Shore Testing:

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BY **DAVID J. HAMMOND**

BECAUSE OF ITS AVAILABILITY AND VERSATILITY, wood shoring is widely used to temporarily stabilize damaged structures during urban search and rescue (US&R) operations. Shoring systems have been developed using well-accepted engineering principles and design specifications. Testing conducted in California since 2000 has sought to verify predicted strengths, and more importantly, the failure characteristics of vertical and lateral wood shoring systems. The sites included the Menlo Park (CA) Fire District, Federal Emergency Management Agency (FEMA) US&R California Task Force 3 (CA-TF3) training site, and the Moffett Field, the National Aeronautics and Space Administration /Ames Research Center (NASA/ARC) Disaster Assistance and Rescue Team (DART) training site.

Most of the testing occurred during Advanced Structures Specialist training (StS-2), funded by the Department of Homeland Security/Federal Emergency Management Agency (DHS/FEMA) US&R Program and the U.S. Army Corps of Engineers (USACE) US&R Program. All tested shoring systems conform to current FEMA US&R standard shoring or are intended to become standard shoring in the near future.

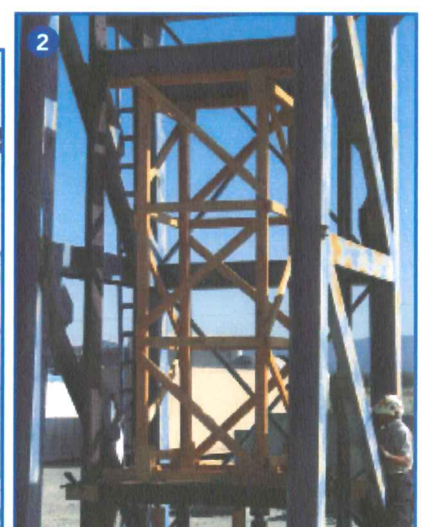
More than 30 tests each were performed on laced post systems and on braced pairs of raker shores, and demonstrated that these shores have safety factors of three or higher compared to recommended design loads. For emergency shoring applications, an essential finding was that observers can clearly see visual overload signs at loads much less than those that will cause failure.

VERTICAL LOAD SUPPORTING SYSTEMS

Laced post shores. All laced post (LP) shore testing was conducted at the NASA/ARC's Moffett Field. The initial testing in 2001 was "proof of concept" testing examining the overall behavior and capacities of standard shoring. Further testing (part of StS-2 training) studied overloaded shoring behavior and its near-failure characteristics. Later tests investigated new concept designs, such as those using plywood lacing/bracing instead of traditional 2 × 4 wood lacing, with the purpose of developing the new plywood laced post (PLP). Note the engineering shorthand for large loads or forces: 1,000 pounds = 1 kilo-pound or 1k.

FEMA design parameters. The following assumptions/characteristics are important for standard FEMA vertical shores:

- Shores should be constructed using readily available wood members.
- Vertical loads should be transferred by direct bearing of header to post and post to sole, using pairs of tapered 2 × wood wedges to make height adjustments.
- Systems should be proportioned and braced so that when overloaded, the crushing of the header and sole can be observed under a much smaller load than that which will cause the posts to buckle and the system to fail.
- Member connections and containment gusset plates should be made from the connecters that are as small as reasonable.
- 2 × wood wedges, used in pairs allow for vertical adjustment, and should start cupping (i.e., the wedge edges move upward as the post crushes the wedges and sole beneath) at about 50 percent of the load that will cause system failure. This should provide a "structural fuse" that will warn of an overload.



(1) OARF-2 test setup. Photos courtesy of author. (2) Vertical load tester (280k-VLT) test setup.

- The design strength of a LP shore using four 4 × 4-inch posts is based on the perpendicular-to-grain compression design strength of No.1 Douglas fir lumber. The LP design strength is 32k. Design strength = working load = design load.
- It is reasonable to expect that, on average, a properly constructed LP shore using No.1 Douglas fir lumber will fail at three times the design strength.
- FEMA vertical shores have only minimal lateral stiffness and strength; therefore, if a structure is so badly damaged that it needs lateral support, then lateral shoring should be installed.

