A Review of the Temporary Shoring Used to Stabilize the Pentagon After the Terrorist Attacks of September 11th, 2001

(L to R: Structural Specialists Leo Titus, VA-TF1, Richard Kahler and Bernie Denke, VA-TF2 discuss monitoring operations)

A Final Scholarly Paper
Submitted by

Leo J. Titus, Jr., P.E.
Structural Specialist
Virginia Task Force One Urban Search & Rescue Team

Principal
ECS, Ltd., Chantilly, Virginia, USA

Submitted to Dr. M. Sherif Aggour, P.E.
University of Maryland, Department of Civil Engineering

May 3, 2002

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Introduction

The attacks of September 11th, 2001 presented new challenges to fire and rescue personnel and to the engineering community. The nature of the attack was hardly expected, and the results were devastating. In the hours following the attacks, the Federal Emergency Management Agency (FEMA) deployed its Urban Search and Rescue teams to both the World Trade Center in New York City and to the Pentagon in Arlington, Virginia.

During the deployment at the Pentagon, four FEMA Urban Search and Rescue Task Forces worked together to assess the structural damage and to stabilize the structure to allow recovery of victims and evidence. A fifth Task Force from New Mexico (NM-TF1) was brought in during the last few days to relieve the teams that had been there all week and to finalize shoring operations. This paper is a review of the shoring performed by the Urban Search and Rescue Task Forces during their deployment at the Pentagon.

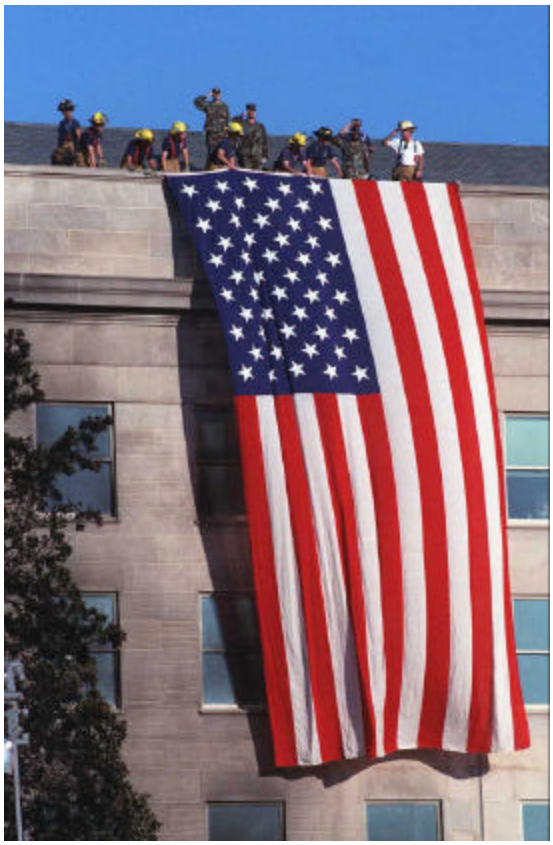


Figure 1. Members of the United States military, Arlington County Fire Department and the Fairfax County Fire Department drape a large American flag over the side of the Pentagon, September 12, 2001.

Overview of the FEMA Urban Search & Rescue Response System

FEMA established the National Urban Search and Rescue (US&R) response system in 1989. At present, there are 28 US&R Task Forces in the United States. Each maintains an inventory of search and rescue equipment and is prepared to deploy within six hours of activation by FEMA.

When deployed, an US&R Task Force is made up of 62 specialists grouped into four major areas of expertise: Search, Rescue, Technical and Medical. These groups include professional firefighters, paramedics, doctors, engineers, heavy rigging specialists, K-9 search dog teams, logistics, communications and planning personnel.

A copy of the September 13th, 2001 VA-TF1 organizational chart from the Pentagon Incident is shown in Figure 2. The organizational chart was updated and reprinted at the beginning of each shift. It provides an example of how a Task Force is organized during a deployment. The four squads that are shown on the chart are made up of mostly professional fire fighters specially trained for urban search and rescue. During a deployment, their primary function is search and rescue of live victims. For the majority of the Pentagon deployment, these four squads operated as "shoring squads", constructing the shoring that stabilized the structure.

