# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 3 - HAZARD IDENTIFICATION & BUILDING MONITORING*

### OBJECTIVES

The objectives of this unit are to familiarize the student with the most common signs of distress exhibited by damaged structures. We have previously discussed Material Behavior and Collapse Patterns, and will now apply this knowledge to the Disaster Site.

- We will first discuss how Concrete and Masonry crack, and how these cracks can be “**READ”** to predict future performance of these structures.
- We will then identify the most common Hazardous Conditions that will occur in the four types of buildings that we have previously identified.
- Finally we will discuss the various tools and methods that are currently available to Monitor Buildings

**TERMINAL OBJECTIVES**

- The Student shall understand the most common signs of distress exhibited by damaged structures.
- The Student shall understand to the most common Hazards found in damaged structures, and methods that have been used to used to Mitigate them

**ENABLING OBJECTIVES**

- Understand the importance of the various types of Cracks in Concrete and Masonry Structures.
- Understand the common Hazardous Conditions that occur in Light Frame, Heavy Wall, Heavy Floor and Precast Buildings
- Discuss the common methods and equipment used to Mitigate Structure Hazards

### CRACKS IN REINFORCED CONCRETE & MASONRY

A favorite statement in building design and construction is; "**If its not cracked, its not concrete**," since cracks must form in concrete for the reinforcing steel to be stressed in tension. Most normal concrete develops cracks that are narrow (hairline) as a result of shrinkage, temperature change, and predictable structural behavior.

***We need to apply our knowledge regarding Material Behavior & Collapse Patterns to Disaster Site***

### SHRINKAGE CRACKS

- Usually occur in slabs, beams, walls, and even in columns within 60 days of the pour, after the concrete is allowed to dry out.
- Diagonal cracks will originate from most re-entrant corners in slabs and walls i.e. window, door, and floor openings.
- Straight cracks (more or less) occur often at five to twenty feet on center in long wall and/or floor surfaces, depending on the amount of reinforcing steel, numbers of pour joints, and curing conditions.
- The reinforcing steel within the structure is intended to hold the structure together as it shrinks, and keep these cracks small.

Cracks in Reinforced Concrete & Reinforced Masonry

- shrinkage cracks
- temperature cracks
- tension cracks
- diagonal tension cracks in beams
- diagonal tension cracks in walls

***If it’s not Cracked it’s not Concrete***

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### TEMPERATURE CRACKS

- Occur in roughly the same pattern as shrinkage cracks, and are difficult to differentiate from them.
- When the temperature of a concrete structure is decreased, it must shorten (shrink) and, therefore, it cracks, and the reinforcing steel attempts to hold it together.
- Reinforced concrete structures will, obviously, have more observable temperature/ shrinkage cracking when subjected to the winter cold.

### TENSION CRACKS

- These most often occur in concrete slabs and beams when bending caused, tension forces stretch the reinforcing steel
- Cracks must form in the concrete in order to transfer the force to the steel, but the cracks normally are quite numerous, small and undetectable (except to the trained eye).
- They form, perpendicular to the long axis of the member, and as long as they remain hairlike, the structure is behaving normally.

### DIAGONAL TENSION CRACKS

- Occur in high shear stress zones of beams and girders in a typical pattern (HAZ-DTEN) under normal vertical load conditions.
- In shearwalls, large diagonal tension cracks will form when the walls are heavily loaded by severe earthquake shaking (HAZ-DTEN).
- Earthquakes will normally cause a diagonal crack in each direction (Cross Cracking) in the highly stressed areas of shearwalls (i.e., between window openings, over stacked door openings) since the shear force reverses causing diagonal tension cracking in each direction.

Shrinkage & Temperature Cracks

- Occur in slabs, walls, beams, & columns.
- Diagonal cracks originate at re-entrant corners in slabs & walls (openings)
- Transverse (more or less straight) cracks occur at 5 to 20 ft apart in long slabs & walls
- Nominal rebar normally keep cracks small

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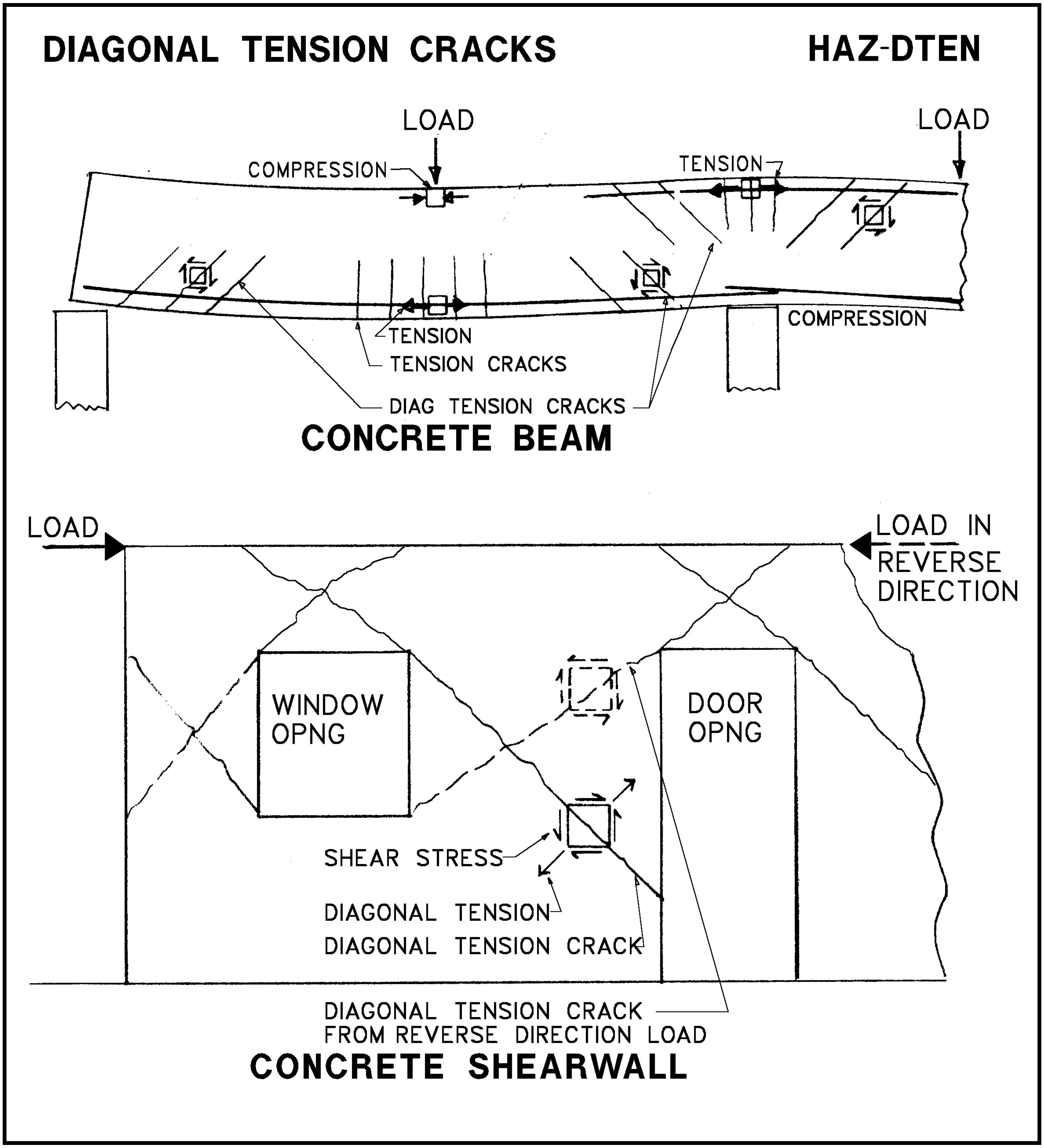
**DIAGONAL TENSION CRACKS (continued)**



## MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
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### CRACKS IN REINFORCED CONCRETE WALLS

- The stability of concrete box-buildings will probably depend on the post-cracked strength of the shear walls. Even with unsightly diagonal cracking, a shearwall may still have significant strength (HAZ-CK).
- The clamping action of the gravity loads, as well as the vertical rebar will tend to hold the irregular surface of the cracks together, preventing the opposing surface from sliding. In addition the rebar that cross the crack can also act as dowels.
- Both these resistive actions are lessened when there is enough shaking, or continued reshaking due to aftershocks that the crack widens, concrete chunks fall out, and the rebar can be seen in an offset curved condition. In this later degraded condition a shearwall has become unreliable and must be evaluated accordingly.

### CRACKS IN URM WALLS & UR CONCRETE WALLS

- Shrinkage, temperature, and diagonal tension/shearwall cracks also occur in URM and UR concrete walls. In these walls, however, cracking indicates a significantly degraded structure.
- Diagonal tension cracks form in these walls between openings, as they do in reinforced concrete walls due to earthquake shaking. In addition cracks are often created at wall corners, with the bottom of the crack at the corner and the top extending up to the roof. This is caused by the action of the disconnected roof diaphragm pushing against the corner, attempting to push it out. URM diagonal cracks tend to follow a stair step pattern (HAZ-CK). That is, the crack follows the weaker mortar, rather than going through the bricks. This results in cracked surfaces that are smoother than those in reinforced concrete.
- **Masonry walls** with significant diagonal tension cracks must be considered to be capable of a sudden, brittle failure. There is some clamping force on the horizontal steps of the cracks due to the gravity force, but no vertical bars to add clamping or dowel action. The greater smoothness of the joints also reduces the friction that could be developed by the clamping of the vertical force.
- **Unreinforced Concrete Walls** also perform poorly during quakes. They tend to break apart in pieces, defined by whatever crack pattern existed prior and/or by the original pour joints.

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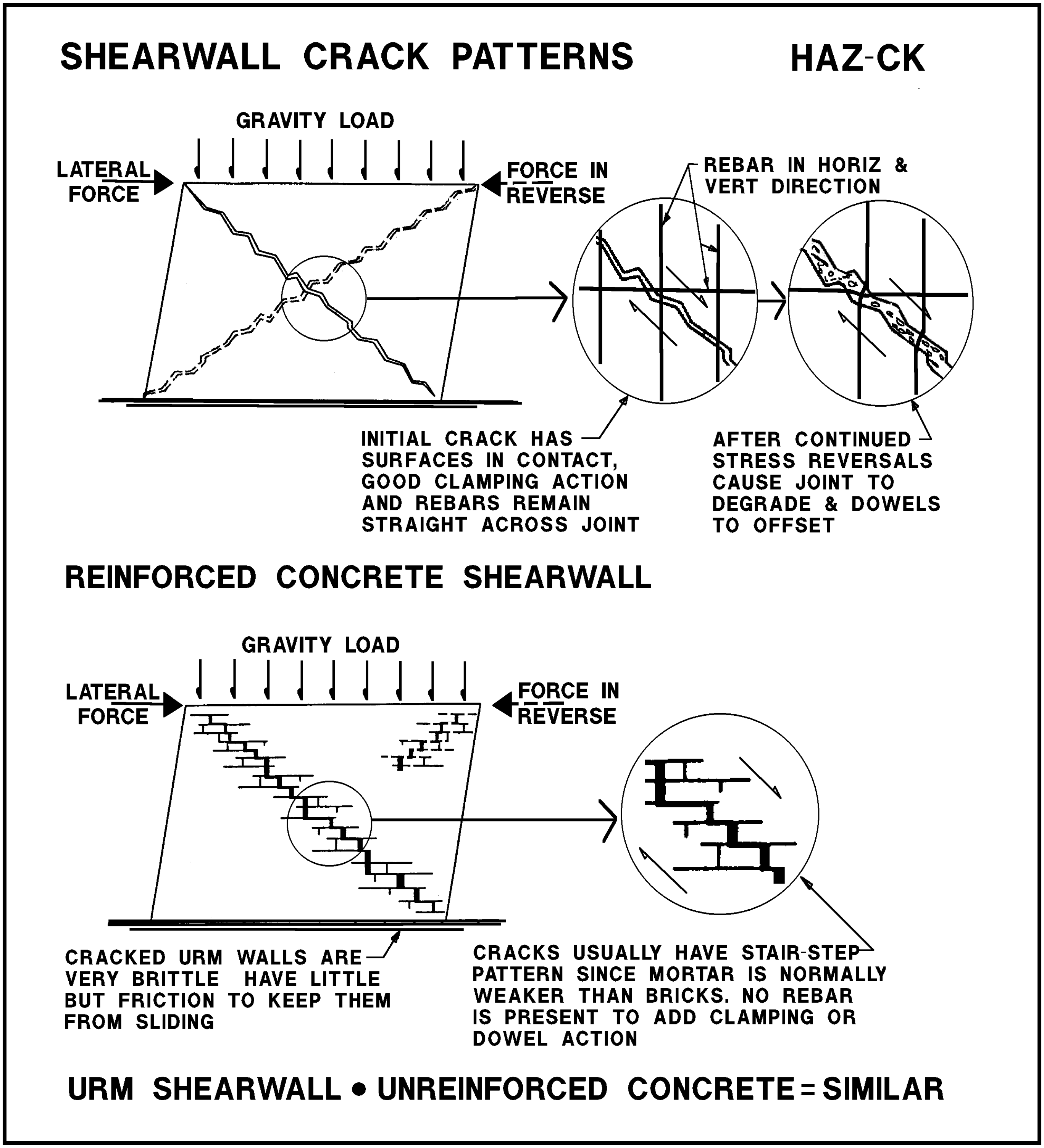
**CRACKS IN REINFORCED CONCRETE & URM SHEARWALLS**



# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 3 - HAZARD IDENTIFICATION & BUILDING MONITORING*

### HAZARD IDENTIFICATION

In damaged, partly collapsed and collapsed structures we can identify three types of hazards:

- **Falling** where part of the structure or its contents are in danger of falling.
- **Collapse** where the volume of enclosed space made by the structure will be reduced, as stability is lost.
- **Other** -toxic gas, carbon monoxide, asbestos, other hazardous materials (discussed in Haz Mat 1st Responder Course).
- Falling and collapse hazards will be discussed here. The degree of hazard in both cases is strongly related to mass and how additional failure may occur. Brittle, sudden failure potential must be recognized as contrasted to structures where material ductility and redundant configuration could provide some warning of an additional collapse.
- The problem of identifying, let alone properly evaluating these hazards, is staggering. A well-trained engineer may, at best, be able to rate the risk of various hazards on some arbitrary scale like bad, very bad, and deadly. We must consider that:
  - Judgments can not be precise.
  - We must try to identify brittle vs ductile behavior.
  - Partial collapse is very difficult to assess.
  - The cause of the condition is very important input (i.e., earthquake with expected after-shock, windstorm, etc.).
- In evaluating, if a specific structure is at rest, one could state, on the positive side that the structure that was moving had enough resistance to stop moving and achieve, at least temporary stability. However, the damaged structure is difficult to assess, weaker, and more disorganized than the original.

  - Try to identify the load path, and visualize what could happen during an aftershock or wind gust.

  - Small, nonstructural elements and debris (loose materials) may be greater hazards than overall structural stability especially in wind gusts and small aftershocks.