Vertical load testing devices. The initial tests were performed in 2001 at the NASA/ARC site using a 150-ton bridge crane that had been part of the Outdoor Aeronautical Research Facility (OARF). Each shore was loaded with "free weights" consisting of a 38k slab placed on top of the shores, and additional concrete blocks that weighed 25k a pair. The blocks were suspended in pairs, and then lowered onto the 38k slab, one pair at a time. As each pair of blocks came to rest on the 38k slab, its suspension chains become slack. The total possible load was 138k, and most of the LPs failed as the third pair of 25k blocks was being lowered (somewhere between 88k and 113k). Steel brackets restrained the 38k slab from moving laterally. Each laced post specimen was 12.5 feet high. The test setup was designated OARF-1.

Table 1. LP Shore Tests (2 × 4 or 2 × 6 Lacing)

Shore	Year	Tester	Lacing	Failure	Comments
LP-1	2001	OARF-1	2 × 4	100k	Failed at knots in posts
LP-2	2001	OARF-1	2 × 4	90k+	System failure because of inadequate bracing
LP-11	2004	OARF-1	2 × 4	90k+	Failed at knots in posts
LP-12	2004	OARF-1	2 × 4	90k+	Failed at knots in posts
LP-13	2004	OARF-1	2 × 4	NA	38k load, followed by lateral load test (1.2k max)
LP-21	2005	OARF-1	2 × 6	110k+	Best performance yet
LP-22	2005	OARF-1	2 × 6	90k+	Posts were split prior to test because of excess nailing from standard five 16d nails used for 2 × 6 lacing
LP-23	2005	OARF-1	2 × 6	NA	Pneumatic struts with 2 × 6 lacing. Two cycles of 2-inch lateral with 38k, then end test with no failure
LP-24	2005	OARF-1	2 × 4	100k+	Two cycles of 2-inch lateral with 38k, then vertical load to failure. Very good performance
LP-31	2005	OARF-2	2 × 4	103k	New loading system. Failed at knots in posts
LP-41	2006	OARF-2	2 × 4	103k	New loading system. Failed at knots in posts
LP-51	2007	280k-VT	2 × 4	100k	280k tester. Failed at knots in posts
LP-61	2008	280k-VT	2 × 4	103k	280k tester. Failed at knots in posts

Note: 1k = 1,000 lbs.
Except as noted, shores used 4 × 4-inch posts and 2 × 4 or 2 × 6 lacing.
Source: Table by author.

Test findings.

1. Except for LP-2, all specimens performed as a system with adequate bracing. LP-2 used only one midbrace per side instead of two, which is inadequate for this height.
2. LP systems supported three times the design load prior to failure.
3. Wedge cupping occurred 1.5 to 2.0 times the design load.
4. Header splitting occurred at about 2 times the design load.
5. Properly constructed FEMA LP shores should provide adequate warning of overload, allowing time for mitigation.
6. In most cases, the failures occurred at post knot locations near the intersection of the 2 × lacing with the posts.
7. Deflection (vertical compression of system) was normally less than a ½ inch at design load, and increased to between two and three inches just prior to failure. Most deflection resulted from crushing of the header and sole.

Table 2. PLP Shore Tests (4-foot× 4-foot Layout)

Shore	Year	Tester	Lacing	Failure	Comment
LP-32	2005	OARF-2	2-24" plywood	103k	Failed at post knots, similar to 2 × diagonal tests
LP-42	2006	OARF-2	3-12" ply	83k	Failed in buckling, 12-inch plywood is inadequate
LP-52	2007	280k-VT	2-24" ply	100k	Failed at knots in posts, similar to 2 × diag. tests
LP-53	2007	280k-VT	2-24" ply	88k	Failed at knots in poorest quality posts
LP-62	2008	280k-VT	4-24" ply	115k	Failed at knots in posts. Very good performance
LP-63	2008	280k-VT	5-24" ply	144k	Plywood was too close = impractical

Note: 1k = 1,000 lbs.
Source: Table by author.

Test findings.

