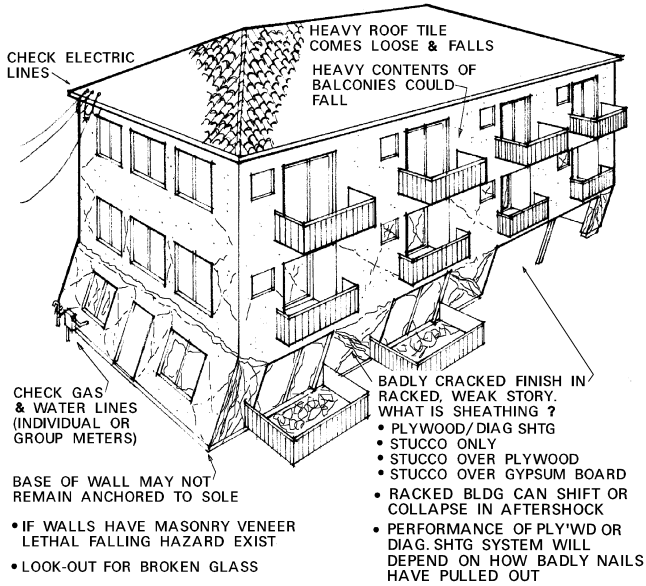
MULTI-STORY LIGHT FRAME BUILDING - HAZARDS



CHARACTERISTICS

- Mostly wood frame, box type – up to 4 stories.
- Residential or Light Commercial.

KEY PERFORMANCE ASPECTS

- Many walls create redundant structures w/ductile failure modes, dependant on sheathing type.
- Presence of concrete floor fill can enhance possibility of P-delta collapse.

TYPICAL FAILURE MODES

- Failure in Wall Sheathing – Racking of Walls.
- Failure should be slow and noisy.
- Soft/Weak stories can rack and collapse.

COMMON COMBINATIONS

- Many are built over R/C parking garages.

MULTI-STORY LIGHT FRAME BUILDING (continued)

EXPECTED PERFORMANCE – for the following:

- **Progressive Collapse** – Extensive connection failures. Members & components are likely to remain intact.
- **E. Quake** – Generally good performance - common failure is ductile racking of first story. Raked stories are subject to ratcheting and P-delta collapse in Aftershocks.
- **Explosion** – Walls become disconnected from floors (horizontal diaphragms), leading to part or total collapse.
- **Fire** – Rapid combustion and collapse unless fire resistant.
- **High Energy Impact** – Little resistance to collapse in immediate area. Remainder of structure remains stable.
- **Wind** – Damage is highly dependent on wind speed vs. shape and proper detailing. Tornados can destroy even well constructed wood buildings.
- **Struct Overload/Defect** – Roof failures due to snow, especially on longer span roofs.

CHECK POINTS

- Badly cracked and/or leaning walls.
- Leaning first story in multi-story buildings.
- Cracked, leaning/loose veneer or chimney.
- Offset of building from foundation.
- Separated porches, split level floors/roof.
- Connection failures - nail pullout/bolt pull-through.

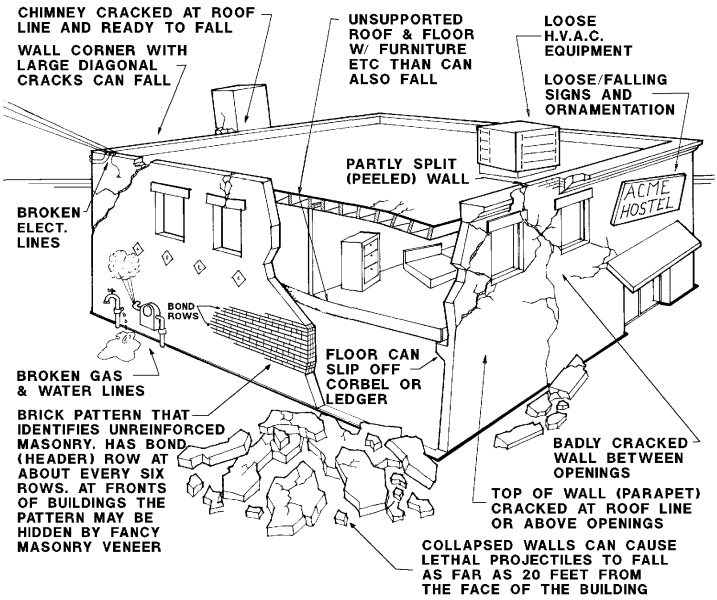
HAZARD REDUCTION

- Shut off gas and reduce other fire hazards.
- Avoid or pull-down damaged veneer and chimneys.
- Place vertical and/or lateral (diagonal) shores.
- Monitor changes in racked/leaning structures.

