

HKIE Fire Division 9th Annual Symposium

Rock Cavern Fire Engineering Design

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0. Agenda

- 1. Introduction
- 2. Review of Fire Safety Issues
- 3. Fire Safety Strategy
- 4. Case Study

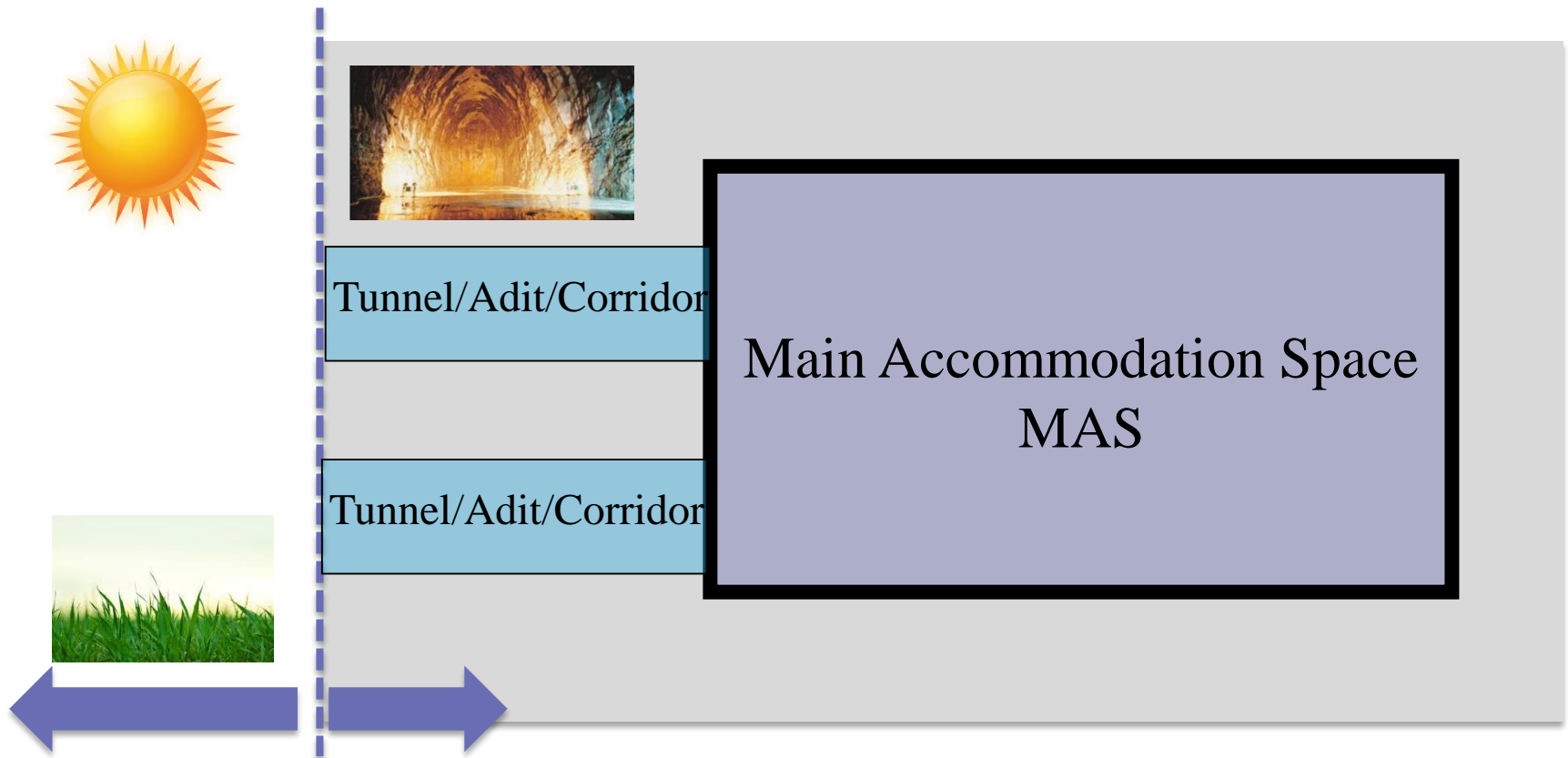
1. Introduction

- Perception of ‘Rock Cavern’?
- Rock Cavern vs Underground Structure

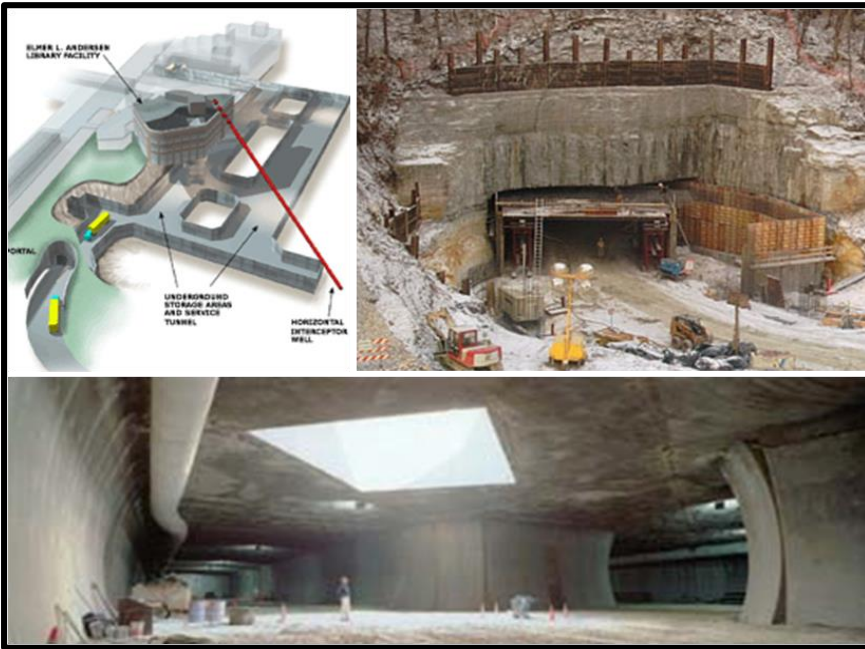


