

ASSESSMENT OF HEAT INDEX IN OUTDOOR BUILDING CONSTRUCTION ACTIVITIES -A STUDY IN SEMI-ARID CLIMATE, HYDERABAD

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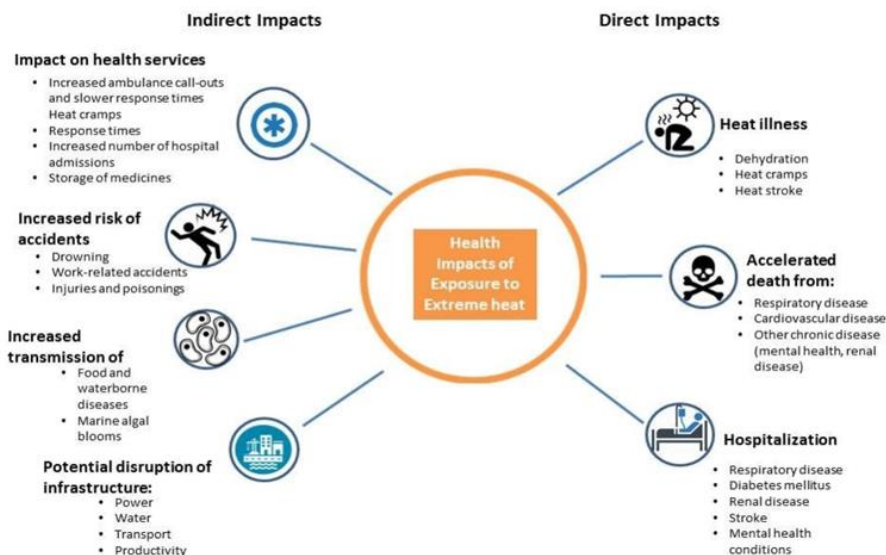
Abstract:

Temperature and humidity are physical occupational hazards that have impact on worker’s performance and health. The study investigates temperature and relative humidity during worktime in pre-monsoon, monsoon, post monsoon and winter seasons, measured using Thermohygrometer, in semi-arid climate Hyderabad, for outdoor building construction activities at different elevations like earth work excavations, laying of foundations, brickwork, painting etc and heat stress index as evaluated. As per National Weather Service (NWS) US, Heat index >1250 F considered as extreme danger, 104-1240 F as Danger, 91-1030 F extreme caution, 80-900 F as caution. The conclusions drawn are extreme danger condition in pre-monsoon in earth-work excavation, bar cutting, column shuttering, bar bending, removal of shuttering, concrete pouring, brickwork, and carpentry during 1.30 to 4.00pm. During monsoon, only Caution and Extreme caution conditions existed. During post monsoon Danger condition reported in column shuttering at 4.00 pm and caution, extreme caution mostly. In winter Comfortable conditions existed mostly and cases of caution and extreme caution also exist.

Keywords: Temperature, Humidity, Building construction activities, heat stress index.

1.Introduction

Temperature (heat and cold) is one of the physical hazards in the construction industry. Construction work is continuous throughout the year. Also, some construction activities may take place during nighttime. So, construction workers are exposed to various temperatures which vary from time to time and season to season. Exposure to certain high temperatures causes some health problems that may cause temporary to permanent problems. Exposure to various temperatures causes headache, heat cramps, heat attacks and leads to pre-mature death. Heat causes indirect health problems, shows impact on human behavior, and the mental health of the worker which increases the Psychological stress on the human body .





2.Review of literature

Yasmeen et.al (2020) discussed that construction workers frequently deal with humid, hot temperatures on job sites as a result of global warming. This may have an impact on employees' health and cause heat exhaustion at various phases of the workday. Instead of doing an on-site investigation, various chamber experiments have been done recently to determine the labour heat-stress level. Using ten acclimated workers performing seven various sorts of activities, an on-site experiment was carried out in Chongqing throughout the summer of 2017 (July to mid-August) to evaluate the physiological status of the samples. Measurements were made of the workers' physiological states and the surrounding conditions. The results show that whereas heavy lifting constituted moderate intensity work for indoor bricklayers, outdoor bricklayers worked at a high intensity. At a high relative humidity and wet bulb globe temperature (WBGT) of 31.5 °C

Moochialdin, A et.al (2022) reported that extremely hot and humid (EHH) conditions have a direct impact on the health and safety of construction workers. The purpose of this study is to investigate the issue of EHH weather and the manner which it affects the physiological wellness of construction workers. By measuring the physical characteristics of the workers—their age, height, and weight—as well as the kinds of activities they perform and the tasks they are assigned, evaluates the effects of EHH weather on their physiological health. The measurements are taken from 35 multinational workers. Then a quantitative analysis was used to assess the extent to which the weather had affected people's physiological states. The results provide empirical evidence that the recorded Heart Rate (HR) exceeded the acceptable physiological zones for construction workers exposed to extremely hot and humid weather conditions.

