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VALIDATION OF A THERMAL COMFORT INDEX FOR PUBLIC OUTSPACES

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ABSTRACT *The thermal feeling of comfort is difficult to evaluate, particularly in urban public spaces because of the complexity of their urban components and of the environmental parameters. Our research aims to avoid to this difficulty by qualifying thermal comfort in urban outspace, through the formalisation of a suitable comfort index. The objective is to quantify comfort for an environment where the individuals thermal feelings depend on the climatic conditions. This last point leads also to the appropriation of space by the users. An approach, validated for closed enclosures by Fanger, P.O. and his research team, succeeded in determining the " Predicted Mean Vote " (PMV). Our paper suggests to determine environmental conditions, which will make it possible to validate an index, equivalent to the PMV, used to evaluate the thermal comfort of urban outspaces.*

1 Introduction

The majority of the models developed for the qualification of the physiological comfort of the individual are related to interior spaces. A study allowing to estimate the external comfort would be useful to establish a suitable model.

As for interior spaces, the formalisation of a physical indicator of thermal comfort in outdoor spaces will use various environmental parameters. In urban spaces, these parameters are subject to several modifications due to the fluctuating environmental conditions. Therefore, the quantification of comfort requires, the knowledge of the environmental disparities which influence these parameters, and their distinction from those of indoor spaces.

The PMV (Predicted Mean Vote) is one of the most performing models for the evaluation of the comfort in interior spaces. Established by Fanger and its research team, it makes it possible to evaluate moderate thermal environments. The question of its application in the outside space was hardly tackled (*Berger/1998*). This problem could be set in term of qualitative characterisation of the individual comfort in an urban environment subject to various climatic constraints, and to lead to an external thermal indicator an "outdoor PMV": (PMVe).

The recourse to a " PMVe " is oriented towards the study of the environmental factors. However, the environmental complexity of the urban space involves more difficult physical factors to manage, and makes more delicate the quantification of thermal comfort. The determination of environmental conditions for the application of the Fanger’s index is then necessary in order to adapt a specific model for outspaces.

2 Predicted Mean Vote: comfort index for outspaces

The PMV allows to evaluate the thermal comfort of a closed enclosure. Its calculation requires the knowledge of six basic parameters: air temperature (T_a), radiant temperature (T_g), air velocity (V_a) and relative humidity (H_r), as well as the activity level of people expressed in Met and the clothing given in Clo (*Fanger/1987*).

To characterise comfort, Fanger used a scale describing the individual physiological feelings noted from -3 to +3. On this scale, a comfort situation is obtained for: -0,5 < PMV < 0,5. Apart from the limits of this scale, the PMV is not compatible with individual comfort evaluation. (*Olesen/1982*). This compatibility corresponds to environmental limits for which $10<T_a<30$°C, 30<Hr<70%, $0<V_a<1$m/s and $10 <T_g< 35$°C (*LSI/1997*).

3 Thermal comfort in outspaces

The application of Fanger’s scale in external environments imposes physical conditions integrating the space in a moderate environment where the limits of the PMV are respected.

We know that the feelings and the reactions of an individual in a given space are based on physiological needs characterising homeothermy. These needs return to the requirements of an adequate acclimatisation in an environment defined by various physical factors.

From a perceptive point of view, whatever the environment is, indoor or outdoor, the individual can express thermal answers related to equivalent physical parameters. Its physiological reactions depend, in the same way, on comfort conditions corresponding to various requests like the nature of environment.

Thus, the use of a thermal feelings indicator in outdoor spaces points back to the study of the individual physiological comfort, in an environment with various structural and conjectural components different from those of a closed room. The complexity of the urban space imposes physical constraints that incite to the recourse to the census of environmental conditions in favour of the possibilities of applying a model equivalent to Fanger's one.

4 Validation of a comfort index in the outdoor space: the " outdoor PMV " (PMVe)

The use of the " PMVe " in the urban space requires the study of the possibilities to put it into application. We emit the hypothesis that the transposition of the PMV in these spaces would be possible only if they offer environmental conditions equivalent to those of moderate indoor environment.

By now, we can compare the outside space to a closed enclosure whose principal walls are ground, buildings and the sky vault. These walls are certainly less concrete than a closed room, but they show all thermals characteristics of surfaces included in the energy exchanges and hygrothermic comfort.

4.1 The physical approach of comfort between outdoor and indoor spaces

We can talk about the comfort only if the environment remains pleasant during a certain time linked to the activity level, to the clothing, and to the physical parameters intervening in each space. These parameters yield to different implications in comfort according to their intervention space.

