BUILDING DESIGN GUIDANCE AND SAFETY PLANS 3

This chapter addresses explosive blast and CBR concerns from terrorist attacks, highlighting mitigation measures, including architectural, structural, and building envelope systems, and school safety plans. After the site design considerations to enhance protection presented in Chapter 2 have been taken into account, additional building design measures, such as hardening and CBR mitigation measures, must be considered to protect school occupants. Historically, the majority of fatalities that occur in terrorist attacks directed against buildings are due to building collapse. This was true for the Oklahoma City bombing in 1995 when 87 percent of the building occupants who were killed were in the collapsed portion of the Murrah Federal Building.

When considering mitigation measures for explosive blast threats, the primary strategy is to keep explosive devices as far away from the school building as possible (maximize stand-off distance). This is usually the easiest and least costly way to achieve a desired level of protection. In cases where sufficient stand-off distance is not available to protect against progressive collapse of a school building (i.e., schools located in urban settings), hardening of the building's structural systems may be required. Designers should try to minimize hazardous flying debris during an explosive event because a high number of injuries can result from flying glass fragments and debris from walls, ceilings, and non-structural features. Another consideration is to balance the hardening of the building envelope so that the columns, walls, windows, and glazing have approximately equal response for damage and injury/casualty for the design basis threat weapon at the available stand-off distance. Window design is the element that is usually the most diverse in conventional construction. Good blast engineering is a multi-disciplinary effort that requires the concerted efforts of the architect, structural engineer, mechanical engineer, and the other design team members in order to achieve a balanced building envelope.

When considering mitigation measures for CBR hazards, heating, ventilation, and air conditioning (HVAC) systems are of particular concern. A school building can provide protection against CBR agents released outdoors if the flow of fresh air is filtered or interrupted; however, HVAC systems can also become an entry point and distribution system for hazardous contaminants. If installed, HVAC air filtration and air-cleaning systems can reduce the effects of a CBR agent by removing the contaminants from the air within a building. There are a variety of ways to protect school building occupants from airborne hazards. These protective measures can be as simple as defining a protective action plan or as complex as strict design measures practical only for new construction. Specific HVAC design measures will be discussed in this chapter. In addition, Chapter 5 contains a discussion of CBR protective actions.

School building design should be optimized to facilitate emergency evacuation, rescue, and recovery efforts through effective placement, structural design, and redundancy of emergency exits and critical mechanical/electrical systems. Through effective structural design, the overall damage levels may be reduced to make it easier for people to get out safely and allow emergency responders to enter safely. The designer must also balance measures to protect people with the requirements of the Americans with Disabilities Act Accessibility Guidelines (ADAAG), Uniform Federal Accessibility Standards (UFAS), National Fire Protection Codes (NFPC), and all applicable local building codes. Additional information is available in FEMA 426, *Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings,* and FEMA 427, *Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks.*

3.1 ARCHITECTURAL

Several architectural considerations can be implemented to mitigate the effects of a terrorist bombing on a school facility. These considerations often cost nothing or very little if implemented early in the design process.

The shape of the school building can contribute to the overall damage to the structure. For example, "U" or "L" shaped buildings tend to trap shock waves, which may exacerbate the effect of explosive blasts. For this reason, it is recommended that re-entrant corners be avoided (see Figure 3-1). In general, convex rather than concave shapes are preferred when designing the exterior of a school building. Other considerations follow:

- Orient school buildings horizontally rather than vertically to reduce the building's profile and exposure.
- Elevate the ground floors of school buildings above grade to prevent vehicles from being driven into the facility.
- Avoid eaves and overhangs, because they can be points of high local pressure and suction during blasts. When these elements are used, they should be designed to withstand blast effects.
- Locate utility systems away from likely areas of potential attack, such as loading docks, lobbies, and parking areas.
- Orient glazing perpendicular to the primary facade to reduce exposure to blast and projectiles (see Figure 3-2).
- Avoid having exposed structural elements (e.g., columns) on the exterior of the school.

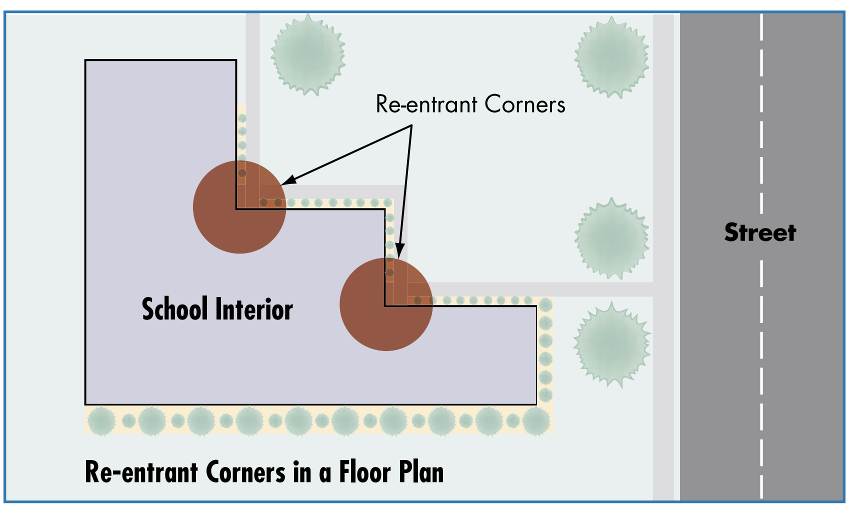


Figure 3-1 Re-entrant corners in a floor plan

SOURCE: U.S. AIR FORCE, *INSTALLATION FORCE PROTECTION GUIDE*

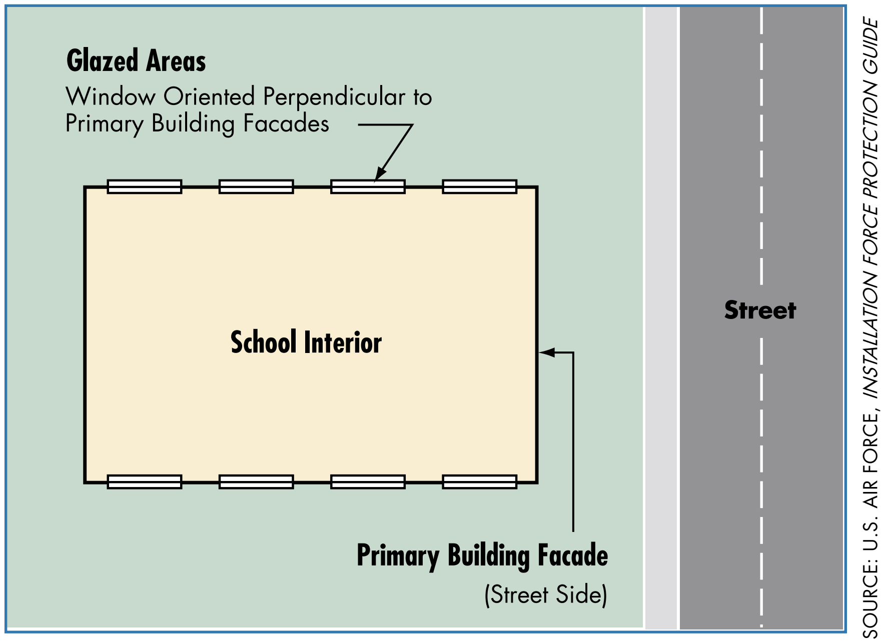
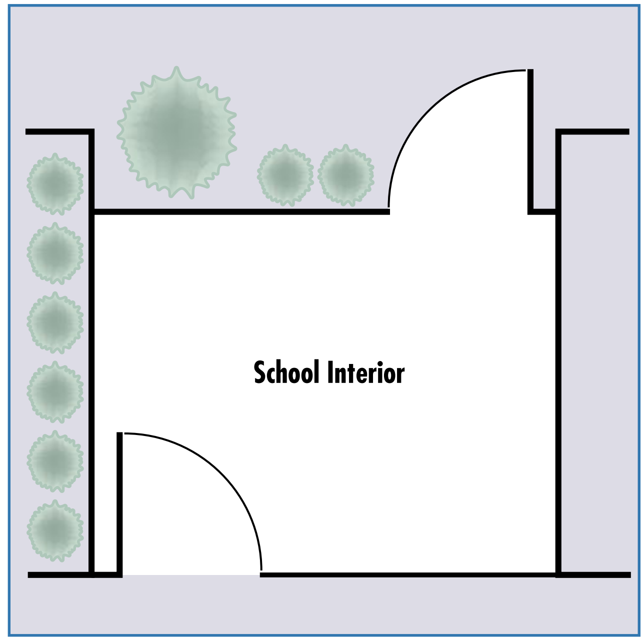


Figure 3-2 Glazed areas oriented perpendicularly away from streets

- Connect interior non-load bearing walls to the structure with flexible connections.
- Place areas of high visitor activity away from key assets.
- Eliminate hiding places within the school building.
- Locate assets in areas where they are visible to more than one person.
- Use interior barriers to differentiate levels of security within a school building.
- Stagger doors located across from one another in interior hallways to limit the effects of a blast through the school structure (see Figure 3-3).
- Provide foyers with reinforced concrete walls, and offset interior and exterior doors from each other in the foyer.
- Locate stairwells required for emergency as remotely as possible from areas where blast events might occur.

