Urban search and rescue and the role of the engineer

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ABSTRACT: Previous international incidents have highlighted the need for specialist task forces to be engaged in Urban Search and Rescue (USAR) activities for retrieving victims from collapsed buildings. These task forces comprise personnel from a range of rescue agencies. A review of New Zealand's USAR capabilities has shown that there is presently a lack of capability and organised structure to deal with USAR events and has recommended the establishment of specialist USAR task force units in New Zealand. These units include professional engineers to advise on structural aspects of rescue operations. A research project is being conducted to establish the framework for training of professional engineers in urban search and rescue situations, as no formal training methods exist in New Zealand at present. The education includes developing a familiarity of the organisation of specially trained USAR task forces. An engineering perspective of a recent Category 2 USAR course is presented.

1 INTRODUCTION

While most research relating to the field of earthquake engineering has focussed on methods of preventing structural collapse during seismic attack, there has also been a desire to clarify the role the engineer will play following a major disaster that involves structural collapse. This is in line with the strategy developed by the New Zealand Society for Earthquake Engineering to promote the need for a higher level of preparation to respond to major New Zealand earthquakes (NZSEE, 2002). The disaster does not need to be confined to earthquakes; it can also include landslides, volcanoes, and other events such as the collapse of the World Trade Center Twin Towers. Two of the key tasks that engineers are likely to be involved in following a major event that involves structural collapse are urban search and rescue and building safety evaluation.

Urban Search and Rescue involves the location, rescue and initial medical stabilization of victims trapped in confined spaces following a structural collapse (FEMA, 2002). Search for the injured and rescue of those trapped are among the most important and urgent post earthquake activities. Research has shown that the majority of survivors from earthquake induced building collapses are rescued within the first 24 hours (Jones, 1997). Examples include the 1980 earthquake in southern Italy, where 94% of people were rescued during the first 24 hours. Those conducting USAR activities can themselves become victims, as a high level of risk is associated with these activities. These risks can be lessened if time spent within dangerous situations is kept to a minimum and if those involved take precautions. These precautions include awareness of falling hazards and the use of temporary shoring to stabilise weakened structures. Engineers can play a vital part in ensuring the safety of rescue activities by being involved in the assessment of damaged structures. The engineer needs to be comfortable dealing with high-pressure situations and able to make rapid decisions. A familiarity with disaster environments and specialist task force structures needs to be developed. Familiarity requires engagement with emergency service agencies and specific prior training.

This paper looks at how previous international events have led to greater USAR preparedness and traces the development of New Zealand's USAR capability. The paper then focuses on the role the engineer can play in USAR activities and determines the necessary training for engineers to be effective in events that involve USAR. This training is intended to provide a valuable continuing professional development module for practising engineers. The contents of engineering training courses are summarised. The paper also presents an engineering perspective of a recent USAR technician course for members of the emergency rescue service.

2 PREVIOUS INCIDENTS

A number of disaster events in recent years have required urban search and rescue procedures to free trapped victims. Many of the incidents have led to greater preparedness measures and the establishment of more specific training for personnel involved in USAR. Some of the incidents show the benefits of prior training with effective responses provided by specialist teams to perform rescue operations.

The Mexico City earthquake of 1985 was one of the first large-scale urban earthquakes that resulted in many of the victims being trapped in modern, heavy concrete buildings. Although many people were rescued alive, mostly by the spontaneous volunteer activity, many victims were lost due to inappropriate rescue techniques (Krimgold and Gelman, 1989). There were no urban search and rescue teams in Mexico City, which led to the delay in the location and extrication of trapped people. Also, too many rescue personnel took risks without proper assessment and as a result, an estimated one hundred rescue workers were killed because of further building collapse while trying to find survivors (Olson and Olson, 1987). Foreign rescue teams eventually assisted the rescue efforts. This led to the initial development of a well-trained and equipped specialist team approach to the problem. Rescue was shown to need a multi-disciplinary approach, involving structural engineers familiar with the characteristics of building design, architects familiar with building use, and emergency medical personnel familiar with the injury patterns associated with building collapse (Krimgold, 1988).