VICTIM ACCESS

- Vertical access through floor/roof from above collapsed area.
- Horizontal entry through existing cavities, or through walls.
- Remove or shore hazards near victims, if required.

HEAVY WALL- URM BUILDING - HAZARDS



CHARACTERISTICS

- URM Ext walls, wood floors/roof - box type – to 8 stories.
- Lack of wall strap anchors – Red Brick & CMU low-raise.
- Residential, Commercial and Industrial occupancies.

KEY PERFORMANCE ASPECTS

- Walls Brittle with little resistance to unanticipated loads.
- Redundant interior walls may prevent floor collapse.

TYPICAL FAILURE MODES

- Walls separate from roof/floors, leading to falling walls and collapsed roof/floors.
- Cracked/pealed walls create brittle falling hazards.

COMMON COMBINATIONS

- Heavy timber, light frame walls & floors.
- Steel joist floors w/concrete fill in multi-story buildings.

HEAVY WALL- URM BUILDING (continued)

EXPECTED PERFORMANCE – for the following:

- **Progressive Collapse** – URM walls likely to disintegrate, and interior structure may stand independently.
- **E. Quake** - Poor performance - out of plane ext wall failures, loss of connection to floors leading to partial or total collapse. Many lethal Aftershock falling and collapse hazards.
- **Explosion** – Walls become disconnected from floors (horizontal diaphragms), leading to part or total collapse.
- **Fire** – Loss of roof/floors will leave walls unbraced. Collapsing roof/floors can thrust walls in or out.
- **High Energy Impact** – Ext URM walls disintegrate upon impact leaving lethal falling hazards & possible floor collapse. **Massive masonry is more resistant.**
- **Wind** – Roof vulnerable to uplift, leading to partial or total collapse or roof & walls. Massive masonry is more resistant.
- **Struct Overload/Defect** – Roof failures due to ponding and snow. Wood decay, brick disintegration or remodeling in older buildings.

CHECK POINTS

- Loose, broken parapets and ornamentation.
- Connections between exterior walls and roof/floors.
- Cracked wall corners and openings, plus peeled walls.
- Unsupported and partly collapsed roof/floors.

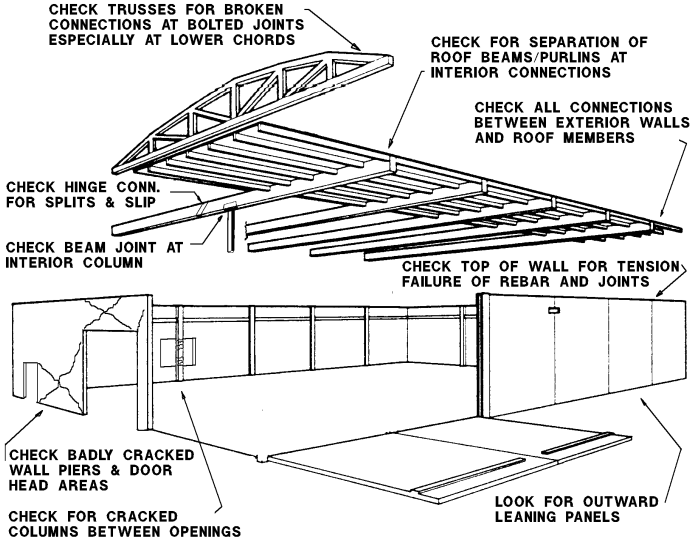
HAZARD REDUCTION

- Shut off gas and reduce other fire hazards.
- Diagonally shore. tie-back, avoid, remove hazardous walls.
- Shore hazardous roof/floor beams, etc.
- Monitor changes in racked/leaning structures.

VICTIM ACCESS

- Vertical access through floor/roof from above collapsed area.
- Horizontal entry through existing cavities and openings.
- Remove bricks by hand, excavator, or crane w/clamshell.
- Remove or shore hazards near victims, if required.