- Wherever possible, do not discharge stairs into lobbies, parking, or loading areas.
- Separate unsecured areas of the main school building as much as possible. For example, a separate lobby pavilion or loading dock area outside of the main footprint of the building provides enhanced protection against damages and potential building collapse in the event of an explosion. This can also be done by creating internal "hard lines" or buffer zones, using secondary stairwells, elevator shafts, corridors, and storage areas between public and secured areas.



SOURCE: U.S. AIR FORCE, *INSTALLATION FORCE PROTECTION GUIDE*

Figure 3-3 Offset doors through the foyer

- Place parking areas outside the main footprint of the school building to reduce the vulnerability to catastrophic collapse.

3.2 BUILDING STRUCTURAL AND NON-STRUCTURAL SYSTEMS

For schools that require high security measures, explosive blast threats may govern building design. A structural engineer should determine the school design features needed to achieve the desired level of protection against the design blast threat, considering both the collapse of the school building as well as incipient injuries and fatalities of students, faculty, and staff.

Progressive collapse is a situation where local failure of a primary structural component leads to the collapse of adjoining members which, in turn, leads to additional collapse. Hence the total damage is disproportionate to the original cause. Progressive collapse is a chain reaction of structural failures that follows from damage to a relatively small portion of a structure.

All new school buildings should be designed with the intent of reducing the potential for progressive collapse as a result of an abnormal loading event, regardless of the required level of protection. The following structural characteristics (from GSA *Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization* Projects, November 2000) should be considered in the initial phases of structural design. Incorporation of these features will provide a much more robust structure and decrease the potential for progressive collapse.

- **Redundancy.** The use of redundant lateral and vertical force resisting systems is highly encouraged when considering progressive collapse. Redundancy tends to promote a more robust structure and helps to ensure that alternate load paths are available in the case of a structural element(s) failure. Additionally, redundancy provides multiple locations for yielding to occur, which increases the probability that damage will be constrained.

- **The use of ductile (flexible) structural elements and detailing.** It is critical that both the primary and secondary structural elements be capable of deforming well beyond the elastic limit without experiencing structural collapse. Hence, the use of ductile construction materials (i.e., steel, cast-in-place reinforced concrete, etc.) for both the structural elements and connection detailing is encouraged. The capability of achieving a ductile response is imperative when considering an extreme redistribution of loading such as that encountered in a structural element(s) failure.

- **Capacity for resisting load reversals.** Both the primary and secondary structural elements should be designed to resist load reversals in the case of a structural element(s) failure.

- **Capacity for resisting shear failure.** Primary structural elements maintain sufficient strength and ductility under an abnormal loading event to preclude a shear failure. If the shear capacity is reached before flexural capacity, a sudden, non-ductile failure of the element could potentially lead to a progressive collapse of the structure.

Both the GSA and DoD take a threat-independent approach to progressive collapse. The goal of a threat-independent approach is not to prevent collapse from a specific design threat, but to control and stop the continuing spread of damage after localized damage or localized collapse has occurred.

The GSA and DoD require that the structural response of a building be analyzed in a test that removes a key structural element (e.g., vertical load carrying column, section of bearing wall, beam, etc.) to simulate local damage from an explosion. If effective alternative load paths are available for redistributing the loads, originally supported by the removed structural element, the building has a low potential for progressive collapse.

For higher levels of protection from blast, cast-in-place reinforced concrete is normally the construction type of choice. Other types of construction such as properly designed and detailed steel structures are also allowed. Several material and construction types, although not disallowed by these criteria, may be undesirable and uneconomical for protection from blast.

The following guidelines are commonly used to mitigate the effects of blast on structures and to mitigate the potential for progressive collapse. See sidebar for details and more guidance.

❍ Use multiple barrier materials and construction techniques to mitigate the effects of blast on a structure at less expense than a single material or technique.

The following additional references are recommended:

- Biggs, John M. Introduction to Structural Dynamics. McGraw-Hill. (1964).
- The Institute of Structural Engineers. The Structural Engineer's Response to Explosive Damage. SETO, Ltd., 11 Upper Belgrave Street, London SW1X8BH. (1995).
- Mays, G.S. and Smith, P.D. Blast Effects on Buildings: Design of Buildings to Optimize Resistance to Blast Loading. Thomas Telford Publications, 1 Heron Quay, London E14 4JD. (1995).
- National Research Council. Protecting Buildings from Bomb Damage. National Academy Press. (1995).

- Incorporate internal damping into the structural system to absorb blast impact.
- Use symmetric reinforcement to increase the ultimate load capacity of the structure.
- Incorporate design redundancy and alternative load paths to help mitigate blasts and reduce the chance of progressive collapse. The Murrah Federal Building's structural system did not have any redundancy for the slab and beam systems.
- Strengthen the structural system to help resist the effects of a blast.
- Incorporate inelastic or post elastic design to allow the structure to absorb the energy of the explosion through plastic deformation.
- Recognize that components might act in directions for which they were not designed. This is due to the engulfment of structural members by blast, the negative phase, the upward loading of elements, and dynamic rebound of members. Making steel reinforcement (positive and negative faces) symmetric in all floor slabs, roof slabs, walls, beams, and girders will address this issue. Symmetric reinforcement also increases the ultimate load capacity of the members.
- Ensure that lap splices fully develop the capacity of the reinforcement.
- Stagger lap splices and other discontinuities.
- Control deflections around certain members, such as windows, to prevent premature failure. Additional reinforcement is generally required.
- Use wire mesh in plaster to reduce the incidence of flying fragments.
- Avoid the use of masonry when blast is a threat. Masonry walls break up readily and become secondary fragments during blasts.

- Use ductile connections for steel construction and develop as much moment connection as practical. Connections for cladding and exterior walls to steel frames should develop the capacity of the wall system under blast loads.
- Avoid single-point failures that can cascade, producing widespread catastrophic collapse. A prime example is the use of transfer beams and girders that, if lost, may cause progressive collapse and are, therefore, highly discouraged.
- Incorporate redundancy and alternative load paths into design to mitigate blast loads. One method of accomplishing this is to use two-way reinforcement schemes where possible.
- Minimize column spacing so that reasonably sized members can be designed to resist the design loads and increase the redundancy of the system. A practical upper level for column spacing is 30 feet for the levels of blast loads described herein.
- Minimize floor to floor heights. Unless there is an overriding architectural requirement, a practical limit is generally less than or equal to 16 feet.
- Use architectural or structural features that deny contact with exposed primary vertical load members in school lobbies. A minimum stand-off of at least 6 inches from these members is required.
- Minimize the use of venetian blinds and false ceilings, and locating equipment such as light fixtures, partitions, ductwork, and air conditioners above ceilings wherever possible. These items may become flying debris in the event of an explosion. Placing heavy equipment such as air conditioners near the floor rather than the ceiling is one idea for limiting this hazard; using exposed ductwork as an architectural device is another possibility.

3.3 BUILDING ENVELOPE

3.3.1 Building Exterior

The exterior envelope of the school building is the most vulnerable to an exterior explosive threat because it is the part of the building closest to the weapon. It also is a critical line of defense for protecting the occupants of the school building.

The design philosophy to be used here is that simpler is better. Generally simple geometries, with minimal ornamentation (which may become flying debris during an explosion) are recommended. If ornamentation is used, it is recommended that it consists of a lightweight material such as timber or plastic, which is less likely to become a projectile in the event of an explosion than, for example, brick, stone, or metal.

