# FULL-SCALE STUDIES OF WIND CONDITIONS ON SUBWAY RAILWAY PLATFORM DUE TO TRAIN MOVEMENTS

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## Introduction

The Mass Transit Railway (MTR), a subway railway system, is an integral part of an extensive transportation system serving Hong Kong, one of the world most congested cities. Moving trains act as pistons which push and suck air into the tunnel and create gusty winds along the platform (Sugihara et al., 1995, 1997; Gerhardt and Krueger, 1998). This induced airflow may produce discomfort and even potential danger for passengers waiting on the platform, particularly for the aged and young children. Any increase in train speed to meet growing passenger demands is expected to exacerbate this problem.

The aims of the project are to study the wind conditions on MTR platforms, to investigate their effects on passengers, and to study the effectiveness of various remedial measures. This paper presents the preliminary results of full-scale measurements of wind conditions on the platforms of two MTR subway stations due to moving trains.

## Measurement program and equipment setup

Full-scale measurements were conducted on two MTR stations, Diamond Hill which has an open plan design, and Quarry Bay a confined tubular design, as shown in Fig. 1. These two designs are believe to generate different wind conditions on the above station platforms. Several locations shown in Fig.1 along the platform were selected for wind speed and wind direction measurements while trains were arriving at and/or leaving the platform. Most of the measurements were taken at approximately 1 m from the edge of the platform, with a few selected positions a further 1 m behind. At each measurement position, a laptop computer linked to an ultra-sonic anemometer with an averaging time of 1 second was used to continuously record the wind speed and wind direction at 1.5 m above the ground level.

According to standard MTR operation, the speed of a train is not to exceed 33 kph when it reaches a pre-set location ahead of the platform at which point a computer-controlled braking sequence slows the train at such a rate that it stops at pre-determined set-down and pick-up positions along the platform. During travelling along tunnels between stations, the train driver is expected to set the train speed according to track conditions and established speed limits. Hence some variations in the wind velocities along the platform are expected between individual arrival or departure.

Measurements were taken for two hours at each MTR station during non-peak hour time. Multiple measurements were taken at nearly all measurements positions. Since the MTR trains were running a normal service during the measurements, there was no special sequence to control the arrival at or departure from in-bound and out-bound platforms. This "randomness" of train arrivals and departures has a significant impact on the wind velocities on the platform as will be shown in the following section. The movements of passengers alighting and boarding the train close to the ultra-sonic anemometer also created localised turbulence but the effects are considered to be minimal compared with the wind gusts generated by passing trains.

## Results and discussions

A summary of recorded peak gust wind speeds on both the Diamond Hill and the Quarry Bay MTR stations is presented in Table 1. It is clearly evident that winds on the platforms were generated by both the train movements along the platform on which measurements were taken (denoted Local, and LA for arriving train, LL for departing train) and those along the opposite tracks (denoted Opposite, and OA for arriving train, OL for departing train).

Without the influence of train arriving or departing from the opposite tracks, the peak gust wind speeds caused by an arriving train (LA) have the highest value at near the platform end for both Diamond Hill (4.5 m/s) and Quarry Bay stations (6.6 m/s). In general, wind speed decreases when the measurement position was moved along the platform from the platform end

to the platform front. This is not unexpected as the train decelerated once it reached the platform and came to a stop at the platform front.

The peak gust wind speeds caused by an arriving train (LA) were of similar magnitude and have the highest value at near the platform front for both Diamond Hill (4.3 m/s) and Quarry Bay stations (6.0 m/s). These peak gust wind speeds were usually recorded a few seconds after the entire train has entered the tunnel. Evidently, much of these winds were due to the suction effect caused by the rapidly accelerating train.

The generally higher peak gust wind speeds measured at Quarry Bay are most probably due to the more confined tubular design there. It is noted that the gust winds were also consistently high at the well-defined exit openings which form the only connections with the opposite platform and the station hall above.

The arrival and departure of trains at the opposite platform, either acting alone or in addition to those at the local platform on which wind measurements were being taken, produced confused wind flow on the platform, as shown in Figs. 2 and 3. Furthermore, the combined effect caused the highest measured peak gust wind speeds at both Diamond Hill (6.4 m/s) and Quarry Bay (7.1 m/s) stations. In the case of Diamond Hill station, the departing train at the opposite platform sucked in a lot of air from the local platform into the tunnel, as seen in Fig. 2. In the case of Quarry Bay, the train arriving at the opposite platform drew air from the local platform through one of the exit opening connecting both platforms, as shown in Fig. 3.