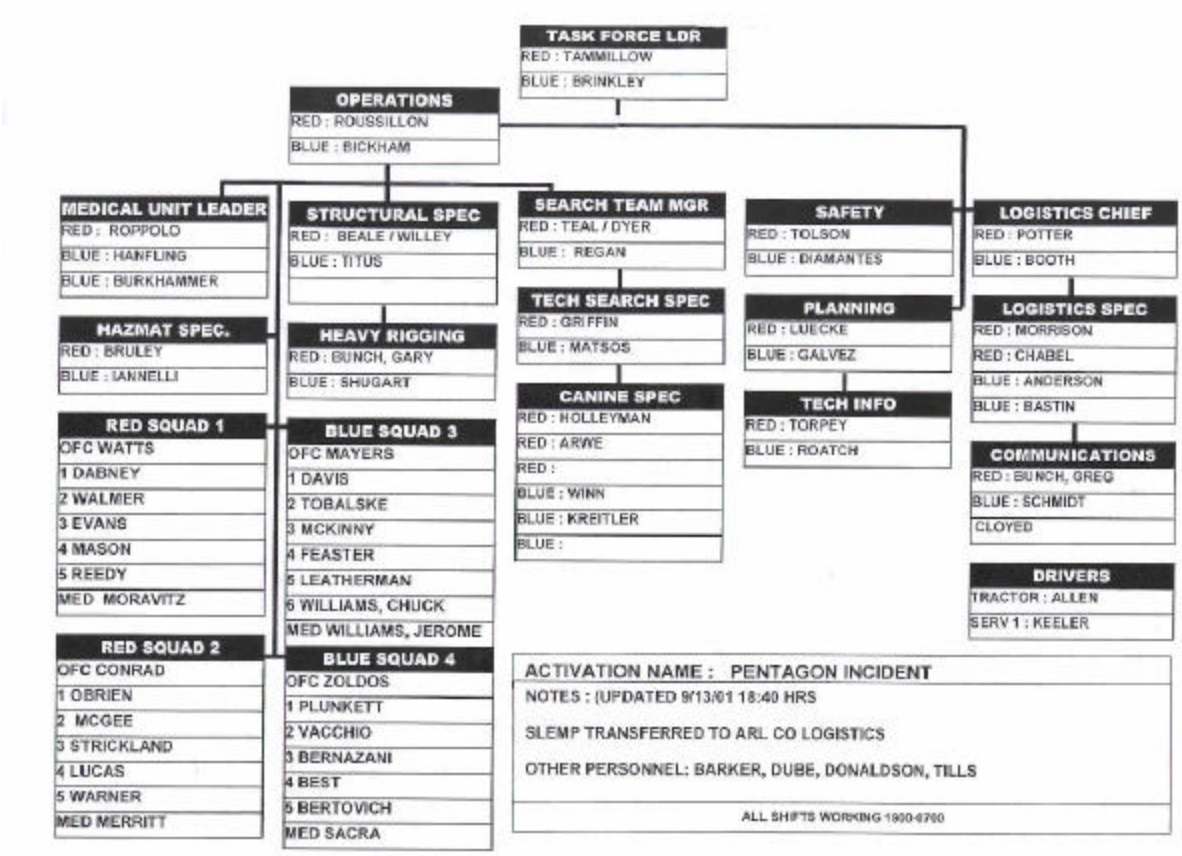


Figure 2. Organizational Chart for the Pentagon Incident, September 13th, 2001

The equipment carried by the Task Force includes sensitive listening equipment, cutting and drilling tools, structural monitoring equipment, temporary shoring devices, medical supplies as well as enough food, water and shelter to supply a 62 person Task Force for up to 72 hours.

The role of the US&R Task Force is to utilize the skills of the Task Force members and the specialized equipment to search damaged structures for potential live victims, provide emergency medical care to victims, evaluate structural hazards for rescue personnel and stabilize damaged structures during rescue operations.

The Fairfax County FEMA US&R Task Force, Virginia Task Force One (VA-TF1), is one of the most experienced groups in the FEMA system. VA-TF1 has been deployed by FEMA to the Oklahoma City bombing in 1995, and several hurricanes. In addition, VA-TF1 is one of only two US&R teams authorized by the United States State Department to deploy overseas. VA-TF1 has been deployed to earthquakes in Armenia, the Philippines, Taiwan, Turkey and the terrorist bombing in Nairobi, Kenya.

Role of US&R Structural Specialists

Whenever a US&R Task Force is deployed, two Structural Specialists are assigned to the team. According to the FEMA Field Operations Guide (FOG) for the US&R response system, Structural Specialists are "…responsible for performing the various structural assessments for the Task Force during incident operations." The FOG outlines five major duties of the Structural Specialist during deployments:

1. Evaluating immediate structural conditions that will be entered by Task Force personnel during operations.

2. Determining the type and amount of structural hazard mitigation in order to reduce risks to Task Force personnel.

3. Cooperating and assisting search and rescue workers.

4. Being accountable for all issued equipment.

5. Performing any additional tasks assigned during a mission.

The Structural Specialist works closely with the rescue and shoring squads as well as the Safety Managers, Heavy Rigging Specialists, Hazardous Materials Specialists and Operations Managers. During the Pentagon deployment, the Structural Specialist's role was primarily evaluating structural damage, guiding shoring operations and monitoring movements of the building. The Structural Specialists that were assigned to the Pentagon incident in September of 2001 are listed below:

VA-TF1: Dean Tills
Tony Beale
Leo Titus
Stan Murphy

VA-TF2: Dennis Clark (IST)
Bernie Denke
Richard Kahler

MD-TF1: Mark Tamaro
Tom Stanton (IST)
Victor Hare
Robert Frances

TN-TF1: Anthony Kirk
James Chastain

NM-TF1: Michael Hessheimer
Gerald Wellman

Figure 3. FEMA Structural Specialists review the building plans and plan shoring operations.

Background of the Terrorist Attack at the Pentagon

American Airlines Flight 77, a Boeing 757 out of Dulles Airport, flew into the west side of the Pentagon at approximately 9:38 a.m. There were 64 people on board and the plane carried 30,000 pounds of fuel intended for the long trip to California.

The Pentagon is divided into five wedges. The area of impact was near the division of Wedge 1 and Wedge 2. The section known as Wedge 1 had been under renovation and was scheduled for final completion on Wednesday, September 12th, 2001. The plane reportedly was flying very low and struck the building at the first and second story levels. Figure 4 shows the approximate point of impact between Wedges 1 and 2.