Hazards in Damaged Structure

- Falling hazards
- Collapse hazards
- Other hazards

**Identification Problems**

- Judgments cannot be precise
- Partially collapsed structures difficult
- Collapsed structure has come to rest, but it is now weaker and more disorganized than original structure.
- Earthquake may have caused partial collapse, but building remainder may be weakened & ready to collapse in Aftershock.
- ***Structures Collapse in Aftershocks***

## MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
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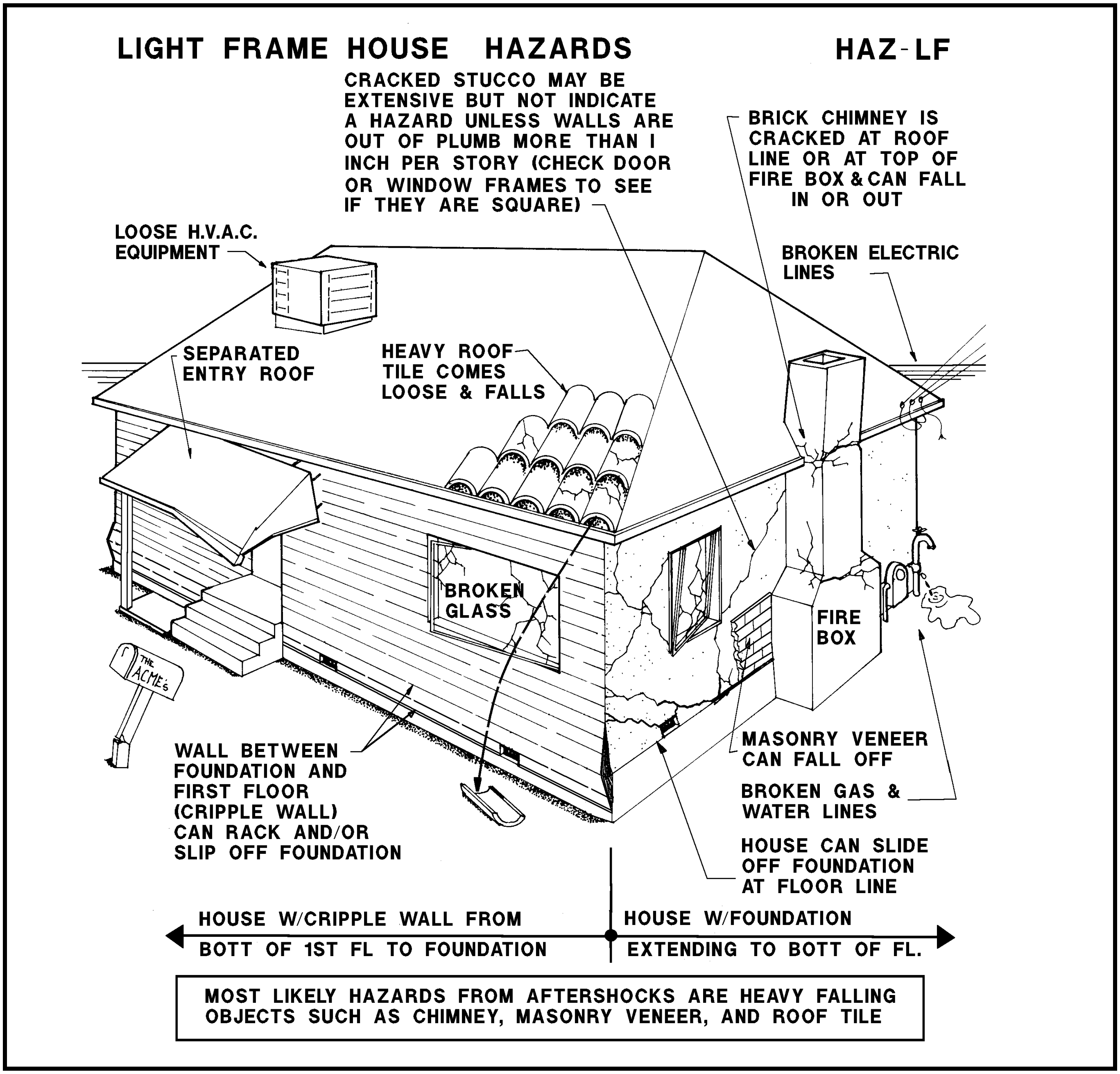
### LIGHT FRAME BUILDING HAZARDS

Principal weakness is in lateral strength of walls and connections.

- **Check Points: (HAZ-LF)**
  - Badly cracked or leaning walls.
  - Offset residence from foundation
  - Leaning 1st story in multi-story buildings.
  - Cracked, leaning masonry chimney or veneer.
  - Separated porches, split level floors/roof.



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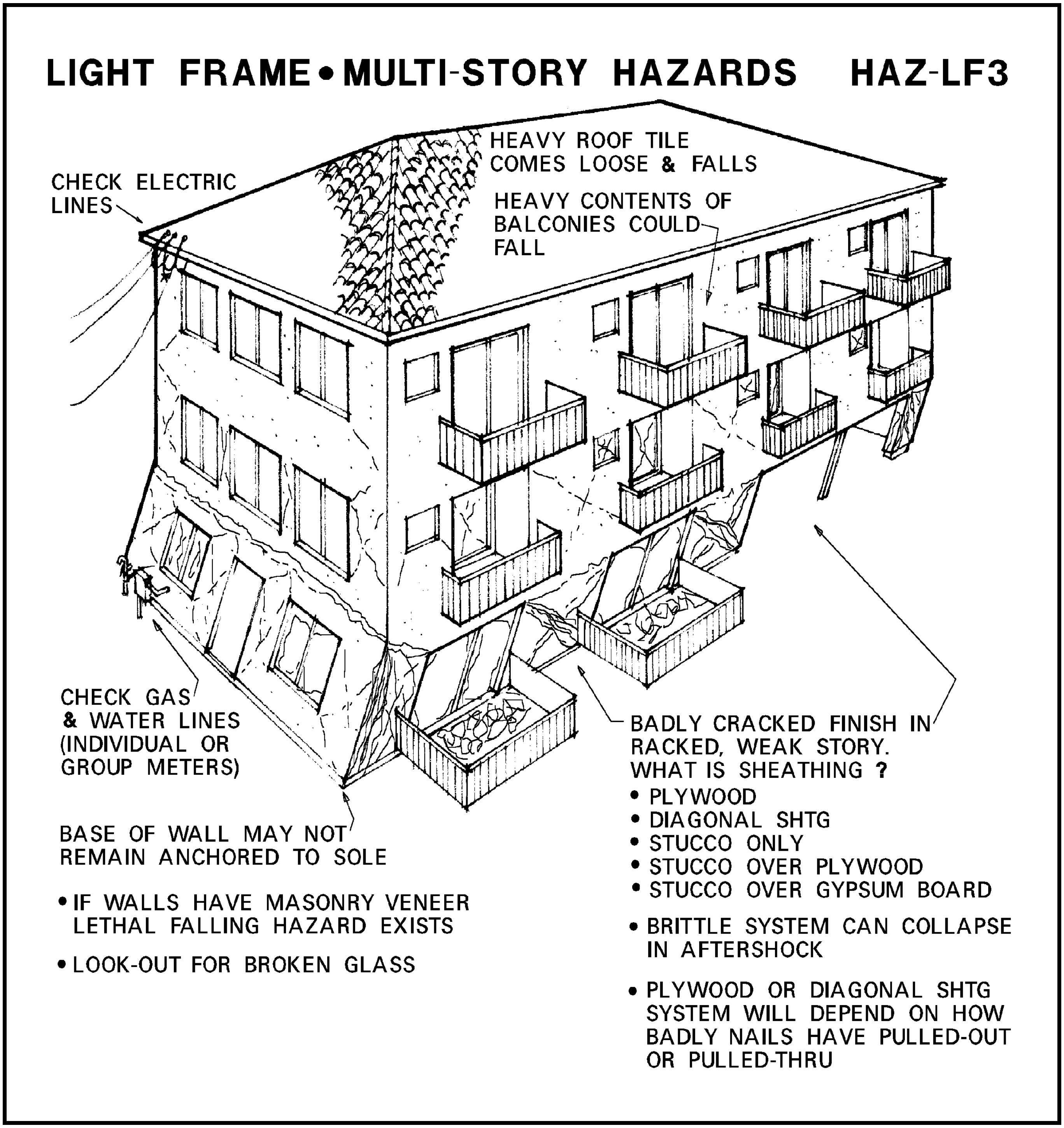
**LIGHT FRAME BUILDING HAZARDS (continued)**

- In less than three story structures additional collapse is unlikely due to the lightweight of this type of construction. Collapse of this type is often slow and noisy. Falling masonry chimneys and masonry veneers are the most brittle types of behavior for these structures



## MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
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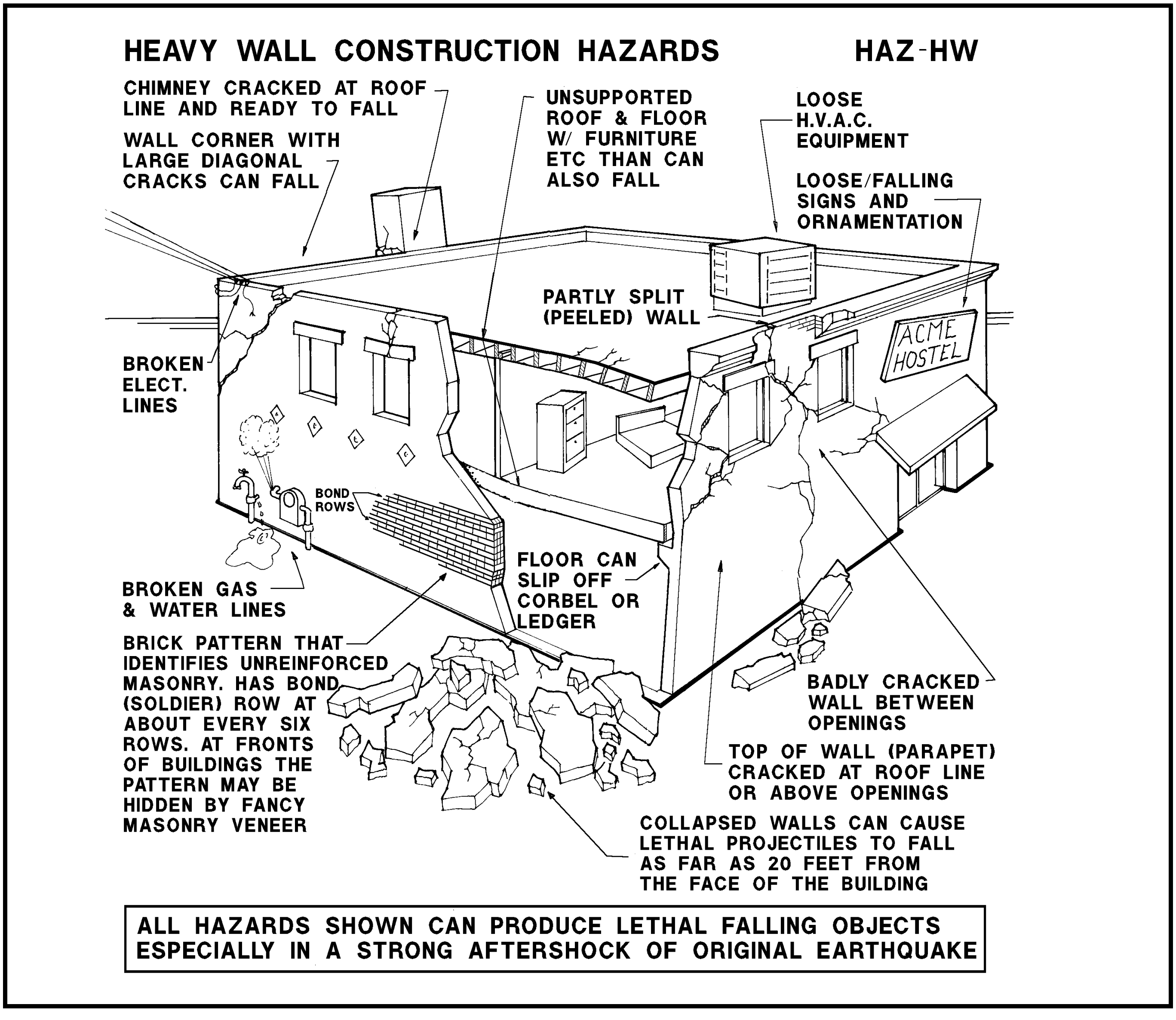
### HEAVY WALL BUILDING HAZARDS
Principle weakness is in lateral strength of walls and their connections to floors/roof.

- **Check points: (HAZ-HW)**
  - Loose, broken parapets and ornamentation.
  - Connection between floor and wall.
  - Cracked wall corners, openings.
  - Peeled walls (split thickness).
  - Unsupported and partly collapsed floors. **ALL FAILURE WILL PROBABLY BE BRITTLE**
- Falling hazards are very common in unreinforced masonry buildings due to the combination of weak and heavy wall elements. Collapse of adjacent buildings can occur due to the falling hazard of party walls.



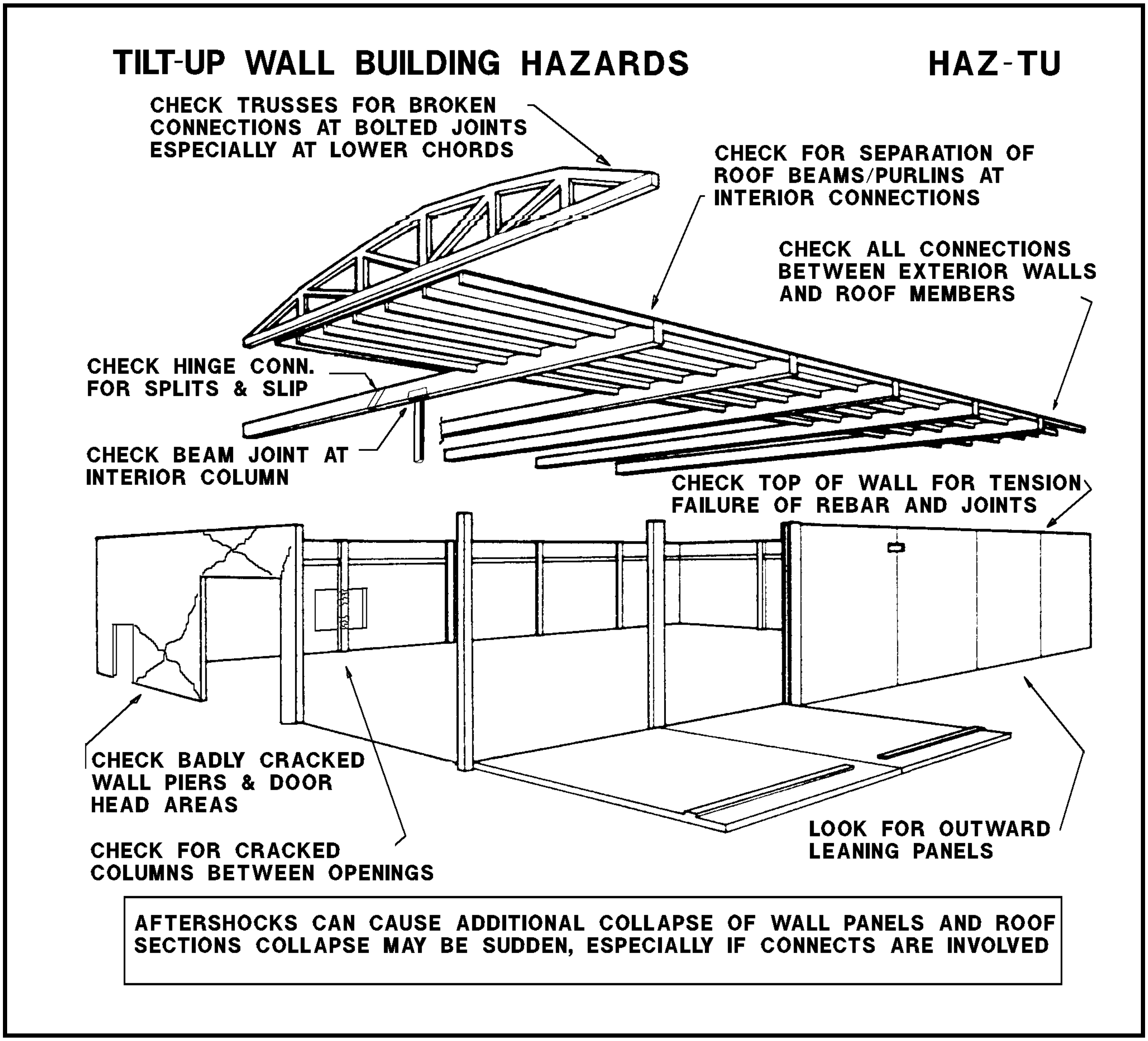
# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS

## *PART 3 - HAZARD IDENTIFICATION & BUILDING MONITORING*

### HEAVY WALL BUILDING HAZARDS TILT-UP

(Low rise reinforced masonry wall buildings w/light roof are similar)
Principle weakness is in connections between wall and floor/roof.

