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# Measurement of Thermal Stress levels of Construction workers using Humidex Index

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## Abstract:

Open field workers such as construction workers have to carry out physical work in hot and humid conditions hence they are more vulnerable to thermal stress. The objective of the study was to assess thermal stress levels perceived by construction workers using the Humidex index. Field studies were conducted in October 2020 at two construction sites. One of the sites was in the hot and humid town of Mombasa and the other a comparative site in a cooler town of Nairobi in Kenya. 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 thermal stress, unlike their counterparts in Nairobi who were working under little or no discomfort. The study hypothesized that construction workers in Mombasa are at a significantly high risk of heat stress due to the hot and humid environmental conditions. A paired t-test was performed for Comparison using Humidex Index results in Mombasa and Nairobi for hypothesis testing. At P=0.000, using a Significance Level α=0.05, the null hypothesis was rejected. Therefore Construction managers and contractors were recommended to measure the levels of Humidity 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 thermal stress.

*Keywords* — Construction workers, Thermal Stress, Hot & Humid, Humidex

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## I. INTRODUCTION

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). 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 illnesses that have a relation to heat (Hancher & Abdi-Elkhalek, 1998). 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). Xiang et al. (2014) found that workers in the construction industry are one of the groups of workers most likely to be affected by climatic heat stress, second only to agricultural workers

In Kenya, construction workers who work under intensive heat include site labourers undertaking steel reinforcement works and masonry works such as block laying and slab casting. Working under Intensive heat causes reduction in productivity and hence the need for optimizing Labour productivity to meet the demands of the project. 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 has resulted into heat exhaustion, accidents on-site and reduction in overall productivity for construction workers. Reduced productivity causes delay on site and therefore has consequences to the overall project. Lamka, (2015) who studied productivity in construction sites in Kenya, noted that delays on site has caused losses on project's profit to the contractor; increased cost to the client and strained the working relationship between the parties in a project. This therefore creates a need to investigate methods that would allow construction activities to progress at an efficient pace during the hottest months and reduce negative impacts on construction projects.

In Kenya, regulations that exist to prevent heat related illnesses in the construction industry are few even though workers in the construction industry are among the ones who are likely to experience them. Although fatalities and illnesses related to heat can be prevented with appropriate rest cycles, rehydration and shade, and, there aren't any guidelines in the construction industry in Kenya to ensure construction workers work at optimum productivity during the hottest months in Mombasa.

The objective of the study was to assess heat stress risk on construction workers using Humidex index in Mombasa, Kenya. Humidex is a measure of how hot we feel. It is a parameter intended for the general public to express how the combined effects of warm temperatures and humidity are perceived. It provides a number that describes how hot people feel (CCOHS, 2020). The body attempts to maintain a constant internal temperature of 37°C at all times. In hot weather, the body produces sweat, which cools the body as it evaporates. As the humidity or the moisture content in the air increases, sweat does not evaporate as readily. Sweat evaporation stops entirely when the relative humidity reaches about 90 percent. Under these circumstances, the body temperature rises and may cause illness. Humidity can be described as the amount of water vapour that is within a given space. Humidity is measured as Relative Humidity which is a moisture percentage in air in relation to the amount it is able to hold when saturated at that particular temperature (NIOSH, 2016).

The construction industry is driven by productivity and target completion dates and therefore heat stress prevention measures are not high in the priority lists of contractors and not enforced on construction sites but plays a major role in the overall performance of a project. It is well known that environmental conditions affect productivity, injuries and accidents on site and the health of workers. While studying the various ways of improving productivity of a project and reducing accidents on site, researchers should also look at environmental conditions such as heat, which could be the underlying cause of reduction in productivity and an increase in accidents on site and not the carelessness of workers and the often blamed poor planning by construction managers.

## II. METHODOLOGY

The study began by reviewing previous literature relevant for this research to get an in-depth understanding of heat stress in hot and humid environments. Based on the approaches to methodologies studied in other related research papers, the researcher opted for cross-sectional case study through analytic observations with limited participation.

A case study is essentially an intensive investigation of the particular unit under consideration. (Kothari C. R., 2004). It was imperative that the field study assess construction workers in their natural environment with minimal participation and interference. Target population is the aggregate of all persons and items that conform to a given specification (Mugenda, 2003). The research set a specification of the population as workers working on a construction site during a specific stage in construction. At this specific stage construction workers are highly susceptible to heat stress because of the long hours of direct sun exposure.

The target population is therefore as follows:

- Construction workers undertaking their job on a construction site
- The stage of construction is the slab casting stage
- The construction site is in the hot and humid environment of Mombasa.