- In indoor space: the principal external physical parameters intervening in the comfort feeling are the air temperature, moisture, the movements of the air, and the long wave radiation. The determination of the Fanger's model including these four parameters allows to quantify the comfort and the thermal environment with the individual adaptability.

- In outdoor space: the presence of the solar radiation distinguishes this environment from the indoor space especially in summer. The approach of comfort cannot ignore this component; it would probably change, at a significant degree, the evaluation of comfort in outdoors. Moreover, a variation remains distinctive in this space: the very fluctuating air velocity.

4.1.1 Effects of the solar radiation

Except the wind, the solar radiation is the more influencing parameter of external comfort, the individual looks for it in winter and tries to protect himself from it in summer.

It constitutes a significant component of the energy assessment. When the thermal radiation effect is blurred by the action of strong wind velocity, the solar radiation becomes the leading factor of the radiate assessment. Its presence, its nature and its intensity, depend of the state of the sky.

4.1.2 The influence of air velocity

Especially, in hot and dry atmospheres the wind has a strong ability for cooling. High wind velocities increase the convective exchanges, control the surface temperature and decrease the solar thermal load.

An air velocity beyond 4m/s accentuates these convective exchanges and disturbs all the other energy movements in the atmosphere. In this case the comfort is difficult to apprehend. However, airflows remain pleasant until the limit of 0,15m/s in winter, and 0,25m/s in summer (*Thellier/1989*).

4.2 Conditions for validating the "PMVe"

The application of a " PMVe " in outpaces will require compatible environmental conditions with those of the indoor spaces. They are conditions where the individual could have the same adaptation or defences to the offered climatic requests.

The presence of solar radiation and wind fluctuations makes the approach of outside comfort more complex. This aspect must be carefully tackled in order to find a possibility to evaluate their implication in the appreciation of comfort.

Thus, we will examine the conditions of wind velocity and state of the sky, in order to develop the favourable conditions to the formalisation of an outdoor comfort model.

4.2.1 Conditions of air velocity: weak or strong

The strong air velocity favours the convective exchange, make critical the air temperature, and put the other mode of exchange particularly the radiate exchange in second position. We emit the hypothesis that the velocity limit between weak wind and strong wind is 1m/s, which corresponds to the higher accepted limit for a moderate environment where the calculation of PMV is possible.

From a dynamic point of view, low wind velocity makes it possible to prevent thermal risks due to the aerodynamic fluctuations and to eliminate mechanical discomfort. Strong wind velocity place in foreground the discomfort caused by the mechanical embarrassment accentuated by the interaction of the urban forms with the winds flow. In this case, the discomfort due to the aerodynamic disturbances overrides the thermal comfort concerns.

4.2.2 Conditions of state of the sky: covered or clear

The sky in the atmosphere can be untrammelled or covered partially by a scattered distribution of clouds, or completely by an homogeneous layer. Its state participates to the formation of the atmosphere physical phenomena. It defines the level of illumination, the presence or the absence of direct solar radiation, and the homogeneity or heterogeneity of the heaven vault as an emissive surface. Thus, its nature guides heat exchange and modifies the values of air temperature and radiant solar intensity. Atmospheric variability results from this and orientates partly the microclimatic changes.

We are interested in the extreme states of the sky, in order to evaluate the adequate energy environment for the establishment of a thermal index.

4.2.2.1 covered sky

Taking into account a covered sky will reduce the fluctuation of solar radiation and thus the effect of the short wave radiation. Under these conditions, the illumination comes from the diffusion of direct energy by the layer of clouds. In a point on the ground, this illumination depends on the portion of sky that can be intercepted or seen taking into account the surrounding physical obstacles.

However, the direct solar radiation being not accessible in the closed enclosures, it’s not taken into account by the Fanger’s model. Therefore, the choice of a covered sky would be closed to the outdoor conditions by identifying the sky to a radiant ceiling.

4.2.2.2 clear Sky

Under conditions of clear sky, the solar radiation component prevails. The temperatures distribution in outspace follows the illumination and solar radiation distribution.

