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Objective Thermal Comfort of Sport Facilities

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***Abstract*—Sport Facilities facing some problems related to the comfort felt by the player. The static air conditions are common during indoor exercise. High level humidity in the air is not very supportive to the process of evaporation of sweat that is needed when exercising. This condition can make people can do their activities well because discomfort feel by the player during the game, as well as spectator feel. This paper presenting objectives thermal comfort measurement felt by the player and spectator of sport facilities. The research approach used qualitative research, by measuring the climatic factors (air temperature, wind speed, air humidity), insulation of cloth and activity. By using PMV-PDD index, then the all the parameter to describe thermal sensation. The results showed that player and spectator have different thermal sensation of those sport facilities. Sports facility in West Java gave a warm thermal sensation to heat. This means that sports facilities do not provide thermal comfort.**

Keywords—thermal comfort; sport facilities; PMV-PDD index

I. INTRODUCTION

Sport is a form of physical activity that is planned and structured, done repeatedly for the purpose of improving physical fitness. Sporting activities are very important for human beings and become one of the basic human needs. Regular physical activity, especially for young people will enhance your health and fitness, helping the growth of bones and muscles, helps control weight and improve self-esteem [1].

Therefore, the facilities for exercise was supposed to pay attention to comfort, to sporting activities that take place in it can run well. This comfortable conditions which will give ease for users to carry out its activities in the space. In addition, some specific types of sports require special design considerations to support implementation. Certain types of sports are demanding restrictions on the quantity of air that is allowed, so it will not interfere with the course of the game. Then the comfort is one of the conditions of the space to be used.

The problems that often arise in the sports facilities are less thermal comfort for the users. Static air conditions are common during indoor exercise. High humidity is not very supportive to the process of evaporation of sweat that is very needed when exercising. Designs that take into account the climatic conditions of the environment with the needs of its users will produce the ideal thermal comfort to run sports activities within the building.

In this paper will be discussed the objective measurement of thermal comfort at sports facilities, felt by the spectator and players based on calculations

II. THEORETICAL STUDIES

A. The Definition of Thermal Comfort

The comfort conditions of an environment depend on the interaction between several factor, i.e. physical, physiological and psychological factors. This is in accordance with the definition issued by WHO (World Health Organization) in 1999, defines thermal comfort as healthy is a condition of complete well-being, both physical, mental or social. Not only is defined as absence of disease.

Other opinions about the sense of comfort and a feeling of comfort is a person's comprehensive assessment of his environment. Humans assess the environmental conditions based on the stimuli that enter into themselves through the six senses through the nerves and digested by the brain to be assessed. In this case involved not only physical biological issues, but also feelings. Sound, light, smell, temperature and other stimuli are captured at once, then processed by the brain. Then the brain will provide a relative assessment of whether the condition is comfortable or not. Discomforts in one factor may be covered by other factors [2].

Comfort in relation to the building can be defined as a situation where it can provide a feeling of comfort and fun for its inhabitants [3]. While thermal Comfort in architecture, is a State-related nature that can affect humans and may be controlled by architecture [4].

Then, thermal comfort is a condition where the body temperature is stable at a comfortable limit which means the body does not feel the disturbance caused by the thermal factor which is made possible by the balance of body temperature and environment and the climate factor that is in the comfort zone.

Comfort is influenced by several factors, namely air temperature, radiant temperature, air humidity, wind speed, clothing insulation, and activity [5].

Air temperature, is one of the most dominant factors in determining thermal comfort. Units used for air temperature are Celsius, Fahrenheit, Reaumur, and Kelvin Humans are said to be comfortable when body temperature is around 37%. Air

temperature between a region with other regions is very different.

Radiant temperatures are heat derived from radiation of objects that emit heat, one of which is solar radiation.

Humidity is the content of water vapor in the air. As for the factors that affect the air humidity, i.e., solar radiation, altitude, air pressure, wind, place the air density, and temperature.

