URBAN SEARCH & RESCUE SHORING (USAR)

PRESENTED BY: WALTER G. M. SCHNEIDER III, PH.D., P.E., CBO
CENTRE REGION CODE ADMINISTRATION
& THE PENNSYLVANIA STATE UNIVERSITY
Structural Assessment

ATC-20 Building Types
- W1 - Dwellings & small wood bldg
- W2 - Wood bldg over 5000sf & 3+ story
- S1 - Steel moment resisting frames
- S2 - Braced steel frames
- S3 - Light metal bldg
- S4 - Steel frames w/ C1P concrete walls
- C1 - Concrete moment resisting frames
- C2 - Concrete shear wall bldg
- C3/S5 - Conc/steel frame w/ um infill walls
- TU/PC1 - Tilt-up concrete wall bldg
- PC2 - Precast concrete frame bldg
- RM - Reinforced masonry bldg
- URM - Unreinforced masonry bldg
- Mobile Homes & Manufactured Units
Why did the Structure Fail

- Earthquake – Motion that accelerates structure
- Wind
- Blast
- Fire
- Structural Overload
- Structural Failure
- Storm Surge
- Vehicle Impact
- Landslide
Earthquake Basics

- Extent of damage is determined by
  - Type of shaking that occurs at site
  - Coupled with the structures response
- Magnitude (energy release)
  - Mag. 8 releases about 30 times as much energy at Mag. 7
  - Determines POTENTIAL number of effected structures
- Aftershocks
  - Earthquakes are unique type of disaster
  - Just keeps on giving
NFPA 1670, 5- Collapse Patterns
Based on WW-2 Aerial Bomb Damage

- Lean-To
- Vee
- A-Frame
- Pancake
- Cantilever
Rapid Structure Triage Process-1

- Done immediately after deployment of US&R Task Force - all structures in assigned area.
  - Rapid assessment w/ scoring system and sketch map of area w/ bldg I.D.
  - TF RST Team(s) would be followed by Search Team(s) within 15-30 minutes
  - Assumes that the local jurisdiction has been so overwhelmed that damaged structures need to be prioritized
RST Team Configuration

- Hazmat Spec (HMS)
- Structures Spec (StS)
- Tech Info Spec (TIS)
- Rescue Team Mgr (RTM)
- Search Team Mgr (STM)
- Others as determined by TFL
RST – Critical Information

Considered to be Risk / Benefit

- **Occupancy** - type of activity and where the most individuals would have been located.
- **Time of day** - when disaster occurred
- **Disaster Type** - possible after-forces & risk of secondary collapse
- **Structure size & type** - potential no. of victims + difficulty of access & hazards
- **Collapse type** - indicates type of voids & potential for victim survival
Rapid Structural Triage Form RST-1

<table>
<thead>
<tr>
<th>Task Force:</th>
<th>Date/Time of Disaster:</th>
<th>See Form RST-2 for Instructions</th>
</tr>
</thead>
<tbody>
<tr>
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**AREA MAP**

<table>
<thead>
<tr>
<th>BLDG ID</th>
<th>FLOOR AREA:</th>
<th>No. OF STORIES:</th>
<th>OCCUPANCY:</th>
<th>MATERIAL: (Circle all that apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td>WOOD</td>
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**CRITERIA for PROBABILITY of Viable Victims** (check one in each line)

<table>
<thead>
<tr>
<th>TYPE:</th>
<th>PROBABILITY</th>
<th>VICTIM ACCESS EFFORT</th>
<th>TYPE OF VOIDS</th>
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<tr>
<td></td>
<td>LOW</td>
<td>MEDIUM</td>
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**CRITERIA for ASSESSMENT of RISK** (check one in each line)

<table>
<thead>
<tr>
<th>CHANCE OF FURTHER COLLAPSE</th>
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<td>POOR</td>
<td>UNKNOWN</td>
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**SLOW-GO** (circle if applies) | FIRE | HAZMAT | OTHER: |

**Notes:**

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**BLDG RATING** (Circle one each line)