HEAVY WALL- TILT-UP BUILDING - HAZARDS



CHARACTERISTICS

- Conc. ext walls, wood floors/roof, some steel fl w/concrete fill.
- Long span roof (50ft+) and floors (25ft+).
- Similar performance with CIP conc. or reinforced CMU walls.
- Office, Commercial & Lt Industrial occupancies – to 4 stories.

KEY PERFORMANCE ASPECTS

- Robust ext walls, but may have weak connection to roof.
- Post 1995 and retrofit building should perform better.

TYPICAL FAILURE MODES

- Walls separate from roof/floors, leading to falling walls and collapsed roof/floors. Long span collapse is probable.

COMMON COMBINATIONS

- Light frame walls & floors – 1.5″concrete fill on floors.
- Steel joist, long span floors w/concrete fill.

HEAVY WALL- TILT UP BUILDING (continued)

EXPECTED PERFORMANCE – for the following:

- **Progressive Collapse** – Out-leaning wall/walls could progress to roof/floor collapse in bay adjacent to exterior. Remainder could stand independently – but poorly braced.
- **E. Quake** – Pre 1995 - poor performance – out of plane ext wall failures, loss of connection to roofs leading to partial or total collapse. Lethal Aftershock falling and collapse hazards.
- **Explosion** – Walls become disconnected from floors (horizontal diaphragms), leading to part or total collapse
- **Fire** – Loss of roof/floors will leave walls unbraced. Collapsing roof/floors can thrust walls in or out.
- **High Energy Impact** – Impact on exterior walls likely to be localized. Could lead to localized roof/floor collapse.
- **Wind** – Roof vulnerable to uplift, leading to partial or total collapse or roof and walls. Penetration through large doors can lead to critical uplift and blow-out pressures.
- **Struct Overload/Defect** – Roof failures due to ponding and snow. Wood decay in older buildings.

CHECK POINTS

- Connections between exterior walls and roof/floors.
- Beam to beam and other interior roof connections.

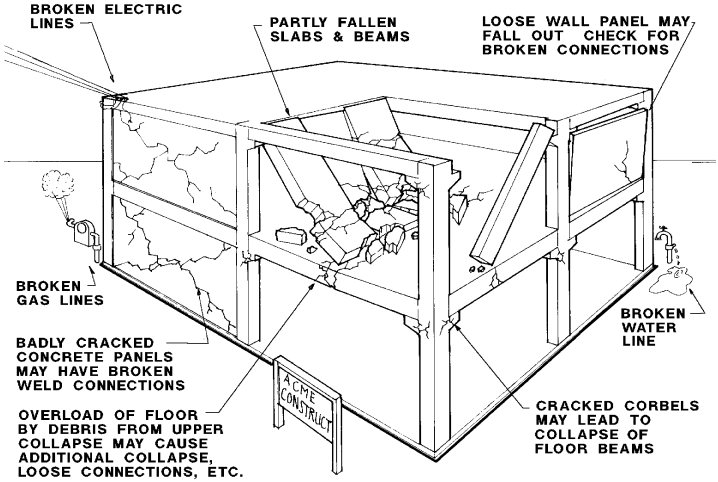
HAZARD REDUCTION

- Diagonal or Raker shore concrete walls.
- Shore hazardous roof/floor beams, etc.
- May pull-down leaning walls after dealing w/roof support.
- Monitor changes in racked/leaning structures.

VICTIM ACCESS

- Vertical access through floor/roof from above collapsed area. Horizontal entry through existing cavities and openings.
- Cut holes in wall panels, 2 feet min. from joints.
- Remove large wall panels and roof sections by crane.

PRECAST BUILDINGS - HAZARDS



AFTERSHOCKS ARE LIKELY TO CAUSE LARGE, LOOSELY CONNECTED CONCRETE PARTS TO SHIFT AND FALL. DEBRIS PILES OF LARGE CONCRETE PARTS CAN ALSO SHIFT AND TRAP RESCUE WORKERS. BE ESPECIALLY CAREFUL OF STANDING STRUCTURES WITH OUT OF PLUMB COLUMNS SINCE ADDITIONAL COLLAPSE IS MORE PROBABLE THAN OTHER TYPES OF STRUCTURES.