In 1989 the Loma Prieta earthquake struck northern California with two sites requiring USAR efforts (EERI, 1990). A 2.4 kilometre stretch of collapsed freeway saw the use of specialist equipment to help locate trapped victims, and structural engineers who assessed the collapsed spans to determine the relative safety of a rescue effort in a given span. Following the Loma Prieta earthquake, the State of California established eight specialised USAR teams, each consisting of 56 people (EERI, 1995). These teams became the model for the United States USAR task force system that is co-ordinated and partly funded by the Federal Emergency Management Agency (FEMA). Working groups were created to evaluate the criteria necessary for various rescue roles and determine the equipment needed to outfit a complete task force. The USAR program in the United States has now grown to 27 teams across the country with 62 members in each team. Two 'structural specialists' (i.e. structural engineers) are in each team.

The 1994 Northridge earthquake was one of the first real tests of the newly created USAR task forces. The earthquake produced relatively few casualties, mainly because it was in the middle of the night, but the task force responses were considered effective and a number of rescues were made (NZSEE, 1994). The two most significant organised rescues occurred at the Northridge Meadows Apartment and at the parking structure of the Northridge Fashion Complex. The USAR task forces were able to demonstrate their competency and the benefits of previous training exercises.

The Oklahoma City Bombing of April 1995 partially collapsed a nine-storey reinforced concrete structure. The event demonstrated the workings of the USAR Task force system and also the interaction between the engineer and the remainder of the Incident Support Team (Hammond, 1995). Seven USAR task forces were deployed within the first three days; ultimately eleven USAR teams and 37 engineers were involved over the sixteen-day operation. A number of dangerous situations existed at the site that required the input of a structural engineer. Collapse and falling hazards identified included badly damaged columns still supporting high gravity loads, and large portions of slabs hanging by a few reinforcing bars. The columns required bracing and temporary supports needed to be devised for hanging slabs so that rescue operations could proceed safely. Conflict between engineers and rescue workers occurred during the rescue operations and highlighted the different priorities that can exist, notably that the primary focus of the rescue personnel is to ensure victim survival, compared to the structural engineer whose primary focus is to ensure rescuer safety. The Oklahoma City incident highlighted the need for engineers to be included in the Incident Support Team and validated the structural specialist training courses that had been developed in the USA. It was concluded that three engineers with no previous USAR training were less able to deal with the problems presented.

The 1999 Chi-Chi earthquake in Taiwan resulted in over 2,400 fatalities and 10,000 injuries. 5,004 rescues took place, mostly through the actions of volunteers. Although the government response was considered reasonably timely and effective the need for a more structured response was identified (EERI, 1999). As a result of this event a professional Taiwan USAR unit was established. The unit consists of 48 fire fighters, 4 paramedics, and 4 engineers, and operates within Taipei, the capital city. Members of the unit undergo six weeks training in Taiwan, plus six weeks training in the USA. This also includes the engineers who are expected to be fully proficient in the use of specialist rescue equipment. This training corresponds to an advanced New Zealand Category Two course (refer later section).

3 DEVELOPMENT OF A NEW ZEALAND USAR CAPABILITY

New Zealand's first strong thoughts on the need to develop a USAR capability resulted from the observations of the NZSEE reconnaissance team visit to the Northridge earthquake in 1994 (NZSEE, 1994). Major collapse sites visited by the team saw rescue operations carried out by the Los Angeles Fire Department and USAR task forces that were beyond the capability of anything other than a professionally organised unit. The reconnaissance team was particularly concerned at New Zealand's state of readiness in comparison. The need to formulate, train and equip a rapid dispatch team of specialists for New Zealand was seen to be long overdue. The Fire service and military were identified as the best organisations to undertake this role. This was an example of post-earthquake preparedness being taken seriously in New Zealand for the first time.

Following the Northridge event a training course took place at Palmerston North in 1996 to establish New Zealand's first USAR unit. The unit was principally comprised of members of the New Zealand Fire Service. The unit however was only partly functional due to lack of financial support and specialist equipment. It was inadequately resourced because the New Zealand Fire Service was not charged with overall responsibility for the USAR unit.

