Appendix 3.4 - USA – SR 99 Alaskan Way Viaduct (AWV) Tunnel in Seattle

1. SUMMARY – SR-99 AWV TUNNEL

The Sr-99 Alaskan Way Viaduct (AWV) Tunnel is an urban State Motorway Route located in Seattle, Washington, USA. The number of inhabitants within the City of Seattle limits is 700,000 while the total within Seattle/Tacoma/Bellevue Metropolitan Area is 3,800,000 people.

The AWV tunnel is 2,835 km long. It includes a single tube on two levels for the main tunnel as well as cut-and-cover tunnel structures on both north and south entrances. The tunnel is extended to the south by a new 1.6 km section near the Seattle stadiums.

Figure 1 - SR 99 Tunnel situation and Elliott Bay

The tunnel design is based on the 2010 AASHTO LRFD 4th Edition design specifications and contract specific design criteria. The seismic design is based on the AASHTO Guide Specification for LRFD Seismic Bridge Design 2009, and the fire safety and operation design are per NFPA 502, 2008. The construction of the tunnel is based on the AASHTO Technical Manual for Design and Construction of Road Tunnels – Civil Elements 2010.

Figure 3 - SR 99 Tunnel alignment

Figure 2 - Cross section

The SR 99 Tunnel is designed to withstand an earthquake that only happens every 2,500 years on average translating approximately to a 9.0 magnitude of the Richter scale without collapsing. Rising sea levels in the event of a tsunami, it is highly unlikely that a wave would overtop the seawall and reach the tunnel. The Washington State Department of Transport (WSDOT) and the City of Seattle have estimated that this could only happen during a very high tide – a combination of events estimated to occur only once every 6,000 to 24,000 years. Washington’s early warning technology would allow for restricting tsunami occurrences. If necessary, drains and pump systems would help to quickly remove any water from the tunnel.

The tunnel's safety equipment makes the SR 99 a safe facility for users. The tunnel was designed to withstand an earthquake, flooding or other disasters. The tunnel also includes state-of-the-art ventilation, fire detection and extinguishing, safety and lighting systems. The safety elements include: escape routes, emergency power supply, ventilation, drainage, incident response, ITS, emergency notification, fire detection and suppression.

The tunnel has a single tube, built with a tunnel boring machine (TBM shield) below the water table. The two end structures were built in cut-and-cover. The bored tunnel has a diameter of 17.37 m. The tunnel is for motor vehicles only. Pedestrians, bicycles and vehicles carrying flammable or dangerous products are prohibited.

2. MAIN CHARACTERISTICS

2.1 GEOMETRY

The horizontal alignment and geological conditions are quite constraining. In addition, the tunnel feeds into an existing interchange on the south end of the port of Seattle and the stadiums. From south to north, the tunnel has downhill slope beneath the City of Seattle to a 67m depth. It then slopes upwards to the northern end where the interchange with the secondary road network of the City of Seattle is located.

Each traffic direction has a two-lane configuration of 3.35 m each with a 2.43 m safety and a 0.61 m shoulders respectively. The large curves of the route provide for a good sight distance. Evacuation corridors and emergency exits are located on the west side and shoulders of 0.61 m are on the east side.

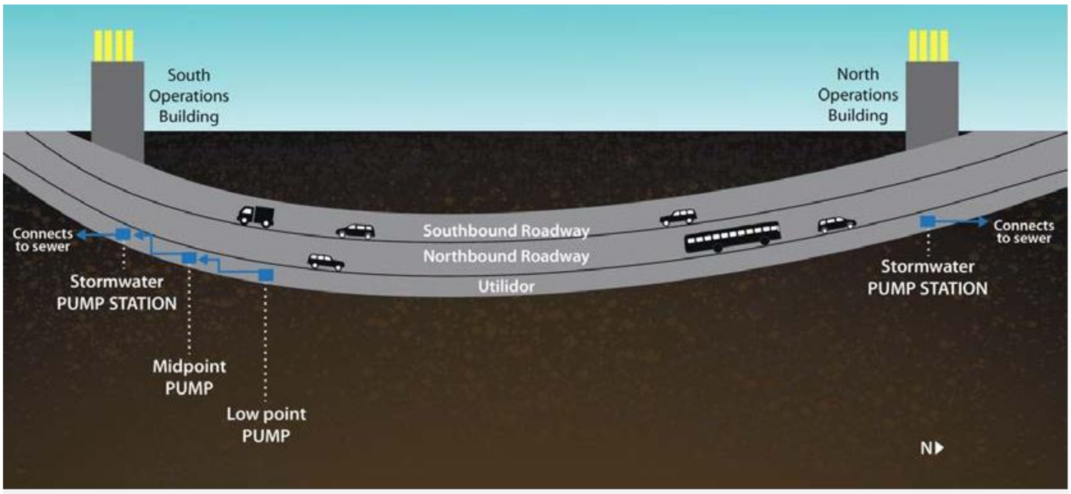

Figure 4 - Tunnel vertical alignment

At the tunnel’s north portal, downtown access is by on- and off-ramps near Seattle Centre. From the south, new on- and off-ramps near the stadiums connect the SR 99 to the waterfront surface street.

