Airflow modeling analysis of the Athens airport train station

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Abstract

The present work aims to investigate the maximum CO distribution in the Athens-Greece airport train station platform for long-term exposure. A model based on the numerical solution of the three-dimensional flow field of the Athens-Greece airport train station was developed for this reason The work was performed using the CFD package called *FLOVENT*® V3.2.

The initial study of the CO level at the train station was performed without mechanical ventilation at the train station platform. Three different cases were examined by varying the wind magnitude and direction. Subsequently, four extra scenarios were examined with and without mechanical ventilation. The results obtained from the scenario with mechanical ventilation were compared to the ones from the scenario without mechanical ventilation. In all the above cases, the CO emissions from the vehicles in the two nearby highways were also taken into account. It is concluded that the maximum CO level in the case with mechanical ventilation is higher than in the case without. This is due to recirculation zones that create locally high levels of CO in the platform area. On the other hand, the average level of CO is lower at the platform with the ventilation on.
Keywords: emissions level, mechanical ventilation, numerical prediction.

1 Introduction

A study undertaken to investigate the CO levels in the Athens-Greece Airport train station platform is presented in the present article. Several external wind conditions will be studied and these will be compared to cases with mechanical

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ventilation at the train station platform. The work was performed using the Computational Fluid Dynamics tool called FLO*VENT*® V3.2.

The primary objective of the study is to determine the CO levels on the train station platform under different external wind conditions. The CO level should not exceed 25 ppm for long term exposure (i.e. 8 hrs), per World Health Organization Recommendations, [1].

2 Model description and results

Airflow and heat transfer within a fluid are governed by the principles of conservation of mass, momentum and thermal energy. These conservation laws may be expressed in terms of partial differential equations, the solution of which forms the basis of computational fluid dynamics (CFD).

The finite volume based approach was used, requiring the region modelled to be sub-divided into a number of small volumes or grid cells. During the program solution, the developed CFD model integrates the relevant differential conservation equations [2] over each computational grid cell, assembling a set of algebraic equations which relate the value of the variable in a cell to the value in adjacent cells. Since the equations display strong coupling (variables are dependant upon surrounding values and other variables) the solution is carried out iteratively.

2.1 Baseline cases

2.1.1 Model assumptions

The following assumptions were done in the present study:

- The wind speed is 15 m/s from the North direction. A velocity profile was applied at the North face of the solution domain, which varied from 1 m/s at ground to 15 m/s at 10 m. This is based upon local meteorological data. Additional Iterations were performed with different wind speeds and directions. See Table 1.
- Ambient temperature is 32 C.
- Total CO release rate is 1.9E-3 kg/s.
- 400 cars are releasing CO at a rate 2.61g/mile.
- The CO source was uniformly distributed along the roadways.
- Small items, which do not affect the general airflow patterns, were not included in the model.
- Thermal loading from lights, people, trains, etc, were considered insignificant and were not included.
- The CFD solution domain size is 350m x 350m x 50m with 801,248 grid cells. The maximum aspect ration is 15.6.
- The model was solved on a system with dual 2.4 GHz CPUs and 2.0 G RAM. The model solved in approximately 550 iterations and in 5.1 hours.

2.1.2 Model geometry

The model geometry and boundary conditions are shown in the following figure.