CHARACTERISTICS

- Factory built lightweight concrete parts – up to 14 stories.
- Systems w/o interior concrete panels are greatest problem.

KEY PERFORMANCE ASPECTS

- Highly engineered systems, but often brittle connections.
- Little capacity for unanticipated loads.
- Residence type may be highly redundant due to many walls.

TYPICAL FAILURE MODES

- Failure of interconnections between parts leading to partial or total collapse, depending on redundancy.

COMMON COMBINATIONS

- May have CIP floor slabs or reinforced concrete topping.
- Use of Reinforced Masonry shear walls and metal stud walls.
- PC is used as floor panels in masonry & steel buildings.

PRECAST BUILDINGS (continued)

EXPECTED PERFORMANCE – for the following:

- **Progressive Collapse** – Failed single story columns have lead to progressive collapse. Heavy elements vs. brittle connections are critical issues. Members retain strength.
- **E. Quake** – Very poor performance – except for multi-wall residence buildings. Failed connections lead to partial or total collapse. Aftershock falling, shifting and collapse hazards.
- **Explosion** – Poor performance due to weak-link connections leading to part or total collapse.
- **Fire** – Could cause annealing of tendons and prestress loss.
- **High Energy Impact** – Impact on ext elements likely to be localized. Brittle connections could be damaged.
- **Wind** – Unlikely to be damaged by wind. Exterior skin and curtain walls could be damaged/destroyed.
- **Struct Overload/Defect** – Failures in connections, leading to cascading structure failure. Members should retain integrity.

CHECK POINTS

- Beam/column connections, broken welds and cracked corbels.
- Column cracking at top, bottom and wall joints.
- Wall connections at floors, columns and foundation.
- Badly cracked walls and columns plus falling hazards.

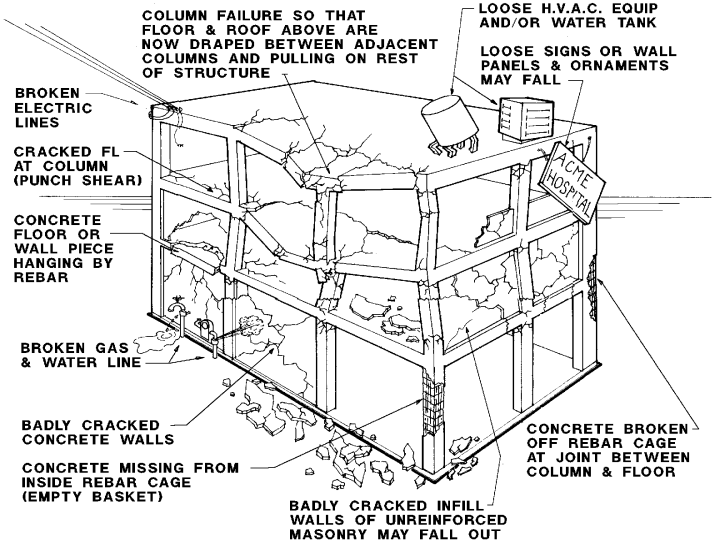
HAZARD REDUCTION

- Remove/avoid leaning/hanging, concrete elements.
- Shore damaged roof/floor beams, especially next to bad columns.
- Remove/shore unstable wall and floor elements.
- Monitor changes in racked/leaning structures.

VICTIM ACCESS

- Vertical access through thin horizontal sections from above.
- Horizontal entry through existing cavities and openings.
- Cut holes in wall panels, 2 feet min. from joints.
- Carefully remove large wall/floor sections by crane.

HEAVY FLOOR BLDGS (CIP non-DUCTILE) - HAZARDS



CHARACTERISTICS

- Cast in Place (CIP) concrete frames and highway structures, – up to 12 stories.
- Few concrete walls, but URM infill in older buildings.
- Eastern US – (Western pre 1975) Office & Commercial.

KEY PERFORMANCE ASPECTS

- Brittle failure modes when loaded beyond capacity.
- Post 1975 Ductile Frames in western US have systems that can absorb considerable energy w/o loss of integrity.

TYPICAL FAILURE MODES

- Beam-column joint failure or column shear leading to partial or total collapse.
- Collapse can be partial or complete pancake.

COMMON COMBINATIONS

- May have URM and/or metal stud wall partitions.