Wind speed, Wind speed is the speed of the air flow that moves horizontally at a height of two meters above the ground. It is affected by the characteristics of the surface of the path.

Clothing Insulation, the types and materials of clothing worn may also affect thermal comfort. One of the ways of man to be able to adapt to the thermal State in the immediate surroundings is by way of dressing. For example, wearing a thin summer dress and thick in the winter. Clothes can also reduce the release of body heat.

Activities by humans will increase the metabolism of the body. The higher the intensity of the activities carried out, the greater the increase in metabolism that occurs in the body, so that the greater the energy and heat emitted.

B. Thermal Comfort Index

According to Sugini, thermal comfort index is the size measure used to indicate thermal quality [6]. Based on the revelation it can be interpreted that the thermal comfort index is an indicator to determine the environmental thermal conditions. This indicator is composite and is mathematically calculated from some parameters that have been tested in determining thermal comfort.

The thermal comfort index to be used in this study is the PMV thermal comfort index (Predicted Mean Vote). PMV is an index introduced by Professor Fanger of the University of Denmark which indicates the sensation of cold (cold) and hot (hot) felt by humans on a scale of -3 to +3.

PMV is associated with 6 parameters and is the average value that describes how the perceived by many people about the cold and hot. Those parameters are grouped into two: First, Climatic factor which includes air temperature, the temperature of the radiation, wind speed, and humidity. Second, personal factors, which include metabolic rate that is determined by activity and level of resistance factors of apparel specified by clothing.

Individual differences connected with the relation between PMV and PPD (Predicted Percentage of Discomfort) or comparison discomfort index.

TABLE I. RELATION BETWEEN PMV, PPD, AND THERMAL SENSATION

PMV	Thermal Sensation	PPD%
+3	Hot	100
+2	Warm	75
+1	Slightly Warm	25
0	Neutral	5
-1	Slighly Cool	25
-2	Cool	75
-3	Cold	100

If the PMV moves from 0 to another direction, then PPD increase. Then it is expected to keep the PMV is close to 0. Sugini said that the concept of comfortable zone is ranging between PMV =-0.5 to + 0.5 [6]. The limits of 0.5 indicates the limit conditions under neutral or zero degree acceptable coolness. The limit of + 0.5 indicates the limit above zero degree movies or neutral warmth could still be accepted.

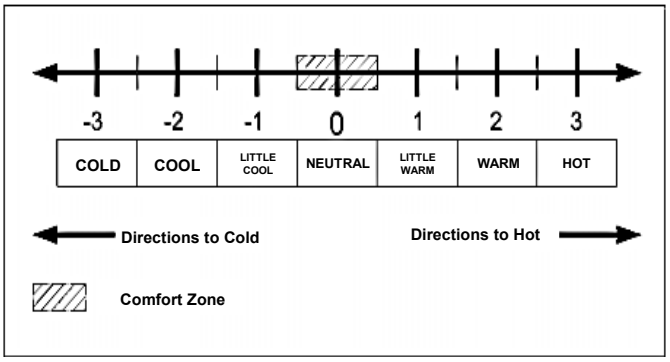


Fig. 1. Thermal Comfort Zone by PMV Franger.

III. METHOD

This study uses a quantitative approach, with an objective thermal comfort level measurement by using a measuring instrument.

This research was conducted in West Java with the objects of research are 5 sport facilities built by the government of West Java Province. On the above considerations then the sports facilities to be evaluated is the new indoor sports observed are:

- GOR Futsal Jatinangor
- GOR Tenis meja Jatinangor
- Gymnasium UPI
- Sporthall UPI
- GOR Pajajaran Bandung

As instrumentation in this research used Thermo-Hygrometer and Anemometer. The measurement data will be calculated using the PMV equation

IV. RESULTS AND DISCUSSION

From the measurement results on each study object, then obtained data about the thermal comfort indicator at the highest condition of each study object. So from the five

objects of study that have been carried out objective measurements, it can be concluded the data is as follows:

TABLE II. RECAPITULATION OF AVERAGE THERMAL COMFORT INDICATOR ON 5 STUDY OBJECTS

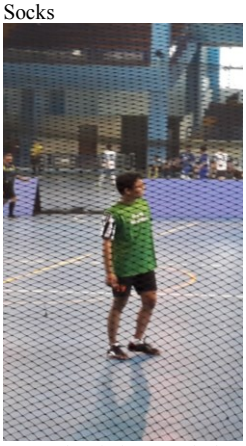
No	Object	Time of measurement	Average		
			T	*RH*	*V*
1	GOR Pajajaran	12-1 pm	29.1	90.2	0.5
2	Gymnasium UPI	12-1 pm	27,8	82,95	0.9
3	Sporthall UPI	12-1 pm	29.2	92	0,15
4	GOR Futsal Jatinangor	12-1 pm	30.6	67.9	0.45
5	GOR Tenis Meja Jatinangor	12-1 pm	32.2	67.5	0.0

The three climatic indicators, i.e. temperature, wind velocity and relative humidity is done by measurement. Among the other two indicators, namely clothing insulation and metabolic values are done by observing the clothing and activities of players and spectators. The results of observations are as follows:

A. *Clothing Insulation*

From the observation of the type of clothing used by the player and the spectator it can be concluded that the five sports facilities have the same spectator and player character in dressing. Clothes used by players are shorts of t-shirts, sleeveless or short sleeves, and underwear. While the spectator generally use short sleeve shirts, jeans trousers and underwear. So the value of clothing insulation players are 0, 19 clo and 0.36 clo spectators.

TABLE III. THE PLAYER AND SPECTATORS'S CLOTH INSULATION

Sport Facility	Player's Cloth Description	Spectators' Cloth Description	Insulation value (Clo)
GOR Pajajaran	Short pants T-Shirt/sleveless Shirt Underware Socks  Example of player's cloths	T-Shirt Long Pants Underware  Example of spectators's cloths	**Spectators:** =0,09+0,25+0,04 **Total=0,36** **Players:** =0,06+0,09+0,04 Total =0,19
Gymnasium UPI			
Sporthall UPI			
GOR futsal			
GOR Tennis meja			

Source of Clo: Innova in Satwiko [2].

B. *Metabolic Value*

Metabolic value obtained from direct observation in the room, by looking at a glance activity of the spectator and players, then compare observations with regulatory standards that contain metabolic values.

TABLE IV. METABOLIC VALUE OF PLAYER AND SPECTATOR

No	Sport Facilities	Spectators	Player	Metabolic Value (met)
1	GOR Pajajaran	Sit and Claps	Playing basketball	Spectators: 2,2, Player: 6,3
2	Gymnasium UPI	Sit and Claps	Playing futsal	Spectators: 2,2, Player: 6,3
3	Sporthall UPI	Sit and Claps	Playing Badminton	Spectators: 2,2, Player: 3,8
4	GOR futsal	Sit and Claps	Playing futsal	Spectators: 2,2, Player: 6,3
5	GOR Tennis meja	Sit and Claps	Playing futsal	Spectators: 2,2, Player: 6,3

Source of Metabolic Value [7].

From the results of measurements of air temperature, wind speed, and humidity, as well as observations on the value of clothing insulation and metabolism then calculated by the PMV equation. Refer to Sugini research about thermal comfort using PMV equation, is done by Microsoft Excel software already in the input formula equation of the PMV [6]. It can be downloaded for free at the website www.tanabe.arch.waseda.ac.jp. The same application is also available on the page http://comfort.cbe.berkeley.edu/. The result of the calculation is as follows:

TABLE V. RESULT OF MEASUREMENT OF PMV

No	Object	Average			Clo		Met	
		T	*RH*	*V*	*Athlet*	*Spectator*	*Athlet*	*Spectator*
1	GOR Basket Pajajaran	29.1	90.2	0.5	0,19	0,36	6,3	2,2
2	Gymnasium UPI	27,8	82,95	0.9	0,19	0,36	6,3	2,2
3	Sport Hall UPI	29.2	92	0,15	0,19	0,36	3,8	2,2
4	GOR Futsal Jatinangor	30.6	67.9	0.45	0,19	0,36	6,3	2,2
5	GOR Tenis Meja Jatinangor	32.2	67.5	0.0	0,19	0,36	6,3	2,2

TABLE VI. RESULT OF MEASUREMENT OF PMV-PPD AND THERMAL SENSATION

No	Object	PMV		PPD		Thermal Sensation	
		Player	*Spectator*	*Player*	*Spectator*	*Player*	*Spectator*
1	GOR Pajajaran	5,12	1,33	100%	42%	Hot	Slightly Warm
2	Gymnasium UPI	3.5	0,67	100%	15%	Hot	Slightly Warm
3	Sport Hall UPI	3,82	2.18	100%	84%	Hot	Warm
4	GOR Futsal Jatinangor	5,21	1,55	100%	54%	Hot	Warm
5	GOR Tenis Meja Jatinangor	7,42	2,73	100%	93%	Hot	Hot

The table above shows that there is a difference in the value of PMV-PPD and the thermal sensation felt by the player and the spectators at each sport facility. Thermal sensation perceived by the player, on the five objects of study shows heat sensation with PPD up to 100%. The 100% percent rate on PPD when compared to the PMV relationship table, PPD and thermal sensations below, indicates that the five objects do not provide thermal comfort to the players.

But unlike the sensation felt by the spectator. The spectator with the activity of sitting and clapping or cheering movements, resulting different thermal sensation felt by the player. Pajajaran's GOR and UPI Gymnasium give a slightly warm thermal sensation. While Sporthall UPI and GOR Futsal Jatinangor give a warm sensation. Only Jatinangor table tennis GOR gives hot thermal sensation to the spectator.

When compared with the PMV index below, the Pajajaran GOR and UPI Gymnasium are quite comfortable from the thermal side. While SportHall UPI and GOR Futsal Jatinangor not comfortable. Only GOR Table tennis Jatinangor very uncomfortable.

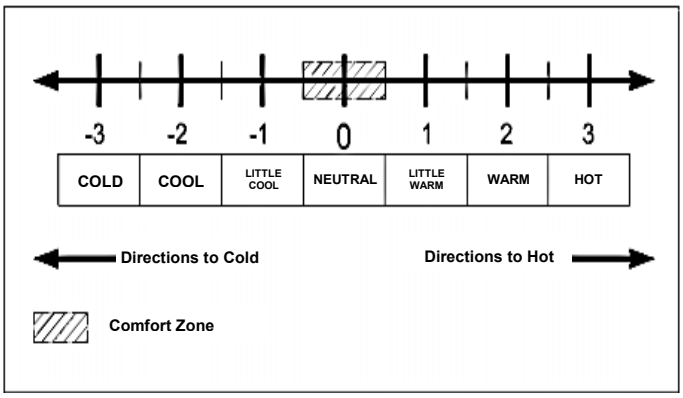


Fig. 2. PMV Index.

V. CONCLUSIONS

The objective thermal comfort in terms of temperature measurement, relative humidity and wind speed, as well as observation of clothing insulation and metabolic values, indicates that:

The five objects of study, all give a thermal sensation to the player. This means for players / athletes who do sports activities in his feel very uncomfortable.

UPI Gaming and UPI Gymnasium give a rather warm sensation to the spectator. This means that the viewers get enough thermal comfort in both sports facilities. While Sport Hall UPI and GOR Futsal Jatinangor provide a warm sensation for the spectator. This means that the spectator does not get thermal comfort on both sports facilities. Only GOR Table tennis Jatinangor that gives hot sensation to the spectator. Means the spectator is very uncomfortable thermally when doing activities inside.

Both for the player and for the spectator, the five study objects generally do not provide thermal comfort.

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