- Rock cavern unique nature in terms of fire safety design
 - Long travel distance (upwards, downwards or at grade) & way-finding
 - External firefighting and rescue unlikely
 - Accumulation of heat, smoke, gases

1. Introduction



- Case by case: Occupancy Classification / Use of rock cavern development



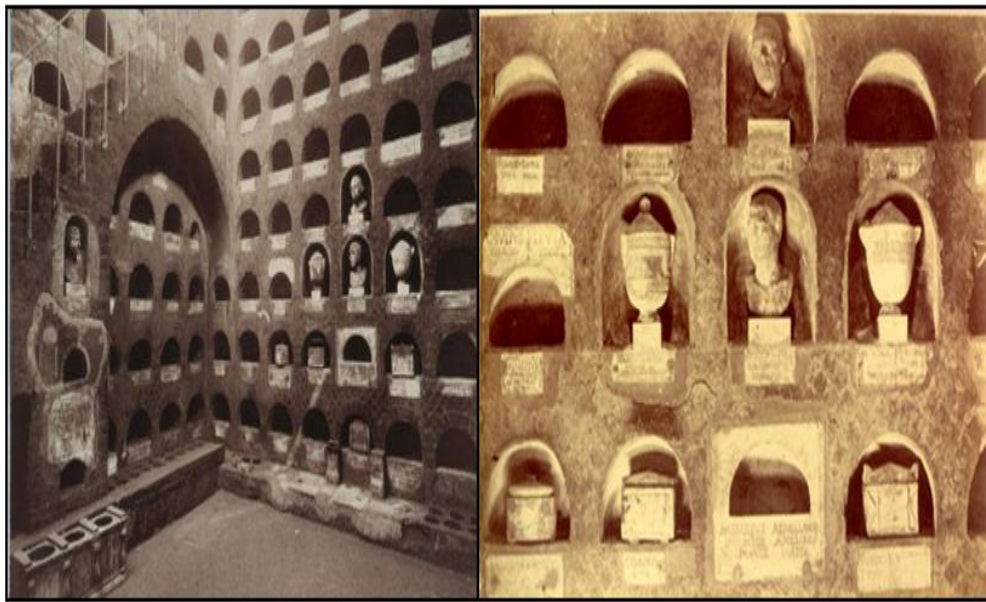
Andersen Library Caverns, University of Minnesota, USA