Yildizel, et.al (2015) discussed that Construction workers performance is impacted by workplace temperature both physically and psychologically. Both high and low temperatures have a direct impact on worker productivity, and thermal stress also contributes to workplace mishaps. Given the nature of the construction industry where building sites are situated in exposed places subject to extreme weather, workers are comparatively more vulnerable to heat stress than employees in other industries. In this study, the construction business was specifically examined. Depending on the local climate, the impact of heat stress on workers' performance and health was examined, and several suggestions for coping with heat stress were provided.

Li, X ,et.al (2016) done this study to provide industry practitioners with a better understanding of the impacts of high-temperature conditions on construction labour productivity. Such information could assist in the establishment of plans to prevent heat-stress injuries and help improve the safety and comfort of construction labour working environments. On-site WBGT (Wet Bulb Globe Temperature) data and labour productivity data related to direct work time, indirect work time and idle time were measured for two construction projects involving 16 rebar workers in the summer of 2014 in Beijing, China. The period from 14:00 to 15:00 was identified as the most hazardous for workers throughout the day, and the period from 07:00 to 09:00 was identified as the least hazardous time. Productivity models were further used to analyse the collected data. The model results demonstrated that high-temperature environments decrease labour productivity, with the percentage of direct work time decreasing by 0.57% and the percentage of idle time increasing by 0.74% when the WBGT increased by 1 °C. Moreover, the percentage of direct work time increased by 0.33% when the workers' experience increased by 1 year and decreased by 0.72% when the workers' age increased by 1 year. Overall, the results demonstrated that high-temperature environments impose heat stress on the human body and decreases labour productivity in the construction industry.

3.Methodology

In the study the heat stress index is calculated by measuring the parameters temperature and humidity in the construction sites during work-time. Worker working in such environment feels thirsty, tired ness, not showing interest towards wearing of PPE (PERSONAL PROTECTIVE EQUIPMENT) increase the causing of danger causing hazards. By considering the various related factors such as



individual personal heat tolerance, physical activity, attire, and heat acclimatization the risk level of heat stress can be evaluated by heat stress index.

The National Weather Service (NWS) United States, has given a general guideline and categorizes heat stress index values into different risk levels and developed the formula to identify the potential risks involved with respect to heat and temperature. The heat stress index can be measured in Fahrenheit (F).

The following are the reference heat stress index values.

Sl.no	Heat stress index in °F	Risk level	Effect
1	80-90	Caution	Caution to heat sensitivity people
2	91-103	Extreme caution	Heat cramps and heat exhaustion
3	104-124	Danger	Heat cramps, keta exhaustion , prolonged exposure causes heat stroke
4	>= 125	Extreme danger	Heat related illness occurred

Hyderabad is located in Telangana state and climate is semi-arid , too little rain to featuring to tropical Savanna climate .According to the Indian Meterological Department (IMD) the following are the divisions of the Indian climate

Winter: December to Early April.

Summer or pre-monsoon : April to June

Monsoon or rainy: June to September.

Post Monson: October to December

The data was collected from the year 2021 to 2023 in respective months .

In each construction activity, the temperature and humidity were measured with the help of Thermohyrometer while the worker performing his task, in order to identify his exact exposure to temperature and humidity. The readings were noted in MS excel sheet to evaluate the heat stress index. The following is the expression for evaluating the heat stress index. the heat index or heat stress index is a complex mathematical model is the combined effects of temperature and humidity with respect to heat.

As per NWS ,US the formula of heat index is obtained from collection of data through scientific studies and observations to the body responses for varying levels of heat and humidity . Parameters involved in the equation are

- Temperature (T): The actual air temperature in Fahrenheit.
- Relative Humidity (RH): The percentage of moisture in the air.
- Various coefficients and constants: These are derived from statistical analysis of data and are used to weight the contributions of temperature and humidity.

The coefficients and constants in the formula are determined based on extensive observations of how the human body reacts to varying levels of heat and humidity, considering factors such as sweat evaporation rates, skin temperature, and physiological responses.

$$\text{Heat Index} = (-42.379 + 2.04901523 * T + 10.14333127 * RH - 0.22475541 * T * RH - 6.83783 * 10^{-3} * T^2 - 5.481717 * 10^{-2} * RH^2 + 1.22874 * 10^{-3} * T^2 * RH + 8.5282 * 10^{-4} * T * RH^2 - 1.99 * 10^{-6} * T^2 * RH^2)$$

The various Building construction activities considered are Earth-work excavation , Laying of foundations , bar cutting , bar bending ,Formwork , concrete pouring , Remove of shuttering , Slabing and reinforcement ,painting and Carpentry.

4.Results.

