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Short Review Paper

Analysis of heat stress and its impact on thermal comfort

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Abstract

Rise in ambient atmospheric temperature is a serious concern in tropical countries. It induces irreversible thermal stress in human population especially those involved in outdoor activities. Thermal stress reduces productivity of working population due to generation of thermal and even raises casualty issues if the extent of stress situation is sufficiently high. Thus it is absolutely necessary to understand the regional features of thermal stress so that effective precaution may be suggested to save precious human lives of all economic status. Present research summarizes an account of thermal stress measurements based on calculation framework, indices of measurement and prevention strategies.

Keywords: Discomfort, dry Bulb temperature, heat indices, thermal stress.

Introduction

Now a days, a great interest is grown to study the heat stress as well as heat environment in the sites of construction areas. Not only workers of the industry but travelers and country soldiers are also exposed to the acute heat stress of environment. This may cause decrease of their work efficiency and productivity. During the summer time the employees have to work in construction sites many hours in thermally stressful environments along with tremendous work load. Consequently they have to face direct and physiological effects of heat stress. Thus, for over a century there are so many attempts made to examine different kinds of heat stress indices. Some researches indicate that wet globe temperature is a main factor which affects heat stress level. At industry sites when we want to estimate heat stress equation for the workers the metabolic rate is the main complicated portion to calculate. In this article we mentioned some of the difficulties to estimate universal heat stress indices and we describe a simple path to describe the level of the thermal stress in environment.

Casualty: Percentage of casualty due to heat stress in different work places has been shown in Table-1. Most stress occurs in the field of civil and construction site.

Exchange of heat with environment

To maintain the normal body function we have to maintain our body core temperature of around 37^0C. If a constant heat exchange takes place between our body and the surroundings then only it is possible. The amount of exchanged heat is a function of the total metabolic heat produced, the heat gained from the surroundings and sweat evaporation by the body. These factors are related with the amount of heat exchanged. The fundamental heat balance equation is given by

$$\Delta H = (N - W_{mech}) \pm (R + C) - E_V \quad (1)$$

Where: ΔH = change in body heat content, $(N - W_{mech})$ = net metabolic heat production, W_{mech} = mechanical work, $(R + C)$ = radiative and convective heat exchange, E_v = loss of heat due to evaporation.

Table-1: Casualty percentage in heat stress (work pattern wise).

Work type	Casualty (%)
Civil works	28.7
Construction	26.0
Carriage	13.5
Traffic and Inspection	5.7
Cleaning	4.2
Furnace and metal processing	3.7
Automobile	2.6
Assembly	1.6
Delivery	1.6
Others	12.5

At heat balance ΔH =0, so

$$(N - W_{mech}) \pm (R + C) = E_{req} \quad (2)$$

Where E_{req} indicates the amount of required evaporation to get heat balance.

Now we have to consider another term namely maximum evaporative capacity of the surrounding environment (E_{max}). The ratio E_{req} / E_{max} is known as "heat strain index" which was proposed by Belding and Hatch[7]. To solve Equation (1) and Equation (2) we have to know several parameters.

Heat stress indices: Heat stress index of any human thermal environment is a single value parameter which varies with the thermal strain which is experienced by the individual[8]. There are so many indices like WBGT and HSI have been suggested throughout the world.

Analysis of heat stress: It is noticed that in construction areas, different metabolic rate ranging from low to high is required for different occupations. To examine the risk of heat stress we can take heavy load worker as sample. The outside temperature of air was assumed to vary within the limit 25^0C to 35^0C to represent thermally stressful environments.

If we study the graphs of heat stress index (HSI) of different metabolic rate versus dry bulb temperature (DBT), we can conclude at rest or low metabolic rate the value of heat stress indices are low[9]. But for moderate metabolic rate its value rises and becomes larger for high or very high metabolic rates. So, heavy load workers have high metabolic rate, the risk factor due to heat stress become very large when the dry bulb temperature crosses 28^0C.

Affects of heat stress on the productivity in urban areas

The micro level studies have revealed the affect of heat stress on the workers productivity and their physical performances in their workplaces. We consider the influence of air temperature of urban built up areas, land surface temperature, speed of wind and humidity using UrbClim model.