July 2000 saw the establishment of a steering committee to review New Zealand's current USAR capability. This multi-agency committee identified a lack of overall capability with limited and unevenly distributed USAR resources to the extent that the unit would be incapable of addressing anything more than a minor structural collapse (MCDEM, 2001). The committee also identified a lack of co-operation between the rescue agencies, as no one agency was responsible for co-ordinating and managing the integrated multi-agency resources and activity process required for an effective USAR response. The report also identified that there were no engineers in New Zealand with formal training or previous experience in USAR procedures.

The steering committee made a number of recommendations to establish a minimum USAR capability. Amongst the recommendations was the need to establish three fully trained task forces, based in Auckland, Palmerston North, and Christchurch, similar to the task forces developed overseas. These multi-agency units are likely to be led and co-ordinated by the New Zealand Fire Service. It is intended that each task force be supported by a minimum of two structural engineers. The committee also recommended that it remains possible to employ international USAR teams in the case of a major disaster that is beyond the capability of the New Zealand resources.

To further assist the development of a New Zealand USAR capability, a category training system has been developed for members of the emergency response services. The three-category system shown in Table 1 is based on methods developed overseas. The system distinguishes between the basic skills required for a first responder, technical skills for those involved in actual search and rescue operations, and specific management skills. Two Category One courses have been to date and a Category Two technician course was held in October 2001 to re-establish the Palmerston North task force unit to fully functional status. The category qualification structure has been recognised by the NZQA framework system and has gained unit standard status.

Table 1. USAR Category Training System for Emergency Services

Role	**Awareness**	**USAR Responder**	**USAR Technician**	**USAR Manager**
Skills	Awareness CD Rom	USAR Awareness (Assessed) First Aid CIMS General CD Rescue	Basic CD Skills Compulsory Skills & Specialist Strands	Advanced CIMS Operations Management General Management
CAT		**1**	**2**	**3**
Qual	NZQA unit standard available, but not compulsory.	Industry Certificate in USAR (Responder)(Level 2 as option)	National Certificate in USAR (Technician) Level 4	National Diploma in USAR
Card*		USAR RESPONDER	USAR TECHNICIAN	USAR MANAGER

In summary New Zealand has made progress in developing a basic USAR capability. This follows on from the recommendations made by the steering committee review. A fair amount of work however remains to be done to achieve the recommended minimum USAR capability.

4 DEFINING THE ROLE OF THE ENGINEER

The main role of the engineer in USAR procedures is to provide *critical* information, and not to make all the critical decisions (Hammond, 1995). Task Force leaders will consider the advice of the engineer along with others and will proceed with the rescue operations after considering this advice. The opinion of the engineer may not always be adhered to and some aspects of a rescue will take place without the input of engineering advice. These engineers need to be well prepared to make difficult decisions, in an environment that is very different from the orderly design office. The environment during a USAR event is likely to be chaotic, with many uncertainties relating to the safety status of buildings and many traumatised people. The engineer also needs to be aware of the roles of the other members of the task force. Most of the task force come from rescue backgrounds and are used to making rapid, high-pressure decisions as part of their normal occupation and will take a significant risk in order to save a life. Therefore a conflict in focus can arise between engineers and rescue workers as previously discussed – rescuers save victims, whereas engineers focus on rescue safety.

The engineer is likely to perform a number of tasks during a USAR operation. One of the first jobs of the engineer is likely to be structural triage. The purpose of structural triage is to prioritise which structures to concentrate rescue efforts on so as to maximise the amount of return for the rescue effort. This becomes particularly critical when multiple collapses result from a major earthquake. Another important task for the engineer is to advise on building stability during rescue efforts. This may involve recommending methods of providing temporary support, or 'shoring', of the structure. The engineer is also likely to act as an 'extra pair of hands', helping out with physical tasks during rescue efforts.

