Central - Wan Chai Bypass and Island Eastern Corridor Link (CWB) Introducing Air Purification System in Road Tunnels

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ABSTRACT

The Central - Wan Chai Bypass and Island Eastern Corridor Link (CWB) will be a strategic infrastructure for relieving the traffic congestion along the northern shore of Hong Kong Island and meeting the traffic demand in the next decade.

The works of the CWB mainly comprise construction of 4.5 km dual three-lane trunk road of which a 3.7 km section will be a tunnel connecting Rumsey Street Flyover in Central to Island Eastern Corridor at North Point. Similar to other road tunnels in Hong Kong, various engineering systems would be required for the CWB, for examples, fire safety system, tunnel ventilation system, lighting, traffic control and surveillance system, incident management process and evacuation system etc.

In today's major infrastructure projects, the expectations from the public and the impact to the environment are amongst the top priority areas for design considerations. There is no exception for CWB. We are exploring the use of the latest technology in air purification for the CWB, with the aim of enhancing the quality of tunnel exhaust to achieve a greener and more sustainable development.

This paper is intended to provide a brief introduction on the considerations in developing design solutions for purifying tunnel exhaust from the CWB. The advantages and contributions to the Hong Kong environment will also be addressed.

1. INTRODUCTION

The Central - Wan Chai Bypass and Island Eastern Corridor Link (CWB) will be a strategic infrastructure for relieving the traffic congestion along the northern shore of Hong Kong Island and meeting the traffic demand in the next decade.

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2. REVIEW OF CWB CHARACTERISTICS

The CWB is a trunk road connecting the existing Rumsey Street Flyover in Central and the Island Eastern Corridor Link (IEC) in North Point. The existing east-west corridor (Connaught Road Central/Harcourt Road/Gloucester Road) on Hong Kong Island is already operating beyond its capacity. Previous and recent strategic transport studies have predicted further increase in traffic demand along this east-west corridor, and confirmed the need for a parallel east-west trunk road to avoid more extensive and frequent traffic congestion and gridlock on the existing road network.