Table 1: Heat index values during excavation work during four seasons in India as per IMD

April -June (Pre-monsoon)				June -September (Monsoon)				October -December(Post Monsoon)				December -April(winter)			
Temp (F)	Humidity	Heat index		Humidity	Temp(F)	HEAT INDEX		Temp (F)	Humidity	HEAT INDEX		Temp (F)	Humidity	HEAT INDEX	
89.6	48	93.0	Extreme caution	38	86.0	85.0	caution	84.2	35	82.8	caution	82.4	34	81.1	caution
93.2	52	102.4	Extreme caution	37	85.6	84.5	caution	89.6	36	88.9	caution	82.4	34	81.1	caution
94.1	54	105.9	Danzer	34	79.3	79.1	comfortable temperature	93.2	42	96.7	caution	82.94	32	81.4	caution
96.8	57	115.8	Danzer	30	78.6	78.4	comfortable temperature	95.4	44	102.0	extreme caution	82.94	30	81.2	caution
96.3	58	115.1	Danzer	40	88.5	88.6	caution	95.0	44	101.3	extreme caution	82.22	31	80.7	caution
95.0	48	103.8	Extreme caution	41	91.2	92.9	extreme caution	93.2	40	95.8	extreme caution	80.6	29	79.5	comfortable temperature
86.4	46	87.3	caution	42	90.9	92.7	extreme caution	86.0	35	84.5	caution	80.6	29	79.5	comfortable temperature
84.0	40	83.3	caution	45	91.4	94.9	extreme caution	86.0	45	86.6	caution	83.3	30	81.4	caution
91.8	46	96.0	Extreme caution	48	92.3	98.1	extreme caution	86.9	47	88.3	caution	82.4	31	80.9	caution
94.1	46	100.6	Extreme caution	41	90.3	91.5	caution	87.4	47	89.1	caution	80.6	30	79.6	comfortable temperature
95.5	50	106.5	Danger	42	93.0	96.4	extreme caution	89.6	50	93.9	extreme caution	81.5	32	80.3	caution
96.4	54	112.0	Danzer	46	94.1	100.6	extreme caution	86.0	47	87.1	caution	82.4	34	81.1	caution
96.8	60	118.6	Danzer	44	93.6	98.4	extreme caution	86.0	45	86.6	caution	78.8	30	78.5	comfortable temperature
95.5	60	114.7	Danzer	41	86.0	85.7	caution	82.4	40	81.8	caution	77	28	77.5	comfortable temperature
86.4	40	85.9	caution	38	80.6	80.2	caution	80.6	37	80.1	caution	81.5	30	80.1	caution
88.2	41	88.4	caution	45	85.6	86.1	caution	89.6	40	90.1	caution	82.4	32	80.9	caution
90.3	45	93.0	Extreme caution	40	81.5	81.0	caution	88.7	40	88.8	caution	82.76	33	81.3	caution
97.7	55	116.5	Danger	40	80.6	80.4	caution	86.9	38	86.1	caution	82.4	30	80.8	caution
100.8	57	128.5	Extreme Danger	39	80.4	80.1	caution	85.6	34	84.0	caution	75.2	29	76.9	comfortable temperature
104.4	60	146.2	Extreme Danger	32	78.6	78.6	comfortable temperature	99.3	30	101.2	extreme caution	75.2	29	76.9	comfortable temperature
101.3	60	134.2	Extreme Danger	35	84.9	83.4	caution	90.3	29	88.1	caution	71.6	28	76.0	comfortable temperature
96.8	57	115.8	Danzer	40	86.2	85.6	caution	82.4	34	81.1	caution	80.6	29	79.5	comfortable temperature
87.1	42	87.2	caution	48	89.6	93.0	extreme caution	83.3	35	82.0	caution	82.04	32	80.7	caution
90.3	42	91.9	Extreme caution	42	84.2	83.8	caution	80.6	35	79.9	comfortable temperature	84.2	35	82.8	caution
92.8	47	98.6	Extreme caution	38	81.5	80.8	caution	78.8	30	78.5	comfortable temperature	82.4	32	80.9	caution
94.6	50	104.4	Danzer	35	81.3	80.4	caution	79.3	31	78.9	comfortable temperature	81.5	30	80.1	caution
97.2	55	115.0	Danzer	30	80.6	79.6	Comfortable temperature	78.6	30	78.4	comfortable temperature				
93.6	54	104.5	Danzer												

Table 2: Heat index values during bar cutting work during four seasons in India as per IMD

April -June (Pre-monsoon)				June -September (Monsoon)				October -December(Post Monsoon)				December -April(winter)			
Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	risk level	Temp(F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level
78.8	35	78.8	Comfortable temperature	86.0	32	84.0	increased caution	78.8	35	78.8	Comfortable temperature	69.8	24	75.1	comfortable temperature
80.6	40	80.4	caution	86.0	31	83.9	increased caution	80.6	40	80.4	caution	69.8	27	75.6	comfortable temperature
81.3	41	81.0	caution	82.4	30	80.8	increased caution	81.3	41	81.0	caution	70.5	30	76.1	comfortable temperature
82.4	50	83.2	caution	84.2	34	82.6	increased caution	82.4	50	83.2	caution	70.7	33	76.5	comfortable temperature
83.1	54	84.8	caution	82.4	30	80.8	increased caution	83.1	54	84.8	caution	82.4	35	81.2	caution
84.7	57	87.9	caution	82.4	38	81.6	increased caution	84.7	57	87.9	caution	83.3	37	82.2	caution
75.2	32	77.1	Comfortable temperature	82.4	39	81.7	increased caution	75.2	32	77.1	Comfortable temperature	84.2	40	83.5	caution
76.6	34	77.8	Comfortable temperature	84.0	48	84.7	increased caution	76.6	34	77.8	Comfortable temperature	86.0	44	86.3	caution
78.8	38	79.0	Comfortable temperature	84.0	49	84.9	increased caution	78.8	38	79.0	Comfortable temperature	87.8	48	90.0	caution