- **Check Points: (HAZ-TU)**
  - Connection between floor/roof & exterior wall.
  - Connection between beams and columns, both exterior & interior.
  - Badly cracked walls and/or columns.
- Connection failure will often be brittle. Wall/column failure and shear failure may be more ductile, but single curtain wall reinforcing provides little confinement.



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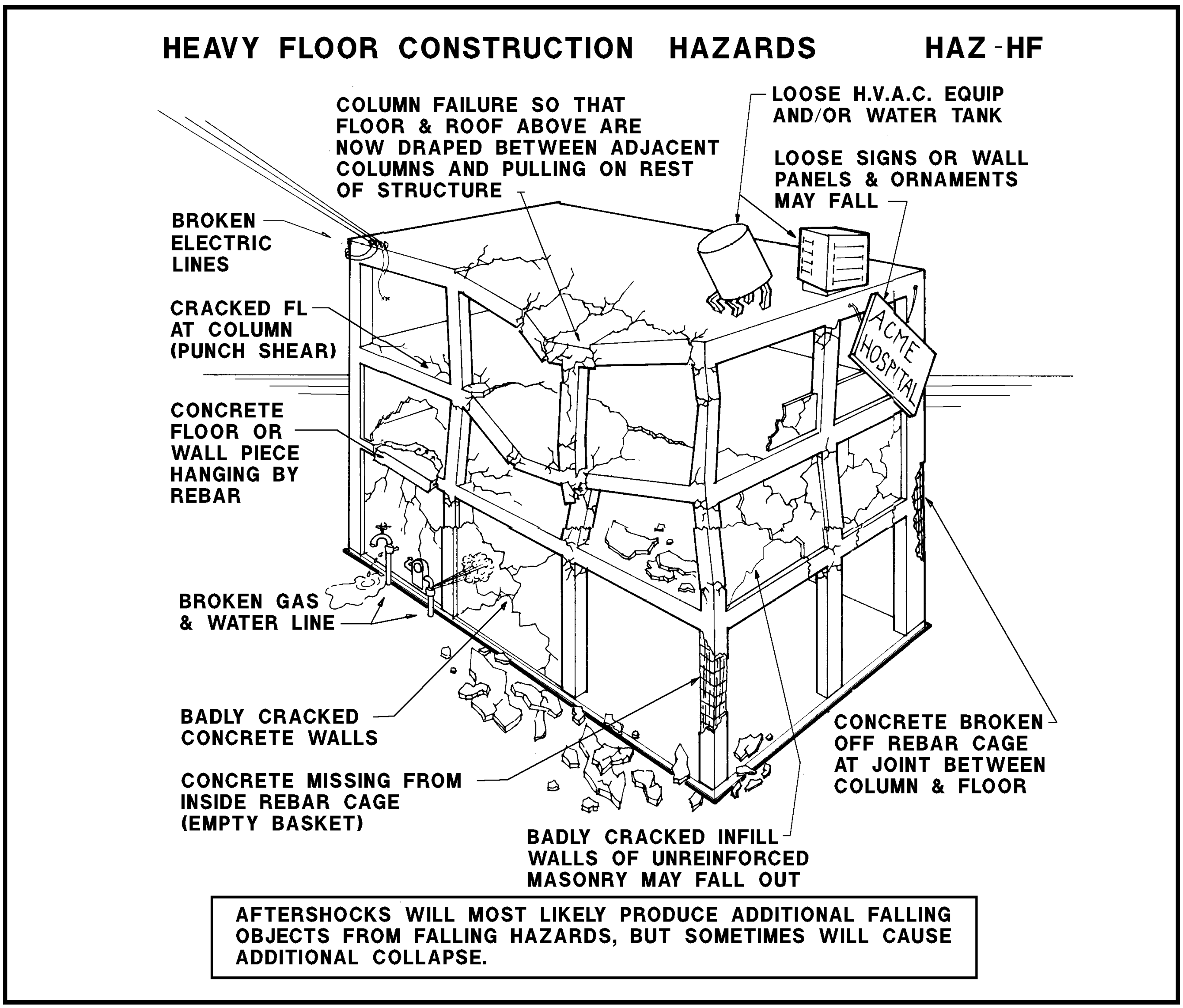
**HEAVY FLOOR BUILDING HAZARDS CONCRETE FRAMES**

Principle weakness is lack of adequate column reinforcing that can properly confine the concrete and inadequate connection between slabs and columns.

- **Check Points: (HAZ-HF)**
  - Confinement of concrete in columns (empty basket).
  - Cracking of columns at each floor line (above and below floor).
  - Diagonal shear cracking in major beams adjacent to supporting columns and walls.
  - Cracking in flat slabs adjacent to columns.
  - Attachment of heavy non-structural, unreinforced masonry walls (infill walls).
  - Cracks in concrete shear walls and/or stairs.
- Ductile behavior may still be possible if concrete is confined by reinforcing and the reinforcing is still within lower yielding range.



# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
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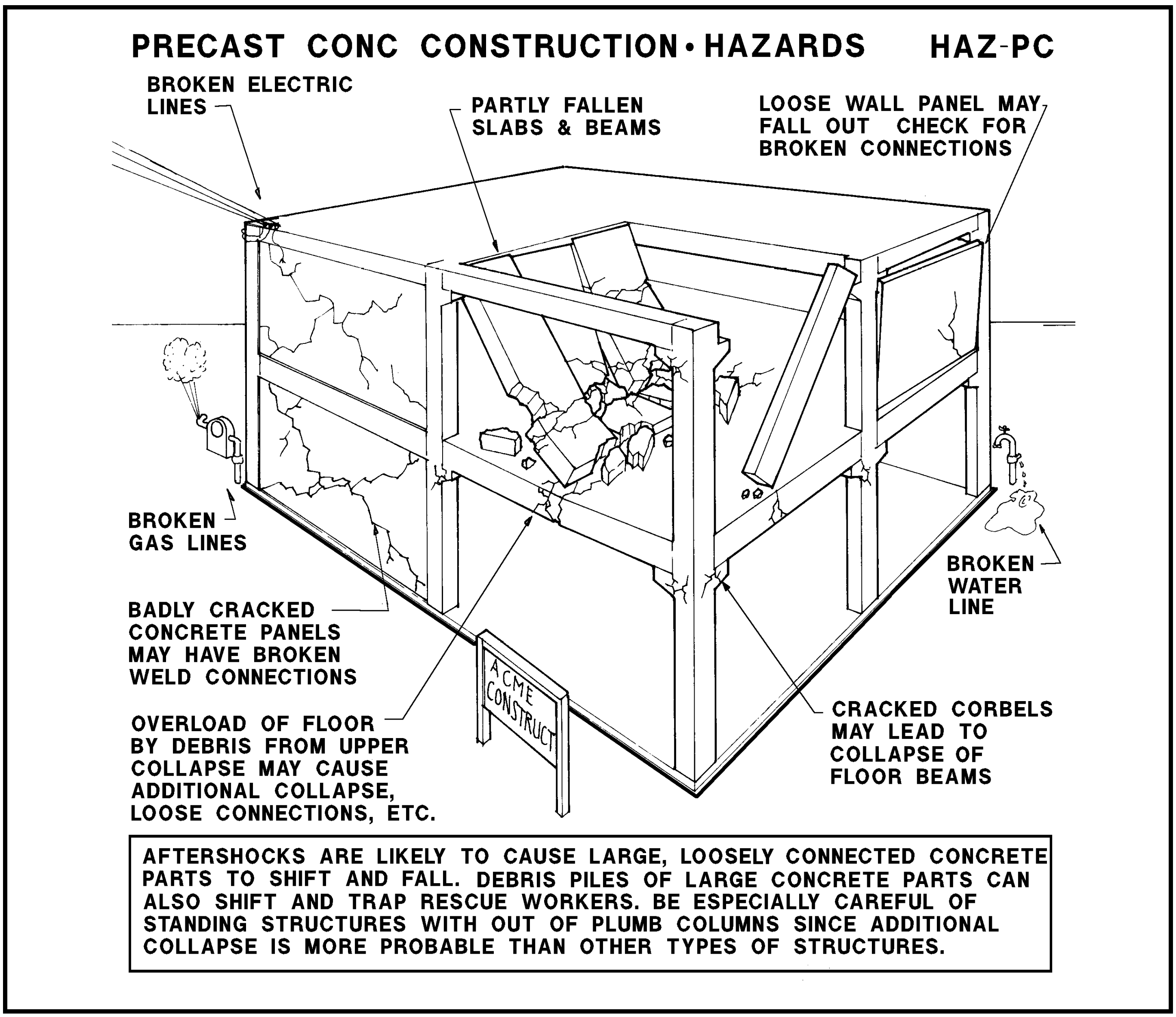
### PRECAST BUILDING HAZARDS
Principle weakness is in interconnection of parts: slabs to walls/beams; beams to columns; walls to slabs, etc. It is very difficult to make connections adequate to transfer the strength of parts, which is necessary to survive a maximum earthquake. These buildings can have fairly heavy walls and floors but neither is as heavy as Heavy Wall or Heavy Floor types.

- **Check points: (HAZ-PC)**
  - Beams to column connections C broken welds, cracked corbels.
  - Column cracking at top, bottom, wall joints.
  - Wall panel connections.
  - Shear wall connections at floors, foundation.
  - Badly cracked walls.



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### PRECAST BUILDING HAZARDS (continued)

- These structures are often made from lightweight concrete. It should be noted that lightweight concrete splits more easily than normal weight concrete.
- Most failures that occur due to broken connections will be brittle.
- Since individual building parts may be quite strong, cracked concrete failures may be ductile if adequate bonded reinforcing is present.
- Depending on extent of collapse many falling hazards may be present.

Other Hazard I. D.

- PostTensioned Concrete Slabs present unique Hazards 2s
  - After cables become loose, slabs act more like unreinforced concrete.
  - Cables normally extend full length/width of slab . (? loose full length of cable)
  - If cables are still stressed, must cut with great care.
- Geologic Hazards - effect structures 2s

### SUMMARY OF HAZARD IDENTIFICATION

The problems of identifying hazards after structural collapse are extremely difficult.

- Buildings are often complicated and there are many different types and configurations.
- What remains after the triggering event may have come to rest, but the danger of further collapse and/or falling objects is often present?
- These hazards should be identified by a qualified engineer who understands the basic behavior of structures.
- Brittle conditions pose the greatest threat due to the probability of sudden failure.
- As many hazards as possible should be identified, and probable risk factors assigned to them.
- Measures to avoid or mitigate the danger can then be factored into the overall search and rescue effort.

Hazard Identification Summary

- Structure has come to rest but many hazards may remain
- Aftershocks & strong winds may cause falling objects & additional collapse
- Hazards need to be identified & relative risk factors assigned
- Mitigation measures then need to be designed in concert with the SAR effort

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS

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### HAZARD ASSESSMENT for US&R

Based on the previous section on Hazard Identification, we need to add some additional considerations for US&R, since staying out of the structure is normally not an option.

- Assessment applies to building structural system and individual void systems.
- First question should be do we need to be in this area at all?
- Hazard avoidance is the preferred option
- What are global vs. local hazards
- **Look up first**! Small, nonstructural elements may be greatest hazards.
- Debris and other loose materials can fall in wind gusts and aftershocks - these are hazards during hazard assessment
- Identify Vertical and Lateral load systems
  - Brittle or Ductile behavior
  - What Redundancy is present?
- Can the hazards be mitigated to an acceptable level?
  - What is the risk during the mitigation?
- Check for potential instabilities
  - Building stability and Rubble stability
- What caused the collapse?
  - Has the structure collapsed to a stable condition?
- What if there is an aftershock?
  - What is the plan?
  - What are the escape routes and/or safe havens?
- Before changing the existing configuration, evaluate the effect of the change on the load path

### HAZARD MITIGATION

The basic alternatives to deal with structural collapse or falling hazards are as indicated on page following

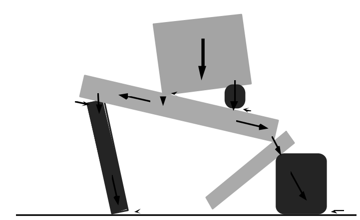
**Hazard Assessment**

- Applies to building structural systems and individual void systems
- First question should be
  - **do we need to be in this area at all?**
- Hazard avoidance is the preferred option
- Local vs global hazards

**Hazard Assessment**

- Look up first! Small nonstructural elements can be the greatest hazard
- Debris and other loose materials
  - **wind, aftershocks, etc. can knock off loose materials**
  - **these are hazards during Hazard Assessment**
- Identify load path

**Load Path Concept**



**Hazard Assessment**

- Identify vertical & lateral systems
- Brittle or ductile behavior
- Check for redundancy
- Can the hazards be mitigated to an acceptable level?
  - **What is risk during mitigation?**
- Check for potential instabilities
  - **Building stability**
  - ***Rubble stability***

**Hazard Assessment**

- What caused the collapse?
- Has structure collapsed to a stable condition?
- What if there is an aftershock - what is the plan? (Safe haven areas / escape routes)
- Visualize what could happen during an aftershock or wind gust
- <u>Before</u> changing the existing configuration evaluate the effect on the load path

## MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
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### HAZARD MITIGATION (continued)

- **AVOID** Plan direction of SAR activities away from hazard and its effects. Access of badly collapsed structure should start from the top, rather than from the edge (between layers), or than by tunneling. The use of mining techniques of tunneling and shoring with individual vertical posts has lead to aftershock caused shore failures. Consider alternatives, consult with others, be as resourceful as possible.

- **EXPOSURE REDUCTION** One of the most efficient methods of hazard reduction is to limit the time of exposure, and to limit the number rescuers that are being exposed to a potentially dangerous situation. Because of the natural tendency of rescuers to be helpful and **Part of the Action**, one will often find more than the minimum required number in a confined space especially when a live rescue in nearing completion. Risk is a function of both severity and exposure.

- **REMOVE** May be more efficient than shoring. Parts of URM walls may be removed by hand, using aerial ladders for upper portions, or in larger pieces using crane and clamshell. Precast concrete sections are more easily removed by small cranes or other concrete removal machines, due to their moderate size and lack of interconnections compared to cast in place concrete. If at all possible - Lift Off, Push Over, or Pull Down (safely of course) as a first choice

- **SHORE** Provide both vertical and lateral support, build safe haven areas. This will be discussed in detail in its own section, with special emphasis on slow/forgiving failure modes. Lateral bracing of damaged columns, beams, and entire leaning buildings may be required. Tension tieback bracing can also be effective for holding walls, and cranes have been used to temporally suspend parts of damaged buildings.

- **MONITOR** as discussed previously, methods including the use of crack measuring devices, Theodolites and other tilt measuring devices (Change in Tilt) are used to monitor damaged structures. To be effective these devices must be continually read and accompanied by an effective alarm system that activates an efficient evacuation plan.

- **RECOGNIZE** and refer hazardous materials to Hazmat Specialist. Eliminate/Shut off all possible fire hazards.

**Simple Hazard Mitigation**

- Avoid
  - **Need effective barrier system**
- Removal
  - **Lift off, push over, pull down**
- Exposure reduction
  - **How long do we need to be in the area?**
  - **Risk is a function of severity and exposure**
  - **limit time exposed to hazard**
  - **limit number of personnel exposed**

***Similar to Time, Distance, & Shielding Rule used in Hazmat***

**Other Hazard Mitigation**

- Vertical & Lateral Shoring
  - **system with slow failure mode**
- Lateral Bracing
- Lateral Tieback
  - **when shoring isn't practical**
- Vertical Tieback
  - **use crane to hang structure**
- Monitor - with alarm & escape system
- Recognize & Refer Hazard (hazmat)

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
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### METHODS TO MONITOR STABILITY

- The following indicators have been used to monitor damaged structures in an attempt to warn of change in stability:
  - Plumb bob.
  - Engineers transit or theodolite.
  - Electronic tilt-meters and levels
  - Crack measuring device

- A simple plumb bob and string can be used for small to moderate structures to determine changes in position of one story from another, between a story and the ground, or between an upper part of the wall and the ground.

