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RESEARCH ARTICLE OPEN ACCESS

Construction Site Heat Stress Levels using the WBGT Index

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Abstract:

People undertaking construction work in hot and humid environments are at a high risk of heat stress because of their nature of work which is demanding. The objective of the study was: to assess the duration of exposure to direct sunlight, perceived physical exertion and workload intensity of construction workers on site during slab construction; to measure the heat levels of a construction site in a hot and humid environment; and to assess heat stress risk on construction workers using the WBGT index. The levels of exposure of construction workers to direct sunlight was recorded, perceived exertion recorded using the Borg CR10 perceived exertion scale and workload was classified based on the ACGIH screening criteria. Wet, Dry and Globe thermometer temperature were recorded in degrees Celsius (°C). Using the WBGT Index to assess the heat stress risk, the study found out that, construction workers in the hot and humid environment of Mombasa were working under great discomfort and were likely to suffer from heat stress, unlike their counterparts in Nairobi who were working under little or no discomfort. It was further noted that temperatures on construction sites could reach higher levels than the reported meteorological data. Therefore Construction managers and contractors were recommended to measure the levels of WBGT on construction sites in hot and humid environments and issue alerts to construction workers working in the open environment to protect them from the likelihood of heat stress. Changes to dress code, worker rotation and flexible working hours were also to be adopted. It was concluded that heat exposure guidelines for hot and humid environments in Kenya should be developed by the authorities.

Keywords — **Heat Stress, Construction site, WBGT, Hot and Humid, Construction workers**

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I. INTRODUCTION

Construction is a strenuous physical activity in nature and with the majority of construction work being done in the open where direct solar radiation puts workers at a high risk of heat stress. Slab casting in Kenya is mostly done manually on site with only a few machines such us hoists and mixers generally to save on costs. It is during slab casting stage that workers are mostly prone to heat stress because the work is commonly done during the daytime and has to be completed by the end of the day. Construction workers have to endure strenuous activities such as carrying aggregates into the mixer for the entire day. Such strenuous work in hot and humid environments can result into impairments which can lead to accidents on-site. Construction workers who are prone to prolonged exposure to intense heat and humidity are likely reduce their interest and concentration, therefore increasing their irritability which may lead to illnesses that have a relation to heat (Hancher & Abdi-Elkhalek, 1998). It is estimated by the ILO that by 2030, 2 per cent of total working hours worldwide is projected to be lost every year. The reasons being workers will find it too hot to work at certain instances or because workers will have to work at a slower pace. Western Africa may have a 5 per cent productivity reduction by the year 2030 (International Labour Organisation, 2019). The effects of the rise in temperatures are felt differently across jobs and employment industries. Jobs that involve working in the open sun with high physical exertion levels are mostly affected by the rise of heat levels. Construction workers and those in the agriculture sector working in the open are expected to be severely affected (International Labour Organisation, 2019). Physiological heat strain depends on the exposure time and the degree of maintaining a core body-temperature 36.5°C to 37.5°C, skin temperature of 30°C and head temperature 34°C to 35°C (Yi & Chan, 2014). Economically heat stress is increasingly becoming a challenge to economic activity. Businesses ability to operate during the hottest hours is reduced and it can be costly to adapt to these new conditions (International Labour Organisation, 2019).

Reduced labour productivity has an association with external outdoor temperatures above 24°C to 26°C. At 33 to 34°C, workers lose 50 per cent of their work capacity while operating at moderate intensity (International Labour Organisation, 2019). The objectives were to assess the duration of exposure to direct sunlight, perceived physical exertion and workload intensity of construction workers on site during slab construction, to measure the heat levels of a construction site in a hot and humid environment and to assess heat stress risk on construction workers using the WBGT index. The assumption is that Construction workers participating in the study will have acclimatized to the climate of Mombasa and the activity that will be measured is steel bar reinforcement works and slab casting. This is because it is assumed that steel reinforcement bar works and slab casting works are one of the most labour intensive and time consuming activities on a construction site and it is normally done in the open sun. It is important for construction managers to familiarize with the prevailing environmental conditions the site is located. These environmental conditions affect. The study area was confined to Mikindani, Jomvu constituency of Mombasa County. In this region there exists a variety of formal building construction sites that are easily accessible and in close geographical proximity. Mombasa being a hot and humid environment provides the best location for the study construction workers ability to focus on their work and be productive. Heat in hot and humid environments affects the construction workers in two main ways: The rate of productivity and heat related health and safety issues.