Iron Mountain Storage Facility, USA



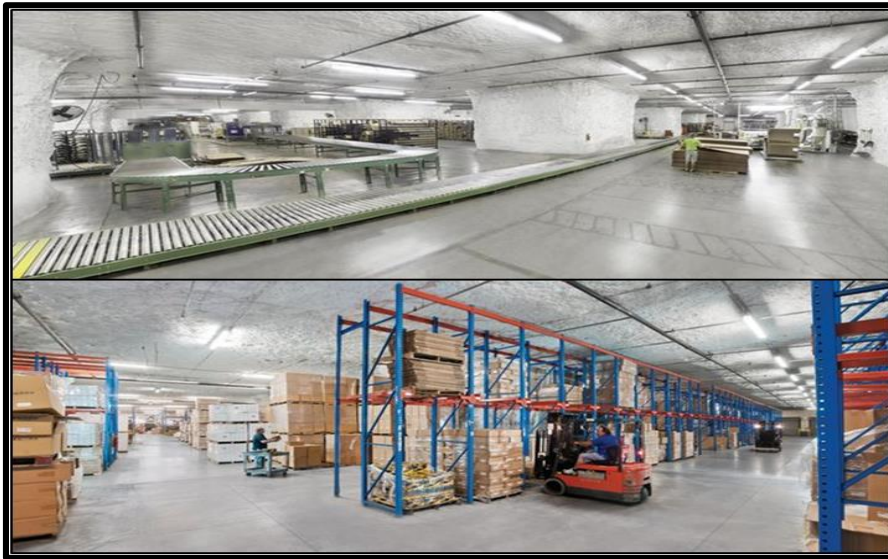
Gjøvik Mountain Hall Facility, Norway



Typical Roman Columbarium Facility, Italy



The Underground Ammunition Facility, Singapore



Warehousing facilities at Subtopolis, Kansas City, USA



Pionen White Mountain Data Centre with Glass Walkway and Boardroom, Sweden

1. Introduction

Land Use Category	Cases
Archives	Elmer L. Andersen Library, University of Minnesota, USA Iron Mountain Storage Facility, USA Carey Salt Mine and Underground Vaults and Storage, USA DeepStore, UK National Archives of Norway, Norway Royal Library Archives, Sweden
Industry	Waferfab Chip Factory, Switzerland Subtropolis, USA Yamazaki Mazak Corporation Factory, Japan
Storage / Warehousing	Bussen Underground, USA Springfield Underground, USA Ekeberg Warehouse, Norway
Oil / LPG Storage	Underground gas storage facilities, Ukraine The Sture Terminal, Norway Jurong Rock Caverns, Singapore
Data Centre	Pionen Data Centre, Sweden Green Mountain Data Centre, Norway

1. Introduction

Land Use Category	Cases
Dangerous Goods	Underground Ammunition Storage Facility, Singapore Nuclear Waste Storage, Sweden Industrial By-product Storage, Norway Minosus Waste Facility, UK
Indoor Games / Sports Hall	Jaegers Subsurface Paintball, USA Br üinig-Indoor Underground Shooting Centre, Switzerland It äkeskus Swimming Complex, Finland Gjøvik Mountain Hall, Norway Altitude Training Facility, Japan
Columbarium / Mausoleum / Mortuary	Tuskulënai Manor Columbarium, Russia Franciscan Columbarium, Singapore
Power Stations	Dinorwig Power Station, UK Iowa Stored Energy Park, USA Underground Nuclear Power Plant, France
Substations	Leicester Square Substation, UK Meijo Substation, Japan



The Island West Transfer Station



Inside the WSD Western Salt Water Service Reservoir at HKU



Shouson Wine Cellars and Clubhouse Facilities (reuse of wartime bunker) MTR West Island Line Magazine



1. Introduction

Land Use Category	Cases	Remark
Railway station	Tai Koo, Sai Wan Ho, Sai Ying Pun, Hong Kong University, Admiralty, Lei Tung, Ho Man Tin	Purpose built cavern station
Research laboratory	Underground Laboratory in Aberdeen Road Tunnel	Reuse of tunnel cross passage
Service Reservoir	WSD Western Salt Water Service Reservoir at Hong Kong University Stanley Sewage Treatment Works	Purpose built
Wine storage	Shouson Wine Cellars and Clubhouse Facilities	Reuse of air-raid shelter
Refuse transfer station	Island West Transfer Station (Kennedy Town)	Purpose built
Explosives treatment	Kau Shat Wan Explosive Depot, MTR West Island Line Explosive Magazine	Purpose built / Decommissioned

1. Introduction

Land Use Category	Potential Land Uses (Existing in HKPSG)	Other Potential Land Use (Proposed to be added to HKPSG)
Commercial Uses	Retail	Food/wine storage Food and beverage
Industrial Uses	Industry Storage / Warehousing Oil bulk storage LPG bulk storage	Data center Research / Testing laboratories Container storage
Government, Institution or Community Uses	Slaughterhouse Civic centre Incinerator Indoor games/Sports hall Wholesale market Refuse transfer facility Sewage/Water treatment plant Service reservoir Transport connections & networks Columbarium/Mausoleum/Mortuary	Archives Vehicle parking Cultural/Performance venue Explosive depot/magazine Indoor swimming pool/complex Maintenance depot Vehicle (including bus) depot Recreational complex Underground quarry
Public utilities	Power station	Public utility installation

1. Introduction

Year	Events for rock cavern development in HK
2013-2017	Long term strategy for cavern development – Feasibility study (Strategic Cavern Study)*
2012-2014	Reclamation and Cavern Development*
2010-2011	Enhanced use of underground space in HK – Feasibility Study (Cavern Feasibility Study)*
2009	09/10 Policy Agenda – Launch strategic studies
2008	HKPSG (revised section for rock cavern development)
1994	Guide to fire safety design for cavern
1992	Guide to cavern engineering (Geoguide 4)**
1991	Hong Kong Planning Standards & Guidelines (HKPSG, new section for rock cavern development)
1992-1994, 2000	Cavern areas studies (CAS)
1990-1991	Cavern project study (CAPRO)*
1988-1989	Study of the potential use of underground space (SPUN)*
1982	Underground oil storage study

Source: <http://www.cedd.gov.hk/eng/index.html>

1. Introduction

Strategic Cavern Study

Policy guidelines

Facilitate Cavern Development for public and private sectors

Systematic relocation of government facilities

Separate Pilot Projects:

- Sha Tin Sewage Treatment Works
- Sai Kung Sewage Treatment Works
- Sham Tseng Sewage Treatment Works
- Diamond Hill Services Reservoirs
- ...

