J. Appl. Environ. Biol. Sci., 4(2)348-360, 2014

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Identifying and explaining the reducing risk factors and the factors influencing safety in road tunnels

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ABSTRACT

Growth of various industries particularly transportation industry on the one hand increases the level of public welfare and on the other hand reduces the level of safety incidents. Certainly in line with the progress of different industries, safety level should also be increased. Transportation industry is divided into several categories that road transport is one of them, among them on of the most important parts of the road passages, are tunnels. Tunnels are of such technical buildings of the ways that using them has many advantages, including reducing travel time, reducing fuel consumption, reducing environmental pollution, but functionality and performance of tunnels is severely affected by safety systems. Events mostly occurred in the tunnel because of its special structure have more serious outcomes than other places along the road. Therefore how to build secure tunnels and how to maintain it is essential. In this study, we identify the risks affecting the safety of road tunnels and then divided them into three categories: basic agents, intermediaries and mother.

KEY WORDS: transportation , risk factors, safety, road tunnels

INTRODUCTION

Mediating factors and basic factors are subgroups of mother factors.

1 - Mother Factor

In this study, mother factors in safety of the tunnel are classified into two following categories:

1-1 Active agents (risk reducers)

1-2 Reaction agents (severe risk reducers)

1-1 Action mediate agents

The most important action mediating factors in safety of tunnels includes:

1 1-1 Structural features and design

1-1-2 Safety systems and installations

1-1-3 Signs, safety equipment

1-1-1 structural features and design

The most basic elements of structure and design are divided into seven factors, each of which is described below:

1-1-1-1 Tunnel arches

Tunnel arches in general can be divided into two categories: horizontal and vertical. Arch impacts on the horizontal and vertical vision of the driver [1]. Existence of arc before, after or inside of the tunnel route, as Figure 6-3 emphasize the importance of the matter due to the limited space of the tunnel. Accident rate in horizontal arcs is 1/5 to 4 times to the accident rate in a direct line. And severity of crashes in arcs is so that 25 to 30 percent of all accidents with losses occur in arcs [2].

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Figure 6-3 - Vertical and horizontal arch of tunnel GRAZ in Austria

1-1-1-2 slope of tunnel

Slope can be divided into two general states of rising slopes and descending slopes. The rising slope (ramp) sometimes has a negative effect on accident rates, because tardy vehicles particularly at the tunnel entrance which the driver cannot realize his distance to the front car due to changes in light, so the vehicle can reduce speed balancing tunnel level and then to increase the mortality rate. Descending slopes due to lowering the levels of friction and in safety levels in braking can have a negative impact on accident rates [3].

1-1-1-3 tunnel width

Usually tunnels are expensive structures, so trying at times to make it with a minimum width. Sometimes both environmental and operational constraints, particularly in the urban tunnels lead to reducing the tunnel width. In any case, width of roadway should not be less than the width of the road leading way [4], thus reducing the width of the shoulder is usually applied to the way. Because the shoulder of way is effective in improving road safety and drivers will use it to escape from possible dangers, this issue i.e. reducing the reducing shoulder width and or losing it must be noticed to all drivers, and this job will be possible by the use of prognosis boards.

1-1-1-4 Length of the tunnel

One of the main factors affecting the safety of the tunnel is the tunnel length. It might seem that increasing the tunnel length has not a special effect on the safety of the tunnel, but with little attention it will be concluded that increasing the length of the tunnel influences directly on: selection of lighting system, determining the type of ventilation system, type of leading and warning equipment, escape and rescue routes and other factors of a tunnel. [5]

1-1-1-5 tunnel pavement

The upper layers of the level of way Including rough gravels and sometimes including sticky materials and vehicles can drive on it are called road pavement [6].

In road pavement, two features including surface quality and friction rate are useful in safety. Material of the pavement layer in general is divided into two categories: [7]

1 - Concrete layer

2 - Asphalt layer 1 (conventional and flexible layer)

According to research conducted in general, if the pavement layer is made of concrete, it has greater benefit [8].