Palmer and Creagh (2013) noted that if the humidity increases then productivity decreases. This study will seek to identify the methods that can maintain productivity at optimum levels during hottest months in the hot and humid environment of Mombasa, Kenya. Thus, it was an enquiry to gather facts and figures on the present methods used by contractors in ensuring construction workers in hot and humid conditions maintain productivity during the hottest months in Mombasa. The study is limited to two construction sites, one in a hot and humid environment and a comparative site in another environment. The study did not concentrate on a large population because it required a construction site undertaking a particular activity The following was excluded from the study:

- workers who have not been acclimatized to the environmental conditions
- Interaction and interference with the workers while working

“Heat stress” refers to body heat that is received in excess which the body is not able to tolerate without physiological impairment (Kjellstrom et al., 2016). Wet Bulb Globe Temperature (WBGT) is a combination of a weighted average between different measures of heat. These include wet-bulb, globe and dry-bulb or air temperature which reflects the combined effect of humidity, temperature, wind and sun rays. It is used in the measurement of the performance of athletes, soldiers and in this case outdoor workers such as construction workers (Epstein & Moran, 2006; Lemke & Kjellstrom, 2012). WBGT also serves as the metric for heat stress standard by the International Organization for

Standardization ISO 7243 which is used for determining ergonomic effects of thermal environments. After the WBGT is measured, the adjustment in clothing is factored in and workload converted into metabolic rate. ACGIH, Threshold Limit Values (TLV) and Action Limit table is used to find out about the risk of exposure to heat stress. Action Limit (AL) is used for determining risk of un-acclimatized workers while TLV for workers who are acclimatized (NIOSH, 2016).

Construction workers are predominantly affected by heat stress. This is because of immense body heat production caused by physically tasks that are demanding, and conditions that are hot and humid (Yi & Chan, 2017). Construction workers are vulnerable to heat stress because majorities participate in heavy work in the open outdoors. WBGT can be used to measure both indoor and outdoor environments as follows:

1. Measuring WBGT for outdoor environments with direct exposure to the sun:

WBGT=0.7xTempwet bulb + 0.2xTempglobe + 0.1xTempair

2. Measuring WBGT for indoors or outdoors without direct exposure to the sun:

WBGT=0.7xTempwet bulb+0.3xTempglobe

Where:

Tnwb	:	natural wet bulb temperature
Tg	:	globe temperature
Tdb	:	dry bulb/air temperature

Clothing has an effect on the heat exchange rate between the air and the skin. To calculate heat exchange it is necessary to apply correction factors that reflect the characteristics, type and amount of the clothing an individual is wearing (NIOSH, 2016).

The ACGIH metabolic work rates represent impacts to the body core temperature from the heat produced internally as exertion increases. Select a work category in the ACGIH TLV's and BEI'S that best represents the workload using the examples as a guide. If different work activities are planned for the day, using the heaviest workload activity to determine the estimated metabolic rate (MRest) will indicate if it is possible the workers exposure will exceed the TLV or AL without controls. Using the lowest expected work load will indicate if other controls are necessary to reduce exposure for any work activity (i.e., scheduling work at a different time).

Multiply the metabolic rate by the ratio of the workers body weight to 70 kg (154 lbs) to determine the MRest.