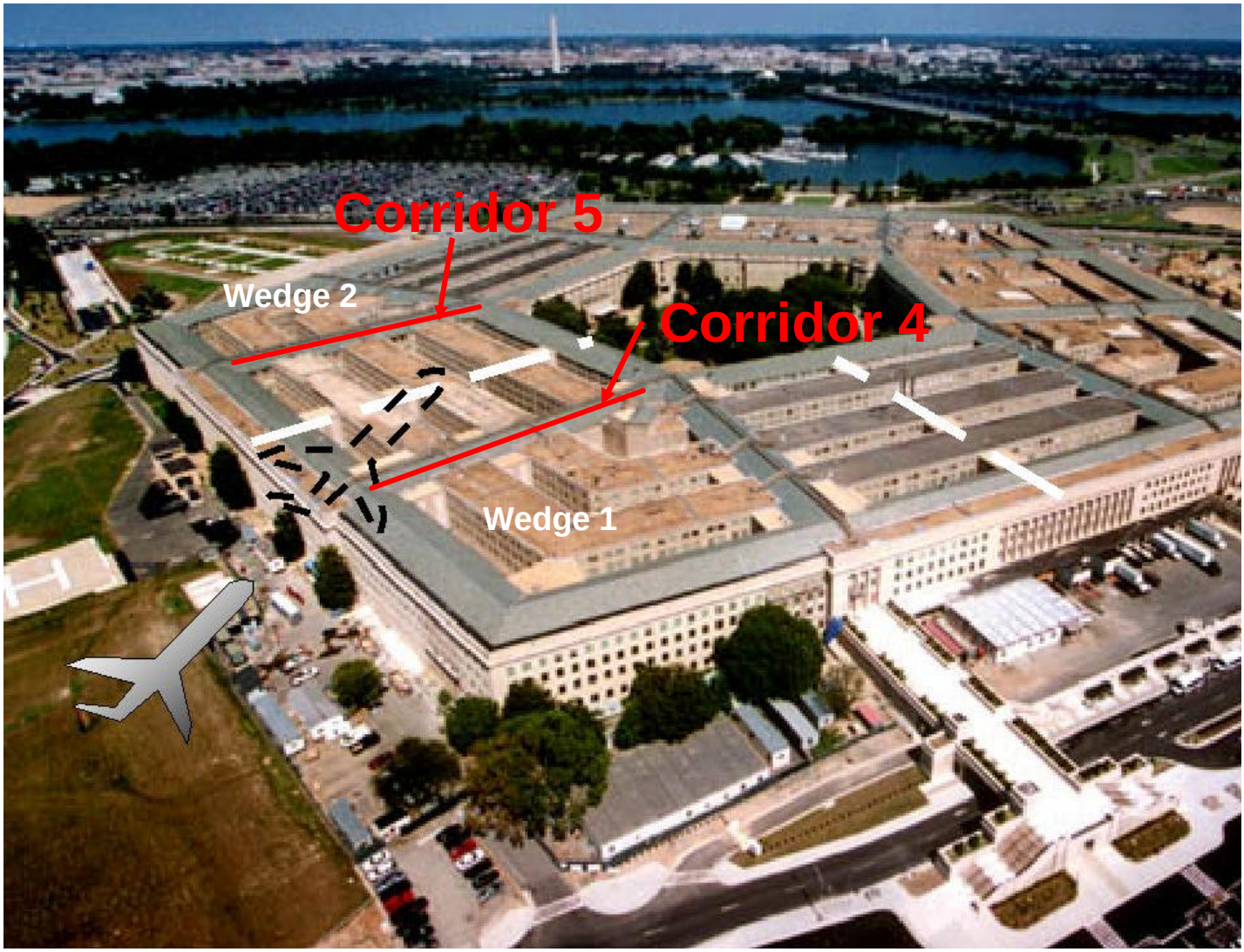


Figure 4. Approximate location and angle of impact and its relationship to Wedge 1 and Wedge 2 (Tills, 2001)

Deployment of FEMA Task Forces to the Pentagon

The Fairfax County FEMA US&R Task Force, Virginia Task Force One (VA-TF1) was alerted at 10:56 a.m. on the morning of September 11th. Task Force members were instructed to contact Task Force headquarters and report to Fire Station 18 in Falls Church, VA as quickly as possible with full gear.

Two buses were chartered and the Task Force, along with its truck loads of equipment were escorted by police to the Pentagon. The entire team and the convoy of supplies arrived at the Pentagon at approximately 1:00 p.m., less than three and a half hours after the impact. Figure 5 is a photograph taken from one of the Task Force buses at approximately 1:00 as they first arrived on site. As Figure 5 shows, the Arlington County Fire Department was still fighting the fire when VA-TF1 arrived at the scene.

Figure 5. 1:00 p.m. September 11th, 2001.
Photo taken by Leo Titus from one of the VA-TF1 buses.

FEMA deployed four other US&R Task Forces to the Pentagon. The majority of the remaining FEMA US&R teams were deployed to the World Trade Center in New York City. VA-TF1 was the first FEMA team to arrive on site. MD-TF1 out of Montgomery County, MD arrived later in the afternoon on September 11th. VA-TF2 out of Virginia Beach arrived later during the night. TN-TF1 arrived from Tennessee during the day on September 12th. The last FEMA team arrived from New Mexico (NM-TF1) a week later to assist in finishing the shoring operations. A group of United States Army rescue specialist from the Military District of Washington (MDW) were also on site assisting in the shoring operations.

In addition to the US&R Task Forces, FEMA had an Incident Support Team (IST) in place in the early hours of the incident. The IST is a small group of experienced US&R veterans that provide logistical and planning support to the Task Forces during the operation.

On a typical deployment, a Task Force will split into a day shift and a night shift. However, since there were four Task Forces on site during the Pentagon incident, two teams worked the day shift and two worked the night shift. The two Virginia Task Forces were assigned to the night shift, 6:00 p.m. to 6:00 a.m., while the Tennessee and Maryland Task Forces were on the day shift. The IST held daily transitional meetings at 6:30 a.m. and 6:30 p.m. as the shifts changed to exchange information and update everyone on the previous shift activities.

Initial Reconnaissance and Evaluation of the Structure

Soon after arriving at the site, two reconnaissance teams were organized by VA-TF1. The mission of the reconnaissance team was to enter the building and search for live victims, assess structural damage and identify rescue hazards. Each team was comprised of a canine search specialist, hazardous materials specialist, structural specialist and several rescue squad members.

As the reconnaissance teams entered the building, the magnitude of the destruction was realized. The debris from the impact and explosion extended from the floor to the ceiling. This made maneuvering very difficult as the team attempted to move through the building. Figures 6 and 7 are pictures taken on the first floor of the Pentagon in the first days after the attack. They illustrate the obstacles that the recon teams were faced with. Other conditions which made the reconnaissance even more difficult were the intense heat, smoke and scalding water falling from the fire suppression activities on the upper floors.

