Heat Stress, a Hidden Cause of Accidents in Construction

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Abstract:

Extreme heat stress has deep impacts on physiological reactions, which results into occupational injuries and deaths. In this article an attempt is made to understand the impact of heat stress on construction accidents in Oman. The literature review on the heat stress is discussed in the first section followed by the analysis of 623 accidents of a highway project. The analysis of these accidents reveals that more severe accidents on this project took place from 11:00 – 17:00. The semi-structured interview held with some of the workers involved in these accidents confirmed excessive heat as one of the main reason behind these accidents. The health profile of the same workers is measured in terms of their Body Mass Index and blood pressure. The results show that 80% of the workers from the selected sample were found as overweight or obese and 40% of the participants were hypertensive. The safety performance of such workers is particularly discussed in relation to heat stress. The effective implementations of day time break in summer, a healthy diet, appropriate sleeping habit, scheduling physically demanding tasks at early morning and evening and adopting light colour and loose fitting uniform could reduce the impact of heat stress.

Key Words: Health & safety, Safety & hazards, Management.

1. Introduction:

International Labor Organization data for the year 2015 indicate that every year 108,000 workers died on construction site due to different occupational safety and health conditions. This number is nearly 30% of all occupational deadly injuries. Different statistic reveals that construction workers in different developed countries are 3~4 times more likely to die from accidents at site compared to workers in other industries. In the developing world, There is a higher risks (3~6 times more) of death linked with construction work in developing countries (ILO, 2015). Many construction workers suffer and die from work related diseases developed from past influence to risky materials, such as asbestos and other chemicals. Construction industry is known as one of the world's major industrial sectors, which include sub-sectors such as building, civil engineering, demolition and maintenance. Construction industry is further reported for a major portion of gross domestic product (GDP) in different countries for instance, 6.10% in the U.K., 5.50% in Japan, and 9.0% in Oman (ONS, 2017; SHJ, 2017; NCSI, 2017). Statistics reported in a daily newspaper (Times of Oman) on 9th of June, 2014, noted that a total of 723,000 residents were working in the construction industry. The ongoing and planned development projects in different sectors, including construction, for financial year 2015-2016 is shown in figure 1. The construction sector projects stand out

as the largest one, amounting to US$ 43.16 Billion. According to the budget report, spending on development projects are estimated at US$ 3.12 Billion (OMR1.2 Billion), representing the amount to be paid during the year 2017, as the actual work progresses (TOM, 2017).

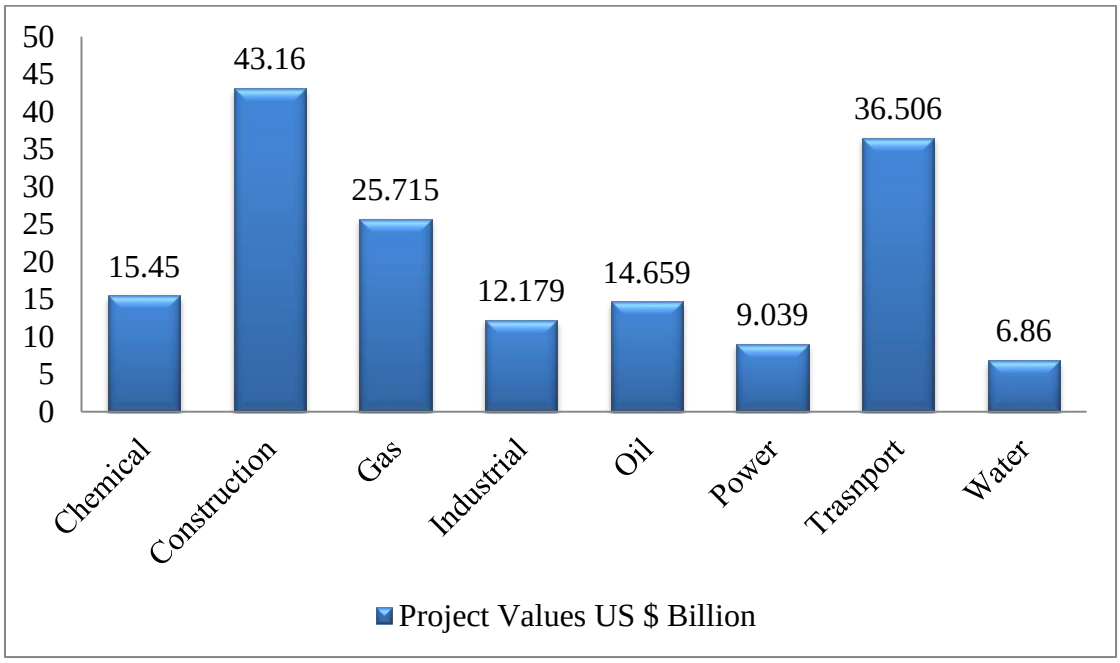

Figure 1: Values of Ongoing and Planned Projects in Different Sectors of Oman (Deloitte, 2015).

Construction industry is growing rapidly in different developing countries and thus recognized as a main sources for providing jobs to different labors. However, at the same time it is recognized as one of the risky industries. The construction workers job may include variety of task while they are working in different projects. These projects may be related to building, repair and maintenance; renovation and demolishing; transportation including construction of highways, bridges and airports; and projects related to docks and harbors. Construction workers are expected to be open to different types of risk during their works such as dust and condensation; stiff working situation; handling heavy load; hot climatic condition; working at heights; excessive noise; vibration and heavy machinery; and different chemicals. Different causes of accidents and illness in construction industry are renowned and thus can be prevented (ILO, 2015). A news article appeared in a daily newspaper (Times of Oman) on 28th February, 2015; revealed that officially there is no statistics that how many construction workers were injured at work. However, the data of ten reputable construction organizations shows that in 2014 more than 3500 construction workers required medical treatment due to work injuries. Due to the severity of injuries, around 10% of these

workers were hospitalized. The report further reveals that roughly 18% of these workers, who were hospitalized, died at their work or in hospital. In comparison to the last year data, the number of injured workers rose by 246 (TOM, 2015-a). For different reasons including reputation, the company owners hesitate public such information. One of the elements in the proposed model for an improved safety performance in construction in Oman was the occupational safety and health regulations (OS&H) (Umar and Wamuziri, 2016). A review of the current OS&H regulations in Oman conducted by Umar et al. (2018) identified area for improvement and suggested the revision of these regulations on a periodic basis on a similar pattern as of Construction Design and Management regulations (CDM) in the UK, to effectively meet the industry safety expectation.

In construction organizations in Oman, most of the workers are foreigners (92% of total workforce) and as such they are not insured under the government authority (NCSI, 2015). As per law of the country, construction organizations are required to seek private insurance for their workers; however as the risk associated with construction workers is high their insurance premium is comparatively more. Construction organizations further bear high cost at the time of recruitment and pay for repatriation, compensation and replacement in case of accidents involving injuries and death. There is potential for construction organizations to reduce the cost associated with accidents either direct or indirect by properly understanding the factors which affect workers safety performance. Exposure to extreme heat is a renowned occupational health hazards which results into illnesses ranging from pain to death. A study conducted in Australia noted an increase in daily injury claims with every $1^{o}C$ increase in maximum temperature up to $37.7^{o}C$ (Xiang et al., 2014). McInnes et al. (2017) revealed a positive association among excessive heat exposure and acute occupational injuries in different types of male workers who were doing heavy physical tasks. In this article, an attempt is made to understand the potential impact of heat stress on worker safety performance working on a highway construction project in Oman. Different types of accidents took placed in this project over a period of six years are presented and discussed. Physical and health related factors such as Body Mass Index and Blood Pressure of some of the workers involves in these accidents supported by a face to face interview is measured and interpreted with heat stress implications.