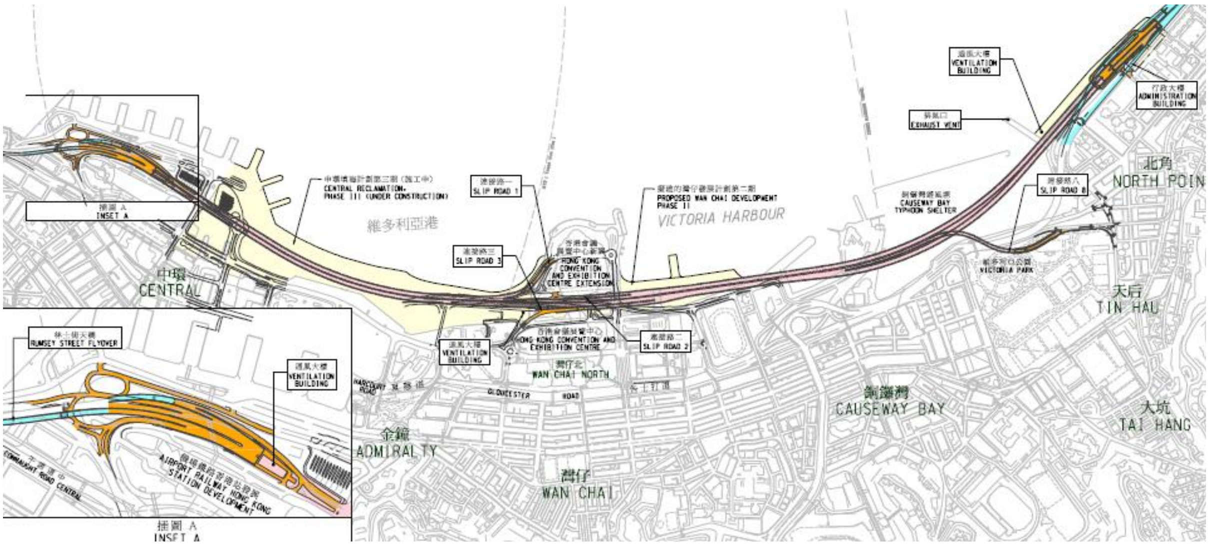

Figure 2: Alignment of the Central – Wan Chai Bypass

The CWB consists of a dual 3-lane road tunnel approximately 3.7km in length between Central and North Point traversing the northern part of Wan Chai. For the eastbound tunnel, slip roads connect the CWB and the Wan Chai North area near the Hong Kong Convention and Exhibition Centre with an exit Slip Road 1 and an entry Slip Road 2. For the westbound tunnel, an exit Slip Road 3 daylights from under the Exhibition Atrium Link at Wan Chai and an entry Slip Road 8 leads the traffic into the CWB from the Causeway Bay area near the Victoria Park. Along the tunnel, there are 3 ventilation buildings housing the tunnel ventilation system, namely the West Ventilation Building (WVB) at Central; Middle Ventilation Building (MVB) at Wan Chai North; and East Ventilation Building (EVB) at North Point.

2.1 Possible Effects on Air Quality

With the construction of the CWB tunnel, the possible effects to the environment include the following:

- Reduce the traffic pollutants along most of the north shore of Hong Kong Island between Central and Causeway Bay/North Point by diverting the traffic to use the CWB tunnel.
- Centralize tunnel emission through the ventilation buildings.

2.2 Possible Solutions to Tackle Air Quality Impacts

It can be seen that air quality impacts is one of the major environmental issues to be addressed in the design of the CWB tunnel. Several strategies on minimizing the air quality impacts to the public have been studied and will be implemented in the CWB project. They include:

- High level discharge with vertical velocity
  The vitiated air discharged from the ventilation buildings will be emitted at a high level. Also, a vertical discharge velocity will be imposed to the air stream to eject the discharged air up to a high level for dispersion. This can reduce the impact to the surrounding environment by better dispersion.
- Offshore discharge
  The design will look for the opportunities for offshore discharge. One possible way to achieve this is to separate the ventilation shaft from the ventilation building such that the vitiated air discharged from the ventilation building will travel to a remote ventilation shaft for discharging, which is far from the ventilation building as well as the general public occupied area. This helps reduce the impacts to the general public.
- Installation of Air Purification System (APS)
  To improve the air quality, an air purification system is proposed for CWB. The proposed air purification system comprises an electrostatic precipitator and a de-nitrification system for removal of Respirable Suspended Particulates (RSPs) and NO_2 in the exhausted air respectively.
- Portal emission control
  The airflow discharged from the tunnel portal will be accompanied with a certain portion of vehicle emissions from the tunnel traffic. To control the amount of portal emission, a high suction pressure will be applied to draw back the vitiated air to be discharged via the ventilation building/ventilation shaft so that impacts to the air quality of the area around the tunnel portal can be reduced.

2.3 Performance Standards and Objectives

The Air Pollution Control Ordinance (APCO) stipulates the statutory requirements on controlling air pollutants from a variety of sources. The Hong Kong Air Quality Objectives (AQOs) specify the maximum allowable concentration of different pollutants. The relevant AQO are listed in **Table 2.3-1**.

Table 2.3-1: Hong Kong Air Quality Objectives

Pollutant	**Maximum Concentration ($\mu g\ m^{-3}$)**			
	Averaging Time			
	1 hour	**8 hour**	**24 hour**	**Annual**
Total Suspended Particulates (TSP)	---	---	260	80
Respirable Suspended Particulates	---	---	180	55

(RSP)				
Sulphur Dioxide (SO_2)	800	---	350	80
Nitrogen Dioxide (NO_2)	300	---	150	80
Carbon Monoxide (CO)	30,000	10,000	---	---
Photochemical Oxidants (as Ozone, O_3)	240	---	---	---

The Practice Note on Control of Air Pollution in Vehicle Tunnels provides guidelines on control of air pollution in vehicle tunnels. Typical guideline for tunnel air quality is presented in **Table 2.3**-2.

