WINDTECH CONSULTANTS PTY LTD
19 Willis Street
Arncliffe NSW AUSTRALIA
Phone (02) 9567 0722
Fax (02) 9567 0733
Email
reception@windtech.com.au

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Assessment and Optimisation of natural ventilation for the University of NSW main service tunnel

Introduction

A wind tunnel study has been carried out by WINTECH to establish the atmospheric wind driven natural ventilation potential for the UNSW Kensington Campus Main Service Tunnel. These predictions are then compared with the guidelines provided by Safe Work in Confined Spaces AS2865-1995 as well as other relevant standards such as AS1668-2. The main service tunnel (MST) carries main services to several campus buildings. Natural Gas, bore water, town water and electricity are the main services supplied via this tunnel.

The tunnel does not carry any hot water or steam supply lines. The under ground tunnel is constructed in reinforced concrete approximately 3.8m below the ground level. The average effective cross-section of the tunnel is approximately 3m x 3m (area=9m2). The overall length of the tunnel is approximately 400m. The two main entrances to the tunnel are at Robert Webster Building and Electrical Engineering Building. These access doors are kept closed at all times.

The interior of the service tunnel is made of reinforced concrete. Potential pollutant gases include Radon, bioaerosols, natural gas and Ozone. In addition, there is the potential problem of slow oxidation processes such as corrosion, aerobic micro-organisms etc. will consume the oxygen within the tunnel. Adequate air circulation is necessary to replenish the oxygen levels to safe limits. Inside the tunnel pollutant concentration depend on the strength of the pollutant sources and the rate of pollutant removal. The steady state indoor pollutant concentration is given by the equation:

$$C_i = C_o + S / Q$$

Where :

C_i = steady state indoor concentration
C_o = outdoor concentration
S = total pollutant source strength

Q = ventilation rate (outdoor air only)

The objective of ventilation is to maintain C_i as close as possible to C_o. This can be achieved by minimising S and maximising Q. In cases of radon and bioaerosols supply of fresh air Q will remove moisture and hence reduce the source strength S making S / Q smaller. This will further reduce the requirements of air changes applicable to the MST.

The tunnel is located below the main mall of the Kensington Campus. Initial tests were undertaken to assess the feasibility of providing two stacks rising 10m above ground from the two ends of the MST. As it is aesthetically not preferred to provide stacks immediately above the tunnel at ground level, two stack locations adjacent to existing buildings were also evaluated.

A ventilation criterion for the service tunnel

According to the AS 1668-2 for a Prison Cell of area 5m2 and a height of 2.5m with one person requires a minimum outdoor airflow rate of 3.5 L/s. This converts to 1.008 air-changes per hour (ACH). Taking this as a datum the approximate ACH required for UNSW MST can be conservatively estimated as half of this amount, 0.5 ACH. Considering the volume of the tunnel 400 x 9m3 = 3600m3 this leads to a minimum required outdoor air flow rate of 0.5*3600*1000/3600 L/s = 500L/s.

Selection of natural ventilation openings

The use of stacks is the most effective way of naturally ventilating an underground space. The use of existing entrances as air-inlets would significantly improve the performance of the stacks. Inlet openings for the MST need to be fire-rated and hence the use of fixed louvre panelled openings at the inlets were proposed.

As the entrances would serve as points of relatively positive pressure, their ideal location would be at the base of a long building, facing a predominant wind direction for the site. The potential stack locations have been identified at areas where significant cross-flow can occur from any direction, inducing a relatively large negative pressure. The resistance to airflow through the stacks should be minimised, particularly at the locations of bends and exhausts in order to.

Wind driven ventilation

The characteristics and locations of the openings deter-mine the above wind driven pressure differences and the resultant flow of air. The wind pressures acting on different openings will determine the internal static pressure of the tunnel in order to maintain the continuity equation (mass flow rate of air into the tunnel is equal to the mass flow rate of air out of the tunnel).

The wind driven airflow rate can be calculated using the following set of equations.

$$P_{wk} - P_i = 0.5\ K_{tk}\ pV_{k2}$$

$$M_{wk} = pV_kA_k$$

$$EM_{wk} = 0$$

where :

P_{wk} = total pressure at opening k due to wind
P_i = interior pressure in the tunnel at equilibrium
K_{tk} = total pressure loss coefficient for the opening k
p = density of air
V_k = average velocity at opening k
M_w = mass flow rate of air through opening k
A_k = Effective area of opening k

The stack effect

As there are no significant heat sources within the service tunnel, the ventilation is driven almost entirely by the external wind flows. If the stack is built from a heat conducting material, it may be possible to use the solar energy entering the stack through the outer skin as a possible ventilation driver. However, reliance on the stack effect alone would certainly not provide adequate ventilation.

A study of the contribution of thermally driven ventilation concludes that even in the case where heat is transmitted into the stack through the outer skin, this component accounts for between 1 and 2 percent of the total required airflow.

Wind driven ventilation : results & discussion

The use of only 2 stacks, one at each end of the service tunnel, with no air inlets did not provide adequate ventilation. Use of the existing entrances as air inlets allowed the stacks to work more effectively as ventilators. Depending on the particular opening configuration and stack characteristics used there is a large variation in the natural ventilation potential. Air Changes per Hour (ACH) between 1.74 to 14.11 are predicted.

An optimum stack diameter of 0.3m was selected. A 33 percent increase in stack diameter increased the ACH by only 4%. As such it is not economical to further increase the diameter of the stacks.

The provision of a third inlet at the northern end of the service tunnel, 500mm in diameter results only 5% increase in the ACH. However, an increase in the size of this third inlet to 3m x 3m results in an increase in the ACH by 205%. For practical reasons, the client did not pursue the option of a third inlet.

Properly designing the entry, bends, and exit conditions of the stack as well as opening up the air inlets at entrances results in a 600% improvement in ACH. Therefore it will be more economical to reduce the restrictions to the natural airflow by streamlining and opening up the restricted passageways.

Increasing the height of the stacks from 10m above ground to 3m above adjacent buildings (to be within the freestream flow), in effect 4m higher at the eastern end and 15m higher at the western end, results in about 1% reduction in ACH. This slight overall reduction is mainly a result of increased friction due to the larger lengths of the stacks.

Different combinations of pairs of stack locations did not result in any significant change in the ACH.

As discussed earlier the requirement as per AS2865 and AS1668.2 would be around 0.5 ACH for restricted usage. The lowest ACH prediction in the above analyses per-forms 3.5 times better than the minimum required ventila-tion condition. By designing the stacks and openings with due consideration to minimise restrictions to the natural airflow larger ACH can be achieved.

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