



**WORLD TRADE CENTER DISASTER:
*STRUCTURAL ENGINEERS AT GROUND ZERO***

Prepared for:

**National Council of Structural Engineers Associations -
Structural Engineering Emergency Response Plan
(SEERP) Committee**

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CHAPTER 1: INTRODUCTION

1.1 Purpose

This document was written as a resource for the preparation of an emergency response plan for mobilizing structural engineers for a search and rescue operation under extreme emergency conditions. More specifically, it was developed for preparing a response plan that uses structural engineers after a major collapse or failure.

This document alone is not an emergency response plan. Instead it should be used for the purpose of stimulating discussion and for presenting ideas as the first step in preparation of a comprehensive Structural Engineering Emergency Response Plan (SEERP). The SEERP would need to be prepared so that it can be implemented in conjunction with an overall state or federal government emergency response plan.

1.2 Required Response

This document provides commentary and observations based on the structural engineering emergency response to the Ground Zero search and rescue operations at the World Trade Center (WTC). The unprecedented need for technical assistance mandates that the structural engineering profession takes appropriate steps to reach a level of readiness to ensure the most immediate, efficient and effective response possible in the future.

As a result of the events that occurred on September 11, 2001, the structural engineering profession should do the following:

- Prepare a comprehensive Structural Engineering Emergency Response Plan (SEERP) that is completely ready to implement before a disaster occurs.
- Ensure the plan is uniform for all states so that structural engineers responding from any state can be fully integrated into the local response effort.
- Ensure the plan is uniform for all states so that government agencies throughout the United States can work efficiently with the structural engineers.

1.3 Immediate Task

Time is of the essence in the preparation of the SEERP. It is recommended that this detailed response plan be prepared by an engineering organization that is national in scope. It is envisioned that the generic SEERP be prepared by a national organization in a format that each state engineering organization would adopt, modify, and train engineers for an appropriate response when the need arises.

1.4 Source Material

The information presented in this document was obtained from two sources. Much of the information was obtained from discussions with structural engineering teams that worked at Ground Zero. The other source was the author's own opinions based on working at Ground Zero.

Nothing in this document should be interpreted as a criticism of any of the structural engineers or structural engineering organizations involved with any aspect of the emergency response. Any questions regarding this issue should be resolved by referring to Chapter 11 of this document.

CHAPTER 2: GROUND ZERO OPERATIONS AT THE WORLD TRADE CENTER

2.1 General

Groundbreaking for construction of the World Trade Center took place on August 5, 1966. Tower One, standing 1368 feet high, was completed in 1970, and Tower Two, at 1362 feet high, was completed in 1972. The structural design for the World Trade Center Towers was done by Skilling, Helle, Christiansen and Robertson. It was designed as a tube building that included a perimeter moment-resisting frame consisting of steel columns spaced on 39-inch centers. The load carrying system was designed so that the steel facade would resist lateral and gravity forces and the interior concrete core would carry only gravity loads.

The towers had a total of 9,000,000 square feet of usable space with more than 200 elevators and 43,000 windows. Each floor of the towers had nearly one acre of floor space with occupancy of the two towers totaling 50,000 people. Until 1975, the World Trade Towers were the tallest buildings in the world. At the time of the collapse they were the sixth tallest buildings in the world.

On Tuesday, September 11, 2001, a terrorist attack resulted in the total collapse of the towers and surrounding structures. A brief overview of the events of the collapse is as follows:

- 8:45 a.m. Tower One was impacted at the 90th floor by a hijacked commercial jet. The impact breached part of the framing from the 96th to 103th floors. The jet was carrying large amounts of fuel for a cross-country flight, and therefore, caused an intense fire within the building.
- 9:03 a.m. Tower Two was impacted at the 87th floor by a second hijacked commercial jet and was also carrying a large amount of fuel. The impact breached part of the framing from the 87th to 93th floors
- 10:05 a.m. Although it was the second structure impacted, Tower Two collapsed after approximately 60 minutes of intense fire within the structure.
- 10:30 a.m. Tower One collapsed after a little more than 100 minutes of intense fire within the structure.

The collapse of the structures, along with the collateral damage, produced a pile of debris weighing more than two billion pounds, over 5,000 fatalities and thousands of injured civilians and rescue workers.

Search and rescue operations began immediately after the collapse. However, falling debris and a thick layer of smoke prevented any large scale effort on the day of the collapse.

On the morning after the collapse, convoys of construction equipment were rounded up to respond to the immediate need for search and rescue. Shortly after, an army of ironworkers, heavy machinery operators, firemen, policemen and many others descended on the site to assist in the massive search and rescue effort. At the request of Rudolph Guiliani, Mayor of the City of New York, the Structural Engineers Association of New York (SEAoNY) organized structural engineers to assist in the disaster response effort.

2.2 Division of Disaster Site

The boundaries of Ground Zero, which encompassed approximately 16 acres, were as follows:

East Boundary:	Church Street
North Boundary:	Vesey Street
West Boundary:	West Street
South Boundary:	Liberty Street

The City of New York Department of Design and Construction divided the site into four quadrants with one contractor assigned to each zone. The zones were as follows:

Zone 1:	Contractor - AMEC Area included the WTC North Tower along West Street.
Zone 2:	Contractor - Bovis Lend Lease Area included the WTC South Tower along Liberty Street.
Zone 3:	Contractor - Tulley Area included the east half of the WTC site.
Zone 4:	Contractor - Turner/Plaza Area included the northern edge of the WTC site and WTC Building 7.