79.5	42	79.8	Comfortable temperature	84.6	54	86.8	increased caution	79.5	42	79.8	Comfortable temperature	82.4	36	81.3	caution
82.4	44	82.3	caution				comfortable temperature								
80.6	40	80.4	caution	80.6	32	79.7	increased caution	82.4	44	82.3	caution	71.6	28	76.0	comfortable temperature
							comfortable temperature								
71.6	28	76.0	Comfortable temperature	80.6	33	79.8	increased caution	80.6	40	80.4	caution	73.0	29	76.3	comfortable temperature
72.3	31	76.4	Comfortable temperature	83.8	49	84.7	increased caution	71.6	28	76.0	Comfortable temperature	73.2	31	76.6	comfortable temperature
89.6	40	90.1	extreme caution	84.2	54	86.3	increased caution	72.3	31	76.4	Comfortable temperature	74.1	35	77.0	comfortable temperature
							increased caution								
91.0	48	95.6	extreme caution	80.6	51	81.5	increased caution	89.6	40	90.1	extreme caution	74.8	42	77.5	comfortable temperature
68.0	24	74.9	Comfortable temperature	81.3	56	82.9	increased caution	91.0	48	95.6	extreme caution	77.0	30	77.7	comfortable temperature
69.8	26	75.4	Comfortable temperature	82.0	61	84.7	increased caution	68.0	24	74.9	Comfortable temperature	78.8	32	78.6	comfortable temperature
73.4	30	76.5	Comfortable temperature	81.3	61	83.6	increased caution	69.8	26	75.4	Comfortable temperature	79.7	33	79.2	comfortable temperature
77.0	33	77.9	Comfortable temperature	83.1	30	81.3	increased caution	73.4	30	76.5	Comfortable temperature	82.4	38	81.6	caution
82.4	45	82.5	caution	85.1	35	83.6	increased caution	77.0	33	77.9	Comfortable temperature	80.6	44	80.7	caution
-	-	-	-	88.2	47	90.3	increased caution	82.4	45	82.5	caution	81.3	48	81.8	caution
-	-	-	-	84.9	58	88.5	caution	-	-	-	-	-	-	-	-
-	-	-	-	86.2	61	91.8	extreme caution	-	-	-	-	-	-	-	-
-	-	-	-	82.4	58	84.6	increased caution	-	-	-	-	-	-	-	-

Table 3: Heat index values during Laying of foundations work during four seasons in India as per IMD

April -June (Pre-monsoon)				June -September (Monsoon)				October -December(Post Monsson)				December -April(winter)			
Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level
83.1	38	82.2	caution	82.4	30	80.8	caution	72.3	20	74.9	comfortable temperature	86.0	48	87.3	caution
83.3	39	82.5	caution	82.4	31	80.9	caution	73.0	21	75.3	comfortable temperature	87.4	49	89.8	caution
86.0	42	85.9	caution	82.8	34	81.4	caution	74.1	24	76.1	comfortable temperature	82.4	40	81.8	caution
87.8	45	89.1	caution	83.1	34	81.7	caution	82.4	30	80.8	comfortable temperature	82.4	35	81.2	caution
86.0	41	85.7	caution	75.2	28	76.8	comfortable temperature	83.3	32	81.6	caution	82.4	36	81.3	caution
87.4	43	88.0	caution	75.2	30	77.0	comfortable temperature	89.6	48	93.0	extreme caution	83.1	38	82.2	caution
88.7	46	90.8	caution	75.2	31	77.1	comfortable temperature	68.7	21	74.2	comfortable temperature	83.5	39	82.6	caution
91.4	46	95.4	extreme caution	76.5	35	77.8	comfortable temperature	69.4	22	74.6	comfortable temperature	84.2	39	83.3	caution
98.6	54	118.2	Danger	78.4	37	78.8	comfortable temperature	70.5	25	75.4	comfortable temperature	69.8	22	74.6	comfortable temperature
99.5	56	123.1	Danger	82.4	57	84.4	caution	73.0	30	76.4	comfortable temperature	69.8	23	74.9	comfortable temperature
99.5	57	124.3	Danger	83.3	63	87.1	caution	80.6	41	80.4	comfortable temperature	71.6	25	75.6	comfortable temperature
78.8	46	79.6	comfortable temperature	83.3	63	87.1	caution	84.2	47	84.8	caution	75.2	30	77.0	comfortable temperature
78.8	46	79.6	comfortable temperature	83.1	62	86.6	caution	87.8	54	92.2	extreme caution	82.4	38	81.6	caution
80.4	51	81.3	caution	84.2	33	82.5	caution	86.7	54	90.3	caution	81.5	32	80.3	caution
82.4	59	84.8	caution	84.2	35	82.8	caution	83.1	31	81.4	caution	82.9	32	81.4	caution
82.9	64	86.7	caution	86.9	38	86.1	caution	83.3	32	81.6	caution	83.3	34	81.9	caution
89.6	71	105.4	Danger	78.3	33	78.4	comfortable temperature	86.0	42	85.9	caution	84.0	35	82.6	caution
93.2	74	119.9	Danger	78.8	35	78.8	comfortable temperature	87.4	48	89.5	caution	84.9	36	83.6	caution
95.0	74.3	127.2	Danger	82.4	42	82.0	caution	87.8	51	91.1	extreme caution	-	-	-	-
94.1	72	121.3	Danger	89.6	48	93.0	extreme caution	-	-	-	-	-	-	-	-
86.0	62	91.8	extreme caution	89.6	50	93.9	extreme caution	-	-	-	-	-	-	-	-
77.0	32	77.8	comfortable temperature	89.6	50	93.9	extreme caution	-	-	-	-	-	-	-	-
82.4	35	81.2	caution	80.6	46	80.9	caution	-	-	-	-	-	-	-	-
84.2	36	82.9	caution	80.6	44	80.7	caution	-	-	-	-	-	-	-	-
89.6	45	91.8	extreme caution	78.8	40	79.2	comfortable temperature	-	-	-	-	-	-	-	-
93.2	57	105.7	Danger					-	-	-	-	-	-	-	-