Table 2.3-2: Tunnel Air Quality Guidelines (TAQG)

Air Pollutant	Design Criteria / Max Concentration
Carbon Monoxide (CO)	100 ppm
Nitrogen Dioxide (NO_2)	1 ppm
Sulphur Dioxide (SO_2)	0.4 ppm
Visibility	0.005/m

2.4 Outline of Approach for Air Purification

To meet the tunnel air quality requirements and achieve a cleaner emission, the following two technologies for removal of dust particles and nitrogen dioxide, the two most significant pollutants in tunnel exhaust, can be considered in the design for CWB Tunnel.

2.4.1 Electrostatic Precipitator (ESP)

Electrostatic Precipitator is an electrical device to capture dust particles in the contaminated air using electrostatic principles. By doing so, visibility in the tunnel could be maintained to the required standard and the air eventually emitted from the ventilation buildings or shaft contains lower level of RSP. For its application in CWB, apart from the above-mentioned benefit, the electrostatic precipitator is also required to capture dust particles before the chemical process of NO_2 removal, so that a higher efficiency of the NO_2 removal could be achieved.

The processes within an ESP include:

- Dust ionizing - electrically charge dust particles;
- Dust captured - by the Coulomb force in the electric field;
- Less dust discharged to outside.

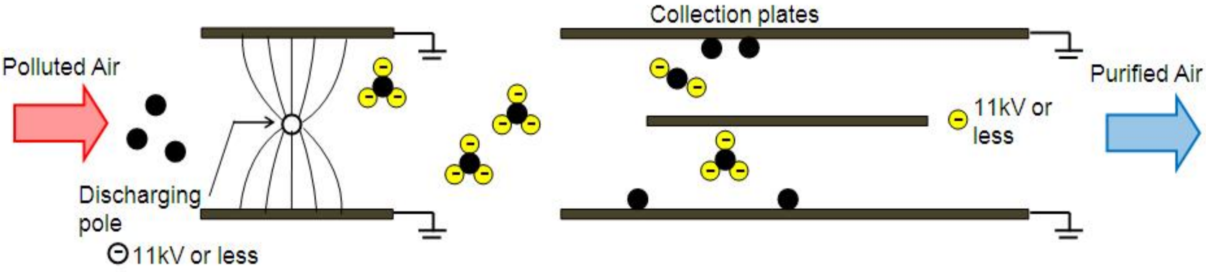

Figure 2.4-1: Operating Concept of Electrostatic Precipitator

Comparing with other dust filtration technologies, the use of ESP has the following advantages:

- High reliability – electrodes are durable, thus low maintenance required;
- High efficiency – expected to achieve 80% removal of RSP for application in the CWB;
- Low performance degradation over time;
- Only electricity source is required to drive the operation.

2.4.2 NO_2 De-nitrification

NO_2 de-nitrification is a quite complicated chemical process. The current NO_2 de-nitrification technologies fall into two streams, namely absorption and decomposition. As described above, there should be a dust removal process via ESP before the air enters the NO_2 de-nitrification system.