The UrbClim model is a model which is designed to model the urban climate of a few hundred meters. This model calculates the impact of urban development on the very important parameters. To evaluate the future urban city climate, the UrbClim model has been tagged with the output of eleven global climate models (GCM). The city climate which includes heat stress decreases the productivity of the factories and companies. The thermal properties of different types of buildings such as offices, industries, factories in a city will vary greatly. This indoor climate also affects the productivity of those industrial plants.

To calculate the reduction in productivity of individual worker due to heat stress, we have to follow ISO standards. This international standards is based on Wet Bulb Globe Temperature (WBGT).

The productivity of workers can be expressed by the proportion of a full working day in which a worker can do a job under many different heat conditions. Within upper and lower bound temperatures, the productivity of a worker is a non –increasing function of the WBGT. The worker productivity is zero above the upper WBGT bound and is 1 below the lower bound. So, we have to consider the productivity loss function for each sector based on work intensity in that sector.

Control of heat stress

If our body is unable to decrease heat by sweating then there are so many illness which can affect our body, even may cause death. So, we have to control heat stress to some extent. Generally heat stress is also attached with humidity and large environmental temperature. The efficiency as well as response to work of workers at the construction sites can be affected by relative humidity, movement of air, radiant heat, etc. Beside these factors workers may be associated with some personal risk factors like age, excess body weight, high blood pressure, heart diseases etc. So, it is very hard to say who will be suffering from thermal stress at construction sites.

In order to restrict or prevent heat stress, we have to find out the risk of thermal stress and calculate a secured and efficient management system[10]. Proper environmental control, monitoring of workers and administrative control can prevent accidents and decrease adverse health effects. Appropriate education and training for the workers is a main factor to tackle the problem. Instead of this, both employer and employee should be responsible to control the heat stress.

Thermal comfort

The term thermal comfort is defined as "that condition of mind which expresses satisfaction with the thermal environment". From that point of view we can express term comfort as a subject of sensation. From the view of climatic environment the thermal comfort zone in summer is slightly higher than that of the winter, being 23^0C-27^0C in summer and 20^0C-25^0C in winter.

Any person should be in thermal comfort if there is a heat balance in his body, his body sweat rate in comfort limits and if his skin temperature be also within comfort limits[11]. According to Fanger, a person be in thermal comfort if: i. his body is in heat balance, ii. rate of sweat is in comfort limit, iii. the mean skin temperature is in tolerate limit.

If the temperature of the core of body is within a range of 36.5^0C-37.5^0C, the highest skin temperature is at 30^0C and body

stem and head temperature is within 34^0C-35^0C then thermal comfort can be attained. But any deviation of these results causes a sensation of discomfort.

From Equation (1), we can conclude that heat comfort will be achieved when heat dissipation rate from the body will same to rate of production of metabolic heat in the body. At thermal comfort heat storage (ΔH) will be zero. Thermal comfort can be measured by the value of the ratio of (E_{req}/E_{max}). If this ratio exceeds 20% (0.2), workers are shifted from a comfort condition to the uncomforting condition. The performance of a worker decreases when the ratio increases to 0.4 to 0.6. But when the ratio exceeds the value 0.6, work will be stopped or will be performed only for a certain time limit. When the ratio exceeds the value of 0.8 there will be some risk factors come to play regarding heat illness[12]. Now a days there have been so many research works going on to find the condition which will produce thermal comfort and how thermal stress can be minimized.

Conclusion

Large number of heat stroke incidents occurs every year due to hot and humid environment of the workplace. Also improper clothing in heavy jobs makes it more complicated. Now the increasing rate of risk in heat stress is a matter of great concern. It becomes a huge challenge to us to control the fatalities. At this situation, the following guidelines may be helpful to control and manage the worse situation. i. Well ventilated construction, ii. Short work hours with break, iii. Intake of sufficient water and salt, iv. Air and moisture permeable clothing, v. Checking of health condition regularly, vi. First aid and Emergency transportation facility, vii. Proper Occupational health education and also, viii. Heat stress index like WBGT may be applied to assess the situation well in advance.

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