3.3.2 Exterior Wall Design

The exterior walls provide the first line of defense to prevent airblast pressures and hazardous debris from entering the school building. At a minimum, the objective of design is to ensure that these members fail in a flexible mode rather than in a brittle mode such as shear. The walls also need to be able to resist the loads transmitted by the windows and doors. Beyond ensuring a flexible failure mode, the exterior wall may be designed to resist the actual or reduced pressure levels of the defined threat. Special reinforcing and anchors should be provided around blast-resistant window and door frames.

Poured-in-place reinforced concrete will provide the highest level of protection, but solutions like pre-cast concrete, reinforced concrete masonry unit (CMU) block, and metal studs may also be used to achieve lower levels of protection.

For pre-cast panels, consider a minimum thickness of 5 inches with two-way reinforcing bars placed at spacing not greater than the thickness of the panel. Connections into the structure should provide as a straight a line of load transmittal as practical, using as few connecting pieces as possible.

For CMU block walls, use 8-inch block walls, fully grouted with vertical centered reinforcing bars placed in each cell and horizontal reinforcement at each layer. Connections into the structure should be able to resist the ultimate lateral capacity of the wall. A preferred system is to have a continuous exterior CMU wall that laterally bears against the floor system. For increased protection, consider using 12-inch blocks with two layers of reinforcement.

For metal stud systems, use metal studs back to back and mechanically attached, to minimize lateral torsion effects. To catch exterior cladding fragments, attach a wire mesh to the exterior side of the metal stud system. The supports of the wall are to be designed to resist the ultimate lateral capacity load of the system.

When designing schools in areas perceived as high risk, engineers and architects should consider the following recommendations:

- Substitute strengthened building walls and systems when stand-off distances cannot be accommodated.
- Use ductile materials capable of very large plastic deformations without complete failure.
- Design exterior walls to resist the actual pressures and impulses acting on the exterior wall surfaces from the threats defined for the school building.
- Design exterior walls to withstand the dynamic reactions from the windows.
- Design exterior shear walls to resist the actual blast loads predicted from the threats specified. Consider shear walls that are essential to the lateral and vertical load bearing system, and that also function as exterior walls, to be primary structures.
- Consider reinforced concrete wall systems in lieu of masonry or curtain walls to minimize flying debris in a blast.

- ❍ Reinforced wall panels can protect columns and assist in preventing progressive collapse, because the wall will assist in carrying the load of a damaged column.
- ❍ Give special consideration to construction types that reduce the potential for collapse where exterior walls are not designed for the full design loads.
- ❍ Consider use of sacrificial exterior wall panels to absorb blast.

3.3.3 Window Design

Window systems (e.g., glazing, frames, anchorage to supporting walls, etc.) on the exterior façade of a school building should be designed to mitigate the hazardous effects of flying glass during an explosion event. In an effort to protect school occupants, designers should integrate the features of the glass, connection of the glass to the frame (bite), and anchoring of the frame to the building structure to achieve a "balanced design." This means all the components should have compatible capacities and theoretically would all fail at the same pressure-pulse levels. In this way, the damage sequence and extent of damage are controlled. Table 3-1 presents six GSA glazing protection levels based on how far glass fragments would enter a space and potentially injure its occupants. Figure 3-4 depicts how far glass fragments could enter a structure for each GSA performance condition.

Table 3-1: Glazing Protection Levels Based on Fragment Impact Locations[1]

Performance Condition	Protection Level	Hazard Level	Description of Window Glazing Response
1	Safe	None	Glazing does not break. No visible damage to glazing or frame.
2*	Very High	None	Glazing cracks, but is retained by the frame. Dusting or very small fragments near sill or on floor acceptable.
3a*	High	Very Low	Glazing cracks. Fragments enter space and land on floor no more than 3.3 feet from the window.
3b*	High	Low	Glazing cracks. Fragments enter space and land on floor no more than 10 feet from the window.
4*	Medium	Medium	Glazing cracks. Fragments enter space and land on floor and impact a vertical witness panel at a distance of no more than 10 feet from the window at a height no greater than 2 feet above the floor.
5*	Low	High	Glazing cracks and window system fails catastrophically. Fragments enter space, impacting a vertical witness panel at a distance of no more than 10 feet from the window at a height greater than 2 feet above the floor.

* In conditions 2, 3a, 3b, 4 and 5, glazing fragments may be thrown to the outside of the protected space toward the detonation location.

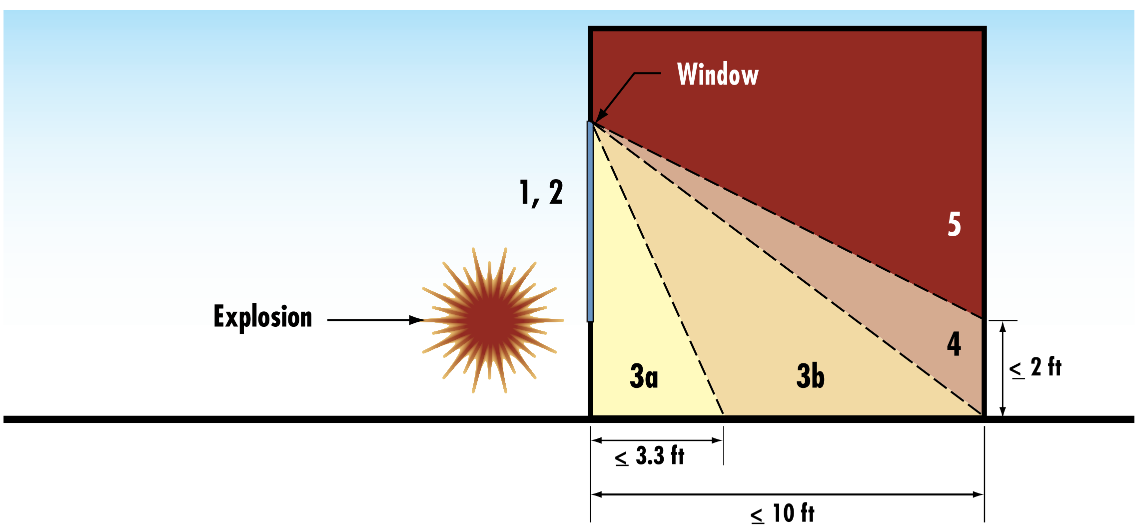


Figure 3-4 Side view of a test structure illustrating performance conditions of Table 3-2

[1] From GSA PBS-PQ100.1, *Facilities Standards for the Public Building Service*, June 14, 1996

The divide between performance conditions 3a and 3b can be equated to the "threshold of injury." The divide between performance conditions 4 and 5 can be equated to the "threshold of lethality." The GSA glazing performance conditions shown above correlate with the DoD levels of protection presented in Table 3-2.

Table 3-2: Correlation of GSA Glazing Performance Conditions and DoD Levels of Protection for New Buildings

GSA Glazing Performance Condition	Corresponding DoD Level of Protection for New Buildings
1	High
2	Medium
3a	Low
3b/4	Very Low
5	Below Antiterrorism (AT) Standards

FEMA 426, *Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings,* contains a detailed description of window system design considerations. Although not all windows in a school can be designed to resist the full forces from very large explosive blast events, hardened window systems can provide significant protection for students, faculty, and staff. Preferred systems include: thermally tempered glass with a security film installed on the interior surface and attached to the frame; laminated thermally tempered glass; laminated heat strengthened, or laminated annealed glass; and blast curtains. Glazing systems that do not provide any protection include: untreated monolithic annealed or heat-strengthened glass and wire glass. Figure 3-5 depicts an unprotected window after a large explosion.