1-1-1-6 Tunnel widening (width of open spaces of shoulders) and parking

Tunnel widening shoulders is usually done by creating a way shoulder for tunnel. Shoulder is outer part of the road surface or in other words the width of the free distance of roadway from the pavement

which acts as a sidelong fulcrum and provides possibility to emergency stop or pass of rescue services and saving vehicles with problems. The width of free distance of the shoulder of the way must be supplement to the lane of roadway and there must be the general and good width and safer [9].

Designing the emergency stop or parking is one of the strategies to reduce the chance of adverse events, because doing so cars with problems can go out of the flow of traffic and not to cause other cars to stop and create more problems. In two-way tunnels with a length of more than a kilometer, a place for emergency stop should be considered in every five hundred meters and if the tunnel is more than three kilometers, the size of a stop should be designed in a way that a truck can redirects or bypass in it [10].

1-1-1-7 tunnel height (vertical open space)

The minimum free height or the height of upper arch of roadway should be equal to the maximum altitude of the heavy vehicle that are allowed to use way, in addition, space necessary for dynamic move of the vehicle due to the roughness of the road pavement and suspension equipment of the vehicle. The addition space has a similar function to difference between width of transmission line and width of vehicles. Table 1-3 provides a list of free space and tolerances according to what is done in some countries. [11]

Table 3-1 – free spaces and tolerances in some tunnels of other countries.

کشور و نام دستورالعمل یا سایر منابع	حداقل ارتفاع آزاد بالای سواره‌رو (m)	ارتفاع آزاد بالای سواره‌رو (m)	روادارای اضافی به عنوان حاشیه ایمنی برای تابلوها، چراغ‌های روشنایی، فن‌ها و غیره (m)	روادارای برای تابلوها، چراغ‌های روشنایی، فن‌ها و غیره (m)	روادارای برای روسازی و ساخت و سازهای بعدی
اتریش RVS 9.232		۴/۷۰	تعریف نشده	حداقل ۰/۲۰	مشخص نشده
دانمارک (تجربی)	۴/۰۰	۴/۶۰	۰/۲۰	تعریف نشده	تعریف نشده
فرانسه CETU		۴/۵۰ (راه در شبکه بین‌المللی) ۴/۷۵ (راه‌های با رتبه بالا)	۰/۱۰	تعریف نشده	۰/۰۵-۰/۱۰
				روادارای کلی ۰/۴۰ - ۰/۳۰	
آلمان RAS-Q1996/RABT94	۴/۲۰	۴/۵۰	تعریف نشده	تعریف نشده	تعریف نشده
ژاپن، طرح راه		۴/۵۰	تعریف نشده	تعریف نشده	تعریف نشده
هلند ROA	۴/۲۰	۴/۵۰	۰/۲۰	۰/۳۰	تعریف نشده
نروژ، راهنمای طراحی تونل‌های راه	تعریف نشده	۴/۶۰	۰/۱۰	تعریف نشده	۰/۱۰
اسپانیا دستورالعمل ۱-۳	تعریف نشده	۵/۰۰	تعریف نشده	تعریف نشده	تعریف نشده
سوئد- تونل ۹۹		۴/۵۰	۰/۲۰	۰/۴۰	
سویس (تونل‌های مستطیلی شکل)	تعریف نشده	۴/۵۰	۰/۲۰	۰/۴۰	
سویس (تونل‌های تخم‌مرغی شکل)	تعریف نشده	۴/۵۰			
انگلستان TD27(DMRB6.1.2)	۵/۱۰	۵/۳۵	۰/۲۵	۰/۴۰	تعریف نشده
ایالات متحده آمریکا AASHTO	تعریف نشده	۴/۹۰ (آزادراه‌ها) ۴/۳۰ (سایر راه‌ها)	تعریف نشده	تعریف نشده	تعریف نشده

1-1 - 2 systems and safety installations

1-1 -2-1 Lighting

One of the strategies to reduce accidents and increase road safety is to ensure the proper understanding in drivers of the tunnel environment. Drivers need to receive all the visual information required in a reasonable distance to prepare for the driving situations beforehand. What causes to get a proper understanding and accurate information from the environment in tunnels is adequate light [12]. For lighting design, the tunnels are divided into 6 sections.