Each quadrants was assigned not only a contractor, but also structural engineers, subcontractors and rescue workers. The boundaries changed slightly as the work progressed to accommodate logistic issues.

2.3 Contribution by Structural Engineers Around Ground Zero

At the site, teams of structural engineers contributed by resolving many technical issues such as the following:

- Inspecting more than 400 buildings around the perimeter of Ground Zero.
- Designing a tieback system for the slurry wall foundation of the WTC.
- Determining the stability of structures to allow access for crime evidence retrieval.
- Inspecting isolated portions of buildings to allow access for utility companies.
- Designing shoring and bracing for unstable buildings.
- Determining areas where heavy equipment could safely work.

2.4 Structural Engineers at Ground Zero

The structural engineers at Ground Zero assisted the fire department and demolition contractors in search and rescue efforts. This assistance included monitoring distressed buildings to avoid catastrophic failure in the area of search and rescue workers, determining order of debris removal and assisting with overall construction safety issues.

Each team was composed of three structural engineers. At least one member of each team was required to be a licensed engineer in the state of New York. During the first five days, the teams worked eight hour shifts around the clock. This was later changed to twelve hour shifts.

Each shift began by attending a briefing meeting which was coordinated by the staff of the command center. Each of the teams ending their shift gave a brief summary of completed work and outstanding issues to all present. After that time, the four teams that had just come from Ground Zero met individually with their corresponding replacement team to discuss issues in greater detail.

The new teams would then proceed to their respective zones accompanied by the team that had completed their work in that zone. As part of this process, there was an introduction to the current contractor superintendent and possibly the lead person for the fire department.

At the end of their shift, the engineering teams proceeded back to the command center to brief the new teams. Each team was required to prepare a short written report regarding the activities in their zone.

CHAPTER 3: THE HIERARCHY

3.1 Overview

The nature and magnitude of the disaster will dictate which entity will have overall charge or who will have major input into the search and rescue operations. It is beyond the scope of this document to present or predict any type of search and rescue hierarchy. Some of the entities that would be involved and general comments about them are presented in this section. Part of the proper planning should include at least some face to face meetings with these agencies.

Federal Emergency Management Agency (FEMA)

Mission: FEMA is an independent agency of the Federal government to the President of the United States. Their mission is to reduce the loss of life and property and to protect the nation's critical infrastructure from all types of hazards through a comprehensive, risk-based, emergency management program of mitigation, preparedness, response and recovery.

Comments: The Ground Zero structural engineering teams noted that they had little direct communication with FEMA. It was also noted that FEMA is an excellent resource for training and reduction of the impact of disasters.

Army Corp of Engineers

Mission: The United States Army Corps of Engineers is made up of 650 military personnel and 35,000 civilians. In addition to being in charge of water resources and managing construction of military facilities, they are ready to provide assistance for needs arising from national emergencies. The Army Corp of Engineers is the world's largest public engineering, design and construction management agency.

Comments: The Army Corp of Engineers provided useful assistance to teams. As part of the site safety plan, structural engineers monitored an unstable structure with surveying equipment, which was of poor quality. The Army Corp of Engineers became aware of this situation and provided not only quality surveying equipment, but also a qualified person to man the equipment.

Office of Emergency Management (OEM)

Mission: Major cities have an Office of Emergency Services. This department is typically a component of the Mayor's staff and is responsible for strategic emergency planning for the city.

Comments: Several of the Ground Zero structural engineering teams noted that they were impressed with workers from the City of New York's Office of Emergency Management (OEM). It was a common sentiment that it would be well worthwhile to coordinate the pre-planning with the city's Office of Emergency Services.

3.2 Structural Engineering Hierarchy

The upper level of the search and rescue operations will consist of the fire department, FEMA or other agency. Somewhere below this upper level of protocol, the structural engineers will fit into the hierarchy of the search and rescue plan. It is probable that the structural engineering teams involved in search and rescue will be working under the direction of the City's Office of Construction and Design.

The City of New York employed the services of an engineering firm (LZA-Thornton Tomasetti) to oversee structural engineering operations for the WTC disaster. The Ground Zero structural engineering teams believed that contracting with the firm to oversee the structural engineering operations was a proper method for dealing with the disaster. Having a contractual arrangement with an engineering firm ensures that there will be an obligation to staff a command center rather than relying on volunteers. Since the scope of damage caused by a terrorist attack can not be predicted, it may be wise that the governing authority have a contract with a secondary command center team in the event that the primary team can not respond. It should be noted that the primary and secondary teams should not have offices near the same location.

The engineering command center, where briefings and technical meetings were held, was headquartered in a public elementary school just inside the security perimeter and had telephones and basic necessities for operations.