Figure 6. First floor interior damage.

Figure 7. First floor interior damage

The reconnaissance quickly determined that it was unlikely there were any survivors in the building due to the intense fire caused by the jet fuel. The fire had been so intense, it has been estimated that the heat in some areas exceeded 2,000 degrees Fahrenheit. Since it was unlikely that there were any survivors, the mission quickly turned from a rescue operation into recovery of victims and evidence.

Safe completion of the mission meant that a significant amount of stabilization of the building would be required. Building plans were provided to the structural specialists by contractors that were associated with the Pentagon Renovation Program. These contractors had offices at the Pentagon and were on site at the time of the attack. The damage was surveyed and mapped by the Structural Specialists and plans for stabilizing the structure were underway.

Overview of the Structural Damage

In order to have a better understanding of the damage caused by the attack, it is necessary to review the layout of the Pentagon structure. In addition to the five wedges previously discussed (Wedges 1 through 5), the Pentagon is comprised of five rings (rings A through E). The "A" ring is the innermost ring, and going outward, B, C, D with E being the outermost ring. The plane entered E ring at an angle and the force of the explosion punched through three of the five rings of the Pentagon. A nine foot diameter exit hole was created in the wall of C ring and the remainder of the debris from the impact ended up in the alley between C ring and B ring known as A & E Drive. Figure 8 identifies the rings of the Pentagon and the approximate point of impact.

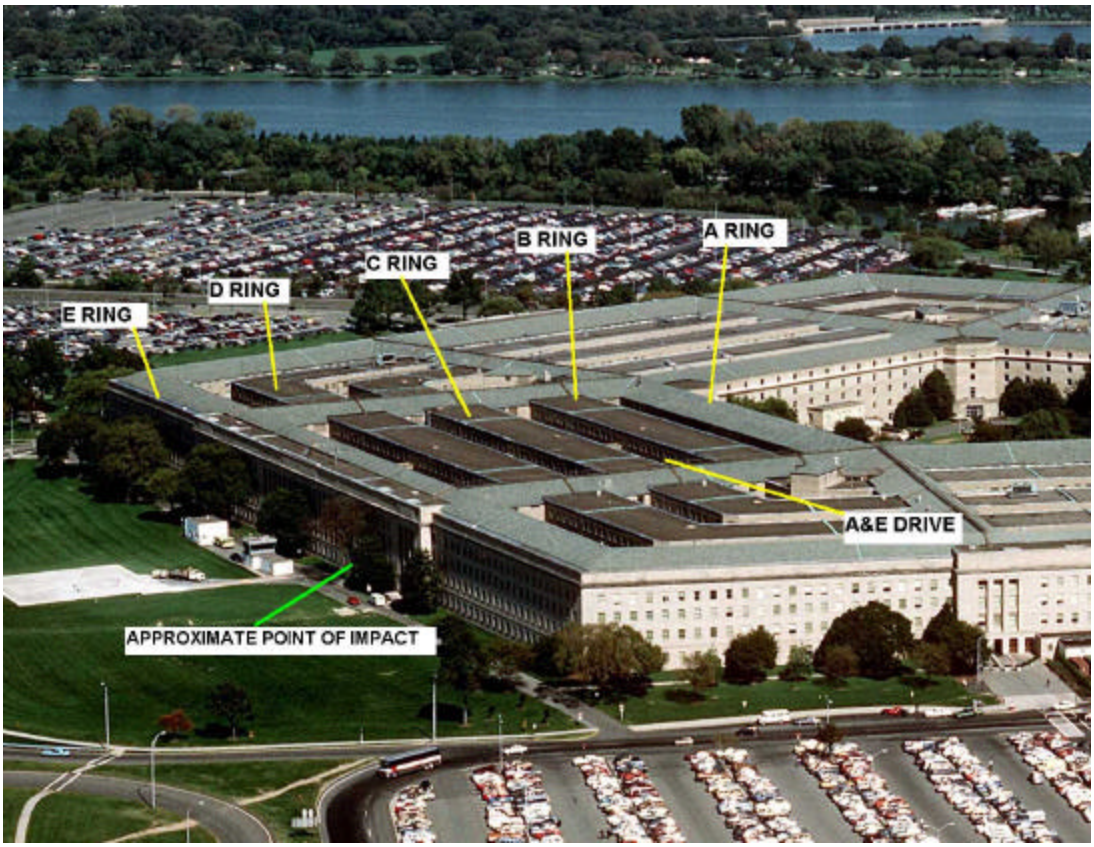


Figure 8. Identification of the five Pentagon rings and the approximate point of impact.

The most significant damage was where the building actually collapsed. This area, referred to as "the collapse zone", actually remained standing for about 20 minutes after the initial impact. This is important since it allowed time for people to escape. The plane struck very close to an expansion joint in the building. When the portion of the building collapsed, it left a clean vertical break along the expansion joint.

The portion of the structure to the north of the collapse zone had significant column damage and appeared very unstable. Two columns were missing and a third had been severely damaged. This meant that the corner was now a cantilever spanning 3 column bays (approximately 80 feet) and it was not known how long it would hold up before collapsing. Figure 9 shows the missing columns adjacent to the collapse area. This photograph was taken at approximately 3:00 p.m. on September 11th.