- Larger structures and/or taller walls left standing will require the use of a surveyor's instrument capable of turning a vertical angle. A transit or theodolite have been used successfully to monitor the movement of multi-story high walls that remained standing after the collapse of the structure's floors. What needs to be continually checked, is the relative position of the wall or building top from the bottom, to see if instability is progressing. Tilt-meters could also be used to detect building motion.

- A Wireless Digital Tiltmeter System is available from:

  Applied Geomechanics (408) 462-9368
  1336 Brommer St, Santa Cruz, CA 95062

  The receiver can be coupled with a laptop computer or palm pilot type unit (with an alarm) to indicate when pre-determined angular movement has occurred. A complete system with 3 Tiltmeters and the receiver costs about $10,000. (1999)

- Electronic levels, sensitive to an angle change of 0.1 degree, with digital read-out, can be purchased at Home Depot and other tool mail order houses for about $100. They can be mounted on a structure, the angle recorded, and any subsequent change would then need to be observed by a TF member. They are supplied with a battery saver feature that turns them off in five minutes if no change in angle is sensed. This feature can be defeated by a modification: write D Hammond at shirham@concentric.net

  Made by: Smarttool Technologies
  2040B Fortune St, San Jose, CA 95131
  (1-800-SMARTLEVEL)

**Devices Previously Used in US&R**

- Plumb bob
- Laser Pointer or Level
- Engineers transit or theodolite
- Electronic tilt meter & levels
- Crack measuring devices

**Use of Devices**

- Plumb Bob hung from small structure to compare to a point on the ground - observe change in a leaning structure
  - Use of Laser Pointer or Laser Level could be more accurate & effective
- Transit / theodolite to establish a vertical line that will compare a point on a dangerous building to a point on the ground to detect additional tilt / movement

**Use of Devices**

- Tilt meters with alarms placed on structures to measure and signal any movement
  - can set alarm at any angle change
  - measures angle change of 0.01 degree
  - new wireless system being developed that will be read by Laptop
  - $10,000 sys with 3 digital bi-directional sensors, receiver, & laptop computer

Use of Devices

- Electronic Levels (Smartlevel) placed in pairs on structure to measure change in any angle
  - measures angle change of 0.2 degrees
  - cost is in $100 to $300 range, each
  - must be continually read (no alarm)
    - lower cost models cannot be set on zero when placed in vertical position
  - use binoculars for remote reading
  - must alter device to turn battery saver off
    - available on Smartlevels only

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### CRACK MEASURING DEVICES

Cracks in concrete or masonry shearwalls or concrete moment frame beams can be monitored in several ways. Obviously, it is important to know if the cracks in a damaged building are of a constant width or enlarging. Methods that have been used include:

- Marking an "**X**" across the crack with the center on the crack. Significant lateral movement changes can be observed.
- Placing folded paper in cracks or use automobile thickness gages (.004" to .025") to measure a specific location.
- Adhesive or other tape may be placed across the joint to measure change, but dusty conditions may prevent tape from adhering. (Need to be prepared to clean surfaces if this is only option that is available.)
- Two parallel sticks (rulers) can be taped across a crack with a perpendicular line being drawn across both of them (or existing lines on two rulers can be aligned). If the crack changes width, then the originally straight line will be offset.
- Plastic Strain gages (about $15 ea. in1999 ) may be placed across cracks to also indicate change. (mount with paste type epoxy)
  Made by: Avongard, (708) 244-4179
  2836 Osage, Waukegan, IL, 60087
- It should be noted that if the structure has significant changes in temperature, the cracks will change width, due to the temperature change. The larger the structure the larger the change.

> Cracks can be Monitored by
> - Drawing or sawcut 'x' centered on crack
> - Inexpensive ($15) plastic strain gage can be placed at crack
> - Spray paint cracked area

### <u>METHOD TO MONITOR DISASTER SITE</u>

### SEISMIC TRIGGER DEVICE

This can be installed at the site to sense the initial **P** waves of strong aftershocks. Since the P waves travel at 5 km/sec max. and the damaging **S** waves follow at approx. 3 km/sec, a warning signal could be triggered at a building site prior to the damaging effects of the **S** wave.

- The device comes in a portable carrying case and would need to be bolted to a solid slab/foundation, etc. somewhere near a damaged building.

> Method to Monitor Disaster Site
> - Time delay for S waves to travel from Fault to Site gives opportunity for warning of Aftershocks
> - Seismic Trigger deployed at Disaster Site
>   - warns when P wave arrives
>   - destructive S wave arrives later
> - Pager System
>   - pagers at disaster site are signaled from sensors at fault that measure Aftershocks

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### SEISMIC TRIGGER DEVICE continued

- For sites within 10 km of the aftershock origin there would not be enough warning to be useful.
- For sites over 50 km away there would be would be time to escape to cover etc. (seven seconds + )
- A device of this type was used at a site after the Loma Prieta Earthquake. The 1996 cost of the device was approximately $6000.00 and is manufactured by:

  Earthquake Safety Systems
  2064 Eastman Ave., Ste 102 Ventura, CA 93003
  (805) 650-5952

Method to Monitor Disaster Site
- Time delay for S waves to travel from Fault to Site gives opportunity for warning of Aftershocks
- Seismic Trigger deployed at Disaster Site
  - warns when P wave arrives
  - destructive S wave arrives later
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  - pagers at disaster site are signaled from sensors at fault that measure Aftershocks

### AFTERSHOCK WARNING SYSTEM

The U.S.G.S., and others, have discussed making an aftershock warning system available to US&R Task Forces during the first week after an earthquake.

- The system uses an array of sensors near the fault to detect aftershocks.
- A warning signal is relayed by repeaters to individual pagers that will be given to each task force that is involved in rescue operations.
- For sites that are about 10 km from the active fault, there will be only 3 seconds warning.
- For sites that are 50 km away there will be 12 seconds warning (proportionally greater warning for greater distance from aftershock origin).

### SUMMARY OF HAZARD I.D. & MONITORING METHODS

- We discussed to "**READ"** Concrete and Masonry cracks in order to predict structural behavior
- We then learned to **IDENTIFY** the most common Hazardous Conditions for simple buildings
- And finally it should be understood that US&R operations will need to be carried out in partially collapsed and badly damaged uncollapsed structures. These pose the greatest threat for additional collapse and entrapment of rescue workers. Using the suggested Monitoring Methods, it is possible, in most cases, to recognize when further collapse is likely.

SUMMARY
- Crack patterns in reinforced concrete
- Crack patterns in URM
- Post Earthquake Hazard I.D.
  - Light Frame
  - Heavy Wall
  - Heavy Floor
  - Precast Concrete
- Hazard Assessment & Mitigation
- Methods to Monitor Buildings
- Use Murrah Bldg.., OKC as Example 64s

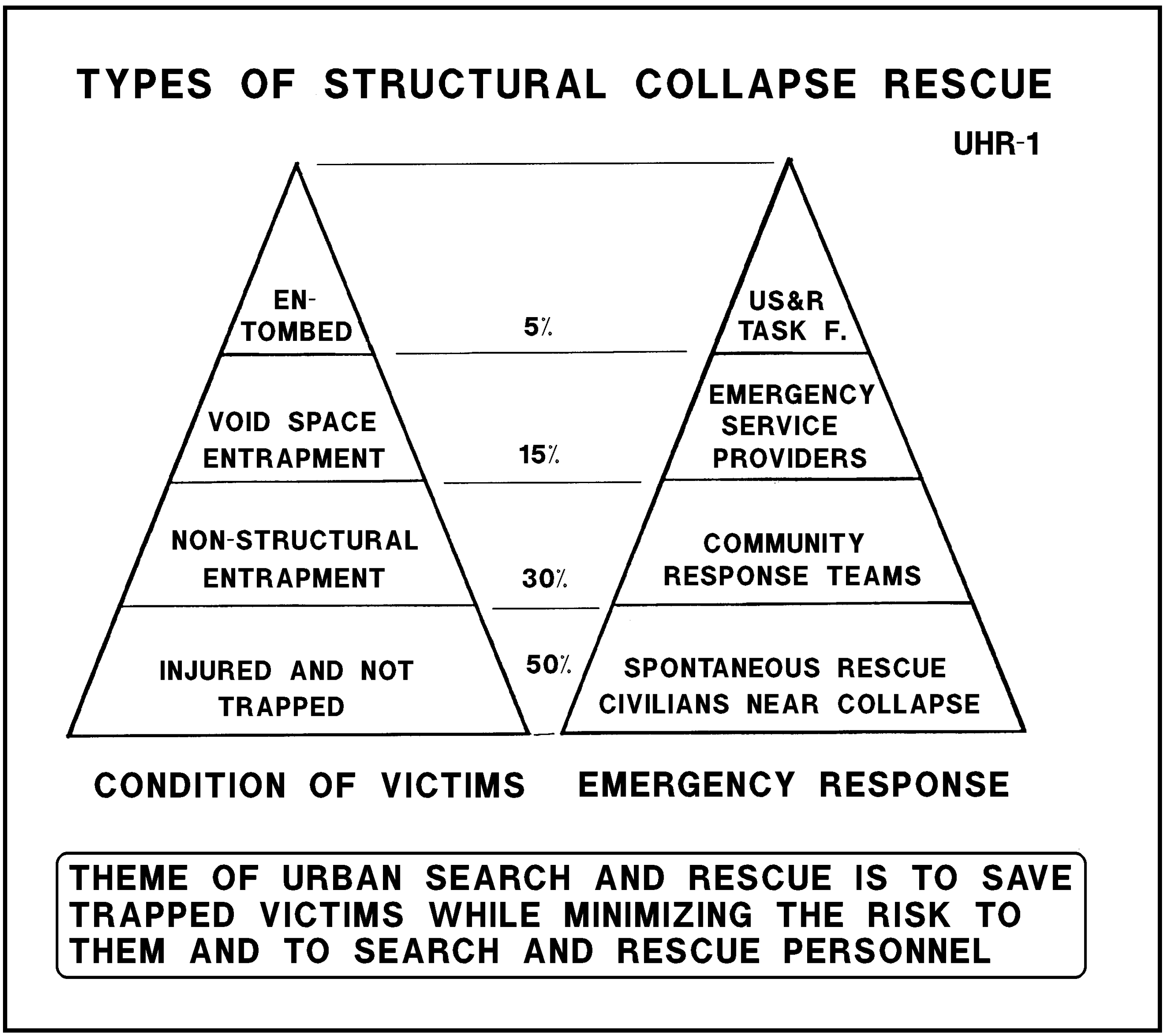
## MODULE 1C STRUCTURAL ENGINEERING SYSTEMS

### *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

**Strategies** will be presented from a Structures Hazards point of view. Other input such as medical urgency, availability of special equipment and/or trained personnel, other hazardous conditions will also need to be considered.

**THE THEME OF US&R MUST BE TO SAVE TRAPPED VICTIMS WHILE MINIMIZING THE RISK TO THE VICTIM AND THE US&R FORCES**

It is important for all to understand the typical chronology of a US&R incident, especially one caused by a devastating earthquake. The emergency response normally occurs in the following phases:



# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

**The Objectives of this section are given in the adjacent slides**

### PHASES OF LARGE DISASTER (continued)

- **Initial spontaneous response** C unskilled, neighbors, community response teams, passers-by will heroically help remove lightly trapped and/or injured victims. These rescuers have often acted far beyond their normal skill level and often save three-fourths or more of the total. Survival rates are relatively high, since victims are normally not entrapped. Professional firefighter, law enforcement officers, and emergency medical personnel may participate and better organize the response. This phase will often end during the first night.

- **Planned Community Response** by local trained community response teams. Call-out and visual search would be used to locate and rescue the non-structurally trapped. Some lifting of objects (furniture, bookcases, etc.) would be done as well as mitigation of hazards (extinguish small fires, turn off gas, observe/refer hazardous materials).

- **Void Space Rescue** by local emergency services rescue forces. Search elements would help prioritize site to make better risk vs. benefit judgments. Rescue would proceed using existing cavities, duct/plumbing shafts, basements, and/or small cut openings in easily breachable floors and walls. Some shoring might be done to provide safe haven areas and otherwise protect emergency responders and/or victims. This phase may start the first day, but often, not until after some organizing efforts have taken place, requiring at least one hour.

- **Technical, Urban Search & Rescue** by trained US&R forces, aided by equipment. Site or sites would be re-evaluated, re-searched, and prioritized for the ten- daylong effort. Extensive cutting, shoring, etc. may be done to penetrate the structure. Cranes may be used to remove layers of structural debris or parts of the structure that are hazardous.

**TERMINAL OBJECTIVES**

- The Student shall understand the Phases of a large disaster and how the FEMA US&R Task Force most commonly is deployed to perform it's initial tasks.
- The Student shall understand to the most appropriate strategies to be used to effect rescues in various types of structures.

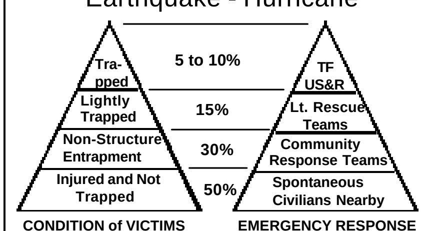
**ENABLING OBJECTIVES**

- Understand what normally occurs during the initial phases of Task Force Deployment
  - Structure Triage
  - Building I.D. and Marking Systems
- Understand the Basic Strategies that should be employed to produce the best results for most structures.

**ENABLING OBJECTIVES**

- Discuss Strategies that should produce best results for specific types of Buildings.
  - Search
  - Hazard Reduction
  - Victim Access including the cutting of concrete
- Learn from the presentation of examples from previous incidents.

Phases of Large Disaster
Earthquake - Hurricane



# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### INITIAL INFORMATION GATHERING

Information gathering techniques will be crucial to the efficient transition of the US&R forces into the incident. It is important for these incoming forces to carefully verify information obtained from the first responders and other individuals at the disaster site. By the time the information exchange takes place, the first responders will probably be subjected to the following:

- A many hour period of physically and emotionally draining work. Feelings that it's not possible that other victims have survived within a badly collapsed structure.
- A need to experience closure; that the incident is over.
- Feelings by relatives/friends of the missing that they have surely survived and are entrapped.
- The information gathering must therefore, proceed as swiftly and unemotionally as possible, while testing all current assumptions. Information from others on structural safety issues should be recorded, but the Search Specialist should perform his own assessment, independently, as in any good check.