MRest = work expectations (Watts from figure 2.5) x worker body weight
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70 kg or 154 lbs

Where:

MRest = Estimated Metabolic rate
Work expectations (Watts f) =
Light(180W), Moderate(300), Heavy(415) and Very Heavy(520)
Worker Body Weight = as measured in kg

Workload can be converted into metabolic rate using the TLV's in ACGIH"2017 TLVs and BEIs". This is because as workload increases because of work demands and physical exertion, metabolic rate increases. To determine the degree of heat stress exposure, the work pattern and demands must be considered (ACGIH, 2017). The Threshold Limit Value **(**TLV) is the temperature at which there is a heat hazard present for an acclimatized worker and the Action Limit (AL) is the temperature at which there is a heat hazard present for a non-acclimatized worker.

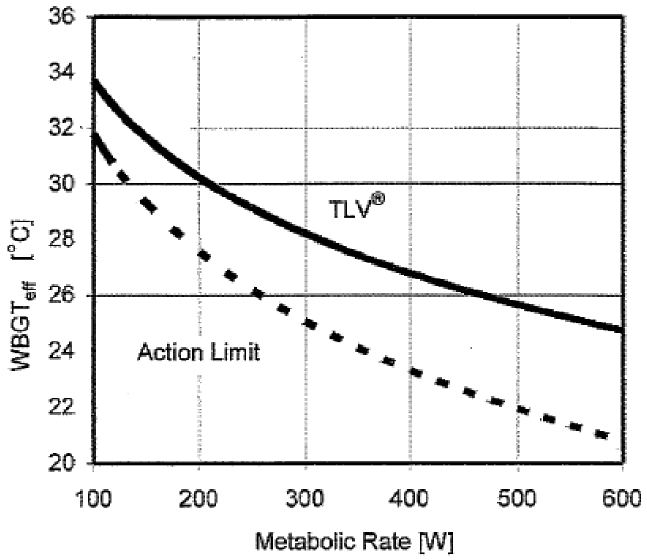

Fig. 1 ACGIH TLV & Action Limit Source: ACGIH (2017)

TLV® (solid line) and Action Limit (broken line) for heat stress. WBGTeff is the measured WBGT plus the Clothing-Adjustment Factor. Determine the TLV or AL by using Figure 1, ACGIH TLV & Action Limit. The TLV is where the $WBGT_{eff}$ and the metabolic rate intersect with the solid line and AL is where they intersect with the dotted line. If there are conditions above TLV related to heat related disorders such as fatigue, nausea, dizziness or light headedness then regimens should be applied such as work rest or stopping work and providing shade.

II. MATERIALS AND METHODS

In this study, a descriptive quantitative approach was preferred because the aim was to provide an accurate description of the event. The event being construction workers manually carrying out floor slab construction work in a hot and humid environment. The research was an observational analytic study. The study sought to observe subjects rather than interact with them because, the researcher wanted to observe workers undertaking their jobs without interruption so as to have a clear understanding on what takes place when workers are exposed to heat stress. The target population which formed the focus group is therefore construction workers undertaking any kind of work during slab casting stage. The work undertaken is mostly manual with less use of machinery which is commonly undertaken by the smaller contractors such as NCA 7 and 8 because this is the most vulnerable group in relation to heat stress issues. Workers were 18 years and above and below the age of 50 years. This is because thermoregulatory function declines with age therefore older people are particularly sensitive to temperature extremes (Wilson, 2011). Construction workers aged 50 and above would probably not be able to meet the physiological demands of the work involved and therefore are likely to suffer from heat stress. Both genders were selected. Another criterion was that workers should have carried out construction work for more than 2 weeks within the past 30 days in the region for the purposes of acclimatization. Some of the workers anticipated for the research included:

- Rebar worker – fixes slab steel bars
- Sand loader – Loads sand into the Concrete mixer
- Ballast Loader – Loads ballast into the Concrete mixer
- Vibrator operator – Operates the vibrator during slab casting
- Concrete mixer operator – Operates the concrete mixer during slab casting
- Concrete distributor – Carries concrete from the concrete mixer/hoist and pours it to the slab.
- Tally manager – Tallies the number of sand, ballast, cement and water poured into the concrete mixer
- Form work constructor – Prepares formwork for slab casting and monitors formwork during slab casting
- Electrician – The electrician monitors electrical conduits installed during slab casting
- Plumber – The plumber monitors plumbing installations during slab casting
- Foreman/ Site supervisor – Supervises and monitors the entire process of slab casting