Figure 5 - Tunnel North and South accesses and interchanges

2.2 CROSS SECTION

2.2.1 Road Tunnel

The tunnel cross section comprises two decks, each with unidirectional traffic. The upper deck carries the southbound and the lower deck carries the northbound SR-99 traffic. Each deck has two 3.35 m-wide traffic lanes and a 2.43 m-wide hard shoulder. On the lower deck, the hard shoulder is on the right of the slow lane, and on the upper deck the hard shoulder is located on the left of the fast lane. The vertical clearance of the lower deck is 4.85 m and 6.0 m for the upper deck.

Figure 6 shows the general arrangement of the cross-section: the traffic available area, ventilation ducts, utility corridor, technical and electrical rooms, as well as the emergency escape gallery and the pumping stations.

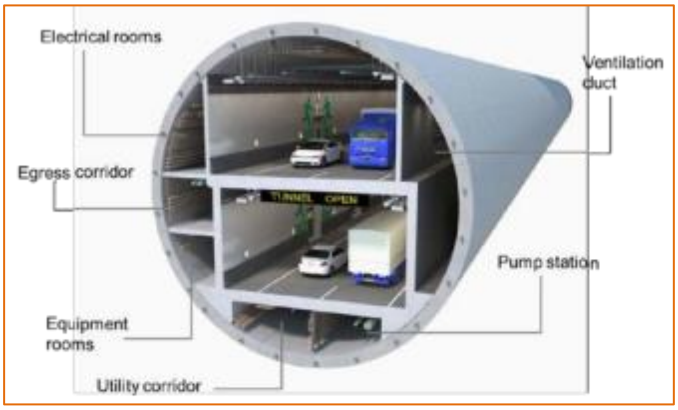

Figure 6 - Tunnel cross section arrangement

Concrete fire protection known as “Grace Monokote” is sprayed on ceilings and portion of walls for both northbound and southbound roadways.

2.2.2 Escape Facilities

❑ Emergency Exits – Escape Gallery - Refuge Areas

The tunnel has an evacuation gallery aimed to protect road users in case of fire incidents. It is parallel from the roadways and equipped with independent ventilation and fire control systems. This gallery is separated from the tunnel roadways by concrete walls. Access to the escape gallery is provided about every 198 m.

In the event of a fire, users will be required to follow the shoulder lane towards the emergency exit and a secure area that is connected to the escape gallery, as well as to the tunnel roadway not affected by the fire.

People with reduced mobility (PRM) may use secure areas located at the foot or top of the access stairs to the escape gallery. These areas are equipped, ventilated, under CCTV control, equipped with a telephone and connected to the Control Centre. The PMR are safe and will be rescued by the emergency personnel.

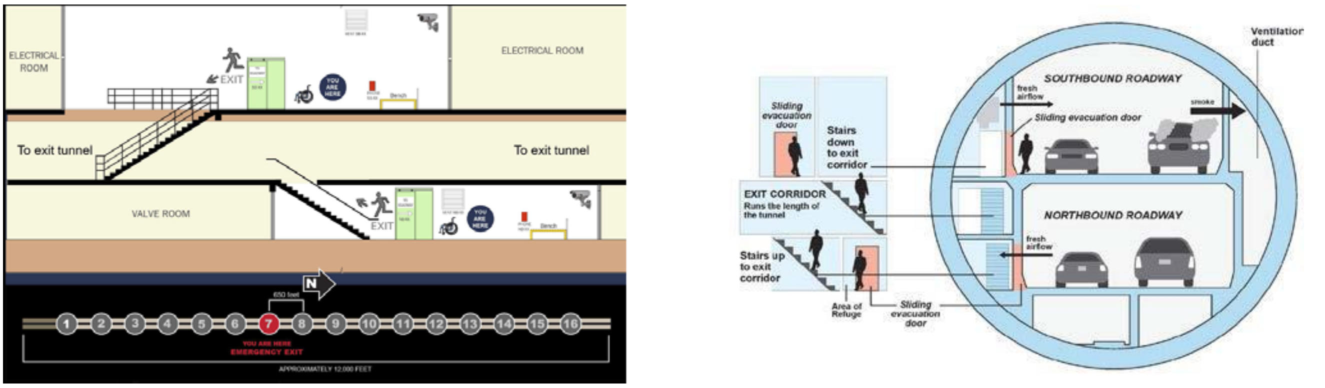

Figure 7 - Enclosed emergency escape routes with independent ventilation system and emergency exits