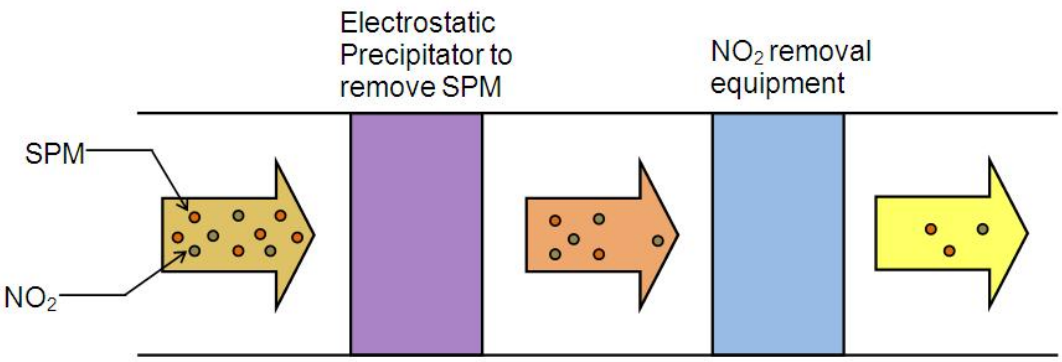

Figure 2.4-2: Operating Concept of NO_2 De-nitrification System

The proposed NO_2 de-nitrification system adopts the absorption techonology. After the exhaust air has been treated by ESP, it is allowed to pass through NO_2 de-nitrification device where NO_2 is neutralized by the absorbent (refer to figure above). The alkali potassium hydroxide is used as the absorbent. A well maintained NO_2 de-nitrification system can achieve an efficiency of up to 80% absorption.

2.5 Different Approaches for Different Configurations of Tunnels

Depending on the tunnel size and local constraints, the APS could be installed either in the tunnel, a bypass tunnel or tailored plant room outside the tunnel.

For the CWB tunnel, the APS would be installed inside the ventilation buildings, in consideration of the limited space available within the tunnel. The untreated air inside the tunnel would be extracted out of the tunnel tube to the APS system, where the air is treated. The purified air would be either expelled at the exhaust ventilation shaft to the surroundings or released back to the inside of the tunnel tubes via ventilation ducts.

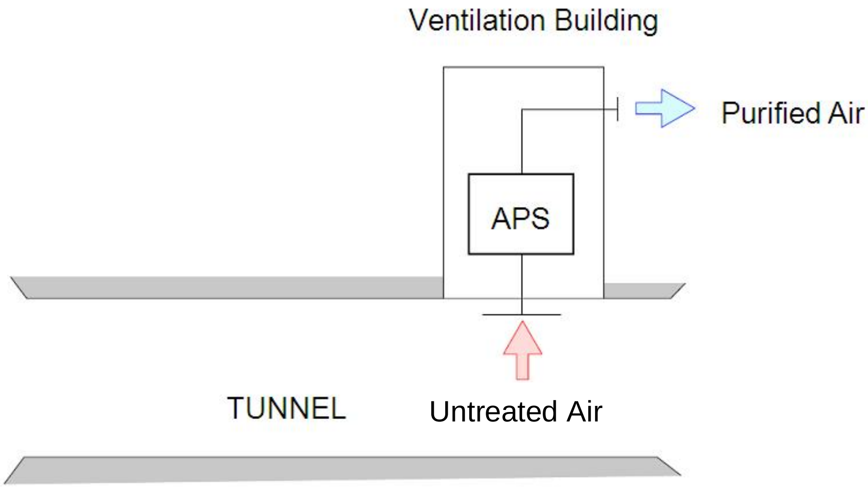

Figure 2.5-1: APS Configuration for Ventilation Building Installation

Alternatively, if space contiguous to the tunnel is available, the bypass system could be adopted. The polluted air would pass through the APS in the bypass tunnel, where the pollutants are removed. The treated air would then be released inside the tunnel as a purified air supply.