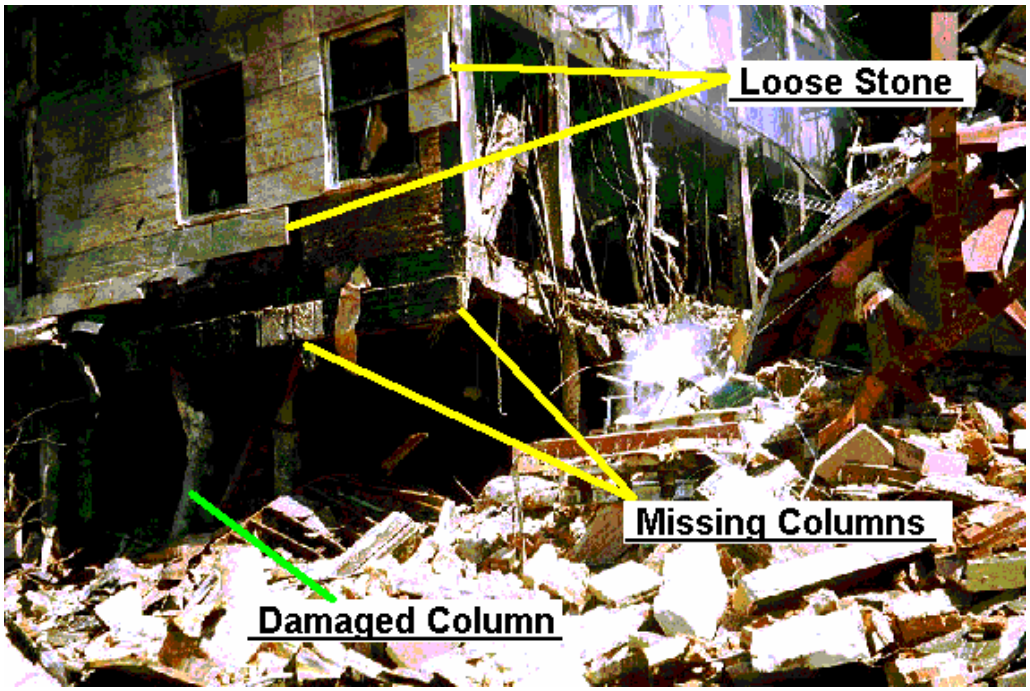


Figure 9. Missing Columns. The corner of the structure adjacent to the collapse was missing two columns and one was severely damaged. The section cantilevered approximately 80 feet.

During the week the FEMA Task Forces were on site, the Structural Specialist devoted a good deal of time to thoroughly mapping the damage. Figure 10 was created by the Structural Specialists using plans provided by the Pentagon Renovation contractors. The damage mapped on the plan reveals the angle of entry of the plane and its path through the outer three rings of the building.

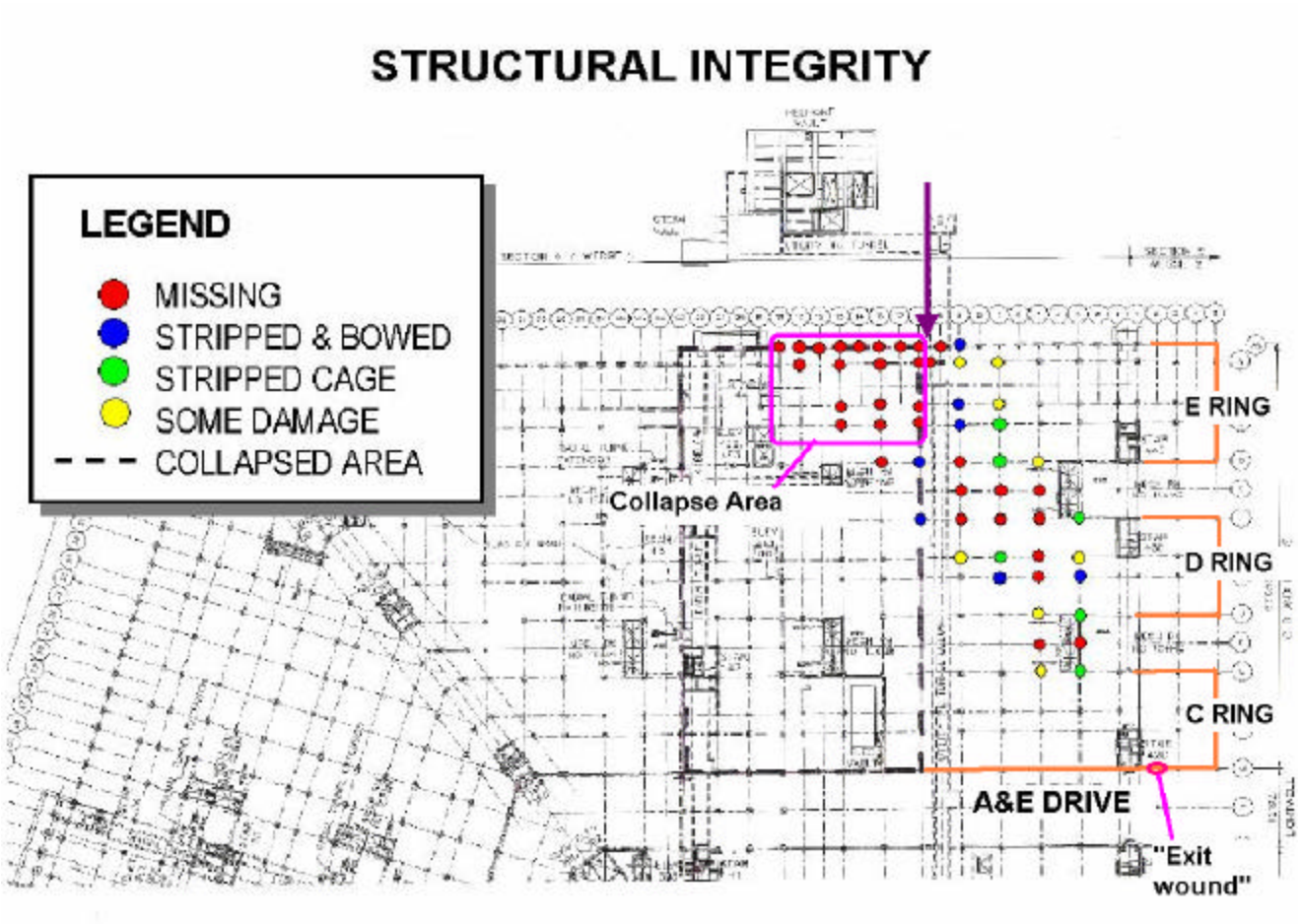


Figure 10. Structural Integrity Plan. Indicates missing and damaged columns. (Tills, 2001)

Figure 11 is a photograph taken in A&E drive showing a 9 foot diameter "exit wound" where the plane debris exited the C ring. There were very few identifiable plane parts in the wreckage. Most of the plane disintegrated from the intense heat of the fireball. Other than some fire and smoke damage, there was a relatively small amount of damage in the A and B rings.

