SAFETY FACILITIES IN THE HSUESHAN TUNNEL, TAIWAN

Der-Ching HSU[1]

ABSTRACT

The Hsueshan Tunnel, with a length of nearly 13km is a twin-tube highway tunnel of the Taipei-Ilan expressway in Northeastern Taiwan. It will be the longest highway tunnel in Taiwan and one of the longest twin-tube highway tunnels in Southeast Asia when completed. This tunnel shortens the travel time between Metro-Taipei and Ilan County, and will promote development and prosperity in the Ilan region. This tunnel will be opened in 2005 and heavy traffic is predicted. The most important safety issue for this tunnel is how rescue and evacuation operations will be carried out in case of an incident or fire inside the tunnel. This will be difficult in the confined space of the tunnel. Therefore, this highway tunnel needed to be designed not only to prevent traffic accidents and fires but also to provide personal safety facilities.

The safety facilities included in the design are the vehicular/pedestrian cross connections, the layout of the emergency parking bays, the function of the pilot tunnel, the distribution of information through changeable message signs and changeable speed signs, the closed circuit television monitoring system, the emergency public address system, wireless communication, the emergency telephone system, the AM/FM rebroadcast system, the fire alarm detection/protection system, the ventilation system, the evacuation and rescue sign system, fire emergency lighting, and air quality detection system. All the facilities were laid out in the various sections and then were connected by cable to different tunnel stations. The stations were located at intervals of about 1.4km alongside the tunnel, to accommodate the power devices and safety facilities. There is a central control center located at the Pinglin Interchange and a sector control center at the West Portal that are both linked to the tunnel stations for monitoring and controlling all the safety facilities installed in the Hsueshan Tunnel. This paper describes the safety facilities designed for the Hsueshan Tunnel.

INTRODUCTION

The Hsueshan Tunnel is part of the Taipei-Ilan Expressway. The Taipei-Ilan Expressway will run from Nankang, an eastern suburb of Taipei, to the East coast of Taiwan near Ilan. (See Fig.1) Due to the mountainous terrain, tunnels will account for 20 km of its total length of 31 km. The longest tunnel is the 12.9 km long Hsueshan Tunnel.

Because a highway tunnel is a closed space for vehicular use, when a car accident or fire suddenly happens inside a tunnel, the rescue and evacuation operations will be confined to the space of the tunnel. Therefore, it is necessary to limit all potential hazards and to provide safety facilities for the road users so as to allow vehicles to pass safely through the tunnel.

The safety facilities installed in the Hsueshan Tunnel will provide space for an emergency refuge shelter and provide sufficient information to drivers to recognize the downstream traffic situation. Information on the traffic situation inside the tunnel will also be transmitted to the central traffic control room to assist the traffic management staff to make decisions on traffic control strategies and to take appropriate actions in the event of an accident.

SAFETY FACILITIES

The safety facilities to be provided for in the Hsueshan

1. Engineer, Sinotech Engineering Consultants, Ltd. E-mail:dchsu@mail.sinotech.com.tw

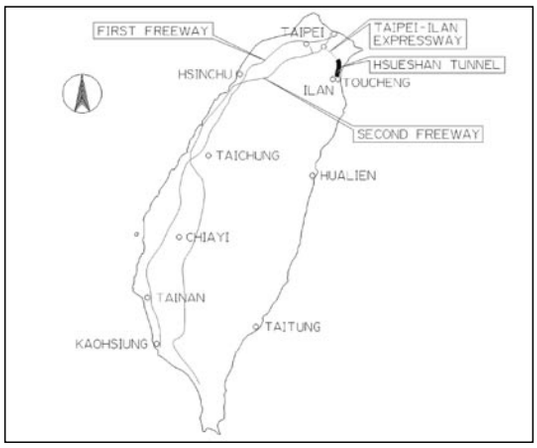

Fig.1 Location of Taipei-Ilan Expressway

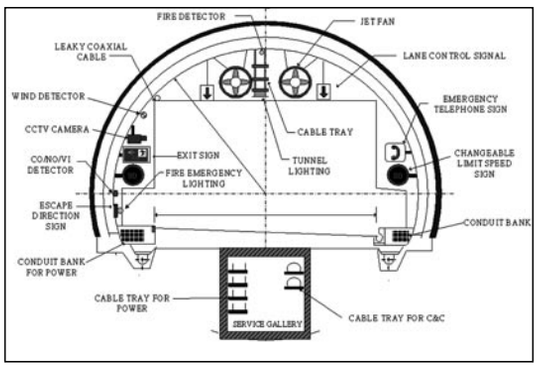

Fig.2 Safety Facilities Layout in Hsueshan Tunnel

Tunnel to ensure traffic safety and personal safety will include the following items: (see Fig. 2)