The structural engineering teams for Ground Zero were supplied to the engineering command center through SEAoNY. Having the teams organized by the state's structural engineering association is an efficient and logical way to staff the search and rescue teams. A logical extension of this position is that these same associations be responsible for organizing and preparing structural engineering teams prior to a disaster. Even though the organizing should be done on a state by state level, a uniform system should be used for all states. The use of a uniform system has an advantage such that if the scope of the emergency requires out of state engineering teams, these teams would have a complete understanding of the system. For this reason an emergency response program may be best prepared under the auspices of a national structural engineering organization.

CHAPTER 4: EQUIPMENT

4.1 General

Usually the more equipment available, the more prepared you are. This may not be the case for Ground Zero search and rescue efforts. As previously noted, the engineering teams met at a local engineering office and then walked as a group to the command center. This would normally have been a two mile walk. When you include the extra walking from the site access, you have quite a long way to carry your gear. After getting briefed at the command center, the teams had to walk to Ground Zero, which was another half of a mile for some of the teams. The reverse route was then taken at the end of a demanding shift, which was spent standing the whole time. For this reason, one has to balance the value of more equipment with having to carry it around.

It is amazing that within days of the disaster, every type of personal equipment or toiletries needed had been donated and were available at the site. Personal items donated included shoes, helmets, construction vests, gloves, toothpaste, even underwear and undershirts. Available equipment included shovels, flashlights, buckets, picks, etc. Warm food was provided from major fast food chains, as well as local restaurants and bottled water was readily available at the edges of Ground Zero.

Americans may be accustomed to the generosity of their fellow citizens, but it is not prudent to rely on supplies being available. First, if events such as what occurred on September 11, 2001, keep reoccurring, the resources to donate may eventually be depleted to some extent. Second, a more widespread disaster at several locations may also thin out the resources. Third, consider that there may be no supplies for the first few days.

4.2 Personal Equipment

The minimum recommended equipment needed for the structural engineering search and rescue teams is as follows:

Flashlight & Batteries	Tape measure
Heavy work gloves	Orange construction vests
Construction helmet	Rain gear
Eye protection	Clipboard and paper
Cellular phone	Two-way radios
Respirator	Hearing Protection
Camera	

4.3 Team Equipment

Each team should consider having access to the following available equipment if appropriate:

Binoculars
Hammer
Micrometer

Surveying equipment
Concrete rebound hammer
First aid equipment

4.4 Hazardous Site Equipment

It is not unrealistic to expect that a future terrorist attack may pose some type of biochemical or environmental problems. Handling of these situations is beyond the expertise of structural engineers. Issues such as special clothing and respirators need to be resolved. It may be wise for the pre-planning to consider consulting with a professional experienced with these types of problems.

CHAPTER 5: THE STRUCTURAL ENGINEERING TEAM

5.1 Preparation

There was an overwhelming consensus among the structural engineers at Ground Zero that it is of the utmost importance to have structural engineering teams in place before a disaster strikes. This is not a criticism of any entity for the absence of having the teams in place for the WTC terrorist attack. Prior to September 11, 2001, it was difficult to imagine a disaster of this magnitude. We know now that such an event can occur and we must prepare accordingly. With advance preparation, a structural engineering team can be ready within hours to assist in a search and rescue operation. This not only increases the chances of a successful search and rescue operation, it provides a safer working environment for the rescue teams. The importance of having teams in place prior to a disaster can not be overemphasized.

The first step in the organizational process is to determine the role of the structural engineer. In typical emergency situations, it would not be unusual for a structural engineer to be in charge of the site. However, this will not be the case in a large scale disaster when primary focus will be on search and rescue, not on stabilizing structures. Some mixture of federal, state, and city authorities will be in charge of the site and it is likely that structural engineering teams will be assigned as advisors to an entity in charge of a particular zone of the disaster area. It would be prudent to prepare a mission statement for the structural response teams that lay out the role to be played in the full disaster team. To understand the level of participation expected of the structural engineers, this mission statement can only be determined after consultation with the various levels of governmental authorities.

5.2 Team Size and Organization

A workable team size is three to four engineers. The use of teams consisting of two engineers is not desirable for several reasons. During shift changes, the team leader leaves the field to brief the oncoming team of engineers. This would leave a team with only one engineer in the field, which is inadequate for the work load. Also, the third engineer can be used as a liaison to adjacent zones when demolition begins to overlap, handle issues that arise outside the zone, and work on specialty issues. A team with more than three or four engineers may be cumbersome for making quick decisions.

A suggestion to consider is that all team members be from one company or a group of engineers that have worked together in the past. Utilizing one company has the benefit of a pre-existing hierarchy where the senior person within the company assumes a leadership role or delegates that authority. A team formed from a single company that has experience in site work will have knowledge of each other's capabilities, strengths and weaknesses. This allows for the optimal use of individual talents, as well as a reduction in the time that it takes the team to start work.

Each team should have a team leader that would be responsible for various aspects of the work such as report submittal, attending briefing meetings, etc. In the day to day operations of an engineering practice, the team leader, or project manager, ultimately makes all major decisions.

This approach is not practical in disaster situations. Each team member must be capable of making decisions on an individual basis because it can be expected that issues will arise at opposite ends of a zone at the same time. This will preclude the use of a hierarchy system where the team leader must review all major decisions. The team leader should be considered the conduit for the receiving and sending of information, the assigning of tasks, and similar issues, but not as the ultimate authority of the team.

