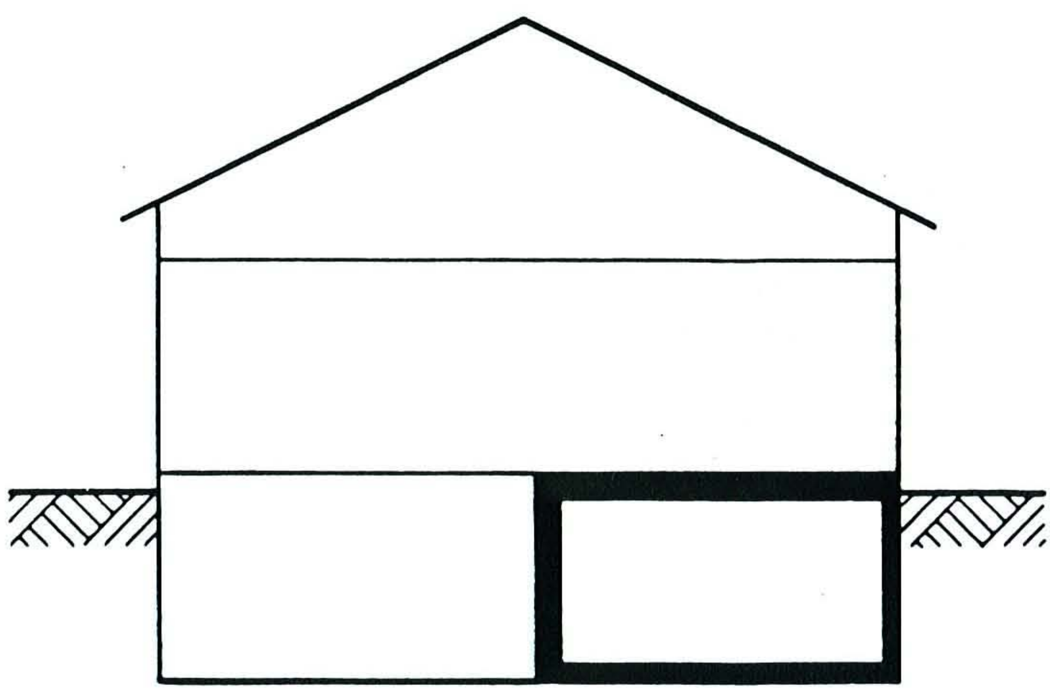
TWP 1966

TECHNICAL DIRECTIVES
for the
CONSTRUCTION of PRIVATE AIR RAID SHELTERS
and
THE 1971 CONCEPTION of the SWISS CIVIL DEFENSE

Swiss Federal Department of Justice and Police Office of Civil Defense

English Language Edition



Contents

PART I. TECHNICAL DIRECTIVES FOR THE CONSTRUCTION OF PRIVATE AIR RAID SHELTERS (OF 15 NOVEMBER 1966)

LIST OF ABBREVIATIONS AND SYMBOLS

BZS	Federal Office of Civil Defense
TWP	Technical directives for private shelter construction
BMG	Federal law of 4 October 1963 concerning measures to be taken for civil defense construction
BMV	Decree of 15 May 1964 concerning measures to be taken for civil defense construction
MZS	Civil defense information sheet
SEV	Swiss Electrotechnical Society
SIA	Swiss Society of Engineers and Architects
EMPA	Federal Bureau for Testing Materials
SR	Shelter room
RE	Decontamination room
S	Air lock
T	Toilet
PT	Blast door
PD	Blast hatch
DT	Pressure door
FW	Escape passage
NA	Emergency exit
FR	Escape tunnel
MD	Wall break-out panel
MDS	Wall exit
H	Height from ground level to roof (gutter)
NL	Natural ventilation
FRL	Fresh air ventilation
FIL	Ventilation through gas filters
LF	Air intake
AL	Air outlet
ESV	Explosion protection valve
VF	Primary filter
GF	Gas filter
VA	Ventilating apparatus
UV	Excess pressure valve (blast valve)
UK	Lower level
OK	Upper level
P	Pressure (force per unit area)
g	Acceleration of gravity
g_e	Weight of the structure
σ_{Bzul}	Allowable soil pressure under peace conditions
σ_{fld}	Stress in the plastic range due to dynamic loading of the reinforcing steel
β_w	Compressive strength of concrete cubes
μ	Percent of reinforcing steel in the concrete section
m_x^+, m_y^+	Bending moments in the plastic range per unit length around the major and minor axes at the center of a concrete slab
l_1, l_2	Short and long span of a rectangular slab
d	Depth of concrete slab or beam
h	Effective depth of concrete to reinforcing
λ	Degree of plastic fixity, relation of m_x^- to m_x^+
x	Ratio of the plastic bending moment in the minor and major axes $x = m_y^+ : m_x^+ = m_y^- + m_x^-$

Chapter 1. Basic Data and Assumptions

1.1 LEGAL BASIS AND DOMAIN OF APPLICABILITY

Article 2 of the Federal Law of 4 October 1963[1] concerning The Construction of Civil Defense requires the creation of the necessary shelters in all new structures and for all renovation for the protection of the population. According to article 8 of the same law the additional costs attributable to civil defense should not comprise more than 5% of the total building cost (not including land). Contributions can be paid toward further increases in civil defense costs when they are technically justified. This is the case when an improvement in the shelter or its furnishing is in the public interest (Article 10 of the law of 15 May 1964 concerning the Construction of Civil Defense[2]).

These instructions apply to the construction of private defense shelters with a protective range of 1 to 3 atmospheres pressure. They are applicable to cast-in-place concrete shelters of approximately rectangular floor plan and section which are to be constructed as a part of a new building.

The preparation of directives requires a number of simplifying assumptions by their very nature, especially as regards the effect of weapons and the effectiveness of many parts of the shelter. These simplifications are especially evident in Appendix C which contains practically complete solutions for typical small shelters These solutions can therefore only be applied directly to small shelters without further study. For shelters with more than 25 occupants the arrangement and dimensions must be determined according to chapters 2 and 3.

Large installations, multi-purpose structures, tunnels, and prefabricated shelters as well as installations for civil defense units require special attention. Until the issue of appropriate technical directives for the design of such installations and equipment, the guideline published by the Federal Office of Civil Defense of 23 April 1965[3] and the supplement of 4 March 1966[4] shall apply. Detailed data may be obtained from the Weapons Effect Handbook (1964 Edition, Office of Civil Defense).

Deviations from these Technical Directives for Civil Defense Shelter Construction may only be made on the basis of competent and recognized sources which can prove that the prescribed extent of protection can be achieved by economical means.

1.2 EXTENT OF PROTECTION

The extent of protection for private shelters will, in general, be determined for one atmosphere of overpressure. (See the Recommendations of the Federal Office of Civil Defense of 23 April 1965[3] concerning minimum requirements for construction.)

The possibility is thereby left available to the Federal Department of Civil Defense to set other limits of protection (3 atmospheres as a rule) at the request of a Canton in special cases. In judging the protection offered by a civil defense shelter one must avoid the conception that a 3 atmosphere design, for example, is worth three times as much as a one atmosphere shelter. It can be shown that for an equivalent population density the probability of survival is increased by only about 25% when the limit of protection is raised from 1 to 3 atmospheres.

The following may be considered as special cases in which the Federal Office for Civil Defense maintains their normal contribution even for a limit of protection of three atmospheres:

1. The increase of the protection limit from one to three atmospheres does not increase the cost of the shelter more than 25%.
2. The 5% rule (article 8, paragraph 1 of the Federal Law of 4 October 1963[1]) is still respected.

1.3 ASSUMED USE OF THE SHELTER

It has been assumed that the concept of entry, habitation, and leaving of a shelter will probably be different than, for instance, it was during the last world war. For the planning of shelters it is advantageous to distinguish between the following four phases of shelter use and to investigate their requirements on shelter space separately.

1.3.1 Peace Phase

During peacetime the shelter will be used as a cellar or storage room. With reference to the economy of civil defense measures these peacetime uses should be impeded as little as possible. These requirements should especially be considered by the arrangement and design of the entrances, the lighting, the moisture-proofing, sanitation, furnishing, utilities, and the natural ventilation.

1.3.2 Pre-Attack Phase

The time between the recognition [and arrival] of approaching bombs or rockets, the so-called warning time, has been assumed to be very short and is not sufficient to move into the shelter.

The authorities will therefore instruct the population to live in their shelters during any threatening or existing state of war. It must be possible to prepare the shelter for war within 24 hours for habitation by the occupants. This changeover from the peacetime to the pre-attack phase requires the accomplishment of the following works:

1. Evacuation of all objects unnecessary to civil defense.
2. Introduction of all the necessary supplies such as food, water, sanitary supplies, etc., that are not already stored in the shelter.
3. Furnishing of the shelter with seats and bunks, communication equipments (battery radio), and tools to dig out with.
4. Sealing of all openings of the shelter, as well as checking the ventilation equipment, the air intake, and the emergency exit.

Until the attack or the "all clear (Endalarm)" days or weeks may pass. During this time of occupation there is a limited traffic between the shelter and the outside world, which may permit the execution of the most important work as well as the supply of food.

1.3.3 Attack Phase

This is the phase when the shelter is actually subject to the effect of weapons such as thermal and light radiation, primary nuclear radiation, air pressure and concussion, falling debris, shrapnels, fire, and gas.

1.3.4 Post-Attack Phase

If an atomic explosion has taken place close to the ground one must assume a stay in the shelter of several days or even weeks because of the radioactive fallout. This stay may be interrupted immediately after the attack or after several days in order to accomplish the most necessary work, but only for a limited period. Gradually the time spent outside of the shelter may be increased according to the recommendations of the ABC service of the civil defense corps and may be used for cleanup work, for example. The different operational phases often place conflicting requirements on the arrangement of the shelter. The more thoroughly the designer analyses these requirements the closer he will come to a balanced and economical solution for any individual project.

1.4 APPLIED FORCES ON THE SHELTER DURING THE ATTACK PHASE

1.4.1 Assumed Threat

It is assumed that the civilian population is primarily threatened by atomic weapons of medium to large size but also secondarily by chemical, biological, and conventional weapons. Although the design and dimensions are principally determined for atomic weapons it can be established that a good atomic shelter offers good protection against chemical, biological, and conventional weapons whereas the converse is not always true.

1.4.2 Protection against Atomic Weapons

1.4.2.1 Development of the explosion. In the instant of explosion a strong radiation of heat and light lasting several seconds is emitted. Simultaneously the initial nuclear radiation begins. The shock wave strikes the shelter several seconds after the explosion. With its arrival a wind several times stronger than a hurricane begins. This lasts as long as the excess pressure, that is to say a few tenths of a second or a few seconds for large bombs. At the same time large quantities of debris are hurled through the air. Flammable material will be ignited by the heat rays. If the explosion is near the ground radioactive fallout can begin after half an hour and last many hours or days.

1.4.2.2 Mechanical effect. A 1 atmosphere shelter can withstand the effects of an atomic explosion at that level distance where the maximum atmospheric over-

Table 1-1. 1 and 3 atmo. distances for low level explosions

Energy equivalent	Distance for a pressure of	
	One atmosphere	Three atmospheres
1 KT[a]	0.3 km (0.2 miles)	0.2 km (0.15 miles)
10 KT	0.6 km (0.4 miles)	0.3 km (0.2 miles)
100 KT	1.2 km (0.8 miles)	0.7 km (0.4 miles)
1 MT[b]	2.6 km (1.6 miles)	1.5 km (0.9 miles)
10 MT	5.6 km (3.5 miles)	3.2 km (2 miles)
100 MT	12.0 km (7.5 miles)	7.0 km (4.4 miles)

[a] 1 KT = 1 kiloton = energy equivalent of 1000 tons of TNT (trinitrotoluol).
[b] 1 MT = 1 megaton = energy equivalent of 1 million tons of TNT.

pressure is 1 atmosphere. The bomb size and ground distances for which an overpressure of 1 and 3 atmospheres occur for a low level bomb are listed in Table 1-1.

For comparison, the bombs dropped on Hiroshima and Nagasaki in 1945 were 12 and 22 KT respectively.

Figure 1-1 shows the magnitude of the overpressure acting from all sides as function of the distance from the explosion center of a low level bomb of 1 KT and 1 MT equivalent energy.

The air pressure creates a pressure wave in the ground similar to that of an earthquake. The approximate strength of this shock is given in Table 1-2. These are indicative values which apply to unfavorable, that is, soft ground. In a hard ground the velocities and deformations are smaller. Higher instantaneous accelerations than those given in Table 1-2 occur. These peak values can generally be neglected in the design.

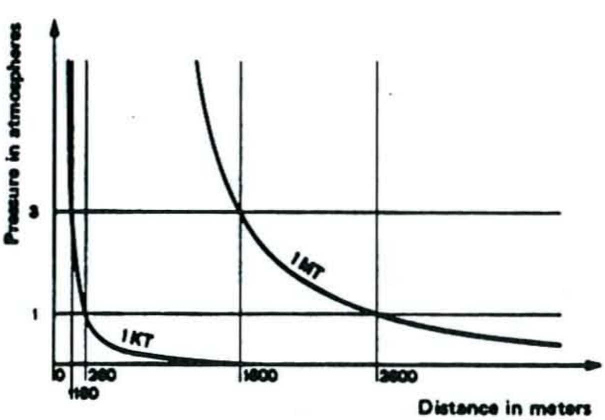


Fig. 1-1. Maximum overpressure as a function of the distance from the explosion center for a ground level explosion.

Table 1-2. Concussion on a shelter due to an atomic explosion

	Concussion of the shelter	
	1 atmos.	3 atmos.
Acceleration	2 g[a]	6 g
Velocity	0.5 m/s (1.5 ft/s)	1.5 m/s (4.5 ft/s)
Displacement	0.5 m (1.5 ft)	0.7 m (2.8 ft)
Relative displacement between shelter and ground	5 cm (2 in.)	7 cm (3 in.)

[a] 1 g = gravitational acceleration = 9.81 meters/sec^2 (32.2 ft/sec^2).

1.4.2.3 Initial nuclear radiation. The initial nuclear radiation is propagated outward from the fireball of the explosion in a similar way as light. The following radiation intensities are created by the explosion of an atomic bomb:

1. At a distance corresponding to 1 atmos. pressure for a 10 KT explosion, explosion height zero: 20,000 roentgens.
2. At a distance corresponding to 3 atmos. pressure for at 10 KT explosion, explosion height: low 70,000 roentgens.

For larger bombs the radiation in the 1 and 3 atmos. pressure zones is less, and by smaller bombs it is more than the values indicated.

The permissible radiation in the shelter has been set at 100 roentgens. For bombs bigger than 10 KT the radiation protection offered by shelters designed according to these Technical Directives is greater than necessary; for smaller bombs it may be too little. In addition the radiation intensity (for a given pressure) is dependent on the explosion height and the direction of the explosion with respect to the shelter.

1.4.2.4 Radioactive fallout. The radioactive bomb debris, which is mixed with vaporized material from the ground in the case of ground level explosions, are blasted upward and condense to dust and sand-like particles after cooling. These are precipitated after hours or days and give maximum local radiation doses of 20,000 roentgens. The maximum rate of dosage is to be reckoned as 5,000 roentgens per hour. Shelters which are dimensioned according to these Technical Directives provide sufficient protection against this slightly penetrating radiation so that the dosage inside the shelter resulting from secondary radiation is generally negligible.

1.4.2.5 **Projectiles, debris, and dust.** The shock of the atom bomb hurls whole sections of buildings and installations through the air. The shelter walls resist this effect, which can present one of the greatest dangers for the unprotected person near an atomic explosion.

The load caused by the debris from collapsing houses occurs only after the air pressure from the shock has diminished and is carried by the shelter.

An enormous quantity of dust is created from this debris. This dust must be kept out of the shelter by the airtight walls and the filter for the artificial ventilation.

1.4.2.6 **Thermal effect.** The heat and light radiation from atomic bombs – which is one of the greatest danger for the unprotected person – is not influential for the occupants of a shelter. Burning or glowing debris can, however, heat the roof and walls which are not against the earth to such an extent that it could be a determining factor for the design of a shelter.

1.4.3 Protection against Chemical and Biological Agents

The constant positive pressure which is maintained by the artificial ventilation in the interior of the shelter as well as the gas filter and air locks used for large shelters offer a relatively good protection against the penetration of biological or chemical agents into the shelter.

1.4.4 Protection against Conventional Weapons

Shelters which are designed according to these directives are approximately equivalent to types of shelters used in the past as regards the threat from conventional weapons. They are in general not safe against a direct hit by a demolition bomb. Protection is nevertheless offered against concussion and fragments from bombs and shells which fall within a distance corresponding to approximately the conical radius of the explosion, i.e., 5 yards for a bomb with 500 pounds of explosive. Firebombs will not generally be able to pierce the shelter. The shelter roof can also be heated for only a relatively short period by a fire bomb so that this heating is less critical than that caused by the smoldering debris mentioned in article 1.4.2.6.

1.4.5 Protection against Secondary Effects

1.4.5.1 Flooding

1. Limited flooding may be caused by broken conduits or the backing up of destroyed sewers. The proper positioning of the air inlet for the ventilation and attention to the seals around other apertures can protect the occupants against the penetration of this water.
2. Atomic explosions in a lake can cause a flood wave in the area near the shore or down the valley. Since this is of relatively short duration a catastrophic penetration of water into the shelter is not possible. What is important is the drainage of the escape passageways and the connecting cellar.
3. The destruction of a dam could create a flood wave of longer duration in the valley downstream unless this danger is avoided by the precaution of previously lowering the water level. The ventilation can be turned off for approximately 5 hours due to the required minimum volume of the shelter specified by article 2.1.1.3. This and the airtightness of the shelter will provide a certain amount of protection against this type of flooding.

1.4.5.2 Landslides

1. The pressure wave of an atomic explosion can cause landslides or rockfalls in mountainous terrain which may endanger the occupants by blocking the exits.
2. Near lakeshores which consist of shock sensitive soils such as chalk the shelter may be endangered by landslides triggered by the shock wave caused by an atomic explosion.

The Federal Office of Civil Defense is publishing special directives for those areas which are especially endangered by secondary effects. Until their release measures will be determined for each case.

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1. MZS 1.27.
2. MZS 1.64.
3. MZS 2.91.
4. MZS 4.

Chapter 2. Shelter Planning

2.1 DESIGN ELEMENTS FOR THE SHELTER SHELL

2.1.1 Shelter Size

2.1.1.1 Types of shelters

1. The single shelter consists of one cell with a capacity of up to 50 people (Fig. 2-1a).
2. The shelter group is divided into groups of cells each containing a maximum of 50 people and has a total maximum capacity of 200 persons. The cells are surrounded by only one exterior shell and have only *one* entrance (Fig. 2-1b).

Several shelter groups may be situated next to or on top of each other if decentralization is not possible. For

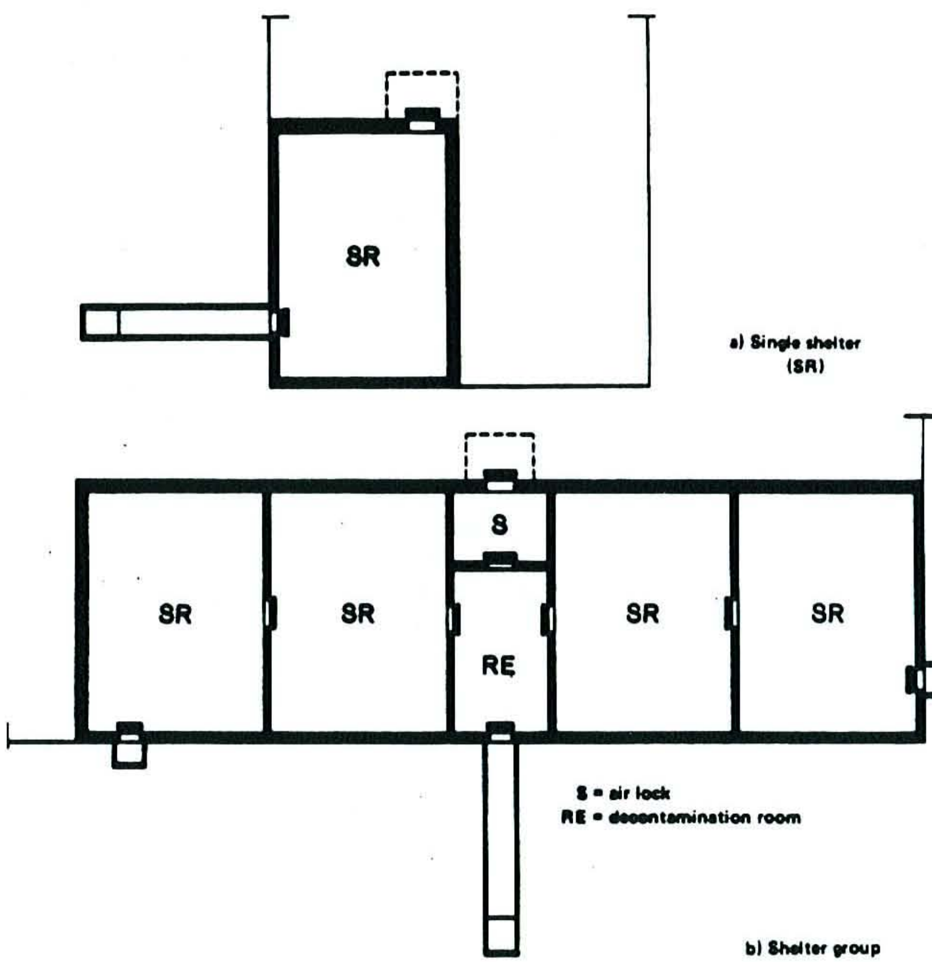


Fig. 2-1. Floor plans of the two shelter types.

large installations a more appropriate solution can often be found by considering the special local conditions as well as the uses rather than simply stringing together standard shelters.

2.1.1.2 The number of places in the shelter. The number of places in the shelter should be equal to the number of persons who normally occupy the building. The requirements for different types of buildings are indicated in Table 2-1. Deviations above or below this number may be authorized by the cantons in individual cases for special reasons. In this case the number of shelter spaces available in a fixed area should be taken into consideration.

Table 2-1. The required number of places in a shelter

Type of building	Number of places in the shelter[a]
Homes and vacation houses	1 per room
Hospitals and nursing homes	1 per bed
Hotels	⅔ per bed
Restaurants, places of amusement (movies, theatres, etc.), schools, auditoriums, and assembly halls	⅔ the number of seats
Churches	½ the number of seats
Offices, administration buildings; industrial and commercial business (factories and shops)	⅔ the number of working places
Stores, warehouses	1 per 20 m^2 (200 sq ft) floor space
Storehouses, permanent exhibitions	1 per 150 m^2 (1500 sq ft) floor space

[a]The figures listed in article 2.1.1.2 are offered here only for the sake of completeness. They cannot be the object of a technical directive since they are affected by the civil defense concept. It is expected that they will be modified at some later date.

2.1.1.3 Minimum space requirements. The following declarations for floor space and volume are provided as a guide:

1. Space requirements per shelter place:
   - floor space — 1 m^2 (10.8 sq ft)
   - volume — 2.5 m^3 (88 cu ft)
2. Additional space requirements:
   - floor space for each ventilator — 1 m^2 (10.8 sq ft)
   - floor space for air lock — 0.05 m^2 (0.54 sq ft) per shelter place
   - floor space for decontamination room — 0.07 m^2 (0.76 sq ft) per shelter place
   - floor space for combined air lock and decontamination room — 0.1 m^2 (1.1 sq ft) per shelter place
3. Minimum size regardless of the number of shelter spaces:
   - floor space for a shelter — 6 m^2 (65 sq ft)
   - floor space for an air lock (max. 54 sq ft) — 2.5 m^2 (27 sq ft)
   - floor space for decontamination room — 3.5 m^2 (38 sq ft)
   - floor space for a combined air lock and decontamination room — 5 m^2 (54 sq ft)
   - ceiling height — 2.0 m (max. 3.0 m) [6′–6″ (max. 10 ft)]

2.1.2 Location of the Shelter

2.1.2.1 Structural requirements. The position of the shelter must satisfy both structural requirements from the shelter standpoint and the requirements for peacetime use. The following is a summary of the structural requirements:

1. The shelter should be as deep underground as possible. Reason: Protection from radiation and flying projectiles and debris.
2. The shelter should have as much of its external surface against the ground as possible. Reason: Protection against radiation, fragments, and projectiles; conduction of heat generated by the occupants of the shelter, protection from heat caused by external fires. Utilization of the support provided by the surrounding soil.
3. The shelter should be located under the massive parts of the building. Reason: Protection against radiation, conventional bombs, and fire.
4. The shelter should be located as far as possible from potential fuel concentrations such as oil or gasoline tanks, large groups of motor vehicles, depots for flammable materials such as wood or plastics. Reason: Reduction of heating effect, intake of clean and cool air by the ventilation.
5. The shelter should be placed so that short emergency exits and air inlets can be extended on several

sides of the building into zones that are free from debris and as free of danger from fire as possible. Reason: Better possibility of unaided exit and intake of fresh air.

