.

Acknowledgment

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References

1) K. L. and B. J. Kosanke, "Report on the Initial Testing of Suspect Tiger Tail Comets", *Fireworks Business*, No. 233, 2003; also in *Selected Pyrotechnic Publications of K. L. and B. J. Kosanke, Part 7 (2003 and 2004),* Journal of Pyrotechnics, 2006.
2) K. L. Kosanke, "HDPE Mortars for Electrically Fired Displays", *Pyrotechnics Guild International Bulletin*, No. 54, 1986; also in *Selected Pyrotechnic Publications of K.L. and B.J. Kosanke, Part 1 (1981 through 1989),* Journal of Pyrotechnics, 1995.
3) Ken Kosanke, "Destructive Testing & Field Experience with HDPE Mortars", *American Fireworks News*, No. 72, 1987; also in *Selected Pyrotechnic Publications of K.L. and B.J. Kosanke, Part 1 (1981 through 1989),* Journal of Pyrotechnics, 1995.
4) K. L. Kosanke, "Further Information about HDPE Mortars", *Fireworks Business*, No. 60, 1989; also in *Selected Pyrotechnic Publications of K.L. and B.J. Kosanke, Part 1 (1981 through 1989),* Journal of Pyrotechnics, 1995.
5) K. L. and B. J. Kosanke, "Repeat Firing from HDPE Mortars", *Proceedings of the First International Symposium on Fireworks*, Montreal, Canada, 1992; also in *Selected Pyrotechnic Publications of K.L. and B.J. Kosanke, Part 2 (1990 through 1992),* Journal of Pyrotechnics, 1995.