Initial Phases of T F Deployment

- Information Gathering
- Building Identification System
- Structure Triage
- Search & Recon - Deployment Options
- Structure / Hazards Evaluation & Marking
- Search Assessment Marking
- Victim Marking

Information Gathering by TF

- Critical for transition from Initial Phase to deployment of US&R TF
- First responders may have experienced:
  - long period of emotional & physically draining work
  - need to feel that no-one else is trapped
  - need to feel closure
  - requests by relatives/friends to find their loved ones (they KNOW they are alive)

Information Gathering by TF

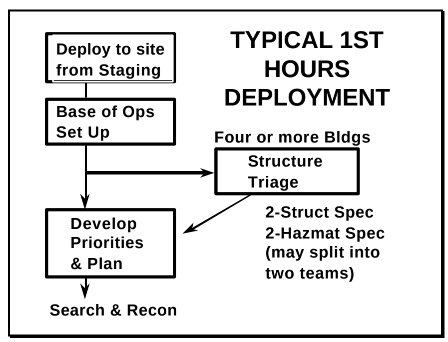
- Task Force must proceed swiftly and un-emotionally
- Must test ALL previous assumptions
- Perform Independent Assessments
- In multi-TF deployments ALL on-coming Struc. & Hazmat Spec should perform Independent Structure/Hazard Assessments

### TYPICAL FIRST HOURS DEPLOYMENT

There are many possible Scenarios to which a US&R Task Force or a number of Task Forces could respond. However, our Operating System Description (OSD) envisions that, after initial setup, a decision needs to be made as to the most appropriate deployment of TF Structure Triage and Search & Recon components. Some initial questions that need to be answered are:

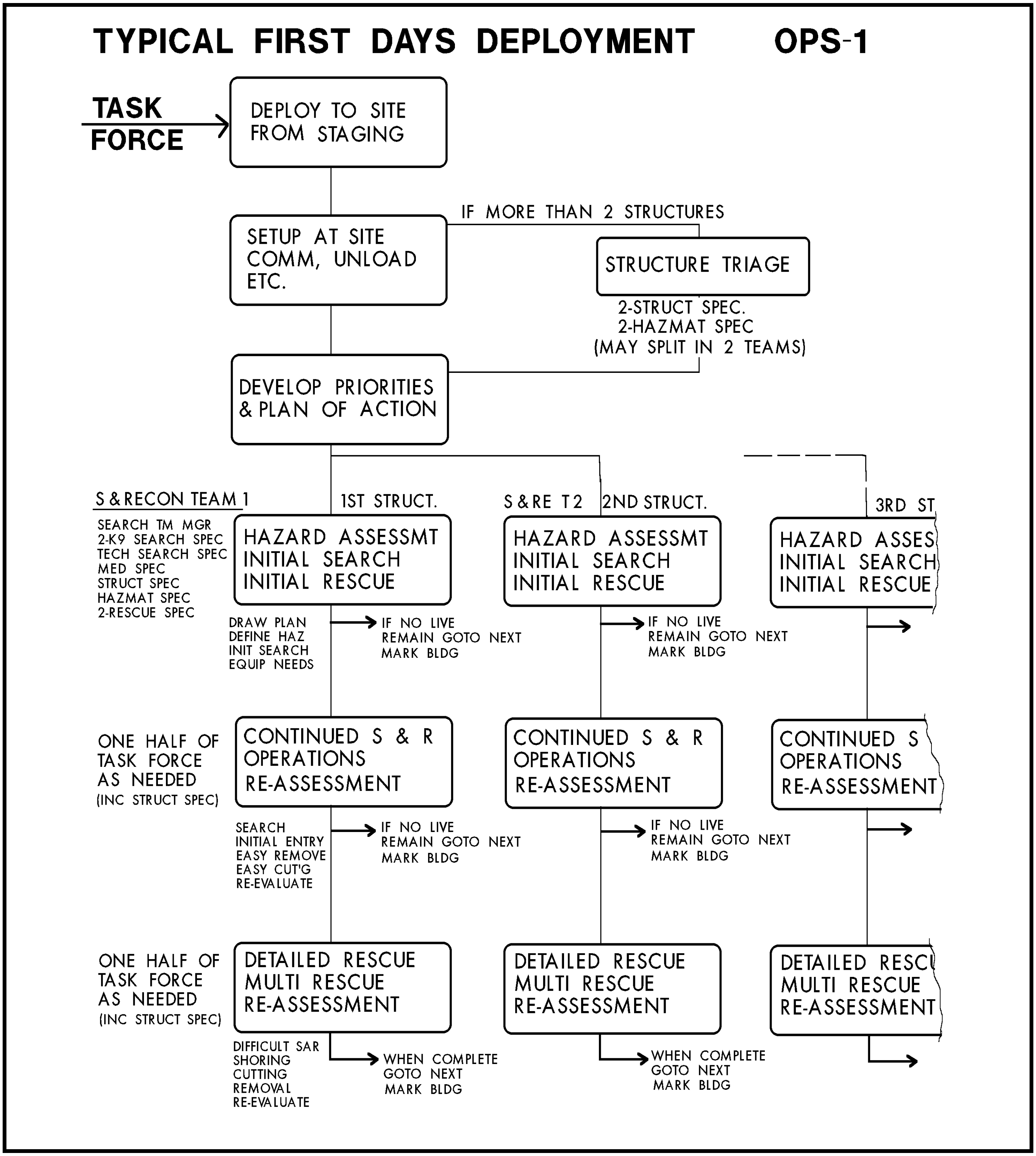
- Is Structure Triage needed or have initial priorities been established by others?
- How many building have been assigned to the TF, and does Search and Recon need to be carried out at one or more locations?
- How remote are the buildings assigned to TF?

On the following page a flow chart is shown to illustrate a simplistic 3 building scenario:



## MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
*PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### TYPICAL FIRST DAYS DEPLOYMENT



# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

## STRUCTURE TRIAGE, STRUCTURE/HAZARDS EVALUATION & MARKING

Appendix D, FEMA US&R Response System is the National standard system for evaluating, identifying, and marking buildings. It is expected that immediately after deployment, the following tasks will be performed :

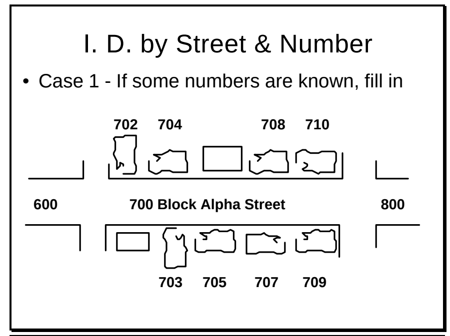
- Identification of individual building.
- Building triage (only if required).
- Structural/Hazard Evaluation & Marking.
- Initial US&R with Search & Rescue Marking.

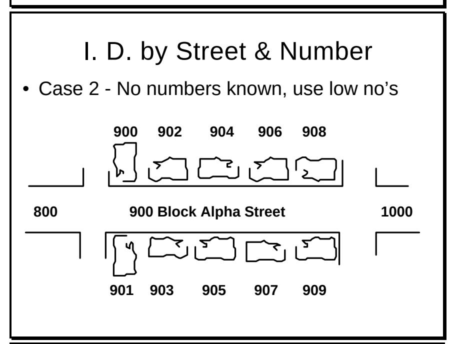
We will discuss each in turn:

### IDENTIFICATION OF INDIVIDUAL BUILDINGS

Standard system to locate building on any block:

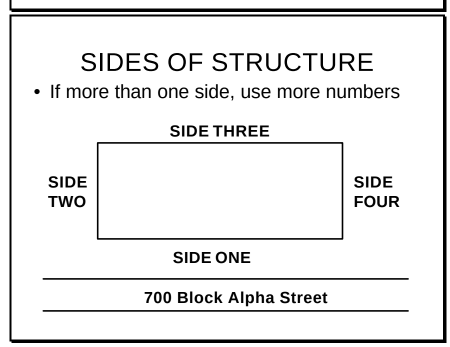
- Use existing numbers and fill in unknowns.
- If all unknowns, keep numbers small, odd and even sides.



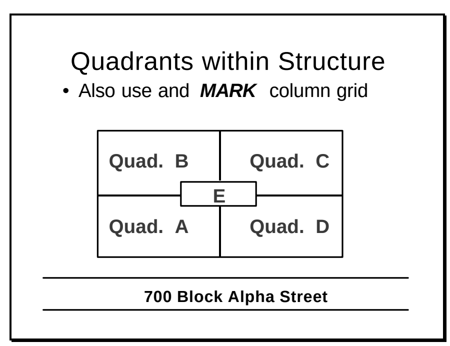

Standard system for building layout:

- Sides 1, 2, 3 and 4; start at street and go clockwise.
- Stories are designated: Ground, 2, 3, 4.
- Basements are designated: B1, B2, and B3.




Quadrants within a building:

- Mark A, B, C, D, etc.
- Most helpful to mark an appropriate number on each column for structures with regular (or irregular) layout.
- Column numbers should be large enough to be read from a distance (like by a crane operator)
- Use existing column numbers if known. (KISS)



# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
*PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

## BUILDING TRIAGE

### BASIC ASSUMPTIONS FOR USE OF TRIAGE BY T F

- Triage will be necessary if there are three or more buildings assigned to a single task force.
- Triage would initially be done by a team of Structures Specialist and Haz Mat Specialist as soon as possible upon arriving at the site, and should be accomplished within no more than two hours. The remainder of the task force would be involved in camp set-up, information gathering, etc. during this time period.
- No planned search operations would begin until initial triage was completed, in order to establish priority.
- The more detailed Structure/Hazards Evaluation and Building Marking would take place (along with the initial search) after structures are initially prioritized. One or more teams of Structures Specialist and Haz Mat Specialist would accomplish Structure/Hazards Evaluation and Building Marking.
- Triage criteria would be re-evaluated after initial search in light of locating live victims.
- If many buildings were involved, triage would probably be done by two teams, each consisting of one Structures and one Haz Mat Specialist. It would therefore, be imperative that the two teams compare assessment criteria, before and after they do the triage work, in order to assure that uniform evaluations are obtained.


- Triage criteria would be re-evaluated after initial search in light of locating live victims.
- If many buildings were involved, triage would probably be done by two teams, each consisting of one Structures and one Haz Mat Specialist. It would therefore, be imperative that the two teams compare assessment criteria, before and after they do the triage work, in order to assure that uniform evaluations are obtained.


- The natural tendency of the Structures Specialist will be to stop at each building and "solve the problem", and not leave a structure where people might be known to be trapped, etc. This tendency must be overcome by maintaining a pre-designated time schedule of 5 to 15 minutes per building, and frequent check-in with task force leadership.

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TRIAGE - RAPID I.D. & PRIORITIZATION OF STRUCTURES

- Done immediately after disaster by special assessment team or by local emergency responders - or
- Done immediately after deployment of US&R Task Force - all structures within assigned area

STRUCTURE TRIAGE

- Rapid (5 to 15 min per bldg) assessment w/ scoring system and sketch map of area w/ bldg I.D.
- Triage team must maintain discipline to evaluate all building in group, not stop to solve problems
- TF leader to use triage score as they see fit and establish initial priority for Search & Recon team

HOW RESULTS OF TRIAGE ARE USED

- To determine where and in what order to deploy local & imported US&R Task Force
- To determine priorities for a Task Force within an assigned area (group of bldgs or wing of multi wing bldg complex)

TRIAGE BY U.S.& R. TASK FORCE

- Struct. & hazmat spec. perform rapid evaluation to collect triage data for assigned site within first few hours while task force is unloading/setting up
- Hazard I.D. & Structure/Hazard marking would occur after first triage is completed
- Initial Search & Recon would occur right after Hazard I.D.

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### TRIAGE CRITERIA

- The following information needs to be considered in determining risk/benefit that will aid in prioritization.
- **Occupancy** the type of activity done in the building, as well as the potential maximum number of occupants.
- **Structural Type** what type of materials are involved, in order to help identify difficulty of access, type of collapse, potential hazard mitigation needs, etc.
- **Collapse Mechanism** how building failed in order to provide an indication of type of voids that might be available for victim survival.
- **Time of Day** refers to the time of the event which caused the collapse. This is a critical factor when combined with the occupancy type. For example, if an earthquake occurs at 2100 hours and collapses an office building and an apartment building, the apartment building would normally represent the higher potential for a successful rescue than would the office building. If the event occurred at 1000 hours, the opposite would be true.
- **Prior Intelligence** information from the general public, local authorities, first responders, etc. relating to known trapped victims.
- **Search and Rescue Resources Available** does the particular building require resources beyond what is readily available to the task force (i.e., is heavy equipment required to gain access).
- **Structural Condition of the Building** generally, can search and rescue operations proceed with a minimum of stabilization effort.

TRIAGE CRITERIA

- Info considered to determine Risk / Benefit
- Occupancy - type of activity and potential maximum number of occupants
- Structure type - type of materials involved to help define difficulty of access & hazards
- Collapse type - indicates type of voids & potential for victim survival
- Time of day - when quake occurred vs occupancy

OTHER CRITERIA

- Resources avail - shoring, cranes, other
- Structural Condition - effort req'd to stabilize
- Prior Intelligence - regarding Victims

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### TRIAGE SCORING FACTORS

The following factors will be used to obtain a numerical score for each structure in a group of buildings. The intent is, the higher the numerical score the better the risk/benefit ratio.

- **ZERO OCCUPANTS PROBABLE** A notation of "ZERO" would be written in the score column if the earthquake occurred at a time of day when the type of occupancy contained in the structure was such that the building would have been normally unoccupied (school rooms on Sunday, retail shops at 6 A.M., etc.). The triage team would then proceed to the next building.

- **TOTAL NUMBER OF POTENTIALLY TRAPPED VICTIMS.** This will be assessed knowing the type of occupancy, the floor area of collapsed entrapping structure, the time of day the incident occurred, and the type of collapse. The following are the average total number occupants for various occupancies:

**Based on units other than area:**

| | |
|---|---|
| Schools | 25 to 35 students per classroom |
| Hospitals | 1.5 occupants per bed |
| Residential | 2.0 occupants per bedroom |
| Others | 1.5 occupants per parking space |

| **Based on area:** | | | **Variation** |
|---|---|---|---|
| Schools, Library | 1 per | 70 SQ. FT. | 50-100 |
| Hospitals | 1 | 100 | 80-150 |
| Multi Residential | 1 | 200 | 100-300 |
| Commercial | 1 | 100 | 50-200 |
| Office, Inc Govt. | 1 | 150 | 100-200 |
| Public Assembly | 1 | 25 | 10-050 |
| EOC, PD, FD | 1 | 125 | 100-150 |
| Industrial | 1 | 200 | 100-300 |
| Warehouse | 1 | 600 | 400-900 |

- The **Time of Day** that the incident occurred may indicate that there was very little possibility of a structure being occupied. The type of collapse (auto garage only, partial collapse) may also indicate that few occupants would remain entrapped even if many occupied the structure during the incident. All these factors should be considered when calculation **Total Number of Trapped Victims**.
- The numerical value of this criteria will vary from 1 to 50 as the number of potentially trapped victims varies from 1 to more than 200. Between 5 and 250 the value is the total number of possible trapped victims divided by 5.

NUMBER OF OCCUPANTS

- Building Code estimates based on area
- Schools - varies 1 per 50 to 100 sq ft
- Hospitals 50 to 200
- Multi-residential 100 to 300
- Commercial 50 to 200
- Office/govt bldg 100 to 200
- Public assembly 10 to 50
- Public safety 100 to 200
- Industrial 100 to 300
- Warehouse 400 to 900

**NUMBER OF OCCUPANTS**
**Other Methods to Estimate**

- Number of Cars in Parking Lot
  - Assembly occupancies
  - Low Rise Office & Light Industrial Bldgs
  - Low Rise Commercial - Shopping Malls
- Number of Bedrooms
  - Multi-unit Housing

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### TRIAGE SCORING FACTORS (continued)

- **CONDITION OF VOIDS.** This criterion will attempt to assess the degree of survivability of the potentially trapped victims. Victims don't survive well in tightly compacted collapsed areas consisting of rubble masonry, badly broken cast in place concrete and precast concrete. Hollow, survivable voids are often found under wooden floor panels, that are collapsed into angular interlocking planes and in reinforced concrete structures, where floors have projecting beam elements, parts of columns/walls and furnishings that hold the slabs apart. Partly collapsed structures may have large triangular voids or entrapped victims in large voids due to blocked exits etc. These large voids have the best chance of having surviving entrapped victims. The value of this criteria will vary from 1 to 20.

- **TIME REQUIRED TO ACCESS VICTIMS.** This will be an estimate of the time required to get to the first victim. It should include the time required to cut through floors/roofs etc., and the time required to shore/brace the access route and appropriate adjacent structures. The numerical value will vary from 1, for more than one day, to 20 for taking only two hours.

- **DANGER OF ADDITIONAL COLLAPSE DUE TO AFTERSHOCK.** This criteria will be represented by a minus number between -1 for low probability to -20 for high probability of additional collapse, assuming the proposed shoring/bracing is installed from criteria 3.

- **SPECIAL OCCUPANCY INFORMATION.** For this criteria one will add 25 points if the occupancy is a school, day care center, hospital, or other occupancy that could involve children. In addition 5 points should be added for each potential live victim that is confirmed by previous intelligence, search, etc.

- 

- **"NO GO" CONDITIONS.** These would include structures that are on fire, have significant haz mat spills or otherwise have conditions that would make search and rescue operations too risky. Buildings with "**NO GO**" conditions would be expected to be re-evaluated when those conditions were mitigated, and some comment would be made regarding this should be recorded on the form.

A simplistic EXAMPLE is shown on the next two pages to illustrate the Triage Method. One could easily prioritize the three structures in the example. They are intended only as a short exercise.