5.3 Disaster Response Experience

Technically sound and timely decisions by the structural engineer may mean the difference between life or death in a search and rescue operation. Structural engineering teams need to consist of structural engineers with appropriate field and disaster response experience. Therefore, when selection of teams are made, field experience and prior participation in disaster services should be considered. Because teams will have the support of the command center to perform design and analysis, design experience may be of less importance. The importance of having dealt with emergency stabilization of structures can not be overemphasized.

Field experience is helpful in working with contractors, understanding crane operations, and assisting in site safety. Having experience in previous emergency or disaster work is also essential. Past dealings with emergency stabilization of buildings or emergency demolition provides useful training for dealing with the pressures of disaster response. Pressures include not only having to make difficult engineering decisions under extreme time constraints; they also include working under chaotic conditions and with workers and contractors that are sometimes overzealous. No previous disaster response experience could fully prepare a structural engineer for a disaster the size of the WTC emergency, but the experience of dealing with emergencies in the past provides the confidence level needed to make decisions.

Structural engineers that have more experience in design aspects rather than emergency field operations will also be needed for the overall disaster response. As discussed in the next chapter, structural engineers with this type of experience would be useful in performing assessments of buildings directly adjacent to Ground Zero.

5.4 Diversity of Location

Teams should be chosen so that a wide diversity of location exists. Choosing engineers that are located in an urban center may be problematic if the disaster makes the team victims rather than volunteers. On the other hand, engineers located further outside an urban area may have limited experience in large structural disasters. Teams with appropriate experience should be chosen so that a wide geographic area within the state is represented. Coordination with national organizations would be helpful in supplying teams from other states in an organized and efficient manner.

5.5 Number of Teams

The number of teams needed would obviously depend on the nature and magnitude of the disaster. A significant sized urban area may consider having 18 to 20 teams within the state to assist in search and rescue operations. The approach used to determine this number is as follows:

- Magnitude: Considering an incident the size of the WTC disaster, this would require dividing the disaster site into four work zones, each staffed with one team.
- Work Shift: The day would be divided into two, twelve hour shifts. It is assumed that a team would work two days on, two days off.
- Availability: Assuming that problems would result from the disaster, travel, and personal issues, this would result in 10 to 20 percent of the teams being unavailable for disaster response. However, maybe a greater percentage of unavailable engineers should be used and the number of teams adjusted accordingly.

5.6 Specialties

There must be some diversity in the structural engineering teams to provide expertise in structures other than buildings. A certain amount of teams should be composed of engineers having experience in bridges, specialty structures and utilities. The extent of specialty teams needed would be tailored to the need for a certain locale. In some parts of the country, a team with expertise in moveable bridges would be appropriate, while in other parts, a team experienced in tunnel structures is needed.

A fortunate occurrence at Ground Zero was that some of the structural engineering teams had designed portions of the World Trade Center, or had previously provided services for the City of New York's subway system. Not only did this provide valuable engineering experience, but their offices had ready access to engineering drawings as they were needed.

CHAPTER 6: GROUND ZERO OPERATIONS

6.1 Environmental Concerns

Structural engineers had concerns about environmental contamination at Ground Zero. Due to the urgency of the situation, the teams proceeded without a full understanding of these environmental conditions. It was assumed that the air was being monitored for contamination by governmental agencies, however, no specific information was filtering down to the structural engineering teams.

The status of the environmental hazards needs to be presented to the engineers in a timely manner so that the extent of risk is understood. Methods of dealing with environmental concerns are presented in Chapter 7.

6.2 Contractor

As previously explained, a general contractor was assigned to each of the four zones. Several of the structural engineering teams were of the opinion that the system may have worked more efficiently if there was a construction manager overseeing all four of the contractors. This would have several benefits including: one contact for all construction related problems, division of work at the edges of adjoining zones and one source for obtaining information on contractor contact names and cellular telephone numbers. However, others felt that this would add another unneeded layer of protocol and that a city's design department can handle this task.

There was a loss of continuity whenever shift changes occurred in the construction or structural engineering teams. Consequently, there needs to be a system in place that notifies the structural engineering teams when there is a change in superintendents, the name of the oncoming superintendent and the contact number for this person.

6.3 Field Briefing

At the time of each structural engineering shift, a briefing session would be held at the engineering command center, which was located several blocks away from Ground Zero. In the first few days of the search and rescue operations, the briefing was accomplished by all the team members completing their shift gathering with the all the team members starting their shifts. This resulted in a period of anywhere from 30 to 60 minutes or longer when there were no structural engineers in the field. To eliminate this void, briefing sessions were later changed to include only the team leader, while the remainder of the team remained at Ground Zero until their replacements arrived to relieve them.

The change in shifts included the completing teams giving the oncoming teams a walk-through of the site while identifying the main problems and issues. An important part of this changing of teams should include the introduction of the new engineering team to the contractor's superintendent and the fire official in charge. At this time, the superintendent should be asked specifically when the next contractor's shift change is and who the replacement will be.