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**BLDG RATING** (Circle one each line)
# Rapid Structural Triage Form

**RST-2**

### Instructions for RST Forms

- **Note:** XR is used to indicate High Risk, since HR indicates Human Remains. XP = High Probability
- The purpose of RST-1 & 2 is to aid in rapidly determining Probability of Viable Victims and Relative Risk for numbers of structures.
- The forms would be used when US&R forces need to respond to a large number of damaged structures following a sudden event.
- Each structure is given a Rating for Viable Victim Probability. LP = Low, MP = Medium, and XP = High Probability
  (Note: Input from Search Team Mgr & Rescue Team Lt or Squad Officer should be sought in determining Victim Viability Rating.)
- Each structure is given a Rating for Risk: LR = Low, MR = Medium, and XR = High Risk.
- These ratings should be based on the criteria listed, and more than one structure may have the same rating.
- The ratings should be based on the best judgments of the team, and must be made very rapidly. This form is only a guide.
- Record GPS coordinates in the provided box. Specify format (always check with IST or Plans to determine proper format & datum).
Sides of a Building

- If more than one side, use more letters

700 Block Alpha Street
Further Breakdown of a Building

- Also use and **MARK** column grid

<table>
<thead>
<tr>
<th>Quad. B</th>
<th>Quad. C</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quad. A</td>
<td>Quad. D</td>
<td></td>
</tr>
</tbody>
</table>

700 Block Alpha Street
Column Grid Layout

- Use existing column grid - If Known

700 Block Alpha Street
Floor Designations

- Ground Floor is 1, Second is 2, Third is 3, etc.
- First Floor below grade is B-1, Second is B-2, etc.
Structure / Hazards Mark

- **Low Risk** for US&R Ops, with low probability of further collapse.
  - Victims could be trapped by contents
  - Bldg could be completely pancaked or soft 1st story collapse
  - Bldgs could be up to 2-story wood construction
Medium Risk for US&R Ops, and structure is significantly damaged.
- May need shoring, bracing, removal, and/or monitoring of hazards
- Building could be partly collapsed
Structure / Hazards Mark

- **High Risk** for US&R Ops, and structure may be subject to sudden collapse.
  - Remote search Ops may proceed at significant risk.
  - If US&R Ops are undertaken, significant and time consuming mitigation should be accomplished.
Structure / Hazards Mark

- HM indicates hazardous material condition in or adjacent to structure.
- Arrow next to marking box indicates the direction of safest entry.
No entry until gas is turned off. When it’s mitigated, should line out the HM mark and record new date and TF.
Search Markings

2’ x 2’ “X” near each entry

TF indicator, date & time of entry

Crossing slash is made as TF exits and then other info is added

First slash is made when entering
Search Assessment Mark
Modified Mark for Incomplete Search

If TF exits w/o completing search, crossing slash is not made, but filled circle is added.

Indicates Floors or Quadrants Completed
F = Floors  Q = Quads

If Only an Exterior Search is done as in Hurricanes
Shoring Basics

- Need Posts / Shores with Adjustability & Positive Connections
- Need Lateral Bracing
- Need System with Forgiveness
Weights of Building Materials

- Reinforced concrete = 150 pcf
- Concrete columns & beams weigh more
  (16'sq w/ 5% rebar = 170pcf)
- Masonry = 125 pcf
- Wood = 35 pcf (dry)
- Steel = 490 pcf
- Concrete or masonry rubble = 10 psf per inch
Weights of Building Construction

- **Concrete floors** = 90 to 150 psf
  - Light weight concrete is about 80%
- **Steel systems w/ conc fill slabs** = 50 to 70 psf
- **Wood floor** = 10 to 25 psf
  - (post 1960 wood floors may have concrete fill)
- **Add 10 to 15 psf for wood/metal interior walls**
  - each floor
- **Add 10 psf or more each floor or furniture etc.**
  - More for storage
- **Add 10 psf or more for Rescuers**
Basic Shoring Assumptions

