POLICY BRIEF

June 2019

Heat Stress Effect on Labour Construction Productivity

SUMMARY

Heat stress is not yet counted into serious issue in Cambodia. Major group impacted by heat stress are the group, working in Wet Bulb Globe Temperature (WBGT) higher than 29°C, including construction workers, farmers, garment workers, industry workers, etc. Today we know and understand how climate change can affect our lives and how to have the better adaptation in the future climate conditions; this is crucial to governments, businesses and communities alike.

This brief describes finding on the effect of heat stress to construction labour productivity (CLP). Labour productivity improvement was considered as case study because the weight this sector has in the national economy. Measurement results showed that the construction labour had a higher level of heat stress in the afternoon. The productivity was significantly higher in the morning work session and the lower environmental stress was in the morning. Besides that, the CLP losses were relation between the physical strain, core temperature, high temperature working environment, and long period of working hours.

Indicate that these are recommendations base on the finding, direct work activities shifting to the morning work session (start at 6am) and late afternoon (start at 2pm) are proposed to take into consideration. During the high WBGT, the worker is recommended to work under shading with enough wind speed. Due to the loses of the CLP relation with the physical strain, core temperature, work rest schedule (WRS), impact of heat stress to labour product and health are highly recommended to have further study for Cambodia weather condition. Similarly, CLP including WRS and specs on type of clothing was already studied and adopted the regulation of construction sector in Hong Kong. Thus, the well-studied of uniform could help reduce core temperature of the CL during working hot ambient condition. Once, the regulation on construction sector is ready, CLP and health are ready for adaptation of climate change and economic change.

BACKGROUND

Heat stress is contributed by the external factor including air temperature and humidity, radiant temperature, air velocity, clothing, and physical activity. When feeling of hot, body heat storage or body's thermoregulation system tends to respond with attempt to increase heat loss. The response help to keep safe body core temperature, but it can also cause strain on body (Heat Strain), and when heat cannot be removed from the body enough, it can eventually cause heat related illness and even death (Parsons, 2014). The level and symptoms of heat stress can be seen in Figure 1. Heat stress can be defined by Wet Bulb Globe Temperature (WBGT).

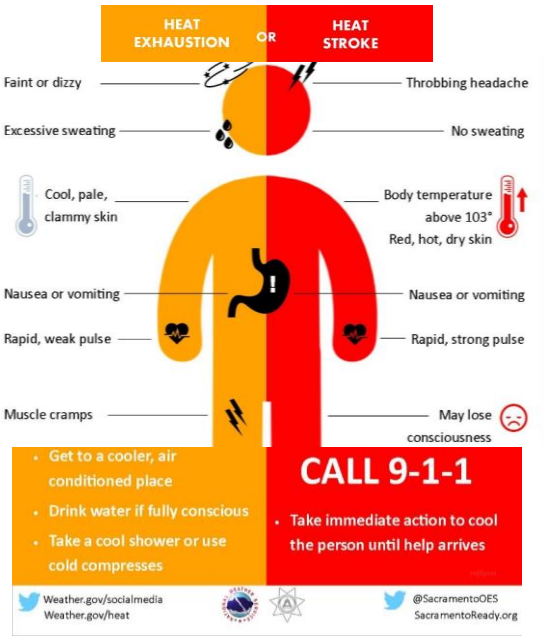


Figure 1 Heat-related illness symptoms and responses (Anon., 2019)

Construction workers are the group of people working under direct sunlight and with heavy physical activities for long working period. They are the potential group to get risk from heat stress effecting to working productivity and health. According to Royal Government of Cambodia, (2015), a low labour productivity (LLP) in Cambodian construction projects; LLP was

strongly evidenced by prevalence of cost and time overruns, Thust, 2013; Durdyev et al., (2017b). As reported by Durdyev et al., (2017a, 2017b), The construction industry is one of the most significant drivers of the Cambodian economy and contributes over 30% to the growth of the country's GDP, World Bank, (2014).

