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Thermal comfort conditions at the platforms of the Athens Metro

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Abstract

The current study aims at the comparison of the field measurements at the platforms of the Athens Metro with those recommended by international standard thermal comfort and to the investigation of the relationship of environmental parameters between platforms and the outdoor space. The levels of air, operative and globe temperature as well as air humidity and air velocity were continuously monitored at the platform space of two stations with different depth and design features in summer. The predicted mean vote (PMV) model and the predicted percentage of dissatisfied (*PPD*) index were used. The results reveal that the operative temperature at both stations is far from the traditional still-air comfort zones. For the case of elevated air movement of 1.2 ms^{-1} and considering the occupants have local control of air speed, 20.3% of the values at the station with the greatest depth do not exceed the upper limit. Furthermore, 64% of the variation in air temperature at the platform of the station with the smallest depth is explained by outdoor air temperature, while the corresponding percentage for the station with the greatest depth is 29%. Passengers experience sudden change of air temperature and *PMV*, especially at the station with the smallest depth, during their transition from the platform to the interior of air-conditioned train carriages and vice versa.

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Keywords: Human exposure; subway platforms; passengers' thermal comfort

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1. Introductory remarks

The strong majority of the research studies concerning the underground urban transport are mainly focused on the air quality issues inside and outside the railing network [1-8]. However, since it is suitable for the carriage of high

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passenger flows, the prevailing thermal conditions both inside the trains and on the platforms is of importance for the passengers' thermal comfort.

The international standards literature for thermal comfort classes are based on *PMV* and *PPD* indices [9,10]. Ampofo et al. [11] worked on the definition of acceptable criteria for thermal comfort in the subway. This study demonstrated that *PPD* values up to 50% can be considered as acceptable for a typical subway environment [11]. This happens because in rapid transit systems passengers spend a relatively short period of time unlike in other cases [11].

A recent field study in the interior of train coaches of Athens Metro showed that during the warm period the thermal regime within air-conditioned cabins is "slightly warm" while within mechanical ventilation cabins it is "warm" [12]. In the Seoul field study it was found that there was a weak linear correlation between the number of passengers and the train cabin air temperature in rush hours [7].

Similar performance was identified for the Budapest Metro stations, the *PMV* ranged between -1.4 and 0 in winter in the passenger areas, suggesting "slightly cool" or "cool" thermal environment, while in summer, the *PMV* ranged from 0 to +1.4, indicating "slightly warm" thermal environment [13]. Other relevant work referring to Tehran, Shanghai and Seoul experimental campaigns showed interesting findings the details of which can be found in the international literature [14-16]. More details concerning the Athens Metro cabin measurements can be found elsewhere together with the description of the experimental campaign methodology and the instrumentation details [12].

The present study aims to compare the field measurements of air temperature, operative temperature and vapour pressure on platforms with those recommended by international standards for thermal comfort, between two subway stations of Athens Metro, with different depth and design features, in summer. The *PMV* levels were also compared with the recommended thermal comfort classes. Furthermore, the relationship of air temperature and relative humidity between platform space and outdoor environment was investigated. Finally, the diurnal differences of thermal conditions between the platform and the air-conditioned carriage of the train that just have arrived at the platform were studied.

The experimental data were collected from two stations of Line 3, Doukissis Plakentias and Syntagma. The metro station at Syntagma is approximately 200 m below ground and it has four underground levels, while the platforms of Line 3 are situated at the fourth sub-level. Due to its depth the station acts as a zero-identity "black hole" in relation to the urban environment [17]. It is one of the busiest stations of the Athens Metro since it is located in the centre of Athens and it is an interchange station between Lines 2 and 3 of the network, while it is a transportation hub for the buses and the tram.

The metro station at Doukissis Plakentias is approximately 50 m below ground and it has two sub-levels. The Line 3 platforms are located at the second underground level. Furthermore, in a distance of about 1 km after the station Line 3 emerges at the surface.

The ventilation system at the platform and passenger areas provide fresh air from the outdoor environment under normal operation conditions, while in the case of emergency it extracts smoke as well.

Standards ISO-7730 [10] and ASHRAE-55 [9] propose PMV model and the indices *PMV* and *PPD* so that to predict the degree of discomfort and the thermal sensation of individuals exposed to a moderate indoor thermal regime. This model uses the heat exchange theory in order to associate four physical variables. In the present case the air and the mean radiant temperature, the air humidity, the air velocity and two other personal variables, i.e. metabolic rate and clothing insulation was used. The 7-point thermal sensation scale, i.e. +3 = hot; +2 = warm; +1 = slightly warm; 0 = neutral; -1 = slightly cool; -2 = cool; -3 = cold, is also employed.

The clothing insulation was estimated at 0.5 clo, while the average metabolic rate for the passengers was selected to be 70 Wm^{-2}.

Mean radiant temperature was computed using the globe temperature by employing the formula [18]:

$$t_r = \left[\left(t_g + 273\right)^4 + \frac{1.10 \times 10^8 V_a^{0.6}}{\varepsilon D^{0.4}} \left(t_g - T_{air}\right) \right]^{1/4} - 273 \qquad (1)$$