Impact of weather conditions on construction labour productivity in Qatar

Ahmed Senouci*
Department of Construction Management,
University of Houston,
Houston, Texas 77204-4020, USA
Email: asenouci@uh.edu
*Corresponding author

Mohammed Al-Abbasi
Supreme Education Council,
Qatar Building,
Corniche Street, Al Dafna Area,
Doha, 35111, Qatar
Email: abbasi2211@hotmail.com

Neil N. Eldin
College of Technology,
University of Houston,
Houston, Texas 77204-4020, USA
Email: neldin@uh.edu

Abstract: Qatari construction projects frequently encounter significant delays. One of the major causes of these delays is ignoring Qatar’s extreme weather conditions on labour productivity. This paper studies the impact of temperature, humidity, and wind on labour productivity in Qatar for four construction trades, namely, formwork, masonry, plaster, and ceramic tiles. These trades were chosen because they are time-consuming and commonly found in most construction projects. Weather and trade labour productivity data were recorded between July 2013 and February 2014. The results showed that weather conditions have a high impact on trade labour productivity. They also showed that the labour productivity in the summer can be as low as half of that in the winter. Linear regression models were developed to predict trade productivity on a given day of the year.

Keywords: extreme weather; weather impact; labour productivity; linear regression; construction delays.


Biographical notes: Ahmed Senouci earned a PhD in Civil Engineering in December 1991 from the University of Wisconsin-Madison. He has over 25 years of professional experience in the area of civil engineering and obtained over $4.7 million of funded research and published over
Impact of weather conditions on construction labour productivity in Qatar

Mohammed Al-Abbasi has more than 20 years of work experience in the field of Civil Engineering. He is currently working as a Civil Engineer at Qatar Education Supreme Council. He earned a BS in Civil Engineering in 2002 and an MS in Engineering Management from Qatar University.

Neil N. Eldin is a civil engineer with over 30 years of professional experience in the area of sustainable construction materials and construction engineering and management. His industrial experience involved design, procurement, and construction of various structures including power plants, petrochemical plants, offshore facilities, and buildings. In his recent assignment as project manager for NEPCO/ENRON, he was responsible for the design, procurement, and construction of two LNG power plants amounting to over $350 million. He has successfully obtained over $1.5 million of funded research and documented his findings in over 60 peer-reviewed publications; of which 35 are top quality journal papers.

This paper is a revised and expanded version of a paper entitled ‘Impact of weather conditions on construction labor productivity in State of Qatar’ presented at the 9th International Conference on Construction in the 21st Century (CITC-9), Dubai, United Arab Emirates, 5–7 March, 2017.

1 Introduction

Qatar is currently experiencing a high rate of economic growth and urban development. The economic growth rate in Qatar is currently one of the fastest in the world. Because it was selected to host the FIFA World Cup in 2022, Qatar plans to invest more than $40 billion in infrastructure projects including a new airport, a metro system, a high-speed rail network, and 40,000 more hotel rooms. Qatar also plans to invest $4 billion to build nine new modular stadiums and renovate another three. This situation has recently raised many concerns about the construction industry significant problems in terms of delays and time completions. One of the major sources of construction delays in Qatar is the reduced labour productivity during the summer months due to the extreme weather conditions, which has a significant impact on project schedules. During extreme weather conditions, workers’ productivity may tremendously decrease. Moreover, workers have reduced working hours due to government regulations forbidding outdoor work from 11 am to 3 pm in the summer when the weather is extremely hot and humid. The reduction in labour productivity and working hours may be a major source of construction delays and additional costs. Contractors do usually ignore the impact of extreme weather conditions during the computation of labour productivity and activity durations, which results in an inaccurate estimation of project duration.

The objective of the study is to determine the impact of temperature, humidity, and wind on the productivity on four construction trades in Qatar, namely, formwork,
masonry, plaster, and ceramic tile. These construction trades were chosen because they are present in all types of building construction and are time-consuming.

2 Literature review

Construction projects, in general, are executed in an outdoor environment, and therefore are affected by weather conditions. The weather impact is one of the main factors causing delay and cost overruns on construction projects (Baldwin et al., 1971; Koehn and Meilhede, 1981; Laufer and Cohenca, 1990). Benjamin and Greenwald (1973) reported that almost 50% of construction activities are sensitive to weather conditions. The weather impact on construction activities can be in the form of reduced labour productivity and/or work stoppage. Reduced labour productivity is generally attributed to reduced human performance due to the combined effect of temperature, humidity, and wind velocity. The weather-related work stoppage is attributed either to the inability of construction personnel to work under severe weather conditions such as heavy rain, snow, and (or) gusting winds, or simply to the compliance with safety regulations in such adverse weather conditions.