1 – Access region

This area is located outside of the tunnel and deriver has not been into the tunnel yet; in other words it said the length of access road to the tunnel entrance. Since the driver is going to go from a bright environment to a dark environment, in order to control the brightness variations easier and matching eye of the driver in this region, following strategies can be provided: planting trees two sides of the route leading to tunnel, using artificial structures and cover of the roof of the tunnel to the outside of the tunnel [13].

2 - Match Point

Inside the tunnel there is a point where the driver's view power because of the entering the tunnel entrance (tunnel being dark) will start to decrease rapidly so the rate of light must be in a way that the driver be able to see the vehicle at 30 meters before him as soon as he entered the tunnel.

3 - The threshold region

It said to the first area in the entrance of the tunnel. The light intensity is below the input area (match point). Generally illumination of the tunnel entrance must be greater than the rest. At the moment of entry into the tunnel or threshold region, in the absence of adequate lighting it will lead to momentarily blinding of driver because the pupil need time to adapt to darkness. Thus the rate of accidents is higher in entrances than other parts of the tunnel, so in order to reduce the amount of accidents at different times of day and night we need suitable lighting. Different authorities had expressed the maximum allowable difference in light intensity between the tunnel and the outside 1 to 10.

4 - Transfer Zone (facultative)

This region is after threshold region which luminance is less than the threshold region, and makes the driver ready to enter the middle section.

5 - The middle part

The main part of the tunnel which the lowest lighting limit for tunnel is applied in this section.

6 – Exit part

A part of end of the tunnel which affects the driver's vision because of the light out of the tunnel like the entrance part. The amount of light designed in existing section of the tunnel must increase so person exiting the tunnel should not suffer from the light out of the tunnel with impudence and high amount of light. In figure 1-1 division of tunnel brightness sections is shown based on the brightness required in areas [13, 1 4, 15].

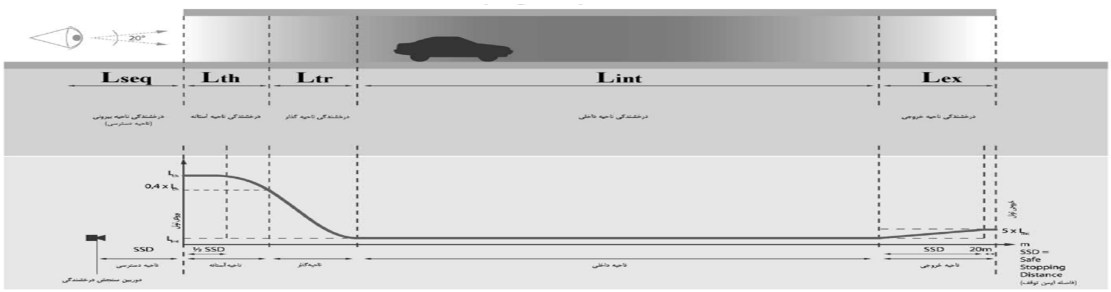


Figure 1-1 – division of bright regions in tunnels based on the brightness required

1-1 - 2 -2 ventilation system

Ventilation system is designed considering the amount of increased pollutant emissions from vehicles and a large amount of smoke resulting from a big fire in the tunnel. Types of ventilation systems include:

A) Natural ventilation

Natural ventilation is limited to a short tunnel in which tunnel acts like a cylinder and vehicles let the polluted air like a piston. Every vehicle according to its speed and its cross-section brings some air into the tunnel or leads it out. If the tunnel is unilateral (one way), this action will be effective and in bilateral (two way) mode, if the traffic on both sides is equal, ventilation is neutral, when the traffic is not equal, the amount of ventilation will be the difference between the amount of traffic, the two sides from each other. It is necessary to note that the use of natural ventilation, depending on traffic volume and a one way or two-way of traffic is advised only to tunnels with a length of 250-800 meters [4].