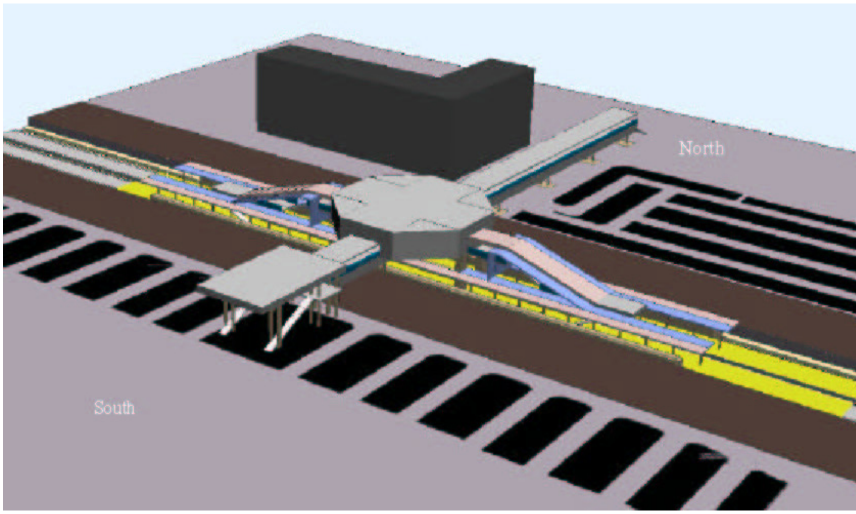

Figure 1: Isometric view of the Athens-Greece train station (viewing in the North West direction).

2.1.3 Baseline results

The CO levels along the train platform are well below the limit of 25 ppm. The maximum level in the platform area is 0.5 ppm. The following figures show the airflow patterns around the train station and CO level plots with an external wind speed of 15 m/s from the North.

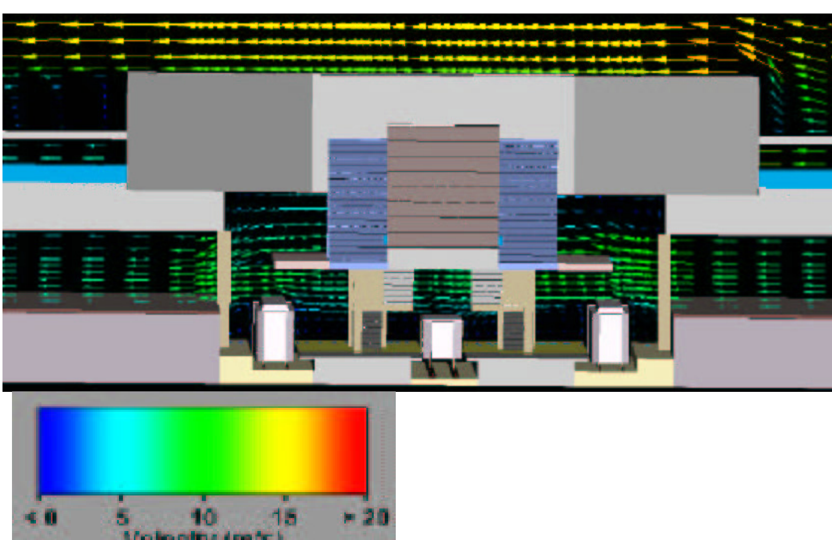

Figure 2: Airflow velocity plot through the center of the building (viewing in the West direction).

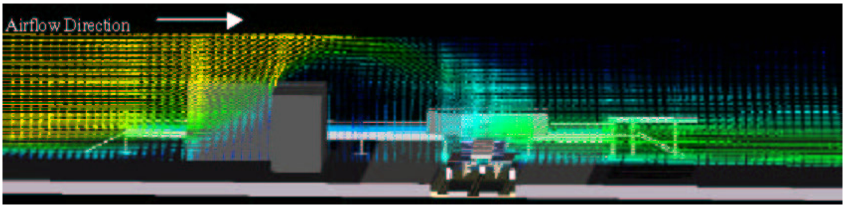

Figure 3: Airflow velocity plot across the Hotel (viewing in the East direction).

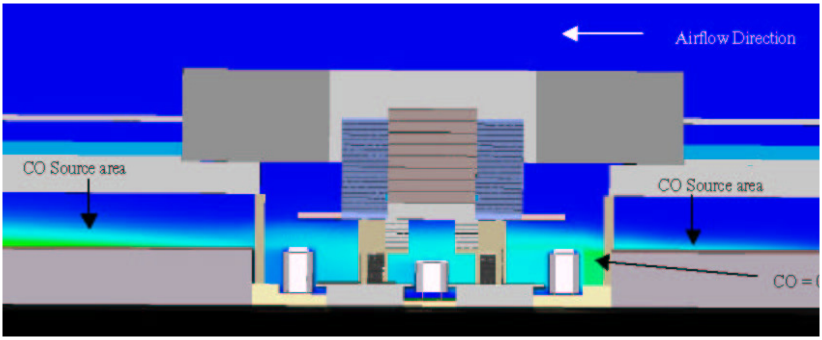

Figure 4: CO plot through the center of the building showing the platform area. The maximum platform CO level is 0.2 ppm.