The population is therefore likely to be small based on the purpose of the research. This will therefore inform the sampling method to be used. The study adopted purposive sampling which is a type of non-probability sampling because of the nature of the research which involved studying a construction site with a limited number of construction workers. Purposive sampling is widely used in qualitative research for identification and selection of information related to the phenomenon of interest. Purposive or judgmental sampling is a strategy in which particular settings persons or events are selected deliberately in order to provide important information that cannot be obtained from other choices (Maxwell, 1996) It is where the researcher includes cases or participants in the sample because they believe that they warrant inclusion. The method aims at obtaining data from a focus group that is purposively selected rather than from a statistically representative sample of a broader population.

A. *Preliminary study*

A preliminary study was undertaken to reduce the bias in selecting the number of participants in the study. The preliminary study was also conducted to find out about the number of construction workers that were working during slab casting using the manual technique at five construction sites in Mombasa. The preliminary study found out the following:

TABLE I
ASSESSMENT OF THE TARGET POPULATION

Construction site Location	Workers at risk	Other workers	Target population per site
Mikindani	12	4	16
Kisauni	21	7	28
Changamwe	17	3	20
Makande	18	5	23
Bombolulu	13	3	16
Total	**81**	**22**	**103**
Average number of workers per site			**21**

Source: Field Study, 2020

It was noted that larger sites preferred to use machinery for slab casting rather than manual labour. Smaller sites constructing residential units and apartments less than four storeys preferred the use of construction workers to undertake manual casting of the slab.

From the preliminary study, 21 (±2) Construction workers were purposively selected as subjects to be studied per construction site, therefore only sites with 19 or more construction workers at the slab construction stage were to be considered. The margins of tolerance of (±2) was identified to allow the research to find a construction site with a definite range of workers between 19 and 23 rather than a site with exactly 21 workers but still maintain the confidence levels as shown in Table 1.

Field survey data was collected using the WBGT method. Yi & Chan (2017) revealed that WBGT has the highest validity in forecasting the impacts of occupational heat exposure in the construction industry. Measurements were taken using a Wet and Dry bulb thermometer whose model is SK-RHG skSATO made in Japan. For radiant heat measurements a globe whose diameter is 150mm/ 6inch was used. The 150mm/ 6inch globe thermometer is regarded as a standard in the Industry as ISO 7243 2008. The study also adopted a comparative study in a non humid environment to increase the reliability of the results. The key items in the study were the length of time (duration) a construction worker is exposed to heat in the open while working in relation to the level of temperature (WBGT) recorded during the field study. The units of observation are therefore the environmental and occupational parameters that affect construction workers. Construction workers consent was sought through the foreman/construction manager and their participation was voluntary. Before the study was conducted, a pre-study data collection sheet was filled with the assistance of the researcher.

Since slab casting is commonly a one day event in Kenya, a preliminary study was undertaken to find out about the number of construction workers per site in 5 different site locations. An average of 21 (±2) construction workers per construction site was observed. The preliminary study also noted the job description of the workers and activities on site. 11 job categories were identified and recorded. A site meeting the criteria of the minimum number of construction workers in a site was identified at Kwa-Shee, Mikindani ward in Mombasa County. On the day of the field investigation, a qualitative field survey was undertaken at the construction site. The site selected was at the concrete slab construction stage and the traditional manual concreting was being undertaken. This includes construction workers were performing manual loading and pouring, with the only machinery on site being a concrete mixer, a hoist and a concrete vibrator. The study used continuous monitoring and observation approach to identify the levels of exposure to direct sun radiation. To carry out the investigation, the researcher undertook a passive role by observing the activities of the Construction workers on the construction site. The aim was to record the length of time spent in the open field under direct exposure to the sun while working, record the perceived exertion using the Borg CR10 perceived exertion scale and classify workload based on the ACGIH screening criteria. The Borg CR10 developed by Gunnar Borg in 1982 which uses several cues such as breathing pattern, sweat and fatigue level to determine the level of perceived exertion.

