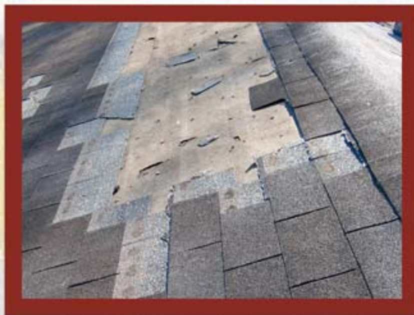
Three-Tab Shingle Performance During Hurricane Ivan, 2004



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In order to have verifiable, replicable results, the evaluation of material performance in roofing systems is usually dependent upon controlled laboratory testing. Laboratory tests are most often conducted using new materials that have been installed in strict conformance with manufacturers' guidelines. While roofing systems are usually installed with new materials, installation can often be at variance with manufacturers' guidelines. This is particularly true of three-tab, asphalt-composition shingles, one of the most popular steep-slope roofing materials – especially during the latter half of the 20th century.

Hurricane Ivan's rampage through the southeastern portion of the United States in September 2004 provided an opportunity to observe the real-world performance of this ubiquitous roofing material as it relates to age. In the city of Mobile, Alabama, an 18-building housing complex had shingles from three distinct installations with a similar level of workmanship prevailing throughout the complex (*Photo 1*). That there was a correlation between age and performance was not a surprise. What was unexpected was how well the shingles performed, despite their age and poor installation.

Photo 1 – Typical configuration and condition of building structure within the housing complex.

Three-tab, Asphalt-composition Shingles

Although widely used during the latter half of the 20th century and still quite popular today, three-tab, asphalt-composition shingles are a relatively recent roofing product.

Built-up or composition roofing, from which asphalt-composition shingles were derived, developed in the late 18th and early 19th centuries. One prominent historic example was the use of an application of pine tar to canvas sheeting for the low-slope roofs of the Octagon House (1800) in Washington, D.C. More common after 1847 was the use of coal tar with heavy paper sheeting.[1] Composition shingles, however, required a more solid waterproofing agent than either pine tar or coal tar.

Although natural asphalt had been available since antiquity as a waterproofing agent, widespread use of asphalt did not occur until the development of the petroleum industry during the second half of the 19th century. Initially, asphalt-composition shingles were hand cut from manufactured sheets of "stone-surfaced," rolled roofing. This first occurred in 1903 by Herbert M. Reynolds, a roofing manufacturer and contractor of Grand Rapids, Michigan. By 1906, Bird & Son had introduced a notched, two-tab shingle. This incremental innovation was soon followed by the now familiar three-tab shingle, as well as a variety of other shapes and sizes. All major roofing manufacturers offered a 12-inch x 36-inch, three-tab shingle by 1935, composed of asphalt, reinforcing felt, and granular surfacing. After World War II, this became

Photo 2 (left) – The long wing of Building 1 had an "old" shingle roof, typical of nine buildings in the complex.

Below: Photo 4 – The long wing of Building 16 had a "moderately old" shingle roof, typical of five buildings in the complex.

the dominant composition shingle type, with minor changes such as the transition from organic felt to fiberglass mat for reinforcement and from English dimensions to metric dimensions (0.33 meter x 1.0 meter).[2]

Hurricane Ivan

On September 16, 2004, Hurricane Ivan made landfall near Gulf Shores, Alabama. Widespread property damage occurred along the storm's path. The Mobile area was hit with peak wind gusts ranging from 74 mph at WKRG Studios in the downtown area to 105 mph at Battleship Park on Mobile Bay. Rainfall likewise varied according to location, with Andalusia, Alabama, recording nearly 10 inches, while Bates Field recorded slightly more than 5-1/2 inches, with the heaviest rainfall occurring east of Ivan's center as it moved northward into central Alabama.

18-building Housing Complex

The housing complex was comprised of 18 buildings that contained 30 one-bedroom and 53 two-bedroom residential units. The complex was reportedly constructed in 1972 and included a storage building located near the center of the complex, which was no longer standing. Exterior walls were constructed of concrete-masonry units (CMU). Interior walls were constructed of wood framing with plaster finish. The roofs were constructed of wood trusses and sheathed with 1 x 6 wood decking, over which were installed felt underlayment and three-tab asphalt-composition shingles. A roof slope of 5:12 was generally provided.