Figure11. A&E Drive. The plane exited through C ring and left a pile of debris. The water is from the fire fighting activities. Very few traces of the airplane remained intact.

Internal structural damage in Rings C, D and E was significant. Concrete columns were blown apart and twisted into unrecognizable pieces of rubble. The spiral reinforcing steel in the columns had an eerie skeletal appearance. Several beams were missing and holes were blown up through the second floor. Figure 12 is a good example of the internal damage to the concrete structure. Additional pictures of the structural damage are included in the appendix.

Figure 12. Internal damage to concrete columns and beams.

In addition to the structural damage from the initial explosion and subsequent fire, there was a tremendous amount of debris from all of the furnishings, utilities and miscellaneous interior finishes. The debris created obstacles for the shoring crews during the operations. Before each shore could be constructed, the debris had to be cleared from the area where the shore was to be built.

Although the damage was significant, analysis of the damage has indicated that the renovation of the building played a significant role in saving lives. Most casualties in a blast effected building are caused by flying glass and debris. The force protection measures installed during the renovation likely reduced the number of casualties by reducing the amount of debris forced into the building by the explosion (Winston, 2001). Fortunately, because the renovation was still officially under construction, several offices were vacant at the time of the incident, so the number of casualties was less that what it would have been if was occupied at full capacity. (Evey, 2002)

In addition to reduced casualties, it is believed that the newly installed sprinkler system and force protection reduced the amount of damage that would have likely occurred if the renovation had not been completed. In Wedge 2, where the renovation had not yet started, the amount of damage from fire was significantly greater that the Wedge 1 section. Figures 13 and 14 are a comparison of the damage to offices in the renovated and non-renovated sections.

Figure 13. Office in Wedge 2. No sprinklers

Figure 14. Office in Wedge 1.
Sprinklers recently installed

Monitoring

Throughout the shoring and recovery operations, the building was monitored by the Structural Specialists and Heavy Rigging Specialists 24 hours per day. Monitoring was done using transits, binoculars, radios and air horns for emergency signaling. Once demolition of the collapsed area started, monitoring was also done from the air using a man basket suspended by a crane. The Structural Specialists took turns going up in the basket to look at the structure from a different angle and to watch for victims as pieces of debris were removed.

Movement of the building or large pieces of debris being monitored with the transits was recorded at 15 minute intervals. In the event significant movement was observed, the Operations and Safety Managers were notified and decisions would be made on whether or not to evacuate the shoring teams. There was some minor movement observed daily believed to be associated with fluctuations in temperature. Other than that, there was relatively little movement of the structure recorded during the shoring operations. However, it was reported that the building began to show some significant movements several weeks after the shoring was completed and just prior to the demolition started to kick off the reconstruction phase.

There were a few occasions where sudden movements of debris and a flash fire required emergency evacuations of the shoring crews inside. Fortunately, there were no serious injuries during the entire operation.

Figure 15. Transit monitoring station.
Transits were set up to monitor several points on the building during the shoring operations.

Shoring Operations

As mentioned earlier, the initial reconnaissance discovered that the structure was unstable and several columns were known to be missing. There were areas inside the building that were unsafe to enter during the initial reconnaissance, so it was unclear on the afternoon of September 11th how many columns would eventually need to be shored.

The U.S. Army Corps of Engineers (USACE) publication Urban Search & Rescue Structural Specialist Training Manual defines shoring as follows: "Shoring for US&R is the temporary support of only that part of a damaged, collapsed or partly collapsed structure that is required for conducting search and/or rescue operations at reduced risk to the victims and US&R forces."

The Structural Specialists on site agreed that the most critical area in need of shoring was the exterior column line, just to the north of the collapse zone. The plan for this area was to construct two nine point crib shores and a solid crib shore to support the vertical loads of the four levels above the damaged area. Figure 16 shows the shoring operations underway in the early morning hours of September 12th.

Figure 16. Start of shoring operations. Photo taken as the first crib shore is being completed at approximately 1:00 a.m. the morning of September 12th, 2001.

However, before the shoring work could begin, there were several logistical challenges that had to be overcome:

1. Lumber to construct the shores had to be requested and delivered. The IST worked with representatives of the Pentagon Renovation Project, the Home Depot and other contractors to get several loads of lumber delivered to the site.

2. Debris had to be removed from hazardous areas before shoring could begin. The United States Army brought several units to the site to provide additional manpower for clearing and removing debris. After stockpiling the debris, it was hauled to a parking lot on the north side of the building where the FBI spread it out and sorted through it for evidence. Occasionally a victim or evidence was found while removing the debris, which delayed operations even longer as the appropriate agency was called in for removal.

3. Loose limestone panels on the exterior of the building (known as "widow makers") had to be knocked down so there weren't any overhead dangers while shoring operations were going on. Several panels were observed located immediately above the areas that required shoring on the exterior column line. Rescue personnel pried off several of the loose panels with crowbars.

4. Areas for lumber storage and cutting stations had to be designated. Initially, a large area of the concrete helicopter pad adjacent to the collapse zone was designated for storage of lumber and shoring supplies and a cutting station was built. Later in the week a second storage and cutting area was set up inside of A & E drive.