HEAVY FLOOR BLDGS (CIP non-DUCTILE) (continued)

EXPECTED PERFORMANCE – for the following:

- **Progressive Collapse** – Members likely to break into smaller pieces. Rubble piles may shift.
- **E. Quake** – Very poor performance – Brittle failures of columns and beam/column connections, leading to partial or pancake collapse. Aftershocks cause added collapse, falling hazards and shifting.
- **Explosion** – Poor slab performance due to reverse gravity loading can lead to loss of column stability and collapse.
- **Fire** – May cause spalling of concrete cover on all elements.
- **High Energy Impact** – Damage limited to area of impact. Could leave damaged members of questionable strength.
- **Wind** – Unlikely to be damaged by wind. Exterior skin and curtain walls could be damaged/destroyed.
- **Struct Overload/Defect** –Construction falsework failures most common. Members break into pieces w/poor integrity.

CHECK POINTS

- Beam/column connections above and below floors.
- Badly confined concrete in columns (empty basket).
- Diag. shear cracks in beams and cracking in slabs near cols.
- Attachment of URM walls and other heavy objects.
- Cracks in concrete shear walls and stairs.

HAZARD REDUCTION

- Shore/avoid badly cracked slabs, beams and/or column.
- Shore/avoid overloaded slabs due to punching shear.
- Remove/shore unstable wall and floor elements.
- Monitor changes in racked/leaning structures.

VICTIM ACCESS

- Vertical access through existing access shafts.
- Vertical access by cutting through slabs from above victims.
- Horizontal entry through existing cavities and openings.
- Cut non-bearing/infill walls after careful assessment.
- Remove large pieces by crane, after rebar has been cut.

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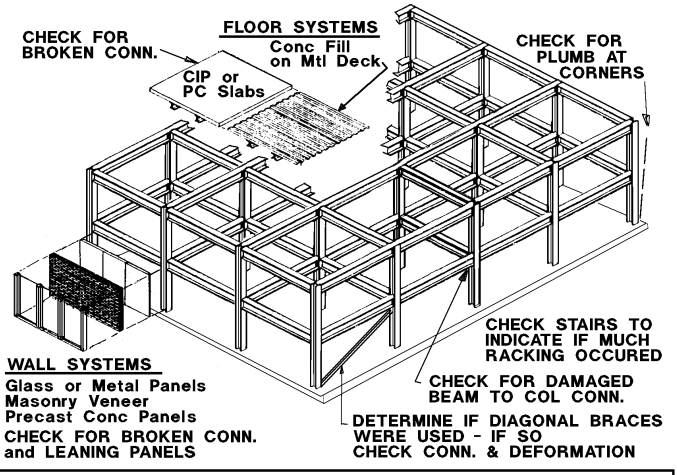
HEAVY STEEL FRAME BUILDING - HAZARDS



SINCE MOST MEMBERS AND CONNECTIONS ARE HIDDEN, BEST INDICATION OF FAILURE IS EXCESS MOVEMENT CAUSING DAMAGE TO NON-STRUCTURAL ELEMENTS AND OUT OF PLUMB CONDIDTIONS

CHARACTERISTICS

- Heavy "W" steel beam & column framing – 2 to many stories.
- Office and Commercial Occupancies, some industrial.

KEY PERFORMANCE ASPECTS

- Normally well engineered, but performance is dependent on ductility of connections. PC floor systems as suspect.
- Welded connections may be subject to brittle failure.
- Diagonally braced frames may have buckled cols or braces.

TYPICAL FAILURE MODES

- Connection failure leading to partial collapse. Total collapse is extremely rare.

COMMON COMBINATIONS

- May have masonry, precast or metal panel exterior walls.
- CIP floors over metal deck, or PC/CIP directly on steel.

HEAVY STEEL FRAME (continued)

EXPECTED PERFORMANCE – for the following:

- **Progressive Collapse** – Rare, since members maintain integrity even with damaged/failed joints.
- **E. Quake** - Good performance of frame - Failure of diagonal bracing and fracture of welded joints have occurred. Facing, especially PC panels could fall and are danger in Aftershocks.
- **Explosion** – Good performance of frame but wall & floor panels could be dislodged. Frame collapse is unlikely.
- **Fire** – Plastic deformation of floors and some joint failure. Strength is regained upon cooling. Collapse very rare.
- **High Energy Impact** – Impacted members are severed/destroyed. Connection failures near impact only.
- **Wind** – Frame at low risk – Skin, especially glass may be destroyed leading to interior partition failure.
- **Struct Overload/Defect** – Failures during erection and long-span failures are most common. Members maintain integrity with failures at joints.

