BAFFLES AS A MEANS OF STATION PROTECTION FROM HIGH AIR VELOCITIES - COMPARISON OF ANALYTICAL AND FIELD MEASUREMENTS RESULTS

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ABSTRACT

Draught relief shafts at certain distance from an underground station are used as a means to relieve pressure waves and to control air velocities at the platforms. Shafts location is usually spaced based on the information on train speed, breaking distance and geometry. As in most cases shafts determine the station limits, their location is a critical factor for project costs. Shafts located adjacent to the platform ends can substantially reduce the project costs however special attention shall be given to their effectiveness to control platform air velocities. Baffles were tested and proved as a means to direct air to improve draught relief shafts effectiveness. Field measurement results of air velocity at the platform and in the draught relief shaft were compared against the analytical and CFD approaches for the Beacon Hill light rail tunnel and station in Seattle and proved the design approach.

Keywords: baffles, platform air velocities, draught relief shaft

1. INTRODUCTION

National and international guidelines require the installation of draught relief shafts at certain distance from an underground station for effective reduction of pressure waves and air velocities at the platforms for passenger’s comfort. Air velocities at the platform should not exceed 5 m/s for comfort and safety. The maximum airflow from tunnel to station depends on ratio of tunnel air velocity to train speed and resistances to airflow.

Geological conditions of the Beacon Hill Light Rail Station did not allow for draught relief shaft location at a typically acceptable distance (20 m – 90 m) from the station ends. Shafts had to be constructed as close as 4.5 m from the end of the platform of the Beacon Hill station. A short length of tunnel between the draught (blast) relief shaft and the station headwall is used for baffle installation to increase the overall impedance and to direct tunnel air into the draught relief shafts. Based on the result of studies and analysis, baffles were designed and installed in Beacon Hill tunnel (Seattle) between the station headwall and draught relief shafts. (1)

While analytical calculations and results of CFD analysis showed that the proposed solution can reduce platform air velocities to meet the comfort requirements, there was no practical evidence, and field measurements and verifications were required. A set of tests with running trains was performed in June 2009 to validate the design solution.

2. BAFFLE PLATES AS A MEANS TO IMPROVE EFFICIENCY OF THE DRAUGHT RELIEF SHAFTS

Design calculations and CFD analysis showed the problems with platform air velocities which will exceed the comfort level of 5 m/s when trains will pass the station at 64 km/hr if the draught relief shafts will be constructed as close as 4.5 m from the platform ends with no baffles. However pressure changes (pressure transients) will be insignificant due to the relatively slow train speeds.
Baffles were proposed at the draught relief chamber area to reduce platform air velocities. Baffle plates are good for both – reduction of station air velocity and reduction of pressure waves. They also reduce steepening of the pressure waves. (2) The ability to use baffle plates is usually constrained by the size of an existing tunnel since plates will reduce the available tunnel cross-section area locally. The remaining tunnel area must allow for sufficient space for the train vehicle dynamic envelope, catenaries equipment, fire standpipe and walkway.

We designed and installed baffle plates (orifice plates) spaced at a distance of 2.5 m along the draught relief chamber of the Beacon Hill station. Plates have been constructed as part of the tunnel wall designed to constrict the flow locally and provide friction losses increasing the overall impedance to the tunnel airflow in the draught relief chamber. Design includes an extension of the platform tunnel in order to create a draught relief chamber which shall accommodate a track damper and baffles (Fig. 1). Baffles were installed in the inbound tunnels damper chamber only. In the outbound damper chamber baffles may create additional pressure to the airflow for further escape, which reduces the effectiveness of the overall station pressure reduction, and thus were not installed.

Fig. 1: Baffles as installed in the Beacon Hill Tunnel in Seattle, WA (looking from the tunnel)

Due to baffles, tunnel airflow faces a set of sudden expansions and contractions in the draft relief chamber. This leads to increased pressure losses and eventually to direction of airflow into the draught relief ventilation shaft. Increased tunnel area will locally reduce tunnel air velocity, while plates will increase turbulence, creating secondary airflows behind them and leading to increased pressure drops. The platform headwall will serve dual purpose. First, it will serve as the last barrier (resistance) to airflow before the station. It shall protect platform adjacent to the headwall from high air velocities. Second, it serves as an architectural and security feature that will hide the track dampers, baffles, and fire equipment from public. The platform headwall will create local increase of air velocity, however the resistance it creates to the airflow will eventually reduce average airflow through the station and hence platform air velocities. Figure 2 shows results of CFD analysis and complicated aerodynamics in the draught relief chamber with lots of turbulence caused by the baffles.

However there was no practical evidence and field measurements to support the CFD analysis results and design decisions, and field verifications were required. A set of tests with running trains was performed in June 2009 to validate the design solution.
3. FIELD TESTS

Air velocity measurements were taken at the northbound platform and in the draught relief shaft simultaneously. Trains in southbound track were operating at low frequency. We established communication with train operators during the tests in order to control their operation and speed.