B) Artificial Ventilation

In long tunnels (more than 1,000 meters), the natural ventilation would not be able to remove contaminants from surfaces and using artificial ventilation is necessary. In general, operation of ventilation

is done either by suctioning polluted air or by suctioning fresh air or a combination of both [15]. Methods of artificial ventilation in tunnels include: [16]

B-1. Longitudinal ventilation

This system is tried to get out the direction of pollution in length of tunnel and vector of traffic from the tunnel using jet fans. This system is used mostly for one-way tunnels, the transverse and semi-transverse ventilation is used in other states [97]. In Figure 4-3, the longitudinal ventilation performance is observed. Similar to natural ventilation system, we can improve the ventilation system performance by digging wells. This type of ventilation system is the best ventilation system for long tunnels [4].

Figure 3-4 - Mode of longitudinal ventilation using jet fans

B-2 Semi-transverse ventilation

In this system one of the following methods in getting pollution out is used: either fresh air is entered to tunnel from ducts located in the floor of or contaminated air sucked from the top of the tunnel. Performance of this system is seen in Figure 5-3. Because this system is so expensive, it is just recommended in tunnels with more than 2000 meters in which there is no possibility of digging wells and using linear system [4].

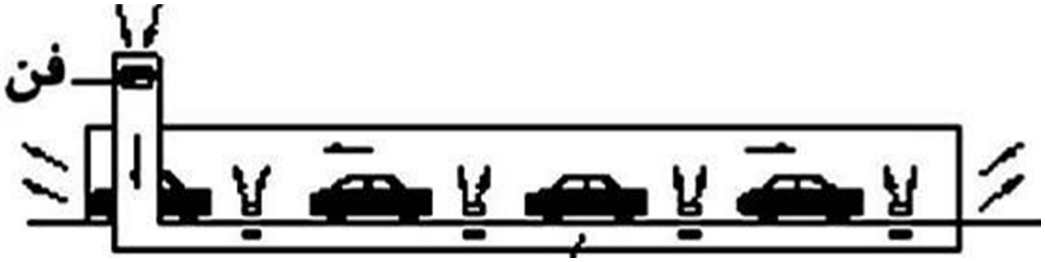


Figure 5-3 – the performance of transverse ventilation system using jet fans

B-3 Total transverse ventilation

In this system, both solutions used in semi-transverse system are used simultaneously, so the cost of this system is much higher than the other two. These systems are only used in special cases and in tunnels with high elongation and high volume traffic [4].

B-4 Combination ventilation

If the tunnel has specific terms and defined systems are not effective alone, simultaneously a combination of two or more methods for the efficient movement of polluted air or smoke is used. This system which is used synchronic two or more types of air conditioning in the tunnel, is called combination ventilation [16].

1-1-2-3 drainage system of tunnels

Drainage consists of collecting and disposal of underground water and surface water, such as rain, either naturally or artificially.

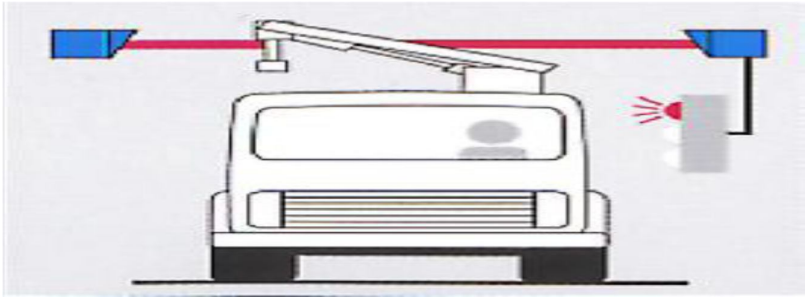
Since there is no rainfall in the tunnel, the glacial is not raised like in the normal form and common ways. If drainage is not done desirably, the underground water will pass the tunnel roof, and when the air temperature is below freezing, the water freezes and will hang from the ceiling like icicle. [14] On the other hand, if the water is in a proximity of voltage cables or other electrical equipment such as tunnel lighting system [18].