Table 4: Heat index values during column shuttering work during four seasons in India as per IMD.

April -June (Pre-monsoon)				June -September (Monsoon)				October -December(Post Monsson)				December -April(winter)			
Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level
82.4	34	81.1	Caution	75.2	40	77.5	comfortable temperature	84.9	32	83.0	caution	68	22	74.3	comfortable temperature
86.0	42	85.9	Caution	76.1	45	78.0	comfortable temperature	85.1	34	83.5	caution	68	22.5	74.5	comfortable temperature
87.4	47	89.1	Caution	76.1	48	78.1	comfortable temperature	85.1	35	83.6	caution	71.6	24	75.4	comfortable temperature
93.2	58	106.4	Danger	78.8	54	80.1	caution	85.3	37	84.1	caution	75.2	32	77.1	comfortable temperature
96.8	64	122.8	Danger	79.0	57	80.4	caution	86.0	40	85.4	caution	78.8	33	78.7	comfortable temperature
102.2	68	149.5	extreme Danger	82.4	62	85.4	caution	87.8	41	87.9	caution	79.7	36	79.4	comfortable temperature
98.6	60	124.6	extreme Danger	80.6	32	79.7	comfortable temperature	91.0	45	94.3	caution	80.6	46	80.9	caution
86.0	48	87.3	Caution	80.6	34	79.9	comfortable temperature	91.4	48	96.3	caution	82.4	46	82.6	caution
87.8	50	90.7	extreme caution	83.5	45	83.6	caution	93.2	45	98.3	caution	66.2	22	74.2	comfortable temperature
93.2	63	110.2	Danger	83.5	50	84.5	caution	94.6	46	101.8	extreme caution	68	23	74.6	comfortable temperature
98.6	74	142.2	extreme Danger	84.7	58	88.2	caution	95.0	47	103.2	Danger	68.9	25	75.2	comfortable temperature
100.0	78	155.1	extreme Danger	83.7	61	87.2	caution	78.8	31	78.6	comfortable temperature	78.8	30	78.5	comfortable temperature
80.6	34	79.9	Comfortable temperature	83.1	60	86.1	caution	80.2	33	79.5	comfortable temperature	82.4	38	81.6	caution
81.5	38	80.8	Caution	69.8	24	75.1	comfortable temperature	80.6	35	79.9	comfortable temperature	80.6	36	80.0	comfortable temperature
84.2	41	83.7	Caution	75.2	25	76.6	comfortable temperature	81.0	36	80.3	comfortable temperature	86	34	84.3	caution

89.6	51	94.3	extreme caution	82.4	32	80.9	caution	82.4	40	81.8	caution	87.8	38	87.1	caution
91.4	57	101.3	extreme caution	84.2	33	82.5	caution	84.2	45	84.4	caution	93.2	39	95.3	extreme caution
84.2	35	82.8	Caution	89.2	52	94.1	caution	89.6	54	95.7	extreme caution	89.6	38	89.5	caution
84.9	38	83.9	Caution	89.8	58	98.1	extreme caution	82.4	32	80.9	comfortable temperature	-	-	-	-
86.0	44	86.3	Caution	89.4	51	94.0	extreme caution	84.2	32	82.4	caution	-	-	-	-
87.8	54	92.2	extreme caution	83.7	48	84.3	-	87.8	35	86.5	caution	-	-	-	-
92.1	60	105.0	Danger	-	-	-	-	90.5	38	90.7	extreme caution	-	-	-	-

Table 5: Heat index values during slabing and reinforcement work during four seasons in India as per IMD