2.1.2.2 **Position in relation to ground water.** Those shelters shall be termed in ground water where the highest yearly ground water level rises more than 18 inches above the elevation of the shelter floor. When this location for the shelter cannot be avoided the following points must be observed:

1. The parts of the structure lying in the ground water must be protected by a flexible waterproofing which has at least the same ductility as the reinforcing steel at a temperature of 8°C (46°F) (waterproof plaster is insufficient).
2. The parts of the structure under the ground water level are to be designed for a pressure 20% higher than that indicated for saturated ground in order to keep the crack small.
3. The emergency exit must lie above the ground water level.
4. The shelter floor must have a slope of at least 0.5%. A pump sump is to be constructed at least 25 cm (10 inches) deep and 40 cm (16 inches) square. A hand pump is to be installed with a capacity of 0.1 l per square meter (0.025 gallons per minute per sq ft) of external wall surface lying under the water level.
5. Where the ground water level is high the shelter can be partially or entirely constructed above ground. In this case the walls and roofs must be thicker in proportion to the heavier radiation (see section 3.3) and the entrance should have a closed cross section as shown in article 2.2.2.2.

2.1.3 Structural Dimensions for Preliminary Design

For the preliminary design of shelters or for the application for building permits the indicative values for concrete dimensions given in Table 2-2 and Fig. 2-2 can be adopted. This table is based on rough approximations. These values will give an overdimensioned design in many cases, especially in terms of nuclear radiation. Therefore the final determination of the structural dimensions must be done according to the detailed data given in chapter 3. The design for a "typical small shelter" in Appendix C may be used as an alternate solution to the detailed analysis of chapter 3 only for 1 atmosphere shelters of little importance (up to 25 places).

2.2 ENTRANCES AND EMERGENCY EXITS

2.2.1 Purpose

The requirements for protection during an attack phase could best be fullfilled if the shelter were to be completely enclosed by a shell of the necessary resistance. However, the need to penetrate this shell with entrances and exits as well as ventilation conduits during the peacetime phase and the before and after attack phases stands in direct contradiction to this. The consideration of these conflicting requirements makes

Table 2-2. Structural dimensions for preliminary design

Structural element	Location	Thickness, cm (inches) 1 atm.	3 atm.
Ceilings	Under buildings	35 (14)	55 (22)
	Not under buildings with soil cover of:	55 (22)	85 (33)
	0 cm		
	30 cm (12")	35 (14)	65 (26)
	more than 50 cm (20 inches)	30 (12)	50 (20)
	Between floors	20 (8)	20 (8)
	Between floors and over or under an air lock	25 (10)	30 (12)
Walls	Entirely in contact with soil (ceiling below ground level)	25 (10)	25 (10)
	Partially in contact with soil (ceiling 60 cm (2 ft) or less above ground)	50 (20)	70 (27)
	Exterior wall uncovered (ceiling more than 60 cm (2 ft) above ground)	80 (32)	120 (48)
	Shelter wall against cellar (or partition between shelter groups)	35 (14)	55 (22)
	Partitions between shelter rooms	20 (8)	20 (8)
	Inner walls of air lock	25 (10)	30 (12)
Floors	Foundation slabs	20 (8)	25 (10)

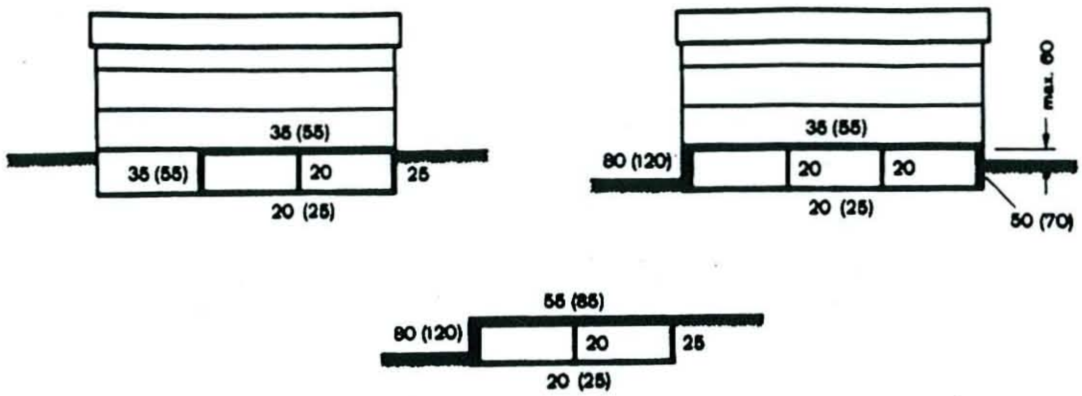


Fig. 2-2. Structural dimensions (in mm) for preliminary design according to Table 2-2. (The values in parentheses are for 3 atm. shelters.)

the design and location of the entrances and exits one of the most difficult jobs of shelter construction. The consideration of the requirements of the various operational phases should include the following facts:

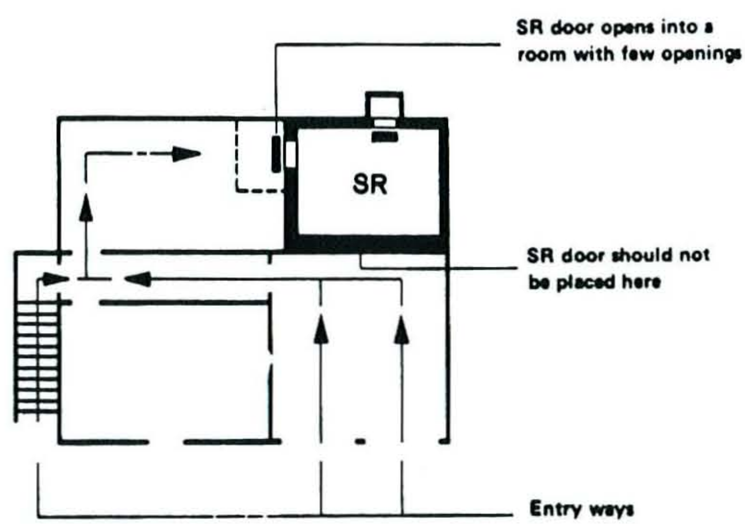
The communication between the shelter and the outside world during the peace and pre-attack phase (and if possible during the post-attack phase) should take place through the entrance (article 2.2.2) passing the air lock and the decontamination room. The emergency exit should only be used if the main entrance is destroyed. The air lock and decontamination room (article 2.2.2.3) will be necessary in the pre-attack phase and in case of contaminated outside air. They will normally be placed in the entrance. The emergency exits (article 2.2.3) improve the possibility of the occupants being able to free themselves after an attack which creates debris. Since all openings represent a weakness in the shelter cover their size and number should be limited to the minimum necessary. Every passageway through the shelter cover should be provided with a closure in accordance with article 2.2.4.

2.2.2 Entrances

The entrance to the shelter consists of the entry way to the shelter, the debris protection for the door, the door itself, and for larger shelters, the air lock and the decontamination room (closures for entrances and exits, see article 2.2.4).

2.2.2.1 Entry way. The entry way must not only serve its purpose as an access but it must also act as an adequate radiation barrier since even a closed door represents a weak spot in the protection against nuclear radiation offered by the shelter cover. The entry to the

Fig. 2-3. Location of entry ways.



shelter must therefore be arranged in the following manner:

1. It should be as narrow as possible and deep under ground or under some massive parts of a building.
2. It should have the fewest possible openings directly outside or into rooms with many direct openings to the exterior.
3. It should avoid the danger of being buried by debris as much as possible. (There are more possibilities for escape through the piles of debris formed by coherent structural elements such as those made of steel or reinforced concrete than there are through the more tightly packed piles of masonry, plaster, or wood.)
4. When an entrance without an air lock leads through an exterior shelter wall more than 40 cm (16 inches) thick the protection against radiation must be improved by a passage way before the entrance. The wall and roof elements must be at least 20 cm (8 inches) thick and the length of the passage way must be at least four times the width. This passage way may be combined with the debris protection for the entrance door (Fig. 2-5).

Entry ways may be reinforced to become actual emergency exits by constructing them as escape ways (see article 2.2.3.3).

2.2.2.2 Protection of the door from falling debris. In order to improve the possibility of the occupants being able to free themselves the danger of a blockage of entrance to the shelter by piles of debris must be kept to a minimum. For this purpose either an entry way at least 2 meters (6 feet) long must be provided (Fig. 2-5) or a concussion-proof cantilevered slab projecting over the door, which are safe against an air blast. The minimum dimensions of this cantilevered slab are 1.3 X 2.0 m (4 X 6 feet).

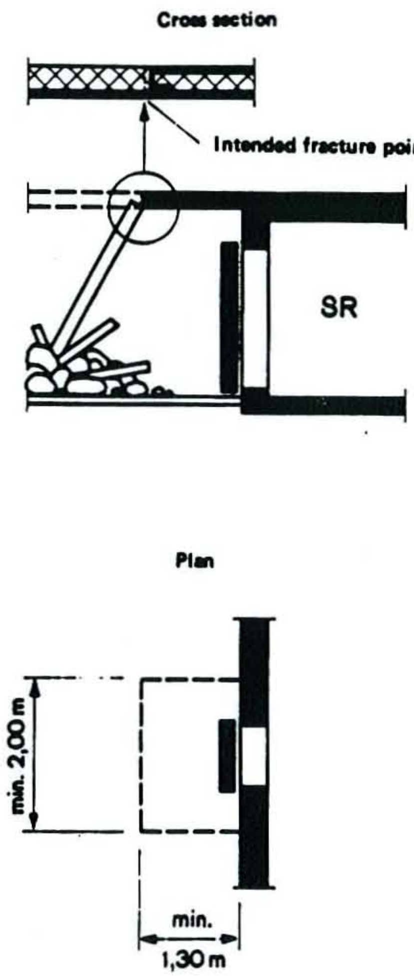


Fig. 2-4. Cantilever slab safe against air blasts as protection of the entrance door against falling debris.

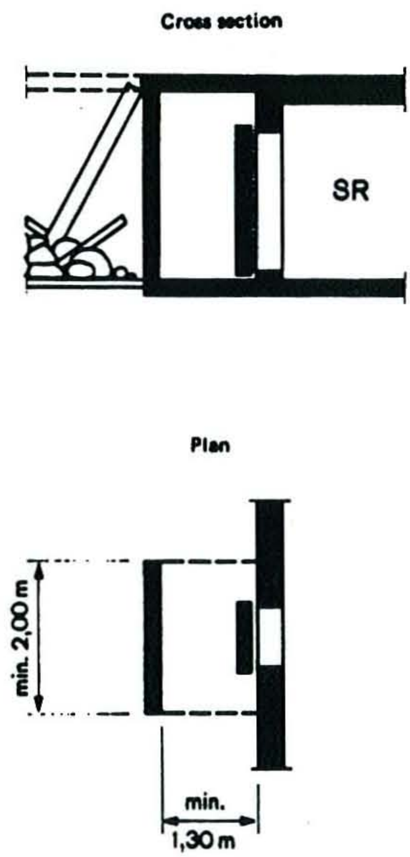
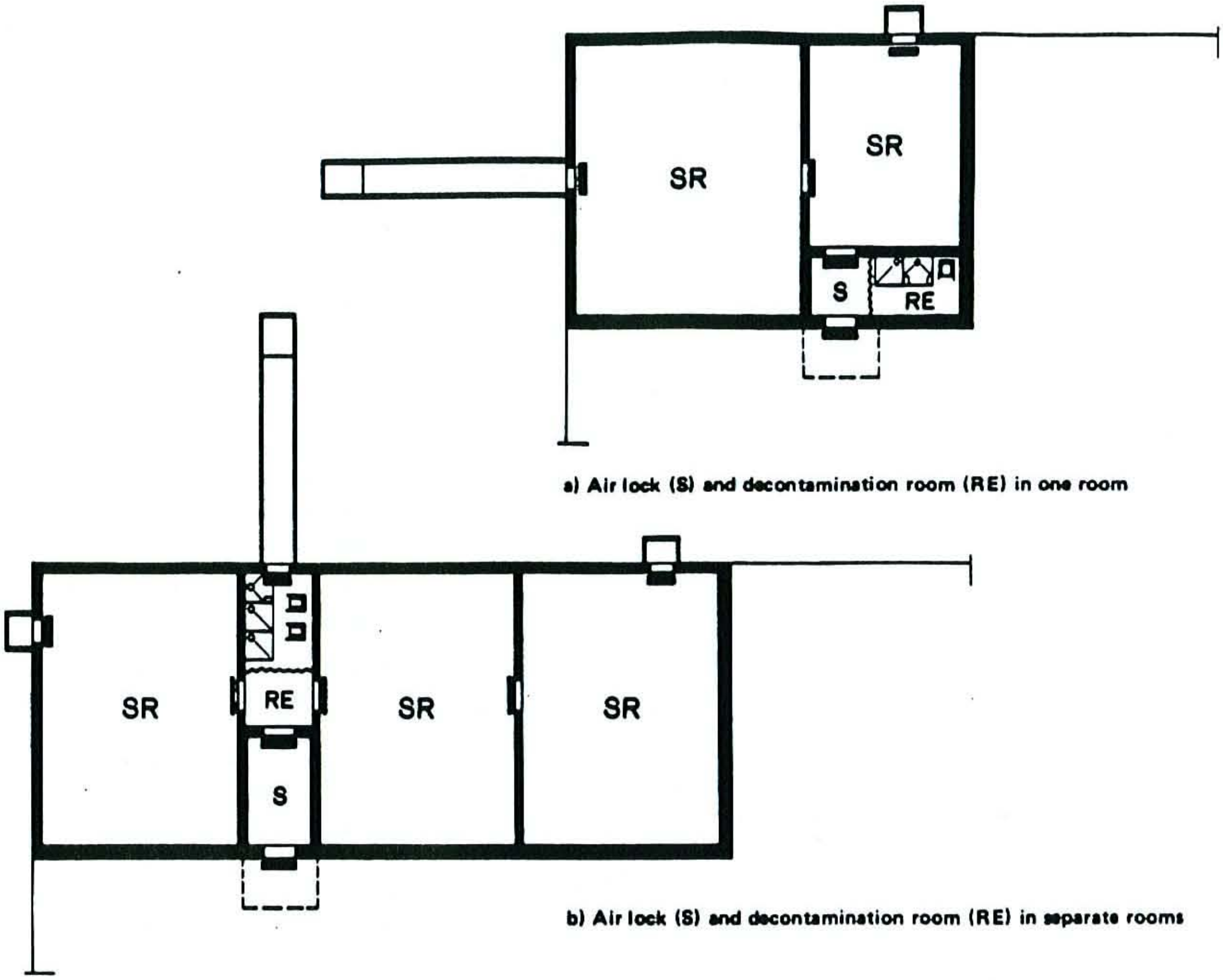


Fig. 2-5. Passage-way safe against air blasts as protection for the entrance against falling debris.



a) Air lock (S) and decontamination room (RE) in one room

b) Air lock (S) and decontamination room (RE) in separate rooms

Fig. 2-6. Arrangement of air locks and decontamination rooms.

2.2.2.3 **Air locks and decontamination rooms.** The air lock is an anteroom with two pressure and gas tight doors (armour-plated) in series which are never to be opened at the same time. Thus even if there is traffic between the shelter and the outside there is never an instant during which the shelter cover is open to penetration by radiation, pressure, or dust.

For a given rate of exhaust air a small air lock is better purged than a large one. The air locks should therefore not be much larger than the suggested minimum dimensions given in article 2.1.1.3 unless there are special traffic problems.

The decontamination room serves as a cleaning and dressing room for persons entering contaminated by poison gas or radioactive dust. (Contaminated clothes should be stripped off and left outside the shelter.) The decontamination room is used also to store the protective clothing (coats, boots, helmets, gloves, gasmasks, etc.) which must be worn at all times by persons leaving the shelter. At least one shower per 100 persons and one toilet for each 30 persons should be built into the decontamination room. Half of the toilets may be built as dry sumps and the rest as latrines.

The air lock and the decontamination room may be combined into a single room for shelters with less than 100 places (see Fig. 2-6a). The requirements for the inclusion of these rooms is determined according to Table 2-3.

Table 2-3. Requirements for the inclusion of air locks and decontamination rooms

Number of places	Inclusion	Air lock and decontamination room
50 or less	Optional	Combined
51 to 100	Required	Combined or separate
101 to 200	Required	Separate

2.2.3 Emergency Exits

2.2.3.1 The requirements for escape without outside help. The occupants of any shelter should be able to free themselves from the shelter after an attack (the principle of escape without outside help). Since the unreinforced entrance may not be passable under some circumstances, other escape possibilities must be provided. The different types of emergency exits are divided into four categories in the order of their dependability:

Category I: Air blast-proof escape passage under the building and through to the outline (article 2.2.3.3).

Category II: Emergency escape-shaft (article 2.2.3.4).

Category III: Escape-tunnel or -chimneys ending within the area of falling debris (articles 2.2.3.5 and 2.2.3.6).

Category IV: Escape-tubes which end outside the debris area or are connected to escape-tube systems (Article 2.2.3.5).

The construction necessary in order to improve the possibilities for the occupants to free themselves depends on the number of places in the shelter and the degree of danger from falling debris. Economic considerations indicate that an expenditure of approximately 10% of the shelter cost is acceptable. The appropriate arrangements of emergency exits for various sizes of shelters are summarized in Table 2-4. These are minimum requirements.

2.2.3.2 Location of the emergency exits. The basic rules for exit arrangement are all derived from the requirements during the attack and survival phase and may be summarized as follows:

1. Emergency exits from the same shelter should end at different sides of the building (if possible opposite sides) and as far as possible from each other.
2. The escape-tunnels should terminate outside the area of falling debris from the building and neighboring buildings if possible (article 2.2.3.5).
3. Escape-tunnels or connections to escape-tunnel systems should be given preference over other emergency exits.
4. The adjacent cellars of row houses should have connecting doors.

Figures 2-7 to 2-10 show the arrangement of emergency exits according to the minimum requirement given in Table 2-4.

2.2.3.3 The design of air blast-proof escape passages. An air blast-proof escape passage from a shelter shall be provided either by a shaft accessible through a wall (Fig. 2-8a) or by passing through an armoured door (Fig. 2-9b) which leads through a cellar out into the open. The shortest possible route should be chosen with the narrowest ceiling span. Examples are given in Fig. 2-11.

Table 2-4. Minimum provisions for escape without outside help

Number of shelter places	Minimum number of emergency exits for category I (escape-way)	II (escape-shaft)	IV (escape-tube)	Figure
13 or less		1		2-7
14 to 50	1	1		2-8a
			1	2-8b
51 to 100		1	1	2-9a
	1	2		2-9b
101 to 200	1	1	1	2-10a
		2	1	2-10b

Note: Emergency exits of category III (escape-shafts and escape-tubes ending in the area of falling debris) may only be used as a partial replacement of category IV exits and only in the case that it is not possible to end the escape-tunnel outside the debris area. In this case a supplementary exit of category I or II is to be added.

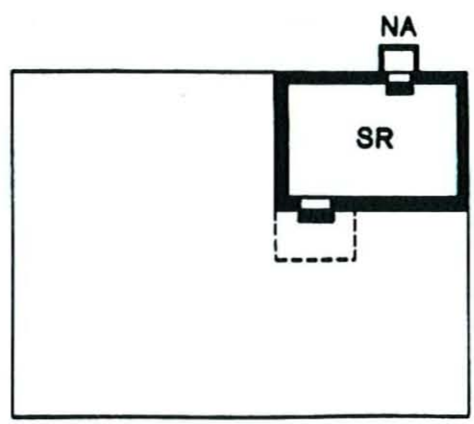
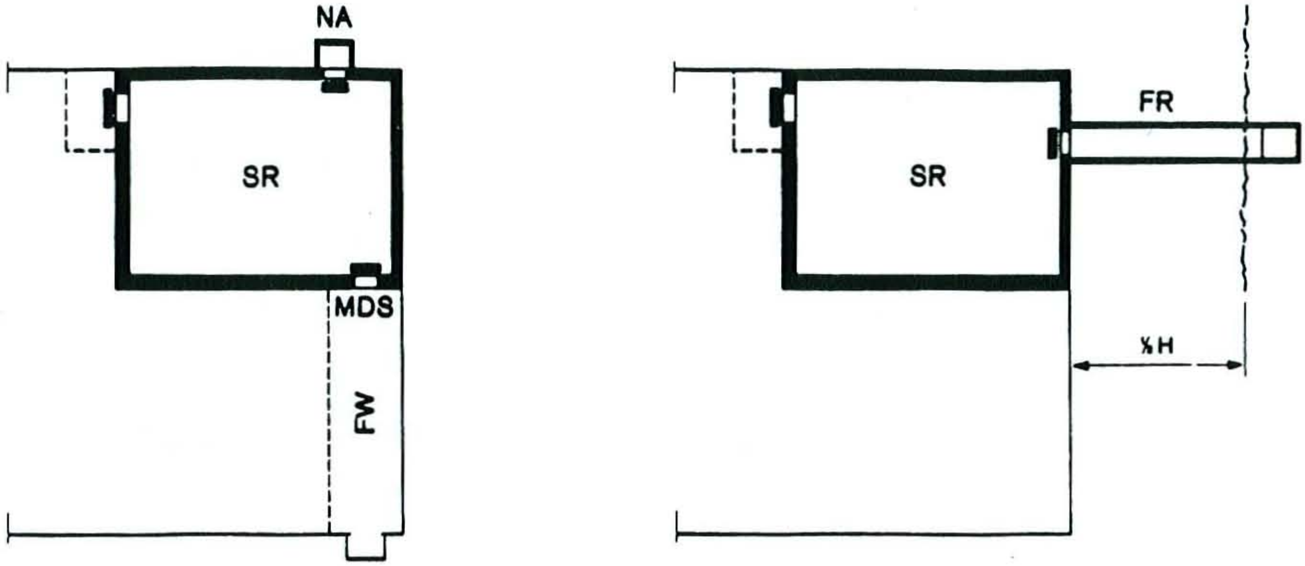


Fig. 2-7. The minimum provisions for the occupants of a shelter of up to 13 places for escape without outside help.



a) 1 Emergency shaft (NA) and
1 escape passage (FW)

b) 1 Escape-tunnel (FR)

Fig. 2-8. The minimum provisions for the occupants of a shelter of 14 to 50 places for escape without outside help.