To help prepare the engineer for USAR incidents, a Structural Specialist course has been run since 1992 in the United States. This is believed to be the only specialist course in the world for engineers that deals with building collapse (Comeau, 2000). This one-week course is conducted annually and is run by the United States Army Corps of Engineers in conjunction with FEMA. The training is undertaken on a voluntary basis but the volunteer engineers become temporary federal employees when the teams are deployed. Engineers retake the USAR training after five years to help keep up-to-date with new developments. Many USA task forces conduct monthly or bi-monthly training for the engineers and the other members of the search and reconnaissance team, as it is very important the members remain part of the team so they can continue to trust each other's judgement during a rescue.

Some New Zealand engineers will have had prior exposure to USAR education for engineers from the lecture series run in New Zealand in 1995 by David Hammond, a prominent figure in the development of USAR training material in the USA. The lecture series was organised by the Red-R organisation (volunteer engineers who participate in international relief work following disasters), and made New Zealand engineers aware of the USA training methods that had been developed.

5 PROPOSED USAR TRAINING METHODS FOR NEW ZEALAND ENGINEERS

A research project conducted at the University of Canterbury (McGuigan, 2002) has developed a framework for training engineers so that they can effectively participate in a USAR event involving multiple collapsed structures. The framework proposes the development of a regional and national capability of engineers to deal with local and major building collapse incidents. The training is intended to help participants go beyond their normal office-based experiences and gain familiarity with the demanding nature of rescue operations. The training will be considered a worthwhile continuing professional development module, providing an opportunity for engineers to develop leadership skills and promote community awareness of the engineering profession. This section discusses a category training system, the course contents and ongoing training requirements for New Zealand engineers to participate in USAR activities.

A progressive training system shown in Table 2 has been recommended for engineers to become familiar in dealing with situations involving USAR. This system incorporates parts of the category training system for emergency services presented in a previous section. The first stage of USAR engineer training requires attendance at a USAR Awareness course that is also part of the training for members of the emergency services. This course will make engineers familiar with the procedures of these organisations. A specific course for engineers only is then required. The content of this Level One engineering course includes the following:

- Causes of Collapse
- Collapse Patterns
- Structural Triage

The Level Two advanced USAR engineering course builds on material taught during Level One training and intends to give the participating engineer more knowledge to deal with collapsed structures. It is intended that the advanced USAR engineering course be a two-day course taught at a single location in New Zealand. The course content includes the following:

- USAR Operations
- Building Monitoring
- Determining damage/vulnerability of structure
- Recommending suitable shoring systems/demolition methods

Table 2 USAR Engineering Training Framework

Course	LEVEL	Duration (CPD Value)	Qualification
USAR Category One Awareness	**1**	1-day (8 hours)	USAR Responder Engineer
USAR Level One Engineering	**1**	1-day (8 hours)	
USAR Category Two Technician	**2**	6-days (48 hours)	USAR Task Force Engineer
USAR Level Two Engineering	**2**	2-days (16 hours)	USAR Advanced Engineer

Task Force Engineers need to attend part of a three week Category Two Technician course for members of the rescue agencies. Six engineers will be trained to this level and will become the specialist engineers who will deploy with the Task Force during an actual event. It is envisaged that the engineers will participate in the first and third weeks of the course. During the first week, the engineers will participate in the structural engineering lectures, tool familiarisation and team building exercises. The benefits of this are that engineers gain first hand exposure of the multi-agency nature of the Task Force and develop working relationships with the members that do the search and rescue work. During the third week, the engineers will participate in a field exercise. The field exercise lasts 72 hours and intends to replicate an actual USAR rescue event. By participating in the exercise, the engineer will gain confidence in his role as adviser on structural matters and the remainder of the team will learn to trust those decisions.

The engineer who participates in task force activities will have achieved 'Registered Engineer' status and will need to possess a number of personal attributes so that they are suitable for actual events. This includes a reasonable level of fitness due to the demanding nature of the exercise and the potential long hours that can be worked. The engineer will need to be adaptable and able to fit in to the regimented nature of the task force structure. A good understanding of practical construction methods and some experience in construction and demolition related work would also be expected. An ideal age for the suitable engineers is considered to be between 30 to 45 years.