- For Existing, "Sound" Buildings - Only
  - Wood Building: one undamaged floor can support one damaged floor
  - Steel Building: 2 undamaged for 1 damaged
  - Reinforced Concrete: 3 for 1
  - Precast Concrete: start at ground

- Assumptions
  - "Normal" loading - no heavy debris, etc
  - Not for buildings under construction
    - See Manual & Input from StS
  - Not for any buildings that collapse unexpectedly - w/o Quake, Blast, etc
Shoring in Multi-story Structures

- **Sequence for multi-story Shoring – Where do you start?**
  - Start directly under lowest "Damaged" or "Overloaded" Floor in order to share the load
  - Keep shoring in all stories vertically aligned

- **Other Strategies**
  - Shore from Outside - In
  - Shore for Team Access & Egress
  - Phased approach – see next slide
    - Spot shore - Class 1
    - 2 Dimensional - Class 2
    - 3 Dimensional - Class 3
Shoring Selection Considerations

- Condition of damaged floor/wall
  - Solid with cracks
  - Badly cracked concrete or masonry
  - Wood joist - Wood truss
  - Steel beam - Steel bar joist
  - PC Concrete - T, Dbl T, I-Beam, Slab (hollow sections)
Shoring Selection Considerations

- Condition of supporting surface
  - Solid ground - slab on ground
  - Rubble covered ground or slab
  - Undamaged floors in multi-story bldg
  - Basement - but now many floors below
- Availability of shoring materials & local contractors
Shoring Selection Considerations

- Damaged buildings often contain vertical as well as lateral instabilities.
- Uncollapsed building have been 10% out of plumb in one story (requires lateral shoring to support 10% of total weight of building + aftershock)
  - StS needs to design
Example of wood joint with good performance
Vertical Shoring Systems

- Wood Posts
- Ellis Clamps & Jacks
- T-Spot Shore
- Window / Door
- Laced Posts
- Ply Laced Posts

- Cribbing
- Steel Pipe
- Metal Frames & Joist
- Pneumatic Shores
- Shores for Sloped Surfaces
## Vertical Wood Shores

### 4x4 Post System with 4x4 Sole

<table>
<thead>
<tr>
<th>Height (ft)</th>
<th>Design Load (lbs)</th>
<th>Header Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>8'-0&quot;</td>
<td>8,000#</td>
<td>Use 4x4 min. if posts are placed directly under floor beams or when supporting intact/rigid concrete slab or beam. See Structures Spec for other conditions</td>
</tr>
<tr>
<td>10'-0&quot;</td>
<td>5,000#</td>
<td></td>
</tr>
<tr>
<td>12'-0&quot;</td>
<td>3,500#</td>
<td></td>
</tr>
</tbody>
</table>

* = based on 660 psi cross-grain bearing
### Vertical Wood Shores

**6x6 Post System with 6x6 Sole**

<table>
<thead>
<tr>
<th>$H =$ Height</th>
<th><strong>Design Load</strong> Each Post</th>
<th><strong>Header Size</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>12'-0''</td>
<td>20,000# *</td>
<td>Use 6x6 min. if posts are placed directly under floor beams or when supporting intact/rigid concrete slab or beam.</td>
</tr>
<tr>
<td>14'-0''</td>
<td>14,500#</td>
<td></td>
</tr>
<tr>
<td>16'-0''</td>
<td>12,000#</td>
<td></td>
</tr>
<tr>
<td>18'-0''</td>
<td>9,000#</td>
<td><strong>See Structures Spec for other conditions.</strong></td>
</tr>
<tr>
<td>20'-0''</td>
<td>7,500#</td>
<td></td>
</tr>
</tbody>
</table>

* = based on 660 psi cross-grain bearing
Assumptions - Vertical Shore

- Configurations show Post Design Load for given heights
- The 4x4 and 6x6 Header Size assumes:
  - Posts are 4 ft max o.c.
  - Post are aligned with floor beams
  - Or that supported concrete is rigid enough to span between posts
  - If not the case - StS must design header
- Max. slope of floor/header is 5% (6" in 10')
2 Post Vertical Shore

Built during training
(Diagonals may be in any configuration, K or parallel)
Wood Cribbing – Class 1?