Damage to the housing complex resulted from two primary causes. High winds from Hurricane Ivan caused some damage to the shingles and removed some roofing components from the buildings. The building complex was also abandoned and vandalized some two years prior to the arrival of Hurricane Ivan. Typical examples of vandalism were plumbing fixtures, electrical wiring, mailboxes, light fixtures, window frames and glazing, and lead flashings at the pipe penetrations through the roofs, as well as charred framing members and interior finishes. Curiously, a 19th building – used as a storage facility for the complex – had existed on the site as late as November 15, 2004, but had disappeared without a trace by January 25, 2005.

Photo 3 – The center wing of Building 12 had a "recent" shingle roof typical of four buildings within the complex.

The total ground area covered by buildings was approximately 48,971 square feet. The total sloped area of roofs covered with three-tab, asphalt-composition shingles was approximately 58,535 square feet. The ages of the shingled roofs were unknown. Topical observation suggested that some of the roofs might have been part of the original (30+ year construction) and are noted in this paper as "old" (see *Photo 2*). Some shingles were definitely installed recently (less than five years agp), and are noted in this paper as "recent" (see *Photo 3*). Other shingles were likely of less recent installation but not original construction (10 to 15 years old), which are noted in this paper as "moderately old" (*Photo 4*).

The determination as to whether missing or damaged shingle tabs were due to the recent hurricane event or were pre-existing due to either age or vandalism was based upon the condition of nail heads exposed to

Above: Photo 5 – Nails were underdriven and located too high with the "old" shingle roof installation on Building 10.

Above: Photo 6 – Nails were underdriven and located too high with the "moderately old" shingle roof installation on Building 2.

weather. Lightly rusted or non-rusted nail heads would suggest recent exposure; heavily rusted nail heads would suggest exposure prior to the hurricane. In addition, in some areas where shingles were recently lost due to a wind event, installation deficiencies undoubtedly contributed to the shingle loss. In particular, under-driven nails or nails located so high as to secure only one layer of shingles, rather than the intended two layers, resulted in roofs susceptible to wind damage (*Photos 5, 6,* and *7*).

Wind Uplift

As most roof consultants are aware, wind damage to roofs occurs due to multiple reasons, including poor installation, wind uplift exceeding the design specifications, and age of the roofing system. Wind uplift occurs when the air pressure inside the building is greater than the air pressure outside the building. As wind passes over the building, there is a decrease in external air pressure and there is a corresponding increase in air pressure differential between the inside and outside of the building.

Photo 7 – Nails were underdriven and located too high with the "recent" shingle roof installation on Building 15.

Left: Photo 8 – The most extensive wind loss of shingles occurred near the roof perimeter and with the "old" shingles, such as on Building 13.

As the internal air pressure tries to equalize itself with the external air pressure, the resulting force, identified as wind uplift, attempts to lift the roof off the building as it tries to return to equilibrium.

Wind uplift can also occur in areas of the roof due to wind drag and air velocity. This creates a situation where shingles are pulled from the roof deck. This phenomenon occurs on roofs even if steps are taken to prevent air infiltration through the deck. Most of the buildings at the housing complex, however, no longer had their end gable louvers, allowing more air infiltration into the attic spaces of the buildings than would normally occur with well-maintained buildings.

In addition to the air pressure inside a building, there are several other factors that can significantly increase wind uplift forces, such as the building's position relative to wind direction and the ground terrain adjacent to the building. These factors create turbulence or vortices (possibly both) that can magnify existing uplift forces.

Wind uplift likely caused the most significant damage to the shingled roofs outside of vandalism and age. Uplift forces near the perimeter of the roof structures were sufficient to remove shingle tabs from portions of some roofs, particularly the older ones (*Photos 8, 9* and *10*).

Assessment

Based on our site visits and visual observations, it is our opinion that on September 16, 2004, Hurricane Ivan caused the damage discussed in the observations portion of this report. In determining what might be appropriate in regards to repairs, we have based our suggestions for repairs on the types of maintenance repairs previously performed at the site. In regard to the roofs, many existing roofs have had damaged or lost shingle tabs replaced by indi-

Above: Photo 9 – Less extensive wind loss of shingles occurred with the "moderately old" shingles, primarily near the roof perimeter, such as on Building 18.

Photo 10 – Very little wind loss of shingles occurred with the "recent" shingles, such as on Building 15.