Field surveys were carried out at two construction sites which are in Mombasa and Nairobi in the month of October in the year 2020. Mombasa is a hot and humid environment and Nairobi was used as a comparative site. The measurements to be taken included the following:

1. Dry Bulb temperature - Measurements were taken using a Wet and Dry bulb thermometer whose model is SK-RHG skSATO
2. Wet bulb temperature - Measurements were taken using a Wet and Dry bulb thermometer whose model is SK-RHG skSATO
3. Globe thermometer temperature. - Measurements were taken using a Globe thermometer whose diameter is 150mm.
4. Humidity – Humidity was found by subtracting the temperature of the wet-bulb thermometer from the Dry-bulb thermometer.

Measurements were taken after every 20 minutes starting at 11am which was considered the beginning of the hottest period of the day. Measurements were taken using a wet and dry bulb thermometer and the Globe thermometer which were placed on the concrete slab being constructed in the open air. The following results were observed as shown in Table II.

Fig. 1 Wet and Dry bulb Thermometer and Globe thermometer in Mombasa

Fig. 2 Wet and Dry bulb Thermometer and Globe thermometer in Nairobi

TABLE II
DESCRIPTION OF ACTIVITIES OBSERVED: EXPOSURE LEVELS, PERCEIVED EXERTION AND INTENSITY OF WORKLOAD

No.	Job title	Weight (kg)	Tasks/Activities observed	Exposure duration	Perceived physical exertion (Borg CR10 scale)	Classification of workload (ACGIH category)
1	Reinforcement bar Worker 1	68	Modification of steel reinforcement bars	Extremely High (4)	Very Hard (7)	Moderate (2)
2	Reinforcement bar Worker 2	76	Modification of steel reinforcement bars	Extremely High (4)	(7)	Moderate (2)
3	Sand Loader 1	85	Carrying sand using buckets at rapid pace	Extremely High (4)	Nearly maximal (9)	Heavy (3)
4	Sand Loader 2	78	Carrying sand using buckets at rapid pace	Extremely High (4)	(9)	Heavy (3)
5	Sand Loader 3	67	Carrying sand using buckets at rapid pace	Extremely High (4)	(9)	Heavy (3)
6	Ballast Loaders 1	82	Carrying ballast using buckets at rapid pace	Extremely High (4)	Nearly maximal (9)	Heavy (3)
7	Ballast Loaders 2	75	Carrying ballast using buckets at rapid pace	Extremely High (4)	(9)	Heavy (3)
8	Ballast Loaders 3	76	Carrying ballast using buckets at rapid pace	Extremely High (4)	(9)	Heavy (3)
9	Vibrator Operator	65	Vibrating concrete	High (3)	Somewhat hard (4)	Moderate (2)
10	Concrete mixer operator	75	Operating concrete mixer	Moderate(2)	Hard (6)	Moderate (2)
11	Concrete distributor 1	87	Using a wheel-barrow to distribute concrete at rapid pace	Extremely High (4)	Maximal (10)	Heavy (3)
12	Concrete distributor 2	75	distribute concrete at rapid pace	(4)	(10)	Heavy (3)
13	Concrete distributor 3	74	distribute concrete at rapid pace	(4)	(10)	Heavy (3)
14	Concrete distributor 4	79	distribute concrete at rapid pace	(4)	(10)	Heavy (3)
15	Tally manager	74	Using voice to control number of materials placed into the concrete mixer	High (3)	Moderate (3)	Light (1)
16	Form work constructor 1	65	Modifying form work	Moderate(2)	Very Hard (7)	Moderate (2)
17	Form work constructor 2	82	Modifying form work	Moderate(2)	Very Hard (7)	Moderate (2)
18	Electrician	70	Modifying conduits	Low (1)	Moderate (3)	Light (1)
19	Plumber	78	Modifying pipes	Low (1)	Moderate (3)	Light (1)
20	Foreman/site supervisor	91	Working around and using voice frequently	Low (1)	Easy (2)	Light (1)

Source: Field Study, 2020

During manual slab construction, construction workers are divided into groups with specific duties. These groups include the loaders, the distributers, and the machine operators as shown in table II. The slab casting stage in Kenya is mainly undertaken by informal construction workers and normally completed within a day. These workers are commonly known as casual workers in Kenya and are attributed as unskilled workers. Construction workers undertaking concreting are required to work until the task is completed.