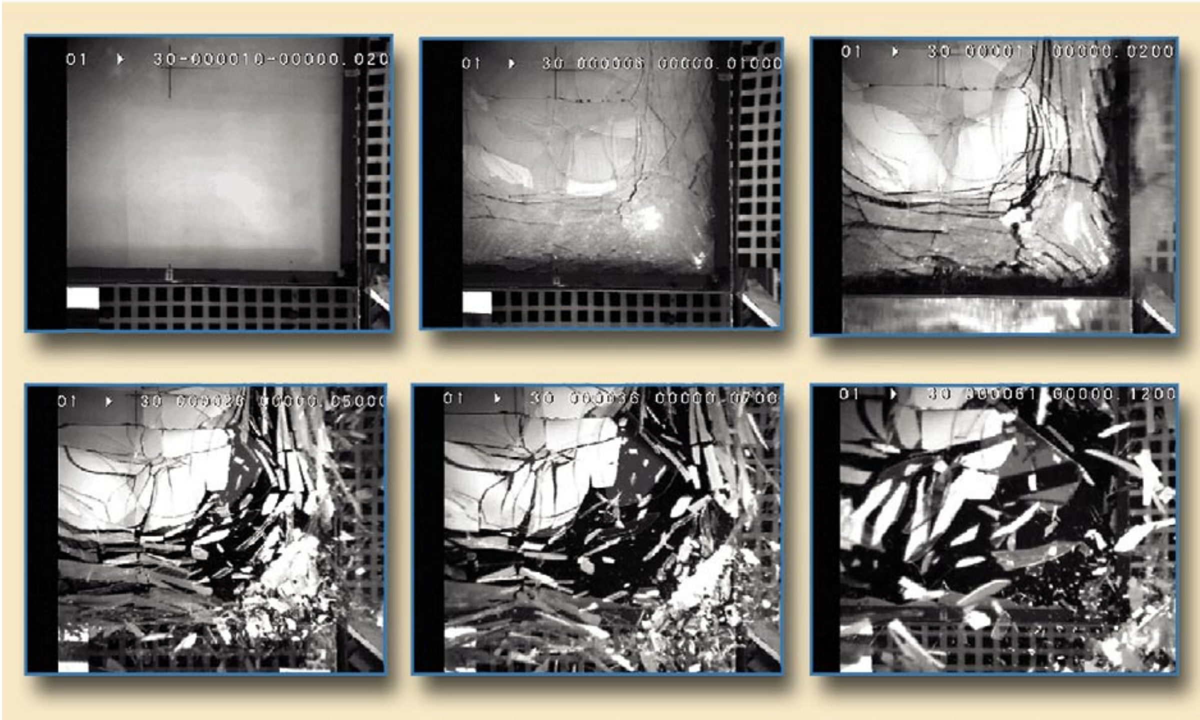


Figure 3-5 An unprotected window after a large explosion

General Guidelines for Windows and Glazing. General guidelines for windows and glazing include the following:

- Do not place windows adjacent to doors because, if the windows are broken, the door can be unlocked.
- In schools requiring high security, minimize the number and size of windows in a façade. If possible, limit the amount of glazed area in building facades to 15 percent. The amount of blast entering a space is directly proportional to the amount of opening on the facade.
- Consider using burglary- and ballistic-resistant glazing in high-risk school areas.
- Consider using laminated glass in place of conventional glass.
- Consider window safety laminate (such as mylar) or another fragment retention film (FRF) over glazing (properly installed) to reduce fragmentation.

- Consider placing guards, such as grills, screens, or meshwork, across window openings to protect against covert entry. Affix protective window guards firmly to the structure. Fire egress considerations must be judged against window guards.
- Position the operable section of a sliding window on the inside of the fixed section and secure it with a broomstick, metal rod, or similar device placed at the bottom of the track.
- Provide horizontal windows 6 feet above the finished floor to limit entry.
- Consider using steel window frames securely fastened or cement grouted to the surrounding structure.
- Minimize interior glazing in high-risk areas (e.g., lobbies, loading docks).

Mullion and Wall Design. The frame members connecting adjoining windows are referred to as mullions. These members may be designed using a static approach when the breaking strength of the window glass is applied to the mullion, or a dynamic load may be applied using the peak pressure and impulse values. Although the static approach may seem easier, it often yields a design that is not practical, because the mullion can become very deep and heavy, driving up the weight and cost of the window system. In addition, it may not be consistent with the overall architectural objectives of the project. A dynamic approach is likely to provide a section that meets the design constraints of the project. To accomplish this, a single-degree-of-freedom solution is often used. The governing equation of motion may be solved using numerical methods. There are also charts available for linearly decaying loads that circumvent the need to solve differential equations. These charts only require that the fundamental period of the mullion (including the tributary area of the window glass), the ultimate resistance force of the mullion, the peak pressure, and the equivalent linear decay time are known.

Peak lateral response of the mullion is to be limited to a 2-degree support rotation. Also, the displacement ductility is to be limited to a 4-

degree support rotation. As with frames, it is good engineering practice to limit the number of interlocking parts used for the mullion.

3.3.4 Doors

Door assemblies include the door, its frame, and anchorage to the building. As part of a balanced school design approach, exterior doors in high-risk buildings should be designed to withstand the maximum dynamic pressure and duration of the load from the design threat explosive blast. Other general door considerations for these types of buildings are as follows:

- Provide hollow steel doors or steel-clad doors with steel frames. Ensure the strength of the latch and frame anchor equals that of the door and frame.
- Consider blast-resistant doors for schools considered to be at high risk.
- Permit normal entry/egress through a limited number of doors, if possible, while accommodating emergency egress.
- Ensure that exterior doors into inhabited areas open outward. In addition to facilitating egress, by doing so, the doors will seat into the door frames in response to an explosive blast, increasing the likelihood that the doors will not enter the school building as hazardous debris.
- Replace externally mounted locks and hasps with internally locking devices because the weakest part of most door assemblies is the latching component.
- Locate hinges on interior or use exterior security hinges to reduce their vulnerability.
- Install emergency exit doors so that they facilitate only exiting movement.
- Consider using solid doors or walls as a backup for glass doors in foyers.
- Strengthen and harden the upright surfaces of a door jamb into which the door fits.

3.3.5 Roof System Design

Control access to school roofs to minimize the possibility of aggressors placing explosives or CBR agents there or otherwise threatening school occupants or critical infrastructure. Designers should consider the following:

- For new school buildings, eliminate all external roof access by providing access from internal stairways or ladders, such as in mechanical rooms.
- For existing school buildings, eliminate external access, where possible, or make roof access ladders removable, retractable, or lockable.
- Provide pitched roofs to allow deflection of explosives.
- Make school roof access hatches secure from intruders.
- Consider designing buildings with a sacrificial sloping roof that is above a protected ceiling (see Figure 3-6).

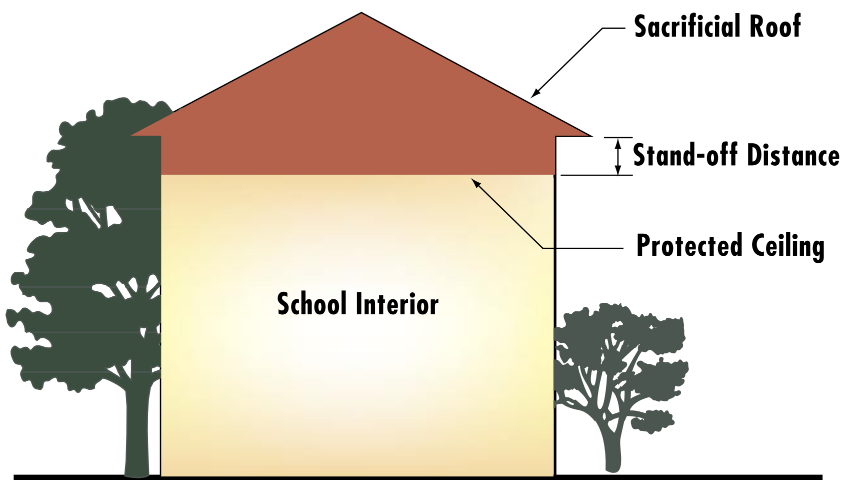


Figure 3-6 Sacrificial roof

3.4 MECHANICAL SYSTEMS

Mechanical systems design standards address limiting damage to critical infrastructure and protecting school building occupants against CBR threats. The primary goal of a mechanical system after a terrorist attack should be to continue to operate key life safety systems for school occupants. School designers should be aware that during an interior bombing event, smoke removal and control are of paramount importance. They should consider the fact that, if window glazing is hardened, a blast may not blow out windows, and smoke may be trapped in the school building. In the event of a blast, the available smoke removal system may be essential to smoke removal, particularly in large, open spaces. This equipment should be located away from high-risk areas such as loading docks and garages. The system controls and power wiring to the equipment should be protected. The system should be connected to emergency power to provide smoke removal. Smoke removal equipment should be provided with standalone local control panels that can continue to individually function in the event the control wiring is severed from the main control system.