SCORING SYSTEM

- System is based on Value Judgments
- Made by Trained Engineer & Hazmat Specialist

SCORING SYSTEM

| | |
|---|---|
| • Zero victims probable, write zero, goto next | |
| • No. of potentially trapped victims<br>**(potential no. of victims divided by 5)** | 1 to 50 |
| • Condition of voids<br>**(compact - separate layers - part collapse)** | 1 to 20 |
| • Time req'd to access victim<br>**(one day to two hours)** | 1 to 20 |
| • Danger of additional collapse<br>**(low chance to high chance)** | -1 to -20 |
| • Special occupancy children | + 25 |
| • Each known live victim | +5 |

NO-GO CONDITIONS

- FIRE
- HAZMAT
- Need to add info on when No-G0 is to be Re-evaluated & Revisited

GOAL OF TRIAGE METHOD

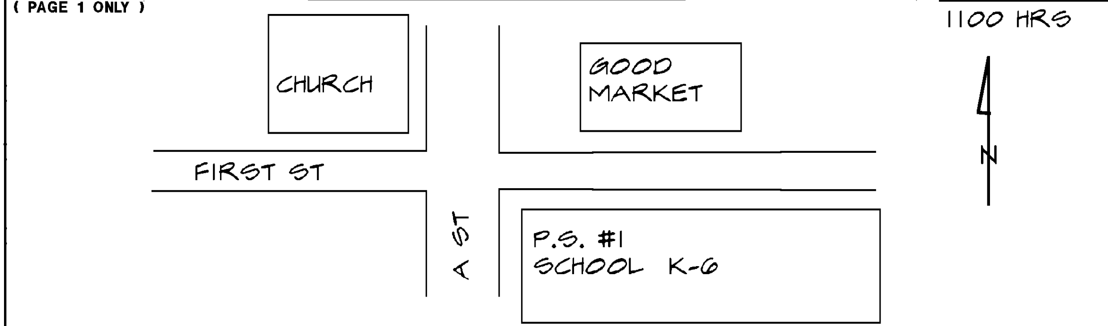
- Intended to be a logical documentation of common sense
- A quick way of recording the value judgments required to make the difficult choices

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### EXAMPLE STRUCTURE TRIAGE FOR SUNDAY EARTHQUAKE

**STRUCTURE TRIAGE • DATE/TIME** 24FEB92/1600 **PG** 1 **of** 1

**MAP** ( PAGE 1 ONLY ) **TEAM & S. SP.** D. HAMMOND/CAL #13 **DATE/TIME OF QUAKE** SUN 23FEB92 1100 HRS




| | | |
|---|---|---|
| BLDG I.D. CORNER 1ST & A<br>FLOOR AREA 10,000 SF<br>STORIES ONE<br>OCCUPANCY CHURCH<br>MATERIAL (CIRCLE ALL THAT APPLY)<br>W C S URM PC | 1. ZERO VICTIMS PROBABLE, WRITE ZERO, GOTO NEXT BLDG<br>2. POTENTIAL NO. OF TRAPPED ÷ 5 ( MIN = 1 MAX = 50)<br>3. CONDITION OF VOIDS 1 VERY COMPACT — SEPARATE LAYERS — PART COLLAPSE → 20<br>4. TIME GET TO VICTIM 1 ONE DAY — 2 HRS → 20<br>5. CHANCE OF COLLAPSE -1 LOW CHANCE — HI CHANCE → -20<br>6. SPECIAL INFO: SCHOOL / HOSPITAL = +25 KNOWN LIVE VICTIM = + 5 EA | <br>40<br>10<br>1<br>-1<br>0 |
| CALCULATE AREA & NO. TRAPPED<br>10,000SF/50 = 200 | NO GO (CIRCLE, WRITE NO-GO & WHEN/IF TO REVISIT)<br>FIRE HM | 50<br>BLDG TOTAL |
| BLDG I.D. P.S.1 @ 1ST & A ST<br>FLOOR AREA 70'X120'X3=25KSF<br>STORIES 3<br>OCCUPANCY SCHOOL<br>MATERIAL (CIRCLE ALL THAT APPLY)<br>W C S URM PC | 1. ZERO VICTIMS PROBABLE, WRITE ZERO, GOTO NEXT BLDG<br>2. POTENTIAL NO. OF TRAPPED ÷ 5 ( MIN = 1 MAX = 50)<br>3. CONDITION OF VOIDS 1 VERY COMPACT — SEPARATE LAYERS — PART COLLAPSE → 20<br>4. TIME GET TO VICTIM 1 ONE DAY — 2 HRS → 20<br>5. CHANCE OF COLLAPSE -1 LOW CHANCE — HI CHANCE → -20<br>6. SPECIAL INFO: SCHOOL / HOSPITAL = +25 KNOWN LIVE VICTIM = + 5 EA | 0 |
| CALCULATE AREA & NO. TRAPPED<br>25KSF/70 = 360<br>IF OCCUPIED BUT REPORT NOT OCCUPIED | NO GO (CIRCLE, WRITE NO-GO & WHEN/IF TO REVISIT)<br>FIRE HM | 0<br>BLDG TOTAL |
| BLDG I.D. MARKET @ 1ST & A<br>FLOOR AREA 100'X120'=12KSF<br>STORIES ONE<br>OCCUPANCY GROCERY<br>MATERIAL (CIRCLE ALL THAT APPLY)<br>W C S URM PC | 1. ZERO VICTIMS PROBABLE, WRITE ZERO, GOTO NEXT BLDG<br>2. POTENTIAL NO. OF TRAPPED ÷ 5 ( MIN = 1 MAX = 50)<br>3. CONDITION OF VOIDS 1 VERY COMPACT — SEPARATE LAYERS — PART COLLAPSE → 20<br>4. TIME GET TO VICTIM 1 ONE DAY — 2 HRS → 20<br>5. CHANCE OF COLLAPSE -1 LOW CHANCE — HI CHANCE → -20<br>6. SPECIAL INFO: SCHOOL / HOSPITAL = +25 KNOWN LIVE VICTIM = + 5 EA | <br>12<br>5<br>10<br>-10<br>0 |
| CALCULATE AREA & NO. TRAPPED<br>12KSF/200 = 60 | NO GO (CIRCLE, WRITE NO-GO & WHEN/IF TO REVISIT)<br>FIRE HM | 17<br>BLDG TOTAL |

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### EXAMPLE STRUCTURE TRIAGE FOR MONDAY EARTHQUAKE

**STRUCTURE TRIAGE • DATE/TIME** 25FEB92/1600 **PG** 1 **of** 1

**MAP** (PAGE 1 ONLY) **TEAM & S. SP.** D. HAMMOND/CAL #13 **DATE/TIME OF QUAKE** MON 24FEB92 1100 HRS


| | | |
|---|---|---|
| **BLDG I.D.** CORNER 1ST & A | 1. ZERO VICTIMS PROBABLE, WRITE ZERO, GOTO NEXT BLDG | |
| **FLOOR AREA** 10,000 SF | 2. POTENTIAL NO. OF TRAPPED ÷ 5 (MIN = 1 MAX = 50) | 1 |
| **STORIES** ONE | 3. CONDITION OF VOIDS 1 VERY COMPACT — SEPARATE LAYERS — PART COLLAPSE → 20 | 10 |
| **OCCUPANCY** CHURCH | 4. TIME GET TO VICTIM 1 ONE DAY — 2 HRS → 20 | 1 |
| **MATERIAL (CIRCLE ALL THAT APPLY)** W C S URM PC | 5. CHANCE OF COLLAPSE -1 LOW CHANCE — HI CHANCE → -20 | -1 |
| **CALCULATE AREA & NO. TRAPPED** 10,000SF BUT NOT TOO MANY OCCUPY ON MON | 6. SPECIAL INFO: SCHOOL / HOSPITAL = +25 KNOWN LIVE VICTIM = +5 EA | 0 |
| | NO GO (CIRCLE, WRITE NO-GO & WHEN/IF TO REVISIT) FIRE HM | 11 BLDG TOTAL |
| **BLDG I.D.** P.S.1 @ 1ST & A ST | 1. ZERO VICTIMS PROBABLE, WRITE ZERO, GOTO NEXT BLDG | |
| **FLOOR AREA** 70'X120'X3=25KSF | 2. POTENTIAL NO. OF TRAPPED ÷ 5 (MIN = 1 MAX = 50) | 36 |
| **STORIES** 3 | 3. CONDITION OF VOIDS 1 VERY COMPACT — SEPARATE LAYERS — PART COLLAPSE → 20 | 1 |
| **OCCUPANCY** SCHOOL | 4. TIME GET TO VICTIM 1 ONE DAY — 2 HRS → 20 | 20 |
| **MATERIAL (CIRCLE ALL THAT APPLY)** W C S URM PC | 5. CHANCE OF COLLAPSE -1 LOW CHANCE — HI CHANCE → -20 | -10 |
| **CALCULATE AREA & NO. TRAPPED** 25KSF/70 = 360 HAVE INFO THAT ABOUT 1/2 GOT OUT | 6. SPECIAL INFO: SCHOOL / HOSPITAL = +25 KNOWN LIVE VICTIM = +5 EA | 25 |
| | NO GO (CIRCLE, WRITE NO-GO & WHEN/IF TO REVISIT) FIRE HM | 72 BLDG TOTAL |
| **BLDG I.D.** MARKET @ 1ST & A | 1. ZERO VICTIMS PROBABLE, WRITE ZERO, GOTO NEXT BLDG | |
| **FLOOR AREA** 100'X120'=12KSF | 2. POTENTIAL NO. OF TRAPPED ÷ 5 (MIN = 1 MAX = 50) | 12 |
| **STORIES** ONE | 3. CONDITION OF VOIDS 1 VERY COMPACT — SEPARATE LAYERS — PART COLLAPSE → 20 | 5 |
| **OCCUPANCY** GROCERY | 4. TIME GET TO VICTIM 1 ONE DAY — 2 HRS → 20 | 10 |
| **MATERIAL (CIRCLE ALL THAT APPLY)** W C S URM PC | 5. CHANCE OF COLLAPSE -1 LOW CHANCE — HI CHANCE → -20 | -10 |
| **CALCULATE AREA & NO. TRAPPED** 12KSF/200 = 60 | 6. SPECIAL INFO: SCHOOL / HOSPITAL = +25 KNOWN LIVE VICTIM = +5 EA | 0 |
| | NO GO (CIRCLE, WRITE NO-GO & WHEN/IF TO REVISIT) FIRE HM | 17 BLDG TOTAL |

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### SEARCH AND RECON TEAM

This group of TF members is comprised of the NINE individuals listed in the adjacent slide. A TF can field two of these groups, and might need to do so if they were faced with the task of locating victims in more than one building. The Rescue Specialist involved on the team could be asked to perform any of the following Search Functions: (in addition to his normal Rescue duties)

- Help setup and operate Technical Search Equipment.
- Cut access holes for equipment and evaluation
- Perform visual and vocal Physical Search
- Help spot for K-9 search
- Help with Hazmat Assessment

SEARCH & RECON TEAM

- nine members (in each of 2 teams on TF)
- search manager
- canine search spec (2)
- tech search spec
- structural spec
- hazmat spec
- medical spec
- rescue spec (2)

### SEARCH & RECON - INITIAL TASKS

As noted in the adjacent slide, the Initial Tasks involve collecting the data that will help define the US&R Problem.

- Where is it, What is it and What are the details?
- What was the Original Configuration and Has it reached a new State of Equilibrium?
- What are our current Problems – Define/Evaluate the Hazards
- How best to remove Victims without creating new ones?

S&R TEAM INITIAL TASKS

- Area plot plan/map and bldg i.d. if no triage
- Structural/Hazard evaluation & marking
- Bldg sketch/plan + bldg cross-section
- Bldg config. & type, inc size & no. stories
- Collapse type, void location, hazard location
- Best victim access, hazard mitigation, etc.

### RECON & HASTY SEARCH

As previously stated, it is best to proceed by taking nothing for granted. Do an independent Search & Evaluations

- The most appropriate search tool will depend on the situation. Redundancy for conformation is VERY important.
- Physical search with Hailing would normally be tried first. A combination may follow.
- A combination that has been effective is to **DETECT** victims with Electronics, **LOCATE** using K9 and/or Physical, and **ASSESS** the victim and confined space with Searchcam/Fiber cameras

**S&R TEAM HASTY SEARCH**

- Find/remove lightly trapped ( not likely for TF )
- Use most appropriate search tools first
- Use redundancy for confirmation - if practicable
- Start rescue operations - if appropriate
- Report to TFL - re-evaluate priorities vs unsearched, next lower priority building

### SEARCH & RECON – FOLLOWING FIRST BUILDING

After finding live victims in the first building, In the situation where numerous building are involved, a decision must be made by TF leadership regarding deployment of the Search & Recon Team.

- Should Search & Recon proceed to determine victim viability in other structures, or stay to aid Rescue Operations?

DIFFICULT DECISION FOR TFL

- Should Search & Recon team leave their first building as Rescue Ops are beginning in order to evaluate the next priority structure
- Do Rescue Ops need the continued support of Structure & Search Spec

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### SEARCH & RECON DEPLOYMENT OPTIONS

Depending on the magnitude of a disaster, Search & Recon could be deployed in one of the several options as follows:

- Type 1 – One or 2 Buildings
- Type 2 – 5 to 10 Buildings, Large E. Quake, Limited Resources
- Type 3 – Many small Structures, Hurricane

### TYPE 1

- Use TF in Blitz mode for first 8 hrs
- Assign 1 Search & Recon Team to each structure
- Re-prioritize based on results of Search & Recon
- Switch TF to half rest, half work (12hr on 12hr off) mode with Rescue Ops based on priorities

### TYPE 2

- Start in Blitz Mode, sending Search & Recon to Bldgs 1 & 2.
- Using both S & R Teams, attempt to complete re-prioritization of all building within first 8 hours. (prior to 1st rest cycle)
- Switch TF to half rest, half work (12hr on 12hr off) mode with Rescue Ops based on priorities

### TYPE 3

- Deploy Search & Recon Team in continuous Hasty Mode.
- Enhance Search & Recon with added personnel to perform immediate simple rescue or
- Stagger Rescue Strike Teams just behind Search & Recon.
- Might enhance TF Rescue Strike Teams with more Struct Spec.