TABLE III

DESCRIPTION OF ACTIVITIES OBSERVED: EXPOSURE LEVELS, PERCEIVED EXERTION AND INTENSITY OF WORKLOAD

Worker category	**Worker No.**	**Workload** Observed	**Work Category** ACGIH	**Worker Weight**	**Metabolic Rate** (est.) W
Reinforcement bar Worker	1	2	Moderate	68	**291**
Reinforcement bar Worker	2	2	Moderate	76	**326**
Sand Loader	3	3	Heavy	85	**504**
Sand Loader	4	3	Heavy	78	**462**
Sand Loader	5	3	Heavy	67	**397**
Ballast Loaders	6	3	Heavy	82	**486**
Ballast Loaders	7	3	Heavy	75	**445**
Ballast Loaders	8	3	Heavy	76	**451**
Vibrator Operator	9	2	Moderate	65	**279**
Concrete mixer operator	10	2	Moderate	75	**321**
Concrete distributor	11	3	Heavy	87	**516**
Concrete distributor	12	3	Heavy	75	**445**
Concrete distributor	13	3	Heavy	74	**439**
Concrete distributor	14	3	Heavy	79	**468**
Tally manager	15	1	Light	74	**190**
Form work constructor	16	2	Moderate	65	**279**
Form work constructor	17	2	Moderate	82	**351**
Electrician	18	1	Light	70	**180**
Plumber	19	1	Light	78	**201**
Foreman/site supervisor	20	1	Light	91	**234**

Source: Field Study, 2020

TABLE IV
DESCRIPTION OF ACTIVITIES OBSERVED: EXPOSURE LEVELS, PERCEIVED EXERTION AND INTENSITY OF WORKLOAD

Comparing Wet Bulb Globe Temperature (WBGT) and Humidex (H) indices in Mombasa (exposed to heat stress) and Nairobi control group (non-exposed to heat stress)

	20mins	**40mins**	**60mins**	**80mins**	**100mins**
WBGT Index					
Group exposed to heat stress conditons (Mombasa)	30.62	30.44	30.39	30.69	30.79
Control group (Nairobi)	25.20	23.51	23.98	23.95	24.42

TABLE V
DESCRIPTION OF ACTIVITIES OBSERVED: EXPOSURE LEVELS, PERCEIVED EXERTION AND INTENSITY OF WORKLOAD

Comparing Wet Bulb Globe Temperature (WBGT) and Humidex (H) indices in Mombasa (exposed to heat stress) and Nairobi control group (non-exposed to heat stress)

	Number of samples	**Range**	**Mean**	**Standard deviation**	**Standard Error (SE)Mean**	***P* value** (*t* test)
WBGT Index						
Group exposed to heat stress conditons (Mombasa)	5	30.39 - 30.79	30.59	0.17	0.075	0.000
Control study (Nairobi)	5	23.42 - 24.98	24.13	0.64	0.286	