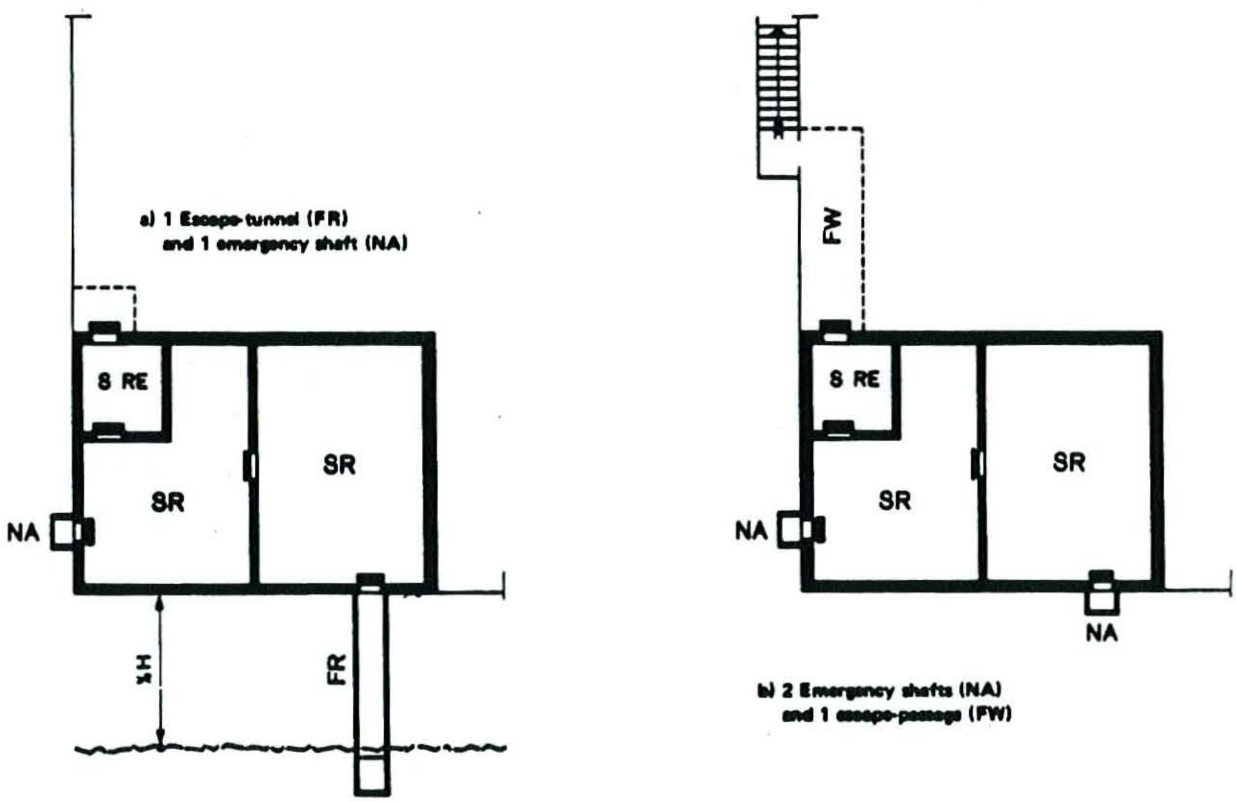
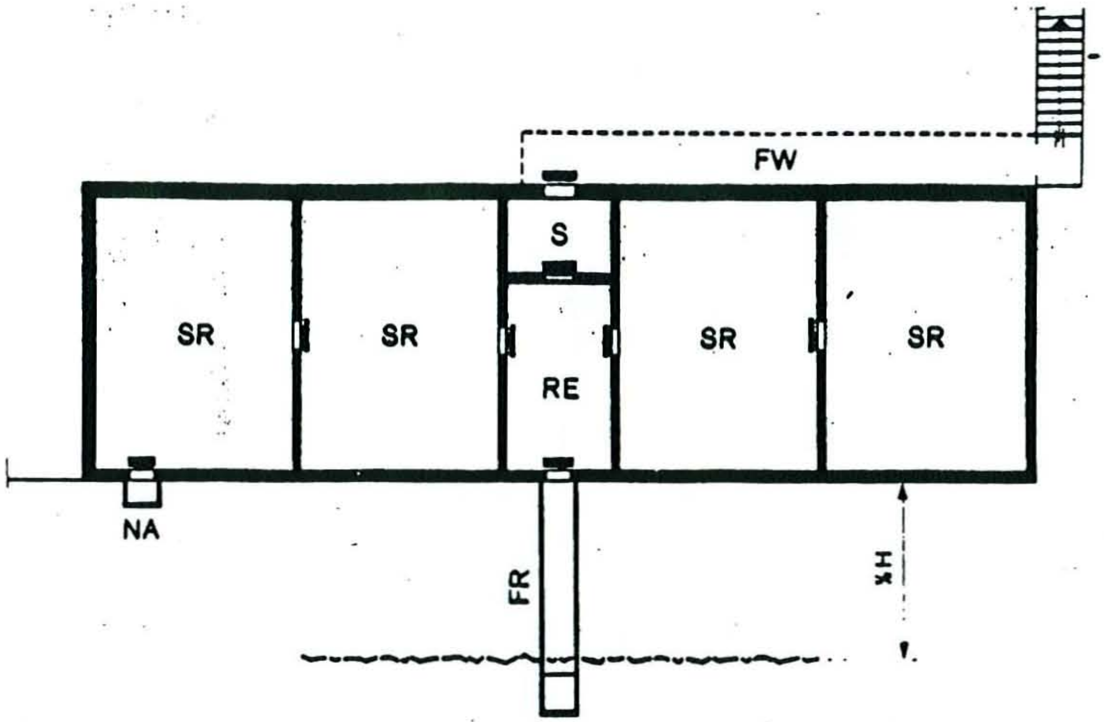
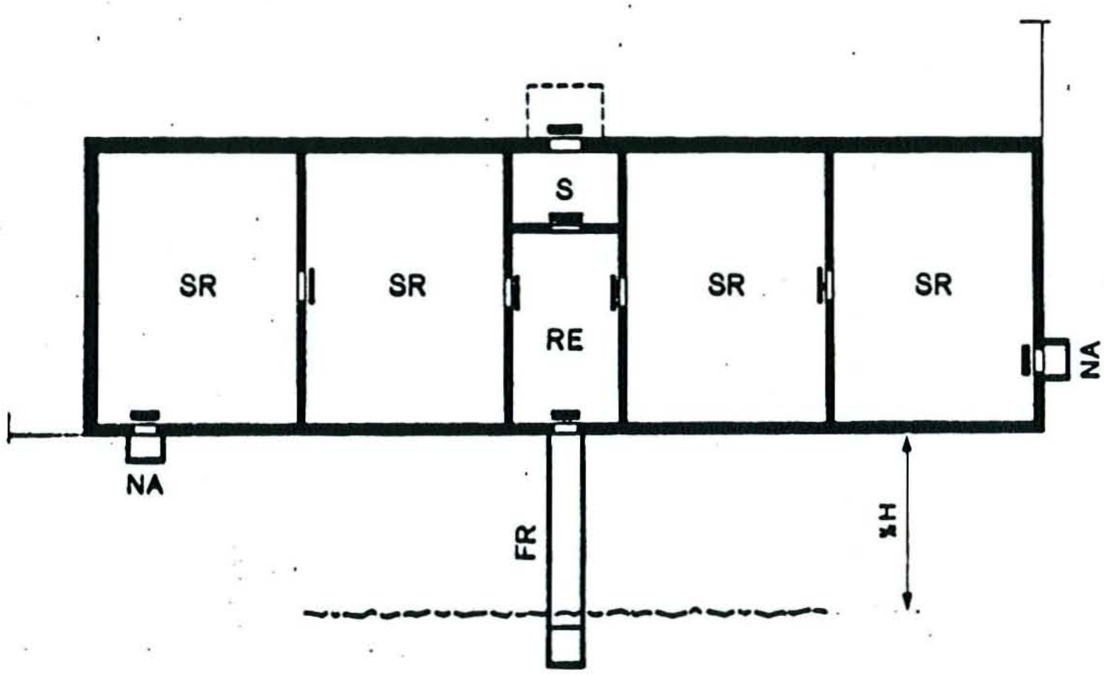


Fig. 2-9. Minimum provisions for the occupants of a shelter of 51 to 100 places for escape without outside help.



a) 1 escape-tunnel (FR), 1 emergency shaft (NA) and 1 escape-passage (FW)



b) 1 escape-tunnel (FR) and 2 emergency shafts (NA)

Fig. 2-10. Minimum provisions for the occupants of a shelter of 101 to 200 places for escape without outside help.

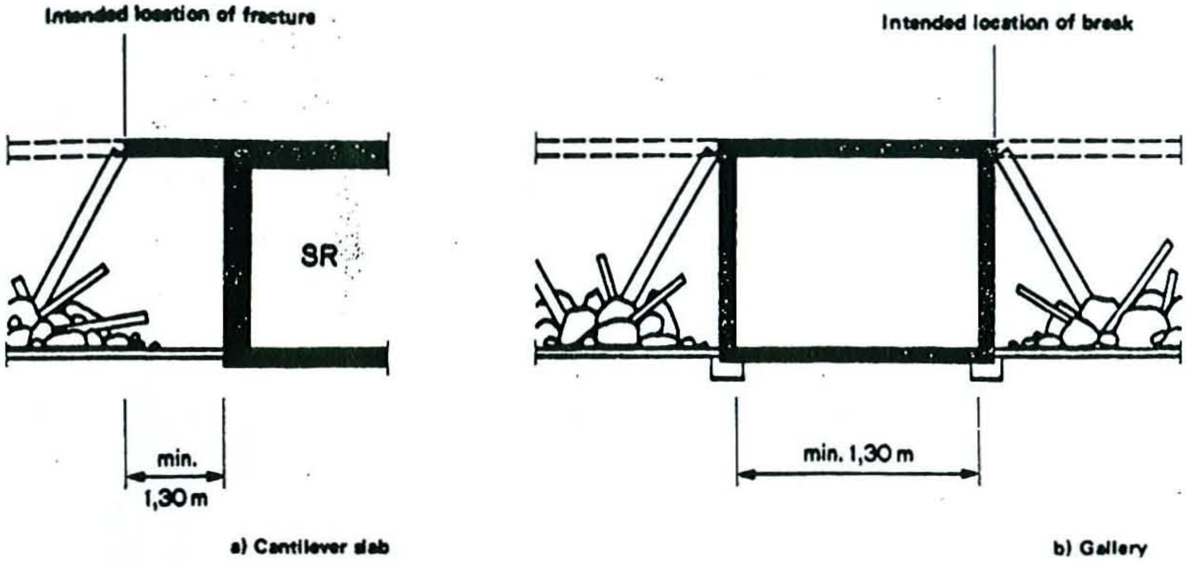


Fig. 2-11. Examples of concussion-proof escape-passages.

2.2.3.4 Design of emergency escape-shafts. Emergency escape-shafts lead through the shelter shell directly to the outside. Their cross section must be 60 X 80 cm (2 ft by 2 ft 8 inches). Escape-shafts may be made with or without light shafts. When constructing an escape-shaft *without light shaft* (Fig. 2-12) the following rules should be observed:

1. The position of the exit shaft is to be marked on the outside wall with the following notice "Emergency shelter escape-shaft" (rescue from the outside).
2. An area of 80 X 100 cm (2 ft 6 in. by 3 ft) above the shaft must not be covered with a concrete slab.
3. The height of the shaft may not be more than 2 meters (6 ft).
4. The shaft opening is to be partially concreted as shown in Fig. 2-12. Foamed plastic must be placed at the exterior for this purpose. The concrete is not to be reinforced. The location of the break-out section is to be marked on the inside.
5. The necessary tools to hole through the wall and dig out the shaft are to be made available inside the shelter.

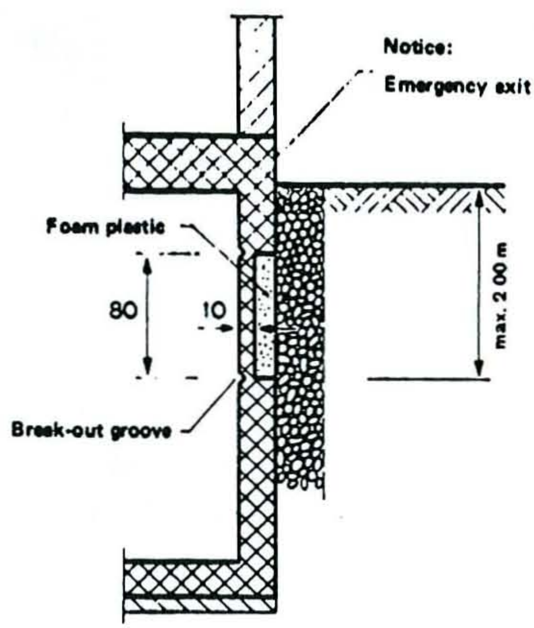


Fig. 2-12. Arrangement of escape-shaft without light opening

When constructing an escape-shaft *with light shaft* as illustrated in Figs. 2-13 and 2-14 the following rules apply:

1. The light shaft is to have a cross section of 60 X 80 cm (2 ft by 2 ft 9 in.) as shown in Fig. 2-14.
2. Rungs are to be placed at 30 cm (one foot) intervals for all shafts over 1.5 m (5 feet) high. If the shaft rises more than 4.5 m (15 ft) intermediate landings are to be built and the cross section must be increased to 80 X 130 cm (2 ft 8 in. by 4 ft).

3. The shaft must be closed at the top with a cover or a grating that is to be removed when the shelter is occupied.
4. The shaft walls are to be made of reinforced concrete but they do not necessarily have to be an integral part of the cellar wall.
5. The opening into the escape-shaft must be deep enough so that the angle of incidence measured from the horizontal to the upper edge of the escape shaft is at least 30 degrees (Fig. 2-13a). If this is not possible empty burlap sacks or plastic bags should be stored in the shelter so that before occupying the

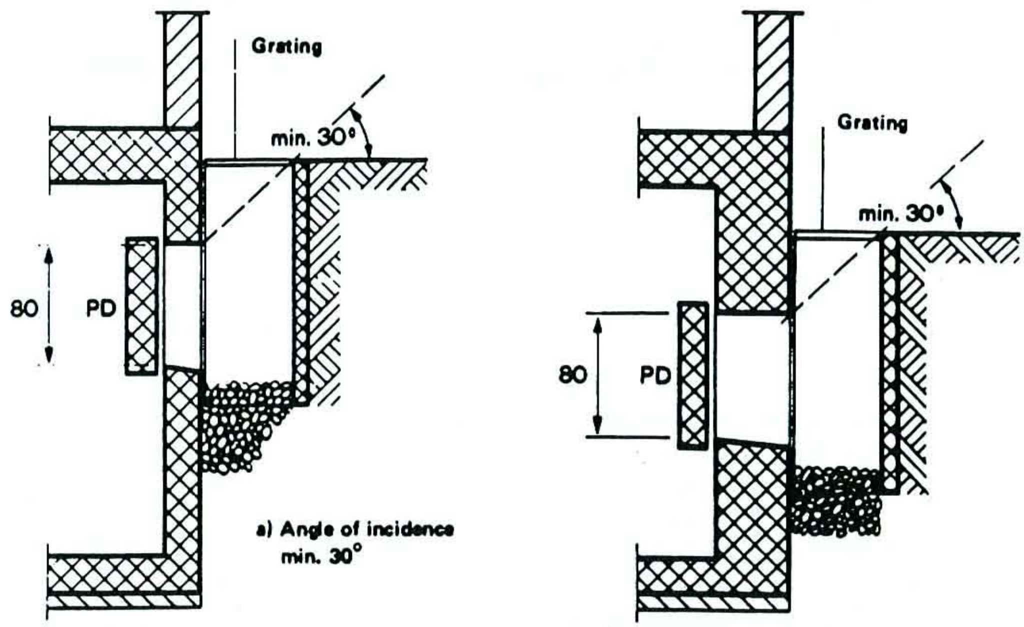
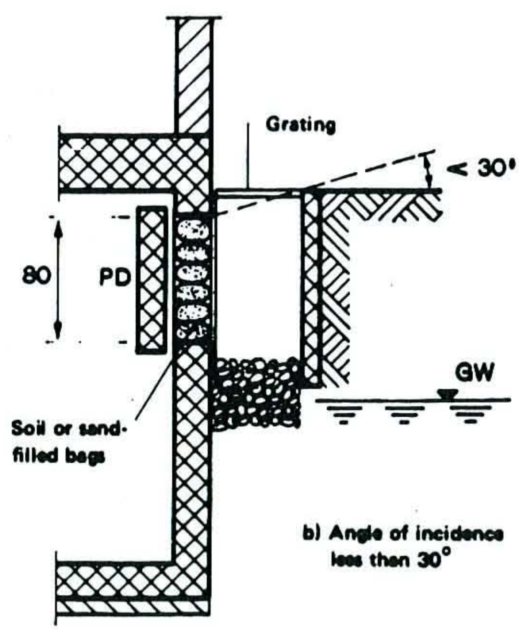


Fig. 2-13. Arrangement of emergency escape-shaft with light opening.



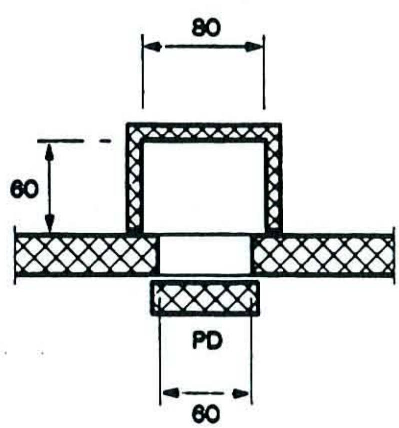


Fig. 2-14. Plan of the light shaft.

shelter they may be filled with earth or sand and placed against the escape shaft opening as radiation protection (Fig. 2-13b).

2.2.3.5 Design of escape-tunnels. Escape-tunnels are the most effective means for escape without outside help. They should end outside the area of falling debris if possible. The area of falling debris is assumed to be a distance out from the outline equal to one half the building height measured under the eaves (see Figs. 2-8b and 2-15).

When designing an escape-tunnel as shown in Fig. 2-15 the following points are to be considered:

1. An armoured cover is to be fastened in place at the shelter end of the tunnel on the inside.
2. Escape-tunnels with exit shafts at the end must have a pressure resistant cover with air holes for air intake in accordance with article 2.3. The occupants must be able to open the cover from the inside. If the exit shaft of the escape-tunnel does not have a pressure

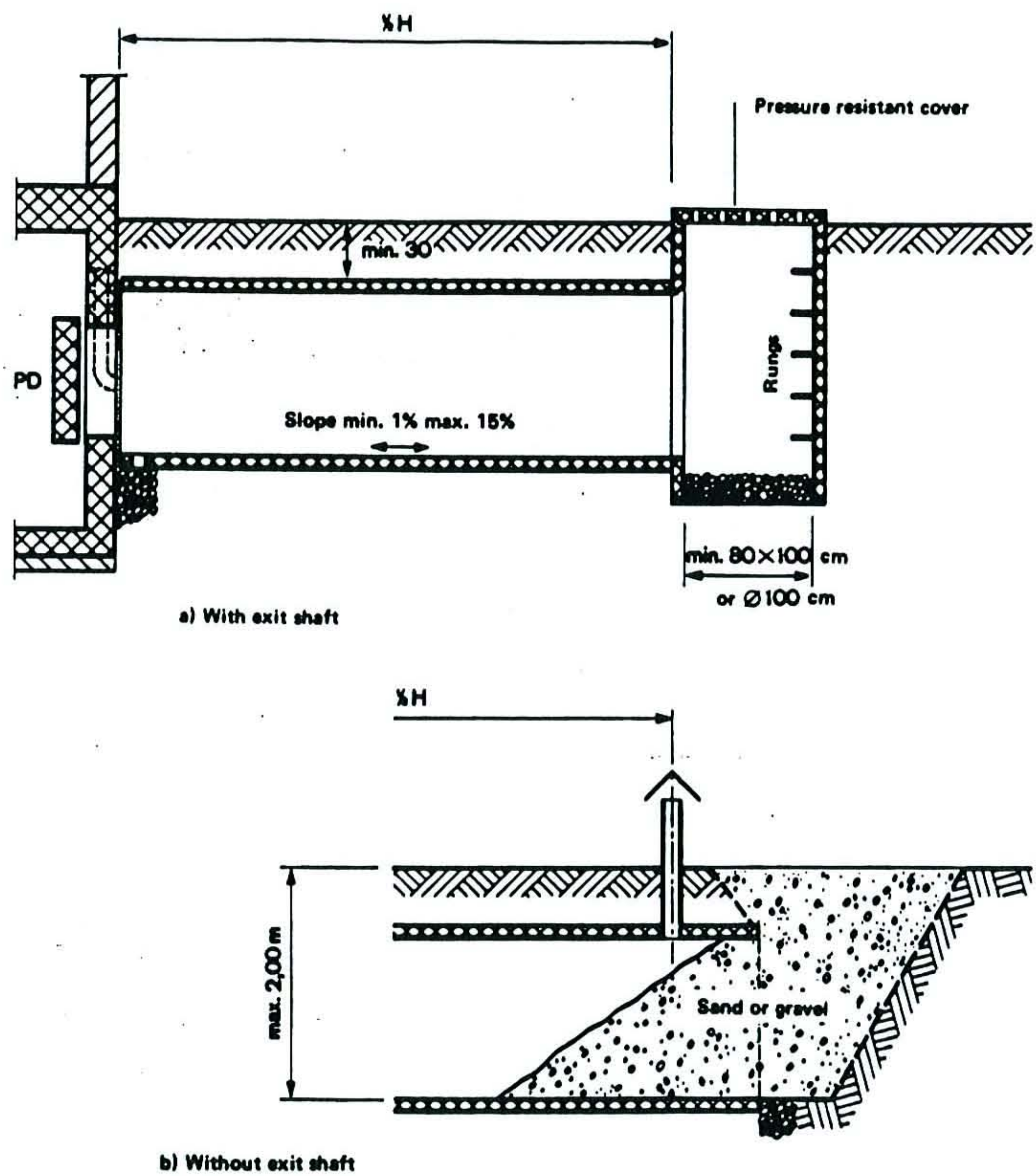


Fig. 2-15. Section showing construction of an escape-tunnel.

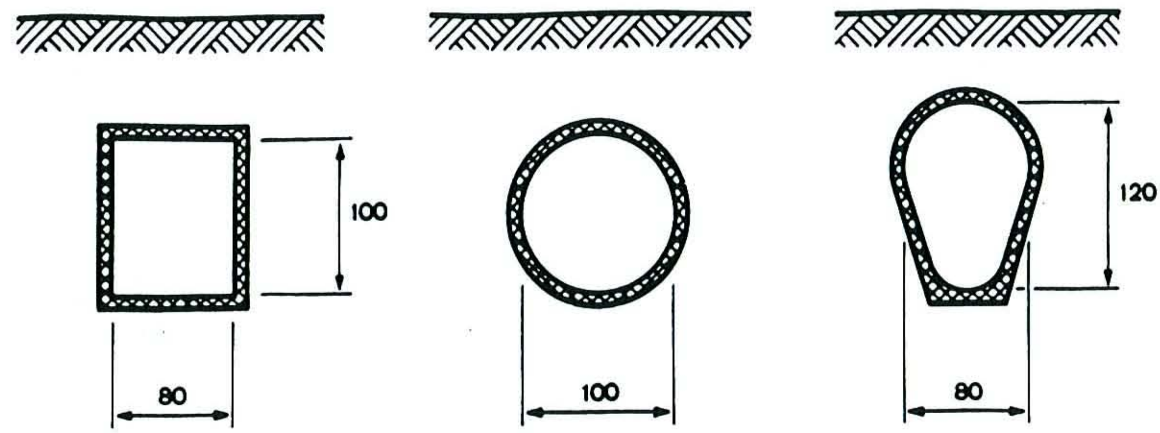


Fig. 2-16. Minimum cross sections for escape-tunnels.

resistant cover the tunnel must be designed according to article 3.4.2.6 as a gallery ending in the open.

3. The exit shaft should have the minimum dimensions of 80 X 100 cm (2 ft 8 in. by 3 ft) or 1 m (3 ft) diameter at the bottom. It may narrow down to 60 X 60 cm (2 by 2 ft) or 60 cm (2 ft) in diameter near the cover. Embedded rungs or a fixed metal ladder must be provided. A shaft over 4.5 m (15 ft) deep must have an intermediate landing and a cross section of at least 80 X 130 cm (2 ft 8 in. by 5 ft).
4. A tunnel end of the type shown in Fig. 2-15b may be constructed as an alternative to the tunnel end with an exit shaft provided that the tunnel is not more than 2 m (6 ft) deep and that the area around the exit is not covered with a concrete slab or a thick pavement.
5. Escape-tunnels must have the minimum dimensions given in Fig. 2-16. In any case the cross sectional area of the tunnel must be at least 0.75 m² (8 sq ft).
6. Escape-tunnels with pressure resistant covers or ends as shown in Fig. 2-15b may be realized in the following ways, for instance:

Concrete or asbestos cement pipe	min. diam. 100 cm (39 in.)
Oval pipe	min. 80/120 cm (30/48 in.)
Rectangular concrete pipe	min. 80/100 cm (30/36 in.)

7. The escape-tunnel must be drained and have a slope of 1% minimum and 15% maximum.
8. In densely built up areas a system of escape-tunnels may be formed by interconnecting several shelters and providing different exit shafts outside the area of falling debris (Fig. 2-17). A connection to a system like this is equivalent to an exit outside the debris area as indicated in Table 2-4.

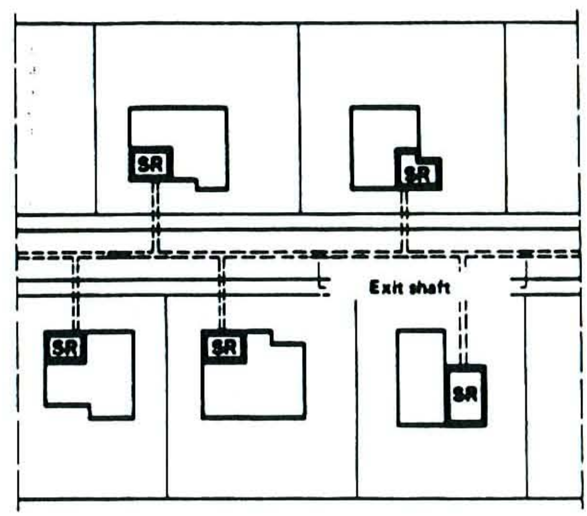


Fig. 2-17. Connection to an escape-tunnel system.