It is interesting to note that passengers standing on a platform tend to feel a far greater level of discomfort as train passes. This is so despite the actual magnitudes of the wind gusts suggest their impacts on a pedestrian would normally be less than that observed on a platform even after taking into consideration the differences in activities: passengers who are stationary on a platform verses pedestrians who are walking. This suggests that the suddenness of the wind gusts, that is the wind speed gradient, associated with a train arriving at or leaving the platform is a more important parameter, in terms of passenger comfort.

**Concluding remarks**

The access to the two MTR stations under normal operating conditions provided an excellent opportunity to study the wind conditions on subway railway platforms due to train movements. The results gathered by these studies form the basis for further work which may include:

- Further measurements on other railway systems such as the new Airport Express and the Kowloon-Canton Railway;
- Comparisons between the full-scale measurement results and measurements taken on scaled models;
- Comparisons between the full-scale measurement results and simulations based on CFD.

**Acknowledgements**

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**References**

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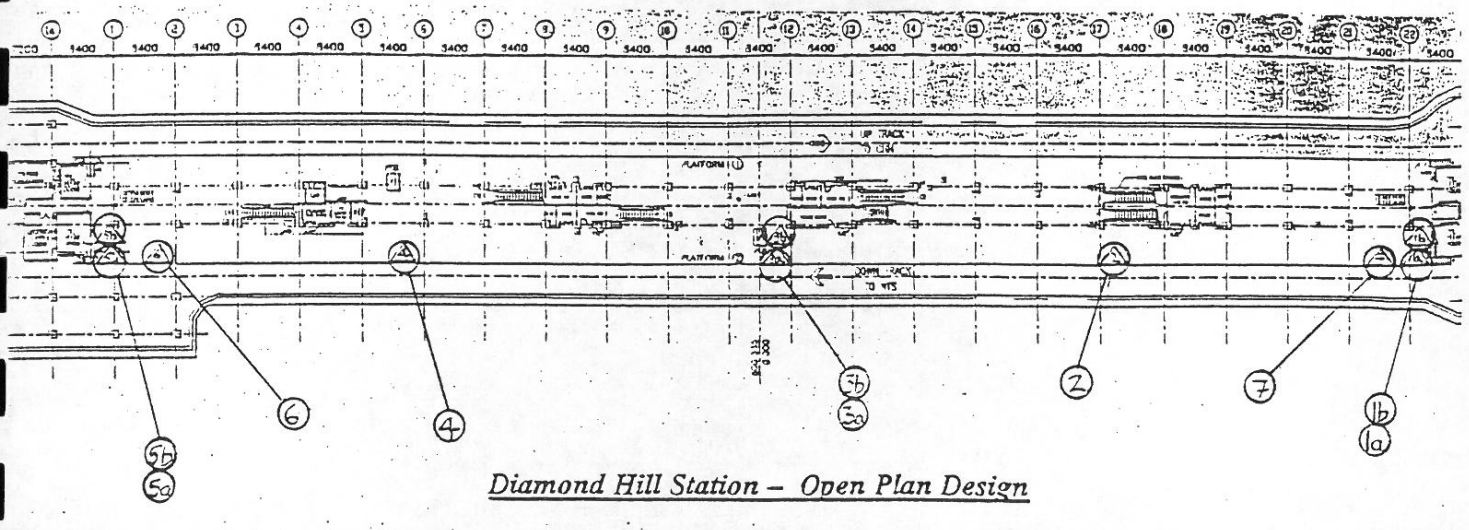
**Table 1 A summary of recorded peak gust wind speeds**