1. With one exception (LP-42), all systems failed at the post knot locations near the upper or lower edge of the plywood lacing. Except for LP-42, failure occurred in using 12-inch plywood lacing, indicating that the plywood was too narrow to adequately brace the posts.
2. These PLP systems supported three times the design load prior to failure.
3. Wedge cupping was observed from 1.5 to two times the design load.
4. Header splitting occurred at about two times the design load.
5. PLP shores with 4-foot× 4-foot post layout can be configured to perform as well as standard LP shores.

In November 2005, the OARF test setup was modified to more precisely measure the loading during the test and at failure. Four 50-ton hydraulic rams supported on steel brackets were installed symmetrically under the slab and loading blocks. The rams would lift the load while the shore was placed under the slab; the load was applied to the shore by reducing the pressure on the rams (i.e., lowering the slab and blocks) and the change in pressure on the rams would accurately determine the load on the shore. As above, the total possible load was the 38k slab and four pairs of 12.5k blocks (138k total). This test setup was called OARF-2 (photo 1).

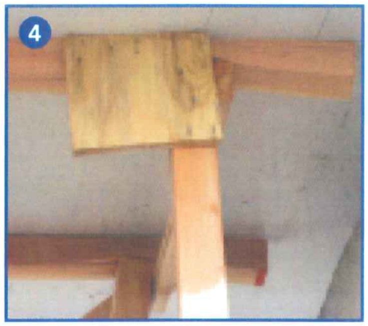
In May 2007 a new testing frame was fabricated at the NASA/ARC Disaster Assistance and Rescue Team (DART), was fabricated using an existing rocket motor test stand. The stand was modified by adding a steel platform as a loading table at the ground level, supported by four 50-ton hydraulic rams. A pair of steel channels were placed at each side of the stand to support two movable head beams for height adjustment. The ram pressure accurately determines the load on the shore specimen. This vertical load tester with a 280k capacity was designated 280k-VT (photo 2).

LP and PLP construction.

- All were between 12.2 and 12.5 feet tall.
- All 4 × 4-inch posts were visually graded unseasoned Number 1 or better grade Douglas fir. They were spaced four feet out to out (i.e., outside to outside).
- All lumber was purchased from a local lumberyard. The 4 × 4 posts were chosen for having the fewest knots and the straightest grain. The 4 × 4 headers and soles were cut from the remaining supply. 2 × material was No.1 or better grade Douglas fir.
- Until 2009, only ¾-inch CDX grade plywood was used. It is noted below when thinner plywood was used for tests conducted in 2009 and 2010.
- Instructors built the shores prior to StS-2 training. In some cases, significant rain occurred between the shores' construction and their testing.
- The shores used hammer- and gun-driven nails. All gun-driven nails had full heads, but were slightly off-center. The 16d nails were vinyl-coated coolers (0.148 × 3.25 inch). The 8d nails were also vinyl-coated (.131 × 2.375 inch).
- The design load for all LPs and PLPs is 32k.

Table 1 shows the results of 13 tests of LP shores using 2 × 4-inch and 2 × 6-inch lacing.

PLP shores with 4-foot × 4-foot layout. The StS2 testing program considered whether plywood strips could replace the 2- × 4-inch lacing (photo 6). Based on ease of construction, it was decided initially to use 24 and 12 inch wide strips within the shores' height, and to tie them together at top and bottom with 12-inch strips. Initially, the tests used ¾-inch-thick plywood; later tests used ⊠-inch and ½-inch plywood. These systems have the posts spaced four feet out to out, can be more rapidly constructed than 2 × laced



(3) The typical conditions at failure. Test specimen LP-31's right-front post split at a knot near the intersection of the upper mid-brace and two diagonals. (4) At the upper right, the right-front post has crushed the header to about half its thickness, which displaced the then-standard 12 × 12-inch full gusset. The standard now recommends using 6 × 12-inch half-gussets, which are quicker to install and allow a better view of the crushing of the header. (5) The right-front post at failure load (3.2 times the design load) crushed the wedges and caused them to cup. Crushing and cupping are quite obvious at about two times the design load and indicate that shore is overloaded and personnel must take action.

systems, and weigh less. The tests demonstrated that the 12-inch-wide plywood strips were inadequate to brace the shores; shores laced this way failed in global buckling. Table 2 summarizes the results of six 4-foot × 4-foot LP tests, using plywood.

