
Guide to
Fire Safety Design for Caverns
1994

Building Authority
and
Fire Services Department
HONG KONG

FOREWORD

In assessing the feasibility of introducing a wider use of underground caverns, the Hong Kong Government commissioned a study on the potential use of space underground (SPUN) in 1988. The study confirmed that for provision of public utilities, warehouses, carparks and similar usage, the use of space underground is a viable alternative to conventional above ground development, and one which could confer significant environmental benefits.

The experience and knowledge gained from the SPUN study should be taken further and used as a basis to formulate design guidelines for underground rock caverns in Hong Kong.

A recommended standard of good practice for the civil engineering aspects of rock caverns is given in the "GEOGUIDE 4 - GUIDE TO CAVERN ENGINEERING", issued by the Geotechnical Engineering Office of the Civil Engineering Department, in March 1992.

The design guidelines here concern fire safety in underground caverns.

The safety of end-users in underground caverns relies greatly on the effectiveness of means of escape and the fire safety measures provided therein by ensuring suitable walking distances to place of safety, early fire warning, automatic fire suppression systems and smoke extraction system to minimize smoke, heat and fire damage.

Due to the lack of any established international safety regulations for underground caverns, reference for formulation of these guidelines has been limited to overseas experience in underground cavern construction revealed in the SPUN study and local experience in deep basement construction. In this light, it is necessary to impose restrictions on the use of underground caverns until more working experience is gained.

These guidelines are applicable only to underground rock caverns for use by public utilities such as sewage treatment works, refuse transfer station and water service reservoirs :

- (a) which accommodate a low population;
- (b) where the users are mainly on - site workers and familiar with the underground cavern;
- (c) where the fire load is generally localized, closely controlled and relatively low;
- (d) where occupancy will not involve sleeping risk; and

- (e) where an effective management scheme is operated and a satisfactory contingency plan for emergency situations is in place.

Storage of oil, gas and other dangerous goods in underground caverns is not covered in these guidelines. Design expertise on this should be sought from experienced users in Scandinavia or other countries such as the USA.

Experience gained in the construction and operation of underground cavern projects will be invaluable to enable these guidelines to be expanded and updated. Any input based on such experience would, therefore, be appreciated. Please address views and suggestions to the Director of Buildings or the Director of Fire Services.

CONTENTS

	Page
1. DEFINITIONS	1
2. FIRE SERVICE INSTALLATIONS	2
3. FIRE WARNING DEVICES	3
3.1 Introduction	3
3.2 Design and types of detectors	3
4. FIRE RESISTING CONSTRUCTION	4
4.1 Compartmentation	4
4.2 Fire resisting period	4
5. MEANS OF ESCAPE	5
5.1 Principles	5
5.2 Population	5
5.3 Escape distances	6
5.4 Restrictions	6
5.5 Place of safe passage	6
5.6 Alternative approaches	7
6. SMOKE MANAGEMENT	7
6.1 Introduction	7
6.2 Smoke control	8
6.3 Smoke extraction rate	8
7. EMERGENCY LIGHTING	8
7.1 Location of emergency lighting	8
7.2 Intensity and duration	8

	Page
8. SIGNAGE	8
8.1 Legibility of signs	8
8.2 Directional signs	8
9. EMERGENCY ACCESS	9
9.1 Emergency vehicular access	9
9.2 Setting-down point	9
9.3 Access for fire fighting and rescue	9
9.4 Fireman's lifts	9
10. FIRE CONTROL CENTRE	9
11. COMMUNICATIONS	10
12. POWER SUPPLY	10
13. WATER SUPPLY FOR FIRE SERVICE INSTALLATIONS	10
14. UTILITY ROOMS	10
15. MAINTENANCE	10
16. CONTINGENCY PLAN	10

1. **DEFINITIONS**

In this Guide the following definitions apply :

"Place of safety" means the open air.

"Place of safe passage" means escape stairs, corridors or another fire compartment adequately protected from fire and smoke, and comprises the elements of the exit or route to be followed to reach a place of safety.