❑ Fire Life Safety Provisions

The main safety provisions are: (a) emergency exit doors at 198 m spacing, (b) motorised and remote-controlled smoke dampers every 33 m (6 dampers open), (c) 283 m^3/s smoke extraction fan at tunnel portals; (d) sprinkler system at a flow rate of 13 mm/min.

The tunnel is also equipped with fire extinguishers, water pipes and fire hydrants.

2.3 TRAFFIC CONDITIONS – BREAKDOWNS AND INCIDENTS

2.3.1 Traffic Conditions

The speed is limited at 72 km/h inside the tunnel. Fixed speed cameras monitor compliance with speed limits inside the tunnel, on its access roads and on the ramps of the interchanges. Users can obtain free information on traffic conditions on their mobile phones before accessing the tunnel.

2.3.2 Incident Management

Real-time traffic technology minimises delays caused by collisions, stalled vehicles or other disruptions in the tunnel. Following a collision, incident detection systems allow tunnel operators to identify and immediately respond to an incident without delay. If an incident were to block one lane of the tunnel, overhead electronic signs would quickly close the lane to travellers, and variable speed limit signs would maximise traffic flow through the remaining open lane. Emergency vehicles would then enter the tunnel and remove the disabled vehicles.

Figure 8 - Overhead electronic signs provide advisory messages.

2.4 SIGNALLING

The main signalling equipment is as follows:

- (a) signalling of the interchanges at each portal by panels with external illumination, (b) boxes with internal

lighting, (c) LED or fibre-optic panels, (d) flashing or blinking lights and (e) lane assignment and closure lights every 198 m.
- (f) three VMS at each access (two signs warning for tunnel closure - one sign requiring exit), (g) tunnel closure signs and traffic signals at each portal.
- Lane control signs (and closure) every 198 m.

The tunnel is equipped with traffic loops and CCTV with PTZ capabilities. Collection of traffic data is made through traffic loops, captors, the use of the CCTV network and others. These traffic management tools or systems are located throughout the tunnel length.

3. VENTILATION

3.1 VENTILATION CONCEPT

The tunnel ventilation system is "semi-transverse" type with single-point extraction.

Fresh air is supplied by longitudinal ventilation with jet fans.

In the event of a fire, the aim of the ventilation system is to prevent smoke from spreading into the traffic space. Therefore, airflow is maintained in the traffic direction in order to avoid smoke- layering upstream of the fireplace. Smoke extraction is carried out by the nearest damper to the fire.

The ventilation of the escape gallery and the refuge areas is fully independent.

The tunnel ventilation is designed for a 100 MW fire load and uses of a deluge system, and passive fire protection on the ceiling and walls.

Fire detection is provided by a fibre heat detection cable and CCTV. In the event of a fire, smoke is released near the tunnel portals by 24 m high exhaust stacks as shown in yellow, Figure 9.

3.2 VENTILATION SYSTEM

The ventilation system includes:

- 8 centrifugal extraction fans located in the operation buildings (four fans in each building). Each fan has the capacity to pull between 3823 to 5097 cubic metres per minute (m^3/min) out of the tunnel. The tunnel’s ventilation system is designed to removing approximately 660 m3/s,
- 4 fresh air supply fans for the exhaust gallery, electrical rooms and maintenance rooms. These fans are located in the operation buildings,
- 17 jet fans near the tunnel portal to bring fresh air into the tunnel.

The tunnel is equipped with 10 air monitoring stations to ensure the air in the tunnel is safe. This is done by means of sensors monitoring carbon monoxide, nitrogen oxides and particulate matter. Ventilation management is automatic with the possibility of manual control.

Figure 9 - Tunnel south operation building and two of the four extraction fans

The jet fans are activated preventively during congestion, when travel speeds are 32 km/h, or slower, or during emergencies. The exhaust fans are activated preventively during congestion or when vehicle speeds are below 8 km/h.

The smoke extraction ducts are located on the east side of the tunnel. They run along the tunnel, are equipped with dampers every 33 m. Six dampers can be opened in the fire area.

Jet fans are located at the entrance and exit of the tunnel and supply fresh air into the tunnel.

The four fresh air fans provide fresh air to maintenance areas, safety refuges, escape gallery, electrical rooms and other ancillary rooms.