2.2.3.6 Design of escape-chimney. Escape-chimneys are air blast-proof vertical emergency exits which lead up through the expected pile of debris. They will be subjected to very large horizontal forces caused by the collapse of the building under the action of an air blast and may only be proposed in cases where it is impossible to build an escape-tunnel outside the debris area. The following points are to be considered when designing an escape-shaft:

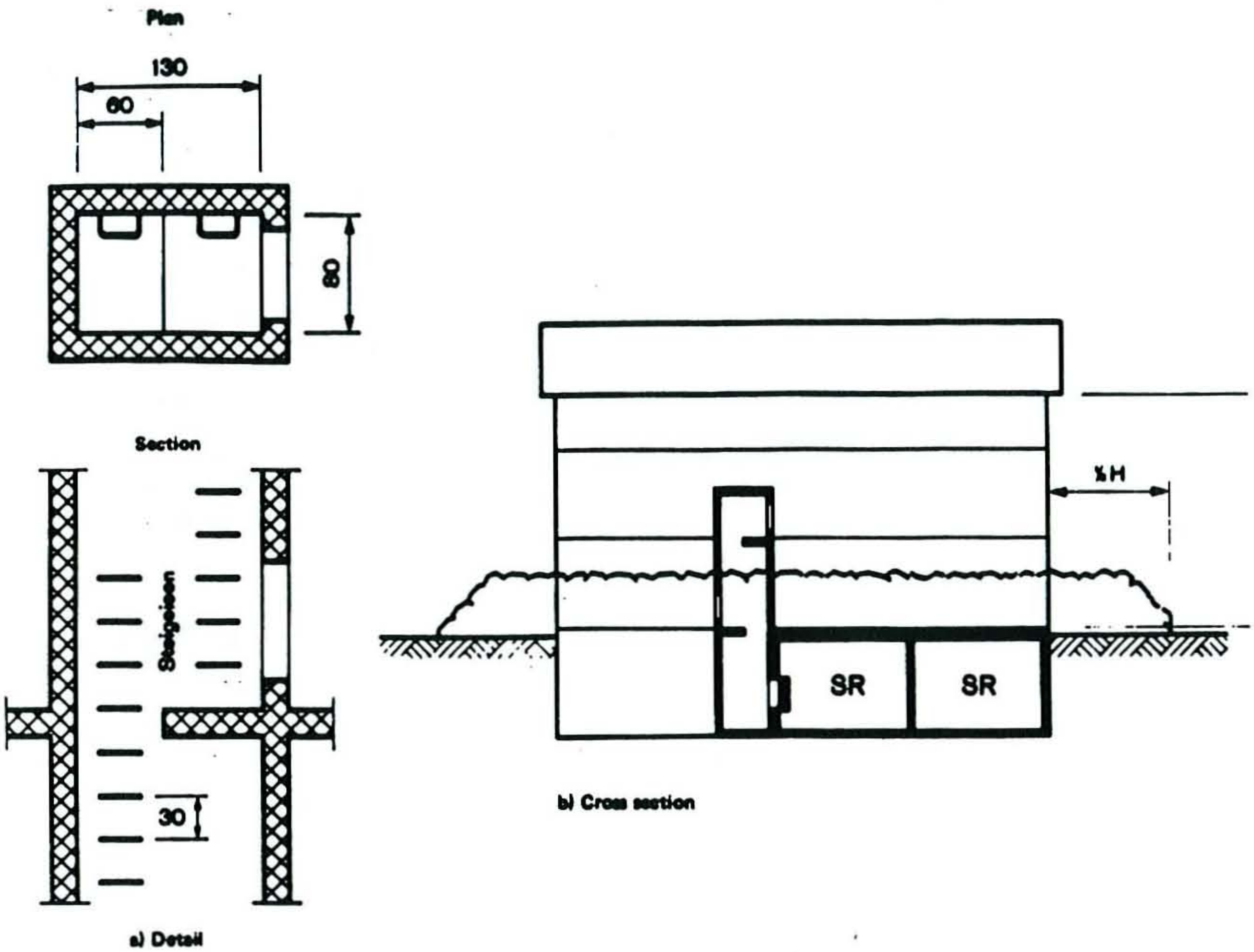


Fig. 2-18. Construction of escape-chimneys.

1. The escape-shaft must lead up at least ¼ of the height of the building as measured under the eaves to above ground level. In addition the end of the shaft must reach at least 1 m (three ft) above the level of the ground floor, but not more than 1 m (3 ft) under the ceiling height of the fourth floor.
2. The shaft should be stiffened as much as possible by existing structural walls and be connected as little as possible to floor slabs.
3. The minimum cross section is 80 X 130 cm (2 ft 8 in. by 4 ft) (Fig. 2-18a).
4. An opening is to be provided at every floor on alternate sides of 60 X 80 cm (2 ft by 2 ft 8 in.). The pressure resistant closure of the shelter is assured by an armoured door (Fig. 2-18b).
5. The shaft is to be equipped with rungs or a fixed steel ladder. Landings are to be placed on alternate sides at every floor as shown in Fig. 2-18b or at least every 4.5 m (15 ft).

2.2.4 Shelter Doors and Covers

2.2.4.1 Door types. Only doors and covers approved by the Federal Office of Civil Defense may be used and they must carry an approval number. These types offer sufficient protection against air blasts and their reflection, radioactive radiation, bomb fragments, dust, gas, and fire in accordance with printed specifications, so that they can be used as indicated in these technical directives in one or three atmosphere shelters. Their interior dimensions are standardized for simplification according to Table 2-5. The door-size 3 is to be considered as an exception and is only to be used where absolutely necessary for peacetime use, such as a passage for lift trucks. This type of door is always to be used with a removable sill.

2.2.4.2 Fastenings for shelter doors and covers. The doors and covers for the shelter are to be fastened in accordance with Table 2-6. From the standpoint of the occupants being able to free themselves the fastenings should be on the inside even for the armourplated PT doors. However, since no internal fastening exists which is sufficiently strong all the fastenings are to be on the outside. The arrangement and opening of the doors is illustrated in Fig. 2-19.

Table 2-5. Standardized interior dimensions of shelter doors and covers

Type of closure	Size	Interior dimension	
		cm	inches
Armourplated door PT	1	80 × 185	$31\frac{1}{2} \times 73$
	2	100 × 185	$39\frac{1}{4} \times 73$
	3	140 × 220	$55 \times 86\frac{1}{2}$[a]
	4	60 × 120	$23\frac{1}{2} \times 47$
Armourplated cover PD		60 × 80	$23\frac{1}{2} \times 31\frac{1}{2}$
Pressure door DT	1	80 × 185	$31\frac{1}{2} \times 73$
	2	100 × 185	$39\frac{1}{2} \times 73$
	3	140 × 220	$55 \times 86\frac{1}{2}$[a]

[a]With removable sill.

2.2.4.3 The location and installation of doors. The following points are to be considered in the design:

1. It must be possible to open all doors completely, leaving the interior dimensions free.
2. All steelplated doors must have 4 cm ($1\frac{1}{2}$ inch) free space both above the floor and under the ceiling.

The following points are to be observed when installing the doors:

1. The doors or covers and their frames and anchors are to be placed in the forms in such a way that they may be concreted with the wall to insure that they are securely held in place. They are to be concreted in place with the door closed and with wedges under it.

Table 2-6. Fastenings for shelter doors

Opening	Door type	Direction of swing
Doors in the shelter shell and air lock	PT	Outward
Emergency exits through the shelter shell leading to escape-tunnels, shafts, or galleries (cellar)	PD	Inward
Interior partition	DT	Either

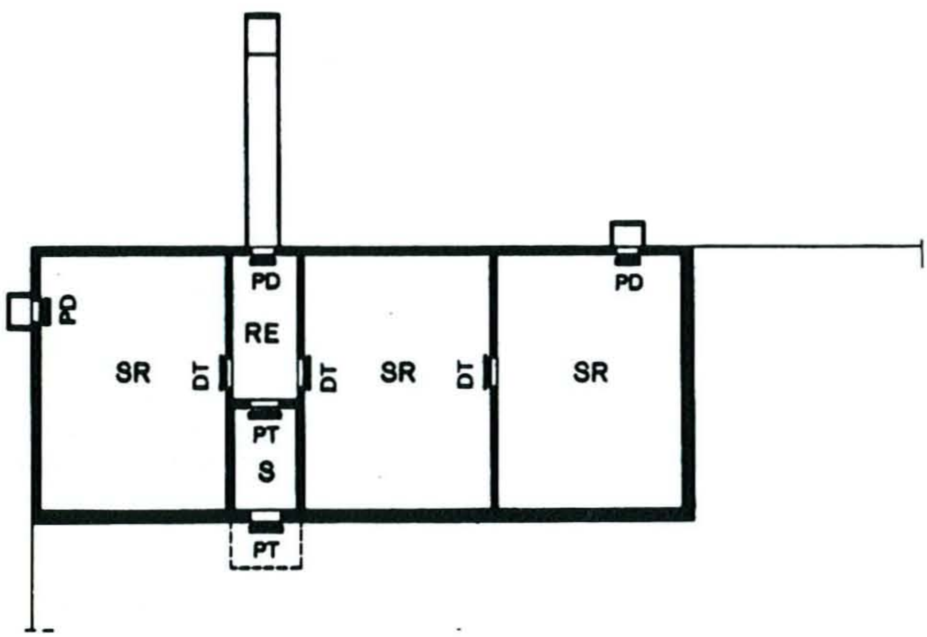


Fig. 2-19. Arrangement of closure elements.

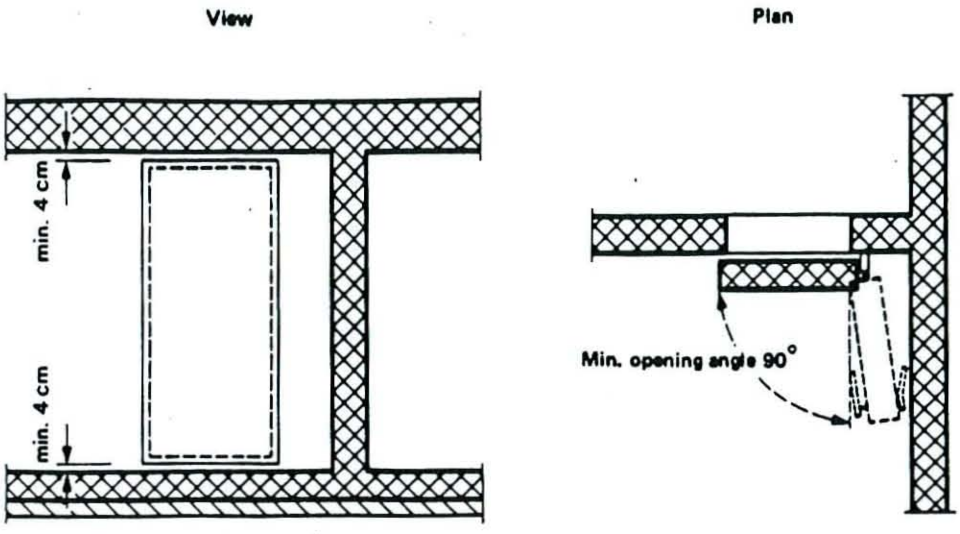


Fig. 2-20. Installation of shelter doors.

2. Steps are also to be taken to prevent any sagging or movement of the door after the forms are stripped (wedges under the door, for instance).
3. During peacetime, the removable door sills must be fixed in a stored position near the door with the hardware for their attachment.
4. All closures must be installed so that they fit tightly enough to maintain an inside pressure of 15 mm (5/8 inch) of water with the ventilation system operating normally bypassing the filters (to be tested at the time of acceptance).

2.3 VENTILATION

2.3.1 Purpose and Requirements

All shelters must be equipped with a ventilating system so that in the interior, even during long periods of occupancy, a physiologically tolerable environment may be maintained. The ventilation apparatus should be able to provide the atmosphere necessary for life, especially oxygen, and exhaust the noxious substances such as carbon dioxide and moisture as well as heat. This exchange must be accomplished in such a way that no damaging effect from weapons can penetrate through the ventilation openings into the shelter. The ventilation apparatus which are authorized and standardized for use in private shelters are designed on the basis of the assumed criteria summarized in Table 2-7.

2.3.2 The Four Types of Ventilation

The four phases of the shelter operation (article 1.3) pose different requirements on the ventilating system which leads to the following types of ventilation:

Natural ventilation (NL)	Primarily for peacetime phase
Fresh air circulation (FRL)	Primarily for pre-attack phase
Filter operation (FIL)	Primarily for post-attack or gas attack phase
Interruption of ventilation	Primarily during attack phase

2.3.2.1 Natural ventilation (NL). During peacetime it must be possible to ventilate the shelter naturally. The ventilation requirements depend on the use to which the shelter is put during this period. In general, sufficient circulation will be created in the shelter by leaving the door and the emergency escape hatch open. If it is necessary to provide better ventilation the additional ducts must be closed with pressure and gas tight covers when the shelter is to be occupied as such. In addition they must be stuffed or covered with sand bags or other material to insure that the protection against radiation is maintained.

2.3.2.2 Fresh air operation (FRL). During the occupancy of the shelter in the pre-attack phase – that is, when the outside air is uncontaminated – the shelter shall be artificially ventilated with fresh air.

The basic minimum capacity for the standard shelter ventilator is based on 6 m^3/hr (3.5 cu ft/min) per person in the shelter. This quantity of air is sufficient to

Table 2-7. Basic criteria for the design of authorized ventilation systems

	Requirements for the shelter atmosphere for long periods	Acceptable for short periods	Desired conditions	A shelter occupant needs or produces:
Oxygen (O_2)	min. 18% vol.	min. 16% vol.	21% vol.	0.018 m^3/hr (0.63 cu ft/hr)
Carbon dioxide (CO_2)	max. 1% vol.	max. 2.5% vol.	0.03% vol.	0.015 m^3/hr (0.53 cu ft/hr)
Room temperature and relative humidity	25°C (77°F) 100%	29°C (84°F) 100%		100 kcal/hr at 20°C (400 BTU/hr at 68°F)
	26.5°C (80°F) 80%	31°C (88°F) 80%		
	28°C (83°F) 60%	33°C (91°F) 60%		
	30°C (86°F) 40%	36°C (97°F) 40%	~50 g	(0.1 lb) water hr at 86°
			~100 g	(0.2 lb) water hr

Table 2-8. Classification of ventilators

Number of places in shelter[a]	Ventilator classification number	Minimum capacity: Fresh air operation, m^3/hr (cu ft/min)	Minimum capacity: Filter operation, m^3/hr (cu ft/min)	Type of power	Power requirement (watts)
7	VA 20[b]	40 (24)	20 (12)	Hand	40
13	VA 40	80 (47)	40 (24)	Hand and electric	50
25	VA 75	150 (88)	75 (44)	Hand and electric	60
50	VA 150	300 (176)	150 (88)	Hand and electric	120

[a]In exceptional cases the number may be increased 10%.
[b]Only for single family homes.

keep the carbon dioxide level below 1% and to provide enough oxygen for the occupants of the shelter. But only a small portion of the heat which is produced can be carried away by the ventilation, however. A large part of the heat must be dissipated through the shelter walls into the ground. During warm, humid weather when the shelter is fully occupied and if the surrounding earth is a poor heat conductor a strong heating of the shelter is to be expected.

2.3.2.3 Filter operation (FIL). When the outside air is polluted – that is, during and after the attack – the air must be passed through a filter in order to remove the dangerous substances such as gases from chemical warfare or radioactive dust. In order to keep the required quantity of activated charcoal and the cost of the filter to a minimum the ventilation rate is reduced to 3 m^3/hr (1.80 cu ft/min) for each shelter occupant. Even this quantity of air maintains physiologically tolerable conditions. Of course, with this type of operation the increase in temperature and humidity will be even more pronounced than with fresh air operation.

2.3.2.4 Interruption of the ventilation. The ventilating system cannot provide protection from gases produced by fires such as carbon monoxide (CO) or carbon dioxide (CO_2). In case of smoldering fires near the air intake or in case of flooding it must be possible to interrupt the shelter ventilation temporarily. The time required to reach the tolerable limit of 2.5% by volume of carbon dioxide in an unventilated shelter having a volume of 2.5 m^3 (88 cu ft) per occupant will be about 3 hours. The dangerous carbon dioxide content of 4% by volume (candlelight goes out) will be reached in about 5 hours.

2.3.3 The Ventilating System

The ventilators are standardized and divided into four sizes as indicated in Table 2-8. The ventilator must be able to create an excess pressure in the shelter of 5 mm ($^3/_{16}$ of an inch) of water pressure so that gas, dust, and smoke cannot penetrate into the shelter through leaks in the shelter shell (cracks around doors or windows, etc.).

The arrangement and components of the ventilation system are illustrated in Fig. 2-21.

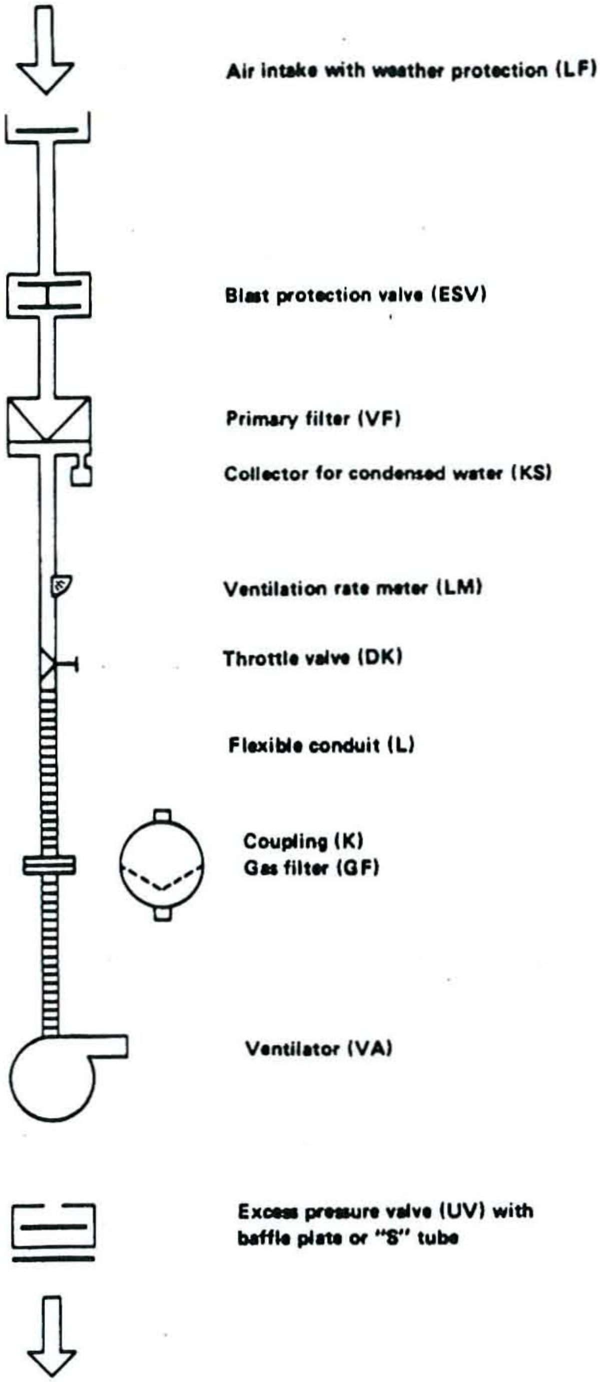


Fig. 2-21. Ventilation system components and arrangement.

2.3.4 Arrangement of the Ventilating Equipment

The ventilating equipment is to be planned at an early stage of the project. The following points are to be considered:

1. All the parts of the ventilating equipment are to be installed in such a way as to be easily accessible.
2. Every shelter is to be ventilated separately.
3. In shelters without air locks or decontamination rooms the exhaust air is to be blown out through the entrance if possible.
4. In order to obtain the best cross ventilation the inlet and the outlet of the ventilating system for the shelter should be located diagonally opposite from each other. If the ventilating conduits are branched they should be provided with regulators so that a thorough circulation of the ventilating air is assured.
5. The air intakes are to be located in such a way that they neither draw air from their own exhaust air outlet or from that of other installations (tank ventilators, exhaust pipes, etc.).
6. Decontamination rooms, toilets, and air locks are to be ventilated with the exhaust air from the shelter. The air lock for a shelter group is to be purged with the exhaust air from not more than two shelters.
7. The ventilators must be located outside of the rented portion of the cellar.

Examples of the arrangement of ventilating equipment are shown in Figs. 2-22 to 2-25.

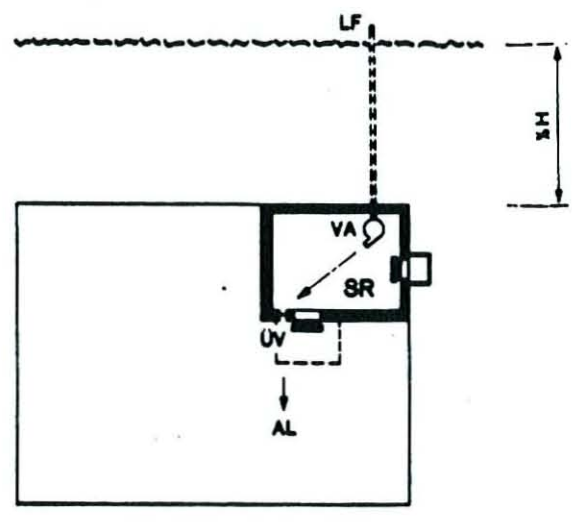


Fig. 2-22. The arrangement of ventilating equipment in a single shelter (up to 50 occupants).

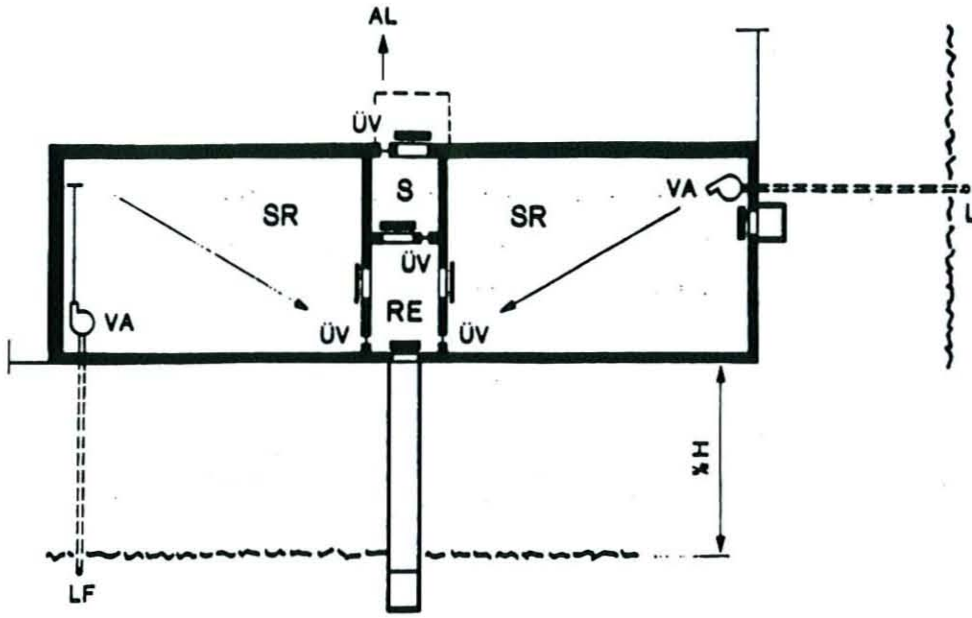


Fig. 2-23. The arrangement of the ventilating equipment in a double celled shelter group (51 to 100 places).

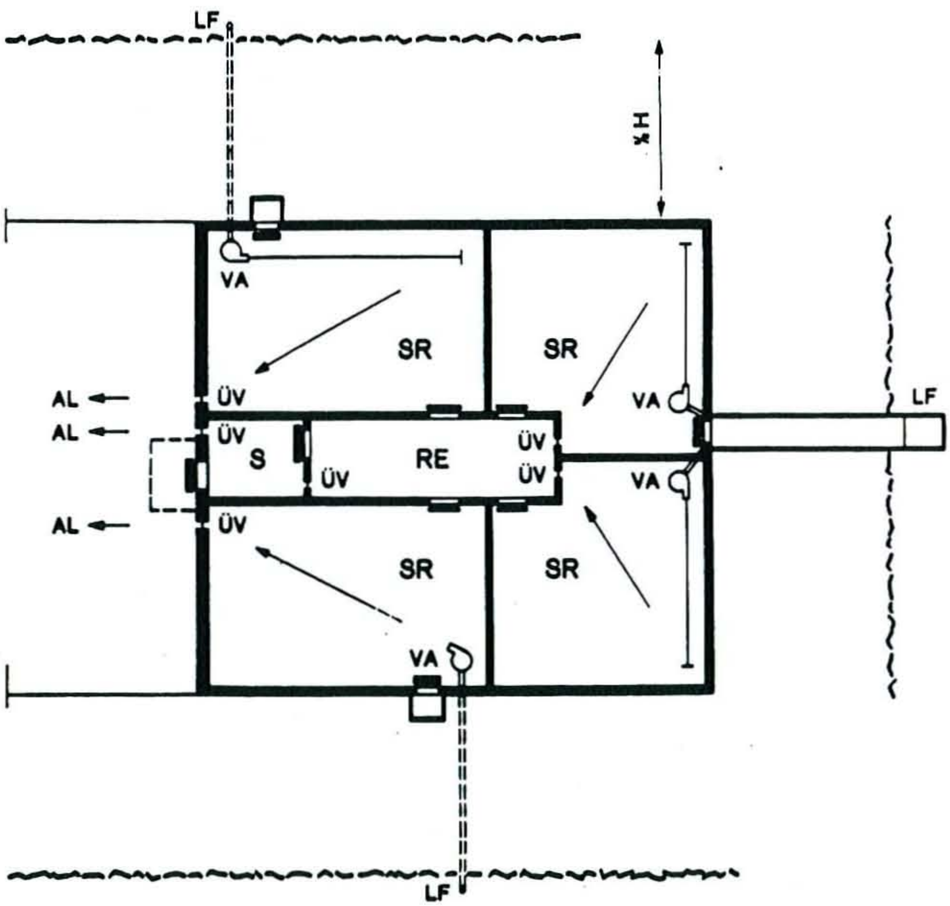


Fig. 2-24. The arrangement of the ventilating equipment in a four-celled shelter group (151 to 200 places).