6.4 Site Access

The process of obtaining access through the security checkpoints going to Ground Zero was disorganized, frustrating and most importantly, resulted in a significant delay. To further complicate the situation, the process was constantly changing. The importance of restricting access to the disaster site is obvious, and it is not difficult to understand the problems faced by security when dealing with the multitude of people trying to access the site. A disaster site the magnitude of the WTC will always present security problems and gaining access will be filled with frustrations and delays.

An overview of how the structural engineering teams gained access to the disaster site is as follows:

- Structural engineering teams met off-site at an engineering firm's office to fill out paperwork and to receive general briefing.
- The teams walked to the perimeter of Ground Zero.
- Security personnel searched for documentation to verify if they were allowed access to the site. In some cases, they asked for verification that the individuals were licensed engineers.
- After much confusion, having to wait in line with hundreds of construction workers, and being sent to various security check points, site passes were eventually issued.
- Engineers proceeded to the engineer command center to be briefed by crew being relieved.

The most desirable solution to checkpoint delays would be to have security passes issued to the team members prior to the disaster. The main problem with this is that it is not known who would have the authority to issue the passes because it is not known ahead of time who would actually control the site. A city issued security pass may be worthless if the Federal government takes charge of the site. Other problems with pre-issued security passes that need to be considered include passes being stolen or copied by individuals who should not have access to the site. The pre-approved security pass concept is not a likely viable alternative.

Since engineers can not change the access systems, it is advised that they be organized and prepared to help security expedite the process. A reasonable method of streamlining the process may be to have a person assigned specifically to facilitate access to the site. This person would determine the process for gaining access and be kept abreast of its changes. It is possible that arrangements could be made with security forces to have the structural engineering teams enter as a group.

Efforts should be made by this individual to handle as much of the access processing prior to the team arriving. The liaison person should be provided with a file that would include a copy of every team members' driver's license, social security and engineering licenses. Having this documentation presented to security in an orderly and professional manner should help expedite the process.

6.5 Identification

Minor details can have significant impacts. SEAoNY provided team members with a stick-on label for their helmets that identified that person as a structural engineer. This minor detail proved to be extremely useful for the following reasons:

- Those needing technical assistance could easily identify the engineers.
- It offered a comfort level as to the availability of technical resources for those not currently needing assistance but who may need help in the future.
- The clear designation of our qualifications as structural engineers resulted in our advice being given its proper weight.

Because of this success, it is recommended that it be used in future situations. It may be even more effective if one style and color of construction helmets be obtained with permanent lettering stating "STRUCTURAL ENGINEERING - EMERGENCY RESPONSE TEAM" or similar for each team member. Since the need for a structural engineer is usually accompanied with some degree of urgency, a highly visible color should be chosen to make the engineer more visible. This would allow for maximum visibility on site and correspondingly, making maximum use of the structural engineer's talents.

The appropriate association, either on a national or local level, should issue some form of identification card that identifies the person as part of an emergency response team. This could be used to streamline the process of gaining access to the site. It may be prudent to have photographs on these identifications, as well as an expiration date to prevent abuse.

It is interesting to note that a copy of an engineering license appeared to be the document that security personnel were most interested in, as well as convinced by. It is suggested that team members obtain another original of their license and add it to the emergency equipment.

6.6 Protocol

As discussed in Section 5.1, the first step in preparing for a disaster is to have a clear understanding of the structural engineer's mission and their position within the emergency response hierarchy. The engineering command center for WTC did a good job of explaining to the structural engineering teams that they would be assigned to one of the four zones and would be under the direction of a fire department official.

It would be helpful to the structural engineer to have an understanding of the overall hierarchy of the site. The engineering command center should prepare a flow chart showing the hierarchy of the entire site, as well as how FEMA, the Army Corp of Engineers, the City and the FBI fit into the overall picture. Most likely, this can not be done in advance since the entities involved would not be determined until the type and scope of the disaster is known. It is also recognized that the hierarchy may change on a day to day basis. This information would be particularly useful for structural engineering teams from out of state who may not be familiar with the arrangement of departments within a city or understand local acronyms (such as DPW and OEM).

As was previously discussed, it is important for the engineering teams to identify and be able to contact representatives of the contractor and city officials. As soon as the emergency teams for the various entities are mobilized, it would be useful to have a person obtain the names of the superintendents working for the contractor, appropriate city personnel and how to contact them. The work zone may easily contain 500 to 1000 rescue workers, making it difficult to identify the contractor and superintendents as they change throughout the day. Therefore, having this information makes it easier to reach the appropriate contractor or city contact when the need arises.

6.7 Field Communication

Cellular phones were used successfully at Ground Zero. However, for the first few days, the cellular phones did not work due to destruction of antennae systems. Therefore, the sole reliance of communication on cellular phones may be ill advised.

The engineers at Ground Zero were provided with amateur quality two-way radios, which were of no use. Not only was communication not heard clearly, but there were many people using the same frequency. It appeared that firemen and police radios provided adequate communication.

The first choice of communications is probably cellular phones. Each member should have their own cellular phone so they can be contacted when needed and also as a safety measure should an engineer get trapped at the site. The command center should keep a current list of all cellular phone numbers during the time of the disaster. It is advised that some amount of police quality two-way radios be made available in the event that the cellular phones do not work.