* Power Supply System
* Emergency Shelter Space and Evacuation Path
* Traffic Control Facilities
* Tunnel Lighting
* Tunnel Ventilation
* Monitoring and Surveillance Facilities
* Fire Alarm and Fire Fighting Equipment
* Evacuation Indication Signs

POWER SUPPLY SYSTEM

The Hsueshan Tunnel has two power substations. They are located at the Pinglin Interchange area and Toucheng toll station area. The Pinglin 161/22.8kV and the Toucheng 69/22.8kV substations will provide 22.8kV of power to all substations of the tunnel by double & loop circuits. These two substations can back each other up using the 22.8kV terminal at the middle portion of the tunnel. In addition, two sets of 3 3W 4160V 2000kW diesel generators are installed at the Pinglin and Toucheng substations, to help promote traffic safety in the tunnel.

EMERGENCY SHELTER SPACE AND EVACUATION PATH

1. Main Tunnel

The walkways on both sides of the main tunnel are designed to provide for emergency passenger evacuation and for access during tunnel maintenance. The curbstone of the walkway is only 150mm high and will not obstruct the opening of vehicle doors during the emergency exiting of vehicles.

2. Vehicular Cross Connections

The vehicular cross connections are designed to be large shelter spaces, and are constructed between the eastbound and westbound tunnels every 1.4 km along the main tunnel. In case of a fire or a serious accident, the vehicles inside the tunnel can access one tunnel from the other tunnel via the vehicular cross connections and people inside the tunnel can also use these cross connections to access to the pilot tunnel for emergency evacuation. (See Fig. 3)

3. Pedestrian Cross Connections

The pedestrian cross connections are designed to be small shelter spaces, and are constructed between the eastbound and westbound tunnels every 350 m along the main tunnel. In the event of an emergency, people inside the tunnel can escape to these cross connections and access the pilot tunnel for emergency evacuation. (See Fig. 3)

4. Emergency Parking Bays

Emergency parking bays are located opposite the vehicular cross connections every 1.4 km along the main tunnel to provide emergency parking in the event of vehicular breakdowns or accidents and to provide

additional space for vehicles moving in and out of the cross connections. (See Fig. 4)

5. Pilot Tunnel

The pilot tunnel is provided with stairways that access the pedestrian and vehicular cross connections. The pilot tunnel will be used for the evacuation of people and as an access road/route for rescue vehicles during emergencies.

TRAFFIC CONTROL FACILITIES

1. Changeable Message Signs

The changeable message signs are installed 150~300 m ahead of the tunnel entrances and at the emergency parking bays. These signs will provide information on traffic conditions in the tunnel and instruct drivers to take appropriate action to ensure traffic safety.

2. Lane Control Signals

Lane control signals are installed at cross-overs in front of the tunnel entrances and above the carriageways in the tunnel every 350 m. They are provided to control the traffic lanes when a serious accident happens inside the tunnel. The green arrow signal shows that the lane is open; the red cross signal shows the lane is closed and vehicles should move into the next lane. The flashing yellow light is used as a warning light to identify an abnormal situation or a change in the existing situation.

3. Changeable Speed Limit Signs

Changeable speed limit signs are installed inside the tunnel at 700 m intervals along the tunnel. The traffic speed limit signs will be adjusted according to the actual traffic flow and will be used to limit the speed of the drivers and control the traffic flow.

TUNNEL LIGHTING

1. Normal Lighting

Fluorescent lighting is provided for the interior of the tunnel. Additional high-pressure sodium lighting is installed at the entrances (including the threshold zone and transition zone) and exit zones to enhance the traffic safety.

2. Emergency Lighting

Some of interior zone lighting installed in the tunnel will be powered by an uninterruptible power supply (UPS) to provide the minimum luminance necessary for traffic safety in the event of normal power failures, and to prevent traffic accidents.