1.2 Heat Stress:

The global temperature statistics for the year 2011to 2015 published by the World Meteorological Organization, shows that the earth temperature, on average rose by 1^{o} C in 2015. Intense high temperatures and heat waves repeatedly arrive throughout the year at low latitudes, and commonly at central latitudes in summer time (Hansen and Sato, 2016). In recent years, many high-impact disasters have been witnessed due to climate change, including drought in Eastern African region between 2010 to 2012,

which resulted approximately 258,000 weather-related deaths; and the 2015 heat waves in Indian-subcontinent region, which led to more than 4100 fatalities. Extreme heat stress has deep impacts on physiological responses, which result in to work-related injuries, deaths and also reduce workers productivity. Construction workers are expected to be affected more by heat stress comparatively more than the workers in other industries, due to the body heat generation caused by physically demanding works in hot and humid working environment (Yi and Chan, 2017).

Fatigue and stress caused by different factors has been considered as a major contributor to some of the world's most famous accidents including the disaster of the Exxon Valdez oil spill, which result into spilling of approximately 41,000 m^3 of crude oil into the sea (NTSB, 1990). Heavy truck accidents are a particular problem in the USA with an estimated 30 – 40% having truck-driver fatigue as a contributing factor (NTSB, 1990a). This is especially important for construction workers who frequently drive to and from sites in inclement weather and long distances e.g. during the construction of nuclear power stations that need to be located away from populated areas. A key factor in fatigue and stress research is the circadian cycle i.e. alertness levels depending on the time of day (Mehta et al., 2017; Larsen et al., 2017). Specifically, there is a drop in alertness during early afternoon (Figure 2). A study of the construction sector in Spain found that occupational accidents are more severe and possibly to be fatal if occur between 13:00 and 17:00. The research conducted by Miguel et al. (2011) found that times closer to the lunchtime is accounted for more than 18% of all accidents and approximately 29% of the accidents involving deaths. In the USA a study found a spike in fatal accidents, accounting for 21.6% of all fatal accidents, between 14:00 and 16:00 (Banik, 2010). Figure 2 shows incidents of service strikes in the UK by time of day. This illustrates an unexplained spike in incidents soon after midday. However, a comparison of a typical circadian cycle (relative 'alertness') shows a drop in alertness coinciding with the afternoon spike in service strikes. Further, the early afternoon spike is more pronounced on Mondays, when sleep-loss may also be a factor.

Similarly, exposure to extreme temperature at work is regarded as a serious occupational health hazard that results in to variety of sickness illnesses ranging from body pain to death. Exposure to severe and extended heat or humidity can decrease workers' energy and focus on their work, increase their irascibility, and lead them to heat related sickness (Hancher and Abd-Elkhalek, 1998; Chan and Yi, 2016). Statistics reported by the Occupational Safety and Health Administration (OSHA) reveals that from 2003 to 2012 the number of workers death each year caused by heat heat-related sickness and injuries stood at 30 (OSHA, 2013). Data collected by The Center for Construction Research and Training in United State statistics further reveals that 17 construction workers died due to heat related factors in 2015 (NSC, 2017). Construction workers in generals and those who engage in scaffolding and form works, steel fixing

and erection and concrete work are particularly considered to be the most affected workers by heat stress. This is very simple to understand, as the daily tasks of these workers normally remain in open area where they have to works under the direct sun heat for several hours. There have been evidences which reflect that the temperature of certain construction sites was noted to be more than the atmosphere temperate. For instance, Chan et al. (2012) concluded that the temperature of a construction site could be as high as 45^{o} C even when the atmosphere temperature remains as 32^{o} C. Middle Eastern region including GCC countries are well known for their hot and humid climatic conditions. A report published in a daily newspaper on 22 January 2017, quoting a reference from World Meteorological Organization, stated that 2016 was the hottest on record where the temperature reached to 50^{o} C (MD, 2016). Similarly, a report published in daily newspaper "Times of Oman" on 10 August 2015, reported the temperature at 48^{o} C (TOM, 2015-b). The annual temperature reported by the directorate general of metrology in Oman, however shows that the maximum temperature was up to 40^{o} C in the month of May and June as shown in figure 3 (DGM, 2018). The summer period in Oman usually remain eight month of the year covering the period from March to October. Thus it is anticipated that construction workers in this region may have been highly affected by heat stress compared to other countries, however this important issue has not yet been properly investigated. The proper understanding of heat stress and its impact on workers production and safety performance may help construction organizations and government regulating body to develop strategies how to protect workers from heat stress. Preventive actions such as work-break cycles, work management, and cool down arrangement by providing drinking water or soft drinks were proposed in Hong Kong to secure the workers' health and well-being in hot and humid working conditions (CIC, 2016; DH, 2010). OSHA instructions on safeguarding workers from heat stress can be adopted to handle safety and health related issues (OSHA, 2017). Some of the OSHA guidelines are;

i. Organizing a comprehensive heat illness prevention programme.

ii. Providing training to workers on how to protect themselves from the hazards that can lead to heat stress.

iii. Providing cool water in construction area easily accessible to workers. At minimum each worker should have 500 milliliter of water for each working hour.

iv. Changing the work schedules to allow frequent breaks so that the workers can take rest and water in shaded facilities.

v. Increasing workloads gradually for those workers who are new to the heat and allowing more frequent breaks. The similar approach should be applied to those

workers who were away from for a longer period so that they can adjust to working in hot conditions.

vi. Designating an experience staff to observer conditions at work area and safeguard workers who are at risk of heat stress.

vii. Considering protective uniform that allows cooling.

Similarly, Yi et al. (2017) appraised the performance of recently designed clothing for construction workers in encountering the heat stress. The tests and observations were carried out on volunteers while exercising in a hot and humid environment by wearing the traditional and the newly designed uniform. They concluded that their newly designed construction uniform could decrease thermoregulatory and cardiovascular stress, and enhance thermal relief. Liu and Wang (2017) observed that conventional safety management of heat stress primarily rely upon the workers' awareness and behaviors. They presented a conceptual model to develop a self-intelligent work place to manage workplace heat stress proactively, by integrating the features of Geographic Information System (GIS) and Building Information Modelling (BIM). Most of the organizations hesitate to invest on safety, as a usual perception that it will cost huge amount which is technically not true if compared with the benefits from investment on safety. Research conducted in the UK on cost and benefit analysis revealed that when total costs of accident prevention were compared to the total benefits of accident prevention, the benefits far outweigh the costs of accident prevention by a ratio of approximately 3:1, which informs that when contractors, regardless of their sizes, spend £1.00 on accident prevention, they get a benefit of £3.00 (Ikpe et al., 2012).

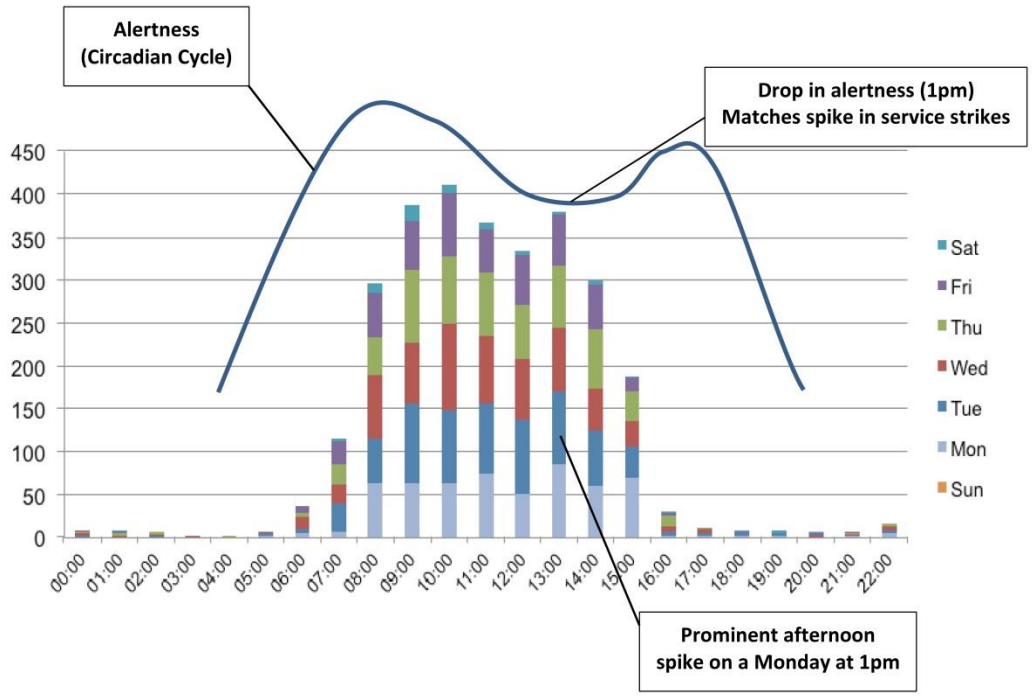

Figure 2: Buried services strikes by time of day (USAG, 2015).