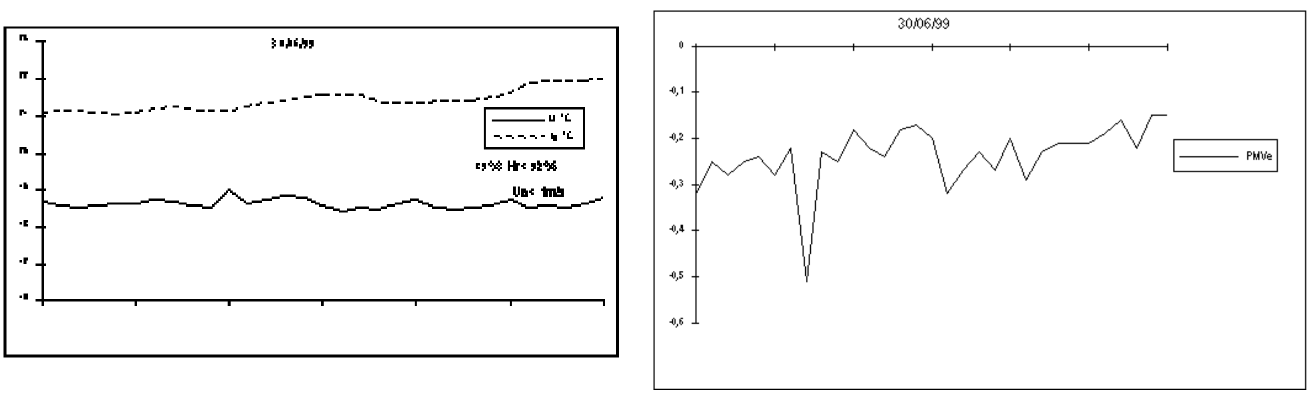
We carried out an experimentation that enabled us to lead to the appropriate conditions of sky and air velocity for the calculation of "PMVe".

4.3 Experimentation

In the established conditions, an experimentation was achieved. A calculation of PMVe results from using MICROCLIMATsoftware [1]. It makes it possible to calculate standardised comfort indices starting from the physical values of parameters depending on the environment and on the individual. The experimentations have been carried out during a hot period in an external space, for a man of average age, with light summer clothing resistance of 0,50 clo and activity level of 2 met which corresponds to activity of walking on ground level with 3,2 km/h. The environmental factors were obtained with measurement done by a portative weather station[2]. The measurements include sequences of measures of half an hour with a step of one minute. The results are given in the following graphs:

4.3.1 Covered sky and weak wind

In covered sky and wind weak conditions, the air temperatures are comfortable. The PMVe marks values which are included in the comfort limits imposed by the PMV. By comparison with the Fanger's psychophysiological scale it becomes possible to deduce the individual thermal feelings, and to qualify comfort in the considered outspaces.



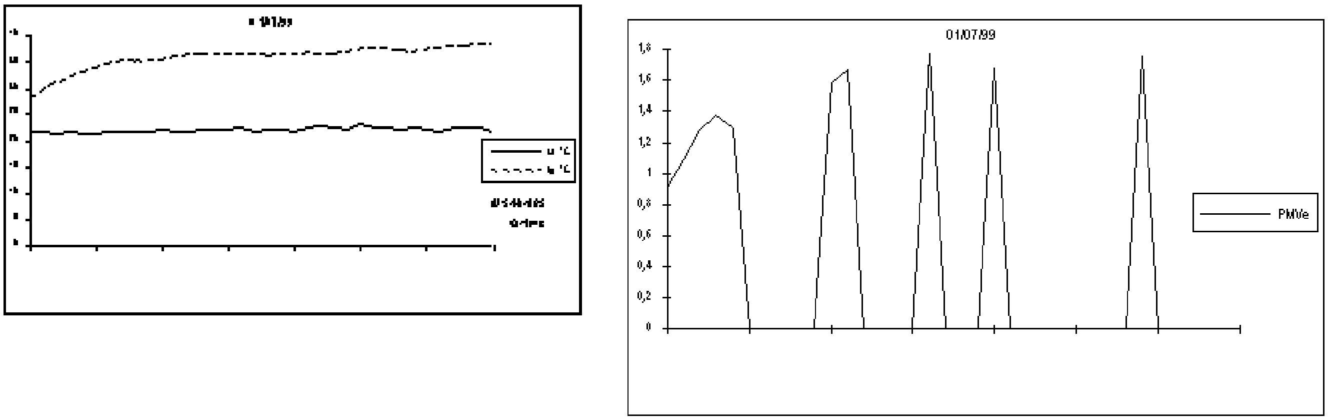
From 10:30:10 AM to 11:01:00 AM

Interval of 5 mn

Fig. 1 Value of radiant temperature and PMVe under covered sky and weak wind

4.3.2 Clear sky and weak wind

Under these conditions, we noticed a significant grow of radiant temperature. For an air temperature of 22°C, the PMVe presents interruptions due to an incapacity to determine compatible values with collected measurements. The strong radiant temperature causes these interruptions, it disturbs the physical conditions of moderate environments. When it is possible to calculate it, the PMVe is registered apart from the comfort levels envisaged by Fanger. In this case, the individual is in discomfort situation, in spite of comfortable air temperatures.



