Simulation of a Subway Environment for Evaluation of the Thermal Comfort

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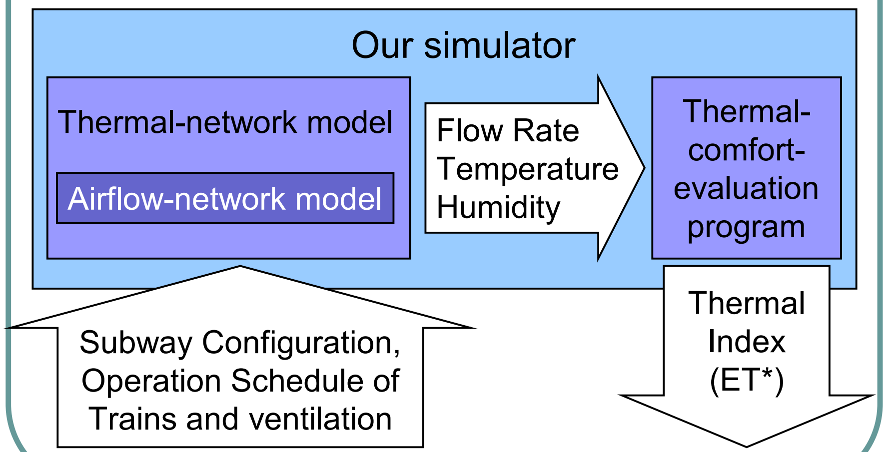
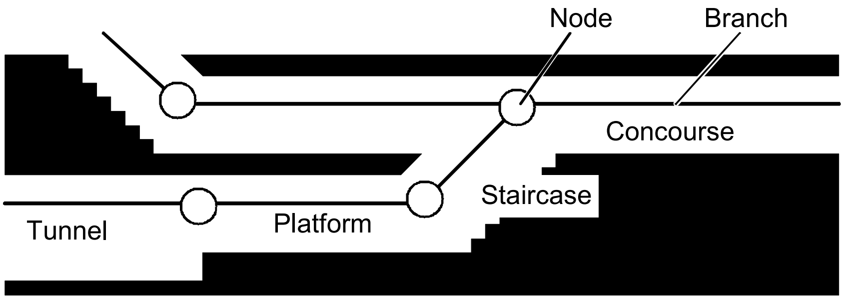
Introduction

- Simulators for subway environments have advanced since 1970s
- Highly advanced simulators are too complicated for application to various fields (comfort, sanitation, cost, etc.)
- We developed a simple simulator for thermal comfort

Outline of our simulator

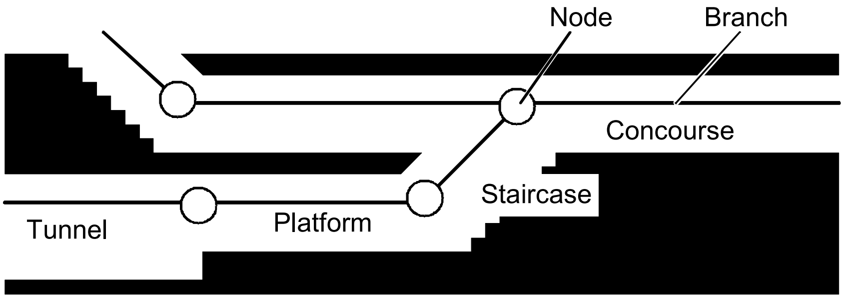


Airflow-network model



- Airflow-network is a set of branches
- Branches represent tunnels, platforms, staircases, etc.

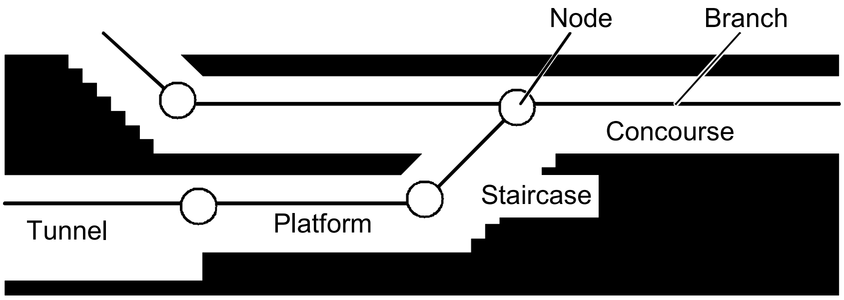
Airflow-network model



- Airflow rate in each branch is predicted by

$$M\frac{dq}{dt} = -R\,q|q| + A(\Delta P_1 + \Delta P_2)$$

Thermal-network model



- Temperature in each node is predicted by

$$\rho c_p V \frac{d\theta}{dt} = Q_{load} + \sum_{\text{inflow}} \rho c_p q\theta + \sum_{\text{outflow}} \rho c_p q\theta$$