PLP with 2-foot × 4-foot layout tests. Following the success of the 4-foot × 4-foot PLP testing, testers connected a pair of double Ts (with posts two feet out to out), spaced four feet out to out, to construct a 2-foot × 4-foot PLP. These shores are even lighter than 4-foot × 4-foot PLP, and because of their two-foot dimensions are easier to prefabricate and carry into a damaged structure. This testing was intended to define the most efficient PLP and propose it as a new FEMA US&R standard shore.

The initial tests in 2005 and 2006 demonstrated that the sides of the shore with two-foot spaced posts would be more difficult to brace, and all of the tests ended with a buckling failure. In 2008, a 96-inch high piece of plywood was placed at mid-height on the two-foot sides, and the shore behaved like the standard LP. Following 2008, since the 96-inch high plywood piece was considered undesirable from an access point of view, other plywood configurations were tried on the two-foot sides, while still using two 24-inch high strips on the 48-inch wide sides.

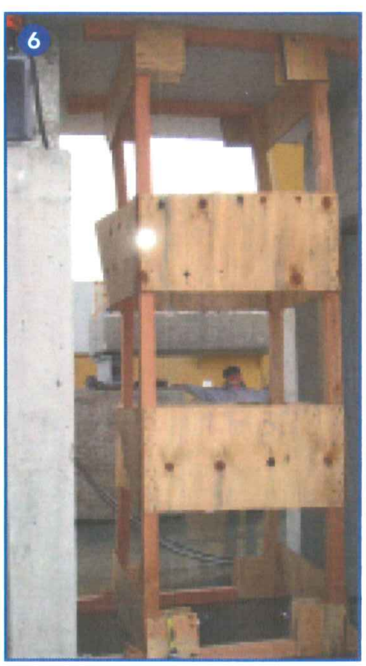
In 2010, it was reasoned that the preferred configuration would be to place the 24-inch high strips closer to the top and bottom of the shore, since the potential buckling curvature is larger near the shore's ends. The PLP-84 and 85 tests were successful and also demonstrated that ⊠-inch plywood could be used. Table 3 summarizes the 18 PLP tests with 2-foot × 4-foot layouts.

Overall LP and PLP findings. A total of 37 laced post tests were performed as a part of FEMA/USACE StS training. The testing not only proved the shores viability and the appropriate design capacities, but allowed the StS students to observe their behavior. The tests demonstrated that, when properly configured, the LP, 4-foot × 4-foot PLP, and 2-foot × 4-foot PLP will indicate overloading at levels well below failure. The cupping of wedges and deformation (crushing and splitting) of soles and headers are "structural fuse" indicators which were repeated in most all of the tests.

In addition, the tests will lead to the likely adoption of the plywood laced post, and the use of thinner plywood and oriented strand board (OSB) for connections in FEMA shores.

LATERAL LOAD SUPPORTING SYSTEMS TESTS

Raker shore testing. All raker shore testing was conducted at the Menlo Park (CA) Fire District / FEMA US&R CA-TF3



(6) Typical failure conditions. LP-32's two rear posts fractured at knots near the top of the upper plywood lacing, and the right-front post crushed the header to about half its thickness, displacing the gusset. (7)The plywood lacing deformed as the shore failed. However, note that the face-grain of the plywood is running in the short direction, instead of the long direction. The plywood's mis-orientation was the shore builders' error. The plywood lacing performed better in other tests when the face-grain was aligned with the long-direction (i.e., from post to post). (8) The post has crushed the wedges and caused them to cup. Note how the plywood gusset has started to buckle as the sole is crushed. Placing the gussets about ¾-inch or so below the top of the header and above the bottom of the sole prevents this. If the shore's actual load is close to the design load (as it should be), crushing would not occur.