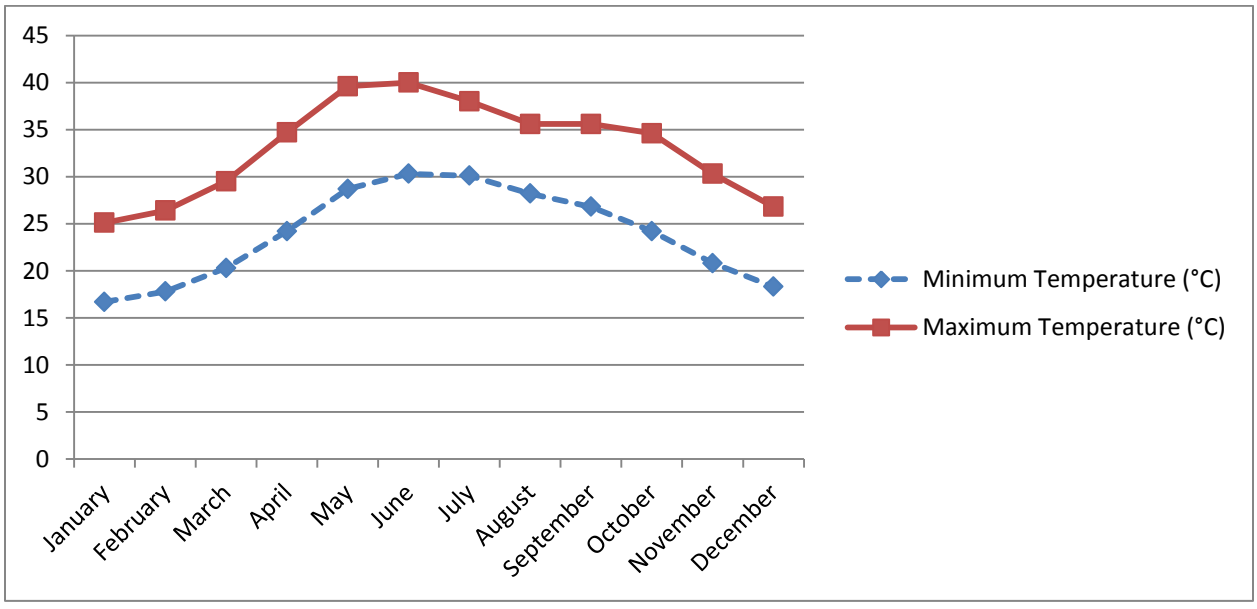

Figure 3: Annual Temperature in Oman (DGM, 2018).

1.3 Aim and Objectives of the Study:

The construction workers in Middle Eastern and Gulf Cooperation Council (GCC) member countries are those who face an extreme working environment due to high climatic temperature. The aim of this study is to understand worker fatigue developed due to heat stress in relation to potential safety errors and accidents. To achieve this, the following objectives have been set:

i) To access and analyze the accident data of partner construction organizations in Oman.
ii) To understand the relationship between heat stress and accidents.
iii) To understand the effect of heat stress on workers safety performance.
iv) To measure and interpret basic health parameters and its impact on safety performance.
v) To propose possible solutions to reduce heat stress for improvement of safety performance.

2. Research Methodology:

To achieve the research objectives, two methods were applied. Method I includes the collection of accident data from partner construction project. This includes the total number of accidents on a specific project and to classify these accidents using appropriate accidents classification model. Accident investigations report prepared by the Health and Safety (H & S) team of the project were used to know the day, time, and workers involved in the accidents. Human factors or errors are one of the main contributors towards accidents; for instance if an accident is caused by a defective equipment or mishandling of materials, thus the main argument is why the defective equipment was available on the site or why worker was allowed to use this defective equipment. Similarly, the case is with the accident causes by materials. There could be several reasons for the human factors which may also include the heat stress because of the geographic condition of the project. Thus, to know this factor, sample of workers involved in these accident were interviewed. To know the impact of heat stress on these accidents, a sample of workers from among those who were involved in the accidents was selected for a semi structure interview. The use of semi-structured interviews in data collection offers different strengths as discussed by Umar et al. (2017) and Umar and Egbu (2018).

The sample was selected in a way to avoid the language barrier, thus the workers who were able to communication in local languages such as Urdu, Punjabi, Hindi and Pushto were selected. On average a total of 2000 employees were working on this project, while a total of 10 workers were selected from those who were involved in any types of

accident. Statistically, it appears that the selected number of workers represents a small sample size, however due to several restrictions including language barrier and availability of workers did not allow the increase the sample size. Apart from this limitation, the face to face interview does provide vital sources of information on the effect of heat stress on these workers safety performance. The selected workers were briefed about the purpose of the interview to reduce any pressure they may have and to allow them to share the accurate information. The briefing and questions used in the face to face interview are appended in appendix I.

Physical examination refers to an evaluation of a body for determining the complete health condition. Many research studies on physical examination have been carried out among different occupations and industries. Calculation of body mass index (BMI) was considered in a research study conducted by Kawai et al. (1995) to assess health profile of 816 white collar workers in Japan. According to Dua et al. (2014), an increased BMI being linked with prehypertension may advise that such persons are at high risk of progressing to frank hypertension. To calculate the BMI, the weight and the height of the participants were measured and the BMI of each worker was calculated using equation No.1.

$BMI = \frac{W}{H^2}$ ……..*Equation No.1* (WHO, 2017)

Where,

BMI = Body Mass Index

W = Weigh in Kg

H = Height in meter

The second part of the research includes the field measurements of Body Mass Index and blood pressure of the same construction workers who were interviewed to see that they are physically fit. For instance the accidents may happened due to human error and possibly the worker may under different stresses including the heat stress; however several health conditions such as body blood pressure, heart beat and body temperature can be directly linked to individual body parameters. An overweight worker could be more affected by heat stress compared to a normal weight worker. A BMI measurement is used to determine if an adult is at a healthy weight for their height. An individual's is calculated by dividing their weight in Kg by the square of their height in m^2. The BMI values from 18.5 to 25 are considered as normal (WHO, 2017). For example, an adult who is 17.5 m tall and weighs 70 kg will have a BMI of 22.9, which is in the normal healthy range. A high blood pressure is regarded as a main cause of

hypertension (Daskalopoulou et al., 2015). Poulter et al. (2015) concluded that if a person is having a blood pressure greater than or equal to 140 mmHg systolic blood pressure (SBP) or greater than or equal to 90 mmHg diastolic blood pressure (DBP) is to be classified a hypertension. Carey and Whelton (2018) noted that hypertension is the leading cause of death and disability worldwide. Overall the blood pressure can directly affect the physical abilities of human, thus such workers are more open to accidents (Beevers and MacGregor, 1999).