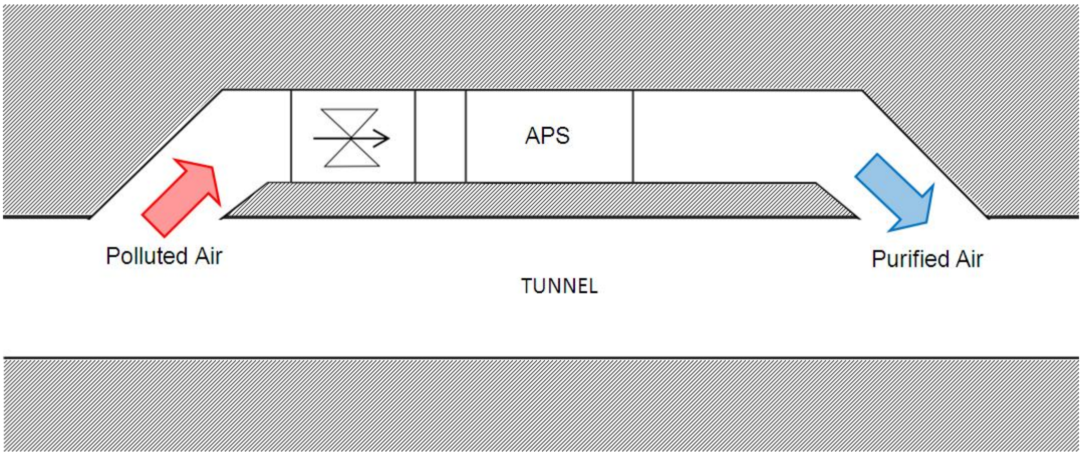

Figure 2.5-2: APS Configuration for In-tunnel Installation

2.6 Constraints

The use of ESP and NO_2 de-nitrification system for a tunnel will increase the spatial requirements for ducts, equipment either inside tunnel, underground or above ground. To properly operate the NO_2 de-nitrification device, the air velocity passing through the absorbents shall not exceed 2.5m/s. That means to cater for a designed volume of air flow, the size of the air duct and space for the associated equipment will be larger compared to the case where NO_2 de-nitrification system is not used.

The original arrangement for the CWB was to place the ESP and NO_2 equipment in the plant room within the ventilation buildings. However, as it was the desire from the public to minimize the visual impact of the ventilation buildings, it was preferred not to expand the exposed structures of the ventilation buildings. The option to relocate the plant rooms to the basements of the ventilation buildings was therefore vigorously explored. Due to limited available space and other physical site constraints, it is now proposed that some of the plant rooms of the APS would be relocated to underneath the CWB tunnel structure.

2.7 Benefits

The costs for the installation and operation of APS are very high. However, the achievement attained by adopting the APS in the CWB tunnel would be its benefits to the environment of Hong Kong. The CWB runs through the central business district and is quite near some residential areas of Hong Kong Island. The efficiency of the APS in removing the dust particulates and NO_2 from the airflow stream could be up to 80%. Cleaner air not only contributes to healthier environment to the residents in the vicinity, reducing rate of respiratory diseases, but also meets with the demand from the public for air quality improvement and investment in cleaner air will be well spent.

2.8 Use of APS in Other Countries

The ESP technology of air purification system has been developed for some time and is now becoming mature. Japan is one of the countries which have been adopting the ESP system for road tunnel projects and possess much experience in its application. For the NO_2 de-nitrification, the technology has been widely used in the industrial field. Application to the road tunnel has been put into reality in the recent years. The advancement of the technology is at a very fast pace and it can be foreseen that these air purification system technologies should reach a much more advance and mature development at the time of installation of the designed systems for CWB.

There are a lot of manufacturers who are capable of providing equipment on these air purification systems for road tunnel applications. Examples of ESP manufacturers worldwide include Aigner of Austria, CTA Technologies of Norway, Kawasaki Heavy Industries of Japan, Mitsubshita Heavy Industries of Japan and Matsushita of Japan.

The use of air purification system has a lot of proven records in Europe, Japan and other countries. Some applications are listed below:

- Norway: Festning Tunnel (1.8km), Hell Tunnel (3.9km), Laerdal Tunnel (24.5km), Stomsas Tunnel (3.7km)
- Italy: Cesena Tunnel
- Japan: Tokyo Aqua-Line Tunnel (9.6km), Kan'etsu Tunnel (11km), Tennozan (2km), Kanmon (3.5km), Asukayama (0.6km), Midoribashi (3.4km), Hanazonobashi and Hasumiya tunnels
- Vietnam: Hai Van Pass Tunnel
- The NO_2 de-nitrification technology has been used in the 10km Central Circular Shinjyuka Tunnel in Japan

3. POSSIBLE DESIGN SOLUTIONS FOR AIR PURIFICATION

The CWB project will take the opportunity to provide a greener and more sustainable development to the public. Tunnel ventilation system is designed to minimize the extent of air quality impact to the outdoor environment at portals and around ventilation building areas. The following aspects have been considered in the design stage in order to enhance the air quality.