Several studies have extensively investigated factors affecting construction labour productivity in Cambodia, Durdyev et al., 2017a, 2017b; Durdyev and Mbachu, 2018. Amongst, poor weather conditions, particularly the extremely hot weather (March to May), can adversely affect construction labour productivity, Durdyev et al., (2017a). However, few studies have quantified the impacts of poor weather conditions on labour productivity in the Cambodian construction industry. This study contributes to bridging this important knowledge gap and intends to formulate specific strategies on promoting construction performance in the Cambodian context. Yi and Chan (2017) comprehensively assessed the impacts of meteorological, physiological, work-related, clothing, and demographic parameters on CLP in Hong Kong. It indicated that CLP decreased by 0.33% when the temperature increased by 1 °C.

Excessive heat stress profoundly affects human physiological responses and thus results in a reduction in construction labour productivity (CLP), Yi and Chan, 2017). CLP can be influenced by various work conditions. Grimm and Wagner (1974) indicated that workmanship declined at relatively high temperatures. Thomas and Yiakoumis (1987) and Koehn and Brown (1985) explored a non-linear relationship between CLP and thermal environments. Hancher and Abd-Elkhalek (1998) developed a CLP model taking both work conditions and climatic environment into account. In Beijing, Li et al. (2016) developed the relationship between CLP and meteorology as well as workers demography. It was found that CLP declined by 0.57% when the temperature increased by 1 °C.

Construction labour productivity can be measured at the industry, project, and activity level (Yi and Chan, 2014). Understanding of the factors affecting CLP at the construction activity level facilitates project managers to better estimate, plan, schedule, and manage tasks, Yi and Chan, (2014). Despite similar contributory factors on CLP in many tasks, the weights of the impact may vary from task to task, Yi and Chan, (2014). Since steel fixing work is one of the most physical demanding and long duration tasks in construction, Chang et al., 2009; Wong et al., (2014), the current study focused on evaluating CLP of steel fixers in hot weather.

FINDING

Cambodia is aiming to be a high-income country by 2050, (Yara, 2019), at the same time, the increasing of global surface temperature changes for the end of the 21st century is likely to exceed 1.5°C (IPCC 2013). By the change of the economic and climate, heat stress (due to climate change) and the work stress (due to the economic change) are the important keys that are required national regulation be to ready for problems experiencing by the developed countries, such a Europe, Australia, Hong Kong, China, etc.

The results from this study were demonstrated on finding the effect of heat stress to labour construction productivity (CLP), considering two main effect of work sessions: morning (AM) and afternoon (PM). The analysis was performed by SPSS 20.0, and statistically significant was set at $p<0.05$ using total of 343 data sets captured environmental, physiological, and perceptual parameters. The dependent variable was %CLP, while the independent variables included WBGT category (1=Risk I, 2=Risk II, 3=Risk III), % maximum heart rate (HR_{max}), thermal sensation (TS), rate of perceived exertion (RPE).

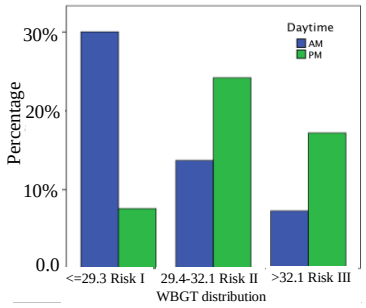


Figure 2 WBGT distribution in AM and PM work session

Figure 2 showed the WBGT distribution in the morning and afternoon direct work sessions, which indicated that the frequency for both high risk and dangerous levels rose in the afternoon direct work sessions.