Figure 17. Lumber storage. Lumber for shoring was delivered to the site by Home Depot and stored on the concrete helicopter pad.

5. Lighting had to be supplied since much of the shoring activity would be done at night or inside the building which had no lighting. The IST coordinated obtaining lighting equipment to allow work to continue 24 hours per day. There was enough lighting to begin shoring the night of the 11th, however, sufficient lighting for the rest of the operations did not arrive until the second day.

6. Monitoring stations with transits had to be set up for the Structural Specialists to keep a close eye on potential shifts in the building during the operation. Three transits were initially set up monitoring the corner of the building adjacent to the collapse zone and a large concrete parapet that was being held up by only a few pieces of reinforcing steel. The Structural Specialists and Heavy Rigging Specialists kept monitoring logs during the entire operation.

Once all of these issues were resolved, the shoring process could begin. According to monitoring logs recorded by the Structural Specialists, shoring began at approximately 11:45 p.m. on the night of September 11th, 2001. A copy of the first monitoring log is included in the appendix of this paper and notes the status of the shoring activity throughout the night. (Titus, 2001)

The US&R teams are trained to construct several different types of shores that may be necessary during a rescue operation. The US Army Corps of Engineers has published a manual titled "Urban Search and Rescue Structural Specialist Field Operations Guide". This guide provides step-by-step instructions on how to build the shores and provides detailed sketches of the shoring systems. Copies of the shoring diagrams that were used at the Pentagon the week of September 11th are included in the appendix.

Several types of shores were used during the shoring operations:

1. Crib Shores
2. Vertical Post Shores
3. Steel Raker Shores

Three crib shores and one vertical shore was constructed on the exterior column line. According to the monitoring log, these shores were completed at approximately 5:45 a.m. the morning of September 12th.

Review of the Shoring

The following discussion covers a brief description of the types of shoring systems that were used during the deployment. Copies of the standard shoring diagrams from the US Army Corps of Engineers "Urban Search & Rescue Structural Specialist Field Operations Guide" (FOG) are included in the appendix.

Crib Shores

Crib shores were the most common type of shore used for two primary reasons. First, they have the highest capacity of all the shoring systems in the FOG. Second, and possibly just as important, there are relatively simple and quick to build. Once debris was removed, a crib shore took approximately one hour to complete.

Crib shore capacities are dependent on the size of the lumber used and the configuration of the lumber. At the Pentagon, 6" x 6" lumber was used for most of the cribbing. The height of the crib shores ranged from approximately 14 feet (floor to beam) to 15.5 feet (floor to slab). There were three different crib configurations used:

1. 4 Point Crib: Two by two member layout, yielding four points of contact. Approximate capacity: 60,000 lbs. (30 tons).

2. 9 Point Crib: Three by three member layout, yielding nine points of contact. Approximate capacity: 136,000 lbs. (68 tons).

3. Solid Crib: Eight by eight layout, yielding one large point of contact approximately 48" x 48". Estimated capacity: 1.1 million lbs. (576 tons). Only one solid crib was used. It was located at the corner of the cantilevered section of the building, immediately north of the collapse zone. The rescue workers decided to build a solid crib at this location because it was thought that it would be more stable in the event debris broke away from the collapsed area and slid into the shoring. (Tills, 2001).

In general, one crib shore was enough to support damaged columns. However there were six locations where the damage was so significant to the columns and beams that two or three crib shores were required to adequately transfer the load from the upper floors. Figures 18, 19 and 20 are examples of some of the crib shores used to support interior columns. Additional shoring pictures are included in the appendix.

Figure 18. 4 point crib shore. Used to support damaged columns still carrying loads.

Figure 19. 9 point crib shore. Used where columns were severely damaged or missing completely.

Figure 20. Crib shore at column 11D. Shoring Squad builds a 4 point crib shore around damaged column 11D.

Vertical Post Shores

Vertical post shores were also a common shoring system used during the Pentagon deployment. Vertical post shoring systems are generally used for support of vertical loads. However, many systems have some limited lateral bracing for increased stability. (USACE, 2001). A disadvantage of vertical post shores is that they are more labor intensive. While crib shores are constructed by simply stacking lumber and shimming into place, vertical shores require more measuring and cutting.

There are several types of vertical post shores in the FOG used by US&R Task Forces. Post systems can be as simple as a single post with a header beam and a footer. More complicated post systems include multiple vertical posts with lateral bracing. All systems collect loads with a header beam and transfer the load to the base. Several examples of the different vertical shores are included in Appendix I.

Vertical post shores do not have as high a capacity as the crib shores and are used to support smaller loads. The capacity of a system depends on its configuration, height and materials used. Vertical post systems can support a wide range of loads from 3,000 to 8,000 pounds for simple post shores, up to 80,000 pounds for laced post shores.

During the Pentagon deployment vertical post systems were used to support beams, floor slabs and overhead debris. They were placed strategically to reduce the risk for the shoring squads as they approached the more critical areas that required the higher capacity crib shores. Figures 21 and 22 are photographs of the different vertical shores built by the US&R Task Forces the week of September 11th.

Figure 21. Vertical Shore.
This vertical shore is supporting a beam which allowed the shoring squads to work with reduced risk while building the adjacent crib shore.

Figure 22. Vertical shores.

Raker Shores

Raker shores are designed to laterally brace walls that have the potential for leaning away from a building. Their capacity range significantly based on the type of system, the height and the angle.

On Thursday, September 13th, the crib shore shims along the exterior wall were over tightened which caused the concrete beam to shift slightly. The Structural Specialists decided that it would be prudent to add a raker shore on the cantilevered section to reduce the possibility of the building wall shifting laterally and possibly collapsing.