For the purpose of data collection, five major construction organizations having major projects in the region were requested for cooperation in this research project. Only two construction organizations which were executing jointly a major highway project with an estimate cost of US $ 305 Million agreed for cooperation with condition that the names of construction organization may not be revealed. This project was started in September 2011 and 82 % of the work was completed by end of 2016.

3. Results and Discussion:

3.1 Analysis of Accidents:

A total of 623 accidents data was provided by the Health and Safety (H & S) team of the project. These accidents were of different types in nature. Based on the accident data, the different types of accidents were initially classified based on their nature under:

3.11 Alternate Work Injury (AWI):

A work injury that results in the injured person being able to perform only restricted (light) duties in the original workplace on the first scheduled work day or shift (or any subsequent work day or shift) on the day after the incident.

3.12 First Aid Injury (FAI):

A work injury that requires first aid treatment, including observations, TT (Tetanus Toxoid) injections, nonprescription drugs, pain killers, examination, oral rehydration, minor dressings even if carried out in the hospital.

3.13 Loss Time Injury (LTI):

A work injury or disease resulting in a fatality, permanent disability or time lost from work of one or more complete work days or shifts, following the fourth day or shift of the incident. Fatalities causes from suicide or natural causes are excluded.

3.14 Medical Treatment Injury (MTI):

A work injury that requires treatment other than the first aid at a hospital or other medical facility.

3.15 Property / Equipment Damage:

These are incidents resulting from workplace activities that caused damage to property or equipment only.

The breakup of these accidents is shown in table 1. Property / equipment damage accidents were at the top with a total number of 580 accidents, followed by MTI (15), FAI (14), LTI (9) and AWI (5). The average numbers of workers on the project during this period (September 2011 to End of 2016) were 2000.

Year	Property / Equipment Damage	Alternate Work Injury (AWI)	First Aid Injury (FAI)	Loss Time Injury (LTI)	Medical Treatment Injury (MTI)	Total	Mean
2011	0	0	0	0	0	**0**	**0**
2012	7	1	1	0	2	**11**	**2.22**
2013	155	0	3	3	4	**165**	**33**
2014	164	2	0	5	5	**176**	**35.2**
2015	179	2	7	1	4	**193**	**38.6**
2016	75	0	3	0	0	**78**	**15.6**
Total:	**580**	**5**	**14**	**9**	**15**	**623**	**--**
Mean	**96.667**	**0.8333**	**2.3333**	**1.5**	**2.5**	**--**	**--**

Table 1: Summary of Different Types of Accidents (2011 to 2016).

Based on the accident reports provided by the construction organization H & S team, these accidents were assessed and classified into different root causes using the model developed by Umar and Egbu (2018). This model identified four categories of “Equipment / Materials”, “Worker”, “Environment” and “Management” as a main cause of accidents. By using this model it has been revealed that a significant proportion of accidents (41 percent) arise from the “Worker”. Furthermore, it is found that Management factor contribution is 31%, Equipment/Materials contribution is 14% and the Environment contribution is 12%. Since the human factor is one of the main cause

of these accidents, thus to understand this factor properly and to develop a relationship with the stress, these accidents were arranged according to their time and day on which they occurred. The results are shown if figure 4. The result shows that the work on the project was carried out on a 24 hours basis. Clearly, the accidents number has increased gradually from 10:00 to 17:00, whereas a decline in number of accidents can be observed after 17:00. This has a direct relationship with the temperature as in Oman; the temperature from 10:00 to 17:00 is normally high compared to the other time of the day. A slightly high number of accidents are also observed in the early morning (3:00 – 6:00) and night time (20:00 – 24:00). This may have no relationship with heat stress but several reasons for example drowsiness of workers and low light arrangement at work place. A huge number of accidents (= 32) was also observed on Saturday at 16:00 – 17:00, which will of course have a relationship with the heat stress, but also Saturday is the first day of the week where the work started for all private sectors.

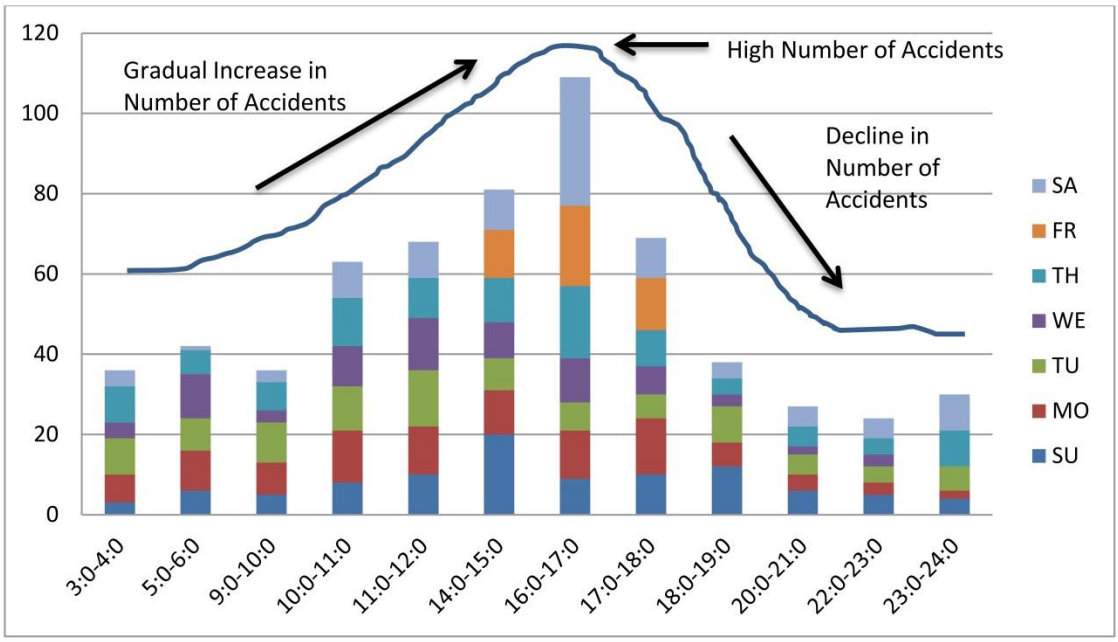

Figure 4: Day and Time of Different Accidents in the Project.

Similarly, to answer the question what time the severe accidents were happened on this project, an analysis of different types of accidents involving injuries with the time as they happened was performed. The result shown in figure 5 indicates that more severe accidents (MTI) took place around 10:00 to 18:00. The maximum numbers of different types of accidents involving injuries were from 11:00 to 17:00. A slight reduction is observed 18:00 – 19:00 which could be because of possible worker shift change while a minor increase can be observed from 19:00 to 24:00.