1 -1-2-4 Automatic safety systems

The most important automatic safety systems for accident prevention can be divided into two sub-systems:

1 – System of Diagnosis of Unauthorized Height of Car

System of diagnosis height of unauthorized vehicle must realize the cars with higher altitude than permissible limit crossing the tunnel and immediately alert the control tunnel center. Automatic Control System of tunnel should in addition to informing the operator; turn on the red lights of the path of cars and to activate the varying message panel for driver to command to stop of the car. Also the Automatic Control System should spin the closed circuit television cameras on car with unauthorized height and let operator to identify him. [17 and 15]



2 – Automatic barrier system of the road

To block one or all lines near the tunnel outfall, we must use electro mechanic barriers. The electro mechanic barriers are installed at the outfall of the tunnel in order to prevent the vehicle to enter the tunnel. The distance of furthest traffic light must be ensured two times more than stop distance. Traffic signs must be installed before tunnels in all tunnels more than 1000 meters length and in necessity announce the closure of the tunnel. Hedges must be at least 50 meters away from the entrance so that there must be enough space for emergency operations of rescue and evacuation. The time required to change the situation of hedge from open to close or vice versa must be adjustable between 2 r 4 seconds. In figure 10-3 a picture of a road hedge in Mont Carlo tunnel in France is shown.

Figure 3-10 - Automatic Barrier

2 - Reactive agents (reducers of gravity of risk)

In this division, various types of affecting factors on reducing risk outcomes is divided into six categories:

2-1 Structural reducers of risk consequence
2.2 Event controlling Systems and Equipment
2-3 Escape and rescue systems and facilities
2.4 The warning equipment, guides and informative
2-5 Aid and safety equipment and systems
2-6 Automatic monitoring and tracking event equipment and systems

2-1 Structural reducers of risk consequence

2-1-1 Fire Resistant Structures

In the event of a serious fire if certain measures are not predicted, the tunnel structure will fall at least locally. Fire resistant arrangement depends on the tunnel type and structure. In general, the main structure of stone tunnels does not need any resisting against fires. Surface asphalt is more flammable than concrete and can ignite at a temperature of about 428 to 530 ° C and can act as fuel to fire [19].

2.1.2 Resistant Equipment against Fire

It is not necessary that all the components used inside the tunnel be resistant to fire. But it is necessary that the means outside of the fire front carry out their work, meaning that the transmission lines and communicative networks need to be connected. Ventilation tools also have to satisfy the fire resistance requirements for the proper control of smoke at high temperatures [17 and 15]. Use or non-use of special facilities and equipment fire-resistant is identified with a comparison of benefits and costs, and reconstructing costs [10].

2-1-3 blast-resistant structures

Blast-resistant structures are not required for safety because a blast with capability of damaging the tunnel, leave no one alive. However, when the possibility of huge explosion is introduced, the strength of the second outfall of the tunnel in the occasion of the blast of first outfall must be controlled. But the strength of tunnel structures and their resistance against the blast are among cases that show the tunnel strength against the explosion and this strength prevents damage to the tunnel. If the protection is considered very serious against explosions due to high costs, is often ignored [20].

2-1-4 earthquake resistant structures

In all parts of the world, subway systems have been used as shelters for earthquake rescue and resettlement.

Factors effective in tunnel against earthquake:

1 - The depth of the tunnel

Earth movement, range of motion, acceleration and particle velocity of the field will decrease by increasing the depth (especially if the ground is soft.)

2 - Form and Size of Tunnel

Whatever the tunnel cross section is larger, it is more sensitive to earthquakes. Also existences of two or more tunnels together usually, cause the static stress concentration in the tunnels.

3 - Status of layering and substance of the earth

Soil conditions and topography of the region may increase or decrease the intensity of ground movements.

4 – Method of Drilling and Construction of Tunnel

Where the depth of tunnel is high, method of drilling is so that the soil surrounding it remains intact, but in surface tunnels such as subway (Metro) often method of excavation and lining are used.

5 - Internal Cover of Tunnel

If necessary, the internal cover is used for tunnel to increase the seismic resistance [21].

2.2 Systems and Equipment Controlling Event

2-2-1 Manual firefighting equipment

Firefighting equipment is including initial sets that give users the opportunity to tackle the fire and control it before meet professionals and firefighters in the early stages. Fire hoses and extinguishers, are considered as two main components of this equipment. All tunnels should be equipped with basic firefighting equipment [22]. A set of initial firefighting equipment and emergency power systems are called allegedly emergency-mail which contain fire extinguisher and fire hose, fire hydrant with high pressure and emergency power systems. In addition to the above items, the best place to call emergency and alarm push buttons are in emergency post. [23] Spacing of 50 m is recommended for both emergency Posts [24]. Emergency post with necessary equipment is observed in Figure 3-10.