Photo 11 – Despite overexposure, repaired portions of "old" shingle roofs performed well during the hurricane, such as these repairs on Building 13.

vidual shingle tabs rather than full roof replacement (*Photo 11*). Only Building 3 (which suffered structural damage from a fallen tree, *Photo 12*) sustained sufficient damage to warrant full replacement of the shingles on the roof. Only three of the 18 existing buildings suffered more than 1 percent loss of covering from Hurricane Ivan. Even with these buildings, the loss of shingles was less than 5%: Building 13, 4.53%; Building 11, 2.55%; and Building 17, 1.95%. As might be expected, each of these

Photo 12 – Although the "old" shingles on Building 3 suffered very little direct wind damage, structural damage from this fallen tree would necessitate replacement of the shingles.

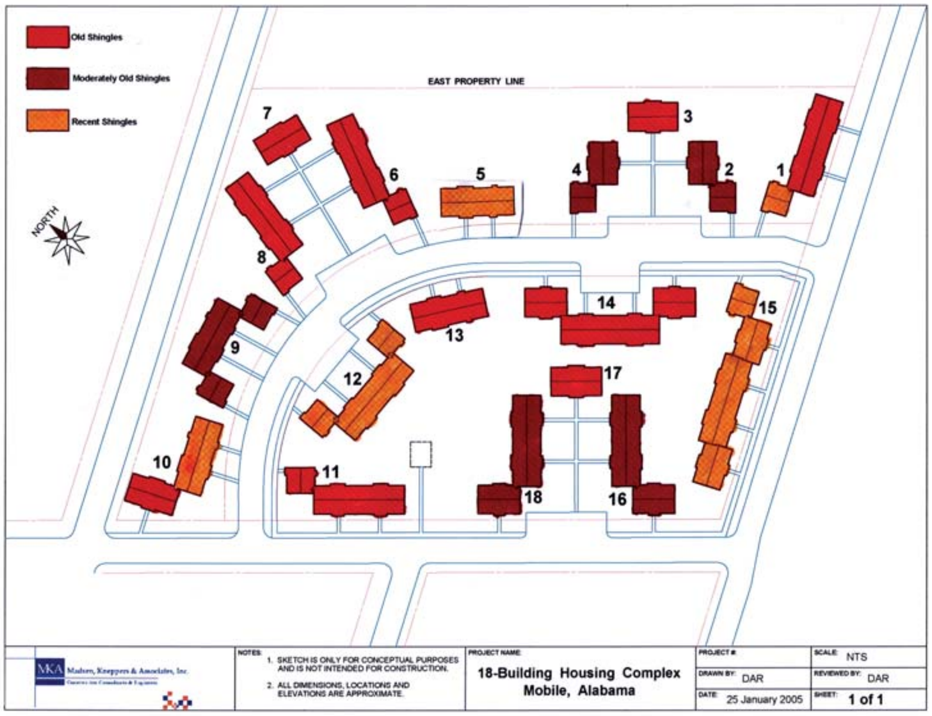

Figure 1 – The "old," "moderately old," and "recent" shingle roofs were each widely distributed throughout the housing complex, as can be seen with the project site plan.

three buildings had "old" shingles (see *Figure 1*). For a complete breakdown of shingle loss per building, see *Table 1* for a building breakdown and *Table 2* for unit breakdown.

Summation

In summary, this housing complex had easily suffered as much damage from vandalism and age as it had from the recent hurricane event, if not more so. Considering that the old variegated brown shingles were likely in excess of 30 years old when Hurricane Ivan passed through Mobile, and that most three-tab, asphalt-composition shingles have a warranted life expectancy of 25 years, and virtually none have a warranted service life expectancy in excess of 30 years, it was remarkable that there was not more hurricane-related damage from wind uplift. This was even more remarkable given some of the installation deficiencies that were observed where wind loss had occurred – the most notable deficiencies being nails placed too high or missing altogether. These particular deficiencies resulted in shingles with too few fasteners to adequately resist wind uplift.

Considering how well the various shingle installations had performed at Mobile, Alabama, this paper should not be viewed as an endorsement of poor workmanship and/or inadequate maintenance. The outstanding shingle performance under adverse conditions at Mobile does suggest three-tab asphalt-composition shingles are a highly viable steep-slope roofing material, even if some consider this product to have less street appeal than its architectural brethren. It also suggests that proper installation and adequate maintenance might have obviated an insurance loss claim.