The study adopted purposive 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. Construction workers working in the open field in a construction site were identified per site and their activities observed without interference. The researcher played a passive role whilst observing the activities of the group who are construction workers. 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 temperature levels recorded during the field study. The study used the quantitative method of data analysis. The analysis was done with the help of Microsoft Office Excel 2007.This is a spreadsheet software program. The indices used for data analysis in this study was the Humidex Index

### A. *Preliminary Study*

A preliminary study was undertaken to reduce the bias in selecting the number of participants in the study. A preliminary study was conducted to find out about the number of construction workers that were working during slab casting using the manual technique at 5 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 |
|---|---|---|
| Mikindani | 12 | 4 |
| Kisauni | 21 | 7 |
| Changamwe | 17 | 3 |
| Makande | 18 | 5 |
| Bombolulu | 13 | 3 |
| | 81 | 22 |

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 research, case-study approach which was qualitative in nature was undertaken through a field survey at the construction. The site selected was at the concrete slab construction stage and the traditional manual concreting was undertaken. This includes construction workers undertaking manual loading and pouring with the only machinery on site being a concrete mixer, a hoist and a vibrator. Prior to the commencement of the study, a pre-study data sheet was administered to the workers. The aim was to capture details of the construction workers that included: age, gender, job description, voluntary participation and clothing worn. The data sheet also identified workers who had acclimatized. Later the temperature of some of the workers was recorded on the same data sheet. All workers Kenyans were between the age of 18 and 50. Construction workers older than 50 years of age were excluded from the study.

## III. RESULTS

Humidity levels on the two construction sites in Mombasa and Nairobi were recorded every 20mins from 11am during slab construction. Humidity levels of above 70% were recorded in Mombasa while Nairobi's highest Relative Humidity levels were at 60% as shown in Table II and Fig 1. Relative humidity in Mombasa stabilized in the second hour of measurement. As time went by Humidity in Nairobi dropped significantly while that of Mombasa remained constant.

TABLE II
COMPARISON BASED ON RELATIVE HUMIDITY BETWEEN NAIROBI AND MOMBASA

| Time (minutes) | Relative Humidity (%)According to RH Table (Nairobi) | Relative Humidity (%)According to RH Table (Mombasa) |
|---|---|---|
| 20 | 60% | 74% |
| 40 | 54% | 63% |
| 60 | 49% | 66% |
| 80 | 49% | 66% |
| 100 | 49% | 66% |
| 120 | 44% | 66% |

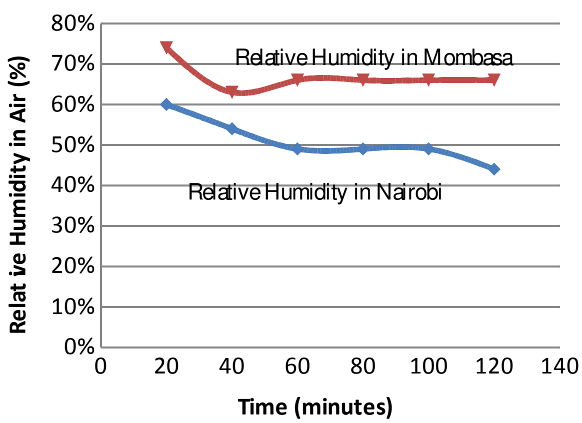


Fig. 1 Comparison based on Relative Humidity between Nairobi and Mombasa

To identify the degree of comfort/discomfort, the Humidex Index chart in Fig. 2 and Fig. 3 was used. The Humidex Index takes into account both heat and humidity levels of the environment. The values of the Dry-Bulb (air) temperature and the Relative Humidity were extrapolated and risk value identified.

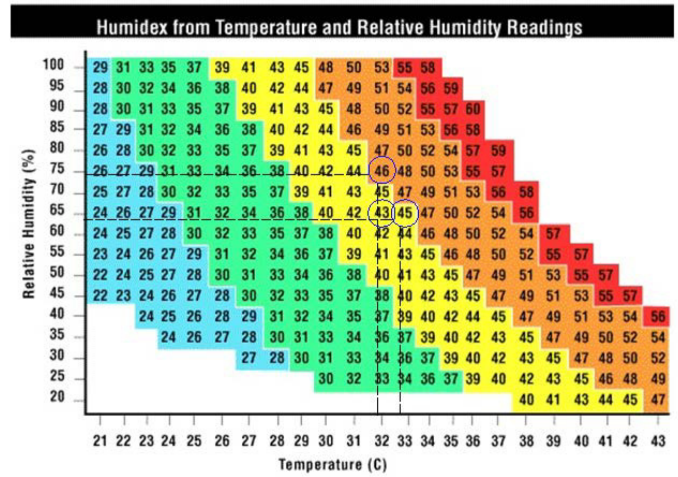


Fig. 2 Assessment using Humidex Index Chart from Readings in Mombasa

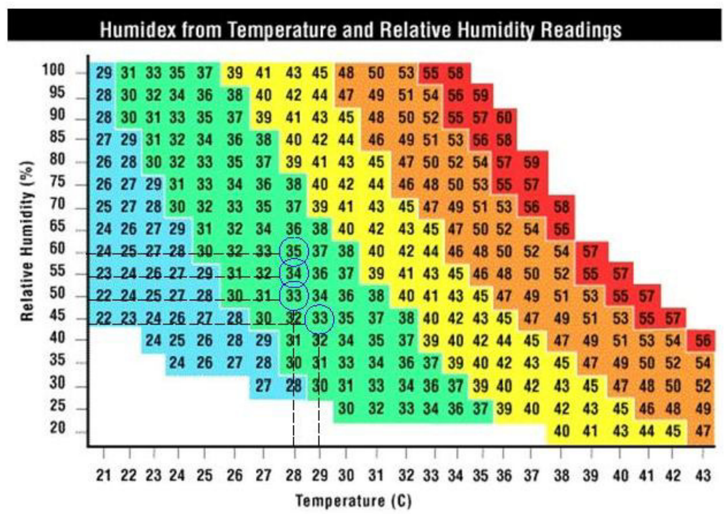


Fig. 3 Assessment using Humidex Index Chart from Readings in Nairobi

The degree of discomfort was analysed in Table 3 based on the Humidex values obtained in Fig. 2 and Fig. 3.