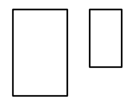
### OTHER OPTIONS

- US Army Corps of Engineers (USACOE) has trained over 80 Structural Specialists that can be deployed with a TF.
- They can be assigned to train with the TF before an incident or be added to the TF at the disaster site.
- They can also be added to the Incident Support Team

*DISASTER TYPE & MAGNITUDE WILL DETERMINE*

*SEARCH & RECON TEAM DEPLOYMENT OPTIONS*

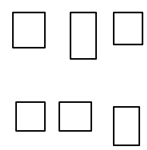
TYPE 1 ASSUMPTIONS



**Few Bldgs**

- Use TF in Blitz mode
- S & Recon Team assigned to each bldg
- S & Recon Team stays to aid in Rescue Operations

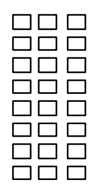
TYPE 2 ASSUMPTIONS



**5 TO 10 BLDGS**

- Large disaster/limited resources
- Start w/ Blitz on 2 highest priority bldgs
- S & Recon Team must get instruction from TFL after hasty search - go to next or stay to help rescue

TYPE 3 ASSUMPTIONS



**MANY BLDGS**

- Many small buildings - Hurricane or Kobe type Earthquake
- S & Recon Team deployed in continuous Hasty mode
- Rescue should be relatively simple/fast
- Deploy rescue w/o Struct/Search
- Could enhance TF w/COE

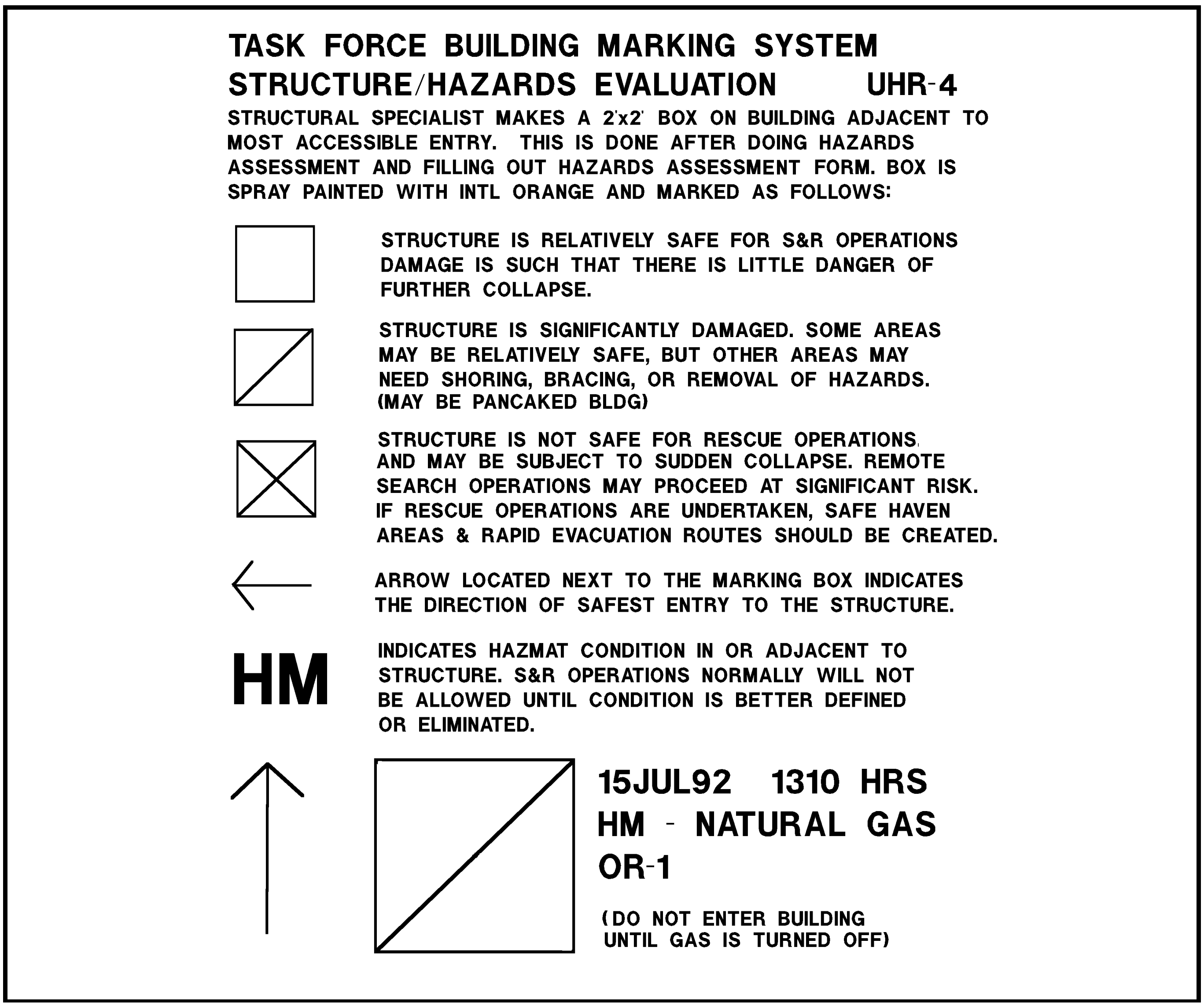
OTHER OPTIONS

- May need to consider other options such as enhancing the TF with additional struct & search support from the Army Corps of Engineers
- Corps has approx.. 100 trained struct spec & 10 unit electronic detection units w/ pairs of operators

## MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
### *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### STRUCTURE/HAZARD EVALUATION & MARKING

- Structural/Hazard Evaluation should take place AFTER a priority list of structures has been established by the leadership, using Triage or just common sense, if only a few structures are involved. The Structure/Hazards Evaluation form has, deliberately, been made different from the ATC-20 "Safety Assessment" placards and forms. It should be assumed the US&R task force will be dealing with buildings that have or would have received a red tag (Using ATC-20). The greatest area of concern is not with the fully collapsed structures, but with those that have partly collapsed. The Search Specialist and Haz Mat Specialist should be prepared to fill out the US&R Structure/Hazard Evaluation Form, identifying structure type, occupancy, hazards, etc. In addition the Search Specialist will generate notes and diagrams regarding search operations (locations of voids, shafts, shoring, etc.). It is anticipated, however, that in some cases the assessment will only indicate that the building is too dangerous to conduct US&R operations.



# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

**<u>STRUCTURE/HAZARD EVALUATION & MARKING</u> (continued)**

- The term safe should be understood by the Structures Specialist in a context very different from that of " **safe for occupancy**". All the structures will be damaged, and the value judgment of "**safe enough for the risks of US&R**" will need to be measured. It is strongly suggested that Structures Specialist works with another person during this phase (just as engineers do in ATC-20 type assessment) for safety reasons as well as being able to have immediate access to second opinions on all critical decisions. The second person would ideally be the other Search Specialist; however, in larger incidents this may be impractical. Each Structures Specialist would, more probably, be paired with a Haz Mat Specialist in order to evaluate all hazards during this evaluation (just as during triage).

- The Structure/Hazard Evaluation Marking is then placed on the building near each entry etc.

**U.S.&R. STRUCTURE/HAZARDS EVALUATION • BY ______**
Where required, circle all the information items that apply
NOTE: AFTERSHOCKS MAY CAUSE ADDITIONAL DAMAGE THAN NOTED

| | |
|---|---|
| STRUCTURE DESCRIPTION<br>BLDG I.D. ______<br>No. Stories No. Basements | MARK ☐ ◫ ☒ DATE/TIME EVALUATE |
| MATERIALS<br>W C S URM PC Other ______ | TYPE OF COLLAPSE<br>PANCAKE SOFT 1ST STORY WALL FAILURE<br>TORSION MIDDLE STORY OVERTURN<br>Other |
| FRAMING SYSTEMS<br>SHEARWALL MOMENT FRAME BRACED FRAME<br>Other | LOCATION OF VOIDS<br>BETWN FLOORS BASEMENT SHAFTS<br>Other |
| OCCUPANCY<br>Hospital Police Sta Fire Sta Emer Op Center<br>Office Bldg School Public Assembly Industrial<br>Hotel Apartment Retail Store Other ______ | DESCRIBE UNSAFE AREAS |
| VICTIM & OTHER INFO | |
| LOCATION OF BEST ACCESS & SAR STRATEGY | DESCRIBE HAZARDS |

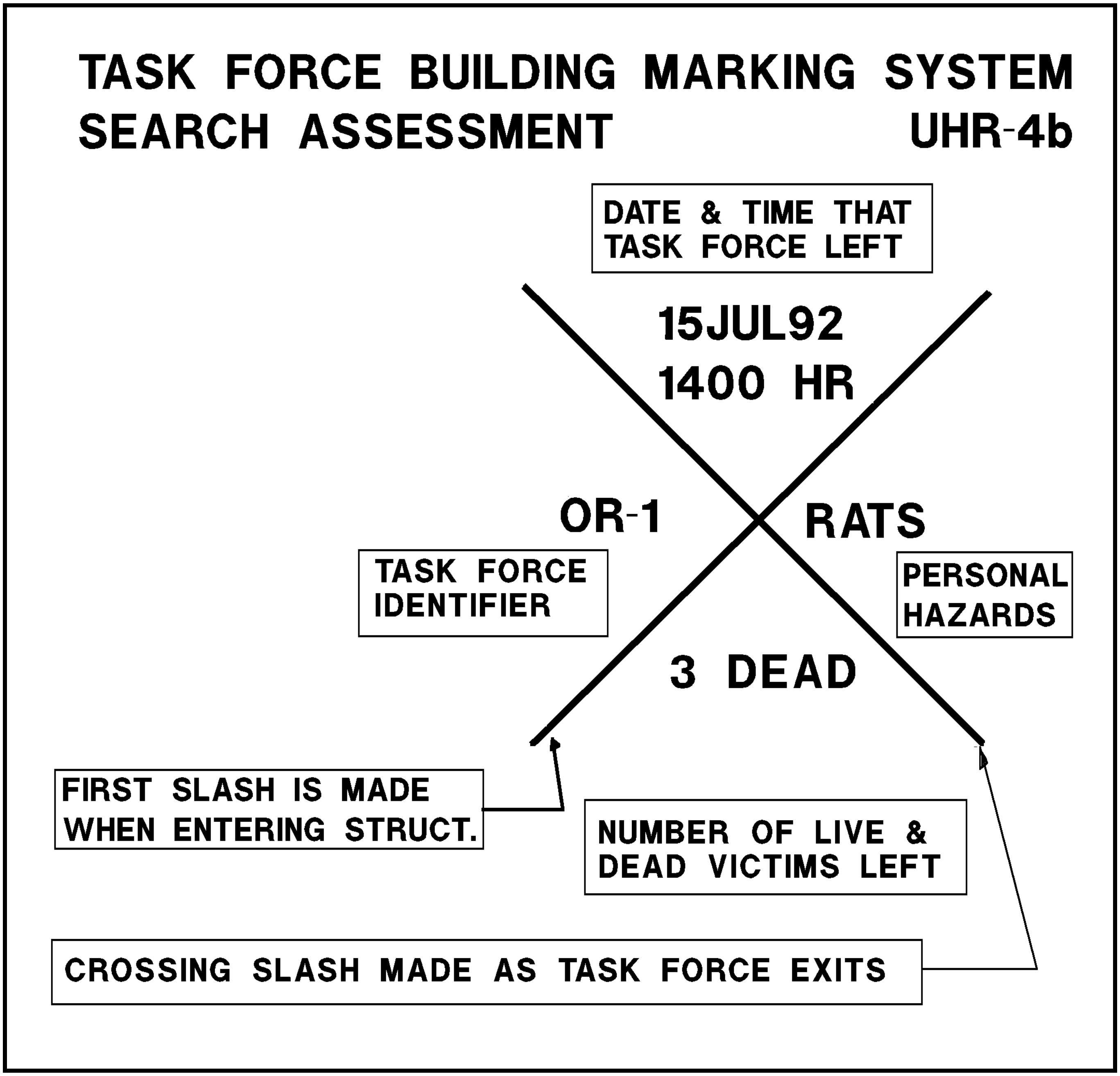
SKETCH

## MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
### *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

**SEARCH & RESCUE ASSESSMENT MARKING**

Standard SAR assessment marking is designed to perform two functions:

- First, when SAR personnel enter the building or parts of the building, the initial diagonal line is drawn so that others will be informed of Aon going operations@.
- When operations are completed in the building (or parts of the building) the crossing diagonal line will be drawn and information added to indicate by whom and what was accomplished.
- The finished mark can then indicate to other SAR forces the outcome of previous operations.

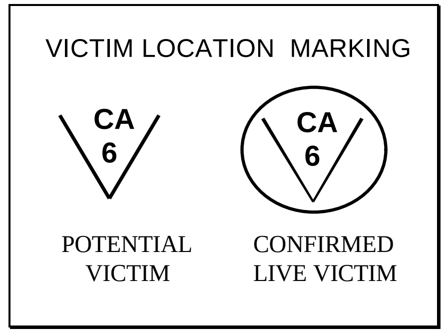


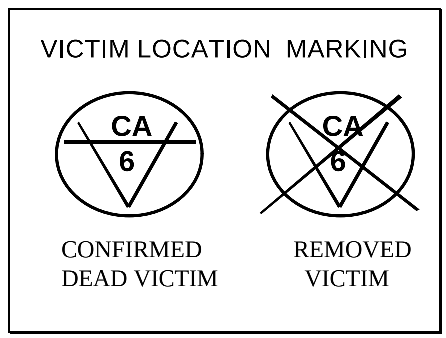
# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### VICTIM MARKING SYSTEM

This series of marks is used to indicate the location of each victim that is discovered on the US&R site.

- The marks are made with orange spray paint or crayon.
- Marks will normally be initiated after Search is performed unless the victim is immediately removed.
- The "**V**" is intended to be about 2 feet high and located as near to the victim as practicable.
- It could be painted on a nearby wall surface or directly on a piece of rubble.
- An arrow may be added to indicate the exact victim location.
- The TF identifier Example "**CA –6**" should be included as shown
- The circle is added when the victim is CONFIRMED.
    - As an example the "**V**" could be placed when only one K9 has indicated that a victim has been located, and the circle could be added when the initial FIND is CONFIRMED by another K9 or some other search tool.
    - It should be noted, however, when K9s are working in pairs, no mark should be made after the first dog indicates a victim because it may influence the second dog.
- A horizontal line is added if the victim is confirmed to be dead.
- An large "**X**" is drawn completely thru the circle after the victim has been removed



# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

## <u>BASIC BUILDING SEARCH & RESCUE PLANS</u>

### BASIC PLAN - FOR INDIVIDUAL BUILDING

- **Reconnoiter Site** collecting as much information as possible
  - Determine structure type - to better assess type of failure, type of hazards, ease of entry and cutting etc.
  - Interview neighbors, survivors, interested people (how many potential victims; where last seen, location of stairs, elevators, basement, etc.).
  - Obtain building plan an/or draw crude plan with special emphasis on probable location of voids, existing shafts, basement.
  - Search Specialists re-assess building in detail to re-identify hazards.

- **Prioritize site** use collected data to obtain best risk/benefit ratio.
  - Conduct callout/listen search.
  - Plan shoring at access, and/or use most efficient access.
  - Determine condition of basement.
  - Avoid falling hazards unless they can be removed and/or shored.

- **Initial Search** **Appendix C, FEMA US&R Response System**, **Search Strategy & Tactics**, addresses this subject. Properly trained search dogs and electronic locators have been used successfully in US&R to locate deeply buried victims. Both have significant limitations, i.e., the dogs must be repeatedly trained in the rubble environment in order to effectively find human scent, not be concerned about their own safety, and to ignore animal, food, and/or sewer gases. Even properly trained dogs may only be able to indicate direction of scent, which is not necessarily the direction of the victim.
- Electronic devices, even when operated by trained personnel, may be only able to detect victims that are very actively sending tapping signals.
  - Use search dogs with "send out" as far as possible into structure. Check alerts with second dog/observer/handler.
  - Use listening/seismic finders if available.
  - Explore existing vertical shaft openings if available.
  - Explore horizontal openings with great care (send dog in and keep people out if practical).
  - In general search from safe, stable areas into unstable.
  - Re-prioritize site vs. location of potential live victims.

**Basic Approach to US&R**

- Identify the Problem
  - Prioritize
- Find Victims
  - Re-prioritize
- Remove Victims
  - Medically stabilize
- Create NO NEW VICTIMS

Basic Building SAR Plan
**(initial phases)**

- Reconnoiter
  - determine structure type
  - obtain / draw plans
  - access hazards
  - interview neighbors, etc.
- Prioritize Site
  - develop hazard mitigation alternatives
  - callout / listen search
  - condition of voids & basement

Basic Building SAR Plan
**(initial phases)**

- Initial Search
  - use K-9 in safe & less safe areas
  - use technical search equip.
  - use existing vertical shaft opngs
  - use existing horizontal opngs with great care
  - search from stable to un-stable
  - re-prioritize vs live finds

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### BASIC PLAN - FOR INDIVIDUAL BUILDING

- **Selected Cutting & Removal** based on priorities of initial search vs. probable hazards.
  - Cut vertical openings and re-search, re-check with dogs and/or listening/viewing devices.
  - Initial shoring for access.
  - Avoid un-shored overhead structures.
  - Recheck all shoring after cutting and removal, loading can change.
  - Continue process of cutting layers, re-searching, and re-prioritizing.
  - Stabilize area at victim to give medical aid.