Communication plans should also include a site evacuation warning system. Rescue workers were performing search and rescue operations next to unstable structures, which were being monitored by structural engineers using surveying equipment. In the event any significant movement was detected, a signal was given to clear the site. The original signal was to consist of shouting. The success of this method was questionable considering the work was in the midst of hundreds of construction workers, several cranes and many power tools. The alarm system was later upgraded to an air horn but those in the area of danger could not hear it unless the engineer ran into the area to blow the horn.

A type of construction emergency alarm system must be provided to the search and rescue structural engineers. The field personnel should be notified of the existence and meaning of the system. The system could be a fire truck siren, continuous beeping of a car horn, or anything noticeable. Using the expertise of structural engineers to monitor the stability of a building and having an agreed way to warn the workers would greatly decrease the potential for injury from a collapsed structure.

6.8 Engineering Command Center

The engineering command center provided overall coordination of the structural engineering teams at Ground Zero. The center was also staffed with structural engineers that were available for providing structural analysis, drawing research and any other technical duty necessary to assist the Ground Zero engineers. This arrangement was very successful.

The engineering command center also required that each engineering team completing their shift prepare a brief report identifying important issues. A standard format kept uniformity among reports and expedited briefing sessions.

Under certain circumstances, improvements of this system would include adding a team that represents the utility companies. This team should be able to identify location of utilities, provide drawings and assess dangers.

A problem that occurred when engineering is done on a shift by shift basis is that not all problems get resolved, but instead get passed on from shift to shift. The engineering command center needs to provide closer monitoring so that problems get resolved in a timely manner. This could be accomplished by the preparation of an overall report for all zones by the engineering command center or a running list of problems and a target time or date for resolving the problem.

6.9 Inspection of Adjacent Buildings

The primary focus of this document is to discuss the participation of structural engineers in emergency search and rescue operations. Another important use of structural engineering services is in the assessment of structures adjacent to the immediate disaster area. It has been recommended by some of the Ground Zero teams that two separate teams perform these tasks.

The assessment of nearby damaged structures is necessary for determining if the structures can be occupied safely. However, there are other reasons for assessment as well. Ground Zero engineers were asked to evaluate the structural integrity of structures to determine if they were safe for government agencies to collect criminal evidence, for utility companies to re-establish service in unmanned switching stations and to determine if loose debris posed a danger to nearby Ground Zero workers.

The suggestion to have two distinct and separate groups of structural engineering teams performing building assessment and search and rescue operations has merit. A portion of the

time spent at Ground Zero was used to assess surrounding buildings. It would have been more desirable to concentrate strictly on search and rescue issues.

As discussed in Section 5.3, the search and rescue team should consist of teams experienced in emergency construction. Likewise, the assessment teams may be better served by being staffed with teams that have design experience rather than field experience, or both.

It was suggested that as part of the preparation plan, a list should be prepared identifying buildings over a given height (i.e. 20 stories). The architect and structural engineering firms used for the design of the buildings should be identified, as well as the actual architect and engineer of record. This information will prove very useful for finding drawings, assigning assessment teams and obtaining other information during a disaster.

Assessment of damaged buildings in the area around Ground Zero followed guidelines of ATC-20. This document, available through the Applied Technologies Council (ATC), provides procedures and guidelines for making on-the-spot evaluations regarding the extent of damage and decisions regarding occupancy of earthquake damaged buildings. Although this document is written for earthquake disasters, it contains very useful information and methods that can be applied to any structural disaster. The document is specifically written for volunteer engineers. Volunteer engineers doing assessment near Ground Zero provided positive feedback regarding the use of this document.

It is recommended that both search and rescue teams, as well as structural assessment teams, be versed in ATC-20. It would be wise to modify the document as part of the preparation plan to better fit a disaster such as WTC. There are other documents available through ATC that would also be useful and they include the following:

- **ATC-20-1:** Field manual that provides a concise summary of ATC-20
- **ATC-20-2:** Updated information following lessons learned from earthquakes occurring from 1989 to 1994.
- **ATC-20T:** Training manual and slides to explain ATC-20 and ATC-20-1.

The usefulness of ATC-20 is that it not only provides information on a preliminary assessments, but it also provides a building posting system regarding the condition and allowed continued use of a building.

CHAPTER 7: CONSTRUCTION SAFETY ISSUES

7.1 Ground Zero Safety Observations

Throughout the search and rescue efforts at Ground Zero, there were thousands of construction workers, firemen, engineers, and other volunteers present. With this large amount of workers involved, injuries of all types could be expected on any construction site. When you add the urgency of a search and rescue operation, the precarious condition of the damaged buildings, and the chaos of a vast construction team that was assembled within days, it was a difficult task to keep the work site safe. The work was further complicated by the constant flare-up of fire in the debris piles and their subsequent suppression by fire fighters.

OSHA recognized the difficulty in balancing compliance with safety regulations during the demands of a search and rescue operation. Their administrators issued a statement stating that OSHA's goal at Ground Zero was to provide as much help as possible and that they were not there in an enforcement role. OSHA also noted that the agency would not issue citations for insufficient training during the time of the emergency.