Acknowledgements

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	Roof Area	Ridge Length	Damaged shingle tabs		Damaged ridge shingles		Damaged Area (SF)		Damage percentage	
			Pre-existent	Hurricane	Pre-existent	Hurricane	Pre-existent	Hurricane	Pre-existent	Hurricane
Building 1	3,687 SF	118.3333 LF	36	1	0	0	15.00	0.42	0.41	0.01
Building 2	2,059 SF	66.3333 LF	33	5	0	0	13.75	2.08	0.67	0.10
Building 3	1,493 SF	47.8333 LF	13	365	0	8	5.42	155.42	0.36	10.41
Building 4	2,059 SF	66.3333 LF	42	2	1	0	17.92	0.83	0.87	0.04
Building 5	2,198 SF	70.5 LF	12	6	0	0	5.00	2.50	0.23	0.11
Building 6	3,517 SF	113 LF	66	28	19	0	35.42	11.67	1.01	0.33
Building 7	1,493 SF	47.8333 LF	2	13	0	0	0.83	5.42	0.06	0.36
Building 8	3,517 SF	113 LF	44	71	0	2	18.33	30.42	0.52	0.86
Building 9	3,754 SF	120.8333 LF	26	7	0	0	10.83	2.92	0.29	0.08
Building 10	3,687 SF	118.3333 LF	20	55	0	0	8.33	22.92	0.23	0.62
Building 11	3,518 SF	113 LF	2	206	3	9	2.08	89.58	0.06	2.55
Building 12	4,303 SF	138.1667 LF	4	0	0	0	1.67	0.00	0.04	0.00
Building 13	2,198 SF	70.5 LF	37	239	9	0	19.17	99.58	0.87	4.53
Building 14	5,467 SF	175.5 LF	66	118	0	0	27.50	49.17	0.50	0.90
Building 15	6,054 SF	195.3333 LF	36	2	0	0	15.00	0.83	0.25	0.01
Building 16	4,019 SF	129 LF	0	35	0	0	0.00	14.58	0.00	0.36
Building 17	1,493 SF	47.8333 LF	0	70	0	0	0.00	29.17	0.00	1.95
Building 18	4,019 SF	129 LF	3107	60	100	0	1336.25	25.00	33.25	0.62
Storage Building	SF	LF					0.00	0.00		
	58,535 SF	LF	3546	1283	132	19	1532.50	542.50	2.62	0.93
Unit Location	Roof Area	Ridge Length	Damaged shingle tabs		Damaged ridge shingles		Damaged Area (SF)		Damage percentage	
			Pre-existent	Hurricane	Pre-existent	Hurricane	Pre-existent	Hurricane	Pre-existent	Hurricane

Table 1 – Overall breakdown of damage by building.