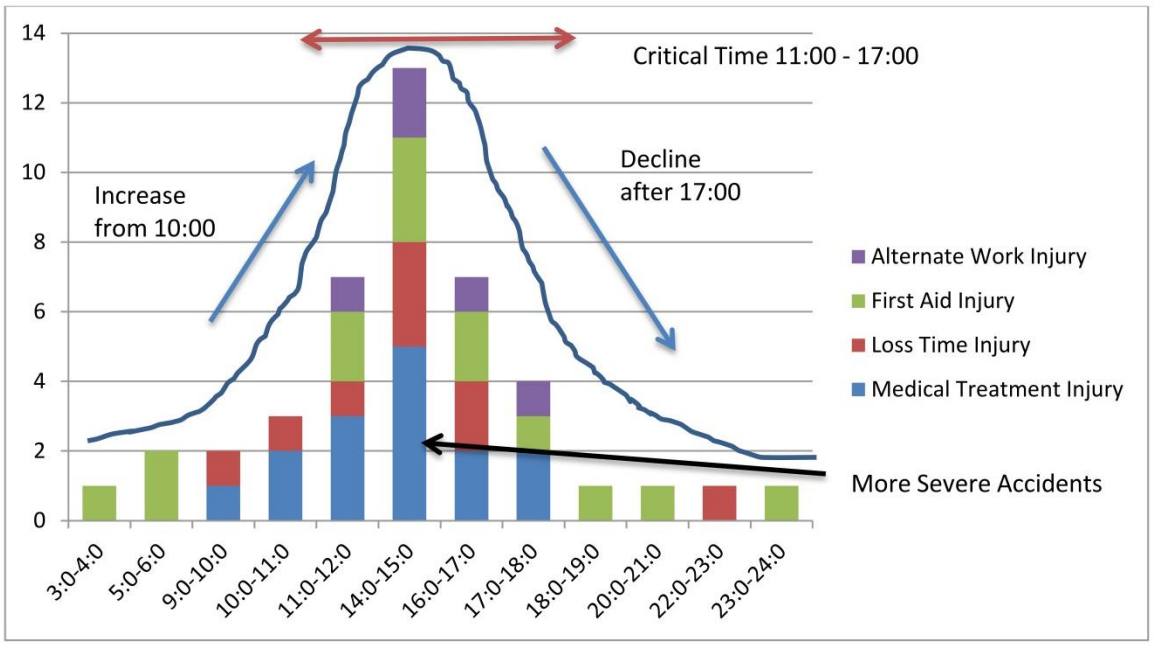

Figure 5: Accidents Involving Injuries and their time.

Both the results shows that majority of accidents in project were happened during day time from 11:00 to 17:00. The direct impact of the heat stress therefore cannot be ignored due to the fact that the project is situated in the area which has hot climatic condition and the time at which the accidents (11:00 to 17:00) happened normally has the highest temperature. A Research conducted in Spain by López et al. (2008) involving 1,630,452 accidents spanning over a period of 10 years (1990-2000), considered the time of these accidents and concluded that a larger number of accidents took placed at break time from 10:00 – 11:00 and 14:00 – 15:00. They further concluded that when workers eat, and drink in the morning break and at lunch time can increase the chances of committing an accident and the severity of such accidents could be more. It is worth mentioning that in Spain, the morning break is normally from 10:00 to 11:00, while the lunch break is from 14:00 to 15:00. Another study carried out by Wigglesworth (2006) in Australia considering the 750,000 compensation claims filed by workers during the period from 1968 to 1988, observed that the number of accidents were comparatively more in the mornings than the accidents in the afternoons. Since, the accidents presented in this article is from a single construction project, thus due to the limitation of the data, this may not be enough to reach a more reliable conclusion that what is a more frequent time of accident in construction in Oman.

It has been noted that hot condition at construction sites especially in summer is also observed by the government agencies responsible for health and safety in the country.

According to the article 16 of the Occupational Safety and Health regulations, Oman; workers must not work at construction sites or in open and elevated areas from 12:30pm to 3:30pm during June, July and August (OSHR, 2008). This regulation are widely published and enforced by Ministry of Manpower, Oman, but still the workers have not yet get the full benefits of the regulation. For instance, the workers should be able to use this time (12:30pm to 3:30pm) to take proper rest; however in most construction sites this do not happened. In figure 6, it can be seen that the workers are not working during the break time but they are taking rest on ground and inside the scaffolding. The workers may have no alternative other than taking rest on ground and scaffolding which trigger an important safety.

Figure 6: Workers Taking Rest During Break Time on Ground and Scaffolding.

3.2 Analysis of Semi-Structured Interview:

All the interviewees agreed that they were tired enough on the day and time of accidents. An interviewee who is a general worker stated that he was sick by fever on the day when he committed the accident. Most of the interviewees answered that the weather was very hot on the day and time when the accident happened. Majority of the workers reported the hot climate as one of the main cause of the accidents. When asked with the question that how they protect themselves from direct heat, two interviewees responded that they used to keep a wet piece of cloth to cover their head under safety helmet. Two of them responded that they used to come to the shadow

area (if available at site) if they feel more tired and exhausted with the heat. Three interviewees reported that in case they feel tired by excessive heat they use to remove their helmet and shoes and lose their uniform to relax. Other responses were pointing out the non-availability of resources such as water for drinking and washing. Some of them reported that they have to work for extended hours due to the shortage of workers and work pressure. Similarly, when the interviewees were asked the question that weather they like to work for overtime, all of them answer with yes. Few of them provided with the reasons stating that it is important for them to work for overtime as this is the way they can get more financial benefits and support their family back in their home countries.

One interviewee who was a dumper driver reported that it is difficult to take day time break in summer time as his duty to supply the required materials to the work place and if he late it suffer the pace of the work. When interviewees were asked with the question that what time you prefer to work, seven out of ten answered that they would prefer to work at night during summer. All workers reported that they don't have any such incentive from the company which helps them to protect from the heat.

Participants were also asked questions on their sleeping habit as this can impact on their work performance and vice versa (Yi and Chan, 2016). Five out of ten reported that they normally sleep for five hours daily, 3 reported that they sleep from 5-6 hours daily and remaining two reported that they normally sleep around 7 hours. This reveals that majority of the participants are under sleep and thus their performance at work would be affected as sleeping habit has a direct link with the body blood pressure (Rees et al., 2013). The exposure to the heat will further affect their body performance such as blood pressure and thus there is a possibility that the workers would not be able to take right decision when dealing with the risk at work.

From the discussion it is reveals that heat stress have some impact on these workers performance including safety performance. According to article 68 of Oman labor law, an employee may not be required to work for more than nine hours a day and to a maximum of 45 hours a week (OLL, 2003). Similarly, article 70 of the same law allowed a worker to work for an overtime of 3 hours per day, up to a maximum of total 12 hours per day. The law also provides criteria on payment of overtime which covers both the overtime for day and night. The overtime should be given to a worker with his consent, that mean that a worker can refused to work for extra hours as overtime. However this is not happening in reality. The first thing is that most of the workforce is coming from developing countries and they prefer to work for overtime so that they can support their family in a better way. Secondly, the companies would like to have the workers who can work for extra hours so that they can catch up with the progress and to avoid hiring of additional workers. Thus in case if a worker refused to overtime, it is most likely the

company will not renew his contract and later the worker will be replaced by one who is willing to accept overtime.

3.3 Result of Body Mass Index and Blood Pressure:

The results of the BMI calculation show that BMI of only two participants was in the range of normal healthy range. The BMI of six out of 10 participants was in the range of overweight while 2 participants were obese. There was no participant who was underweight as per BMI value. The mean value of the BMI of the participants was 28.52+2.78. The details BMI of the entire participant are shown in shown in table 2. The results further reveals that the participants classified as overweight and obese were above 25 years. The research conducted in Denmark by Gupta et al. (2018) reported the BMI of 147 blue collar workers from a variety of professions including construction and observed that BMI of 59% of the participants was more than 25. The mean value of the BMI of the selected participants was 26.4±4.80. Similarly, the mean BMI of 932 construction workers in Hong Kong reported by Yi and Chan (2016) was 24.3±3.70. Their reported BMI results further reveal that 2.8% of the participants were underweight, 36.1% were overweight and 6.5% were obese. The finding of a similar research conducted on 314 male construction workers in Netherland shows that based on the BMI results, 70% of the participants were classified as overweight and 22.7% as obese. (Viester et al., 2017). The BMI result from different studies, however, clearly reflects that the majority of construction workers are not in their healthy range of BMI, which will have different consequences.