- Capacity based on cross-grain bearing area of system
- Allow stress varies from 200 to 1000psi for wood species
- For 2 member x 2 member crib 4x4 Design Load = 24,000# (500psi) 6x6 Design Load = 60,000#
- Limit Height to Width to 3 to 1*
  - See recommended height limit below
- Stability and Deflection Issues
  - Crib can crush as much as 20%
  - *Recommended to Limit Ht to 4 ft for 4x lumber & 6 ft for 6x
  - Overlap corners 4" minimum
4x4 Cribbing w/ 4 Bearings

6000# each contact

Load on all corners
Most Stable - Ht to W = 3 to 1 max

6000# each contact

Poor choice since loading is non-uniform
Keep Ht to W within 1 1/2 to 1
Cribbing Limitations

Current Recommendation is to limit height of 6x cribbing to 6 ft due to stability concerns.
4x4 Wood Box Crib Test

Load = 17k Slab + 25k Blocks
Total Load = 42k = 870psi
Deflection = 6" (24k Design)
Pipe Shores – Class 1

- Not in US&R Equipment Cache
- Rent from Concrete Service Co.
- Design Load based on diameter & length of shore
  - 2" dia. pipe x 10-0 = 6,000#
  - 1 1/2" dia. x 7-0 = 6,000#
- Design Capacity of system using wood header and sole may depend on base plate area
Ellis Shores - 4x4 Adjustable

- Need 2 Ellis Clamps to make a pair of 4x4 into Adjustable 4x4 shore
- Need Ellis Jack
- Failure Mode is by clamp crushing the side grain of the post - Gives Warning
- Design Load = 6000 lb
- Not in current cache
Screw Jack by Ellis

- Adjustable metal foot for 4x4 and 6x6 wood posts
- 6 inch adjustment - set half way to get 3 in. up & down
- Metal Foot is stronger than wood post
- Use sole to spread load
Lateral Shoring Systems

- Horizontal Shores
- Trench Shores
- Raker Shores
- Tiebacks
Fundamental Resource

U.S. Army Corps of Engineers
Urban Search and Rescue Program

Urban Search & Rescue
Structures Specialist

FIELD OPERATIONS GUIDE

7th Edition
August 2012

U.S. Army Corps of Engineers
Urban Search and Rescue Program

Urban Search & Rescue

SHORING OPERATIONS GUIDE

3rd Edition
July 2012
WTC Garage 93
Lift & Drop Collapse
Example of the Unbraced Columns

Steel Tube Diagonals were welded-in to provide bracing
Column E-12
Adequately shored on Day 2, 20Apr95 by local contractor
Boldt Construction
Theodolite in North Parking Lot for East Tower
One also located East of bldg to check Wall Line E
Note trussing of 4” pipes to provide N-S brace
6” pipe on 30deg angle to provide E-W brace
Bracing at 3rd floor
Column F-22

Due to debris can’t complete 2nd floor yet

Note cable tieback due to original, inadequate tightening of drill-in anchors
Braces & Cables were Anchored to Line E (mostly undamaged)
The 30 deg, braces from Line F at 2nd & 3rd
Were both anchored at Line E, 2nd floor
Angles were added so drill-ins could act in shear
Cols F-20 & 22

Steel sleeves from 3/8” plate & angles were placed at 3rd fl. Then filled w/ fast set grout.

Also pipe braces were tied into the sleeves & new collars to more positively attach to column.
Cols F-18, 20 & 22

Smart Levels were then placed to monitor column rotation (buckling mode) between 2nd & 3rd floors.

Used binoculars from the safer area near Line E.
Column F-14

Showing how beam has dropped 3ft.

Wood Shoring supports Vertical Load & Cable

Tieback holds it from moving North when debris are removed to access Victim
Questions?

- wgs101@psu.edu
- 814-280-1390