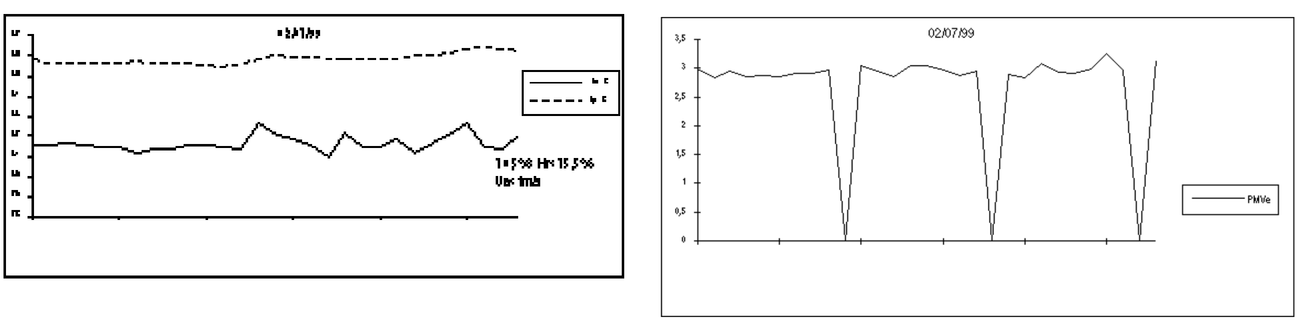
From 10:29:00 AM to 11:03:00 AM

Interval of 5 mn

Fig. 2 Value of radiant temperature and PMVe by clear sky and weak wind

4.3.3 Clear sky and weak wind in the shade

While putting the radiation temperature sensor in the shade of the sun, the PMVe is calculated most of the time, but it remains at the top edge of comfort limits. Due to strong radiant temperatures that increase the air temperatures and accentuate discomfort, the individual feels hot. This measurement makes it possible to note, by comparison with the measurements made with the sun, that a direct contact of the radiation temperature sensor with the direct solar radiation disturbs the calculation of PMVe.



From 14:12:30 PM to 14:42:30 PM

Interval of 5 mn

Fig. 3 Screening by clear sky and weak wind

4.3.4 Clear sky and strong wind in the shade

Measurements by clear sky in the shade with wind velocity higher than 1m/s, are not compatible with PMVe: the individual is apart from the limits of thermal comfort in addition to its perception of discomfort due to the mechanical embarrassment. Measurement has also indicated that even by air velocity lower than 1m/s, a calculated PMVe is apart from the comfort limits. This observation is undoubtedly related to the strong radiant temperatures listed during measurement. For that, the weak winds conditions and low radiant temperatures condition should be present simultaneously to obtain an individual comfort situation at outspaces.

5 Discussion

The results of measurement show that the solar radiation and the wind are prevalent factors in the evaluation of comfort. The other parameters have less influence, particularly the relative humidity whose collected measurements are registered beyond 70 %. It is the threshold of moisture which corresponds to the moderate environments. It’s related to the state of the walls and, to the psychophysiologcal feelings of people.

Strong radiation temperatures and strong wind velocities place the environment apart from the comfort limits. When it is possible to calculate it, the PMVe presents values higher than the intervals of comfort -0,5 / +0,5 and a feeling of heat occurs. The measurements in the shade by weak or strong winds indicate an inadequacy of PMVe to the intervals of comfort also.

Thus, we can note that the condition of covered sky and weak winds in summer are most favourable for the individual comfort. So, the transposition of Fanger’s model in outdoor space and the determination of the outspace comfort in summer become possible. The other conditions don’t satisfy the limits of comfort given by the PMV, and its application is limited. However the question remains open, and could be supported by a manual calculation of PMVe for important temperatures and speeds.

6 Conclusion

Our work aims at establishing a methodological approach for developing a thermal comfort index in outspaces. The interest of this approach is to lead to evaluating quantitatively the comfort in these spaces for a hot period. To reach this goal, we endeavoured to validate the application of the PMV in external space in order to obtain an external model on the basis of those of Fanger.

The environmental conditions which we ended to, enable to note that the extension of the PMV to outspaces is possible, but it implies a reduction of the weather and environmental conditions and a minimisation of the use of space as well. These reductions remain however justified, because they generally correspond to a real space appropriation by the people in the search of their comfort.

However, this study must be supplemented in order to determine the environmental conditions of each season, each one being specific. A wider research is necessary to allow the programming of an adequate external comfort index. This work will lead to modelling various external spaces, and defining indices appropriate to situations not in conformity with those that we defined.

The application of this approach will make it possible to direct the study of the urban morphology influence on thermal outdoor comfort of the individual within previously defined environmental limits.

7 Bibliography

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