Participant	**Age**	**BMI**	**Classification**	**Criteria**
1	24	24.5	Normal	BMI = 0 - 18.5 = Underweight BMI = 18.5 – 25 = Normal BMI = 25 – 30 = Overweight BMI = 30 and above = Obese
2	39	27.8	Overweight	
3	41	29.6	Overweight	
4	49	29.5	Overweight	
5	22	24.0	Normal	
6	33	27.9	Overweight	
7	51	33.2	Obese	
8	46	28.3	Overweight	
9	46	31.3	Obese	
10	43	29.1	Overweight	
Mean ± SD	39.4±10.05	28.52±2.78		

Table 2: Result of BMI and its Classification (WHO, 2017).

The results of this study further reveal that the average DBP of all the participants was equal to 78.3+14.7 (mmHg). Similarly, the average SBP of all the participants was calculated at 136.2+18.3 (mmHg). The results further reveals that 40% (4 participants) blood pressure was more than the threshold and the fall under the hypertension values. Clearly from the BMI results, the majority of participants (80%) are not in the healthy range value. There will be more possibility that such workers would be more affected by heat and thus their safety performance will not be the same as a worker which is classified as normal or healthy. It does indicate that as young workers (age < 25) are healthy thus their safety performance could be better than older workers (age > 25). The argument in terms of heat stress could be valid, but at the same time this need to be kept in mind that the workers with more age become more mature and thus their behavior towards compliance of safety increase which possibly increase safe act (Sawacha and Fong, 1999; Salminen, 2004). Statistics published by the Public Authority (PASI) for Social Insurance in Oman also reveals that more than half of the disbursement cases of work injuries were related to the age group of less than 36 years, representing 76% of the total disbursement cases as shown in figure 7. It is worth mentioning that the PASI only register Omani citizens in their insurance scheme (Umar, 2016). Foreigner workers in Oman are required to be insured under private insurance scheme. Omani workers represent 8% of the total workforce in the construction industry in Oman.

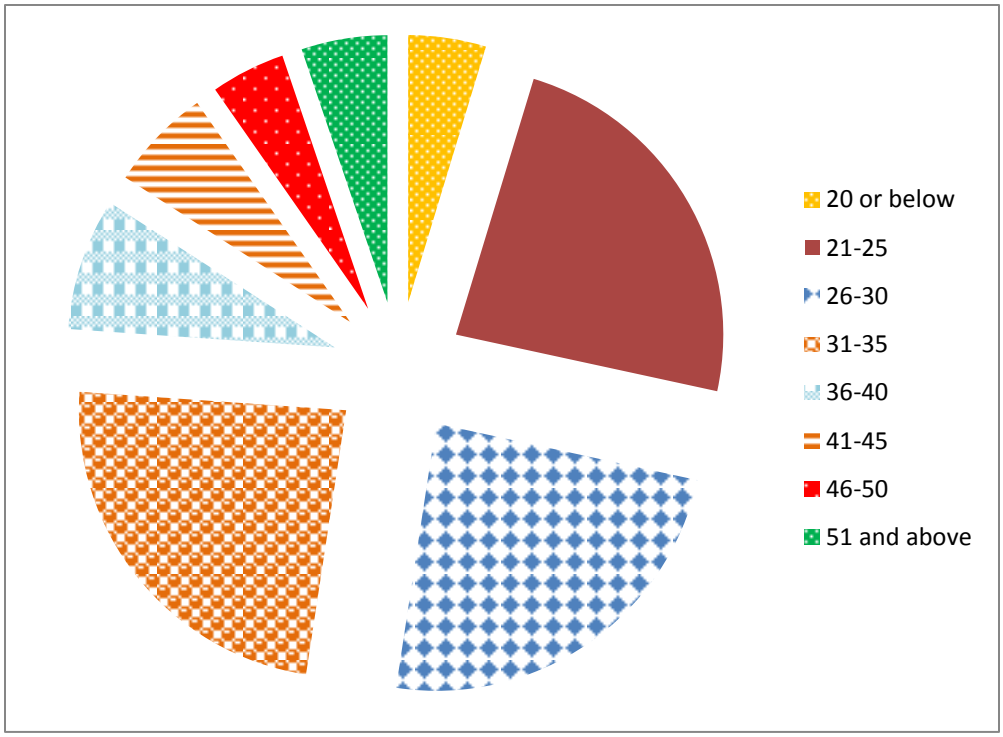

Figure 7: The Distribution of Disbursement by age Group (PASI, 2014).

4. Conclusion and Recommendation:

Global warming has a deep impact on the construction industry, as construction workers are usually exposed to heat stress, particularly those working in in hot and humid areas. Gulf region is well known for its hot and humid climatic condition. This paper discussed the heat stress as one of the cause of accidents in construction. Data from the literature review and from a selected highway project in Oman shows that heat stress can affect the human abilities and thus the safety can be compromised. The analysis of 623 accidents reveals the time of the day where more severe accidents took place was from 11:00 – 17:00. The results of the semi-structured interview with the workers involved in these accidents further confirm the heat stress as one of the cause of these accidents. Other issue such as availability of clean water for drinking and washing, sleeping habit, overtime, and implementation of day time break in summer. These factors are however, indirectly linked with the heat stress. The results of this study show that 40% of the selected workers were more than the threshold and the fall under the hypertension values. The blood pressure of these workers can be further affected by heat stress and their physical demanding job. The results of BMI index of the selected workers show that 80% of these workers are overweight or obese. Construction workers who are overweight or obese will particularly be more affected by heat stress than the workers who have a normal BMI. The implementation of overtime time regulations in true spirit and letter as described by Ministry of Manpower, Oman will help construction organization to protect their workers not only from heat stress but also from other work related stresses. The literature review and the results of this research suggest that construction workers in Oman can be protected from heat stress by;

i) Providing appropriate supervision to monitor environmental condition in relation to heat stress.

ii) Providing clean and cold drinking water at the site of construction.

iii) Allowing workers to take several short break in hot weather condition.

iv) Providing loose and light colour uniform which can ventilate worker body and don’t absorb sun heat.

v) Scheduling more physical demanding works in early morning and afternoon.

vi) Providing training to workers to increase awareness of heat stress and how to protect themselves from this.

vii) Effective implementation of compulsory day time breaks in summer.

vii) Arranging proper rest area at construction site for workers to relax during break.

ix) Maintaining a healthy diet for workers to avoid high blood pressure.

x) Providing flexibility for workers to accept or reject the overtime.

Apart from these recommendations, there is also a need of awareness in construction organizations to realize the importance of construction safety not only for the financial benefits but also as a social responsibility. Although, this research article provides a very useful information on the heat stress in construction industry in Oman, however there were two main limitation if this study. The fist main limitation of this research was the data used in this article is from a single construction project and the second was a small number of workers selected for face to interview. Further research need to be conducted in construction in Oman to understand the effect of heat stress not only worker safety performance but also productivity.

References:

Banik, G., 2010. Trend and causes of fatal accidents in the US construction industry. Southern Polytechnic State University. Georgia, USA. See: http://ascpro0.ascweb.org/archives/cd/2010/paper/CPRT235002010.pdf (accessed: 18/03/2018).

Beevers, D.G.; MacGregor, G.A. Hypertension in Practice, 3rd ed.; CRC Press: Boca Raton, FL, USA, 1999.

Carey, R.M. and Whelton, P.K., 2018. Prevention, detection, evaluation, and management of high blood pressure in adults: synopsis of the 2017 American College of Cardiology/American Heart Association hypertension guideline. Annals of internal medicine.

Chan, A.P. and Yi, W., 2016. Heat stress and its impacts on occupational health and performance. Indoor and Built Environment 2016, Vol. 25(1) 3–5.

Chan, A.P., Yam, M.C., Chung, J.W. and Yi, W., 2012. Developing a heat stress model for construction workers. Journal of Facilities Management, 10(1), pp.59-74.

CIC, 2016. (Construction Industry Council). Guidelines on Site Safety Measures for Working in Hot Weather. Publication Version 2. Construction Industry Council, Hong Kong See: http://www.hkcic.org/eng/info/publication.aspx?langType=1033&id=4458 (accessed 11/12/2017).