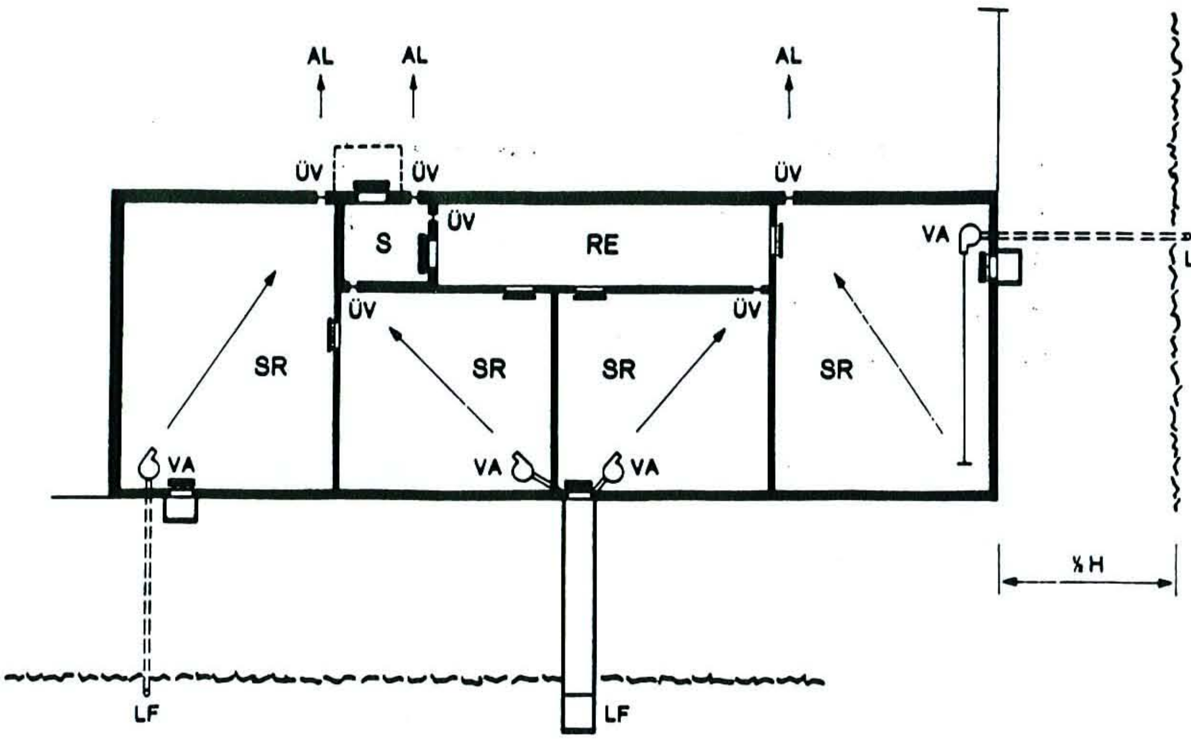


Fig. 2-25. The arrangement of the ventilating equipment in a four-celled shelter group (151 to 200 places).

2.3.5 Components of the Ventilating Equipment

2.3.5.1 Air intake (LF). The following requlations apply to the location and design of the air intake:

1. A separate air intake must be provided for every ventilating system. If this is not possible for structural reasons or the air is drawn from an escape-tunnel then a common ventilating system can be provided for shelter groups of up to 100 places.
2. The air intake is to be located outside the area of falling debris; the air is to be drawn through escape-tubes, for instance (see Fig. 2-26) or through buried, rigid tubes (concrete or asbestos cement pipes) (see Fig. 2-27).
3. If the air intake cannot be placed outside the debris area it may be located as shown in Figs. 2-28a and 2-28b in exceptional cases with the permission of the Cantonal Civil Defense Authority.
4. The connection of the air conduit to the shelter must be done in accordance with section 2.4.
5. The inside diameter of the air intake up to the first filter must be at least:

   100 mm (4 in.) for VA-20 or VA-40 ventilators
   125 mm (5 in.) for VA-75 or VA-150 ventilators
   150 mm (6 in.) for two VA-150 ventilators

   The pressure drop in the conduit and the bends of the air intake up to the first filter and/or explosion-proof valve shall not exceed 10 mm (3/8 inch) of water pressure.
6. The air intakes are to be provided with a removable grill and weather protection on the outside.

2.3.5.2 Blast protection valve (ESV) and primary filter (VF). The purpose of the blast protection valve is to guard the shelter occupants and the ventilating equipment from shock waves and a damaging pressure increase. It must be protected from flying debris and fragments. The primary filter removes the coarse dust (radioactive fallout, airborne dust, and dust from debris) in order to relieve the gas filter. Depending on the construction (i.e., fibre filter, sand, or gravel filter) it is to be placed before or after the blast protection valve.

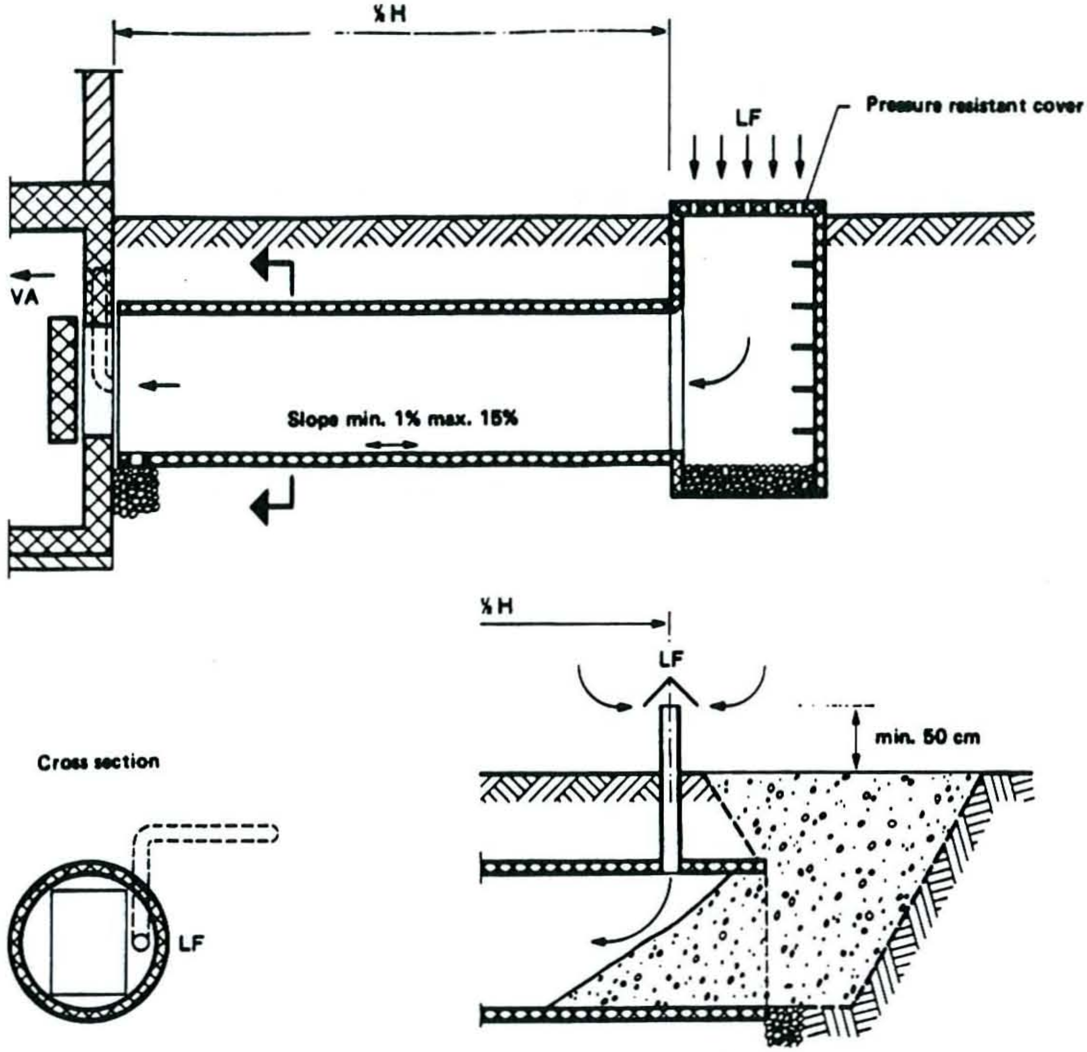


Fig. 2-26. Air intake in escape tunnel.

1. Primary filters, which are placed in the shelter after the blast protection valve, should be as close as possible to the point of entry of the air intake conduit 1.85 m (6 ft) above the floor to make it far enough from the shelter occupants so as not to require special radiation protection.

2. The blast protection valve and the primary filter form a single unit and products of different manufacturers may not be combined.

3. The instructions from the manufacturer approved by the Federal Office of Civil Defense are to be consulted for the installation of the blast protection valve and the primary filter.

2.3.5.3 Ventilator (VA). The space required for ventilators VA 20 to VA 150 are shown in Fig. 2-29.

1. The height above ground of the air intake connection on the shelter side of the pipe is 1.8 m (6 ft) for all ventilators.

2. The instructions for operating the ventilator are to be attached to the ventilator or in the immediate neighborhood.

3. The electrical installation for the ventilator must be in accordance with the household installation code of the SEV.

4. The ventilator and the gas filter must be protected with a plastic cover during peacetime.

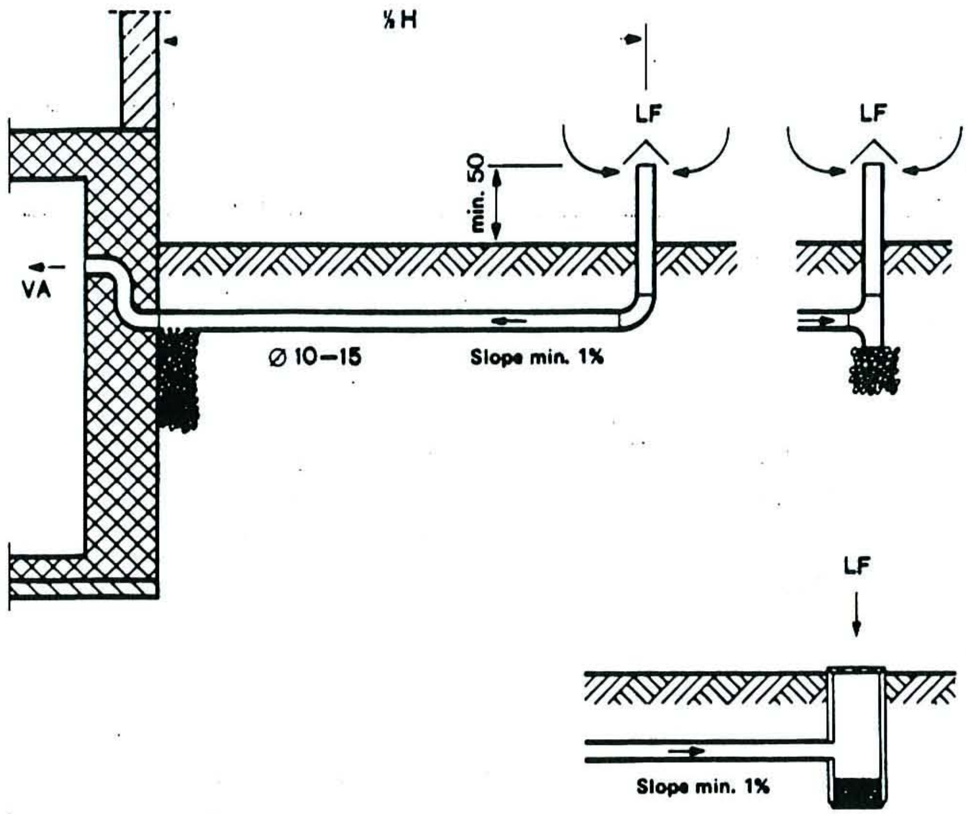
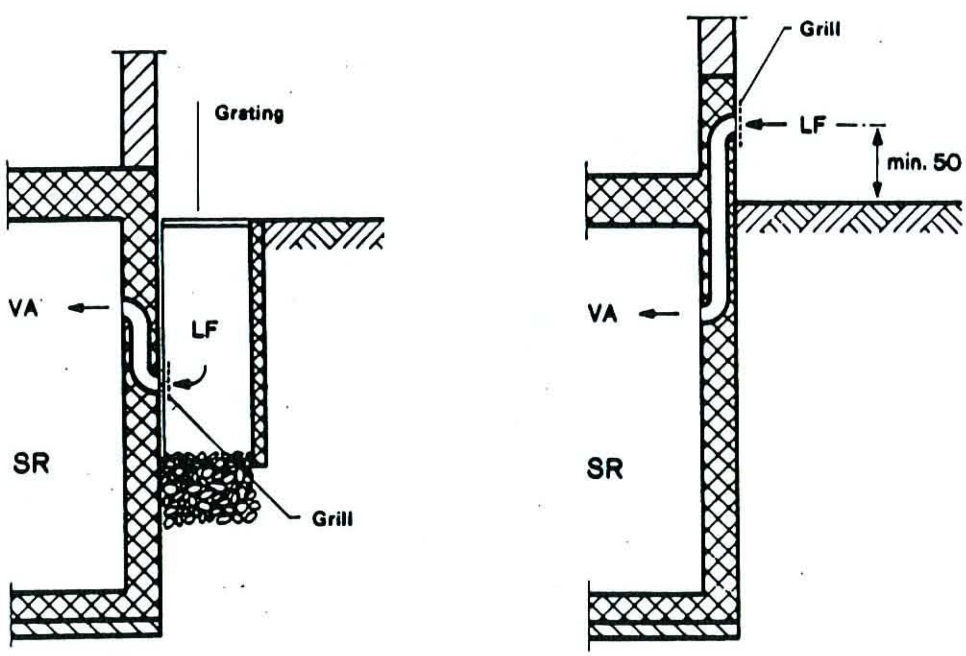


Fig. 2-27. Air intake with pipes outside the area of falling debris.



a) Air intake in emergency escape shaft

b) Air intake in concrete wall or column

Fig. 2-28. Examples of air intakes within the debris area (exceptions).

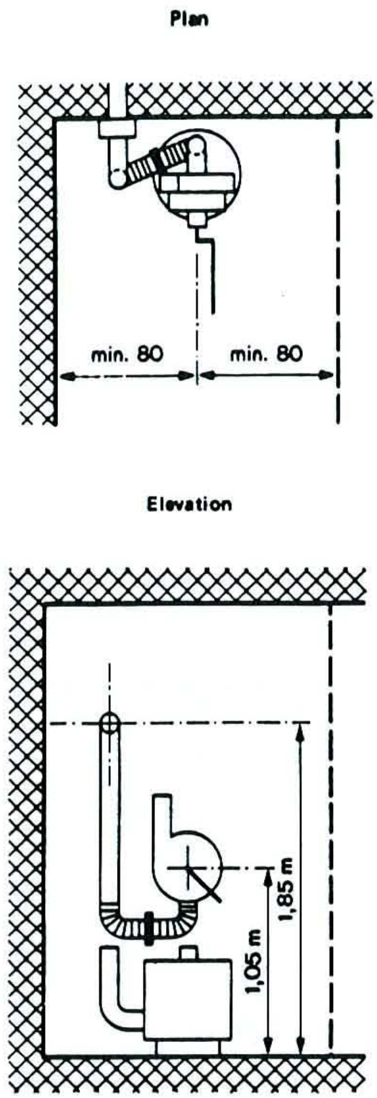


Fig. 2-29. Space requirements for ventilators.

2.3.5.4 **The gas filter (GF).** The purpose of the gas filter is to retain chemical and bacteriological warfare agents (aerosols, vapors, and micro-organisms). The gas filters are to be mounted in the shelter, closed airtight, and sealed with lead according to regulations. The seal may only be removed at the time that the shelter is occupied.

2.3.5.5 **Excess-pressure valve.** The purpose of the excess-pressure valve is to close the air outlet opening when the ventilation is shut off or during an explosion as well as to maintain a certain excess pressure in the shelter during operation of the ventilation.

The following openings are to be protected by excess-pressure valves (see Figs. 2-22 to 2-25):

1. Exhaust air outlet in exterior shelter wall.
2. Ventilation openings in partitions.

The excess-pressure valves are to be located as follows:

1. Exterior walls	1.85 m (6′) above ground
2. Air lock walls	0.4 m (16″) above ground
3. Partition walls	1.85 m (6′) above ground

The excess-pressure valve and air outlet placed in series are to be dimensioned to maintain an excess-pressure of 5 to 15 mm of water pressure ($^3/_{16}$ to $^5/_8$ inch) in the shelter during operation of the artificial ventilation. The air outlets which pass through the exterior walls must have either two elbows or a removable shielding plate as protection against fragments and radiation (see Fig. 2-30).

2.3.6 Construction Hints

Only those ventilators, filters, explosion protection valves, and fittings may be installed which have been approved by the Federal Office for Civil Defense on the basis of tests and which are marked with an approval number.*

All distribution pipes, fastenings, etc. are to be made of non-splintering, shatter-proof materials. The materials must not release any gas at a temperature of +60°C (140°F) and must be corrosion resistant or covered with a corrosion protection. The fastenings and anchors for the ventilation must comply with the requirements of article 3.4.2.9.

2.3.7 Functional Test

The ventilator manufacturer is responsible for the installation of the ventilating system according to regulations, and is to test the operation immediately after completion of the shelter. They shall send a written report of the test results to the competent civil defense authority within one month after the test.

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*The following instructions of the BZS are applicable to the manufacture of small ventilator systems, their parts, and the testing of these elements:

1. Directive of the BZS concerning technical requirements for small ventilators 15 April 1956.
2. Ditto, VA 20, 1st October 1966.
3. Technical Directive of the BZS concerning minimum requirements for explosion protection valves and primary filters for ventilation systems of 15 October 1966.

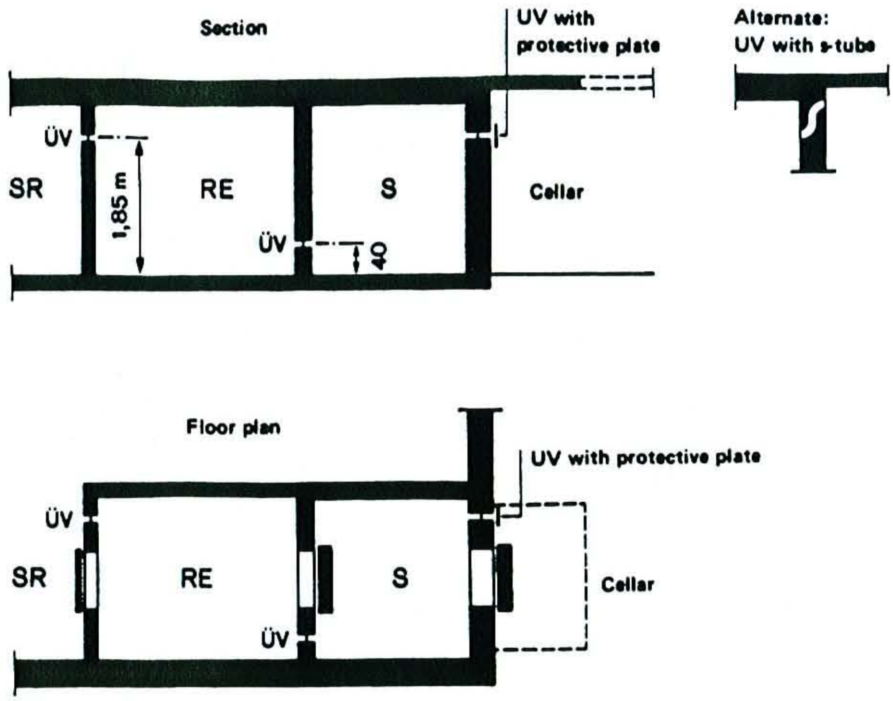


Fig. 2-30. Location of excess-pressure valves (UV).

2.4 FURNISHINGS AND CONDUITS

2.4.1 The Effect of Weapons

The furnishings or conduits which are installed in the shelter will be subject to shocks and vibrations. The more flexible the attachment to the shelter the smaller will be the acceleration forces transmitted.

The conduits which pierce the shelter shell weaken it, especially with respect to the nuclear radiation and the air blast. The number and size of such conduits must therefore be limited.

Air blasts can create excess internal pressure in conduits leading into the shelter.

2.4.2 Furnishings

All furnishings which remain in the shelter during the preattack phase must satisfy the following conditions (for the design see article 3.4.2.9):

1. They must not diminish the protective function, particularly the necessary places available.
2. They may not be made of brittle material such as cast iron, bakelite, or porcelain, etc., due to the high instantaneous accelerations which occur.
3. Furnishings made of brittle materials weighing more than 0.5 kg (one pound) must be shock-mounted on rubber pads at least 5 mm ($^1/_4$ inch) thick. A special authorization must be obtained from the BZS for furnishings weighing more than 5 kg (10 pounds).
4. The anchors and attachments must comply with the requirements of article 3.4.2.9.
5. All equipment which is not fixed must be able to withstand a free fall of 30 cm (1 ft), equivalent to striking the shelter floor.

2.4.3 Conduits

2.4.3.1 General requirements. All the conduits mounted in the shelter must satisfy the same requirements for shock protection as demanded in article 2.4.2 for furnishings.

In addition conduits passing from the outside under ground through the shelter wall must be enclosed in a soft layer at least five diameters long and 5 cm (2 inches) thick because of the relative movement of the shelter and the surrounding earth, as shown in Fig. 2-31, for example.

As protection against nuclear radiation and air pressure the conduits must fulfill the following conditions in all parts of the shelter shell (with the exception of the floor and walls against the earth):

1. Conduit openings through the shelter shell having a total cross section of more than 600 cm^2 (93 sq in.) in one wall must be approved by the Cantonal Civil Defense Authorities.

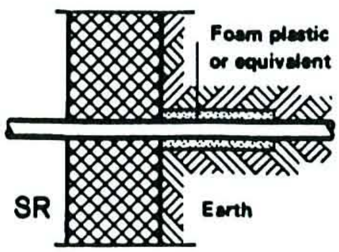


Fig. 2-31. Example of the penetration of an underground conduit.

2. Conduits of more than 250 cm^2 (39 sq in.) cross section passing through the shelter shell are to be provided with a double elbow as indicated in Fig. 2.32a.
3. Conduits buried in the shelter shell must lie in the outer half. If their cross section exceeds $\frac{1}{4}d^2$, where d stands for the wall or roof thickness, the wall or deck must be thickened locally in order to have the normal wall thickness everywhere as shown in Fig. 2-33.

As a protection against air blasts all blockouts of more than 150 cm^2 (23 sq in.) cross section for the passage of conduits should have roughened surfaces (Fig. 2-32b). They should not be made with metalforms or asbesto cement pipe, for example, or else they should be conic with the larger end outward (Fig. 2.32c).

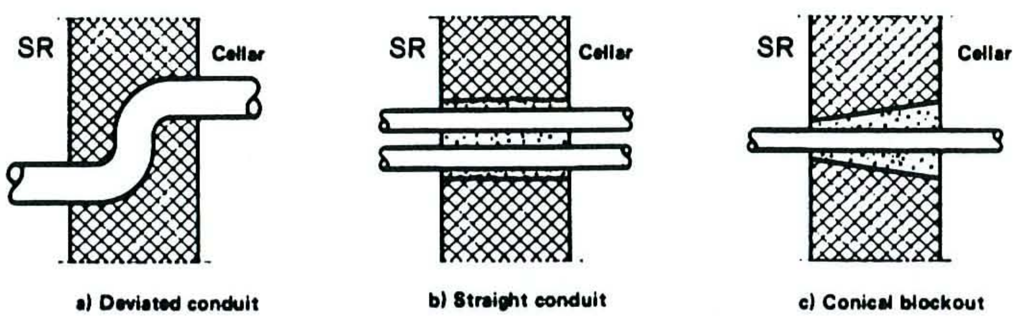


Fig. 2-32. Examples of conduits leading out of a cellar.

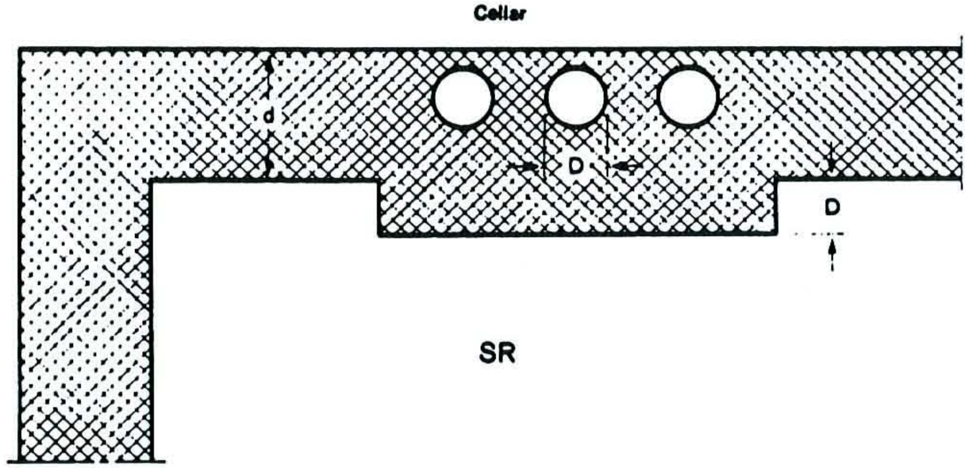


Fig. 2-33. Wall reinforcement around conduits in concrete.