Unit Location	Roof Area	Ridge Length	Damaged shingle tabs		Damaged ridge shingles		Damaged Area (SF)		Damage percentage	
			Pre-existent	Hurricane	Pre-existent	Hurricane	Pre-existent	Hurricane	Pre-existent	Hurricane
Bldg 1-Unit A	745 SF	23.8333 LF	11	0	0	0	4.58	0.00	0.62	0.00
Bldg 1-Unit B	710 SF	22.75 LF	7	0	0	0	2.92	0.00	0.41	0.00
Bldg 1-Unit C	710 SF	22.75 LF	6	1	0	8	2.50	3.75	0.35	0.53
Bldg 1-Unit D	743 SF	23.8333 LF	6	0	0	0	2.50	0.00	0.34	0.00
Bldg 1-Unit E	779 SF	25.1667 LF	6	0	0	0	2.50	0.00	0.32	0.00
Bldg 2-Unit A	779 SF	25.1667 LF	11	3	0	0	4.58	1.25	0.59	0.16
Bldg 2-Unit B	639 SF	20.9167 LF	9	2	0	0	3.75	0.83	0.59	0.13
Bldg 2-Unit C	641 SF	20.9167 LF	13	0	0	2	5.42	0.83	0.85	0.13
Bldg 3-Unit A	746 SF	23.9167 LF	7	365	0	8	2.92	155.42	0.39	20.83
Bldg 3-Unit B	747 SF	23.9167 LF	6	0	0	0	2.50	0.00	0.33	0.00
Bldg 4-Unit A	641 SF	20.5833 LF	15	0	0	0	6.25	0.00	0.98	0.00
Bldg 4-Unit B	639 SF	20.5833 LF	6	0	0	0	2.50	0.00	0.39	0.00
Bldg 4-Unit C	779 SF	25.1667 LF	20	2	1	0	8.75	0.83	1.12	0.11
Bldg 5-Unit A	740 SF	23.8333 LF	3	3	0	0	1.25	1.25	0.17	0.17
Bldg 5-Unit B	714 SF	22.8333 LF	3	0	0	0	1.25	0.00	0.18	0.00
Bldg 5-Unit C	744 SF	23.8333 LF	6	3	0	0	2.50	1.25	0.34	0.17
Bldg 6-Unit A	779 SF	25.1667 LF	17	7	0	0	7.08	2.92	0.91	0.37
Bldg 6-Unit B	762 SF	24.5 LF	23	0	0	0	9.58	0.00	1.26	0.00
Bldg 6-Unit C	606 SF	19.4167 LF	19	6	0	0	7.92	2.50	1.31	0.41
Bldg 6-Unit D	606 SF	19.4167 LF	7	2	8	0	6.25	0.83	1.03	0.14
Bldg 6-Unit E	764 SF	24.5 LF	10	13	1	0	4.58	5.42	0.60	0.71
Bldg 7-Unit A	746 SF	23.9167 LF	2	12	0	0	0.83	5.00	0.11	0.67
Bldg 7-Unit B	747 SF	23.9167 LF	0	1	0	0	0.00	0.42	0.00	0.06
Bldg 8-Unit A	764 SF	24.5 LF	9	31	0	0	3.75	12.92	0.49	1.69
Bldg 8-Unit B	606 SF	19.4167 LF	7	3	0	0	2.92	1.25	0.48	0.21
Bldg 8-Unit C	606 SF	19.4167 LF	5	16	0	0	2.08	6.67	0.34	1.10
Bldg 8-Unit D	762 SF	24.5 LF	15	21	0	2	6.25	9.58	0.82	1.26
Bldg 8-Unit E	779 SF	25.1667 LF	10	6	0	0	4.17	2.50	0.53	0.32
Bldg 9-Unit A	779 SF	25.1667 LF	8	4	0	0	3.33	1.67	0.43	0.21
Bldg 9-Unit B	740 SF	23.8333 LF	5	3	0	0	2.08	1.25	0.28	0.17
Bldg 9-Unit C	714 SF	22.8333 LF	6	0	0	0	2.50	0.00	0.35	0.00
Bldg 9-Unit D	742 SF	23.8333 LF	4	0	0	0	1.67	0.00	0.22	0.00
Bldg 9-Unit E	779 SF	25.1667 LF	3	0	0	0	1.25	0.00	0.16	0.00
Bldg 10-Unit A	740 SF	23.8333 LF	2	0	0	0	0.83	0.00	0.11	0.00
Bldg 10-Unit B	714 SF	22.8333 LF	4	0	0	0	1.67	0.00	0.23	0.00
Bldg 10-Unit C	742 SF	23.8333 LF	3	0	0	0	1.25	0.00	0.17	0.00
Bldg 10-Unit D	744 SF	23.9167 LF	11	34	0	0	4.58	14.17	0.62	1.90
Bldg 10-Unit E	747 SF	23.9167 LF	0	21	0	0	0.00	8.75	0.00	1.17
Bldg 11-Unit A	779 SF	25.1667 LF	1	49	0	0	0.42	20.42	0.05	2.62
Bldg 11-Unit B	762 SF	24.5 LF	1	3	11	2	5.00	2.08	0.66	0.27
Bldg 11-Unit C	606 SF	19.4167 LF	0	103	0	7	0.00	45.83	0.00	7.56
Bldg 11-Unit D	606 SF	19.4167 LF	0	6	0	0	0.00	2.50	0.00	0.41
Bldg 11-Unit E	764 SF	24.5 LF	0	37	0	0	0.00	15.42	0.00	2.02