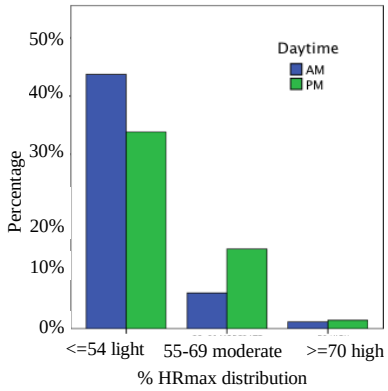
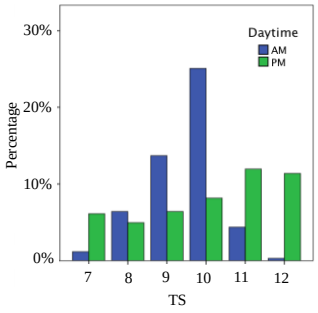


Figure 3 Heart rate distribution in AM and PM work session

Distribution of work intensity indicated that the participants normally undertook light workload and moderate work intensity rose in the afternoon direct work sessions Figure 3.



In the morning work session "slightly hot" was most frequently reported by the participants, while they reported "hot" and "very hot" frequently in the afternoon session Figure 4

Figure 4 Thermal sensation share in AM and PM

In terms of RPE, "moderate", "somewhat hard", and "hard" were the most frequently reported in the morning work session, whereas the participants tended to report a higher level of perceived exertion (from 7 very hart to 10 maximal) in the afternoon (Figure 5).

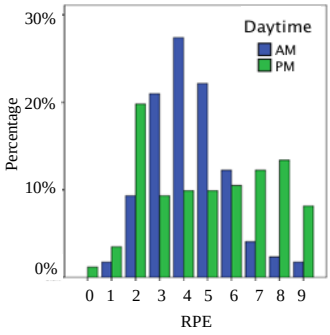


Figure 5 Rate perceive exertion (RPM) share in AM and PM

Morning direct work session, RPE, and $\%HR_{max}$ were positively related to productivity. To be specific, productivity of the participants in the morning was significantly higher than that in the afternoon. The result of a positive relation between $\%HR_{max}$ and productivity echoed to Yi and Chan (2017)'s findings. This is because higher productivity
requires higher energy input of construction workers. It is consistent with the findings that RPE was also positively related to productivity. The results of correlation analysis indicated that RPE was significantly correlated to $\%HR_{max}$, while TS was significantly correlated to WBGT. These findings reinforced that RPE was pertaining to physical exertion and TS was associated with ambient environment (Tikuisis et al., 2002; Yang and Chan, 2015), see figure 5.

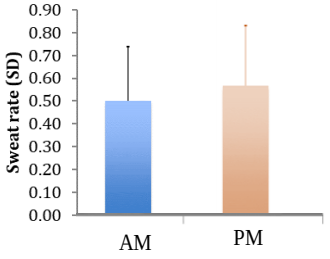


Figure 6 Sweat rate share in AM and PM

A small practical effect was observed in sweat rate between the morning and afternoon sessions, which implied that the participants had a higher level of heat stress in the afternoon, see Figure 6.

To be specific, productivity of the participants in the morning was significantly higher than that in the afternoon. The results of correlation analysis indicated that RPE was significantly related to %HRmax. TS was significantly related to WBGT. However, the current study showed that productivity was not affected by thermal environment and thermal sensation, which is not consistent with previous research (Yi and Chan, 2017; Li et al., 2016). This study revealed that productivity of rebar workers was mainly determined by physical efforts but not affected by thermal environment. Nevertheless, the underlying reasons remained unexplored. Besides ambient environment, managerial issues can considerably affect workers productivity in Cambodia.

RECOMMENDATION

Since heat stress is became an issue in research activity in Cambodia; there are many sectors are alerted on the impact on heat stress due to Cambodia in hot and humid country. This case study is contributed preliminary results to alert all concerned stakeholders to be aware of the heat stress effect. According to obtained results from this study, there are some ideas to improve productivity in construction sectors;

- Avoid working during 11am to 2pm because the highest temperature in the day is between 11am-3pm. Most of participants felt higher level of perceived exertion in the afternoon.
- Shift more direct work activities to morning session, start working earlier and stop earlier, lunchbreak longer, the worker can work in cooler environment and traffic condition is better. Proposed working hour at 6:00-10:00 am (morning session) and 2:00-6:00 pm (afternoon session)
- Study on identification the most efficient of work rest schedule and uniform for the concern working group

Adaptation to mitigate the impact of heat stress is required to have the collaboration and participants from stakeholders including government, private and business sector, researchers, academics, etc. These stakeholders need to open mind to research activity, data sharing, and supporting collaboration among concerned stakeholders.