The key engineering aspects for the USAR engineer to know relate to basic engineering principles. These include knowledge of material properties, establishing load paths of damaged or partially collapsed structures, and determining safety of the collapsed structure. Gravity and potential lateral loads need to be determined for recommending temporary shoring methods. For structures exhibiting excessive lean, 'rules of thumb' are necessary to check if the lean will make the structure unsafe for USAR operations. The variety of different structural types and configurations make it difficult to provide guidance, but with some previous exposure to the nature of unsafe buildings the USAR engineer will be more confident in applying engineering methods.

Ongoing training and refresher courses will need to be held on an annual basis for trained engineers at all Levels. These should be run at the same time as refresher courses for those involved from the rescue agencies. Those involved in rescue operations need to be aware that engineers cannot be available at all times and, that by training a pool of engineers, there should be an adequate number that can be obtained when the need arises.

6 REVIEW OF A RECENT CATEGORY TWO USAR COURSE

A Category Two USAR Technician course took place from October 8 until October 26, 2001, based at Linton Military Camp, near Palmerston North. There were 18 participants on the course. They were mostly from the Fire Service, with the remainder from the Police Force, Civil Defence organisation, and the armed forces, reflecting the multi-agency nature of the Task Force. Two engineers also participated in the course. Most of the course instructors had participated in the original NZ USAR training camp conducted in 1996, including Ernesto Ojeda from the Los Angeles Fire Department who had spent ten days at the World Trade Centre site as a Task Force leader. The course intended to develop a complete task force of 30 members based at Palmerston North. This number includes members of the previous course run in 1996.

The structural engineering components of the course were taught by Engineer Des Bull and were well received by the participants. It was emphasised that engineering is common sense. The information developed by FEMA in the USAR Training Manual was extensively used. The USAR manual contained detailed engineering content including material properties and member design considerations. A lot of this will be second nature to an experienced structural engineer, but is not considered relevant for a USAR technician. The key output of the USAR Manual is the sketches of typical shoring/cribbing details, which are important to know for the USAR technician. A number of previous building collapse scenarios were presented and group discussions highlighted the difference in opinion that can exist between an engineer and rescue personnel as to what constitutes a safe building to enter for rescue purposes.

The course was strong on practical training methods. This included breaking concrete and erecting shoring. Other activities included team-building exercises such as the army confidence course and indoor sports. The training course culminated in a 72-hour exercise. Des Bull advised on structural aspects during the exercise. It was considered an invaluable experience in which an awareness of the stressful nature of the work was gained. It was recommended that any engineer who was to be involved in USAR would need to participate in such an exercise to gain the confidence to deal with a real event.

7 CONCLUSIONS AND RECOMMENDATIONS

Previous international events have often triggered the development of specially trained task forces to deal specifically with collapsed structures. A number of new rescue techniques were developed to deal with large and heavy collapsed structures. Other events have shown the benefits of having well trained and equipped specialist task force units to deal with extricating people from collapsed buildings.

It has been shown that engineers can play an important role in rescue operations, assisting with critical decisions relating to the safety of operations and determining suitable methods to ensure temporary stability of collapsed structures. Engineers need to be suitably trained so that they can be effective in a demanding and dangerous environment, quite different from the engineer's normal environment.

A steering committee reviewed New Zealand's USAR capability and concluded that there is an overall lack of capability. An attempt to address this began by developing a USAR task force unit based at Palmerston North. Further task force units are proposed for Auckland and Christchurch. Training methods for these task forces are modelled on methods developed overseas.

A three level USAR category training system for New Zealand engineers has been proposed. It is recommended that 5 engineers participate in a future category two USAR technician course that will provide New Zealand with an adequate pool of engineers. During this training they will also gain first hand exposure of the nature of rescue operations and the personnel involved. Ongoing training will need to be undertaken to ensure skill levels are maintained.

In conclusion, it must be emphasised that no amount of training can prepare one for the overall effects of a disaster scene, but an appreciation that is gained during previous training goes a long way towards giving an engineer a better idea of what to expect.

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