Designers should consider locating components in less vulnerable areas, limiting access to mechanical systems, and providing a reasonable amount of redundancy. Specific considerations include the following:

- Avoid mounting plumbing, electrical fixtures, or utility lines on the inside of exterior school walls. When this is unavoidable, mount fixtures on a separate wall at least 6 inches from the exterior wall face.
- Avoid placing plumbing on the top of the roof deck of the school building.
- Avoid suspending plumbing fixtures and piping from the ceiling.
- Reduce the number of utility openings, manholes, tunnels, air conditioning ducts, filters, and access panels into the school structure.
- Protect school building operational control areas and utility feeds to lessen the negative effects of a blast.
- Design operational redundancies to survive all kinds of attacks.
- Use lockable systems for school utility openings and manholes where appropriate. Infrequently used utility covers/manholes

can be tack-welded as an inexpensive alternative to locking tamper-resistant covers.

Key HVAC System Considerations. The following HVAC design measures should be considered to mitigate the risk of CBR threats against school buildings. A more detailed discussion of HVAC design considerations is contained in FEMA 426 *Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings* and FEMA 427 *Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks.* HVAC protective actions are discussed in Chapter 5.

- Place intakes at the highest practical level on the school building. For protection against malicious acts, the intakes should also be covered by screens so that objects cannot be tossed into the intakes or into air wells from the ground (see Figures 3-7, 3-8, and 3-9). Such screens should be sloped to allow thrown objects to roll or slide off the screen, away from the intake. Many existing school buildings have air intakes that are located at or below ground level. For those that have wall-mounted or below-grade intakes close to the building, the intakes can be elevated by constructing a plenum or external shaft over the intake (see Figure 3-10).

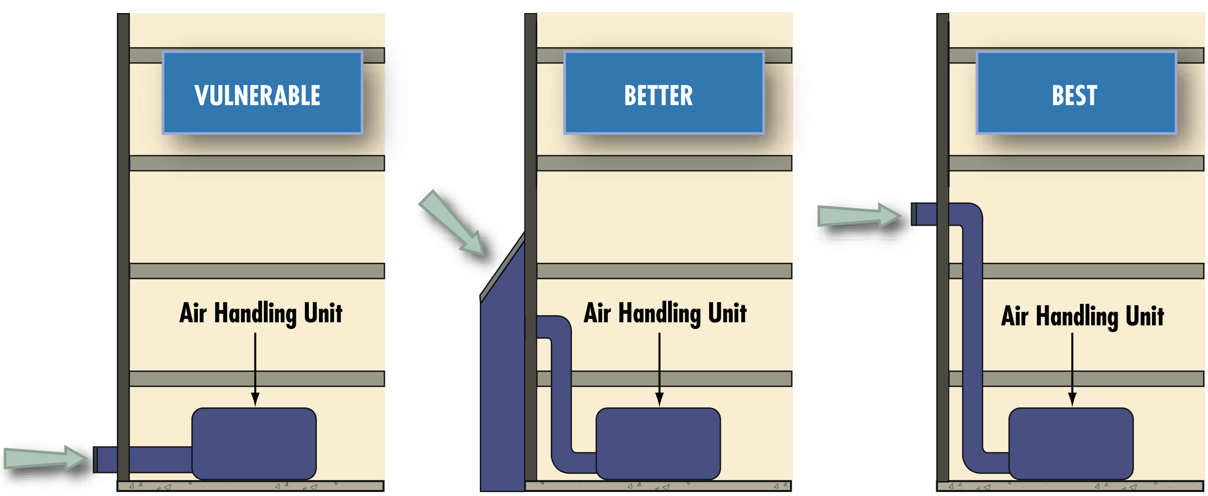
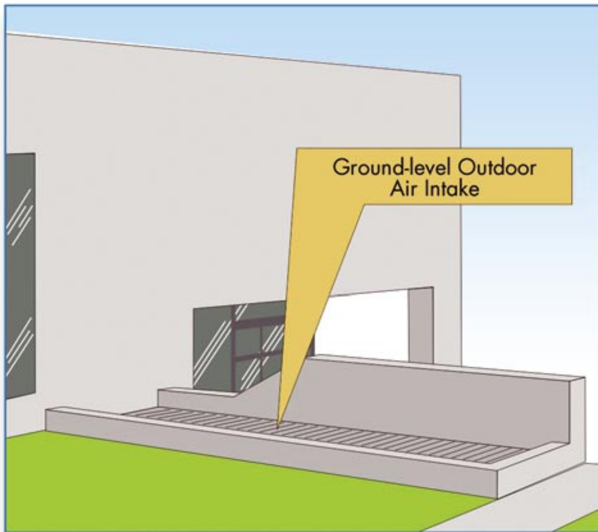


Figure 3-7 Example of protecting outdoor air intakes

SOURCE: CDC/NIOSH, PUBLICATION NO. 2002-139, *GUIDANCE FOR PROTECTING BUILDING ENVIRONMENTS FROM AIRBORNE CHEMICAL, BIOLOGICAL, OR RADIOLOGICAL ATTACKS*, MAY 2002.



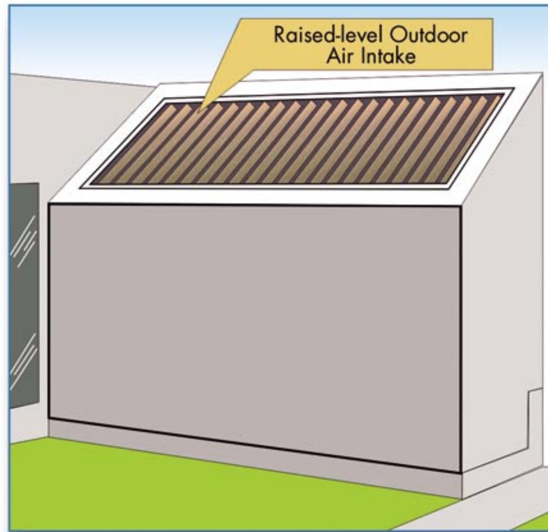


Figure 3-8 Another example of protecting air intakes

SOURCE: CDC/NIOSH, PUBLICATION NO. 2002-139, *GUIDANCE FOR PROTECTING BUILDING ENVIRONMENTS FROM AIRBORNE CHEMICAL, BIOLOGICAL, OR RADIOLOGICAL ATTACKS*, MAY 2002.