Diamond Hill

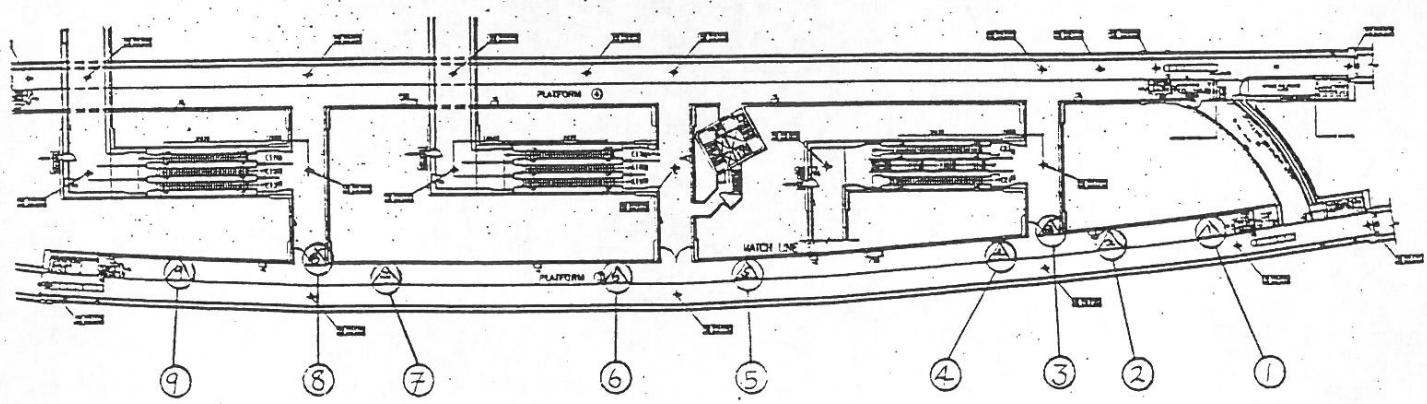
| Point Location | Peak speed (m/s) | | | |
|---|---|---|---|---|
| | Train arriving (LA) | Train leaving (LL) | Opp train arriving (OA) | Opp train leaving (OL) |
| 1a | 4.5 | 3.5 | 4.5 | 6.0, 6.4 (+LA) |
| 1b | 0.6 | 0.6 | 0.5 | 0.9 |
| 7 | 3.9 | 2.8 | 3.8 (+LA) | 5.2 |
| 2 | 2.9, 3.8 (+OA) | 2.3 | 2.1 (+LA) | 3.2 |
| 3a | 3.7 | 3.2 | / | 2.9 |
| 3b | 1.7, 3.4 (+OL) | 3 | / | 2.8, 3.4 (+LA) |
| 4 | 2.2, 2.8 (+OL) | 2 | / | 2.2 |
| 6 | 1.2, 2.2 (+OA) | 3 | 2.2 (+LA) | 1 |
| 5a | 1.4 | 4.3 | / | 1.2 |
| 5b | 1.3 | 2.5 | 1.6 | 1.1 |

Quarry Bay

| Point Location | Peak speed (m/s) | | | |
|---|---|---|---|---|
| | Train arriving (LA) | Train leaving (LL) | Opp train arriving (OA) | Opp train leaving (OL) |
| 1 | 6.6 | 1.7 | / | / |
| 2 | 6.2, 7.1 (+OA) | 2.8 | / | / |
| 3 (Exit opening) | 1.9 | 4.1 | / | / |
| 4 | 4.4 | 1.9 | / | / |
| 5 | 4.4 | 5.2 | / | / |
| 6 | 4 | 3.1 | / | / |
| 7 | 4.1 | 6 | 3 | 3 |
| 8 (Exit opening) | 4.9 | 5.9 | 7.1 | 3 |
| 9 | 2 | 3 | / | / |