CHECK POINTS

- Indications of movement – plumb corners, stair and non-structural damage – as clues to potential structure damage.
- Main beam to column connections – remove finishes as required.
- Broken PC floor and miscellaneous beam bolt connections.

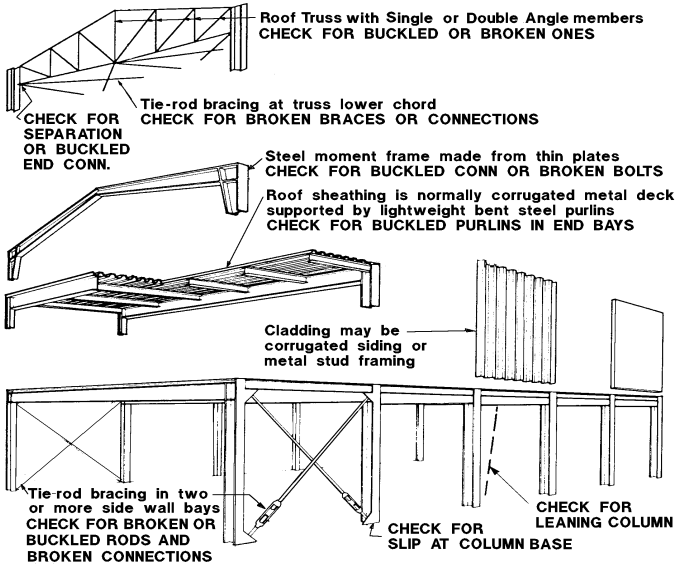
HAZARD REDUCTION

- Shore beams near damaged or broken connections.
- Remove/avoid/tieback damaged exterior facing.
- Monitor changes in racked/leaning structures.

VICTIM ACCESS

- Vertical access by cutting through slabs from above victims.
- Horizontal entry through existing cavities & openings.
- Remove or shore hazards near victims, if required.

LIGHT METAL BUILDING – HAZARDS



CHARACTERISTICS

- Light-gage steel, pre-fab metal buildings – up to 3 stories.
- Industrial and Commercial Occupancies – most 1 story.

KEY PERFORMANCE ASPECTS

- Highly engineered with little redundancy or over-strength.
- Very flexible, especially in lateral direction.

TYPICAL FAILURE MODES

- Weakest Link Behavior – loss of sheathing allows buckling, leading to collapse of supporting structure.
- Diagonal rod bracing elongation & joint failure.

COMMON COMBINATIONS

- May have masonry, precast or tilt-up exterior walls.
- May have wood or metal interior partitions and mezzanine.

LIGHT METAL BLDGS (continued)

EXPECTED PERFORMANCE – for the following:

- **Progressive Collapse** – Joint failure and member buckling could lead to part or complete collapse.
- **E. Quake** – Good performance – Failure of rod bracing is common, but collapse is rare. Minor aftershock response.
- **Explosion** – Skin blown away, possibly leading to frame/roof collapse. Entire building blown away in some cases.
- **Fire** – Rapid loss of strength and collapse due to heating. Long span structure could suddenly collapse.
- **High Energy Impact** – Little resistance to impact. Damage may involve several bays of structure.
- **Wind** – At high risk – as skin is blown away, frames/trusses can buckle and collapse. Frames can rack and collapse.
- **Struct Overload/Defect** – Lateral torsion buckling of built-up members. Joint failure and member buckling, leading to part or complete collapse.

CHECK POINTS

- Broken, elongated and/or buckled rod bracing & connections.
- Buckled purlins, truss members, and steel frames.
- Broken and/or elongated bolt connections + anchor bolts.

HAZARD REDUCTION

- Shore and/or diagonally brace racked building frames.
- Remove loose or lightly connected members and sheathing.
- Monitor changes in racked/leaning structures.

VICTIM ACCESS

- Vertical/Horizontal access by removal or cutting sheathing.
- Horizontal entry through existing cavities and openings.
- Remove or shore hazards near victims, if required.