Without any knowledge of an official report, there appeared to be no incidence of significant injuries despite possible hundreds of thousands of work hours by construction crews doing search and rescue. There were some minor injuries that occurred, however. One structural engineering team complained that triage efforts on the site presented significant problems and suggested that, if possible, the wounded be moved off site immediately.

The workers on site had proper personal protection gear such as helmets, gloves and safety glasses. Safety vests, respirators, helmets and even construction boots were available for the workers at the site. As much as possible, the construction work proceeded in accordance with recognized safety principals. Even Red Cross volunteers wore safety vests, helmets and boots when distributing food and water within Ground Zero. Despite good faith efforts by the workers, it was not practical to have full compliance with OSHA regulations.

7.2 Safety Training

It would be counterproductive to the rescue goals to have workers killed or injured during search and rescue operations. It might serve the engineering teams well to have OSHA training as part of the preparation for their own safety. OSHA has two training certificates that can be obtained. These include the "10 Hour" and "30 Hour" certificate, for which the name comes from the length of training. Obtaining these certificates provides very useful safety training to the industry, including understanding the OSHA statute and other various sections of the requirements. However, the information provided at these certification classes is based on a site that is fully controlled with some degree of planning and scheduling. This was obviously not the case for the WTC disaster.

Non-profit and governmental safety organizations could tailor a safety class that deals with specific issues that would be encountered by structural engineers at a situation similar to the

WTC disaster. The training should concentrate on dealing with the most common types of dangers that would occur at a disaster site. Hazardous material awareness training should be included as well.

7.3 Respirators

The most confusing safety issue at Ground Zero involved the use of respirators. It was not known if respirators were needed, what the appropriate type of respirator was to use and how to use it. This matter needs to be cleared up if the structural engineering response team is to be ready to safely respond to a disaster. A suggested method of resolving this is to obtain information from an organization such as the National Safety Foundation or a respirator manufacturer to provide answers to at least the following:

1. What is the proper respirator to wear for various types of contaminants (chemical, asbestos, dust, etc.)?
2. How do you determine the proper size of respirator to wear?
3. How do you test the respirator to see if it is working properly?
4. What maintenance is needed for the respirator?

It may be possible to include respirator training as part of the special safety training class previously mentioned.

7.4 Environmental Monitoring

The structural engineers working on the search and rescue teams never received definitive information on air contaminants at Ground Zero. It was assumed that the wearing of respirators would be sufficient, even though it was not known what was the proper respirator to wear. A system needs to be in place that provides the proper information to allow teams to make educated decisions on accepting environmental dangers at Ground Zero.

According to information available from the U.S. Department of Labor, OSHA was testing daily for a variety of contaminants near the WTC. OSHA released statements that did not lay to rest concerns such as “...our samples indicate there is no evidence of significant levels of airborne asbestos or other contaminants beyond the disaster site itself. (U.S Dept. of Labor Press Release 01-339)” Another statement was “(the) EPA and OSHA are providing real-time analysis in the immediate vicinity of the debris pile at Ground Zero,... ...This information helps response workers on the scene determine what level of respiratory protection is appropriate to use (U.S Dept. of Labor Press Release 01-339).” This led to two problems. First, it appeared that the engineers on the search and rescue team were not receiving information from this monitoring. Second, even if the information was received, it is doubtful the engineers had the expertise to determine the appropriate respiratory protection level.

Two options should be considered for handling this problem. The first option would consist of assigning an engineering team charged specifically with continuous tracking of the type of environmental monitoring being performed, who was performing it, and what the results were. This team would need to work with OSHA to obtain monitoring results and their significance. The information obtained would be provided to the structural engineering teams on a regular basis at briefing meetings.

The second method would be to arrange for environmental monitoring companies to provide volunteer services during a disaster. This volunteer group would be organized as part of the structural engineering response team. The environmental monitors would go to the site prior to the first structural engineering team being admitted and would then monitor on a regular basis. Obviously, this relationship would need to be in place ahead of any disaster.

CHAPTER 8: LEGAL ISSUES

8.1 Personal Insurance Coverage

The participation of structural engineering search and rescue teams and building assessment teams raises various insurance issues. Some of the structural engineers were able to reach their insurance providers and receive answers on insurance coverage. Others were unable to reach their insurance providers and had to take the risk that they would be covered under their existing policies.

Questions that arose among the structural engineers included the following:

- If I am a personal volunteer and not being paid by my company, will worker's compensation insurance provide coverage?
- If I am a company volunteer and I am getting paid, will the company's workers compensation insurance provide coverage?
- Are there any changes in my medical insurance policy if I am injured on site as a personal volunteer or as a company volunteer?
- Is there specialty insurance coverage available for these types of situations?
- Will professional liability insurance provide coverage for omissions made as a volunteer?

It is suggested that structural engineering teams research these issues with their insurance brokers and carriers to determine if insurance will be in full force or if there is other insurance that should be purchased.

8.2 Liability of Engineers

It was assumed that as volunteers, the structural engineers performing search and rescue would not be held liable for errors and omissions that occurred at Ground Zero. It was not known if this was indeed the case.