3. Fire Emergency Lighting

The fire emergency lighting is installed on the left side tunnel wall, 500 mm above the walkway at 40~50 m intervals along the main tunnel. In the event of a fire emergency, the fire emergency lighting will be turned on automatically to provide the necessary lighting for personnel evacuation and rescue.

4. Lighting for Evacuation Paths

The evacuation paths inside the tunnel, i.e. the pedestrian cross connections, vehicular cross connections, and the pilot tunnel, will be provided with fluorescent lighting for personnel evacuation and rescue. Some of the lighting fixtures will be connected to the UPS power source to ensure the reliability of the lighting during emergency evacuation.

VENTILATION FACILITIES

1. Ventilation facilities for main tunnel

The ventilation system for the Hsueshan Tunnel is an enhanced longitudinal type with three ventilation stations and three interchange ventilation stations. At each of the three ventilation stations the polluted air in each tunnel is exchanged for fresh air using separate fresh and exhaust air shafts. The air at each interchange station in one tunnel is transferred to the other tunnel and vice versa. The jet fans installed above the carriageway are used for smoke exhaust during a fire and for providing longitudinal flow during bidirectional and congested traffic conditions.

2. Smoke exhaust facilities for the main tunnel

In case of a fire in the tunnel, the smoke caused by the fire will be extracted through the exhaust shaft or the portal by exhaust fans and jet fans.

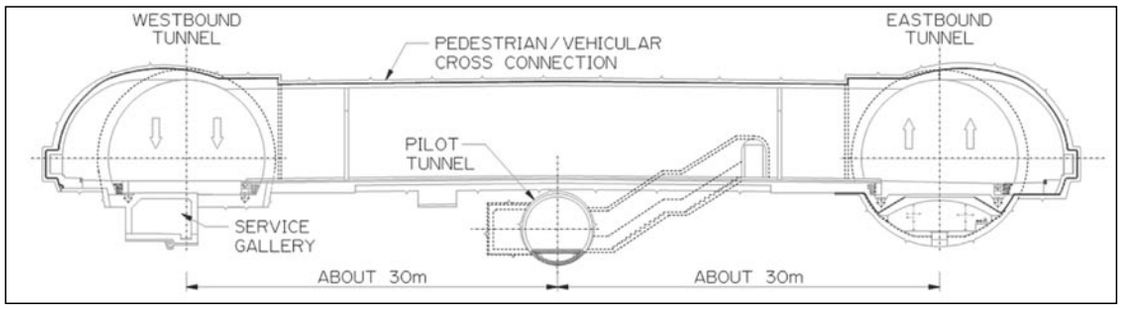

Fig.3 Cross Connection Schematic Layout

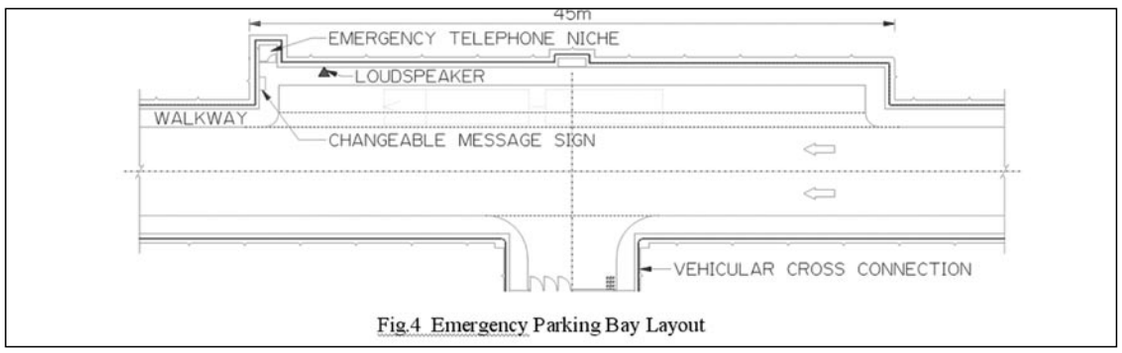

Fig.4 Emergency Parking Bay Layout

3. Ventilation facilities for pedestrian / vehicular cross connections

The fresh air required for the pedestrian / vehicular cross connections will be supplied by the supply fans at portal stations and will be delivered to the cross connections and the two invert galleries under the carriageway of the main tunnel. In case of a fire in one of the two invert galleries, the supply fans will continue to supply fresh air through the other invert gallery and the pilot tunnel.