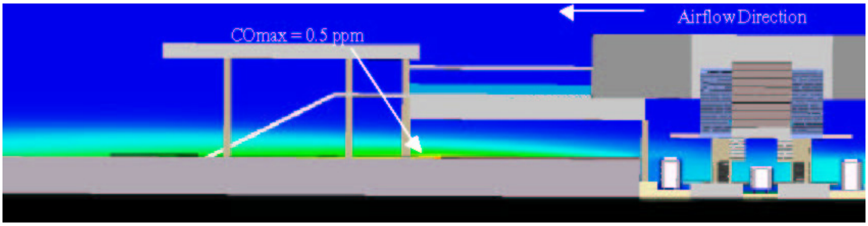

Figure 5: CO plot through the center of the building. The maximum CO level is 0.5 ppm along the ground below the Southern walkway.

2.1.4 Baseline case with different external conditions

Three additional Iterations were studied and compared to the Baseline results to determine the affect on the CO levels at the train station platform. The results are summarized in the following Table.

In all cases analyzed, the maximum CO levels are outside of the train platform area and are well below the limit of 25 ppm. The location of the maximum CO varies depending upon the wind direction. The CO levels along the train platform are, also, well below the limit (more than 5 times lower than the limit of 25 ppm).

Table 1: Summary of CO levels with different wind conditions.

Case	**Summary of Results**		*COmax (ppm)*
		COmax (ppm)	*above the platform*
Baseline	15 m/s North direction	0.5	0.2
Iteration 1	15 m/s West direction	1.1	0.15
Iteration 2	1 m/s West direction	16.5	2.2
Iteration 3	1 m/s North direction	7.9	2.8

The following CO plots show the results of the Baseline and Iteration 1–3. The plots are 2 m above the train station platform.

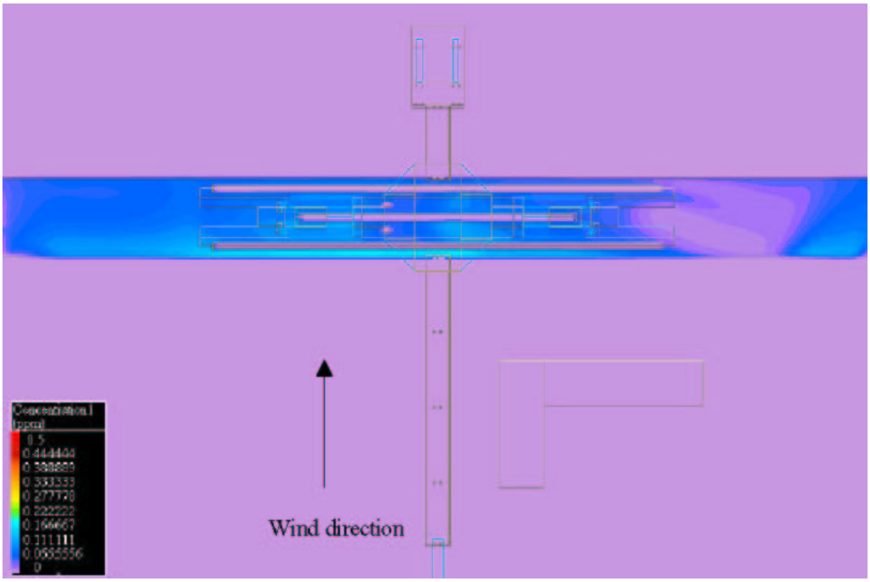

Figure 6: CO plot at 2 m height from the platform. North wind direction at 15 m/s. The maximum CO level on this plane is 0.2 ppm.