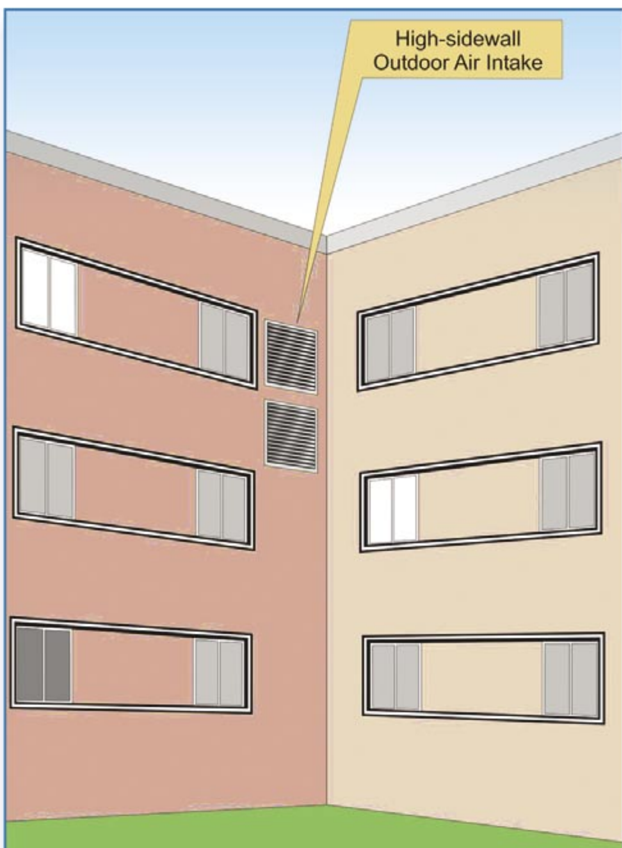
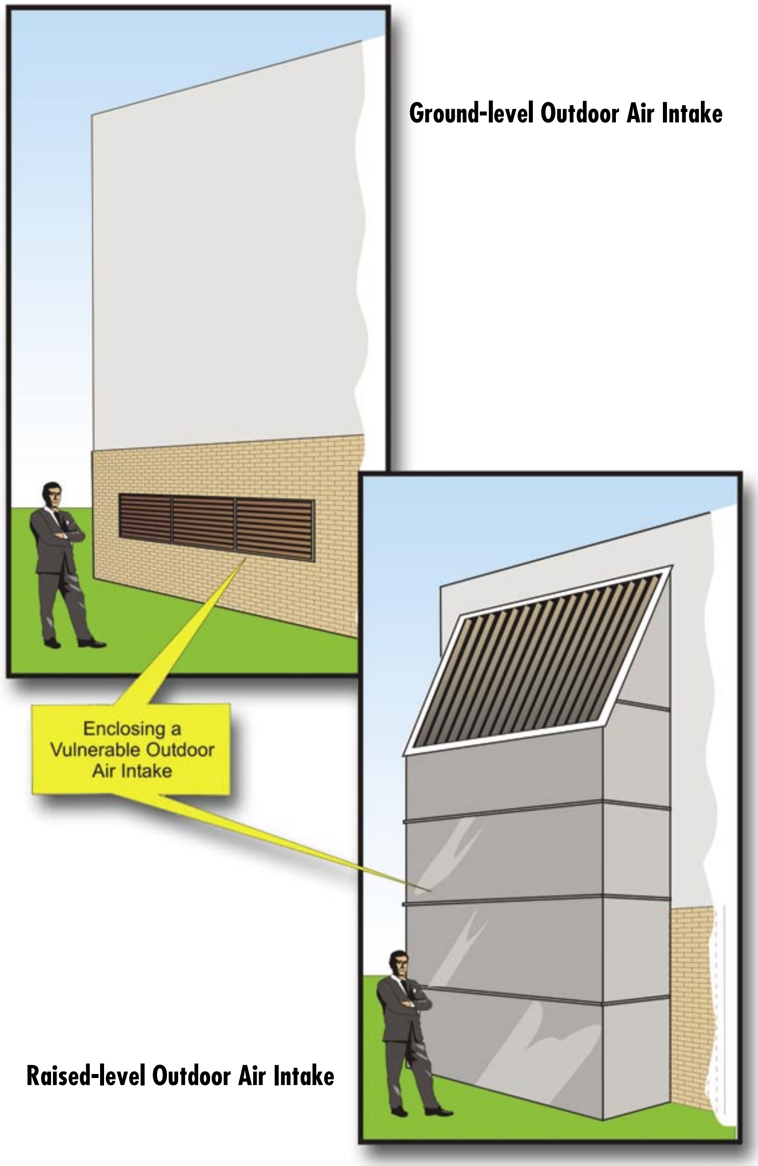


Figure 3-9
Example of elevated air intake

SOURCE: CDC/NIOSH, PUBLICATION NO. 2002-139, *GUIDANCE FOR PROTECTING BUILDING ENVIRONMENTS FROM AIRBORNE CHEMICAL, BIOLOGICAL, OR RADIOLOGICAL ATTACKS*, MAY 2002.

Figure 3-10
Example of enclosing an existing vulnerable air intake

SOURCE: CDC/NIOSH, PUBLICATION NO. 2002-139, *GUIDANCE FOR PROTECTING BUILDING ENVIRONMENTS FROM AIRBORNE CHEMICAL, BIOLOGICAL, OR RADIOLOGICAL ATTACKS*, MAY 2002.



- Provide protection for existing school buildings with air intakes below grade, at ground level, or wall-mounted outside secure areas, with physical security measures (e.g., placing fencing, surveillance cameras, and motion detectors around the intakes to facilitate monitoring by security personnel). These measures can help prevent malicious acts, but are less effective than elevating the intakes, because ground level releases under certain conditions can enter the intakes from points outside the area fenced or under surveillance.

- Maintain physical security on mechanical rooms to prevent the direct introduction of hazardous materials into the system of ducts that distributes air to the school building. This includes locking and controlling the access to all mechanical rooms containing HVAC equipment.

- Restrict access to school building operation systems by outside personnel. To deter tampering by outside maintenance personnel, a school staff member should escort these individuals throughout their service visit and should visually inspect their work before final acceptance of the service. Alternatively, schools can ensure the reliability of pre-screened service personnel from a trusted contractor.

- Restrict access to school building data. Information on building operations (including mechanical, electrical, vertical transport, fire and life safety, security system plans and schematics, and emergency operations procedures) should be controlled.

- Isolate school lobbies, mailrooms, loading docks, and storage areas. Lobbies, mailrooms (includes various mail processing areas), loading docks, and other entry and storage areas should be physically isolated from the rest of the building. These are areas where bulk quantities of CBR agents are likely to enter a school building.

- Consider "shelter-in-place" rooms or areas in schools, where people can stay in the event of an outdoor release. The goal is to create areas where outdoor air infiltration is very low. Usually such rooms will be in the inner part of the school in an area with no exterior windows if possible. The rooms should have doors that are fairly effective at preventing airflow and should contain staging supplies such as duct tape and plastic to help further seal the areas from the hallways. Typically, restrooms are a bad choice, because they have exhaust ducts that lead directly to the outside. Opening and closing a conventional hinged door can pump large amounts of air into the room; if practical, replace the door with a code compliant sliding door to reduce this effect. Additionally, it may be possible to provide purified air to the safe area through modifications to the HVAC system. For more information, see Chapters 5 and 6.

- Ducted returns offer limited access points to introduce a CBR agent. The return vents can be placed in conspicuous locations throughout a school, reducing the risk of an agent being secretly introduced into the return system. Non-ducted return air systems commonly use hallways or spaces above suspended ceilings as a return-air path or plenum. CBR agents introduced at any location above the suspended ceiling in a ceiling plenum return system will probably migrate back to the HVAC unit and be redistributed to occupied areas. Schools should be designed to minimize mixing between air-handling zones, which can be partially accomplished by limiting shared returns.

3.5 ELECTRICAL SYSTEMS

The major security functions of the electrical system are to maintain power to essential school services, especially those required for life safety and evacuation. When designing a school building, architects and engineers should consider providing lighting and surveillance to deter criminal activities, and provide emergency communications. They should also consider the following recommendations:

- Emergency and normal electric panels, conduits, and switchgear should be installed separately, at different locations, and as far apart as possible. Electric distribution should also run at separate locations.
- Emergency generators should be located away from loading docks, entrances, and parking. More secure locations include the roof, protected grade level, and protected interior areas.
- Main fuel storage for generators should be located away from loading docks, entrances, and parking. Access should be restricted and protected (e.g., locks on caps and seals).

- Fuel tanks should be mounted near the generator, given the same protection as the generator, and sized to store an appropriate amount of fuel. A battery and/or UPS could be a viable alternative for a smaller school.

- Conduits and lines should be installed outside to allow a trailer-mounted generator to connect to the school's electrical system. If tertiary power is required, other methods include generators and feeders from alternative substations.

- Emergency power should be provided for emergency lighting in school restrooms, egress routes, and any meeting room without windows.

- School building access points should be illuminated to aid in threat detection.

- Self-contained battery lighting should be provided in stairwells and for exit signs.

- Suspending electrical conduits from the ceiling should be avoided.

- Adequate lighting of perimeters and parking areas should be provided to aid in visual surveillance and to support the use of CCTV.

3.6 FIRE PROTECTION SYSTEMS

The fire protection system inside the school building should maintain life safety protection after an incident and allow for safe evacuation of the building when appropriate. Although fire protection systems are designed to perform well during fires, they are not traditionally designed to survive bomb blasts. Fire protection system considerations include the following:

- A school's fire protection water system should be protected from single-point failure in case of a blast event. The incoming line should be encased, buried, or located 50 feet away from high-risk areas. The interior mains should be looped and sectionalized.

- To increase the reliability of the fire protection system, a dual pump arrangement should be considered, with one electric pump and one diesel pump. The pumps should be located away from each other.

- All school security locking arrangements on doors used for egress must comply with requirements of NFPA 101, Life Safety Code.

3.7 COMMUNICATIONS SYSTEMS

Designers should consider the following:

- **Redundant communications.** The school should have a second telephone service to maintain communications in case of an incident. A base radio communications system with antenna should be installed in the stairwell, and portable sets distributed on floors. This is the preferred alternative.

- **Radio telemetry.** Distributed antennas could be located throughout the school facility if required for emergency communications through wireless transmission of data.