4. Ventilation facilities for pilot tunnel

The pilot tunnel will be ventilated with the fresh air supplied by the supply fans installed in the portal stations and delivered through the pilot tunnel to the pedestrian / vehicular cross connections.

MONITORING AND SURVEILLANCE FACILITIES

1.Monitoring And Control Center

A central control center will be constructed at the Pinglin Interchange area to monitor and control all of the safety facilities installed in the whole the Taipei-Ilan Expressway. A sector control center will be provided at the west portal of the Hsueshan Tunnel to monitor and control the safety facilities installed in the Hsueshan Tunnel.

The operators in the control center will be able to monitor and control all E&M equipment and traffic control facilities in the tunnel area and take appropriate steps to deal with traffic accidents and unexpected emergencies.

2. CCTV Surveillance

CCTV cameras will become, in normal operations, surveillance equipment and will be used for monitoring the traffic situation. In the event of a fire or any other emergency, the CCTV equipment will also be used for confirming the fire signals received in the control center and transmitted from the local fire call points, and for monitoring the actions of fire fighting, rescue and evacuation.

3. Vehicle Detector

Vehicle detectors will be installed at 350 m intervals along the main tunnel to obtain traffic data inside the tunnel, including the number of vehicles, their speeds and occupancy. When the measured value exceeds the preset value, the related equipment for traffic control will be activated to keep the appropriate traffic flow and insure traffic safety.

4. Air Quality Detectors in Main Tunnel

Air quality detectors, such as CO, NOx, visibility and wind detectors, will be installed in the main tunnel to monitor the air quality and control the tunnel ventilation equipment to produce the necessary air volume for the health of the road users and provide the necessary visibility for driving .

5. Luminance Meter

A luminance meter will be installed at a place 150 m ahead of the tunnel portal to control tunnel lighting fixtures and to provide the necessary luminance for driving safely inside the tunnel.

FIRE ALARM, FIRE FIGHTING AND EVACUATION FACILITIES

1. Equipment for Emergency Calls and Fire Alarms

a. Emergency Telephones:

Installed at 175 m intervals along the main tunnel.

b. Emergency Call Points:

Installed at 50 m intervals (built in hydrant cabinets) along the main tunnel.

c. Fire Detectors:

Linear thermal differential type fire detectors will be installed in the tunnel to detect fire causes and initiate fire alarms.

2. Fire Fighting Equipment

a. Hydrant Cabinets:

Installed at 50 m intervals along the main tunnel.

b. Fire Extinguishers:

Two sets of ABC dry powder extinguishers will be installed in every hydrant cabinet.

c. Hydrants:

Located 50 m outside of tunnel portals.

3. Evacuation and Rescue Indication Signs

a. Escape Direction Signs:

Installed at 50 m intervals along the main tunnel.

b. Escape Exit Signs:

Installed at every inlet of cross connections.

4. Communication Equipment

a. Wireless Telephone

Leaky coaxial cable will be provided in the main tunnel and pilot tunnels for wireless communication. The wireless telephone in normal operation will be used by policemen and maintenance people. In the event of an emergency the wireless telephone will be used by rescue and fire fighting personnel.

b. AM / FM Rebroadcast Equipment:

Leaky coaxial cable will be installed in the main tunnel to allow drivers to listen to the AM / FM program inside the tunnel. In the event of an emergency, the operators in the control center will interrupt the normal AM / FM program for emergency broadcasting to instruct drivers to take necessary action.

c. Emergency Public Address Equipment:

Loudspeakers for emergency public address will be installed in the pedestrian / vehicular cross connections and at the emergency parking bays of the main tunnel.

CONCLUSIONS

Long tunnels in an expressway are a particularly sensitive spot. When drivers are faced with an unfamiliar situation they may react differently in a tunnel than when on the open road. They can also be subjected to increased psychological stress and will have difficulty judging speed and distance correctly. Therefore, appropriate measures should be taken to ensure safe passage through the tunnel both under normal conditions and in emergencies. In normal conditions, the safety facilities installed in the Hsueshan

Tunnel are designed for service personnel to get through as fast as possible while maintaining their safety. Therefore, for the Hsueshan Tunnel, the most important consideration is safe traffic management. The tunnel's safety facilities have been integrated with the monitoring/control systems and traffic control systems to provide an advanced traffic management and control system.

REFERENCES

* TANEEB (Taiwan Area National Expressway Engineering Bureau), Detailed Design