"Setting-down point" means an area in between the access tunnel and the underground cavern compartment which provides turning facilities for Fire Services appliances, ample spaces to set up controls and serves as a frontier during the course of fire fighting.

2. FIRE SERVICE INSTALLATIONS

Fire safety requirements stipulated in the Code of Practice for Minimum Fire Service Installations and Equipment published under Section 16(1)(b) of the Buildings Ordinance, Chapter 123, Laws of Hong Kong are also applicable to underground cavern situations. The following features are particularly relevant :

- (a) Audio/visual advisory systems
- (b) Automatic actuating devices
- (c) Automatic fixed installations other than water
- (d) Automatic fixed installations using water (e.g. drencher system, sprinkler system and water spray system)
- (e) Deluge systems in areas where fire may be expected to spread more quickly than the progressive operation of normal sprinkler heads
- (f) Dust detection systems
- (g) Dynamic smoke extraction systems
- (h) Emergency generator
- (i) Emergency lighting
- (j) Exit and directional signs
- (k) Manual fire alarm systems
- (l) Fire control centre
- (m) Fire detection systems
- (n) Fire hydrant/hose reel systems
- (o) Fixed foam systems
- (p) Gas detection systems
- (q) Gas extraction systems
- (r) Portable hand-operated approved appliances
- (s) Pressurization of staircases
- (t) Ventilation/air-conditioning control systems
- (u) Communications systems

3. **FIRE WARNING DEVICES**

3.1 **Introduction**

Occupants in underground caverns are subject to different life risks from those in buildings erected above ground, e.g. easy accumulation of smoke and heat, longer travelling distance in escape route, lack of external communication, etc. It is, therefore, essential to have an early fire warning to overcome undue delay and to call for early attendance of emergency units by means of a direct link to the Fire Services Communication Centre.

This detection system may also be incorporated with other functions, e.g. actuation of fire suppression systems and fire shutters to control fire spread and a smoke extraction system to provide safe means of escape for survival.

3.2 **Design and Types of Detectors**

3.2.1 **Smoke Detectors**

A smoke detection system is preferred. However, in areas where the humidity is high or the atmosphere is dusty, infra-red or other suitable detectors should be considered.

3.2.2 **Addressable Detection**

For more responsive identification of source of alarm, an addressable detection system is more effective and should be used where the cavern layout is complex.

3.2.3 **Cross-zone Detection**

In areas of special risk, e.g. where total gas flooding is used, cross-zone detection as a means to eliminate unwanted alarms may be used.

3.2.4 **Manual Fire Alarm**

The automatic fire detection system should also be linked to the manual alarm to give early warning in addition to the connection to the Fire Services Communication Centre.

4. FIRE RESISTING CONSTRUCTION

4.1 Compartmentation

4.1.1 General

As with buildings erected above ground, underground caverns should be subdivided into compartments by walls or floors not exceeding 28,000 cu m. Departures from this limitation may be acceptable depending on the fire load and limitation of fire spread of individual projects.

4.1.2 Vehicular Access Tunnels

Compartment volume for vehicular access tunnels need not be restricted.

4.1.3 Warehousing

The maximum compartment volume of an underground cavern used for storage purposes should not exceed 7000 cu m.

4.1.4 Fire Shutters

Where fire shutters are used to form compartments, they should be provided with an automatic closing device actuated by a fire detection system in conjunction with a manual control.

4.2 Fire Resisting Period (FRP)

4.2.1 General

The stability of an underground cavern, unlike a basement or above ground structure, is not dependent on internal structural support. Similarly, stability of no other property is affected by a fire in an underground cavern. Hence, an FRP of not less than 4 hours is not an automatic requirement. The FRP of the construction should take account of the fire load. It should be noted that the rock in which the underground cavern is formed provides a comprehensive fire separation, greater than any which it could be replaced by.

For underground caverns of not more than four levels, where the means of escape does not involve ascent of stairs, in general an FRP of between 1 hour and 2 hours would be appropriate, depending on the fire load. In the case of very low fire load such as a water service reservoir, an FRP of not less than 1 hour would be adequate. Where means of escape requires ascent of stairs, a higher FRP should be considered.