Two sets of tests were made:

- With trains operating as scheduled decelerating from 64 km/hr to 24 km/hr before entering the station and stopping at the Beacon Hill station (northbound platform)
- With trains passing through the station at 64 km/hr with no stopping at the station

Air velocity measurements were taken at the following locations:

- At the northbound platform east end at approximately 0.6 m from the edge of the platform at the height of 1.7 m from the top of platform and approximately 8 m from the platform headwall.
- In the east horizontal part of the draught relief shaft between the track damper and the vertical shaft.

Additional measurements were taken in the center of the platform and at the central concourse doors openings to verify the chosen locations. At the center of the platform the maximum air velocity were measured of 1.5 m/s, which confirmed that the location initially chosen represented the highest platform air velocity readings. Air velocity at the central concourse door openings showed the highest reading of 2.5 m/s, which is also well below the criteria of 5 m/s. It should be noted that measurements were taken while construction was still on-going at the central concourse and field conditions do not exactly represent the station operating conditions.
For air velocity measurements we used ADM 870C and ADM 870 with VeloGrid. The “speed read” mode allows registering air velocities at the intervals not exceeding two seconds.

Data was recorded as follows:
- Maximum air velocities in the vent adit
- Air velocities at the vent shaft when train passes the track damper
- Additional measurements as noted
- Tests were video recorded (Fig. 3).

**Fig. 3:** Measurements taken at the platform of Beacon Hill Station (1FP = 1fpm = 0.005 m/s)

It shall be noted that trains entering opposite platform impacted measurement results. Also trains started braking (slowing) at different distance from the station, which impacted the results as well.

### 4. FIELD MEASUREMENTS RESULTS

Air velocity measurements history on Fig. 4 shows that platform air velocities are less than 5 m/s with the exception of two cases when trains passed the station at 64 km/hr with no stopping at the station.

**Fig. 4:** Air Velocity readings at the platform with operation of 14 trains
CFD analysis results were compared against the field measurements. The broken curve on Fig 5 shows CFD predictions of platform air velocities with NO baffles. Those velocities could reach 5 m/s. The solid curve shows CFD predicted platform air velocities at the platforms with baffles, which are significantly lower. Platform air velocities measurements represented by points show reasonably good correlation with CFD predicted velocities, which are in the range of 3 m/s and less. Platform air velocities were always measured less than 5 m/s with trains operating as scheduled by decelerating from 64 km/hr to 24 km/hr before entering the station and stopping.

![Fig. 5: Comparison of CFD analysis results against the field measurements when trains stop at the station](image)

Fig. 6 represents platform air velocities when trains pass through the station at 64 km/hr with no stopping at the station. In this case, the actual maximum platform air velocities represented by bars slightly (by 9%) exceed 5 m/s for a few seconds. The broken curve on Fig 5 shows CFD predictions of platform air velocities with NO baffles. Those velocities could reach 8 m/s. The solid curve shows CFD predicted platform air velocities at the platforms with baffles, which are lower than measured. However velocities could be much higher exceeding the comfort level by over 50% if baffles were not installed. The peak platform air velocities are shown on Fig. 7. Three tests were performed when trains did not stop at the station. These testes demonstrated the effectiveness of baffles in reduction of platform air velocities.
Platform Air Velocity when Trains Do Not Stop at The Station

Fig. 6: Comparison of CFD analysis results against the field measurements when trains do NOT stop at the station

Fig. 7: Peak platform air velocities

Comparison of CFD analysis results against the field measurements when trains do NOT stop at the station. V max at the platforms – maximum gust air velocity registered at the measurement locations for a few seconds.

Simultaneously, measurements were taken in the draft relief shaft and presented on Fig. 8 and 9. The draught relief shaft has cross section area of 23 – 26 m². Maximum air velocities in the draught relief shaft vary from 1 to 2.4 m/s. Measurements were compared against the CFD analysis. Fig 8 indicates that while CFD slightly over predicted air velocities in the draught relief shaft with baffles, the obvious benefits of baffles was proven. Resultant air velocity measurements over time are shown on 9.
Fig 8: Comparison of CFD results against measurements in draught relief shaft

Fig 9: Air velocities in the draught relief shaft – measurements results when trains do not stop
5. CONCLUSIONS

Air velocity measurements confirmed the effectiveness of the baffles design and verified that gust air velocities at the Beacon Hill station were within the comfort level when trains operate in accordance with the schedule at 64 km/hr and stop at the station.

Higher gust air velocities were registered when trains do not stop at the station. Under those circumstances gust air velocities may exceed 5 m/s. However they do not exceed by more than 7% for a few seconds which should not create any problems for patrons at the platform.

Draught relief shaft relieves significant amount of air and effectively control air velocity at the platform. Baffles design is effective for protection of station from pressure waves and high air velocities when draught relief shafts are close to platform ends.

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