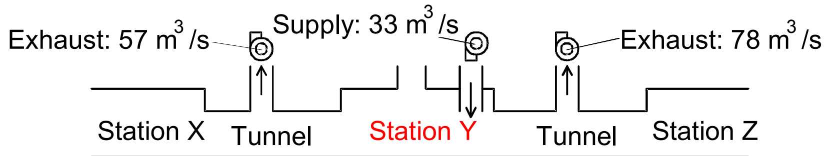
Thermal comfort evaluation

- Thermal index ET* (Gagge et. Al. 1971) indicates thermal comfort quantitatively.
- ET* is the solution of the heat balance equation:

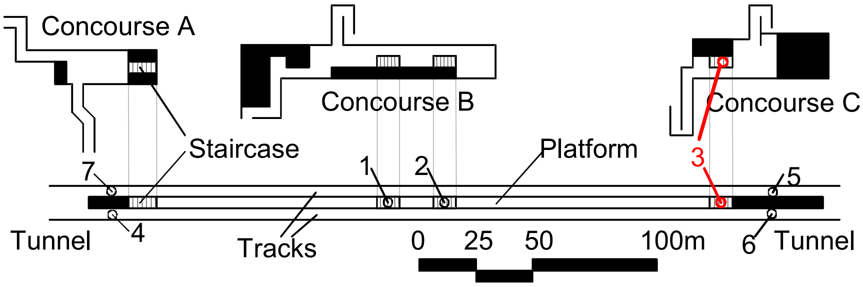
$$H_{sk} - h(T_{sk} - ET^*)F_{cl} - 2.2wh_c(P_{sk} - 0.5P_{ET^*})F_{pcl} = 0$$

- ET* = 22.2 ~ 25.6℃ is comfortable (ASHRAE STANDARD 55-74)

Study on an actual subway station

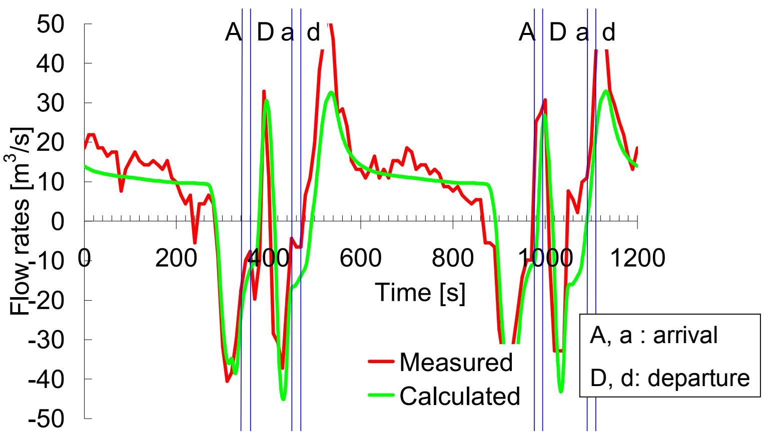


Subway System (Nov. 11th, 1989)



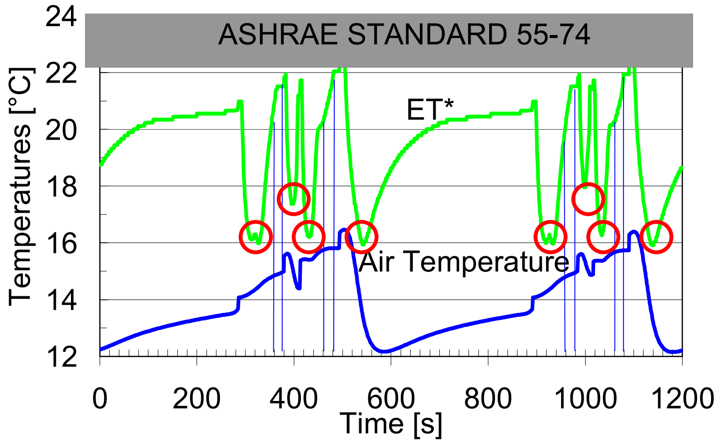
Plan of the actual subway station Y

Validation of the airflow network



Flow rates at staircase 3 (Nov. 11th, 1989)

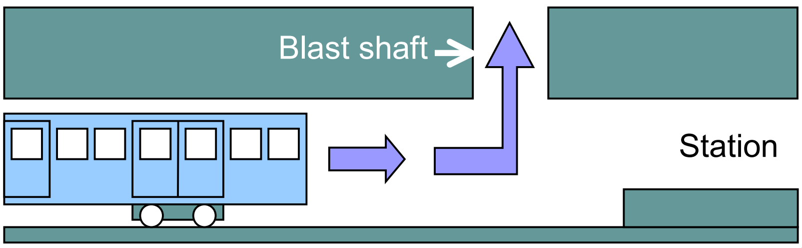
Evaluation of thermal comfort



Assumed commuter's ET* at staircase 3

An idea to maintain thermal comfort

- Airflow due to the train operation (train wind) causes severe decrease in ET*
- Adding blast shaft will prevent the train wind



Conclusion

- A simple simulator was developed for evaluating thermal comfort
- Airflow calculation by the simulator was validated
- Prevention of train wind is necessary to maintain thermal comfort