For underground caverns with four or more levels, the likely duration of time to escape will affect rescue and fire fighting and should be considered when deciding on the FRP. However, in general an FRP of not less than 4 hours would be appropriate.

4.2.2 Rock Support

No special fire protection is appropriate for rock bolts and shotcrete/fibrecrete which form the lining to the underground cavern. Rock anchors require individual assessment as to whether the heat from the fire would result in load loss and what would be the implications of such loss.

5. MEANS OF ESCAPE

5.1 Principles

In the event of fire, people in an underground cavern should be able by themselves to reach a place of safety, either directly or through a place of safe passage, before the fire affected underground cavern becomes untenable.

A place of safe passage should permit the same flow of people and have the same standard of protection from fire and smoke as an escape staircase in an equivalent occupancy in a tall building above ground.

5.2 Population

When determining the total population in an underground cavern, consideration should be given to the number of people expected to use the space under normal conditions plus an allowance for visitors and casual workers such as those employed for maintenance and repair work.

Visitors are not familiar with the layout of the cavern. It may therefore be necessary to provide specially marked routes and viewing areas for them.

5.3 **Escape Distances**

Subject to adequate provision of smoke control and fire safety measures, it is possible to extend escape distances beyond the normal restrictions for buildings erected above ground.

In an underground cavern, the distance from any location to the nearest exit leading to a place of safe passage should be as tabulated below. A distinction is made between positions where there is only one direction of travel and those where there are two or more options.

Distance to Place of Safe Passage

Travel Option	Distance (m)
Single direction	18
Two or more choices of direction	72 (See Note)

Note :

This distance may be extended if it can be demonstrated that fire loads are low and escape routes are extremely simple. Exit time for the individuals in a fire compartment is normally limited to 2½ minutes. In areas with a low population, the exit time will be primarily related to the distance required to travel. In assessing exit times on this basis, a travel speed of 1 m/s would be appropriate.

5.4 **Restrictions**

Means of escape provisions are formulated on the basis that a suitable smoke control system will be provided. Guidance is given in section 6.

5.5 **Place of Safe Passage**

5.5.1 The following are essential safety measures to be provided in a place of safe passage :

- (a) Pressurisation should be provided. If it is not practicable due to the large volume or if the design of the place of safe passage is connected to open air, a suitable smoke extraction system should be installed;
- (b) The enclosure of the place of safe passage should be of fire resisting construction to the required standard;

- (c) Corridor, stairway and doorway forming part of the place of safe passage should have widths, conforming to the Code of Practice for Provision of Means of Escape, for the maximum expected population and should have a clear height of not less than 2 m;
- (d) The door opening between any accommodation and the place of safe passage should be filled with self-closing doors having an FRP of not less than half that of the enclosure of the place of safe passage;
- (e) Where more than 10 m upward vertical travel is required, the escape route is to be designed to carry the maximum expected population plus 25% to allow for a slower travel speed;
- (f) The total horizontal distance should not be excessive. A maximum distance of 750 m may be permitted, provided that people would not be unduly stressed by travelling such a distance;
- (g) Where the place of safe passage is a roadway, a separate footway of 1 m width must be provided;
- (h) Where the place of safe passage is a ramp, it should not at any part be steeper than 1:12;
- (i) Where the place of safe passage is a staircase, its construction should conform to the Code of Practice for Provision of Means of Escape;
- (j) Emergency lighting should be provided in accordance with section 7.

5.6 **Alternative Approaches**

Design may depart from the guidance given here but it must be shown that the principles given in Section 5.1 are nevertheless satisfied. In demonstrating compliance, it may be necessary for the designer to present a detailed analysis concerning movement of people in an emergency, coupled with fire growth and smoke flow predictions.

6. **SMOKE MANAGEMENT**

6.1 **Introduction**

The objectives of smoke management are to limit the lateral and vertical movement of smoke, to extract smoke and hot air, to aid rescue and fire fighting operations and to ensure that the escape routes are free from smoke and heat.