2.4.3.2 Conduits used for civil defense. The following conduits for civil defense purposes are provided besides the ventilation and exhaust air outlet pipes:

1. Water and sewage pipes, if toilets and showers are included in the decontamination room. See article 2.4.3.3 for size limitations. Drains must be provided with covers that may be closed tight due to the danger of water backing up in a blocked off sewer.
2. Communications: A 20 mm (¾ inch) tube must be placed in the shelter wall leading outside or in the cellar so that communication wires or a radio antenna may be installed at some future time.
3. Electric wires for lighting the shelter and for the ventilator.

2.4.3.3 Non-Civil defense conduits.

1. Water pipes under pressure are permitted in the shelter if there is a drain [max diam 15 cm (6 in.)] and a cut-off valve. Pipes of more than two inches in diameter require a special permission from the Cantonal Civil Defense Authorities.
2. Central heating conduits are permitted in the shelter if there is a drain or if the maximum water level in the shelter will not exceed 50 cm (20 inches) in case of a break in the pipe.
3. Gas, fuel, or chemical lines are not allowed in the shelter. They may enter the shelter only as an exception and then with the special approval of the Cantonal Civil Defense Authorities.

2.4.4 Fuel Tanks

If oil or gasoline tanks are located near shelters, the following items are to be considered besides the pertinent Cantonal Fire Protection and Water Pollution Control Regulations.

2.4.4.1 Underground tank not under building. Between the tank and the shelter wall there must be a thickness of earth material of at least 1.5 m (5 ft), or the wall must be reinforced and 50 cm (20 in.) minimum thickness.

2.4.4.2 Tank under building. For oil tanks with a volume of more than 20,000 l (5000 gal) a special approval of the Cantonal Civil Defense Authorities is required.

Oil tanks up to a content of 10,000 l (2500 gal) and 20,000 l (5000 gal) have to have a distance of 3 m (10 ft) and 5 m (16 ft) respectively from the nearest shelter wall; in case of a leak the fuel must not be able to reach the shelter (i.e., place the tank in a basin).

If an oil tank is located adjacent to a shelter, the pertinent shelter wall must be a 75 cm (30 in.) reinforced concrete wall. In this wall openings are not permitted.

Gasoline tanks require a special approval of the Cantonal Civil Defense Authorities.

Chapter 3. Design and Construction

3.1 DESIGN PROCEDURE

The dimensions given in article 2.1.3 used for the preliminary design must be calculated for the final design after receiving the construction permit and before starting the plans, unless the shelter is a 1 atmosphere design for less than 25 persons. Basically this calculation should take into consideration all the weapons effects described in section 1.4 as well as the peacetime loads. The majority of these requirements may be considered as being fulfilled, however, by the minimum limits for concrete thickness and reinforcement given in this chapter as well as the regulations for the layout given in chapter 2. It is therefore permitted to limit the final design to the consideration of the following four groups of loads:

1. fire,
2. primary radioactive radiation,
3. mechanical loads from weapons effects,
4. peacetime loads.

The final concrete thickness will be determined by the requirements for the resistance to the first two effects in accordance with the values given in sections 3.2 and 3.3. In this respect the basic rule is that the critical loading is the one that requires the greatest concrete dimension. The given values have lower limits such that the requirements for all weapons effects not specifically investigated are already satisfied.

The last two groups of loads influence mainly the reinforcement ratio and only rarely the concrete thickness. The design for the mechanical loads from weapons effects is based on the use of the ultimate static loads given in section 3.4. The peacetime loads may not be critical in any way, but it is still the responsibility of the engineer to assure that the structure satisfies all the recognized rules of construction and in particular the SIA codes for loading and concrete design.

In the same way that certain minimum concrete dimensions were determined for the final design, a minimum reinforcement ratio is required (article 3.4.1) which is already sufficient to resist a large part of the loads from weapons effects. The establishment of these minimum values makes it possible to reduce the design of the concrete thickness as well as the supporting reinforcement to the consideration of a few loading conditions illustrated in Table 3-1.

3.2 DESIGN FOR FIRE PROTECTION

Ceiling slabs and exterior walls not against earth must offer protection against heat from fires in the immediate vicinity of the shelter. The necessary thickness of concrete depends on the fire intensity by flammable

Table 3-1. Design procedure for the major structural elements

Structural element	Critical loading for concrete depth[a]	Critical loading for concrete reinforcement[a]
Slabs and free-standing exterior walls	Radioactive radiation (3.3), fire (3.2) (possibly air blast)	Air blast (3.4.2.1), (3.4.2.4)
Exterior walls against earth	Ground shock (3.4.2.3)	Ground shock (3.4.2.3)
Floors	Ground reaction (3.4.2.2)	Ground reaction (3.4.2.2)
Partition walls and intermediate floor slabs (except air-locks)	Construction requirements, shock (3.4.2.5)	Shock (3.4.2.5)

[a]Not including construction requirements and peacetime loads.

Table 3-2. Concrete depth for fire protection

Fire intensity	Concrete depth for ceiling slabs and exterior walls not against earth
Class A. Great fire intensity	
Large quantities of flammable material near the shelter such as:	
1. More than one wooden floor directly over the shelter.	
2. Superstructure in wood.	40 cm (16 inches)
3. Storage of flammable material such as wood, furniture, plastics, hay, and fuel in one of the first two floors directly over the shelter or next to the shelter.	
Class B. Small fire intensity	
All cases not included in class A, in particular:	
1. One family houses, except wooden houses (walls and floors of wood).	30 cm (12 inches)
2. Apartment houses and office buildings of concrete with the exception of class A3. above).	

material near the shelter. The fire intensities have been divided into two groups (Table 3-2).

The concrete dimensions in Table 3-2 must be increased by 15 cm (6 inches) if it is not possible to leave the shelter for long periods due to the radiation of heat from nearby fuel concentrations such as tanks, lumber yards, etc. The minimum requirements for protection from heat generated by fires in underground tanks in the immediate vicinity of the shelter or tanks inside the building limits are included in article 2.4.4.

When choosing the concrete depth for protection against heat from fires any earth cover may be fully considered.

3.3 DESIGN FOR PROTECTION FROM NUCLEAR RADIATION

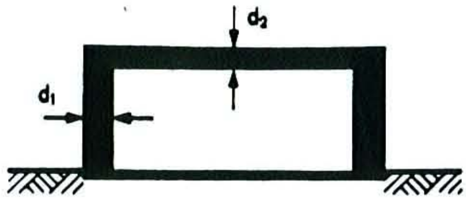
The reduction of the nuclear radiation is accomplished by the mass surrounding the shelter. As a first approximation one can say that it is not so much the type of material but the product of its specific weight times the wall thickness which is important. The radiation protection will subsequently always be given as a thickness of concrete. Other construction materials may be considered on the following basis:

10 cm of earth are equivalent to	7 cm of concrete
4 inches of earth are equivalent to	3 inches of concrete
10 cm of wood are equivalent to	3 cm of concrete
4 inches of wood are equivalent to	$1\frac{1}{4}$ inches of concrete
10 cm of wood are equivalent to	7 cm of concrete
4 inches of masonry are equivalent to	3 inches of concrete

The necessary construction thickness of the shelter shell depends to a large extent on the position of the shelter within the building and relative to the ground. Since the greatest part of the primary radiation strikes just before the shock wave arrives, the building is to be assumed undestroyed.

In the following typical examples the necessary thickness "d" of the shelter exterior is calculated on the basis of the "Handbook of Weapons Effects" (BZS 1964 Edition, Chapter 4). The examples given are sufficient for the needs of private shelters, and appropriate interpolation may be made between two basic types (Fig. 3-1).

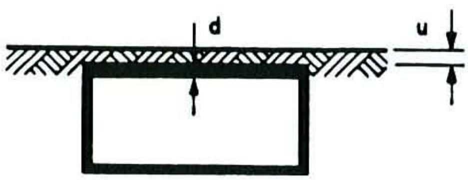
Fig. 3-1. Concrete thickness required for protection from nuclear radiation.



Exposed roof slabs and walls, above ground

	Thickness of shelter shell for	
	1 atmos.	3 atmos.
d_1	= 80 cm (31")	120 cm (48")
d_2	= 55 cm (22")	85 cm (34")

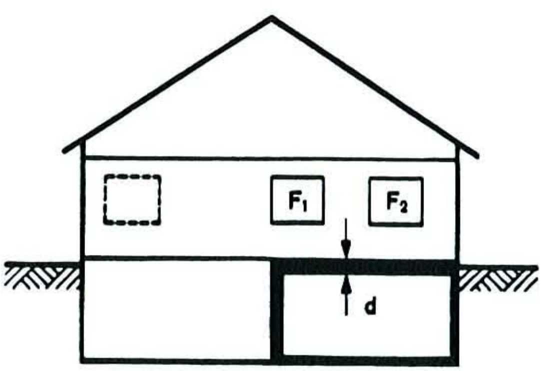
Fig. 3-1a



Roof slabs not under building

	Thickness of shelter shell for	
	1 atmos.	3 atmos.
Earth cover		
u = 0 cm (0") earth	d = 55 cm (22")	85 cm (34")
u = 20 cm (8") earth	d = 40 cm (16")	70 cm (28")
u = 40 cm (16") earth	d = 40 cm (16")	55 cm (22")
u = 70 cm (28") earth or more	d = 20 cm (8")	35 cm (14")

Fig. 3-1b



Roof slabs under building

	Thickness of shelter shell for	
	1 atmos.	3 atmos.
Building over the shelter		
one story	d = 35 cm (14")	55 cm (22")
multistory	d = 30 cm (12")	45 cm (18")

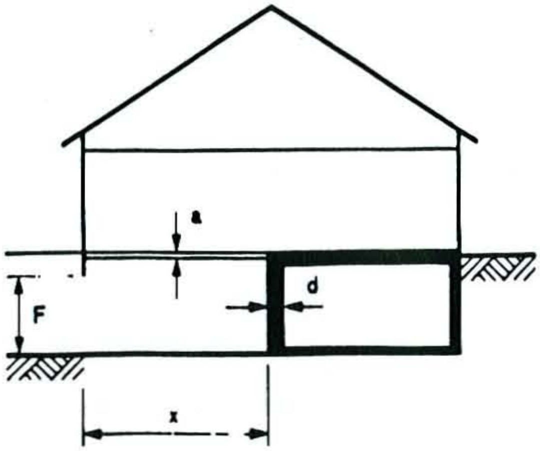
When the floor above the shelter has openings (doors or windows) "F" including more than 50% of the wall surface the values are:

one story	d = 40 cm (16")	60 cm (24")
multistory	d = 35 cm (14")	50 cm (20")

When the shelter is in the second or third basement the sum of the thickness of all the basement slabs above the shelter must have at least the values above.

Fig. 3-1c

(Figure continued on next page)



Cellar walls not against earth

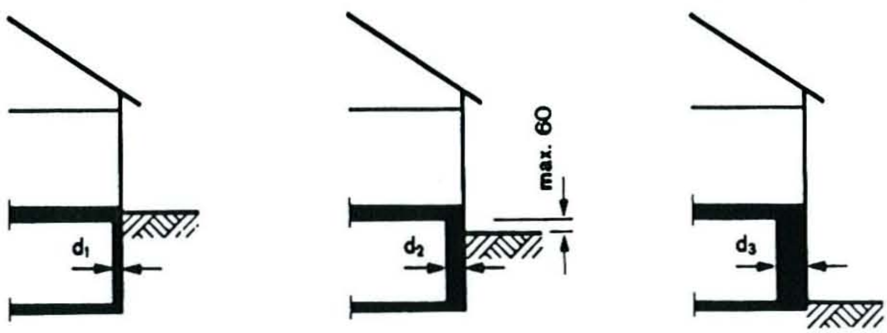
	Thickness of shelter shell for	
	1 atmos.	3 atmos.
a ≤ 15 cm (6") concrete equivalent:		
Z smaller than 0.1	d = 35 cm (14")	50 cm (20")
Z 0.1 to 0.5	d = 45 cm (18")	60 cm (24")
Z more than 0.5	d = 50 cm (20")	65 cm (26")
a > 15 cm (6") concrete equivalent		
Z smaller than 0.1	d = 25 cm (10")	35 cm (14")
Z 0.1 to 0.5	d = 30 cm (12")	45 cm (18")
Z more than 0.5	d = 40 cm (16")	55 cm (22")

F = surface of openings toward the outside (doors, windows) in cellar room adjacent to the pertinent shelter wall.

x = smallest distance from the center of the opening to the shelter wall.

Z = sum of all F/x^2.

Fig. 3-1d



Cellar walls against earth

	Thickness of shelter shell for	
	1 atmos.	3 atmos.
Type of wall		
Completely underground (ground surface not below the underside of the roof slab)	d_1 = 25 cm (10")	25 cm (10")
Partially underground (ground surface not more than 2 ft below the underside of the roof slab)	d_2 = 50 cm (20")	70 cm (28")
Uncovered wall (ground surface more than 2 ft below the roof slab)	d_3 = 80 cm (32")	120 cm (48")

Fig. 3-1e

3.4 MECHANICAL LOADINGS CAUSED BY WEAPONS EFFECTS

3.4.1 Basis for Calculation and Rules for Construction

In order to judge the effectiveness of a shelter it is necessary to know its ultimate resistance when subject to the effects of weapons. To calculate the limit of survival with respect to the mechanical effects of weapons it would be necessary to have a comprehensive knowledge of not only the static resistance but also the permissible energy of deformation and the dynamic characteristics of the structure. Within the scope of these Technical Directives the design may be made in the sense of an approximation by equating the static resistance with the ultimate loads given in article 3.4.2. This ultimate load is composed of the static load equivalent to the weapons effect plus other simultaneous loads (such as the dead load, for example).

The ultimate load capacity may be quickly determined using the plastic design method and the corresponding design charts which are given in section 3.5. Since this design method may not yet be thoroughly familiar it is also permissible to calculate the internal forces and moments resulting from the equivalent static loads using elastic theory and dimension the cross sections for these forces in the condition of rupture. This method generally leads to heavier reinforcement.

1. Resistance of steel: The yield stress for the most commonly used reinforcement steels may be used in the calculations in accordance with the values given in Table 3-3. These values are slightly higher than the normal yield stress since only very quick stress increases are considered. The dependence of the yield stress on the rate of stress increase is a property of steel and is not to be confused with the dynamic behavior of the structure under transient loads.
2. Concrete compressive strength:* The values for compressive strength may be increased by 30% over the usual static test values obtained with cubes, but not more than 100 kg/cm² (1400 psi).
3. Shear and bond strength:* Since the shear and bond stresses may produce brittle failure neither the shear strength nor the bond strength limits may be increased for dynamic loads.
4. Minimum percentage of reinforcement: The supporting parts of the shelter should contain a minimum amount of reinforcement which is to be placed structurally as a main reinforcement. This minimum reinforcement should be at least 0.1% in each direction for any cross section (0.2% of the concrete cross section) with the exception of the undersurface of the floor.
5. When contraction joints cannot be avoided in a shelter they should be placed between partition walls at least 20 cm (8 inches) thick. Openings through these walls must be sealed around the joint with a waterstop.
6. Connections of the shelter with other structures: Other structural elements may be attached monolithically or fixed rigidly to the shelter. These connections or attached structures must be fashioned in such a manner, however, that their collapse does not destroy the shelter shell.

*The values given here for strengths of materials correspond with those in the addendum of 4 March 1966 to the Recommendations of the Federal Office of Civil Defense of 24 April 1965 concerning the minimum requirements for structures. They are to be used in connection with the appropriate SIA codes, especially No. 162 and are valid until the issue of the new appropriate SIA codes.

Table 3-3. Dynamic yield stress for reinforcement steel

Steel type	Yield stress kg/cm² 7–18 mm diam	Yield stress kg/cm² 20–30 mm diam	Yield stress psi Bar No. 3–6	Yield stress psi Bar No. 6–14
Reinforcement steel I	3000	2600	43,000	37,000
Reinforcement steel II SIA code 162 (1956)	4200	3800	60,000	54,000
Reinforcement steel III SIA code (proposed 1966)	4800	4600	68,000	65,000
Reinforcement steel IV (up to 12 mm or bar No. 8)	static yield stress		static yield stress	

7. Steel paneling: The steel paneling on the inside of the shelter may not be more than 2 cm (¾ of an inch) thick. An increased thickness is not allowed because of the danger of popping off.
8. Hooks: End hooks for reinforcement steel may be omitted if a complete load transfer may be obtained without them.
9. No plaster or insulation may be applied to the inside walls or ceiling of the shelter.
10. Relation to the SIA code: All questions of structural form or construction which are not treated by these Directives are to be resolved according to the pertinent regulations of the SIA code.

3.4.2 Assumed Loads

In the following article the static equivalent loads for ground shock and air blast are presented. The former is primarily the governing force for sections of the structure within the shelter such as intermediate floors of walls and attached equipment. The generated loads are distributed in the same way as the dead weight but may be many times as great and act in any direction. The air blast loads act primarily normal to the surface of the shelter shell and create bending and shear stresses in the walls, roofs, and floors. In addition, opposing normal forces occur which must be considered when they reduce the ultimate load of a structural element. For the design of individual parts of the structure (articles 3.4.2.1 to 3.4.2.8) only the loads respectively mentioned need be considered.

3.4.2.1 **Shelter roofs.** The dead weight of the shelter roof and the weight of the earth cover or live loads are to be added to the static equivalent air shock wave pressure p_v (see Fig. 3-2). On the other hand possible loads from the building above, such as debris load, are not to be included.

	Equivalent static load P_v for air blast of	
	1 atmos.	3 atmos.
Roofs under or outside of buildings	10 t/m^2 (2 kips/sq ft)	30 t/m^2 (6 kips/sq ft)

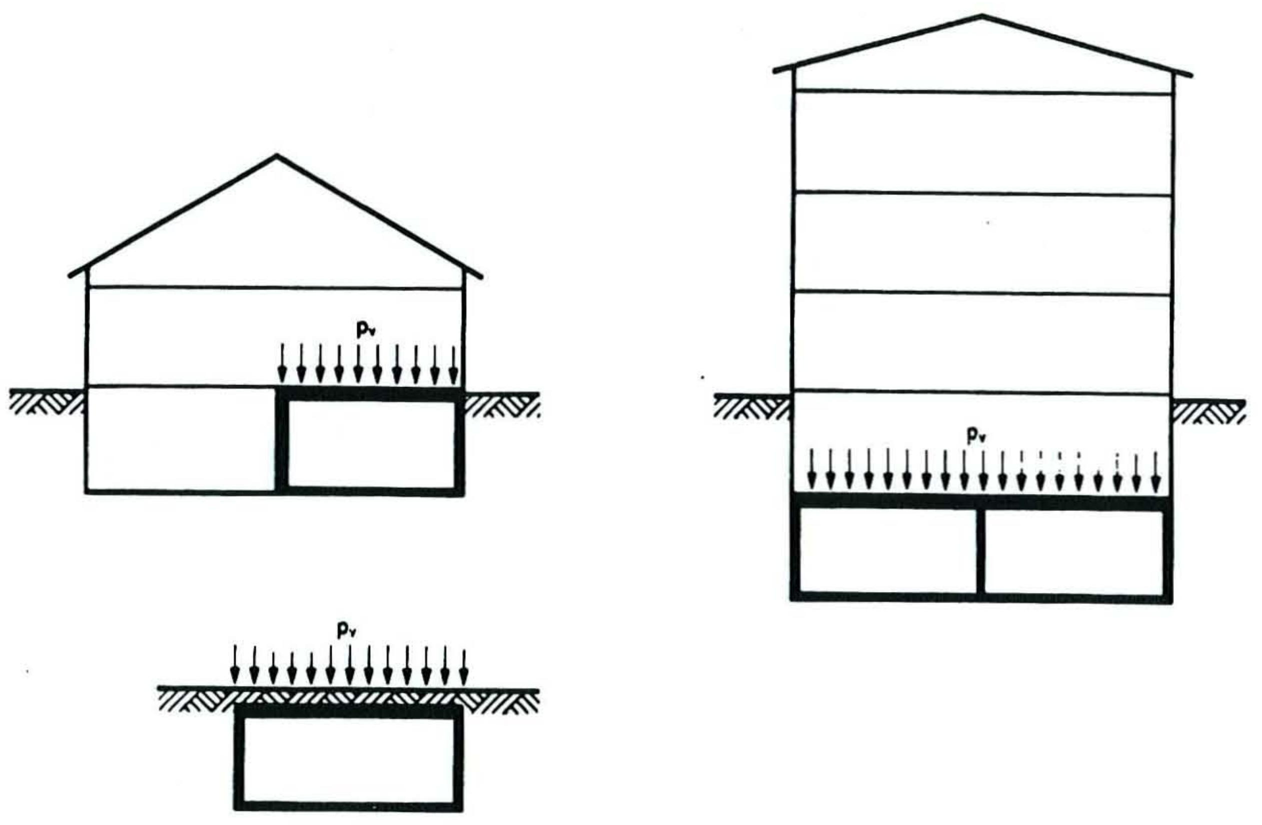


Fig. 3-2. Loads on shelter roofs from air pressure.

3.4.2.2 Floor slabs. The equivalent static load for air blast acting on the floor slab is the same as that acting on the roof (see article 3.4.2.1). The dead weight of the entire shelter (with the exception of the floor slab) and any earth cover are to be included as permanent loads.

These loads are to be assumed as being uniformly distributed over the floor when designing for shear loads.

Type of ground	Equivalent static load p_v for air blast of	
	1 atmos.	3 atmos.
Above ground water	10 t/m² (2 kips/sq ft)	30 t/m² (6 kips/sq ft)
In ground water	12 t/m² (2.4 kips/sq ft)	36 t/m² (7.2 kips/sq ft)

1 kip = 1000 lb.

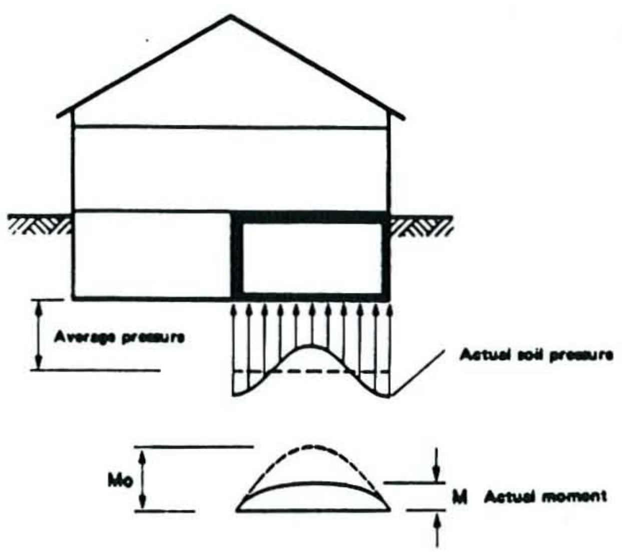


Fig. 3-3. Decrease in the maximum bending moment in the floor slab from moment M_0 to M as a result of the arching effect in the soil.

There is a non-uniform distribution of the ground pressure as a result of the supporting effect of the soil and the actual bending moment M is less than the bending moment M_0 which would result from a uniform soil pressure (see Fig. 3-3). The bending moments may therefore be calculated by assuming the following uniformly distributed equivalent static loads for air blast:

Type of ground	Equivalent static load p_v for air blast of	
	1 atmos.	3 atmos.
Sand or gravel	3 t/m² (600 lbs/sq ft)	10 t/m² (2000 lbs/sq ft)
Silty soils	7 t/m² (1400 lbs/sq ft)	20 t/m² (4000 lbs/sq ft)
Saturated soils	10 t/m² (2 kips/sq ft)	30 t/m² (6 kips/sq ft)
In ground water (see art. 2.1.2.2)	12 t/m²2 (2.4 kips/sq ft)	36 t/m² (7.2 kips/sq ft)

In good soils, especially on rock, the floor slab may be replaced by strip foundations or individual footings wherever the secondary weapons effects described in article 1.4.5 are not possible (Fig. 3-4). In this respect the following applies:

1. The assumption of a uniformly distributed soil pressure for the vertical loading from weapons effects may not exceed four times the allowable soil pressure for peacetime loads, $\sigma_{B\,zul}$.
2. The foundation must be able to resist the loads transmitted from the walls as a result of the simultaneous occurrence of horizontal soil pressure p_h as described in articles 3.4.2.3 and 3.4.2.4 (see Fig. 3-4).