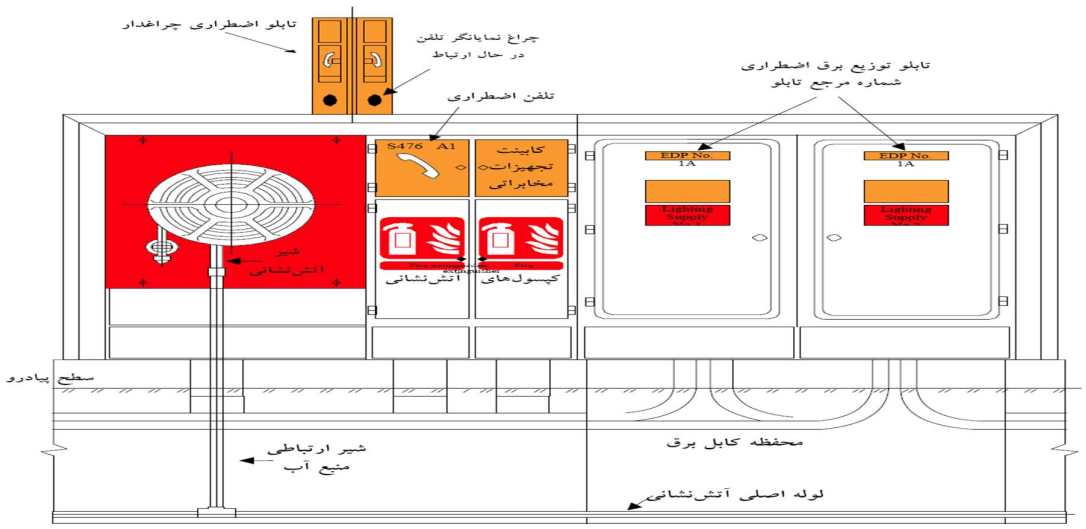


Figure 3-10 - Emergency Post

2.2.2 Automatic firefighting system

For tunnels with high importance and high traffic volume, we can use intelligent systems and automatic firefighting systems which are put in the tunnel roof and body. An automatic firefighting system consists of two main parts:

1 - Fire detection:

A: sensor of thermal line detection [25]

B: Wide temperature sensor [26]

The two sensors are sensitive to heat, but do not have the ability to detect the cold smoke. To address this problem, carbon monoxide, carbon dioxide infrared sensor is used [27].

2 – Firefighting system:

A: Geyser type system [23].

B: Foam sprinklers systems [28].

Pyark does not recommend automatic fire system and tells that if for any reason the geyser system is used, it must be activated after discharging people from tunnels [29].

2-2-3 Exhaust ventilation control and fire

Selecting and designing the ventilation system is chosen mostly according to the requirements of a large fire occurrence and the amount of smoke produced in it and the amount of pollutants in the gases getting out of exhaust of vehicles. Longitude ventilation that in most cases work with very fast fans (jet fan) creates a monotonous flowing in tunnel, and in during fire, directs smoke towards the tunnel exit. This system is suitable for one-way tunnels with low traffic. In other cases, transverse or semi-transverse ventilation is used [27].

2-3 Escape and rescue facilities and systems

1-2-3 Emergency Exits

Because the tunnels are closed environments, we need to consider suitable routes and doors in emergency and people at risk can exit in the least time. One more point about this, the design of emergency doors must be so that passengers be able to find the exit route in crisis condition of shortage of light.

Figure 11-3 a sample of emergency exit door and route guide

When designing emergency exits, following possibilities must be considered for evacuation of tunnel users:
- Exiting the outfall of tunnel on foot.
- Direct contact with the outside (Short tunnels).
- Cross-correlation between the outfalls of the tunnel.
- Special Corridor for Escape [27].