*Diamond Hill Station – Open Plan Design*




*Quarry Bay Station – Confined Tubular Design*

**Fig. 1 Layout of MTR stations and positions of wind measurements**

**Diamond Hill – Pt.1a**
Overall Peak (Combined effect)
Local Train arriving and Opposite Train Leaving (LA + OA)

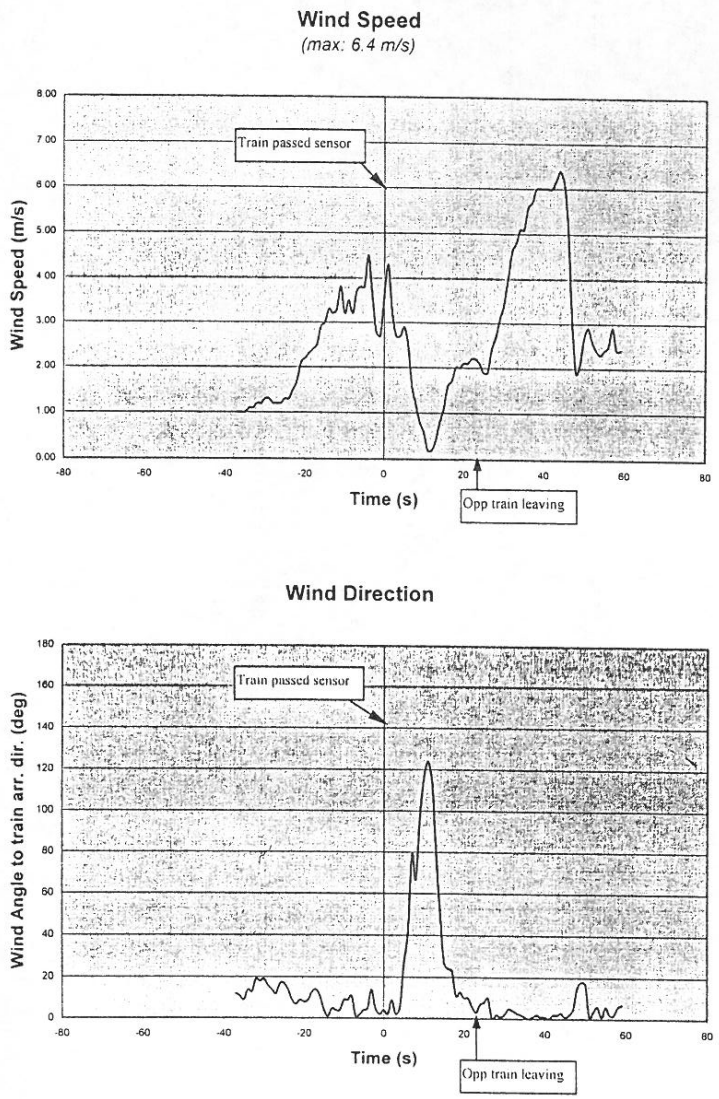



**Fig. 2 Wind record taken at Diamond Hill station**

**Quarry Bay pt.8 OA**

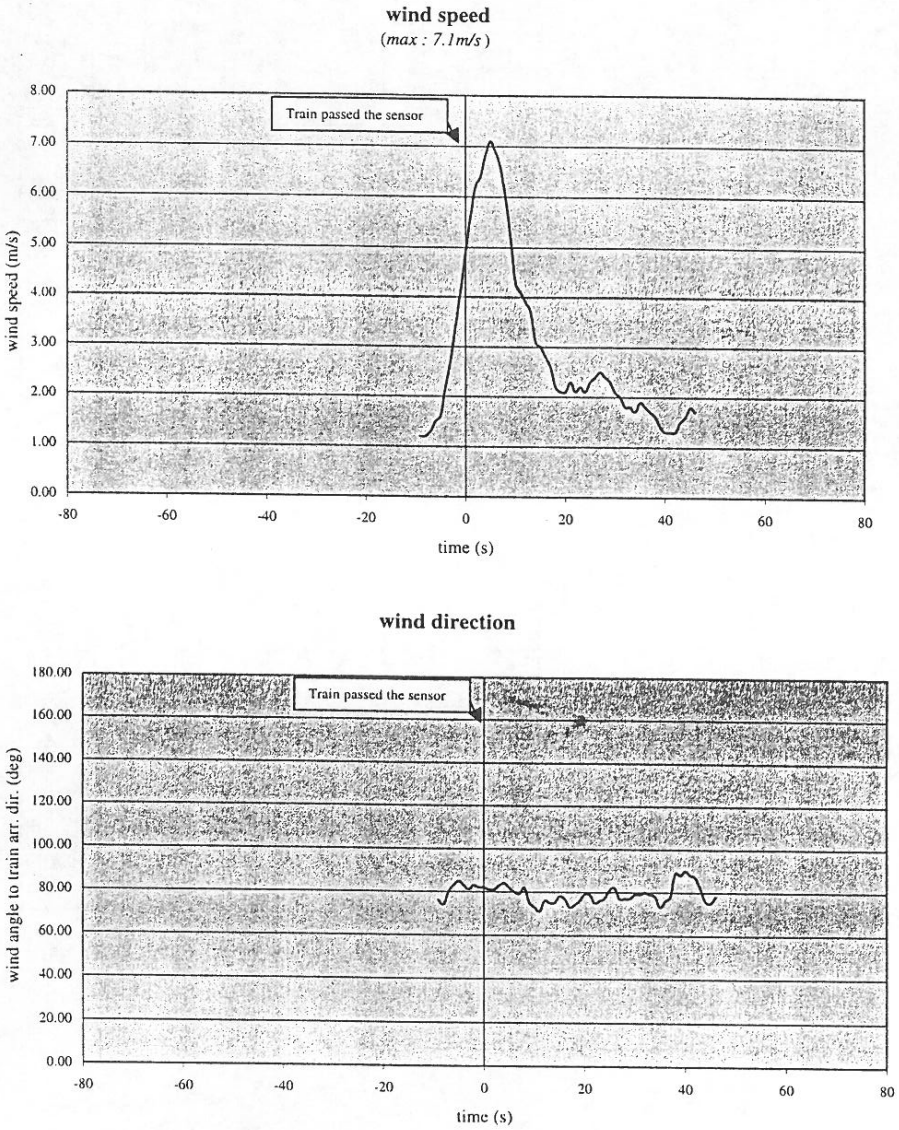



**Fig. 3 Wind record taken at Quarry Bay station**