6.2 **Smoke Control**

It is necessary to have suitably designed mechanical means to prevent the ingress and accumulation of smoke.

6.3 **Smoke Extraction Rate**

The quantity of smoke generated at a particular time depends on the nature of the combustible material and the height to the clear layer. In order to ascertain the required smoke extraction rate, a set of design fires and the calculation method will have to be agreed with the Fire Services Department.

7. **EMERGENCY LIGHTING**

Artificial lighting is the only means of illumination in underground caverns. It is, therefore, essential to provide an emergency system in underground caverns.

7.1 **Locations of Emergency Lighting**

To ensure the effect of emergency lighting is not jeopardised in a smoky situation, it is paramount to install it at suitable locations, e.g. at low level in escape routes.

7.2 **Intensity and Duration**

Emergency lighting should be designed to the requirements of BS 5266:Part 1:1975.

8. **SIGNAGE**

8.1 **Legibility of Signs**

All signs for exits and essential facilities should be legible from a reasonable distance, easily recognized and illuminated.

8.2 **Directional Signs**

Directional signs are to guide people in caverns to correct escape routes and should conform to Table 10 of BS 5499:Part 1:1984.

9. EMERGENCY ACCESS

9.1 Emergency Vehicular Access

Tunnel access should be provided with adequate carriageway, headroom, loading, gradient and turning facilities to permit smooth manoeuvring of major emergency appliances.

9.2 Setting-down Point

A setting-down point should be provided within the underground cavern. Such provision should normally be provided at the end of the access tunnel just before the entry into the underground cavern itself. This setting-down point should provide an area of the highest absolute safety for fire fighting and rescue purposes, and should have an FRP of not less than 4 hours.

Exemption from such a provision may only be considered where it is demonstrated that the fire load is low, the access tunnel is short and the risk to life reflects the low population familiar with their surroundings, e.g. a water service reservoir. The requirement for the provision and siting of setting-down points should take account of, and be integrated into, the design of the means of escape as it is expected that Fire Services personnel will use the protected means of escape route to effect entry into and passage through the underground cavern.

9.3 Access for Fire Fighting and Rescue

Additional access for emergency operations may be necessary to cope with use and design of underground caverns. Early discussion with the Fire Services Department and the Buildings Department will, therefore, be helpful to all parties concerned.

9.4 Fireman's Lifts

If fireman's lifts are provided, the criteria stipulated in Regulation 41B of the Building (Planning) Regulations should be adopted.

10. FIRE CONTROL CENTRE

A Management Office or Security Office in an underground cavern may be used to include a Fire Control Centre to accommodate display and control panels for monitoring, automatic and remote manual control of all Fire Service Installations.

The Fire Control Centre should be located in a fire-rated enclosure to the tunnel portal and with direct access from the open air.

11. **COMMUNICATIONS**

A hard-wired system with intercom/telephones at regular intervals inside the underground cavern should be provided for communication with the Fire Control Centre.

A two-way radio system should be provided for emergency communications. The system should consist of an antennae system, base/repeater transmission units and handheld radio sets. It should incorporate one of the Fire Services mobile frequencies to allow radio communications between Fire Services personnel inside and outside the underground cavern.

12. **POWER SUPPLY**

Fire service installations and other essential services should be backed up by a secondary power supply which may be fed from an independent supply source or a suitable emergency generator.

13. **WATER SUPPLY FOR FIRE SERVICE INSTALLATIONS**

Underground caverns need to have water mains in their access tunnel for fire fighting operations.

14. **UTILITY ROOMS**

Rooms accommodating generator, main switchgear, transformers, fire control and the like should be located outside the underground cavern for safety and operational reasons.

15. **MAINTENANCE**

Fire service installations and equipment are to be installed and maintained to the satisfaction of the Director of Fire Services.

16. **CONTINGENCY PLAN**

An operation manual which includes an evacuation plan in an emergency situation should be prepared for guidance of management staff of the underground cavern. A detailed layout plan of the cavern is to be provided at strategic locations.

Fire drills should be held at suitable intervals.