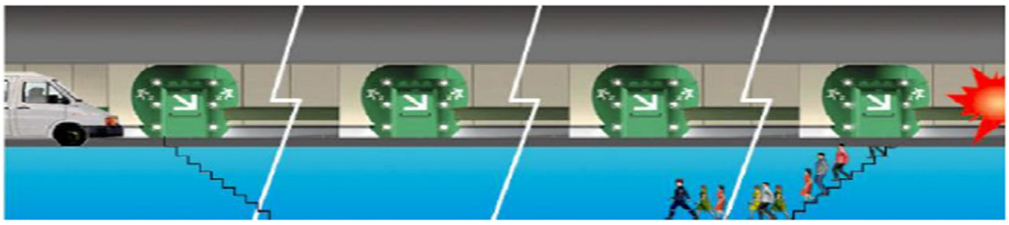


Figure 12-3- a view of Emergency doors and routes

Figure 312-3 shows a view of the doors and emergency routes

3.2 refuges

Refuges are usually created at the a single opening and long tunnels, shelters are usually ventilator rooms equipped with telephone and fresh air that are connected with the outside fresh air by air ducts. In this room, there must be all primary facilities for communication in order to connect with people outside of the tunnel environment and also the basic facilities of rescue such as fire extinguishers and first aid equipment.

4-2 The warning equipment, guides and informative

2-4-1 Warning signs and panels and users guiding

Warning signs and panels are fixed signs which are used to warn users. Some of these alerts include: types of dangerous warning equipment (electrical equipment), types of sirens, traffic lights, warning lights. The main problem about these symptoms and signs is the level of user understanding of such signs. In general, the main objectives of using these signs are making visible the facilities used, reducing the reaction time, and guiding users. Type and shape of using these complement signs is a function of tunnel length, traffic flow volume, road type and so on. [31, 30 and 22].

2.4.2 Equipment for emergency notifications

These equipment are created so that can inform users about the situation in which they are stuck in or users can contact with service providers and finally facilitate the escape situation for people from the scene.

2-4-2-1 Speakers

These devices are used to provide overall direction and guidance to all users of the tunnel in a crisis. There are several problems about using speakers because of its improper acoustic characteristics and the

number of languages needed for informing users but using these equipment is recommended in many tunnels according to their situations.

2-4-2-2 Emergency phone

In times of crisis and emergencies that may not possible to communicate with the mobile phone, however, stable and reliable telephone is very important. Most tunnels are equipped with emergency phones at specified intervals. It is needed to improve safety:

- Communicate with tunnel operator or police
- Communicate with users through tunnel operator or police
- In case of non-availability of other means of communication by emergency services, it will be used to communicate [27].

2-4-2-3 Radio communications

Currently, considering the today technology, the radio signals cannot be received underground. So the tunnel are equipped with rebroadcast systems so may cover some or all users of the emergency condition. In emergency mode, the operator is able to inform drivers on one of the radio frequency and give them safety instructions [32].

2-5 Aid and self-safety equipment and systems

2-5-1 Electric emergency equipment

Emergency lighting equipment including are among replacement emergency systems. Capacity of uninterrupted power supply system must be based on the monitoring and control of power systems, as well as the amount of emergency lighting required should be determined. Uninterrupted power supply system must supply emergency power for at least 2 hours. Outlets of uninterrupted power supply systems need to be placed in emergency posts for fire and rescue forces. Minimum power lighting system, ventilation system, a variety of signs and emergency systems must be provided by the systems of uninterrupted power supply [23].

2-5-2 Emergency lighting equipment

When necessary, the system of uninterruptible supply is responsible for lighting supplement at night. So that it is necessary to provide one of the ten used lights which are in desired condition by uninterruptible supply system. This light is not suitable for continuing the tunnel activity and the tunnel should be closed in the absence of the main generator [23].

2-5-3 Equipment and systems of self-safety

This system must be designed in a way that can stir automatically in the event occurrence and to provide a condition for better control of the situation. The following are the most important safety systems in management failures:

- Using trailer tools ready to be used: for example, when the normal power transmission line of tunnel crashes, power transmission lines used for emergency starts working.
- Safety against failure system: for example, power failure will cause the emergency door been unlocked.
- Unit or in parallel control: for example, if the emergency lighting in one unit fails, other parts continue their work [8].