The liability exposure is a bit more straightforward for the search and rescue teams than for the building assessment teams. A poorly made search and rescue decision would usually manifest itself rather quickly and those likely injured would be other volunteers. A poor building assessment decision may not manifest itself for weeks, months or years. Furthermore, those injured by the building assessment error may be members of the general public.

The liability exposure needs to be evaluated at both the state and federal level.

8.3 Good Samaritan Laws

There are statutes in certain states that insulate particular types of professions when performing a volunteer role. The purpose of such laws is to avoid discouraging people that can provide help because they may be afraid of a lawsuit. It is suggested that a unified effort be made for each state to pursue a type of Good Samaritan law. These laws need to provide engineers volunteering for search and rescue efforts as well as those doing structural assessments, with immunity from any and all lawsuits.

CHAPTER 9: MISCELLANEOUS IDEAS

9.1 Roadway Capacity

It may helpful to know the design capacity of various roads and bridges in advance of an incident. Cranes overloading streets and plazas were a concern at Ground Zero. Knowing the design capacities of certain bridges is important when directing debris out of a city.

9.2 Backup Copies of Team Information

The most efficient way to keep detailed information on team members is on the computer. An astute record keeper would have backup files of this information. However, it would be of little value if computers were damaged by electrical shock, fire or located in condemned buildings. It is recommended that hard copies of team members contact information be kept at various locations to avoid delay in contacting them.

9.3 Single Contact

Once a disaster occurs, the entity organizing and supplying the engineering teams will be flooded with incoming information. This information will include data about volunteers, coordination with Ground Zero, requests from the media, etc. It is recommended that there be a single point of contact for incoming information. There should be one telephone number for all contact with the structural engineering team organizers. The telephone should be attended by a person whose sole function is to take information and pass it on to someone who will handle the issue at hand. Note that a single telephone number does not imply a single telephone line.

Similarly, there should be one e-mail contact. A person should be assigned to distribute the e-mail to the appropriate person who should reply to it. Multiple e-mail addresses and telephone numbers cause confusion that can result in information being lost.

9.4 Transportation to the Site

As previously noted, the structural engineering teams had to walk at least two miles before they even began their shift at Ground Zero. The shift was full of stair climbing to inspect roofs and damaged facades and roaming the site. It was suggested by some of the team members that group transportation to the site would have conserved needed energy.

9.5 Volunteers

Some of the team members raised the question of how to make efficient use of volunteers from architecture associations. Obviously, many architects have structural backgrounds that qualify them to be on the structural engineering teams. Thought should be given as to how to make use of volunteer resources of architectural associations.

It is important to make use of volunteers in a manner that allows those who want to contribute to participate in some manner. Rather than elaborate on the need for being inclusive, it is more effective to reiterate a statement made by a member of SEaONY who was involved in the emergency response. The statement, “Do not underestimate the help you will need,” speaks for itself.

CHAPTER 10: CONCLUDING REMARKS

This document was written as a resource for the preparation of an emergency response plan for mobilizing structural engineers in a search and rescue operation under extreme emergency conditions.

As a result of the events that occurred on September 11, 2001, the structural engineering profession should do the following:

- Prepare a comprehensive Structural Engineering Emergency Response Plan (SEERP) that is completely ready to implement before a disaster occurs.
- Ensure the plan is uniform for all states so that structural engineers responding from any state can be fully integrated into the local response effort.
- Ensure the plan is uniform for all states so that government agencies throughout the United States can work efficiently with the structural engineering teams.

It is recommended that immediate steps be taken to begin the process of preparing a response plan.

CHAPTER 11: ACKNOWLEDGEMENTS

11.1 Structural Engineer Volunteers for the World Trade Center Attack

The participation of structural engineers in a variety of issues at Ground Zero and the surrounding areas was an essential part of an efficient and safe operation. All those that participated in any way are commended for their work. Special recognition is due to the following groups of structural engineers:

- The structural engineering command center was staffed by the engineering firm of LZA-Thorton Tomasetti (led by Dave Peraza, Daniel Cuoco, Tom Scarangelo and Manny Velivasakis). Their leadership of the structural engineering operations under these worst of conditions presented by this disaster was highly commendable.
- The Structural Engineers Association of New York (SEAoNY) organized the teams for various structural engineering tasks. It is not hard to imagine the chaos that would have occurred without their participation. The members should take great pride in knowing that their organization played a successful major role in this difficult operation.
- The structural engineering teams that participated in Ground Zero operations volunteered to provide their services in the hope of helping find survivors and to provide a safer working environment for the rescue workers. They provided these services at the risk of their own safety. As the structural engineering teams passed through security checkpoints, applause from the crowds congregating around the perimeter of Ground Zero was evidence of the great appreciation for the teams' efforts.
- Others that need to be commended for contributing to the structural engineering response include: the engineering firm of Gilsanz, Murray, Steficek LLP that provided office space for initial briefings, Mike Tylk of Tylk, Gustafson, et al for helping organize the structural engineering teams from outside the state of New York, and all of those that provided water, food, equipment and encouragement to the rescue efforts.

11.2 About the Author

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