3.1 Control of Portal Emission

Portal extraction system will be provided for the portals of the CWB tunnel. With the tunnel ventilation system designed for controlling the portal emission, air quality impacts from the tunnel portal would be reduced.

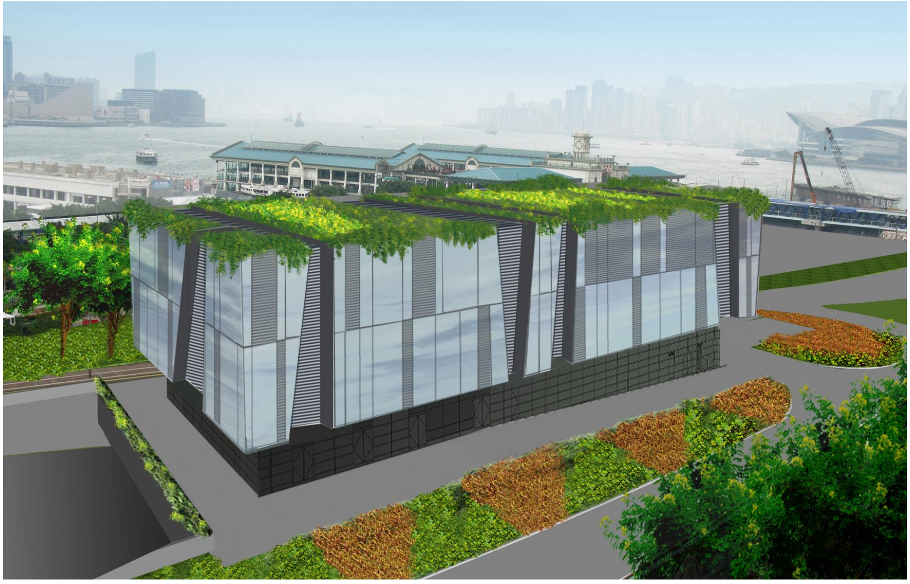

Figure 3.1.1: Tunnel Portal
(Design of ventilation building shown is tentative only)

3.2 Reuse of APS Treated Air

The concept of re-using the treated tunnel air by APS will be implemented. The vitiated air extracted from Slip Road 1 portal and Slip Road 3 portal at the MVB will first be treated by the APS and then be used as the supply air for the westbound and eastbound tunnel respectively. The treated air will be re-charged to the tunnel through the overhead ventilation duct (OHVD) in the tunnel section between west portal and the MVB. As a result, some ventilation fans at the WVB originally used to draw air into the tunnel will not be required and the spatial requirement of WVB can be reduced and optimized.

3.3 Air Purification System at Ventilation Buildings

For CWB, there are three ventilation buildings, namely WVB, MVB and EVB, which are located within the areas of Central, Wan Chai North and North Point respectively. Several provisions would be adopted to enhance the quality of air discharged to the surroundings.

To improve air quality, advance ventilation system will be installed in the three ventilation buildings of CWB. Air purification system comprising electrostatic precipitator and de-nitrification system will be installed in the concerned ventilation buildings. To minimize the land to be taken up, APS plant will be designed to locate at either below the original building basement or underneath the tunnel box structure.

3.4 Offshore Discharge Ventilation Shaft

The air quality at the east ventilation building would be enhanced by locating the vent shaft at the end of the east breakwater of the Causeway Bay Typhoon Shelter (CBTS) and by the installation of APS at the East Ventilation Building to purify the tunnel emissions.

Figure 3.2.2: Vent Shaft Located in the Eastern Breakwater of the CBTS
(Design of vent shaft shown is tentative only)

4. CONCLUSIONS AND WAY FORWARD

The ESP and NO_2 de-nitrification technologies are mature and have been applied in many tunnels worldwide. The use of such technologies in the Central – Wan Chai Bypass Tunnel will improve the tunnel air quality for the motorists and also air quality of the northern shore of Hong Kong Island.

To successfully apply such technology, many local and system constraints have been identified and feasible measures have been developed to tackle them. Detailed engineering solutions will be further developed and finalized in the subsequent stage of the project.

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