Cavern Master Plan

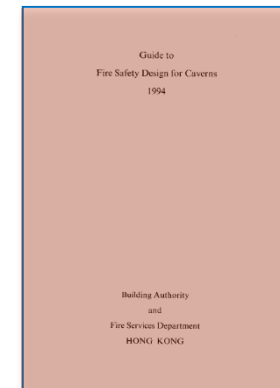
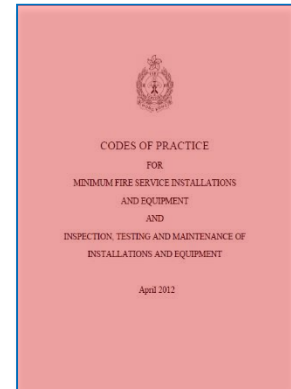
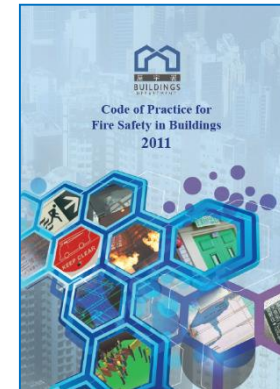
Review technical issues

- Cavern Engineering & Blasting
- Revised Geoguide 4
- Land Ownership
- Economic
- Environmental
- **FIRE SAFETY**

Public Envisioning & Engagement

2. Review of Fire Safety Issues

- **Buildings Ordinance (Cap. 123):**
 - Definition of “**Building**” includes Cavern or any underground space and associated access tunnels and access shafts, etc.
- **Applicable Building Codes:**
 - BD CoP for Fire Safety in Buildings 2011
 - FSD CoP for Minimum Fire Service Installation and Equipment 2012
- **Applicable Guidance:**
 - Guide to Fire Safety for Caverns 1994 (for use of **public utilities**, e.g. sewage treatment works, refuse transfer and water services reservoirs only)



2. Review of Fire Safety Issues

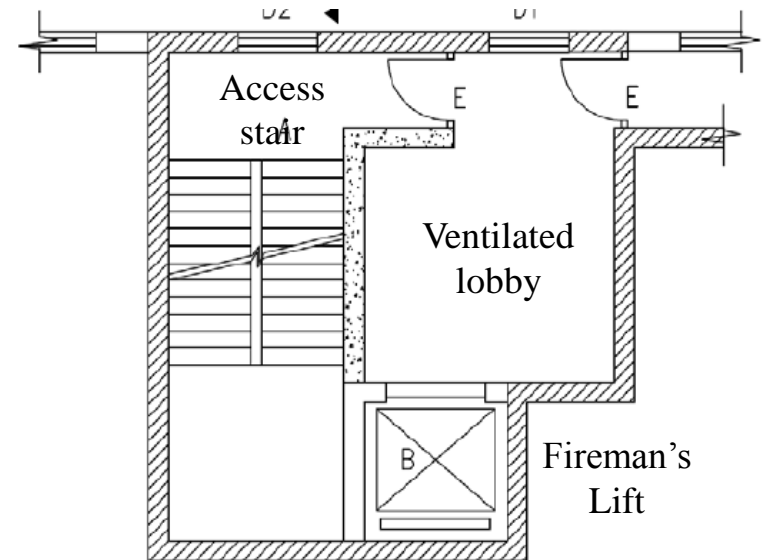
- **FS Code: Means of Escape (MoE)**

- No. of exits – At least 2 (>30ppl) or more, e.g. 751-1000ppl, 4no. exit routes
- Total exit width – e.g. 751-1000ppl, 6m total width
- Travel distance limit (18m/36m, dead-end/total) to exits
- Exit to be pressurized or each exit into the route to be lobby protected

- Places of Public Entertainment (PPE): at least 2no. thoroughfare, width depending on total population
- Basement: at least 1no. dedicated exit route at each level