- **Alarm and information systems.** Alarm and information systems should not be collected and mounted in a single conduit, or even collocated. Circuits to various parts of the school building should be installed in at least two directions and/or risers. Low voltage signal and control copper conductors should not share conduits with high voltage power conductors. Fiber-optic conductors are generally preferred over copper.

- **Empty conduits.** Empty conduits and power outlets can be provided for possible future installation of security control equipment.

- **Mass notification.** All inhabited school buildings should have a timely means to notify occupants of threats and instruct them what to do in response to those threats. School buildings should have a capability to provide real-time notification of building occupants and people in the immediate vicinity of the building during emergency situations. The information relayed should be specific enough to determine the appropriate response actions.

3.8 PHYSICAL SECURITY SYSTEMS

Physical security is defined as that part of security concerned with physical measures designed to safeguard people and to prevent unauthorized access to equipment, certain areas of the school building, and key documents. These days, all security operations face new and complex physical security challenges across the full spectrum of operations.

Although security technologies are not the answer to all school security problems, if applied appropriately, they can enhance security, free up administrators for more appropriate work, and sometimes can save money. At a non-educational building, a typical approach to physical security is:

For example, if someone is breaking into a school facility, it is necessary to have a means of detection so that information can be provided to appropriate authorities. Next, the intruder must be delayed as long as possible so that the response force may arrive. Finally, someone, such as the police, must respond to the incident to catch the intruder. For a school, the National Institute for Justice[2] has recommended expanding this model as shown below:

[2] National Institute of Justice Research Report NCJ 178265, *The Appropriate and Effective Use of Security Technologies in U.S. Schools,* September 1999.

This educational approach emphasizes deterrence by instituting measures both before and after an event to convince perpetrators not to do whatever they are considering. Although, the efficacy of deterrence for high-risk terrorist tactics is questionable, schools have a broad spectrum of threats to consider with any physical security system. Schools are also unique in that they generally have the authority and opportunity to establish consequences for incidents that involve students and occur on school grounds. Figure 3-11 depicts some considerations for the design of a school security system and Figure 3-12 shows examples of physical security devices.

For schools requiring greater security, some general measures are contained in the National Institute of Justice Research Report NCJ 178265, *The Appropriate and Effective Use of Security Technologies in U.S. Schools,* September 1999.

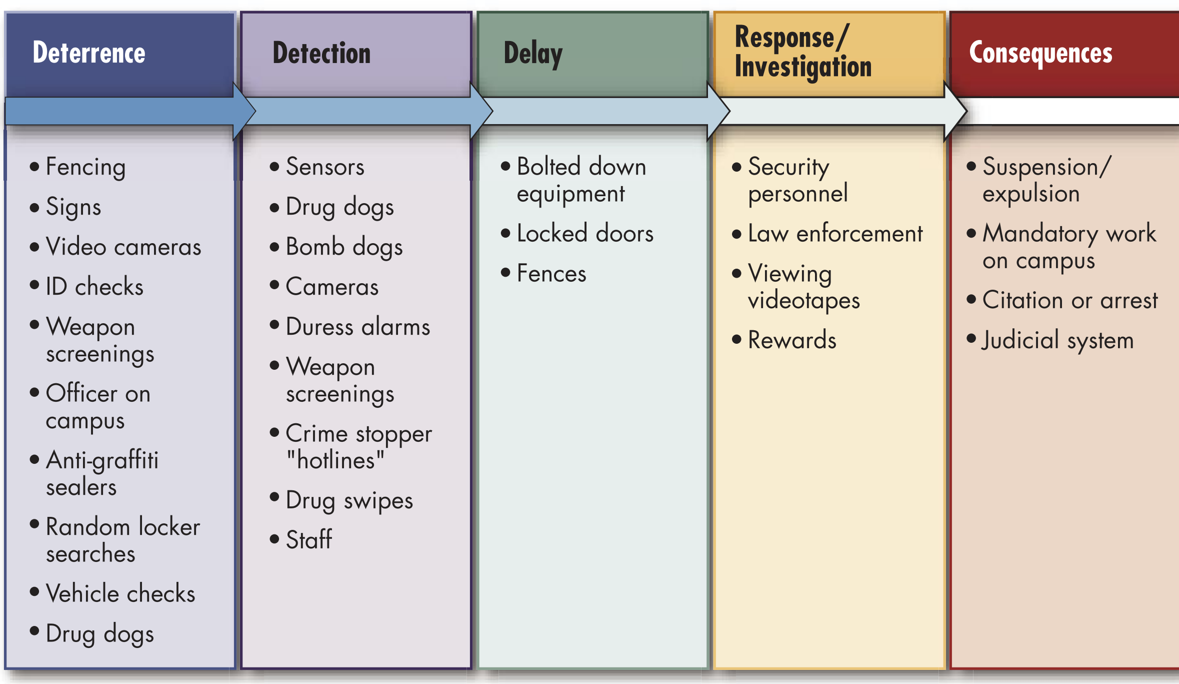


Figure 3-11 Considerations for the design of a new security system

SOURCE: NATIONAL INSTITUTE OF JUSTICE RESEARCH REPORT NCJ 178265, *THE APPROPRIATE AND EFFECTIVE USE OF SECURITY TECHNOLOGIES IN U.S. SCHOOLS*, SEPTEMBER 1999.

Figure 3-12 Physical security devices

Obviously, when considering any physical security measure for a school, it is important to balance its use with the risk of creating a "bunker" or "prison" atmosphere that is not conducive to learning. The measures recommended in this chapter should be applied judiciously and in concert with the threat assessment depicted in Chapter 1, and also with any risk perceived by school administrators.

3.9 SUMMARY OF BUILDING ENVELOPE MITIGATION MEASURES

A general spectrum of building envelope mitigation measures ranging from the least protection, cost, and effort going to the greatest protection, cost, and effort is provided below. Detailed discussions of individual measures can be found earlier in this chapter. Please note this is a nominal ranking of mitigation measures. In practice, the effectiveness and cost of individual mitigation measures may deviate from this example based on specific applications.

- Ensure that all school exterior doors into inhabited areas open outward. Ensure emergency exit doors only facilitate exiting.
- Secure school roof access hatches from the interior. Prevent public access to building roofs.
- Restrict access to school building operation systems.
- Conduct periodic training of school HVAC maintenance and operation staff.
- Evaluate HVAC control options.
- Install empty conduits for future school security control equipment during initial construction or major renovation.
- Do not mount plumbing, electrical fixtures, or utility lines on the inside of exterior walls.
- Minimize interior glazing near high-risk a reas.
- Establish school emergency plans, policies, and procedures.
- Establish written plans for school evacuation and sheltering in place.
- Illuminate school access points.
- Restrict access to school building information.
- Secure HVAC intakes and mechanical rooms.
- Limit the number of doors used for normal entry/egress.
- Lock all utility access openings.
- Provide emergency power for emergency lighting in school restrooms, egress routes, and any meeting room without windows.
- Install an internal public address system.
- Stagger interior doors and offset interior and exterior doors.
- Eliminate hiding places.
- Install a second and separate telephone service.
- Install radio telemetry distributed antennas throughout the facility.
- Use a badge identification system for school access.
- Install a CCTV surveillance system in areas where needed.
- Install an electronic security alarm system in areas where needed.
- Install rapid response and isolation features into school HVAC systems.
- Use interior barriers to differentiate levels of security.
- Avoid eaves and overhangs or harden to withstand blast effects.
- Locate utility systems away from likely areas of potential attack.
- Install call buttons at key public contact areas.
- Install emergency and normal electric equipment at different locations.
- Avoid exposed structural elements.

Continued on next page

- Reinforce foyer walls.
- Use architectural features to deny contact with exposed primary vertical load members.
- Isolate school lobbies, mailrooms, loading docks, and storage areas.
- Locate stairwells remotely. Do not discharge stairs into lobbies, parking, or loading areas.
- Elevate school HVAC fresh-air intakes.
- Create "shelter-in-place" rooms or areas.
- Separate HVAC zones. Eliminate leaks and increase school building air tightness.
- Install blast-resistant doors or steel doors with steel frames.
- Physically separate unsecured areas from the main school building.
- Install HVAC exhausting and purging systems.
- Connect interior non-load bearing walls to structure with non-rigid connections.
- Use structural design techniques to resist progressive collapse of school buildings.
- Treat exterior shear walls as primary structures.
- Orient glazing perpendicular to the primary façade facing uncontrolled vehicle approaches.
- Use reinforced concrete wall systems in lieu of masonry or curtain walls.
- Ensure active fire system is protected from single-point failure in case of a blast event.
- Establish school's ground floor elevation 4 feet above grade.
- Avoid re-entrant corners on the school building exterior.
- Issue CBR personal protective equipment.
- Design exterior walls to resist blast.
- Design school facilities with a sacrificial sloping roof above a protected ceiling.
- Upgrade glazing - laminated glass, safety laminates, FRF, etc.
- Install a 24-hour on-site monitoring center.
- Install HVAC filtering and pressurization.
- Install HVAC CBR real-time monitoring detectors.