Bldg 12-Unit A	779 SF	25.1667 LF	0	0	0	0	0.00	0.00	0.00	0.00
Bldg 12-Unit B	762 SF	24.5 LF	0	0	0	0	0.00	0.00	0.00	0.00
Bldg 12-Unit C	606 SF	19.4167 LF	0	0	0	0	0.00	0.00	0.00	0.00
Bldg 12-Unit D	606 SF	19.4167 LF	0	0	0	0	0.00	0.00	0.00	0.00
Bldg 12-Unit E	764 SF	24.5 LF	4	0	0	0	1.67	0.00	0.22	0.00
Bldg 12-Unit F	779 SF	25.1667 LF	0	0	0	0	0.00	0.00	0.00	0.00
Bldg 13-Unit A	740 SF	23.8333 LF	2	93	0	0	0.83	38.75	0.11	5.24
Bldg 13-Unit B	714 SF	22.8333 LF	22	119	9	0	12.92	49.58	1.81	6.94
Bldg 13-Unit C	744 SF	23.8333 LF	13	27	0	0	5.42	11.25	0.73	1.51
Bldg 14-Unit A	641 SF	20.5833 LF	12	46	0	0	5.00	19.17	0.78	2.99
Bldg 14-Unit B	639 SF	20.5833 LF	17	8	0	0	7.08	3.33	1.11	0.52
Bldg 14-Unit C	742 SF	23.8333 LF	22	49	0	0	9.17	20.42	1.24	2.75
Bldg 14-Unit D	710 SF	22.75 LF	0	3	0	0	0.00	1.25	0.00	0.18
Bldg 14-Unit E	710 SF	22.75 LF	0	1	0	0	0.00	0.42	0.00	0.06
Bldg 14-Unit F	743 SF	23.8333 LF	1	3	0	0	0.42	1.25	0.06	0.17
Bldg 14-Unit G	639 SF	20.5833 LF	8	5	0	0	3.33	2.08	0.52	0.33
Bldg 14-Unit H	641 SF	20.5833 LF	6	3	0	0	2.50	1.25	0.39	0.20
Bldg 15-Unit A	779 SF	25.1667 LF	8	0	0	0	3.33	0.00	0.43	0.00
Bldg 15-Unit B	639 SF	20.5833 LF	4	0	0	0	1.67	0.00	0.26	0.00
Bldg 15-Unit C	635 SF	20.5833 LF	4	0	0	0	1.67	0.00	0.26	0.00
Bldg 15-Unit D	757 SF	24.5 LF	4	1	0	0	1.67	0.42	0.22	0.06
Bldg 15-Unit E	606 SF	19.4167 LF	3	1	0	0	1.25	0.42	0.21	0.07
Bldg 15-Unit F	606 SF	19.4167 LF	3	0	0	0	1.25	0.00	0.21	0.00
Bldg 15-Unit G	757 SF	24.5 LF	5	0	0	0	2.08	0.00	0.28	0.00
Bldg 15-Unit H	634 SF	20.5833 LF	2	0	0	0	0.83	0.00	0.13	0.00
Bldg 15-Unit I	641 SF	20.5833 LF	3	0	0	0	1.25	0.00	0.20	0.00
Bldg 16-Unit A	645 SF	40.8333 LF	0	11	0	0	0.00	4.58	0.00	0.71
Bldg 16-Unit B	643 SF	40.8333 LF	0	23	0	0	0.00	9.58	0.00	1.49
Bldg 16-Unit C	762 SF	24.5 LF	0	0	0	0	0.00	0.00	0.00	0.00
Bldg 16-Unit D	606 SF	19.4167 LF	0	0	0	0	0.00	0.00	0.00	0.00
Bldg 16-Unit E	606 SF	19.4167 LF	0	1	0	0	0.00	0.42	0.00	0.07
Bldg 16-Unit F	764 SF	24.5 LF	0	0	0	0	0.00	0.00	0.00	0.00
Bldg 17-Unit A	746 SF	23.9167 LF	0	2	0	0	0.00	0.83	0.00	0.11
Bldg 17-Unit B	747 SF	23.9167 LF	0	68	0	0	0.00	28.33	0.00	3.79
Bldg 18-Unit A	764 SF	24.5 LF	5	50	0	0	2.08	20.83	0.27	2.73
Bldg 18-Unit B	606 SF	19.4167 LF	8	0	0	0	3.33	0.00	0.55	0.00
Bldg 18-Unit C	606 SF	19.4167 LF	0	10	0	0	0.00	4.17	0.00	0.69
Bldg 18-Unit D	762 SF	24.5 LF	3	0	0	0	1.25	0.00	0.16	0.00
Bldg 18-Unit E	643 SF	40.8333 LF	1543	0	50	0	663.75	0.00	103.23	0.00
Bldg 18-Unit F	645 SF	40.8333 LF	1548	0	50	0	665.83	0.00	103.23	0.00
Storage Building	SF	LF					0.00	0.00		
Color Key	Old		Moderately old				Recent			

Table 2 – Breakdown of damage by unit.

References

[1] "From Asbestos to Zinc, Roofing for Historic Buildings—Composition," http://www.cr.nps.gov/hps/tps/roofingexhibit.htm, accessed on 21 October 2005.

[2] Ibid.

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