2.2 Mechanical venting case

2.2.1 Model assumptions

- The wind speed is 1 m/s from the North direction. A velocity profile was applied at the North face of the solution domain, which varied from 0.1 m/s at ground to 1 m/s at 10 m.
- Ambient temperature is 32 °C.
- Total CO release rate is 1.9E-3 kg/s.

- 400 cars are releasing CO at a rate 2.61 g/mile.
- The CO source was uniformly distributed along the roadways.
- Small items, which do not affect the general airflow patterns, were not included in the model.
- Thermal loading from lights, people, trains, etc, were considered insignificant and were not included.
- The CFD solution domain size is 350 m x 350 m x 50 m with 920,856 grid cells. The maximum aspect ration is 15.6.

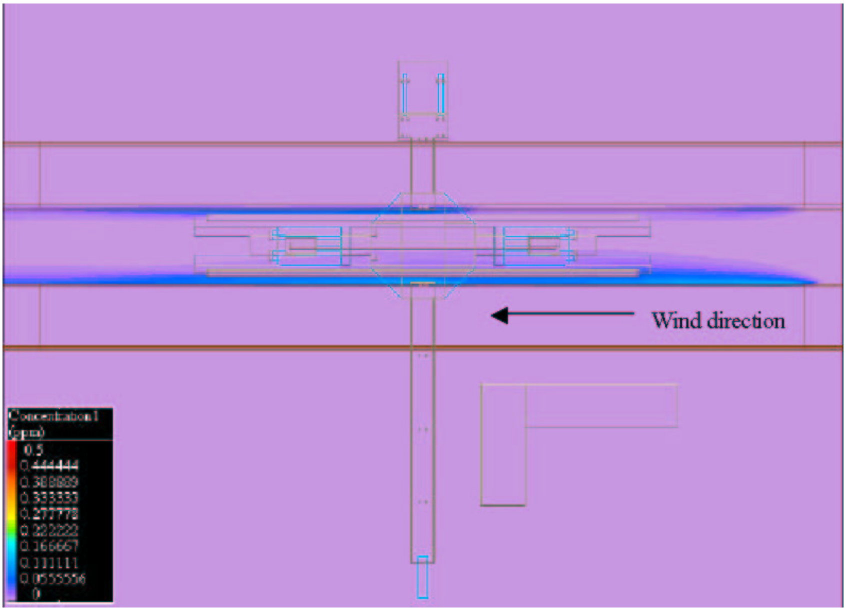

Figure 7: Iteration 1 - CO plot at 2 m height from the platform. West wind direction at 15 m/s. The maximum CO level on this plane is 0.15 ppm.

The model was solved on a system with dual 2.4 GHz CPUs and 2.0 G RAM. The model solved in approximately 750 iterations and in 8.2 hours.

2.2.2 Model geometry

The model geometry and Autocad drawings for the Mechanical Venting Case are shown in the figure 10.

Figures 11 and 12 compare the CO distribution along the train station platform with the same wind conditions with the venting on and off. The CO plot with venting on shows less dispersion of CO along the platform. There are regions where the CO levels are approximately 1.5 ppm without the venting and these are below 1 ppm when the venting is on. The following table shows the maximum CO levels for all cases analyzed.