  

TABLE III
HUMIDEX VALUE AND DEGREE OF DISCOMFORT IN NAIROBI

| | Dry Bulb Thermometer (Tdb) | Relative Humidity (%)According to RH Table | Humidex Value | Degree of Comfort |
|---|---|---|---|---|
| 1 | 28.2 | 60 | 35 | Some Discomfort |
| 2 | 28.1 | 54 | 34 | Some Discomfort |
| 3 | 28.2 | 49 | 33 | Some Discomfort |
| 4 | 28.2 | 49 | 33 | Some Discomfort |
| 5 | 28.4 | 49 | 33 | Some Discomfort |
| 6 | 28.5 | 44 | 33 | Some Discomfort |

TABLE IV
HUMIDEX VALUE AND DEGREE OF DISCOMFORT IN MOMBASA

| | Dry Bulb Thermometer (Tdb) | Relative Humidity (%) | Humidex Value | Degree of Comfort |
|---|---|---|---|---|
| 1 | 31.9 | 74% | 46 | Dangerous |
| 2 | 32.8 | 63% | 45 | Great Discomfort, avoid exertion |
| 3 | 32.3 | 66% | 43 | Great Discomfort, avoid exertion |
| 4 | 32.3 | 66% | 43 | Great Discomfort, avoid exertion |
| 5 | 32.3 | 66% | 43 | Great Discomfort, avoid exertion |

Measurements were taken using a Wet and Dry bulb thermometer whose model is SK-RHG skSATO. In the analysis of values using the Humidex Index, Mombasa recorded 'Dangerous' levels of thermal stress as shown in Table IV. The construction workers were also suffering from 'Great Discomfort' during their slab casting. Workers were likely to suffer heat stroke or heat exhaustion based on these levels of heat stress. Humidex Index chart recommends that workers should avoid exertion at such levels of discomfort. It was noted that higher levels of Humidity in Mombasa was the major factor in the rate of discomfort observed followed by the Dry Bulb Temperature. When humidity is high, construction workers are likely to feel warmer because perspiration evaporates at a slower rate.

  

TABLE V
COMPARISON BASED ON RELATIVE HUMIDITY BETWEEN NAIROBI AND MOMBAS

| Humidex (H) indices in Mombasa (exposed to heat stress) and Nairobi control group (non-exposed to heat stress) | | | | | |
|---|---|---|---|---|---|
| | **20mins** | **40mins** | **60mins** | **80mins** | **100mins** |
| **HUMIDEX Index** | | | | | |
| Group exposed to heat stress conditons (Mombasa) | 46.00 | 45.00 | 43.00 | 43.00 | 43.00 |
| Control group (Nairobi) | 35.00 | 34.00 | 33.00 | 33.00 | 33.00 |

## IV. DISCUSSION

To identify the degree of comfort/discomfort, the Humidex Index chart was used. The Humidex Index takes into account both thermal and humidity levels of the environment. The values of the Dry-Bulb (air) temperature and the Relative Humidity were extrapolated and risk value identified. The Humidex index produced results showing Great Discomfort for construction workers with one Humidex Index reading in Mombasa indicating dangerous levels. The study found out that construction workers could suffer heat stress even in the cooler months of the year because of high humidity levels in the Coastal town of Mombasa. Construction managers can schedule physically demanding work in the morning before the heat levels rise during midday. Construction managers need to keep track of the Humidity levels during construction especially during slab construction which involves physically strenuous activities.

The computed value of test statistic from Table v for the Humidex Index results was $t_o=42.46$. The conclusions about the difference in means is as follows: $|t_o|=42.46>t_{(0.025,4)}=2.776$, and the associated probability is very small P= 0.000.

The results therefore indicate that construction workers in Mombasa are at a significantly high risk of heat stress due to the hot and humid environmental conditions leading to the null hypothesis being 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 Humidex results in the regions of Mombasa (exposed to heat stress) and Nairobi control group (non-exposed to heat stress). The high levels in Humidex 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

## V. CONCLUSIONS

Work and rest schedules should be adopted by contractors to enable workers to recover from an intensive work in hot and humid environments. Humidex guidelines should be adopted. Work rest schedules can also be planned when the conditions are at dangerous levels. Availability of clean drinking water and sun-shades at various points on a construction site should also be implemented. Contractors should be tasked to record WBGT rates throughout the day in a construction site and further colour code the levels of heat stress on a construction site so that construction workers are made aware of the thermal levels in order to adopt recommended health and safety measures while undertaking construction.

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