At the request of the IST, the contractor on site obtained some steel sections (W6 x 25 and W8 x 24) and some miscellaneous plate sections. The US&R Heavy Rigging Specialists and shoring squads completed the fabrication and installation of the raker shore. This raker shore was approximately 14 feet high with a raker angle of about 45 degrees. Adhesive anchors were used for securing the top of the rake to the concrete (Tills, 2001). Figure 23 is a photograph of the raker shore installed. After the raker was installed, no significant lateral movement was observed during the deployment.

Figure 23. Raker Shore for lateral support. Notice the 3 crib shores and 2 vertical post shores for vertical support. The shims at the top of the crib shore were over-tightened causing the concrete beam to shift slightly. VA-TF1 Structural Specialist section leader, Dean Tills, is standing to the left of the raker shore.

Completion of Shoring

Four US&R Task Forces and the team from the Military District of Washington worked 24 hours per day for over a week to stabilize the structure. A fifth Task Force was brought in to relieve the others on the final days of the deployment.

By the end of the deployment, 42 columns required shoring on the first floor using 49 box crib shores. Thirty-five beams were shored on the first floor using T-shores and vertical post shores. On the second floor, six columns were shored with box cribs and five beams were shored with vertical post shores. No shoring was required above the second floor (Stanton, 2001). Other than some minor cuts, bruises and sore feet there were no serious injuries during the operation.

Spreadsheets are included in Appendix II that present a summary of all the shores that were constructed during the deployment.

Figure 24.
Miscellaneous debris is cleaned up in an area where crib shores have been completed.

Closing

VA-TF1 was the first US&R Task Force on site on September 11th. Therefore, they were the first to leave on September 18th. After paying final respects to the victims of the tragedy, the Task Force loaded up all of it's equipment and personnel and headed home to a large group of very excited family members and friends.

By September 14th, 2001, plans were already underway for the rebuilding of the Pentagon. The initial goal is to have the building reconstructed and people occupying the outermost offices by September 11th, 2002. By the time all of the recovery had been completed, there were only eleven months left to accomplish this difficult task that is now known as "Project Phoenix".

Demolition of the damaged portion of the structure, approximately 400,000 square feet of office space, was completed on November 19th, 2001 (Evey, 2002). Construction crews worked day and night, seven days a week. On April 5th, 2002, the last concrete placement for the rebuilt structure was completed and a "Topping Out" party was held to celebrate this important milestone. As of May 1, 2002, Project Phoenix is at least six weeks ahead of schedule. There is no doubt in the minds of the workers that they will exceed their goal. They are dedicated to honoring the memory of the lives lost by showing the world what Americans can accomplish in times of crisis. As the rebuilding continues, the FEMA National Urban Search and Rescue Response System is preparing for the next deployment.

Figure 25. VA-TF1 Goodbye. Members of Virginia Task Force One pay final respects before leaving the Pentagon on September 18th, 2001.

Acknowledgements

The author would like to acknowledge the following individuals who provided information and photographs that aided in the preparation of this paper: From VA-TF1: Dean Tills, P.E., Tony Beale, P.E., Stan Murphy, P.E., and Scotty Boatright. From MD-TF1, Victor Hare and Tom Stanton.

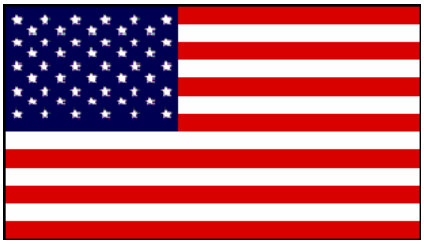
There are too many individuals on the shoring squads to list by name. However, the author would like to acknowledge the tremendous effort by all of the individuals on the shoring squads, the Heavy Rigging Specialists, the other Structural Specialists and all of the other FEMA US&R Task Forces and Military District of Washington members that worked together as a team to accomplish the mission. Specifically, the author would like to express gratitude for the guidance and mentoring during the deployment offered by Rescue Squad Officer, Kent Watts and Structural Specialists, Dean Tills, Tony Beale and Stan Murphy. Their sharing of knowledge and experience was invaluable.

Mr. Allyn Kilsheimer, P.E. of KCE Structural Engineers, PC, was also a valuable source of knowledge during and after the deployment. The author met Mr. Kilsheimer on site the evening of September 11th. He was a part of the Pentagon Renovation team during the recovery operation and since has taken over the oversight of the Phoenix Project.

Some of the contractors that provided materials, equipment and skilled operators included Facchina Construction Co., AMEC Contracting, The Home Depot, Potts & Callahan, Bovis, Dominion Crane, Springfield Crane Rental, Singleton Electric, Rentals Unlimited, National Wrecking, Union Wrecking and the Pentagon Renovation Team

Other Agencies that worked closely with the FEMA Task Forces included the United States Army, the FBI, the United States Army Corps of Engineers, Arlington County Fire Department and Fairfax County Fire Department.

Finally, all of the volunteers and organizations that donated food, supplies and support deserve special recognition. The Salvation Army, The American Red Cross, McDonald's, Wal-Mart, Burger King, the staff at the Crystal City Marriott and many others helped to make the mission a little more comfortable. The cards, letters, emails, flowers and banners sent by school children, teachers, family members and citizens from across the country and the world were read and appreciated by all.



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APPENDIX

I. Monitoring Log from September 11, 2001 and Shoring Diagrams from the US Army Corps of Engineers "Urban Search & Rescue Structural Specialist Training Manual."

II. Pentagon Incident Shoring Tables - Compiled by Tom Stanton, MD-TF1

- First Floor Box Crib Shore Table – Tom Stanton, MD-TF1 (IST)
- First Floor Beam Vertical Shore Table – Tom Stanton, MD-TF1 (IST)
- Second Floor Box Crib Shore Table – Tom Stanton, MD-TF1 (IST)
- Second Floor Beam Vertical Shore Table – Tom Stanton, MD-TF1 (IST)

III. Additional Photographs