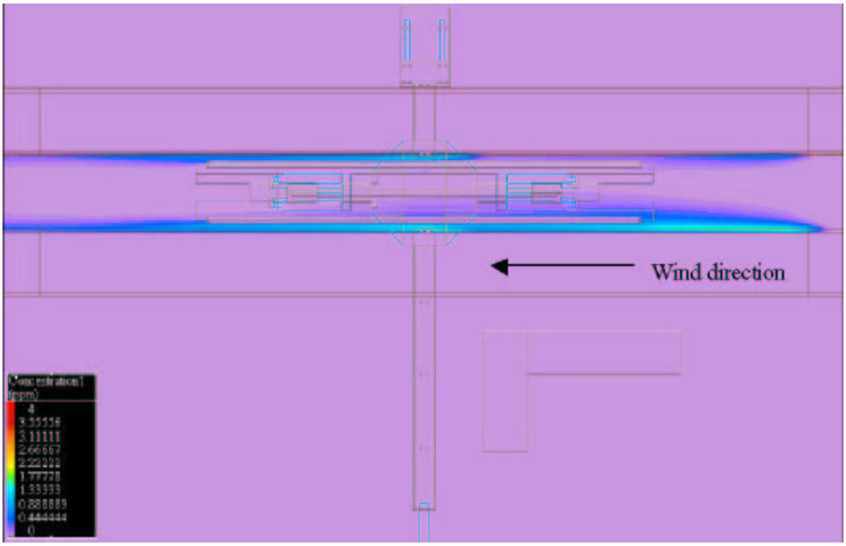

Figure 8: Iteration 2 - CO plot at 2 m height from the platform. West wind direction at 1 m/s. The maximum CO level on this plane is 2.2 ppm.

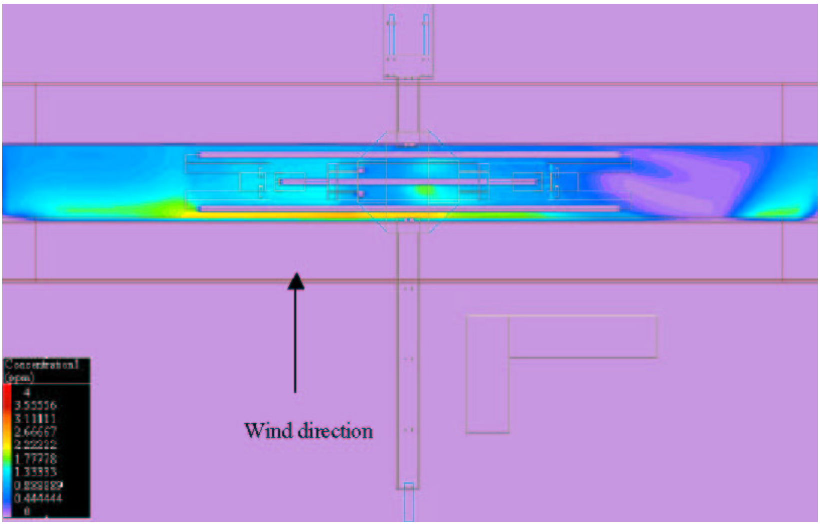

Figure 9: Iteration 3 - CO plot at 2 m height from the platform. North wind direction at 1 m/s. The maximum CO level on this plane is 2.8 ppm.

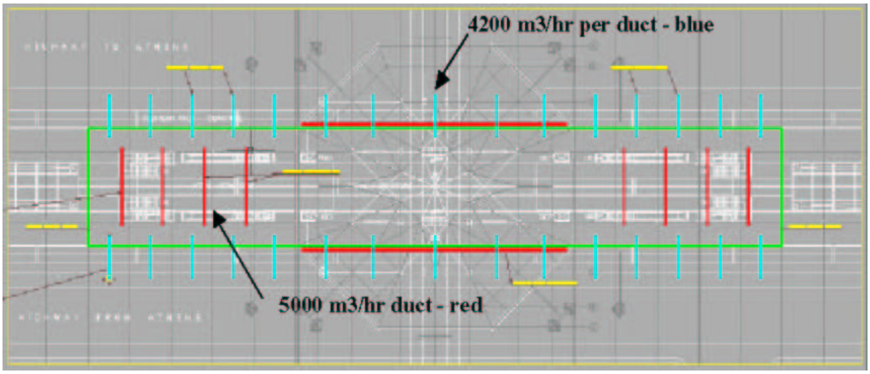

Figure 10: Plan view of the mechanical venting location and flow rates.