Basic Building SAR Plan
**(main phase - days long ?)**

- Selected cutting / removal
  - cut vert opngs & re-search
  - initial shoring for access
  - avoid unshored overhead slabs, etc.
  - re-check shoring after cutting & removal
  - continue - cut opng & re-search
  - shore victim area for rescue ops
  - Struc Spec gives continuing aid to rescue

- **Heavy Search & Rescue**
  - Continue search after prolonged cutting and/or removal.
  - Give victim aid and gain information regarding additional victims.
  - Re-check all shoring after cutting and removal, since loading can change

**Quick Review of SAR Plans**

- **Light Frame**
- **Heavy Wall**
  - **URM And TU**
- **Heavy Floor**
  - **Concrete frame**
- **Precast Concrete**
- **Discuss cutting for victim access**

### SAR PLAN - LIGHT FRAME BUILDINGS

- **Search Items**
  - Callout/listen search may be effective due to lower density of wood floors.
  - Acoustic listening devices will probably be more effective than seismic type sensors in these buildings that have wood floors and walls. Broken wood is relatively poor transmitters of vibrations.
  - Dogs may be able to sent through cracks in wood floors if they are not heavily covered.

SAR Plan - Light Frame Bldgs

- Search Items
  - callout/listen search may be effective due to low density of wood floors.
  - acoustic listening devices will probably be more effective than seismic type in buildings with wood floors & walls.
  - K9 should be able to scent thru cracks in wood floors if they are not heavily covered

- **Hazard Reduction Items**
  - Shut off gas (and electricity) and reduce other fire hazards. (**This applies for all types of buildings)**
  - Assess / refer chemical hazards. **(What's in the typical kitchen?)**
  - Remove / avoid or topple leaning chimney
  - Place vertical and / or lateral shores. Leaning multi-story buildings may be shored using diagonal timbers.

SAR Plan - Light Frame Bldgs

- Hazard Reduction Items
  - shut off gas & reduce other fire hazard (all)
  - assess / refer chemical hazards
  - remove / avoid or topple leaning chimney
  - place diagonal shores on leaning multi-story
  - falling hazards - remove / avoid masonry veneer , etc.

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### SAR PLAN - LIGHT FRAME BUILDINGS (continued)

- **Victim Access Items**
  - Use horizontal entry thru cavities or thru walls.
  - Make vertical access thru holes cut in roof / floor
  - Remove / shore hazards as required.

SAR Plan - Light Frame Bldgs

- Victim Access Items
  - use horizontal entry thru cavities or thru walls
  - make vertical access thru hole in roof/floor
  - remove/shore hazards as required

### SAR PLAN - HEAVY WALL BUILDINGS - URM & TU

- **Search Items**
  - Callout / listen search may be effective due to lower density of wood floors.
  - Acoustic listening devices will probably be more effective than seismic type sensors. Most of these structures will have wood floors that have collapsed in large planes and badly broken masonry, both of which are relatively poor transmitters of vibrations.
  - K9 may be able to sent through cracks in wood floors if they are not heavily covered.

SAR Plan - Heavy Wall Bldg

- Search Items
  - callout/listen search may be effective due to low density of wood floors.
  - acoustic listening devices will probably be more effective than seismic type in buildings with wood floors & badly broken masonry walls.
  - K9 should be able to scent thru cracks in wood floors if they are not heavily covered

- **Hazard Reduction Items - URM**
  - Shore hazardous floors with vertical shores.
  - Remaining uncollapsed URM walls are brittle, aftershock / wind falling hazards. Either avoid, remove, tieback, or raker shore them. May need to shore in both IN and OUT direction.
  - Beware of all falling hazards - peeled, cracked, & split URM walls are very brittle. High potential for falling & collapse hazards.

- **Hazard Reduction Items - TU & Low Rise**
  - Use diagonal or raker shores for hazardous walls.
  - Shore hazardous roof / floor beams, etc.

**SAR Plan - Heavy Wall Bldg**

- Hazard reduction items - URM
  - shore hazardous floors
  - remaining, uncollapsed walls may be aftershock falling hazard. either avoid, remove, tieback, or raker shore them. may need to shore both in and out direction.
  - beware of all falling hazards - peeled, cracked, & split urm walls are very brittle. high potential of falling & collapse hazards
- Hazard reduction items - TU & Low Rise
  - raker shore hazardous walls
  - shore hazardous roof/floor beams

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS

*PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

## SAR PLAN - HEAVY WALL BUILDINGS - URM & TU (cont.)

- **Victim Access Items - URM**
  - Use horizontal entry thru existing openings with great care.
  - Vertical access through wood floors should be easy and least dangerous.
  - Avoid cutting large beams and more than two joists in a row.
  - Avoid cutting walls. Holes can greatly reduce strength of poorly cemented walls - most are important bearing walls
  - Beware of roof / floor joist / beams that are not sitting on their original flat bearings or ledges, they can slide down walls and produce outward forces as they move to find next stable position.
  - Basement may provide good access, but should shore for safety. Failure of wood column or beams can be sudden.
  - Hand removal of bricks may be required.
  - Large pieces of wall may be removed by clamshell or other bucket with thumb. ( need to prevent parts from falling)

- **Victim Access Items - TU & Low Rise**
  - Use horizontal entry thru existing openings with great care.
  - Vertical access through wood roof / floors should be easy and least dangerous.
  - Holes in wall panels should best be made 2 ft min away from joints. If wall has concrete pilaster / column, one may cut opening next to column on side away from joint.
  - Wall panels and large pieces of roof may be lifted by crane or other equipment.

SAR Plan - Heavy Wall Bldg

- Victim Access Items URM
  - use horizontal entry thru existing openings
  - make vertical access thru hole in roof/floor, avoid cutting beams & more than 2 joist in a row
  - avoid cutting walls. holes greatly reduce strength of URM walls - are important bearing walls.
  - beware of roof/floor joist & beams that are not resting on their original bearings. they could slide down walls and produce outward forces as they move down.

SAR Plan - Heavy Wall Bldg

- Victim Access Items URM continued
  - basements may provide good access but should shore floor above for safety. failure of wood post or beams could be sudden.
  - hand removal of bricks may be required
  - large wall pieces may need to be removed by crane/clamshell bucket (parts may fall)

SAR Plan - Heavy Wall Bldg

- Victim Access Items TU & Low rise
  - use horizontal entry thru existing openings
  - make vertical access thru hole in roof/floor
  - holes in wall panels should be made away from joints (next to columns O.K..)
  - wall panels and/or large sections of roof/floor can be lifted by crane

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
*PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

## SAR PLAN - CONCRETE FRAME BUILDINGS

- **Search Items - Heavy Floor**

  - Not likely to hear callout of victims through floors due to high density of concrete.

  - Seismic listening devices can be most effective in these, heavy structures, especially when floor slabs remain intact and form thin void spaces as in pancake type collapse.

  - K9 will indicate direction of scent which may be flowing around large slabs, back and forth across the building. (**Location of victim must be interpreted from conditions**) Area should be re-checked by dogs after layers have been removed. Best time to use dogs C in early morning and at dusk C scent is rising.

SAR Plan - Conc Frame Bldg
- Search Items
  - callout/listen search may not be effective due to high density of concrete floors.
  - seismic listening devices can be most effective, especially when large floor slabs remain intact to form thin void spaces in pancake type collapse
  - K9 will indicate direction of scent which may be flowing around large slabs, back and forth across building
    - **location of victim is interpreted by handler. best time for K9 is early a.m. and at dusk**

- **Hazard Reduction Items - Heavy Floor**

  - In partly collapsed building (upper floors, etc.) is very important to check floors that support debris load.
    - read cracks to determine if more and progressive collapse is probable.
    - multi-story shoring may be only safe procedure.
    - it normally takes at least two un-damaged floors to support shores from one damaged floor that contains little debris (if heavy concrete debris from upper floors is present, shores need to extend down to additional, undamaged floors - two more floors per 12" of debris)

  - Shore / avoid badly cracked beams.

  - Shore / avoid hanging slabs / beams.

  - Shore heavily loaded flat slabs (beamless slabs) - punching shear.

  - Beware of all falling hazards - parts of slabs, walls, etc. May be hanging from exposed rebar - how well is rebar embedded?

  - Monitor structure for Lateral Movement with Theodolite or other tilt measuring device

SAR Plan - Conc Frame Bldg
- Hazard reduction items
  - in partly collapsed bldg - very important to check the floor that supports the collapse debris. read cracks to determine if additional collapse is probable. heavy, multi story shoring may be only safe procedure.
  - shore/avoid badly cracked beams/columns
  - shore/avoid hanging slabs/beams
  - shore/avoid heavily loaded slabs (punching)
  - beware of all falling hazards - many parts of concrete slabs, walls, etc. may be hanging from exposed rebar - how well connected

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### SAR PLAN - CONCRETE FRAME BUILDINGS (continued)

- **Victim Access Items - Heavy Floor**
  - Use any existing vertical shaft.
  - Basement may be good access, but need to evaluate floor slab above and possibly shore. How many basement levels?
  - Preferred access is usually made by cutting thru slabs from above collapse.
  - Best to cut slabs mid-way between beams & columns.
  - Check for thinnest slab area. Pan joist and waffle slabs have ribs spaced 3 ft or so with 3 to 4 inch thick slab between.
  - Do not cut columns - usually do not need to.
  - Avoid cutting concrete / masonry walls. They may be bearing walls. If have masonry infill wall in concrete frame cutting is possible - check first to see if frame is loading wall due to collapse.
  - Remove concrete slabs with Crane after all rebar is cut

SAR Plan - Conc Frame Bldg

- Victim Access Items
  - use any existing vertical access shaft
  - basement may be good unobstructed access but must evaluate floor slab above and shore if req'd.
  - preferred access is most often cutting slabs from above collapse.
  - best to cut slabs mid-way between beams and or columns

SAR Plan - Conc Frame Bldg

- Victim Access Items - continued
  - check for thinnest slab areas. (pan joist & waffle slabs may have ribs up to 3 feet apart)
  - do not cut columns - usually do not need to
  - avoid cutting concrete walls - they may be major bearing walls. some frames may have urm infill walls that may be cut - check first as they may be loaded due to collapse.
  - Remove concrete slabs with Crane after all rebar is cut

### SAR PLAN - PRECAST CONCRETE BUILDINGS

- **Search Items - Precast Concrete**
  - Callout / listen search may be effective. It depends on size of voids between larger pieces of concrete.
  - Effectiveness of listening devices will depend on the interconnection of the collapsed, structural parts. Acoustic sensors may not be effective in compact rubble, and seismic sensors may not be effective due to poor transfer through badly broken concrete parts.
  - K9 search may be effective - again depending on compactness of concrete rubble.

SAR Plan - Precast Conc Bldg

- Search Items
  - callout/listen search may be effective - depends on how compact is rubble .
  - effectiveness of listening devices will depend on the interconnection of the collapsed, structural parts - acoustic sensors may not be effective in compact rubble & seismic may not be effective due to poor transfer thru badly broken concrete parts.
  - K9 may be able to scent thru openings in debris, depends on compactness of rubble.

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### SAR PLAN - PRECAST CONCRETE BUILDINGS (continued)

■ **Hazard Reduction Items - Precast Concrete**

- Remove / avoid hanging pieces of structure. There may be many loose or poorly connected pieces of precast concrete. Use cranes and other equipment.
- Shore beams adjacent to badly cracked columns.
- Remove / shore tilted wall panels or pieces.
- Partly collapsed buildings may have adjacent slabs and/or wall panels that have damaged connections that may break loose in aftershocks or if loading shifts.

■ **Victim Access Items - Precast Concrete**

- Cutting of cored slabs & tee slabs should be done at edges (Thru thinnest part of section and away from ribs).
  - cut half of hole in each of two adjacent precast pieces.
- Don't cut ribs in Tees or walls & do not cut columns.
- Walls may be cut with care.
  - cut holes at least 2 ft away from joints.
  - consider problems of shoring vs. removal (removal may be more efficient).
  - check wall welded joints for signs of movement.
  - some walls may be infill URM and may be cut if not loaded by collapsed concrete pieces.
- Basements may not be good access unless basement walls and first floor slab are cast in place concrete. Shoring may be required in any case.
- Use horizontal access thru existing cavities - use great care
- Lift off loose concrete pieces with cranes or other equipment
- Great care must be taken when lifting and/or shoring large concrete pieces, since adjacent pieces may shift.
- Precast concrete will often weigh about 75% of normal (150 PCF) concrete. It also splits more easily.

SAR Plan - Precast Conc Bldg

- Hazard reduction items
  - remove/avoid hanging pieces/structure
  - shore beams adj. to badly cracked columns
  - remove/shore tilted panels or pieces
  - partly collapsed buildings may have adjacent parts (slabs, wall panels, etc.) that have damaged connections that may break in aftershock or if loading shifts.

SAR Plan - Precast Conc Bldg

- Victim Access Items
  - for access thru thin slabs,
    - **make holes at joints (half hole in each adjoining piece)**
    - **avoid cutting ribs in single and double tees.**
    - **do not cut columns**
  - walls may be cut with care.
    - **cut concrete wall panels at least 2 feet away from joint, if possible.**
    - **some walls may be infill URM and may be cut if not being loaded by collapse.**

SAR Plan - Precast Conc Bldg

- Victim Access Items continued
  - basements may not be good access unless basement walls and slab were CIP concrete
  - use horizontal access thru existing cavities.
  - use cranes to remove large disconnected concrete layers.
  - great care must be taken when lifting and/or shoring large concrete pieces, adjacent pieces may shift
  - precast concrete weighs about 3/4 as much as normal concrete. it also splits more easily.

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
***PART 4 - US&R STRATEGY & STRUCTURE SIZEUP***

## METAL DETECTOR

Hand held metal detectors can be used to locate rebar or prestress cables prior to cutting slabs and walls. This can keep from dulling bits and inadvertently cutting cables.

Metallescanner 6.0 by Zircon is magnetic type that is small and can determine location of rebar as much as 4" deep. Cost $100
Other devices are available with costs from $400 to $2000.

Metal Detector
- Needed to keep drill bits from hitting rebar
- Also to find posttensioning
- New device by Zircon Corp 1997
  - Metalliscanner - 6.0 (cost = $100)
  - Available from Tool Crib (800) 358-3096
  - May be sold at Home Depot/Base, etc
  - Micropowered viewer - ?
- More expensive (up to $2000) devices are available

## CUTTING POST TENSIONED CONCRETE

Post-tensioned concrete contains steel cables ( ½" dia.) that are placed in wet concrete after they are enclosed in a long plastic casing (sometimes called sheath or sleeve). When the concrete hardens, the cables are tensioned by pulling them on one or both ends with a hydraulic jack.

Post-tensioning Cables (P.T.) are then anchored in special steel fittings at each edge of the concrete floor, but remain separated from the concrete by the plastic casing. (un-bonded)

- When P.T. cables need to be cut during US&R Ops, special care needs to be taken to deal with the tension force that will be released .(normally 25,000 lb)
- Cables are most often placed in a Draped Configuration within the concrete. The cable is placed near the bottom of slab / beam near mid-span, and near the top where cables pass over supporting columns or beams.
- It is best to use a Torch to cut the P.T. cables, since the tension can be released slowly. A carbide saw could be used to carefully cut the cables, one wire at a time.
- If the cable is not cut slowly so that the force can be gradually released, parts of the cable may violently project out of the concrete structure.
- Depending where the cable is cut it made project above the floor near their supports, below the floor near mid-span, or project out of the end /side of the concrete slab like a large spear
  - Any of these occurrences can severely injure or kill.

- The TF can mitigate this problem by clearing an area that measures, at least, 10 feet either side of the cable for the full length of the slab / beam. In addition the area outside the building should be cleared for 100 feet and/or barricaded to deal with the threat of the cable spear.

Cutting Posttentioned Concrete
- Problem of end of slab Pop-Out
- Problem of mid-slab cable break-out
- PT structures successfully de-constructed
- Locate tendon needed to be cut
  - clear area 10ft ea side of tendon for full length of structure
  - clear 100ft and /or add padding device at ends
- Slabs may have 2 way tendons
- Slow cut w/ torch or carbide saw

# MODULE 1C STRUCTURAL ENGINEERING SYSTEMS
## *PART 4 - US&R STRATEGY & STRUCTURE SIZEUP*

### SUMMARY

We have discussed the topics in the adjacent slide. We should now present a pictorial review of previous incidents to illustrate the US&R strategies that were employed.

SUMMARY

- Phases of Large Disaster
- Initial Stages of TF Deployment
- Basic Building SAR Plan
- SAR Plans
  - Hazard Reduction & Victim Access
- **Now we will present 5 previous incidents - for Lessons Learned**