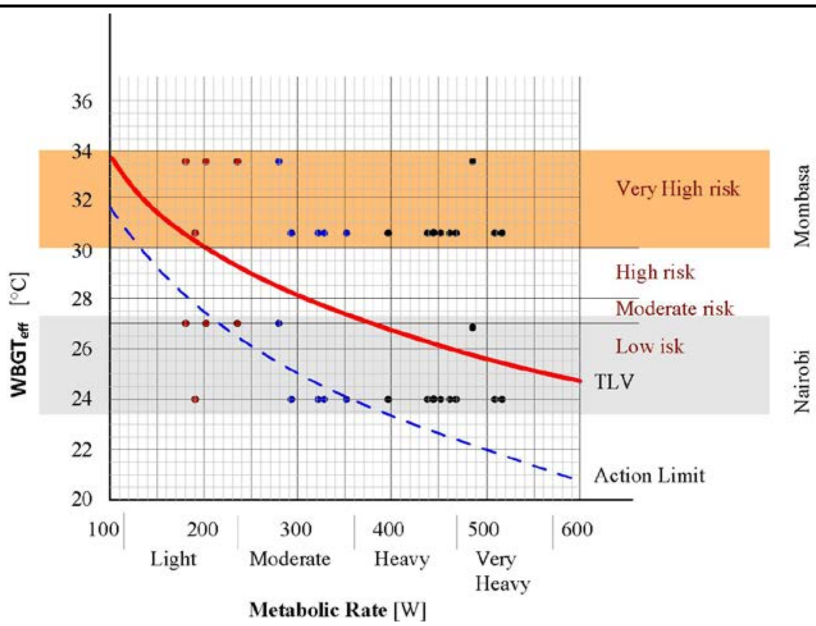

Fig. 3 Wet and Dry bulb Thermometer and Globe thermometer in Nairobi

Figure 3 shows the 20 workers in the study under two different environmental conditions. All Construction Workers in Mombasa were working under 'Very High Risk' according to ACGIH standards which are based on TLV's. All construction workers exceeded their threshold limit. ACGIH recommends that work rest regimens and provision of shade and water among other practices on site should be applied once the TLV is exceeded. It was noted that workers who wore coveralls were at higher risk than workers who were working bare-chested or with light t-shirts and pants/trousers.

Wearing coveralls in Nairobi did not place workers at risk unlike Mombasa. A ballast loader with a metabolic Rate of 486 and WBGT of 27°C exceeded the threshold limits set by ACGIH. The assessment of construction workers therefore shows that workers in Mombasa are at a significantly high risk of Heat Stress unlike Nairobi where Heat Stress would mainly be caused by the type of clothing worn by the construction worker.

B. Hypothesis Test

A hypothesis test was carried using a statistical test to compare and examine the associations between the results of the WBGT in Mombasa and Nairobi. An Independent paired t-test was used for the analysis. A paired t-test is used when we are interested in the difference between two variables (environmental measurements in Mombasa and Nairobi) for the same subject (Heat stress levels). The same group of Construction workers under analysis was investigated under two environmental conditions. The study hypothesis below was investigated.

H^0: Construction workers in Mombasa are not at a significantly high risk of heat stress due to the hot and humid environmental conditions.

H^1: Construction workers in Mombasa are at a significantly high risk of heat stress due to the hot and humid environmental conditions.

The paired ***t***-test was performed for Comparison and Association between WBGT results in Mombasa (hot and humid environment and Nairobi (control environment) using the Minitab® 19 Statistical software developed by Pennsylvania State University Researchers. The criteria for rejection of the null hypothesis are described by the following criteria:

Criteria for rejection: $|t_o| > t_{\frac{\alpha}{2},n-1}$

where:
t_o: test (t) statistic
t : test (t) - Critical value
α: Alpha
n: number of observations

WBGT variables *t*-test

Estimation for the paired difference

Figure 4 shows the results of the difference between Mean and SE Mean at 95% Confidence Intervals. The values were then used for the ***t***-test.

Differences between the Mean and SE Mean of the WBGT Index results in Mombasa and Nairobi

Mean	StDev	SE Mean	95% CI for μ_difference
6.374	0.582	0.260	(5.651, 7.097)

Fig. 4 Differences between the Mean and SE Mean of the WBGT Index results in Mombasa and Nairobi

***P*-value**

The ***P***-value for the test was ***P***= 0.000. The smaller the *P*-value signifies that the null hypothesis should be rejected. A *P*-value of ***P***=0.000 was less than Level of Significance (α = 0.05) and therefore was statistically significant. The Confidence Interval used was 95% was used for the Hypothesis.