Table 3. PLP Shore Tests (2-foot × 4-foot Layout)

Shore	Year	Tester	Lacing	Failure	Comment
PLP-31	2005	OARF-2	2-24" ply	88k	Buckling failure
PLP-32	2005	OARF-2	1-24" ply	88k	Buckling failure and re-test to 65k
PLP-41	2006	OARF-2	2-12" ply	65k	Buckling failure and post failure, 12" plywood not good.
PLP-42	2006	OARF-2	3-12" ply	67k	Buckling failure and post failure, 12" plywood not good.
PLP-51	2007	280k-VT	2-24" ply	90k	Failed at poor post with big knot
PLP-61	2008	280k-VT	4-24" ply	85k	Failed at poor post at big knot
PLP-62	2008	280k-VT	1-96" ply	115k	Very good test. Do additional tests
PLP-71, 72	2009	280k-VT	1-96" ply	125k+	5/8" plywood, very good test
PLP-73, 74, 81	2009	280k-VT	1-96" Ply	105k+	1/2" plywood, very good test
PLP-75	2009	280k-VT	1-96" ply	115k	3/4" oriented strand board (OSB), very good test
PLP-76	2009	280k-VT	48"+24"	115k	3/4" ply, (48" + 24", no 96") very good test
PLP-82, 83	2010	280k-VT	48"+24"	115k+	PLP-82=5/8"ply, PLP-83=1/2" ply
PLP-84, 85	2010	280k-VT	2-24" ply	120k+	5/8"ply, spaced near top and bottom of posts

Note: 1k = 1,000 lbs. Source: Table by author.

Test findings.
1. The 2-foot× 4-foot PLP, up to 13 feet high, can be configured to perform as well as the standard LP and the 4-foot × 4-foot PLP.
2. The PLP system can support three times the design load prior to failure.
3. Cupping of the wedges can be observed from 1.5 to two times the design load.
4. Splitting of the headers can be observed at about two times the design load.
5. Deflection was normally less than ½-inch at design load, and increased to between two and 3½ inches just prior to failure. Most of the deflection resulted from the crushing of the header and sole. Deflection increased significantly for loading above 100k, since the headers and soles become crushed to nearly one-half their original height.
6. PLP shores will be proposed as a new FEMA shore.

(9) The final version of the 2-foot × 4-foot PLP at failure. The posts fractured at knots and the headers and soles gave ample warning of failure as they were crushed and split. (10) PLP-85 after failure, showing extent of crushing of sole, and cupping of wedges. The failure load was 140k (4.4 times design load), which is attributed to the uniform straightness and absence of knots in all four posts.

training site. The initial test in October 1999 demonstrated the capability of the newly constructed raker testing device. Since September 2004, this facility has conducted raker testing as part of Advanced Structure Specialist Training (StS-2). A total of 31 tests have been performed through 2010.

The lateral load testing device ("Raker Breaker") consisted of a 1.5-foot thick, 20-foot-square base slab, a ram-actuated steel frame, and a 12-foot-square tilting wall, which is hinged at its base. A single, 30-ton hydraulic ram moves a single steel strut attached to the center of a torsion beam. The torsion beam is attached to a triangular steel frame at each end with a large steel pin with bearings; this allows for rotation. Two L-shaped steel struts are connected to the top of the torsion beam, and when the torsion beam is rotated, they exerted a force against the tilting wall in two places. The load that is applied to the back of the wall by the L-shaped struts is at a height of about 10 feet above the hinge at the bottom of the tilting wall. The Raker Breaker is designed to exert a maximum force on the tilting wall of 24k (photo 11).

The raker shores to be tested were constructed in pairs, 8 feet apart with standard 2 × lateral "X" bracing placed between them. All of the tested rakers were configured at an angle of 45°, with their insertion points (the point where the center of the raker intersects the wall plate) at eight feet above the bottom of their sole plate. Since the load applied to the back of the wall is 10 feet above the hinge, the force in the rakers is the ram force multiplied by a ratio of 10/8. Therefore, the total force on the pair of rakers is 1.25 times to force applied by the ram.