April -June (Pre-monsoon)				June -September (Monsoon)				October -December(Post Monsson)				December -April(winter)			
Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level
86.0	38	85.0	caution	75.2	20	76.1	comfortable temperature	82.4	56	84.2	caution	69.8	25	75.3	Extreme Caution
86.9	39	86.3	caution	75.2	22	76.3	comfortable temperature	83.1	60	86.1	caution	71.6	27	75.8	Danzer
87.3	42	87.5	caution	76.1	28	77.2	comfortable temperature	86.0	62	91.8	extreme caution	75.2	28	76.8	Danzer
91.4	58	101.9	Extreme caution	80.6	32	79.7	comfortable temperature	89.6	63	100.4	extreme caution	76.1	29	77.2	Danzer
93.2	62	109.5	Danger	82.4	42	82.0	caution	91.0	57	100.4	extreme caution	77	29	77.6	Danzer
86.0	34	84.3	caution	86.0	50	87.9	caution	89.6	57	97.2	extreme caution	82.4	32	80.9	Danger
86.4	38	85.4	caution	71.6	24	75.4	comfortable temperature	82.4	32	80.9	caution	84.2	35	82.8	Extreme Danger
87.4	44	88.2	caution	71.6	26	75.7	comfortable temperature	82.8	34	81.4	caution	77	30	77.7	Danzer
93.2	57	105.7	Danger	75.2	28	76.8	comfortable temperature	83.7	35	82.3	caution	77.9	32	78.2	Danger
94.6	62	113.7	Danzer	82.4	36	81.3	caution	83.8	40	83.1	caution	79.52	35	79.3	Extreme Danger
92.7	60	106.4	Danger	82.4	42	82.0	caution	80.6	38	80.2	caution	79.52	37	79.4	Extreme Danger



89.6	48	93.0	Extreme caution	86.0	51	88.2	caution	80.2	32	79.5	comfortable temperature	82.04	40	81.5	Extreme Danger
90.5	54	97.5	Extreme caution	82.4	56	84.2	caution	80.6	31	79.6	comfortable temperature	80.6	40	80.4	Extreme Danger
91.0	60	102.2	Extreme caution	83.1	58	85.7	caution	81.3	34	80.3	caution	81.5	45	81.6	Extreme Danger
93.2	67	113.6	Danger	86.0	60	91.1	extreme caution	82.0	35	81.0	caution	84.2	47	84.8	Extreme Danger
95.0	70	122.6	Danger	88.2	64	97.4	extreme caution	86.0	45	86.6	caution	87.8	50	90.7	Extreme Danger
93.2	64	111.1	Danger	88.2	65	98.0	extreme caution	86.7	44	87.3	caution	86	48	87.3	Extreme Danger
89.6	48	93.0	Extreme caution	86.0	45	86.6	caution	82.4	32	80.9	caution	86	38	85.0	Extreme Danger
93.2	58	106.4	Danger	87.3	54	91.2	extreme caution	73.4	28	76.3	comfortable temperature	89.6	44	91.5	Extreme Danger
94.6	60	112.0	Danger	91.0	57	100.4	extreme caution	73.9	30	76.6	comfortable temperature	91.4	47	95.8	Extreme Danger
89.6	61	99.3	Extreme caution	92.3	60	105.5	Danger	75.2	32	77.1	comfortable temperature	90.5	45	93.3	Extreme Danger
-	-	-	-	88.7	52	93.0	extreme caution	78.8	34	78.8	comfortable temperature	84.2	40	83.5	Extreme Danger
-	-	-	-	-	-	-	-	80.6	38	80.2	caution	-	-	-	-

Table 6: Heat index values during removing shuttering work during four seasons in India as per IMD

April -June (Pre-monsoon)				June -September (Monsoon)				Risk level	October -December(Post Monsoon)				December -April(winter)				Risk level
Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level		Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	
86	54	89.1	caution	83.3	54	85.1	caution	69.8	27	75.6	comfortable temperature	77.7	30	78.0	comfortable temperature		
84.2	54	86.3	caution	82.9	57	85.2	caution	71.2	32	76.4	comfortable temperature	78.3	34	78.5	comfortable temperature		
80.6	50	81.4	caution	86.0	60	91.1	caution	72.5	34	76.7	comfortable temperature	79.3	38	79.4	comfortable temperature		
80.6	50	81.4	caution	72.5	40	77.0	comfortable temperature	80.6	35	79.9	comfortable temperature	82.4	38	81.6	caution		
93.2	56	105.0	Danger	72.1	37	76.8	comfortable temperature	84.2	38	83.2	caution	72.1	27	75.9	comfortable temperature		
89.6	54	95.7	Extreme caution	80.6	48	81.1	caution	89.6	40	90.1	caution	72.3	29	76.2	comfortable temperature		
89.6	50	93.9	Extreme caution	82.4	50	83.2	caution	86.0	45	86.6	caution	75.2	34	77.3	comfortable temperature		
95	45	101.9	Extreme caution	86.0	55	89.4	caution	94.1	48	101.8	caution	80.6	38	80.2	caution		
89.6	40	90.1	caution	87.8	58	93.8	extreme caution	71.6	25	75.6	comfortable temperature	81.5	41	81.1	caution		
93.2	42	96.7	Extreme caution	80.6	35	79.9	comfortable temperature	75.2	30	77.0	comfortable temperature	70.7	27	75.7	comfortable temperature		
98.6	54	118.2	Danger	81.5	37	80.7	caution	76.1	32	77.4	comfortable temperature	71.1	29	76.0	comfortable temperature		
100.94	57	129.1	Extreme danger	81.3	38	80.7	caution	76.6	33	77.7	comfortable temperature	72.5	31	76.4	comfortable temperature		
98.6	54	118.2	Danger	82.4	42	82.0	caution	78.3	38	78.7	comfortable temperature	73.4	33	76.8	comfortable temperature		
99.5	56	123.1	Danger	82.4	39	81.7	caution	80.6	30	79.6	comfortable temperature	75.0	38	77.4	comfortable temperature		
89.6	50	93.9	Extreme caution	79.7	30	79.0	comfortable temperature	81.5	32	80.3	caution	84.2	34	82.6	caution		
89.6	57	97.2	Extreme caution	71.8	27	75.9	comfortable temperature	86.0	41	85.7	caution	89.6	39	89.8	caution		
90.5	60	100.9	Extreme caution	72.9	29	76.3	comfortable temperature	89.6	45	91.8	extreme caution	82.4	32	80.9	caution		
93.2	68	114.4	Danger	73.6	32	76.7	comfortable temperature	-	-	-	-	86.0	31	83.9	caution		
93.74	71	119.0	Danger	-	-	-	-	-	-	-	-	-	-	-	-		