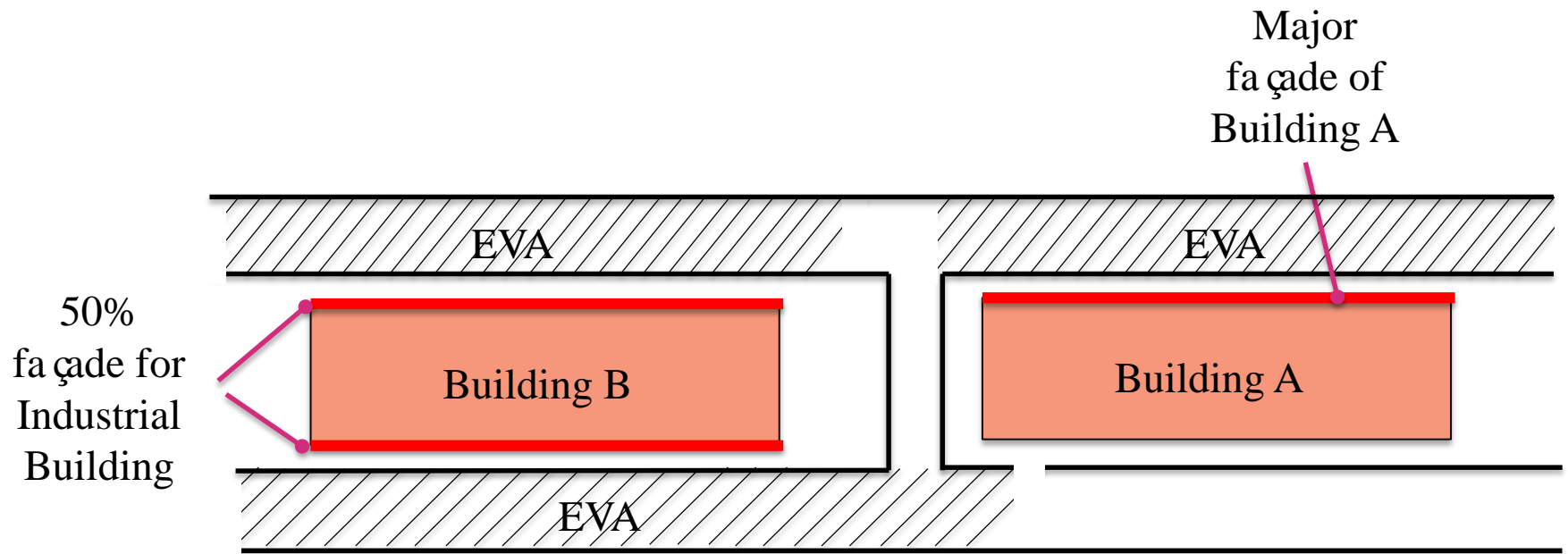
2. Review of Fire Safety Issues

- **FS Code: Means of Access (MoA)**
 - Inadequate facade coverage
 - 25% of facade served as EVA
 - 50% for PPE, and width up to 12m for thoroughfare
 - Building facade <10m from EVA
 - Fire Rescue Stair (FRS) and Fireman's lift
 - to cover 60m length and to be reached within 18m from EVA
 - Basement: Fire fighting and rescue stairways



2. Review of Fire Safety Issues

- **FS Code: Means of Access (MoA)**



2. Review of Fire Safety Issues

- **FS Code: Means of Access (MoA)**

Clause D25.1

A building may be exempted from any or all of the design and construction requirements of EVA stipulated in Subsections D22, D23 and D24 and under the Building (Planning) Regulation 41D(3) in the following cases:

- (a) where the purpose for which the building is to be used constitutes a low fire risk; or
- (b) where the site is situated in an area the topographical features of which make the provision of an EVA or the compliance with requirements in Subsections D22, D23 and D24 above impracticable.

Examples of sites that may be considered as having topographical constraints under Clause D25.1(b) include a site abutting a stepped street or abutting a road or street that is not up to the standards in this Part and the owner of the site has no control over such road or street. For sites located in remote areas or in outlying islands where the vehicles of the Fire Services Department of smaller size can be deployed, the access requirements will be specified by the Building Authority in consultation with the Director of Fire Services on a case-by-case basis.

2. Review of Fire Safety Issues

- **FS Code: Fire Resisting Construction**
 - Compartmentation: 2,500m² ~10,500m² depending on usage
 - Atrium: <3-storey, <15m, <28,000m³, fire rated separation
 - Element of construction: 4-hrs FRR for basement & 2-hrs FRR for aboveground