All rakers were attached to the tilting wall by lag screws, placed through the wall plates, and into a 6- × 6-inch wood sleeper. The two wood sleepers, spaced at eight feet on center were bolted to the tilting wall. Large concrete blocks provided the sole anchorage.

Three types of raker shores were tested as braced pairs, the design strength for raker pairs is 5k.

- 19 pairs of solid sole rakers (including the initial test). Solid sole rakers are the preferred since they may be pre-constructed as a complete triangle, and carried to the damaged wall. Most of these rakers were constructed by students during Rescue Systems 2 training at the training site. All had an eight-foot insertion point.
- 10 pairs of split sole rakers. This type of raker is normally used when there is rubble on the ground or slab next to the damaged wall, and the bottom of the shore

Table 4. Solid Sole Raker Tests

Raker	Year	Cleat Nails	Max Load	Comment
Rak-Initial	1999	16	17k	Pickets failed
Rak-11,12	2004	17	25k	No failure, but lots of deflection of sole into ground
Rak-13,14	2004	17, 6	25k, 24k	After full test, reduce cleat nails to six for cleat fly-off
Rak-21	2005	17	25k	Hem-fir cleats, no failure
Rak-22	2005	17, 8	25k	Hem-fir cleats. After full test, get fly-off with eight nails
Rak-23	2005	17, 6	25k, 23k	After full test, reduce cleat nails to six for cleat fly-off
Rak-31,32	2005	17	30k	No failure
Rak-33	2005	17, 6	30k, 22k	After full test, reduce cleat nails to six for cleat fly-off
Rak-41	2006	14, 6	30k, 20k	After full test, reduce cleat nails to six for cleat fly-off
Rak-44	2006	14	30k	No failure
Rak-51	2007	14	30k	No failure
Rak-61	2008	14	30k	No failure
Rak-71	2009	14	25k	No sole foot on soft soil. Post buckled and sole split
Rak-72	2009	14	30k	Test w/ sole foot. No failure
Rak-81	2010	14	32k	Test without sole foot on hard soil. No failure
Rak-82	2010	14	25k	Bad post, split at 25k

Note: 1k = 1,000 lbs. Source: Table by author.

Test findings.

1. Properly constructed and braced solid sole rakers perform as a system; a pair has a failure strength of at least 30k. Since the design strength for a pair is 5k, the safety factor is about 6.
2. Initial signs of overload can be observed as lateral movement of the nailed cleat on the sole. The movement can be easily observed if vertical lines are drawn across the cleat and sole, prior to loading.
3. Significant vertical movement of the sole directly under the intersection of the raker can occur when rakers are constructed on soil unless an 18-inch square foot is installed under the sole at that intersection. This foot (3-2 × 6 ×18) is specified in the USACE US&R Shoring Operations Guide (SOG) as well as the USACE US&R StS Field Operations Guide (FOG). SOG & FOG, Sect. 3.
4. It is very important to adequately connect the raker wall plates to the supported wall that they are bracing, or the wall plate will tend to move up the wall.
5. The sole anchor for rakers is also very important, or the shore will move away from the wall. Strength and stiffness are both important.

Table 5. Split Sole Raker Tests

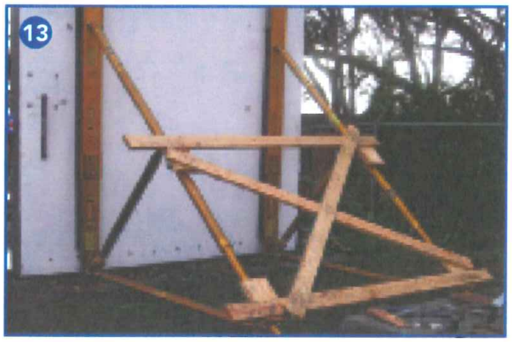
Shore	Year	Top Cleat Nails	Max Load	Comment
Rak-42	2006	14	27k	Bottom of right trough failed in soft soil. Added 18-inch square foot under trough to finish test.
Rak-43	2006	14	27k	Same as Rak-43. Will add select fill to test area
Rak-53	2007	14	30k	Used 18-inch square foot under trough – better result
Rak-54	2007	14	27k	Without foot, so trough bottom failed
Rak-62	2008	14	27k	Without foot so trough bottom failed
Rak-63	2008	14	27k	Added foot, and buckled raker at knots
Rak-73a	2009	14	30k	Used 18-inch square foot under trough, no failure
Rak-73b	2009	14	30k	Without foot on harder soil, no failure
Rak-83a	2010	14	30k	Without foot on harder soil, no failure
Rak-88b	2010	14	30k	Without foot on harder soil, no failure

Note: 1k = 1,000 lbs. Source: Table by author.