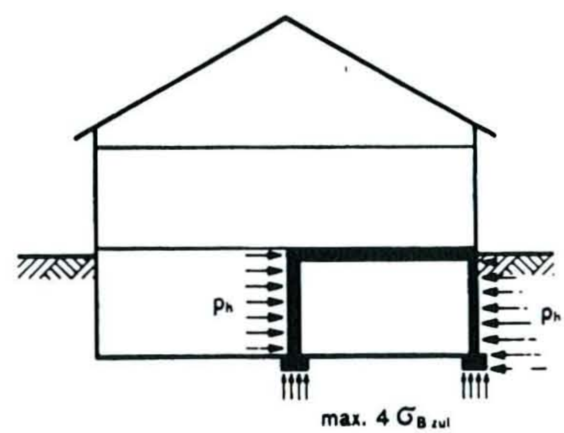


Fig. 3-4. Loads on strip footings for a shelter.

3.4.2.3 Exterior walls against the ground. The earth pressure acting in peacetime is to be added to the uniformly distributed equivalent static load p_h from ground shock indicated in the following table (see also Fig. 3-5).

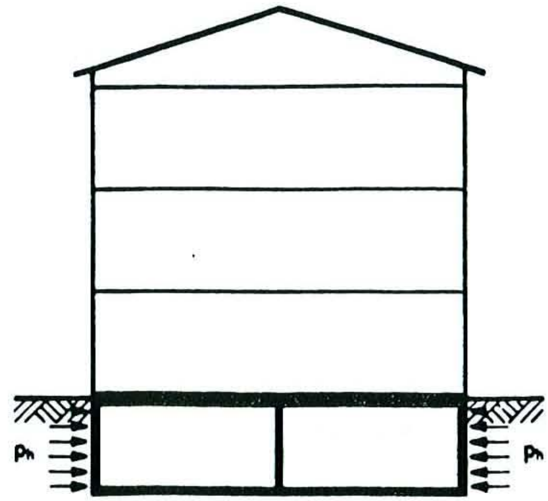


Fig. 3-5. Loads on exterior walls against the ground from ground shock.

Type of soil	Equivalent static load from ground shock for	
	1 atmos.	3 atmos.
Unsaturated	7 t/m² (0.7 tons/sq ft)	20 t/m² (2 tons/sq ft)
Saturated	10 t/m² (1 ton/sq ft)	30 t/m² (3 tons/sq ft)
In ground water	12 t/m² (1.2 tons/sq ft)	36 t/m² (3.6 tons/sq ft)

3.4.2.4 Exterior walls not against the ground. Exterior walls which are not directly in contact with the ground may also be subject to reflected pressure in addition to the excess pressure acting from all sides. This reflected pressure will be diminished to some extent by the surrounding portions of the building; the pressure p_h is therefore dependent on the area of the openings in the adjacent basement such as doors and windows (Fig. 3-6).

F (%)	Equivalent static load p_h from air blast	
	1 atmos.	3 atmos.
less than 50	10 t/m² (1 ton/sq ft)	30 t/m² (tons/sq ft)
more than 50	17 t/m² (1.7 tons/sq ft)	60 t/m² (6 tons/sq ft)

F = area of openings in the exterior wall of the adjacent basement opening directly outside, in % of the total wall surface.

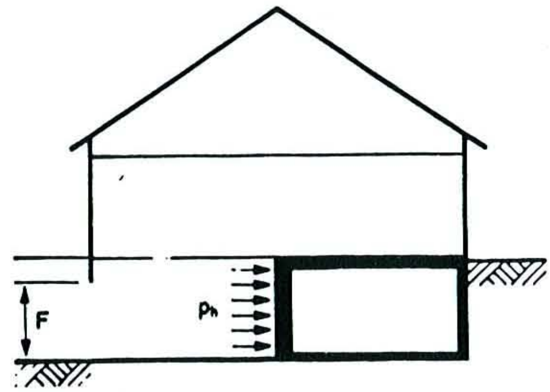


Fig. 3-6. Air blast loads on exterior walls not in contact with the ground.

3.4.2.5 Intermediate floors and partition walls. The ground shock produces accelerating forces similar to seismic shocks which constitute the determining loads from weapons effects for intermediate floors and partition walls. The created loads are distributed in the same way as the dead weight (including all objects fastened to the roof or walls). These loads are several times greater, however, and can act in any direction.

The given loads p are ultimate loads (dead loads are not to be superposed) and are presented as multiples of the dead weight g_e. They are to be assumed as acting perpendicular to the wall or slab and in either direction (Fig. 3-7). Since even greater shock loads than those given may occur for short periods no brittle material such as tile or plaster may be used for intermediate floors or partition walls.

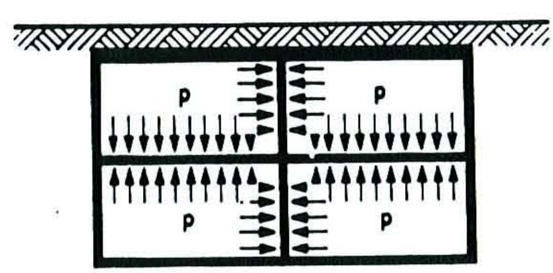


Fig. 3-7. Loads on intermediate floors and partition walls as a result of shock.

	Ultimate static load p for	
	1 atmos.	3 atmos.
Intermediate floors and partition walls	2 g_e	6 g_e

3.4.2.6 **Open-ended galleries.** Galleries with a closed cross section which are closed at one end and lead out into the open at the other must be designed for excess pressure acting from the outside or the inside which may result from reflected air blast (see Fig. 3-8). Other loads which may act simultaneously such as dead weight and earth cover must be added to the given equivalent static load p resulting from air blast.

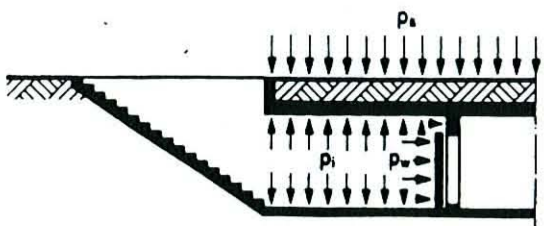


Fig. 3-8. Loads in open-ended galleries resulting from air blast (P_a and P_i do not occur simultaneously).

	Equivalent static load p resulting from air blast for	
	1 atmos.	**3 atmos.**
Net excess outside pressure acting inward	10 t/m² p_a (1.0 ton/sq ft)	30 t/m² (3.0 tons/sq ft)
Net excess internal pressure acting outwards	15 t/m² p_i (1.5 tons/sq ft)	60 t/m² (6.0 tons/sq ft)
Pressure against end wall	24 t/m² p_w (2.4 tons/sq ft)	90 t/m² (9.0 tons/sq ft)

3.4.2.7 **Air locks.** The loads on air locks are the same as those for galleries open at one end (article 3.4.2.6). They must therefore be designed for the net excess internal pressure p_i (see Fig. 3-9). (Dead loads and possible earth cover are also to be added.)

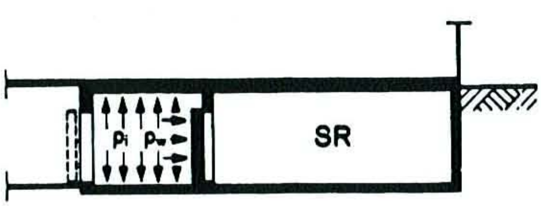


Fig. 3-9. Loads on air locks as a result of air blast.

	Equivalent static load p resulting from air blast for	
	1 atmos.	**3 atmos.**
Walls, roofs, and floors of air locks in the shelter		
In the shelter shell	15 t/m² p_i (1.5 tons/sq ft)	60 t/m² (6.0 tons/sq ft)
Between air lock and SR or RE	24 t/m² p_w (2.4 tons/sq ft)	90 t/m² (9.0 tons/sq ft)

3.4.2.8 **Debris protection for entrances and other supporting structural elements of emergency exits.** The structural elements of escape passages resistant to air blast (article 2.2.3.3) and debris protection of the entrance (article 2.2.2.2), as well as entry ways and cantilever slabs, will be subjected to pressure differences caused by the air blast (Figs. 2-11 and 2-5) and must therefore be dimensioned to resist the following equivalent static loads. These loads may act internally or externally on entry ways and from above or underneath on cantilevered slabs. The dead weight and earth covers are to be added to these loads.

Vertical escape shafts are to be designed as cantilevers fixed in the shelter shell and acted upon by a horizontal pressure from any direction acting perpendicularly to the projected area similarly to a wind pressure.

Covers for the exits of escape tunnels (article 2.2.3.5) are to be dimensioned in the same way as shelter roofs:

Structural element	Equivalent static load p from air blast for	
	1 atmos.	**3 atmos.**
Debris protection of the entrance	7 t/m² (0.7 ton/sq ft)	20 t/m² (2.0 tons/sq ft)
Air blast-proof escape tunnels	7 t/m² (0.7 ton/sq ft)	20 t/m² (2.0 tons/sq ft)
Escape shafts	15 t/m² (1.5 tons/sq ft)	40 t/m² (4.0 tons/sq ft)
Covers for the exit of escape shafts	10 t/m² (1.0 ton/sq ft)	30 t/m² (3.0 tons/sq ft)

3.4.2.9 **Furnishings and conduits.** The furnishings and conduits and their fastenings which are mounted in the shelter must be able to resist the forces of acceleration caused by shock. These forces act at the center of gravity of the object (and may be assumed as being distributed in proportion to the mass) and can act vertically up or down or in any horizontal direction.

Permanent forces (dead weight) are included in the equivalent static load.

	Ultimate static load p for	
	1 atmos.	3 atmos.
Furnishings and conduits	4 g_e	12 g_e

3.5 DESIGN OF RECTANGULAR REINFORCED CONCRETE SLABS BY THE ULTIMATE LOAD METHOD

In this section the engineer will find charts (Figs. 3-10 to 3-14) which indicate the ultimate uniformly distributed loads for underreinforced rectangular concrete slabs. They are based on the classic yield line theory, that is, the ultimate load method for reinforced concrete slabs, and consider only the bending resistance. If the shear stresses have a significant influence on the behavior of beams or slabs at failure these stresses must be considered in the design. The charts may be used for sections without shear reinforcement up to a nominal ultimate shear stress τ_{br} (calculated at the supports) of:

$$\tau_{br} = \frac{Q}{b \cdot h} \leqslant \begin{cases} 0.06\,\beta_w & \text{for } \dfrac{l}{h} \leqslant 8 \\[2ex] \dfrac{\beta_w}{3}\left(1 - 0.1\dfrac{l}{h}\right) & \text{for } \dfrac{l}{h} < 8 \end{cases}$$

where:

l = span length

h = effective slab thickness

β_w = ultimate compressive strength of concrete cubes.

The charts are based on an assumed distributed load of p = 1 atmos. and a (dynamic) yield point of 4800 kg/cm² (68,000 psi) for the reinforcement steel. For other values of p or σ_{fld} the amount of reinforcing varies according to the following proportion:

$$\frac{p}{1\ \text{atmos.}} \cdot \frac{4800\ \text{kg/cm}^2}{\sigma_{fld}} \quad \text{or} \quad \frac{p}{1\ \text{atmos.}} \cdot \frac{68{,}000\ \text{psi}}{\sigma_{fld}}$$

The charts are prepared on the basis of the EMPA formula for calculating the plastic moment m per unit width in underreinforced slabs.

$$m = \mu h^2 \sigma_{fld}\left(1 - \frac{2}{3}\frac{\sigma_{fld}}{\beta_w}\mu\right) \leqslant 0.2\beta_w h^2$$

in which μ is the ratio of longitudinal-reinforcement area to total cross section area above it and σ_{fld} is the dynamic yield stress for the reinforcement. The parameter for the curves is the degree of plastic fixity, that is, the ratio of the plastic moments over the supports m^- and at mid-span m^+. This plastic degree of fixity λ^-, unlike the elastic degree of fixity, is not dependent on the elastic characteristics of the building. It is determined by the distribution of the necessary reinforcement in the span and over the supports, and may therefore be selected to a large extent by the engineer.

In Fig. 3-10 the ordinate gives the required percent of reinforcement μ^+ for the span which may be read directly as a function of the slab slenderness ratio:

$$\frac{\text{span width}}{\text{effective slab depth}}$$

For a given value of l/h and λ^- the necessary percent μ^- of reinforcement may be read from the diagram.

For the design of rectangular plates supported on four edges four different plastic moments must be differentiated: the longitudinal span moment m_x^+ and edge moment m_x^- and the transverse span moment m_y^+ and edge moment m_y^-. A new parameter, a ratio of the side lengths l_1/l_2 is also introduced. Figures 3-11 to 3-14 are applicable for the four degrees of plastic fixity m_x^-/m_x^+ and m_y^-/m_y^+ equal to 0, 0.5, 1.0, and 1.5 whereby zero represents the rectangular plate with simply supported edges. (The degree of fixity is assumed to be the same in both directions.) The ordinate represents the percent of reinforcement steel μ_x^+ in the direction of the principle span and the abscissa is the slenderness ratio l_1/h where l_1 is the shorter span length and h is the effective slab depth. The curve parameter is the ratio of span lengths l_1/l_2 with a chosen fixed ratio of the plastic moments in the principle and secondary direction $\chi = m_y^+/m_x^+ = m_y^-/m_x^-$. This ratio is chosen as 1.0 for the square slab and decreases linearly with the span ratio l_1/l_2.

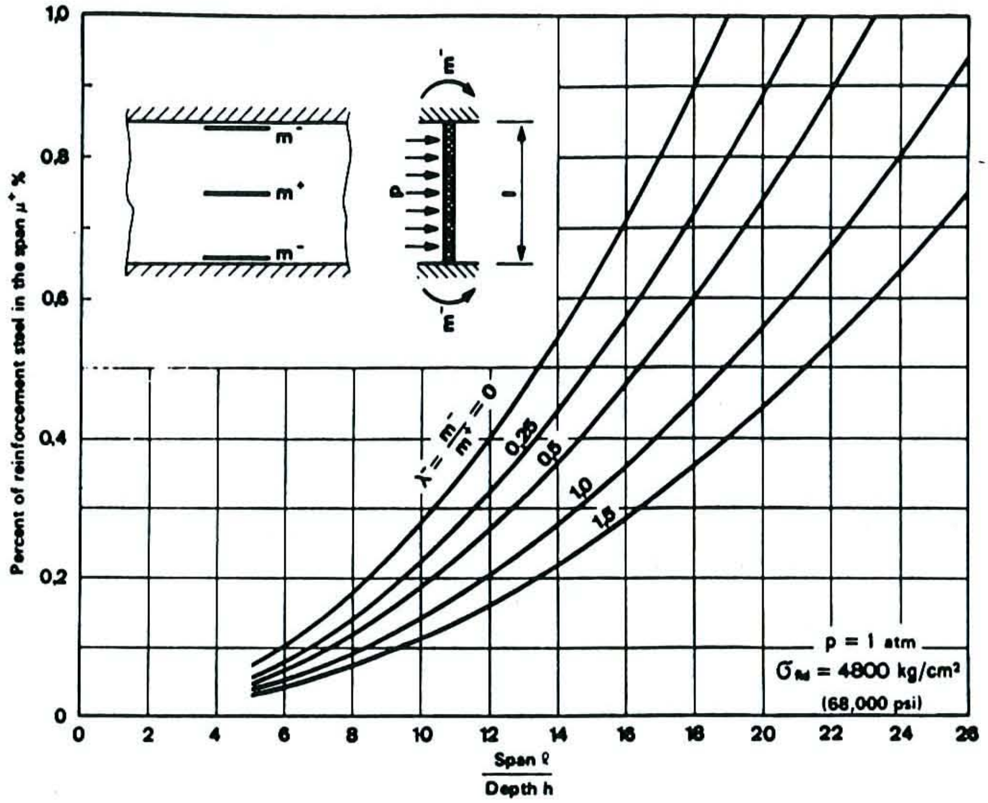


Fig. 3-10. Ultimate load design for a reinforced concrete slab supported on two edges.

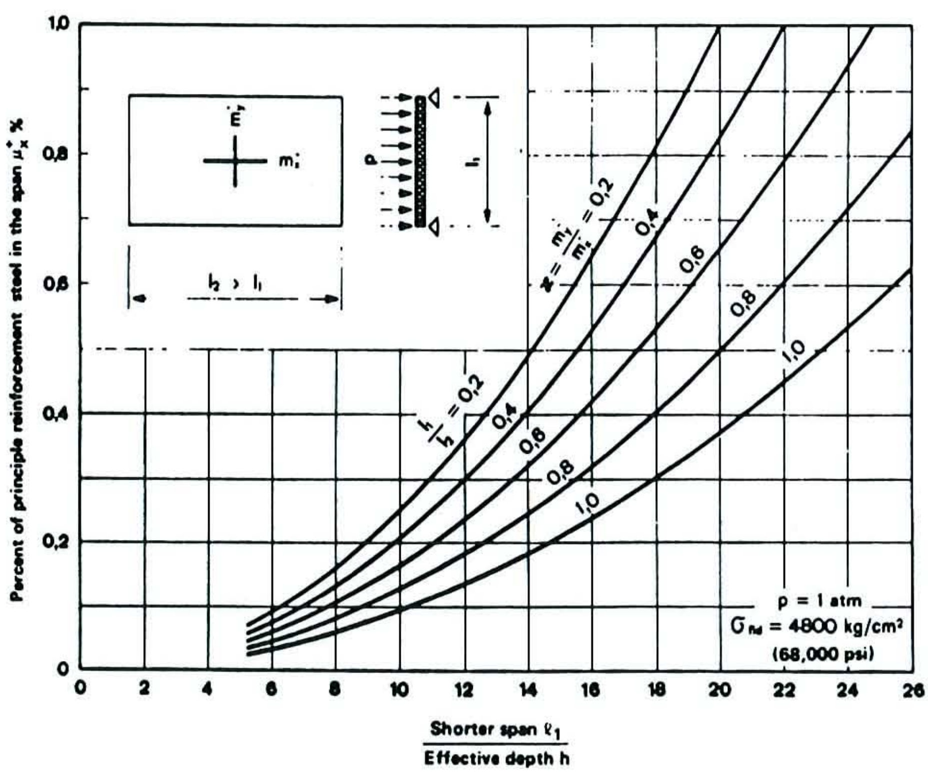


Fig. 3-11. Ultimate load design for a reinforced concrete slab simply supported on four edges.

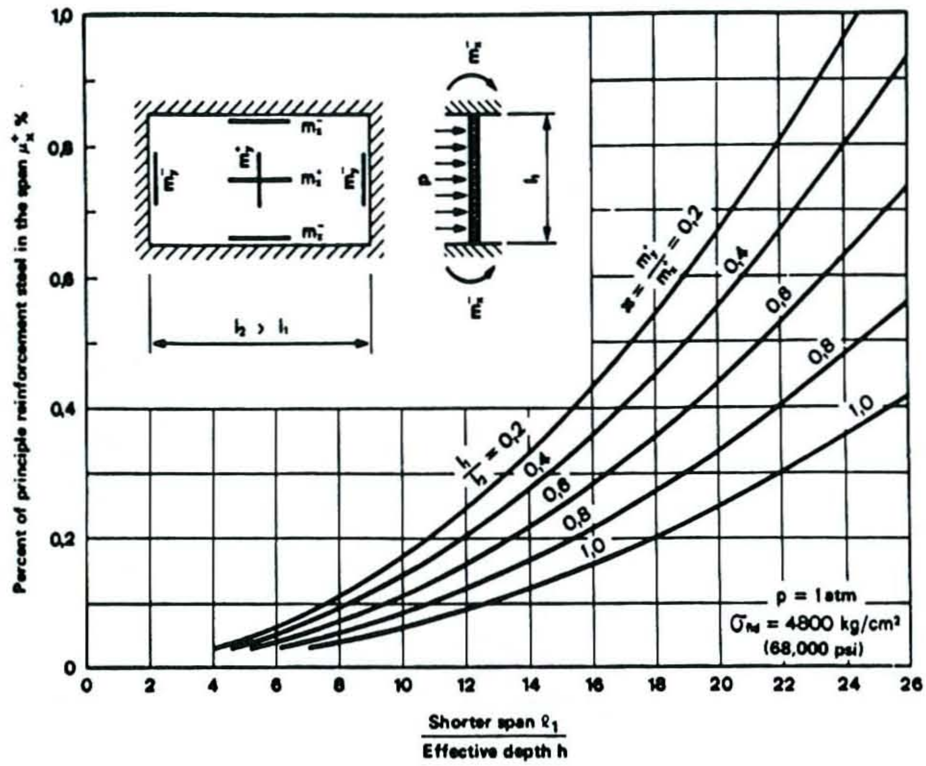


Fig. 3-12. Ultimate load design for a reinforced concrete slab with a plastic edge fixity of 0.5 on four sides.

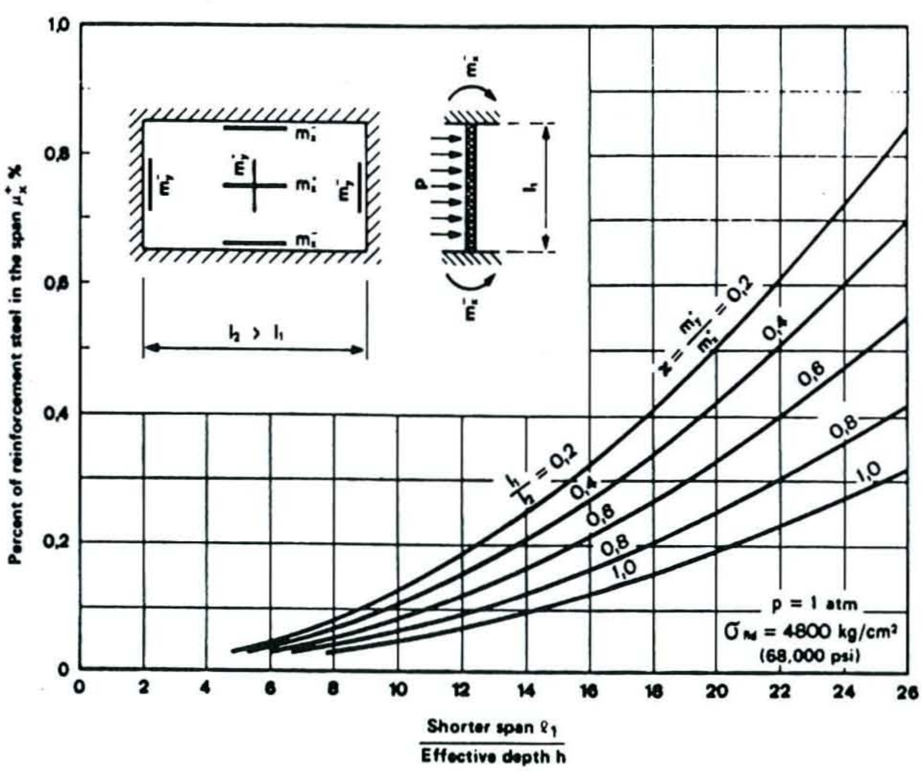


Fig. 3-13. Ultimate load design for a reinforced concrete slab with a plastic edge fixity of 1.0 on four sides.

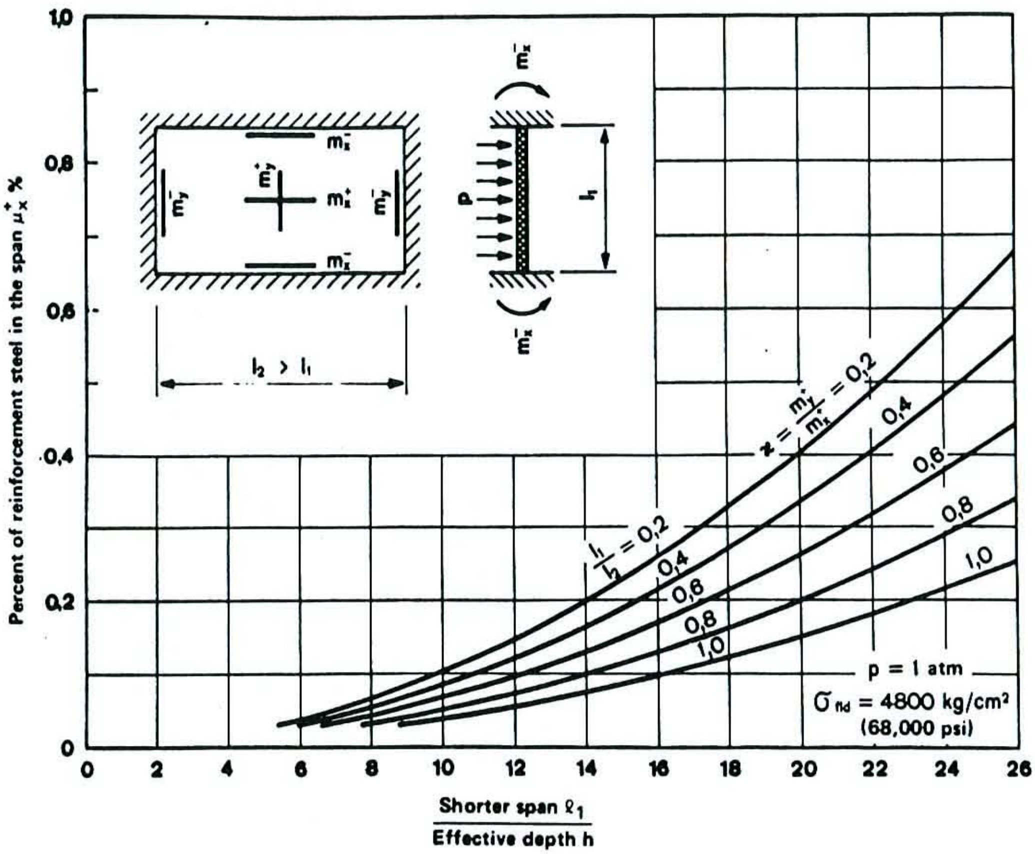
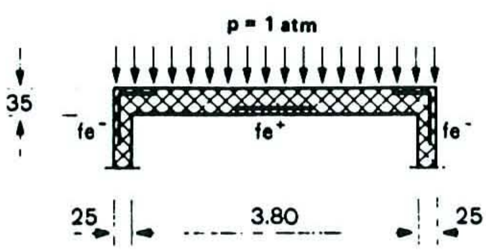


Fig. 3-14. Ultimate load design for a reinforced concrete slab with a plastic edge fixity of 1.5 on four sides.