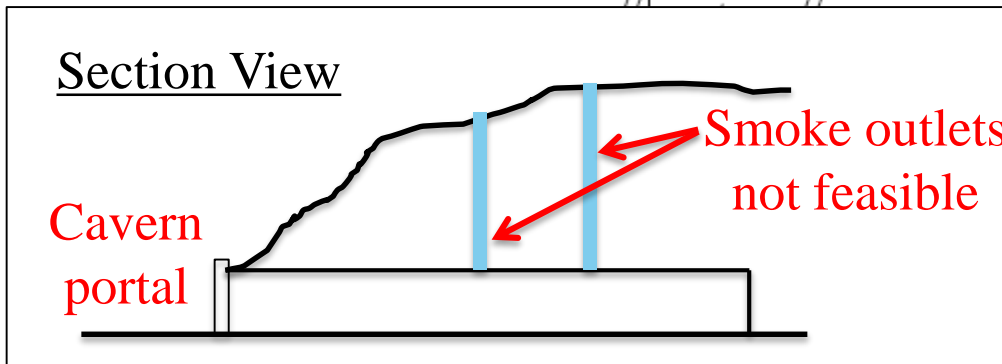
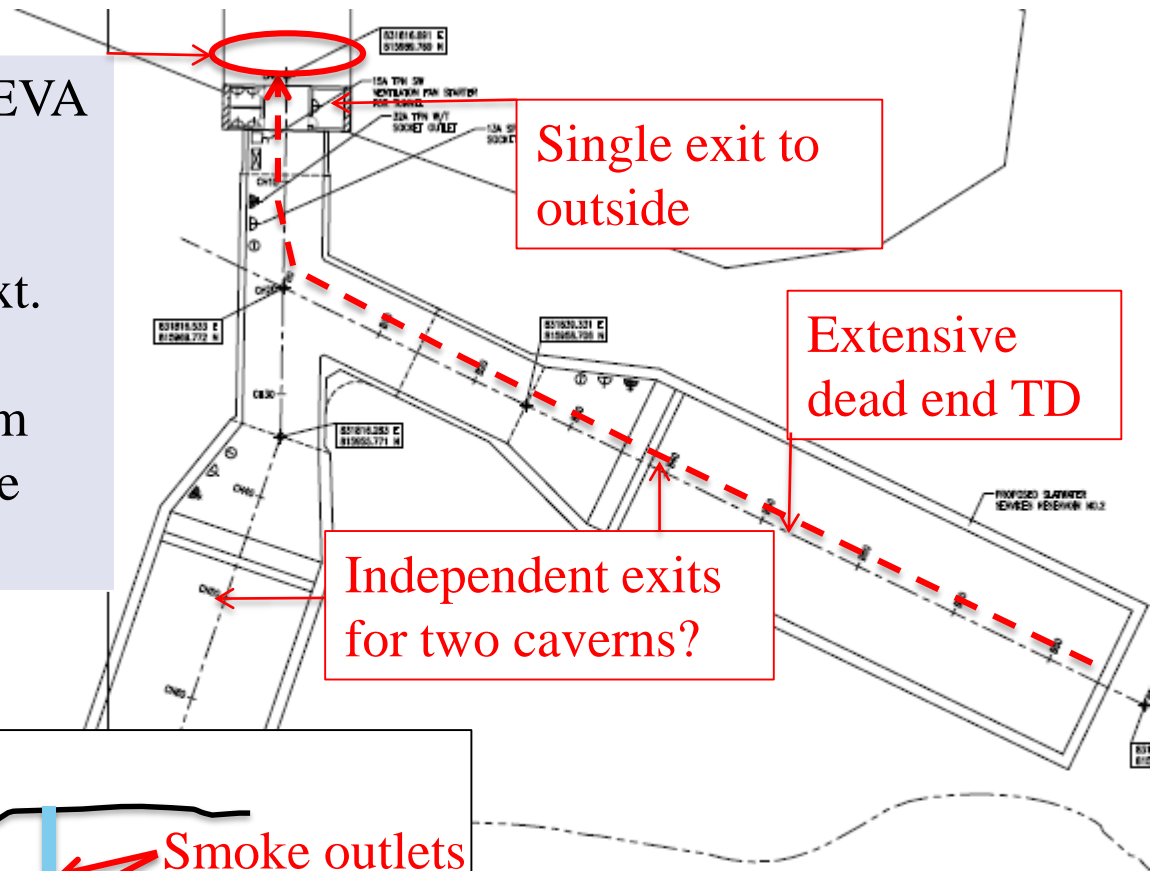
2. Review of Fire Safety Issues

- **FSI Code:** Depending on the ‘usage’, typical requirements are:
 - Audio/visual alarm system
 - Suppression system, including sprinklers
 - Emergency lighting and exit sign
 - Automatic fire detection and fire alarm systems
 - Fire hydrant and hose reel systems
 - Fire extinguishers
 - **Staircase pressurization system**
 - Smoke extraction system
- **Basement:** **Dedicated smoke outlets** for each level; smoke extraction system with **separate system** for each compartment, with each system two independent plants and ductworks



2. Review of Fire Safety Issues

- Limited frontage for EVA ($\ll 25\%$)
- Limited frontage for independent smoke ext. sys. discharge
- Travel distance $> 100\text{m}$
- Cannot provide smoke outlet every 3500m^3



Example: Salt water tanks

2. Review of Fire Safety Issues

- **Guide to Fire Safety for Cavern 1994, Hong Kong**
- Applicable to **public utilities**, such as sewage treatment works, refuse transfer station and water service reservoirs:
 - Low population
 - Familiar with surrounding
 - No sleeping risk
 - Localised, closely controlled and relatively low fire load
 - Effective management, contingency plan
 - Dangerous goods storage not covered

2. Review of Fire Safety Issues

- **Fundamental Objectives:**

- Suitable walking distances to place of safety
- Early fire warning
- Automatic fire suppression systems
- Smoke extraction – minimize smoke/heat/fire damage

- **Key Features:**

- Adopt ‘Place of Safe Passage’ concept, which can be a roadway with a footpath
- Adopt ‘setting-down point’ and recognize internal emergency vehicular access
- Addressable smoke detectors, smoke control system, water supply for firefighting operations, hard-wired emergency communication system and Fire Control Centre at the tunnel portal with direct access to open air.