Test findings.

1. Properly constructed and braced split sole rakers perform as a system, and a pair has a failure strength of at least 30k, leading to a safety factor of 6.
2. Initial signs of overload can be observed as deformation of the trough base. This base should always have an 18-inch square foot placed under it. (shown in SOG and FOG Sect. 3)
3. It is very important to adequately connect the raker wall plates to the supported wall that they are bracing, or the wall plate will tend to move up the wall.
4. The sole anchor for the Trough Base is also very important, or the shore will move away from the wall. Strength and stiffness are both important.

(11) Typical test setup for testing a pair of solid sole rakers. (12) Raker pair after sole cleat fly-off; nails were reduced to only six. (13) Pneumatic raker system with lateral bracing. (14) Test of redesigned pneumatic raker.



must be sloped up to clear the rubble. These rakers were constructed by Rescue Systems 2 students as well as StS instructors.

- Two pairs of pneumatic strut rakers. Each pair of struts came from different manufacturer (Rak-24, Rak 34). StS instructors assembled these rakers just prior to the tests. Both had eight-foot insertion points.

Pneumatic strut raker testing. Pneumatic strut rakers from one manufacturer were tested as a braced pair in March 2005, and the system was loaded to 25k without any significant failures being observed. Initially, the system was assembled with a mid-brace and lateral X bracing placed between the pair. The system is shipped with wood nailers that are connected to the struts with metal clamps. This allows for the nailed connections of the 2 × wood bracing.

Since the test of the braced system resisted the 25k load without failure, the lateral bracing was removed, and the system was reloaded to 25k. It appeared that the raker struts would begin to buckle if the load was increased much beyond 25k. This manufacturer's strut raker system performed well enough to be used as a substitute for wood rakers. The braced system is shown in photos 13.

Strut rakers from a second manufacturer were tested as a braced pair in November 2005. The system was assembled with a mid-brace and lateral X bracing placed between the pair, and wood nailers were attached with metal clamps. The system was loaded to12k, and the mid-brace connections failed, causing the raker struts to buckle. The test was stopped at this point.

Following the test, the manufacturer stated that the mid-brace connection would be redesigned. The company was subsequently sold to another company.

The redesigned raker system was tested in May 2011 during StS2 training, and supported 25k. without failure (photo 14). This strut raker system performed well enough to be used as a substitute for wood rakers.

Wood raker shore testing. A total of 30 tests of raker shores were performed as a part of FEMA/USACE StS training. The testing not only proved the viability of the shores, but allowed StS trainees to observe their behavior. The tests demonstrated that FEMA raker shores, when adequately restrained, have a safety factor of at least 6. The large safety factor is justified since during high winds and aftershocks, it is difficult to determine how much force the shores need to resist.

The tests also demonstrated that, as rakers become highly loaded, the StS can observe deformations in the sole cleat (for solid sole raker), or the trough (for the split sole raker). These indications are not as dramatic as the "structural fuse" indicators for laced posts, but they do provide an observable warning of overload.

Test videos. Videos of tests may be viewed in the Multimedia Section of www.disasterengineer.org. Also, PowerPoint® files summarizing the shoring tests are available in the Library Section of the Web site. Detailed information regarding the proper construction of these shores can be found in Sections 2 and 3 of the US&R Shoring Operations Guide (SOG) and the US&R StS Field Operations Guide (FOG), also available in the Library Section. This site is supported by members of the FEMA US&R Structures Sub-group and Bracken Engineering, Tampa, Florida. ●

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