3.10 RECOMMENDATIONS BASED ON THE HOMELAND SECURITY ADVISORY SYSTEM

Table 3-3 presents recommendations for safety/security measures linked to the DHS Threat Advisory Level. Chapter 6 of the U.S. Department of Education (DOE) *Practical Information on Crisis Planning: A Guide for Schools and Communities* contains similar recommendations.

Table 3-3: Safety/Security Recommendations

DHS Threat Advisory Level	Recommended Actions
Green – Low Risk	❍ Develop school written emergency plans ❍ Coordinate emergency plans with local, state, and federal plans ❍ Ensure selected staff members take a Red Cross cardiopulmonary resuscitation (CPR)/automated external defibrillator (AED) and first aid course ❍ Develop emergency communications plan and lists ❍ Conduct crisis management and communications training for all employees ❍ Disseminate emergency procedures and plans to parents ❍ Develop and implement visitor control procedures ❍ Obtain emergency supplies and equipment ❍ Obtain copies of Terrorism: *Preparing for the Unexpected* brochure from the local Red Cross chapter
Blue – Guarded	❍ Complete recommended actions at lower level ❍ Review and update emergency plans ❍ Upgrade to appropriate visitor control procedures ❍ Review and update emergency communication plan and lists ❍ Inventory and restock emergency supplies ❍ Conduct safety training /emergency drills following the school's written emergency plan
Yellow - Elevated	❍ Complete recommended actions at lower level ❍ Be alert to suspicious activity and report it to the proper authorities ❍ Assess increased risk with public safety officials ❍ Reassess school security measures ❍ Verify that emergency supplies are stocked and ready ❍ Review field trip decisions ❍ Update employee emergency call lists and review callback process with employees ❍ Test alternate communications capabilities ❍ Increase communications with parents and community via web site and e-mail distributions ❍ Distribute copies of Terrorism: *Preparing for the Unexpected* brochure from the local Red Cross chapter and send it home with students in grades K-12, faculty, and staff

Table 3-3: Safety/Security Recommendations (continued)

DHS Threat Advisory Level	Recommended Actions
Orange - High	❍ Complete recommended actions at lower level ❍ Consider canceling outside activities ❍ Prepare to handle inquiries from anxious parents and media ❍ Review and implement increased security measures • Limit parking near school buildings • Restrict visitor access ❍ Discuss children's fears concerning possible terrorist attacks ❍ Review sporting event and extracurricular activity decisions ❍ Place school and district crisis response teams on standby alert status
Red - Severe	❍ Complete recommended actions at lower level ❍ Follow local and/or Federal Government instructions ❍ Coordinate with local and state officials to consider school openings and closings ❍ Listen to radio/TV for current information/instructions ❍ Review and implement increased security measures • Further limiting parking to increase stand-off • Posting/increasing security staff ❍ Activate command and support centers if appropriate ❍ Continue staff, parent, and community communications ❍ Coordinate parent-child reunification process, if necessary ❍ Ensure mental health counselors are available for students, faculty, and staff

3.11 SCHOOL SAFETY EMERGENCY MANAGEMENT PLAN

The DHS has designated the DOE as the lead agency for security related to schools. The DOE has published a guide, *Practical Information on Crisis Planning: A Guide for Schools and Communities*, May 2003, that is intended to give schools, districts, and communities the critical concepts and components of good crisis planning, stimulate thinking about crisis preparedness process, and provide examples of promising practices. Additional information is also available from the National Advisory Committee on Children and Terrorism (NACCT).

The DOE recommends each school crisis plan address four major areas: mitigation/prevention, preparedness, response, and recovery.

- **Mitigation/Prevention:**

  - Conduct an assessment of each school building. Identify those factors that put the building, students, faculty, and staff at greater risk, such as proximity to rail tracks that regularly transport hazardous materials or facilities that produce highly toxic material or propane gas tanks, and develop a plan for reducing the risk. This can include plans to evacuate students away from these areas in times of crisis and to reposition propane tanks or other hazardous materials away from school buildings.

  - Work with businesses and factories in close proximity to the school to ensure that the school's crisis plan is coordinated with their crisis plans.

  - Ensure that a process is in place for controlling access and egress to the school. Require all persons who do not have authority to be in the school to sign in.

  - Review traffic patterns, and where possible, keep cars, buses, and trucks away from school buildings.

  - Review landscaping, and ensure that buildings are not obscured by overgrowth of bushes or shrubs where contraband can be placed or persons can hide.

- **Preparedness:**

  - Have site plans for each school building readily available and ensure they are shared with first responders and agencies responsible for emergency preparedness.

  - Ensure there are multiple evacuation routes and rallying points. First or second evacuation site options may be blocked or unavailable at the time of the crisis.

  - Practice responding to crisis on a regular basis.

- Ensure a process is established for communicating during a crisis.
- Inspect equipment to ensure it operates during crisis situations.
- Have a plan for discharging students. Remember that, during a crisis, many parents and guardians may not be able to get to the school to pick up their child. Make sure every student has a secondary contact person and contact information readily available.
- Have a plan for communicating information to parents and for quelling rumors. Cultivate relationships with the media ahead of time, and identify a Public Information Officer (PIO) to communicate with the media and the community during a crisis.
- Work with law enforcement officials and emergency preparedness agencies on a strategy for sharing key parts of the school crisis plans.

❍ **Response:**

- Identify the type of crisis that is occurring and determine the appropriate response.
- Develop a command structure for responding to a crisis. The roles and responsibilities for educators, law enforcement and fire officials, and other first responders in responding to different types of crisis need to be developed, coordinated, reviewed, and approved.
- Maintain communications among all relevant staff.

❍ **Recovery:**

- Return to the business of teaching and learning as soon as possible.
- Identify and approve a team of credentialed mental health workers to provide mental health services to faculty and students after a crisis. Understand that recovery takes place over time and that the services of this team may be needed over an extended time period.

- Ensure that the team is adequately trained.
- The plan needs to include notification of parents on actions that the school intends to take to help students recover from the crisis.

3.12 EMERGENCY PLANS AND TRAINING

Every school should have a school safety emergency management plan developed in partnership with public safety agencies, including law enforcement, fire, public health, mental health and local emergency preparedness agencies. The plan should address fire, and natural and manmade disasters. A school's plan should be tailored to address the unique circumstances and needs of the individual school, and should be coordinated and integrated with community plans and the plans of local emergency preparedness agencies.

These plans should also consider CBR attack scenarios and the associated procedures for communicating instructions to building occupants, identifying suitable shelter-in-place areas (if they exist), identifying appropriate use and selection of personal protective equipment (i.e., clothing, gloves, respirators) and directing emergency evacuations. Individuals developing emergency plans and procedures should recognize that there are fundamental differences between chemical, biological, and radiological agents. In general, chemical agents will show a rapid onset of symptoms, while the response to biological and radiological agents will be delayed. Issues such as designated areas and procedures for chemical storage, HVAC control or shutdown, and communications with school occupants and emergency responders, should all be addressed. The plans should be as comprehensive as possible, but, as described earlier, protected by limited and controlled access. When appropriately developed, these plans, policies, and procedures can have a major impact upon school occupant survivability in the event of a CBR release.

Staff training, particularly for those with specific responsibilities during an event, is essential and should cover both internal and external events. Holding regularly scheduled practice drills, similar to the common fire drill, allows for plan testing, as well as student and key staff rehearsal of the plan, and increases the likelihood for success in an actual event. School officials should ensure that training is provided to staff that operate and maintain the school's HVAC system. This training should include the procedures to be followed in the event of a suspected CBR agent release. Development of current, accurate HVAC diagrams and HVAC system labeling protocols should be addressed. These documents can be of great value in the event of a CBR release.