Daskalopoulou, S.S., Rabi, D.M., Zarnke, K.B., Dasgupta, K., Nerenberg, K., Cloutier, L., Gelfer, M., Lamarre-Cliche, M., Milot, A., Bolli, P. and McKay, D.W., 2015. The 2015 Canadian Hypertension Education Program recommendations for blood pressure measurement, diagnosis, assessment of risk, prevention, and treatment of hypertension. Canadian Journal of Cardiology, 31(5), pp.549-568.

Deloitte, 2015. Deloitte GCC Powers of Construction 2015 Construction – The Economic Barometer for the Region. Deloitte, Dubai, United Arab Emirates. See http://business-humanrights.org/sites/default/files/documents/Deloitte-GCC-Powers-of-Construction-2015.pdf (accessed: 29/03/2018).

DH, 2010. (Department of Health). Preventive Measures against Heat Stroke and Sun Burn. Department of Health, the Government of the Hong Kong Special Administrative Region, Hong Kong. See: http://www.dh.gov.hk/english/press/2010/100706-3.html (accessed 11/08/2017).

Dua, S., Bhuker, M., Sharma, P., Dhall, M. and Kapoor, S., 2014. Body mass index relates to blood pressure among adults. North American journal of medical sciences, 6(2), p.89.

Gupta, N., Heiden, M., Mathiassen, S.E. and Holtermann, A., 2018. Is self-reported time spent sedentary and in physical activity differentially biased by age, gender, body mass index, and low-back pain?. Scandinavian journal of work, environment & health, 44(2), pp.163-170.

Hancher, D.E. and Abd-Elkhalek, H.A., 1998. Effect of hot weather on construction labor productivity and costs. COST ENG(MORGANTOWN WVA), 40(4), pp.32-36.

Hansen, J. and Sato, M., 2016. Regional climate change and national responsibilities. Environmental Research Letters, 11(3), p.034009.

Ikpe.E, Hammon, F and Oloke.D (2012). Cost-Benefit Analysis for Accident Prevention in Construction Projects. Journal of Construction Engineering Management, 138(8): 991 – 998.

ILO (International Labour Organization); 2015. Construction: a hazardous work. See: http://www.ilo.org/safework/areasofwork/hazardous-work/WCMS_356576/lang--en/index.htm (accessed 11/03/2017).

Kawai, N., Kawai, T. and Kawai, K., 1995. Ultrasonic and laboratory studies on fatty liver in white-collar workers. Nihon Shokakibyo Gakkai zasshi= The Japanese journal of gastro-enterology, 92(7), pp.1058-1065.

Larsen, A.D., Hannerz, H., Møller, S.V., Dyreborg, J., Bonde, J.P., Hansen, J., Kolstad, H.A., Hansen, Å.M. and Garde, A.H., 2017. Night work, long work weeks, and risk of accidental injuries. A register-based study. Scandinavian journal of work, environment & health, 43(6), pp.578-586.

Liu, X. and Wang, X., 2017. Development of a Smart Work Site for Early Warning of Heat Stress. In Proceedings of the 20th International Symposium on Advancement of Construction Management and Real Estate (pp. 863-873). Springer, Singapore.

López, M.A.C., Ritzel, D.O., Fontaneda, I. and Alcantara, O.J.G., 2008. Construction industry accidents in Spain. Journal of safety research, 39(5), pp.497-507.

McInnes, J.A., Akram, M., MacFarlane, E.M., Keegel, T., Sim, M.R. and Smith, P., 2017. Association between high ambient temperature and acute work-related injury: a case-crossover analysis using workers' compensation claims data. Scandinavian journal of work, environment & health, 43(1). p86-94.

MD, 2016. (Muscat Daily), 2016. “2016 Was Hottest Year on Record”. Published in daily newspaper “Muscat Daily” dated 22 January 2017. Muscat Daily, Muscat Oman, 2017. See: http://www.muscatdaily.com/Archive/Oman/2016-was-hottest-year-on-record-WMO-4xdr (accessed: 19/11/2017).

Mehta, R.K., Peres, S.C., Kannan, P., Rhee, J., Shortz, A.E. and Mannan, M.S., 2017. Comparison of objective and subjective operator fatigue assessment methods in offshore shiftwork. Journal of Loss Prevention in the Process Industries, 48, pp.376-381.

Miguel A. Camino Lópeza, Ignacio Fontanedab, Oscar J. González Alcántarab, Dale O. Ritzel (2011). The special severity of occupational accidents in the afternoon: "The lunch effect". Accident Analysis and Prevention, 43 (2011) 1104-1116.

NCSI (2015). (National Centre for Statistics and Information), Oman. Statistical Year Book Issued No. 43. See: https://www.ncsi.gov.om/Elibrary/LibraryContentDoc/ben_Statistical_Year_Book_2015_740d0da1-01d2-4f42-a159-6102a49ecf59.pdf (accessed 15/10/2016).

NCSI, 2017. National Centre for Statistics and Information. Monthly Statistical Bulletin, January, 2017. National Centre for Statistics and Information, Muscat, Oman.

NSC, 2017. (National Safety Council). Summer Heat Can Be Deadly for Construction Workers, CPWR Cautions. National Safety Council, Illinois, USA. See: http://www.safetyandhealthmagazine.com/articles/15778-summer-heat-can-be-deadlyfor-construction-workers (accessed 14/12/2017).

NTSB, 1990. (National Transportation Safety Board. 1990). Marine Accident Report - Grounding of the US Tankship Exxon Valdez on Bligh Reef, Prince William Sound, near Valdez Alaska, March 24, 1989. Washington, DC: National Transportation Safety Board.

NTSB, 1990a. (National Transportation Safety Board. 1999a). Evaluation of U.S. Department of Transportation Efforts in the 1990s to Address Operator Fatigue. Washington, DC: Department of Transportation.

OLL, 2003. (Oman Labor Law). Oman Labor Law, Issued vide Royal decree No. 35/2003. Ministry of Manpower, Muscat, Oman. See: http://www.oman.om/wps/wcm/connect/ac78dc4f-69f0-4ddd-ad36-eefb357a43f6/Omani+Labour+Law.pdf?MOD=AJPERES (accessed 26/12/2017).

ONS, 2017. (Office for National Statistics). Construction statistics: Number 18, 2017 edition. Office for National Statistics, 2017. UK. See: https://www.ons.gov.uk/businessindustryandtrade/constructionindustry/articles/constructionstatistics/number182017edition (accessed 01/02/2018).

OSHA, 2013. (Occupational Safety and Health Administration). Safety stand-down at work sites throughout Southeast to focus on heat-related illnesses and injuries. News Release—Region 4. OSHA, Washington, USA. See: https://www.osha.gov/news/newsreleases/region4/05302013 (accessed 14/12/2017).

OSHA, 2017. (Occupational Safety and Health Administration). Protecting Workers from Heat Stress. OSHA, Washington, USA. See: https://www.osha.gov/Publications/osha3154.pdf (accessed 14/01/2018).

OSHR, 2008, (Occupational Safety and Health regulations, Oman). Occupational Safety and Health regulations, Oman, Ministerial decree no 286/2008; Issued on the 22nd June 2008. Ministry of Manpower, Muscat, Oman. See: http://www.oman.om/wps/wcm/connect/198e373d-866b-46fd-90b9-fd1dd8fec77d/Occupational+health+and+safety+framework.pdf?MOD=AJPERES (accessed 26/12/2017).

PASI, 2014. (Public Authority for Social Insurance). 21th Annual Report 2013. Public Authority for Social Insurance, Muscat, Oman. See: https://www.pasi.gov.om/en/Pages/AboutUs/AnnualReports.aspx (accessed 12/02/2018).