Therefore, to have concreate evident to adopt proposed suggestion above to national regulation, detail and further study on impact of heat stress in varies sectors are required to prioritize for adaptation of climate change.

References

1. Chan, A. P. (2012). Impact of Heat Stress on Construction Workers. Retrieved July 30, 2019, from ssc.hkie.org.hk/DocDown.aspx?imgDoc=13_AlbertChan.pdf
2. Qatar Petroleum. (2015). Industrial cities directorate & Dukhan concession area heat stress guidelines. Retrieved from http://www.qpic.qa/PoliciesAndRegulations/Regulations/QGL-LHH-001%20Heat%20Stress%20Guidelines%20For%20ICD%20102015.pdf?fbclid=IwAR0rUVBKLLayx8TBuLnPDKXMt6SR-DnNOFgV_jc6cpZ4FO9fp1iBz3sNSWA
3. Parsons, K. C. (2003). Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort, and performance. New York, NY10001, CRC Press Taylor&Francis Group.
4. Rowlinson, S., & Jia, A. Y. (2014). Application of the predicted heat strain model in development of localized, threshold-based heat stress management guidelines for the construction industry. US National Library of Medicine, National Institutes of Health , 326–339.
5. U.S. National Weather Sevice. (2019, June 28). Heat Cramps, Exhaustion, Stroke. Retrieved from https://www.weather.gov/safety/heat-illness
6. United States. ((2017, September 15). Occupational Safety and Health Administration. *United States Department of Labor*. Retrieved June 20, 2019, from OSHA Technical Manual, Section III: Chapter 4: https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html
7. Yara, S. (2019, May 29). Cambodia's development vision for a progressive, inclusive, and sustainable society. Retrieved (July 30, 2019) from https://www.khmertimeskh.com/608573/cambodias-development-vision-for-a-progressive-inclusive-and-sustainable-society/
8. Yi, W., & Chan, A. (2017). Effects of heat stress on construction labour productivity in Hong Kong: a case study of rebar workers. International journal of environmental research and public health, 14(9), 1055.

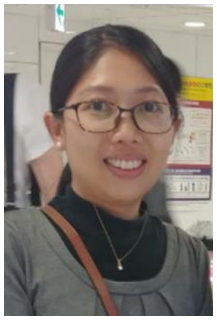
Authors

Dr. Kinnaleth Vongchanh, Applied thermal Lab., Energy Management and Technology Unit, Institute of Technology of Cambodia.

Dr. Sarin Chan, Energy Management and Technology Unit, Research and Innovation Centre, Institute of Technology of Cambodia.

Short Bio

Dr. Kinnaleth VONGCHANH is a lecturer-research in Research Unit for Energy Technology and Management under the Research and Innovation Center of the Institute of Technology of Cambodia. She has been a lecturer and researcher



in faculty of engineering, National university of Laos in 2010-15. She is a lecturer-research from 2015 to present in the Industrial and Mechanical Engineering Department, Institute of Technology of Cambodia. She has awarded many research grant projects and collaboration with many universities such University colleage of London, Université catholique de Louvain, Waseda University, Hongkong Polytechnic University, Institute of Technology of Tokyo, National University of Laos, etc. Most of research topics are related to energy efficiency in buildings, solar drying and waste to energy like creating solid fuel from wastes and heat stress.

Dr. Kinnaleth VONGCHANH obtained her Ph.D degree in 2010 from Institut Teknologi Bandung under the so-called Sandwich Program with Hokkaido University.