Figure 10 - Tunnel jet fans at portals

3.3 ENVIRONMENT - AIR QUALITY

Monitoring of CO and NOx is made at tunnel portals and 10 locations inside the tunnel to meet national ambient air quality standards.

4. FACILITIES AND OPERATIONAL EQUIPMENT

The SR-99 AWV Tunnel is equipped with standard operational and safety equipment. Therefore, there are few specific points for this tunnel.

4.1 POWER SUPPLY

❑ **Normal Power Supply**

The north and south tunnel portals are powered from independent external power stations and the tunnel control system can switch from one substation to the other if needed.

Electricity distribution in the tunnel is provided from 16 electrical substations. It is redundant.

❑ **Emergency Power Supply**

In the event of a complete interruption of the external regional power supply, the tunnel has an autonomous power supply system. It is provided by two generators, as well as sets of UPS (battery systems).

4.2 LIGHTING

The SR-99 tunnel luminaries are equipped with LEDs. The emergency lighting is supplied from both generators. The light signal for emergency exits flashes in the event of an evacuation.

4.3 WATER SUPPLY - DRAINAGE SYSTEM - FIREFIGHTING EQUIPMENT

The tunnel is equipped with a fixed firefighting system, with a capacity of 14 litres/sec per detection and watering zone (total of 208 zones). 1700 sprinkler heads equip the tunnel.

The firefighting dry standpipes are connected to the City of Seattle's water supply. The City of Seattle Fire Department is responsible for mobile firefighting effort.

The tunnel has four pumping stations: one low point pump station, one mid-level pump station and two stormwater pump stations at each portal.

These stormwater pump stations are designed to limit the amount of rainwater flowing into the tunnel. The water is cleaned before being collected and then discharged into the sewer system.

5. CONTROL CENTRE - OPERATION

❑ **Control Centre**

The tunnel has a 24-hour control centre that allows quick response to changing travel conditions and emergencies. Supervision systems provide real-time information to WSDOT's tunnel operators. The control centre has direct lines to the Seattle Fire Department, the Police Department and other emergency responders.

The SR-99 AWV Tunnel is operated by a central control centre at WSDOT Northwest operation centre. There are 34 Full-Time employees for the SR-99 Tunnel operation.

The SR-99 Tunnel control centre comprises a control room which is equipped with a video wall showing the tunnel's layout and CCTV images of inside the tunnel and the neighbouring area. All the information from the equipment inside the tunnel is monitored from the central control centre via the SCADA system.

Figure 11 - WSDOT Northwest Region traffic management centre

- **Safety Equipment**

Figure 12 - Emergency exits to the escape route

- Emergency exit doors to the refuge areas and the escape gallery at a spacing of 198 m. The doors are lighted with strobe lights:
- Power fire extinguishers, emergency phones at each emergency exit, with a direct connection to 911 (police department),
- Pictograms on tunnel walls (walking man symbols) with distances to emergency exits,
- Variable message signs spaced at approximately 99 m c/c.
- Camera network with AID (automatic incident detection): stopped vehicles, wrong way vehicles, pedestrians, debris, smoke.
- Linear heat detectors with a fixed suppression system – sprinklers that operate automatically or manually,
- AM/FM radio rebroadcasting system and public address system.

- **Intelligent Transport System**

Intelligent transport systems and communication with users are provided through the Supervisory Control and Data Acquisition systems (SCADA). SCADA Interfaces with other systems including maintenance management, fire control, security, and emergency phones.

- **Traffic Management**

Dangerous and flammable goods traffic are not allowed in the Tunnel. The WSDOT Tunnel Operator controls particular conditions or restrictions for the maintenance services at the Off-Peak hour closures.

- **Fire Detection - Firefighting System - Fire Response**

The tunnel is broken up into 208 fire detection and suppression zones. The tunnel system fire response would be either automatic or manual:

- Automatic response: the heat detectors on the tunnel roadway ceiling trigger an alarm to the tunnel control system, which then activates the deluge, ventilation and messaging systems for that zone.
- Remote manual response: Should an operator notice a fire (via CCTV, AID, pull station), he can trigger the same fire response through the tunnel control system (there are more than 70 incident detection cameras).

The Seattle Fire Department is the master control of incident with different operators in relationship with the global safety and the intervention in case of fire. The City of Seattle Fire Department is delegated for helping the escape when the fire brigade or emergency services are not on the site.

In the event of a fire, the sprinklers of the fixed firefighting system provide additional contributions to the fire department to fight the fire and reduce the temperature level, while the ventilation systems evacuate the smoke. The tunnel is equipped with cameras that can be used to show the exact location in the event of a fire.