2. Review of Fire Safety Issues

- Prescriptive requirements + **Performance Based Design**
- Functional statements and performance requirements for:
 - Means of escape
 - Fire resisting construction
 - Means of access
 - Fire safety management

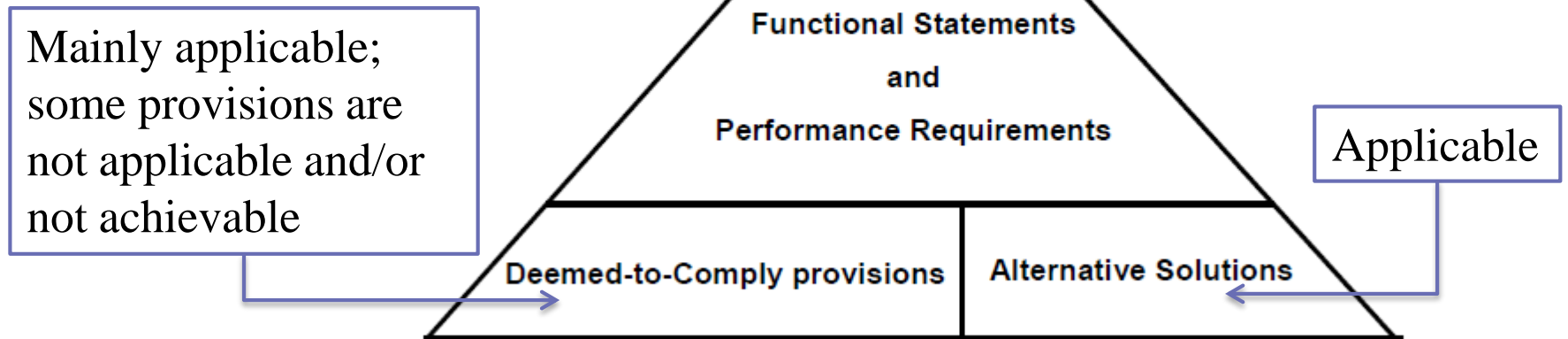
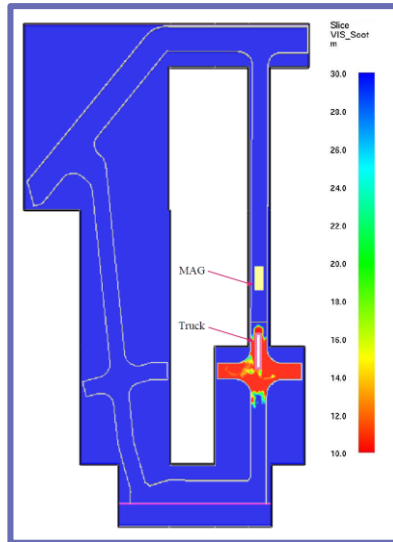


Diagram A1 – Framework for Fire Safety in Buildings

2. Review of Fire Safety Issues

- Development of holistic fire safety strategy
- Non-code compliance and proposed enhanced fire safety measures
- Fire engineering justification