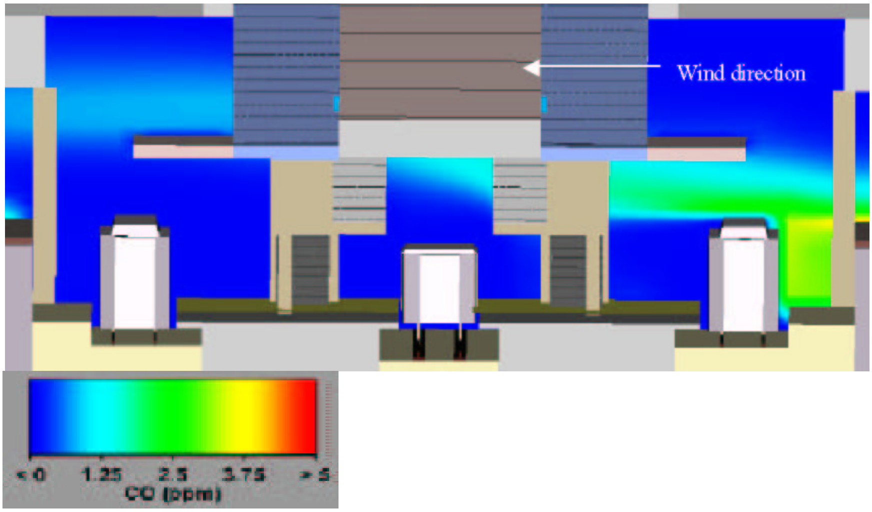

Figure 11: CO plot across the centreline on the platform with a 1 m/s North wind and mechanical venting.

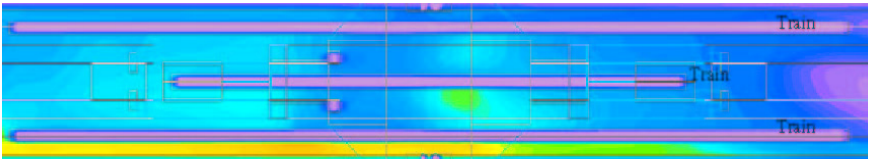

Figure 12: Plan view CO plot of Iteration 3 – 1 m/s North wind; no venting.

The maximum CO levels for scenario 4 are higher than a similar case (Scenario 3) without venting. This is due to recirculation zones in Scenario 4, which created increased levels of CO in the platform area. Overall, the average CO levels are less at the platform with the ventilation on.

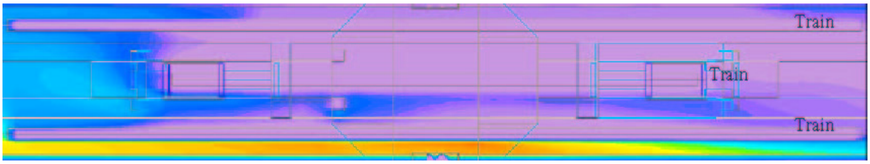

Figure 13: Plan view CO plot of Iteration 4 – 1 m/s North wind; with venting.

Table 2: Summary of CO levels with different wind conditions – all cases.

Case	**Summary of Results**	***COmax ppm)***	***COmax (ppm) above platform***
Baseline	15 m/s North direction off	0.5	0.2
Scenario 1	15 m/s West direction off	1.1	0.15
Scenario 2	1 m/s West direction off	16.5	2.2
Scenario 3	1 m/s North direction off	7.9	2.8
Scenario 4	1 m/s North direction on	9.7	3.4

3 Conclusions

Airflow modelling of the Athens-Greece Train Station was performed to determine the CO levels along the train platform. The CO levels from the baseline model and four simulation scenarios are well below the 25 ppm limit, that is the upper limit for long-term exposure (i.e. 8 hrs) as per World Health Organization Recommendations. These simulations included different wind speeds and direction, as well as, one Scenario with mechanical ventilation. The average CO levels at the platform with the ventilation on have decreased when compared to a similar case without ventilation under the same external wind conditions.

Acknowledgement

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References

[1] Krarti and Ayari, "Overview of Existing Regulations for Ventilation Requirements of Enclosed Vehicular Parking Facilities", ASHRAE paper 4274 (RP-945), 1999, **105**, page 6.

[2] Patankar, S V, "Numerical Heat Transfer and Fluid Flow", Hemisphere Publishing Corporation.

[3] Weather forecast data from the Athens airport whether forecast station.

[4] Weather forecast data from the central Athens whether forecast station.