Example No. 1: Roof of a 1 atmosphere shelter

Given:

Span	l = 400 cm (13 ft 2 in.)
Slab thickness	d = 35 cm (14 in.)
Wall thickness	d_w = 25 cm (10 in.)
Static depth:	
mid-span	h = 32 cm (12½ in.)
edge	h^- = 22 cm (8½ in.)
Degree of plastic fixity (assumed)	$\frac{m^-}{m^+} = 0.25$



To be found:

Effective cross-sectional area of steel reinforcement A_s^+ in the span and A_s^- over the supports:

$$\left(\frac{l}{h} = \frac{158}{12} = 12.6\right) \qquad \frac{l}{h} = \frac{400}{32} = 12.5$$

$\lambda^- = 0.25$

from Fig. 3-10:

$\mu^+ = 0.35\%$ $\quad fe^+ = 11.2\ \mathrm{cm^2/m}$ (0.52 in.²/ft)

The thinner section of the wall will be determining for the moment over the supports. The quantity of reinforcement is proportional to the static depth h, therefore:

At the supports

$$\mu^- = \mu^+ \cdot \lambda^- \cdot \left(\frac{h}{h^-}\right)^2 = 0.19\%$$

$fe^- = 4.2\ cm^2/m$ (0.245 sq in./ft)

The dead weight of the roof [$g_e = 1\ t/m^2$ (200 lb/sq ft) in this case] is to be included when calculating the ultimate load. The steel content must therefore be increased by a factor of 1.1 [1 atmos. plus 1 t/m^2 (200 lb/sq ft) = 1.1 atmos.]. Therefore:

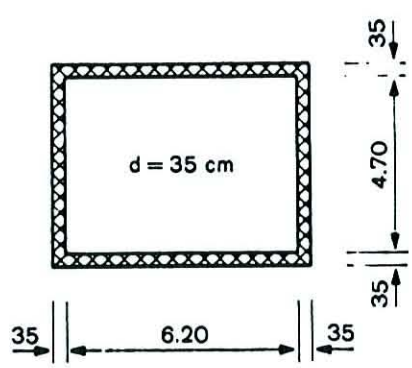
$fe^+ = 12.3\ cm^2/m$ (0.570 sq in./ft)

$fe^- = 4.6\ cm^2/m$ (0.270 sq in./ft)

Example no. 2: Roof of a 1 atmos. shelter

Given:

span length		$l_1 = 500$ cm (16 ft)
span width		$l_2 = 650$ cm (21 ft)
slab thickness		$d = 35$ cm (14 in.)
wall thickness		$d_w = 35$ cm (14 in.)
effective depth:	mid-span	$h = 32$ cm (12 in.)
	edge	$h^- = 32$ cm (12 in.)
plastic fixity (assumed)		$\frac{m^-}{m^+} = 1.0$



To be found:

Cross-sections of steel reinforcement fe_x^+, fe_x^-, fe_y^+, fe_y^-

with:

$$\frac{l_1}{h} = \frac{16 \times 12}{12} = 16.0 \qquad \frac{l_1}{h} = \frac{500}{32} = 15.6$$

$$\frac{l_1}{l_2} = \frac{500}{650} = 0.77 \cong 0.8$$

$$\frac{l_1}{l_2} = \frac{16}{21} = 0.76 \cong 0.8$$

From Fig. 3-13:

$$\chi = 0.8 = \frac{m_y^+}{m_x^-}$$

$\mu_x^+ = 0.16\%$ $\qquad fe_x^+ = 5.1\ cm^2/m$
$= 0.24\ in.^2/ft$

$\mu_y^+ = 0.8 \cdot \mu_x^+ = 0.13\%$ $\qquad fe_y^+ = 4.1\ cm^2/m$
$= 0.19\ in.^2/ft$

Since the degree of plastic fixity λ^- is 1.0 the plastic moments over the supports are the same as in the span. For equal effective depths h^- and h^+ the reinforcement is the same in the span as over the supports. In addition the values taken from the charts for 1 atmosphere pressure must be converted to the ultimate total load including dead weight:

Therefore it follows that : [dead weight $g_e = 1\ t/m^2$ (200 lb/sq ft)]

$$fe_x^+ = fe_x^- = 1.1 \cdot 5.1 = 5.6\ cm^2/m$$
$$= 1.1 \times 0.24 = 0.26 \text{ sq in./ft}$$

$$fe_y^+ = fe_y^- = 1.1 \cdot 4.1 = 4.5\ cm^2/m$$
$$= 1.1 \times 0.19 = 0.21 \text{ sq in./ft}$$

In both examples the required reinforcement is more than the minimum value of 0.1% which therefore does not apply.

Appendix A. Summary of the Most Important Information

This abbreviated summary contains only the most important information from the chapters 1 through 3 and is not meant to be a complete summary of the compulsory regulations. It is intended only as an aid for reference to be used in conjunction with the main text.

1. Applicability of the TWP — Section 1.1

Private shelters in new buildings
Degree of protection:
required 1 atmos.
permitted 1 or 3 atmos.

2. Application of the TWP

Shelter planning (architect)	Chapter 2
Final structural design of the shelter (engineer)	
General	Chapter 3
Exceptions (only 1 atmos. shelters with up to 25 places)	Appendix C
Design procedure	Section 3.1
Dimensions for preliminary design and building permit	Article 2.1.3
Calculation of concrete thickness:	
Fire load	Section 3.2
Radioactive radiation	Section 3.3
Calculation of the concrete reinforcement	
Mechanical effects of weapons (or peacetime loads)	Section 3.4
Fulfilling requirements for the effects of other weapons (Section 1.4)	
Minimum concrete thickness	Sections 3.2 and 3.3
Minimum concrete reinforcement	Section 3.4

3. The number of places to be provided in the shelter — Article 2.1.1.2

Type of building	Number of places
Homes and vacation houses	1 per room
Hospitals and asylums	1 per bed
Hotels	⅔ of the number of beds
Restaurants, places of amusement (movies, theatres, etc.), schools	⅔ the number of seats
Churches and temples	½ the number of seats
Offices and administration buildings, industrial and commercial businesses (factories and shops)	⅔ the number of work places
Stores and warehouses	1 per 20 m^2 (200 sq ft) of floor space
Storehouses, permanent exhibits, and exposition halls	1 per 150 m^2 (1500 sq ft) of floor space

4. Space requirements — Article 2.1.1.3

Per place in the shelter	1 m^2 (10 sq ft) of floor space 2.5 m^2 (88 cu ft) of volume
For each ventilator	1 m^2 (10 sq ft) of floor space
For each air lock	0.05 m^2 (0.5 sq ft)/shelter place min 2.5 m^2 (25 sq ft) max 5.0 m^2 (50 sq ft)
For each decontamination room	0.07 m^2 (0.7 sq ft)/shelter place min 3.5 m^2 (35 sq ft)
For each combined air lock-decontamination	0.1 m^2 (10 sq ft)/shelter place min 5 m^2 (50 sq ft)
Shelter floor space	min 6 m^2 (60 sq ft)
Head room for a shelter	min 2 m (6 ft 6 in.)

5. Structural dimensions for preliminary design Article 2.1.3

Structural element	Location	Concrete thickness 1 atmos. cm	in.	3 atmos. cm	in.
Roofs	Under buildings	35	14	55	22
	Not under buildings with earth cover of				
	0 in.	55	22	85	34
	12 in.	35	14	65	26
	More than 20 in.	30	12	50	20
	Normal intermediate floors	20	8	20	8
	Intermediate floors over or under an air lock	25	10	30	12
Walls	Entirely underground (ceiling below ground)	25	10	25	10
	Partially underground (underside of ceiling not more than 2 ft above ground)	50	20	70	28
	Exterior wall standing free (underside of ceiling more than 2 ft above ground)	80	32	120	48
	Walls facing the basement not against the ground (also partition walls between two shelter groups)	35	14	55	22
	Partition walls	20	8	20	8
	Air lock walls	25	10	30	10
Floors	Foundation slabs	20	8	25	10

6. Requirements for air locks, decontamination rooms, toilets, and showers Article 2.2.2.3

Number of shelter places	Inclusion	Construction of S and RE in one room or separate	Minimum number of showers	Minimum number of toilets[a]
up to 50	optional	S and RE in 1 room		
51–100	required	S and RE in 1 room or separate	1 per 100 places	1 per 30 places
101–200	required	S separate from RE		

[a]Half may be chemical toilets and the rest latrines.

7. Arrangement of emergency exits Article 2.2.3

Number of shelter places	Minimum requirements for unaided emergency exit for stage I	II	IV	Figure
up to 13		1		2-7
14–50	1	1		2-8a
or			1	2-8b
51–100		1	1	2-9a
or	1	2		2-9b
101–200	1	1	1	2-10a
or		2	1	2-10b

Construction of emergency exits

Stage I — Article 2.2.3.3
Air blast-proof escape passage (with cantilever slab or entrance gallery)
Width min 1.3 m (4'3")
Length min 2.0 m (6'6")

Stage II — Article 2.2.3.4
Emergency escape shaft 60 × 80 cm (24 by 32 in.)
With shaft 60 × 80 cm (24 × 32) in. inside
Without shaft: clean sand or gravel fill

Stage III — Articles 2.2.3.6 and 2.2.3.5
Escape chimney and escape tunnel ending in debris area: only allowed exceptionally as partial substitute for stage IV

Stage IV — Article 2.2.3.5
Escape tunnels that terminate outside the debris area (distance = ½ height under eaves) and/or connect to other escape tunnels system
Min cross-section: Concrete pipe 100 cm (40 in.) diam
Oval pipe 80/120 cm (32/48 in.)
Rectangular 80/100 cm (32/40 in.)

8. Shelter doors and shutters Article 2.2.4

Type	Opening	Inside dimensions cm	inches
PT	Outward	80 × 185	32 × 72
		100 × 185	40 × 72
		140 × 220	55 × 87
		60 × 120	24 × 48
PD	Inward	60 × 80	24 × 32
DT	Either way	80 × 185	32 × 72
		100 × 185	40 × 72
		140 × 220	55 × 87

9. Ventilation — Section 2.3

Capacity: Fresh air: 6 m^3/hr (212 cu ft/hr) per shelter place — Article 2.3.2.2

Filtered air: 3 m^3/hr (106 cm ft/hr) per shelter place — Article 2.3.2.3

Air intake: Outside the debris area (distance = ½ height under eaves) in escape tunnel for instance — Article 2.3.5.1

Ventilators — Article 2.3.3

Number of places in shelter[a]	Ventilator type number	Minimum ventilation capacity fresh air operation		Filter operation		Type of power	Power requirement (watts)
		m^3/hr	ft^3/min	m^3/hr	ft^3/min		
7	VA 20[b]	40	24	20	12	Manual	40
13	VA 40	80	48	40	24	Manual and electric	50
25	VA 75	150	90	75	40	Manual and electric	60
50	VA 150	300	180	150	90	Manual and electric	120

[a]In exceptional cases the number of places in the shelter may be increased by 10%.
[b]Only for one family houses.

10. Conduits — Section 2.4

Conduits in the shelter shell — Article 2.4.3.1

Only in the outer half of the shelter walls.

The maximum cross-sectional area is ¼ d^2 without reinforcing the wall

Conduits through the shelter wall — Article 2.4.3.1

Total cross-sectional area in any one wall maximum 600 cm^2 (93 sq in.)

Conduits without double bend max 250 cm^2 (39 sq in.)

Smooth finished openings max 150 cm^2 (24 sq in.) — Article 2.4.3.1

Water pipes up to 2 inch without special permission — Article 2.4.3.3

Sewer pipes — Article 2.4.3.2

Gas and fuel lines not allowed in shelters — Article 2.4.3.2

Communication — Article 2.4.3.2

A 20 cm (¾ inch) diam pipe must be provided in the exterior wall of each shelter

11. Fuel tanks — Article 2.4.4

Underground

The minimum distance from the shelter wall is 1.5 m (5 ft) or the wall must be 50 cm (20 in.) thick

In the basement

Oil tanks of 10,000 to 20,000 l (2500 and 5000 gallons) must be 3 and 5 m (10 and 16 ft) respectively from the shelter or the shelter wall must be 75 cm (30 in.) thick (without opening)

Oil tanks of more than 20,000 l (5000 gallons) capacity require special authorization

In case of a leak the fuel must not be able to reach the shelter (i.e., place the tank in a basin)

Gasoline tanks require special authorization

Appendix B. List of Terms with Definitions

1. TERMS CONCERNING THE EFFECT OF WEAPONS

Fusion bomb

A nuclear bomb which releases its energy through melting of atomic nuclei.

Fission bomb

A nuclear bomb which releases energy through splitting of atomic nuclei.

Ground level, low, and high explosions

Indication of the relative height of a nuclear explosion above ground. Ground level means an explosion near the ground (forming a crater). Low and high designate an explosion of 1 KT equivalent energy at 100 to 200 m (300 or 600 ft) altitude respectively or an explosion of 1 MT equivalent energy at 1000 to 2000 m (3000 or 6000 ft) altitude respectively.

Conventional weapons

Explosive weapons which release energy through molecular reactions (explosive and incendiary bombs, grenades, fragmentation bombs, and shells).

Roentgen

Physical unit for measuring radiation intensity.

Rem

Unit for measuring the biological effect of radioactive radiation.

Fire load

Measure of the existing flammable material in the neighborhood of the shelter, such as kg of wood equivalent per sq meter of floor space (or pounds/sq ft of floor space).

Shock

Collective term for the maximum values of acceleration, velocity, and displacement to which the shelter, as a rigid body, is subjected by the pressure wave propagated through the ground.

Mechanical effects

Comprehensive term for loads due to air pressure, soil pressure, shocks, fragments, debris, etc.

Reflected pressure

That pressure which is created on the surface of a solid object when an expanding air blast strikes it. The reflected pressure is more than twice as great as the impinging pressure due to the compressibility of the air.

2. TERMS CONCERNING THE SHELTER AS A UNIT

Shelter unit

A shelter consisting of one single room for occupancy (the shelter cell) by not more than 50 persons.

Shelter group

A shelter consisting of two to four shelter cells surrounded by one single shelter shell and provided with only one entrance.

Protective capacity

The sum of the protective effect offered by the shelter. For a comprehensive description one should include the maximum values of the effects of each type of weapon against which the shelter may offer some protection. In general only the maximum value for one single critical effect will be given, such as the peak value of the air blast resulting from a nuclear explosion in open terrain measured in atmospheres (i.e., atmospheres of excess pressure).

Shelter shell

The external elements (roof, walls, and floor) of the shelter which separate it from the unprotected surroundings.

Phases of operation

Specially defined conditions for which the shelter must fulfil a certain purpose or function (see section 1.3).

Unaided exit

The action of the surviving occupants of a shelter by which they free themselves from debris without outside help after an attack.

5% rule

An abbreviation for the rule, based on the Federal Law concerning the Structural Measures for Civil Defense of a 4 October 1963, which limits the additional costs for construction of a shelter to normally not more than 5% of the building costs.

3. TERMS CONCERNING SHELTER COMPONENTS

Exterior walls

Walls of the shelter shell.

Underground wall

A wall is against soil up to at least ceiling level.

Partially underground wall

A wall which is covered with soil to within at least 60 cm (two feet) of the ceiling height.

Free-standing wall

A shelter exterior wall which is not in a covered basement or covered with soil to within at least 60 cm (two feet) of the ceiling height.

Uncovered wall

A shelter wall which is in a covered basement.

Intermediate floor or wall

Floor or wall within the shelter shell.

Shelter in ground water

A shelter where the maximum yearly ground water level rises more than 50 cm (20 inches) above the shelter floor level.

Emergency exit

A comprehensive term for all sorts of exits which may be used when the surroundings are destroyed.

Air blast-proof escape passage

An emergency exit which leads out under the building with walls and roofs resistant to air blast. The exit from the shelter is by means of openings in the wall or an armoured door.

Emergency shaft

An emergency exit leading directly through the shelter shell to the building limits.

Escape tunnel

An underground emergency exit leading away from the building.

Escape chimney

An emergency exit consisting of an air blast proof vertical escape tube leading from the shelter above the expected level of debris.

Wall opening

An opening (protected with an armoured cover) in the shelter shell leading to an emergency exit.

Wall break-out panel

An opening in the partition wall between row houses which is closed off in peacetime, but which may be easily broken through in case of war for use as an emergency exit.

Debris area

The ground surface within which piles of debris may be expected to form when the building is destroyed. It extends a distance of $\frac{1}{2}$H in all directions from the face of the building (H being the height under the eaves of that face of the building).

Armoured door PT

A door used to close the entrance through which the occupants pass into the shelter shell or the air lock (the protective capacity in accordance with specifications).

Armoured cover PD

A cover used to close openings in the shelter shell for emergency shafts, escape tunnels, escape chimneys and wall openings.

Pressure door DT

A shelter door which is built into partition walls within the shelter.

Standard door NT

Standard (not brittle) door with no protective effect used in non-structural partition walls.

Air lock

A room placed at the entrance of the shelter with two pressure- and gas-proof doors (PT) in sequence. One of the doors must always be closed. This makes traffic possible with the outside world without opening the shelter.

Decontamination room

A room placed at the entrance to the shelter which serves as a place to clean or change clothes contaminated with poison gas or radioactive dust carried by persons entering the shelter. It may also be used as a toilet or lavatory.

Blast protection valve

A check valve in the ventilation air intake which remains open during normal operation but will be closed automatically in a few milliseconds by an air blast and protect the ventilation system (filter) and the shelter from too great over pressure.

Pressure valve

A quick-closing valve in the air outlet which is opened sufficiently by an excess internal pressure of a few mm of water to permit the exhaust air to escape and closes automatically in case of excess pressue outside (or if the excess internal pressure drops).

Primary filter

A filter placed before the gas filter and the ventilator to eliminate the coarsest dirt from the intake air.

Fresh air operation

A mode of operation for the ventilating system in which the intake air is not drawn through the gas filter. In this mode the ventilating capacity is 6 m^3 (3.5 cu ft)/min per person.

Filter operation

A mode of operation for the ventilating system in which the intake air is passed through the gas filter. In this mode the ventilating capacity is 3 m^3 (1.75 cu ft)/min per person.

Non-civil-defense

All that which does not add to the protection of the shelter.

4. TERMS USED IN THE DESIGN OF THE SHELTER

Ultimate load method

A method of static calculation used to determine the rupture load for a supporting structure.

Failure, failure load

The limiting condition and limiting load, respectively, of a structure. No further loading is possible without inhibiting the function of the structure. The ultimate load is obtained by superposing the equivalent static load from the mechanical effects of weapons and loads acting simultaneously (i.e., dead weight).

Degree of plastic fixity

The ratio of the plastic bending moment over the supports to the bending moment in mid-span for beams or slabs.

Under-reinforced concrete cross-section

A cross-section for which an increase in the bending moment will stress the reinforcing beyond the elastic limit before the concrete fails in compression. (This definition, used in connection with the plastic design method, is different than that for an elastic under-reinforced section.)

Appendix C. A Typical Small Shelter

In order to simplify the final design and detailing for structures of secondary importance after the preliminary planning (data given in Chap. 2) the following almost complete designs for small shelters are presented. Since such typical plans are necessarily based on gross simplifications no special conditions for particular cases are considered. This saving of extra effort in the design at the cost of the quality of the solution is worthwhile only for small shelters. The design included here is therefore only applicable directly to 1 atmosphere shelters with no more than 25 places.

In addition the following conditions must be fulfilled in order to use the typical design:

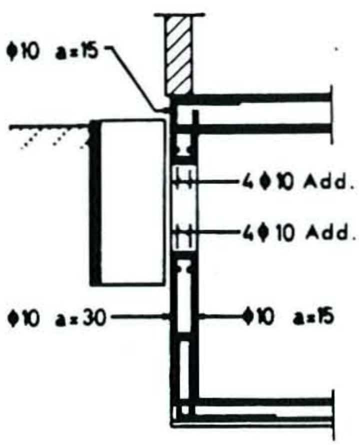
1. The floor elevation must be above the ground water level.
2. The shelter ceiling must not extend more than 60 cm (2 ft) above ground level.
3. The ceiling height of the shelter must not exceed 2.4 m (7 ft 10 in.).
4. The shelter must be under a building.
5. The concrete cylinder compressive strength at 28 days must be at least 300 kg/cm^2 (3200 psi.).
6. The reinforcement steel must be type III (SIA code 162-1966).

If not all of these conditions are fulfilled the design must be prepared in accordance with chapter 3. The structural dimensions for the typical shelter are given in Table C-1. The reinforcement and the construction details are shown on the plan.

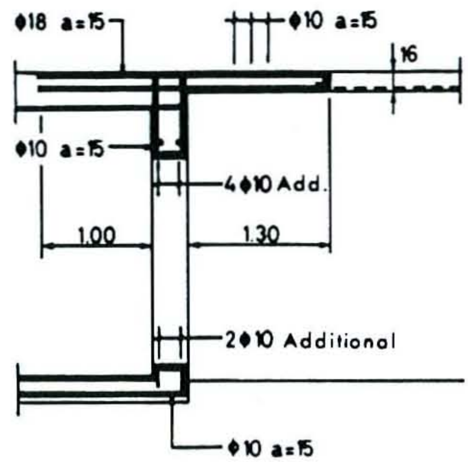
Table C-1. Concrete dimensions for a typical small shelter

Roof	35 cm	14 inches
Floor	20 cm	8 inches
Exterior walls:		
Toward the cellar (free-standing)	35 cm	14 inches
Underground wall (ceiling below ground level)	25 cm	10 inches
Partially underground wall (ceiling not more than 2 ft above ground)	50 cm	20 inches

SECTION A-A



SECTION C-C



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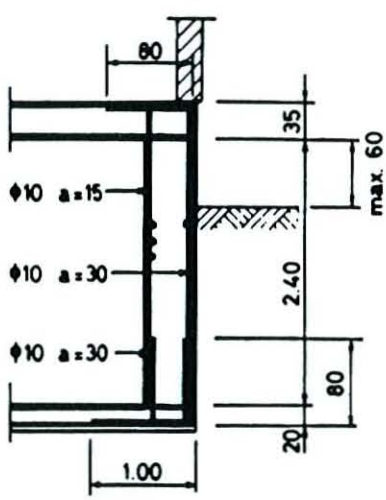

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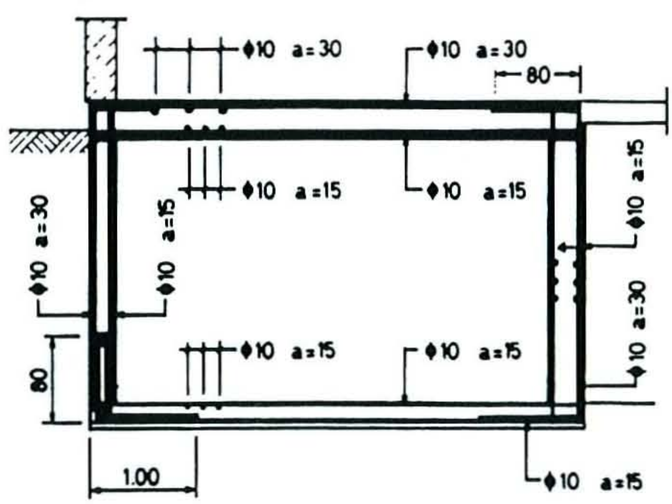

Two-family House H. Müller, Bern

SMALL SHELTER
max. 25m²

REINFORCEMENT SCHEDULE

Bern, 1. April 1967

Consulting Engineering Office
P. Meier
Bern

Reinforcing Steel III
(z.B: Box-Ultra, Caron, Tor)

Concrete min. BH PC 250, β_{w28} = 300 kg/cm²

Steel Overlap
on Earth Side 2,5cm
in Building Interior 1,5cm

FLOOR PLAN