Table 7: Heat index values during Painting work during four seasons in India as per IMD

April -June (Pre-monsoon)				June -September (Monsoon)				October -December(Post Monsson)				December -April(winter)			
Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level
86.0	45	86.6	caution	89.6	45	91.8	Extreme caution	77.0	28	77.5	comfortable temperature	78.3	28	78.1	comfortable temperature
89.6	47	92.6	extreme caution	90.5	48	94.6	Extreme caution	78.4	28	78.2	comfortable temperature	79.7	30	79.0	comfortable temperature
92.8	50	100.3	extreme caution	92.3	50	99.2	Extreme caution	78.8	29	78.5	comfortable temperature	82.4	30	80.8	caution
93.7	52	103.6	Danger	94.1	55	106.6	Danger	80.1	29	79.2	comfortable temperature	82.6	31	81.0	caution
89.6	55	96.2	extreme caution	92.7	55	103.0	Extreme caution	82.0	35	81.0	caution	82.4	32	80.9	caution
93.2	57	105.7	Danger	89.6	49	93.4	Extreme caution	82.6	38	81.7	caution	86.0	42	85.9	caution
95.0	62	114.9	Danger	82.4	32	80.9	caution	80.1	29	79.2	comfortable temperature	80.6	35	79.9	comfortable temperature
96.8	68	127.2	extreme Danger	82.9	32	81.4	caution	81.5	32	80.3	caution	83.3	38	82.3	caution
93.2	67	113.6	Danger	83.3	34	81.9	caution	83.3	35	82.0	caution	81.0	38	80.4	caution
86.0	60	91.1	extreme caution	84.2	36	82.9	caution	85.5	39	84.6	caution	80.6	37	80.1	caution
86.0	45	86.6	caution	82.4	38	81.6	caution	86.0	40	85.4	caution	77.0	29	77.6	comfortable temperature
89.6	48	93.0	extreme caution	83.3	38	82.3	caution	86.0	38	85.0	caution	77.7	30	78.0	comfortable temperature
95.0	54	108.2	Danger	77.0	28	77.5	caution	89.6	45	91.8	Extreme caution	80.6	31.2	79.6	comfortable temperature
96.8	60	118.6	Danger	78.1	30	78.2	caution	89.6	43	91.1	Extreme caution	86.0	40	85.4	caution
98.6	64	129.2	extreme Danger	78.1	30	78.2	caution	89.2	40	89.6	caution	87.8	42	88.2	caution
89.6	45	91.8	extreme caution	80.6	32	79.7	caution	87.8	40	87.6	caution	82.4	41	81.9	caution
87.8	45	89.1	caution	81.5	31	80.2	caution	82.4	32	80.9	caution	82.4	40	81.8	caution
88.7	46	90.8	caution	100.0	32	103.6	Extreme caution	85.1	32	83.2	caution	83.3	41	82.8	caution
86.0	47	87.1	caution	77.0	30	77.7	caution	86.0	34	84.3	caution	84.7	43	84.6	caution
86.2	50	88.2	caution	77.4	34	78.1	caution	82.4	34	81.1	caution	82.4	41	81.9	caution
				78.1	34	78.4	comfortable temperature	83.3	35	82.0	caution	75.2	28	76.8	comfortable temperature
				78.8	38	79.0	comfortable temperature	80.6	35	79.9	comfortable temperature	77.4	30	77.8	comfortable temperature
				77.5	38	78.4	comfortable temperature					80.6	34	79.9	comfortable temperature
				78.4	38	78.8	comfortable temperature					81.3	32	80.2	caution
												80.6	30	79.6	comfortable temperature