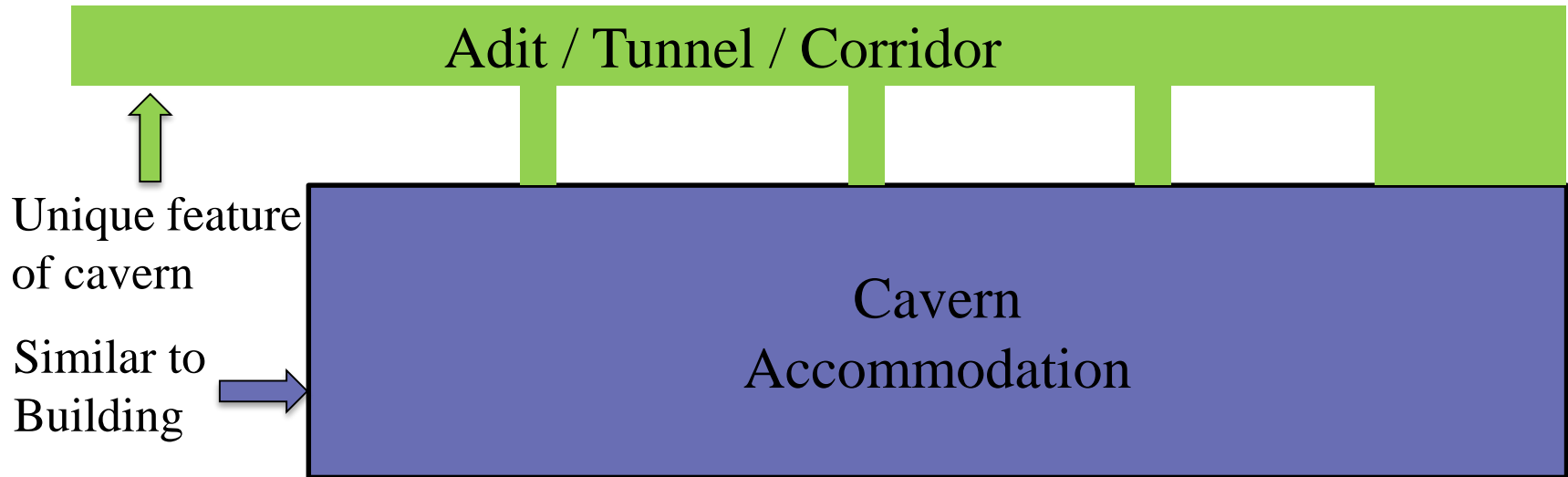


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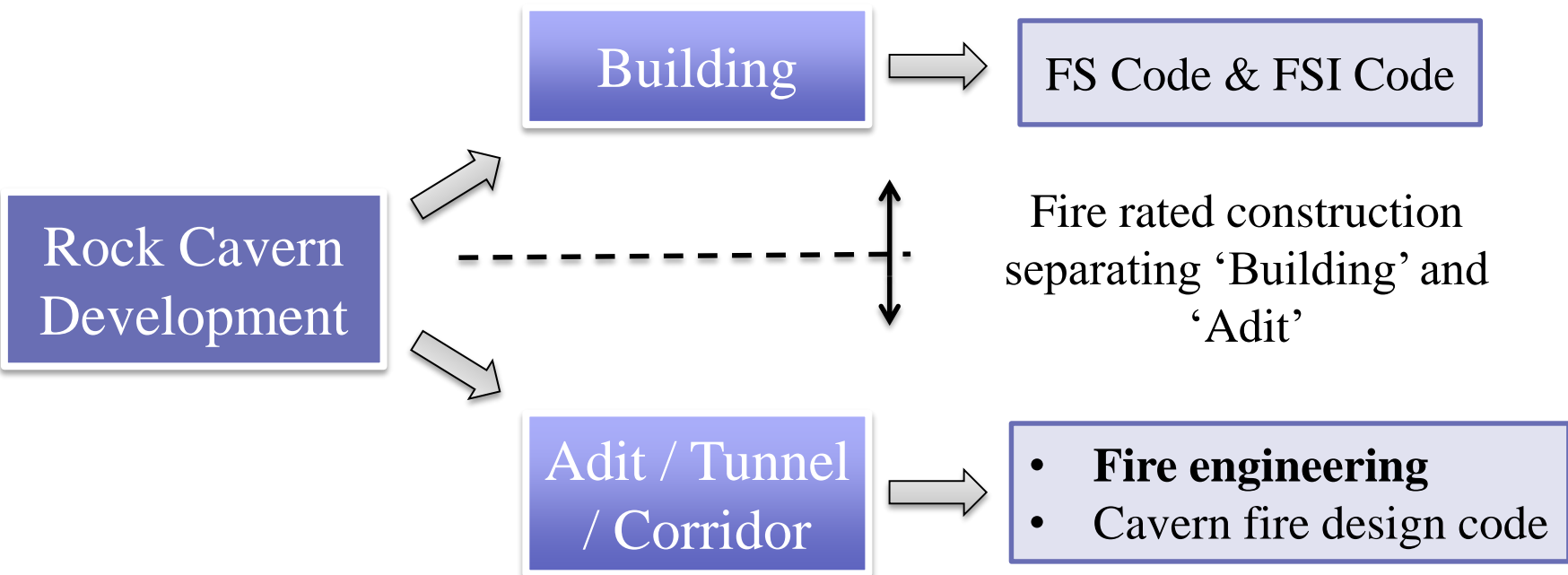
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3. Fire Safety Strategy

3. Fire Safety Strategy



3. Fire Safety Strategy



3. Fire Safety Strategy

Means of Escape

- Adit to be create as “Temporary Place of Safety” within the cavern, by adopting ‘**Place of Safe Passage**’ concept
- Design requirements to suit access/egress adit:
 - Travel distance;
 - Method of estimating the required egress width;
 - One continuous volume;
 - Can be a roadway (like EVA) with footpath
 - Passive fire protection
 - Active fire protection



3. Fire Safety Strategy

Place of Safe Passage

- Walkway for evacuation
- Pressurized or smoke extraction system
- Fire separation from MAS

↑ Exit from cavern

Max. 750m

Adit

Portal

Cavern Main
Accommodation Space
(FS Code)

3. Fire Safety Strategy

- **Principles for Fire Fighting:**
 - Provide direct link to alert FSCC
 - Fire appliances access into “Setting down Point” through a designated access tunnel
 - TD from FRS and fireman’s lift on a specific floor within 60m
- “Setting down Point”
 - Area provided within the underground cavern
 - Ample space to set up control and serves as a frontier for fire fighting
 - Provide turning facilities for FS appliances
- EVA extended to cavern if necessary, to introduce internal vehicular access



3. Fire Safety Strategy

↓ Setting down point

Vehicle turning facility

EVA (internal or external)

Portal



3. Fire Safety Strategy

Fire Compartmentation

- For areas with low fire loads, such as internal EVA or corridors
 - Allow uninterrupted spaces (large space)
 - Separated with high fire loads area, by fire partition or smoke zone separation, etc.
- For areas with high fire loads (main accommodation space)
 - FS Code compartment limitation
 - Fully separated with other areas
 - Locate at close to the external opening as possible

3. Fire Safety Strategy

- **Means of Escape:**
 - “Place of safe passage” – protected corridor or the walkway along EVA discharge to outside
 - Intelligent signage to show available exits
 - Escape distance of 200m is better than descending a 200m tall building
- **Means of Access:**
 - Internal EVA, “Setting down point” , short walking distance to FRS,
 - Multiple access points to the EVA
- **Compartmentation:**
 - MAS to keep within the limits in the Codes
 - EVA and service road remain a large connected space

4. CASE STUDY

Thanks