Poulter, N.R.; Prabhakaran, D.; Causlfield, M. 2015. Hypertension. Lancet, 386 (995): 801–812.

Rees, K., Dyakova, M., Ward, K., Thorogood, M. and Brunner, E., 2013. Dietary advice for reducing cardiovascular risk. Cochrane Database Syst Rev, 3.

Salminen, S., 2004. Have young workers more injuries than older ones? An international literature review. Journal of safety research, 35(5), pp.513-521.

Sawacha, E., Naoum, S. and Fong, D., 1999. Factors affecting safety performance on construction sites. International journal of project management, 17(5), pp.309-315.

SHJ, 2017. (Statistical Handbook of Japan). Manufacturing and Construction. Statistical Handbook of Japan, 2017. Statistics Bureau, Ministry of Internal Affairs and Communication, Tokyo, Japan. See: http://www.stat.go.jp/english/data/handbook/pdf/2017all.pdf (accessed 01/02/2018).

TOM (2017). Time of Oman, (daily newspaper). "Oman budget: Despite austerity, Oman committed to investment" See: http://timesofoman.com/article/99741/Oman/Government/Oman-budget:-Despite-austerity-Oman-committed-to-investment (accessed 19/01/2017).

TOM, 2015-a. (Time of Oman, daily newspaper). Omani companies compromise safety of workers for higher production. Time of Oman, Muscat, Oman. See: http://timesofoman.com/article/48505/Oman/Sunday-Beat:-Omani-companies-compromise-safety-of-workers-for-higher-production (accessed: 29/01/2018).

TOM, 2015-b, (Time of Oman), 2015. “Oman weather: Sultanate likely to record hottest day in the region”. Published in Daily Time of Oman dated 10 August 2015. Time of Oman, Muscat Oman, 2015. See: http://timesofoman.com/article/65283/Oman/Environment/Oman-weather:-Sultanate-likely-to-record-hottest-day-in-the-region (accessed 19/11/2017).

Umar, T. and Egbu, C., 2018. Causes of construction accidents in Oman. Middle East Journal of Management, 5(1), pp.21-33.

Umar, T. and Egbu, C., 2018. Occupational Safety and Health Regulations in Oman. Proceedings of the Institution of Civil Engineers- Management, Procurement and Law. DOI: 10.1680/jmpal. 18-00007.

Umar, T. and Egbu, C., 2018. Perceptions on Safety Climate in the Construction Industry (A case study of Oman). Proceedings of the Institution of Civil Engineers- Management, Procurement and Law. DOI: 10.1680/jmpal. 18-00001.

Umar, T. and Wamuziri, S. (2016) A review of construction safety, challenges and opportunities – Oman perspective. In Proceedings of 5th World Construction Symposium, Colombo, Sri Lanka (Sandanayake YG, Karunasena GI and Ramachandra T (eds)). University of Moratuwa, Colombo, Sri Lanka, pp. 14–22.

Umar, T., 2016, December. Briefing: Cost of accidents in the construction industry of Oman. In Proceedings of the Institution of Civil Engineers-Municipal Engineer (Vol. 170, No. 2, pp. 68-73). Thomas Telford Ltd.

Umar, T., Wamuziri, S. and Egbu, C. (2017). “Factors that Influence Safety Climate in Construction in Oman”. In Fidelis Emuze and Mike Behm (Editors). Proceedings of Joint CIB W099 and TG59 International Safety, Health, and People in Construction Conference. 2017. 11-13 June 2017, Cape Town, South Africa. Pages 99 – 113, ISBN: 978-1-920508-78-4.

USAG, 2015, (Utility Strike Avoidance Group). “2013 Utility strike damages report”, June 2015. Utility Strike Avoidance Group, London, UK. See: http://www.utilitystrikeavoidancegroup.org/uploads/1/3/6/6/13667105/usag_2013_report.pdf (accessed: 18/03/2018).

Viester, L., Verhagen, E.A., Bongers, P.M. and van der Beek, A.J., 2017. Effectiveness of a Worksite Intervention for Male Construction Workers on Dietary and Physical Activity Behaviors, Body Mass Index, and Health Outcomes: Results of a Randomized Controlled Trial. American Journal of Health Promotion, p.0890117117694450.

WHO (2017). (World Health Organization). Health Equity Assessment Toolkit (HEAT). Version 2.0. Geneva, World Health Organization, 2017. See: http://www.who.int/gho/health_equity/heat_technical_notes.pdf?ua=1 (accessed 15/01/2017).

Wigglesworth, E., 2006. Occupational injuries by hour of day and day of week: a 20-year study. Australian and New Zealand journal of public health, 30(6), pp.505-508.

Xiang, J., Bi, P., Pisaniello, D., Hansen, A. and Sullivan, T., 2014. Association between high temperature and work-related injuries in Adelaide, South Australia, 2001–2010. Occup Environ Med, 71(4), pp.246-252.

Yi, W. and Chan, A., 2016. Health Profile of Construction Workers in Hong Kong. International journal of environmental research and public health, 13(12), p.1232.

Yi, W., and Chan, Albert, P.C. (2017). Effects of Heat Stress on Construction Labor Productivity in Hong Kong: A Case Study of Rebar Workers. International Journal of Environmental Research and Public Health. DOI: 10.3390/ijerph14091055.

Yi, W., Chan, A.P., Wong, F.K. and Wong, D.P., 2017. Effectiveness of a newly designed construction uniform for heat strain attenuation in a hot and humid environment. Applied ergonomics, 58, pp.555-565.

Aryal, A., Ghahramani, A. and Becerik-Gerber, B., 2017. Monitoring fatigue in construction workers using physiological measurements. Automation in Construction, 82, pp.154-165.

Tse, M.; Wan, V.T.; Wong, A.M. Pain and pain-related situations surrounding community-dwelling older persons. J. Clin. Nurs. 2013, 22, 1870–1879.

Tse, M.M.Y.;Wan, V.T.C.; Ho, S.S.K. Profile of pain and use of pharmacological and non-pharmacological methods for relieving pain in older persons in nursing homes. J. Pain Manag. 2010, 3, 309–317.

Appendix I

Heat Stress, a Hidden Cause of Accidents in Construction

Semi-Structured Interview:

Briefing: Thank you very much for volunteering for this interview which is part of a research study related to heat stress and accidents in construction. The purpose of this interview is to explore the effect of heat stress on accidents in construction in Oman. The information which you will provide will be used only for the purpose of this research and your answer will not be shared with your employer. Thus, you are assured that any information you will share will have no impact on your job. You are allowed if you don't want to answer any of the questions. Please ask your interviewer if you don't feel comfortable during the interview and would like to change the time of your interview. Please let your interviewer if you have any question (s) or need further information about this research study.

Interview Questions:

1. Part of this study is to compare your Body Mass Index (BMI) with your age. Therefore, could you please kindly let me know your age in years?

2. I have been informed that you were part of an accident at work. Could you please kindly summarize the situation on the day when the accident happened? What was the main reason behind this accident? Were you tired on that day? How was the climatic condition at the time of accident? Is it was very hot?

3. Normally we have a very high temperature in summer which results into sweat and exhaust the body energy. How do you protect yourself from excessive heat in summer? Do you use any method to keep yourself less affected from sun heat?

4. Mostly employees in different sectors like to have additional working hours so that they can increase their earing. What is your thought on overtime? Do you like to have overtime regularly?

5. What would be your prefer time to work for overtime?

6. Could you please let me know that as an overage for how many hours do you normally sleep?

7. As per government rule, workers must not work at construction sites or in open and elevated areas from 12:30pm to 3:30pm during the months of June, July and August. Is there are any factors which do not allow you to take this break?

8. Do you have any suggestion (s) on what need to be done to protect construction workers from heat stress in Oman?