2-6 Monitoring and automatic tracking event systems and equipment

2-6-1 Closed circuit television

To television monitor inside and around the tunnel from the tunnel control room or from distant points, CCTV cameras and televisions should be used. These cameras are used for two purposes:

- To monitor the movement of traffic and vehicle containing dangerous goods
- To track or at least detect any occurrence or accident

Since the operator cannot monitor the entire tunnel permanently, CCTVs equipped with alarm system (Automated traffic accident, telephone ringing or fire alarms) can be used for information to the operator of the status quo [32].

The cameras must be installed at appropriate intervals to cover the entire length of the tunnel and regions around entrances [33]. Figure 13-3 below shows the components of a closed circuit television system.

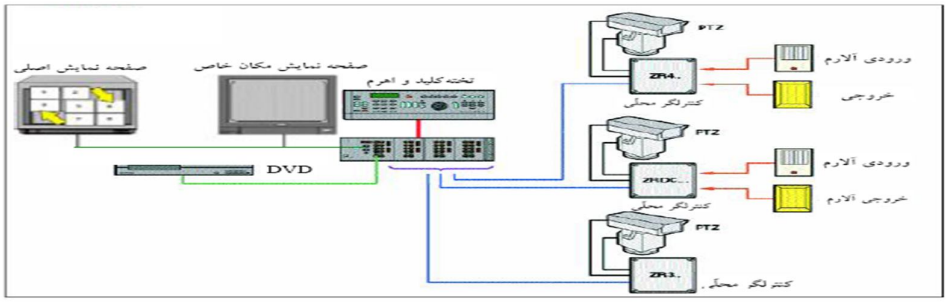


Figure 13-3 Overview of the components of a CCTV system

2-6-2 sensing auto accident

An automated tracking system in traffic incidents is capable to detect any changes in traffic conditions and accidents occurring in the tunnel. Using a combination of automated tracking systems with closed-circuit television enables operator to obtain information quickly about changes to traffic conditions and accidents. This system has a positive impact on reducing consequences of accidents and increasing the speed of appropriate reaction. Such a system along with closed circuit television and other warning systems are very efficient like emergency telephone [10]. Tunnels with a length of more than 1 km must be equipped with a closed-circuit television and an automated measurement system of accident [16].

3 - Suggestions

3.1 Suggestions for increasing safety

With regard to the cases presented in this study, the following recommendations are provided to increase tunnel safety:

- Design and providing the lighting of tunnels considering the width and length of the tunnel
- Careful selection in arrangement and the lifetime of the lamps used for lighting
- Selecting the appropriate gender and characteristics of consuming lamp and its productivity and power
- Choosing bright colors and high reflection coefficient for tunnel hull
- Properly design of ventilation system according to the orientation and the length and width of the tunnel
- Using a smoke detector system and fire in the tunnel
- Existence of conventional fire extinguishing systems in all the tunnels and the use of smart tunnel firefighter
- Designing emergency doors and exit routes at appropriate intervals and designing guidance system
- Put the emergency telephone at appropriate intervals
- The use of smart and up to date technologies of transportation as automatic barriers variable message systems,
- Designing and maintenance of a proper system of drainage for surface and level waters as plan
- Equipping the tunnel with appropriate and sufficient warning, informative and guiding signs
- Using proper pavement for tunnels
- Insulation against leakage of underground water

3.2 Suggestions for management of destruction

Generally, damages which may be occur in tunnels and they must be considered in inspections are as follows:

- Fissuring in tunnel hull.
- Ridges and troughs of the tunnel floor.
- malfunction of lamps, lamps panel and cables.
- Plant and equipment breakage.
- Damage to the valves and fans.
- Injure or dirt of panels.
- Blockage, plant growth or deterioration in the drainage of the tunnel.
- Being dirt or falling materials on entrance panels.
- The problem in fire extinguishers and other relief supplies.
- Damage to the slopes trenches of tunnel entrance and exit.

In addition to the above, every tunnel based on its features has different critical points which should be considered separately in reviews.

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