Critical value

Critical value is the measurement used to calculate the margin of error within a set of data. If the calculated ***t*** value is greater than the critical ***t*** value, then the null hypothesis is rejected. The ***t***-critical value is the cut-off between retaining or rejecting the null hypothesis. Whenever the ***t***-statistic is farther from 0 than the ***t***-critical value, the null hypothesis is rejected.

The computed value of test statistic was $t\_o=24.49$. The conclusions about the difference in m ***P***-value eans is as follows: $|t\_o|=24.49>t\_(0.025,4)=2.776$, and the associated probability is very small P=0.000. Therefore, the null hypothesis of Construction workers in Mombasa are not at a significantly high risk of heat stress due to the hot and humid environmental conditions was rejected. At Significance Level $\alpha=0.05$, and sample size of n = 5, there is a strong evidence found to claim that a significant difference exists in the Wet Bulb Globe Temperature (WBGT) in the regions of Mombasa (exposed to heat stress) and Nairobi control group (non-exposed to heat stress). The high levels in WBGT results found in Mombasa indicate a significant high risk of heat stress for workers in Mombasa and a low risk of heat stress in Nairobi.

III. CONCLUSIONS

To record the duration of exposure to direct sunlight, perceived physical exertion and workload intensity of construction workers on site during slab construction. To carry out the investigation, the researcher undertook a passive role by observing the activities of the Construction workers on the construction site. The aim was to record the amount of time spent in the open field under direct exposure to the sun while working, secondly to record the perceived exertion using the Borg CR10 perceived exertion scale and thirdly to classify workload based on the ACGIH screening criteria. A timer was started at 11am midday. Multiple linear regression study was carried out to find the correlation between the variables. Finally the study was able to identify construction workers at risk of exposure to heat stress based on their amount of time exposed to direct sun-light. The study found that concrete distributors were the most affected by sunlight exposure, high workload intensity and physical exertion followed by ballast and sand loaders.

To measure the heat levels of a construction site in a hot and humid environment. Field surveys were carried out at two construction sites which are in Mombasa and Nairobi in the month of October in the year 2020. Mombasa is a hot and humid environment and Nairobi was used as a comparative site. Measurements were taken using Wet and Dry bulb thermometer whose model is SK-RHG skSATO (Japan) after every 20 minutes starting at 11am which was considered the beginning of the hottest period of the day. Measurements were taken using a wet and dry bulb thermometer and the Globe thermometer which were placed on the concrete slab being constructed in the open air. The Wet-bulb thermometer (Tnwb) recorded temperatures of between 26.8°C to 27.9°C in Mombasa and 19°C to22°C in Nairobi. Mombasa recorded a globe thermometer temperature range of 39.5°C to 44°C while Nairobi recorded 34.9°C to 39°C. Mombasa recorded temperatures between 31.9°C to 32.3°C and Nairobi 28.2°C to 28.5°C. Construction workers in Mombasa showed more interest than their counterparts in Nairobi about the topic and the researcher's measures to avoid heat stress that will be recommended and implemented by an Authority such as NCA. It appeared that they were suffering silently. The comparisons confirmed that environments that are hot and humid have negative effects on construction workers.

The study revealed that all WBGT levels were above to 30°C in the hot and humid environment of Mombasa. This is an indication that heat levels were not conducive for construction and therefore construction managers are advised to pay close attention to the weather patterns in the region.

It is recommended that when the WBGT levels are above 32°C, modifications should be carried out to ensure risk of heat stress is reduced. The study also strongly recommended the development of heat exposure guidelines for hot and humid environments in Kenya. The environment can also be modified under extreme cases. Contractors should be tasked to record WBGT rates throughout the day in a construction site.

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The paper wishes to acknowledge ACGIH Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®) whose guidelines which have been used in the preparation of this template. More information can be found at https://www.acgih.org/science/tlv-bei-guidelines/.

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