Table 8: Heat index values during Carpentry work during four seasons in India as per IMD

April -June (Pre-monsoon)				June -September (Monsoon)				October -December(Post Monsson)				December -April(winter)			
Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level	Temp (F)	Humidity (%)	Heat index	Risk level
89.6	48	93.0	Extreme caution	86.0	38	85.0	caution	84.2	35	82.8	caution	82.4	34	81.1	caution
93.2	52	102.4	Extreme caution	85.6	37	84.5	caution	89.6	36	88.9	caution	82.94	32	81.4	caution
94.1	54	105.9	Danger	79.3	34	79.1	caution	93.2	42	96.7	caution	82.94	30	81.2	caution
96.8	57	115.8	Danger	78.6	30	78.4	caution	95.4	44	102.0	extreme caution	82.22	31	80.7	caution
96.3	58	115.1	Danger	88.5	40	88.6	caution	95.0	44	101.3	extreme caution	80.6	29	79.5	caution
95.0	48	103.8	Extreme caution	91.2	41	92.9	caution	93.2	40	95.8	extreme caution	80.6	29	79.5	caution
86.4	46	87.3	caution	90.9	42	92.7	caution	86.0	35	84.5	caution	83.3	30	81.4	caution
84.0	40	83.3	caution	91.4	45	94.9	caution	86.0	45	86.6	caution	82.4	31	80.9	caution
91.8	46	96.0	Extreme caution	92.3	48	98.1	caution	86.9	47	88.3	caution	80.6	30	79.6	caution
94.1	46	100.6	Extreme caution	90.3	41	91.5	caution	87.4	47	89.1	caution	81.5	32	80.3	caution
95.5	50	106.5	Danger	93.0	42	96.4	caution	89.6	50	93.9	extreme caution	82.4	34	81.1	caution
96.4	54	112.0	Danger	94.1	46	100.6	caution	86.0	47	87.1	caution	78.8	30	78.5	caution
96.8	60	118.6	Danger	93.6	44	98.4	caution	86.0	45	86.6	caution	77	28	77.5	caution
95.5	60	114.7	Danger	86.0	41	85.7	caution	82.4	40	81.8	caution	81.5	30	80.1	caution
86.4	40	85.9	caution	80.6	38	80.2	caution	80.6	37	80.1	caution	82.4	32	80.9	caution

88.2	41	88.4	caution	85.6	45	86.1	caution	89.6	40	90.1	caution	82.76	33	81.3	caution
90.3	45	93.0	Extreme caution	81.5	40	81.0	caution	88.7	40	88.8	caution	82.4	30	80.8	caution
97.7	55	116.5	Danger	80.6	40	80.4	caution	86.9	38	86.1	caution	75.2	29	76.9	comfortable temperature
100.8	57	128.5	Extreme Danger	80.4	39	80.1	caution	85.6	34	84.0	caution	75.2	29	76.9	comfortable temperature
104.4	60	146.2	Extreme Danger	78.6	32	78.6	caution	99.3	30	101.2	caution	71.6	28	76.0	comfortable temperature
101.3	60	134.2	Extreme Danger	84.9	35	83.4	caution	90.3	29	88.1	caution	80.6	29	79.5	comfortable temperature
96.8	57	115.8	Danger	86.2	40	85.6	caution	82.4	34	81.1	caution	82.04	32	80.7	caution
87.1	42	87.2	caution	89.6	48	93.0	caution	83.3	35	82.0	caution	84.2	35	82.8	caution
90.3	42	91.9	Extreme caution	84.2	42	83.8	caution	80.6	35	79.9	caution	82.4	32	80.9	caution
92.8	47	98.6	Extreme caution	81.5	38	80.8	caution	78.8	30	78.5	caution	81.5	30	80.1	caution
94.6	50	104.4	Danger	81.3	35	80.4	caution	79.3	31	78.9	caution	-	-	-	-
97.2	55	115.0	Danger	80.6	30	79.6	caution	78.6	30	78.4	caution	-	-	-	-
93.6	54	104.5	Danger	-	-	-	-	-	-	-	-	-	-	-	-

5. Discussions and Conclusions:

- 1) The extreme Danger condition with respect to heat stress was observed during pre-monsoon in earth work excavation, bar cutting, bar bending, form work, removing of shuttering, concrete pouring, brickwork, carpentry construction activities.
- 2) During monsoon no cases of extreme Danger and Danger have been recorded. Only caution and extreme caution condition reported.
- 3) In Post monsoon in column shuttering activity at 4.00 pm recorded as Danger and others reported as caution and Extreme caution conditions.
- 4) In winter season comfortable, caution and extreme caution conditions were reported in outside building construction activities.
- 5) Through the evaluation of heat stress index in outdoor building construction activities during different seasons in semi-arid climate the control measures for temperature and humidity hazards can be implemented especially administrative measures and use of Personal Protective Equipment such as hats, sun screen, cooling vests to help the workers to protect themselves from heat stress during summer or pre-monsoon season when extreme Danger and Danger conditions were reported with respect to heat index.

6. References :

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