A number of studies have been conducted to establish the relationship between labour productivity and weather conditions for electrical work (National Electrical Contractors Association, 1974), masonry construction (Grimm and Wagner, 1974; Sanders and Thomas, 1991), equipment and manual tasks, and general construction (Koehn and Brown, 1985). The latter provides an industry-wide average considering a number of trades (manual excavation, equipment excavation, steel erection, masonry, electrical, and carpentry). Other researchers considered the impact of weather on work stoppage and established daily rainfall thresholds that would cause the stoppage and interruption of construction activities (Cantwell, 1987; Smith and Hancher, 1989). Thomas and Yiakoumis (1987) developed a factor model for evaluating the productivity of labour-intensive construction activities. The National Cooperative Highway Research Program (NCHRP, 1978) studied the impact of various weather types on different highway construction operations. According to the study, 45% of all highway construction activities are affected to some degree by weather, resulting in substantial additional costs that can run into billions of dollars annually.

Benjamin and Greenwald (1973) proposed a simulation model that integrates the interruptive effect of weather in scheduling. The model simulates construction duration by making daily work/no-work decisions according to the historical hourly weather data and the sensitivity of activities to temperature, precipitation, and wind. Grimm and Wagner (1974) reported that thermal stress in humans is affected by the balance between metabolism and evaporation, convection, and radiation. These heat transfers are affected by environmental conditions of temperature, humidity, air movement, and radiation. Correlations between all thermal stress variables and labour productivity have not been established for construction craftsmen. However, relationships between mason productivity and temperature and humidity have been established. The authors developed graphs that represent mason productivity in all areas in the USA for all months of the year. These graphs are helpful to find the productivity in any location by specifying the month when the activity takes place and using interpolation methodology to find the approximate value of the productivity. Koehn and Brown (1985) reported that humidity and temperature are the most effective factors on productivities because they affect some
relevant factors to productivity, such as the arrival of personnel, transportation of equipment, delivery of material, and environmental protection. The authors proposed the following equations to represent the relationship between productivity and temperature and humidity.

\[
P_c = 0.0144T - 0.00313H - 0.000107T^2 - 0.000029H^2 \tag{1}
\]

\[
P_w = 0.0517T - 0.0173H - 0.00032T^2 - 0.0000985H^2 - 0.0000911T.H - 1.459, \tag{2}
\]

where

\[P_c:\] productivity in cold weather

\[P_w:\] productivity in warm weather

\[T:\] temperature

\[H:\] humidity.

Thomas and Yiakoumis (1987) reported several weather effects on labours productivity, namely,

- bad weather time or paid time
- reduced productivity because of long time working
- repeated work resulted from frost ice, wind, rail, or the need to correct poor quality workmanship
- dismissed, absence, report late of labours due to bad weather
- reduced working schedule, or shortened work weeks that occur during winter months and result in a loss of momentum.

Osama et al. (1995) reported that weather conditions can have an adverse impact on the duration and cost of construction activities. They also reported that the productivity loss due to the impact of weather on construction activities can be either partial or complete. A partial loss is generally attributed to reduced labour productivity while a complete loss is generally to a work stoppage that interrupts these activities. The authors presented an automated decision support system, named WEATHER, for estimating the combined effect of reduced labour productivity, and work stoppage caused by adverse weather conditions on construction sites. The system provides estimates of construction productivity, activity durations, and weather patterns that facilitate the application of risk analysis in planning and scheduling.

Osama et al. (1995) presented an automated support system for estimating the combined effect of reduced labour productivity and work stoppage caused by adverse weather conditions on construction sites. South Dakota DOT (SDDOT, 1997) used available construction and weather records to determine the expected number of working days and delays due to extreme weather conditions. McDonald (2000) examined weather-related delay claims for construction projects and how they can be resolved. El-Rayes and Moselhi (2001) developed a decision support system for quantifying the impact of rainfall on the productivity and duration of highway construction operations. Moselhi and Khan (2012) identified, analysed, and ranked the parameters that affect job-site daily labour productivity to help job-site personnel in planning and comparing their daily targets and to fine-tune their resource allocations according to the daily situation.
Apipattanavis et al. (2012) proposed an integrated framework to identify the weather attributes that cause construction delays and to quantify weather threshold values. Winds speed and temperature will play an essential part on labour productivity in many different ways.

3 Methodology

Four construction trades were considered, namely, plaster, block, ceramic tile, and concrete formwork. They were selected herein because of they are omnipresent in all construction projects and consume extensive manpower and resources. The trade labour productivity was recorded daily on construction sites for eight months, from 1 July to 28 February. This time period covered most Qatari weather spectrum including summer, fall, and winter months. The daily collected data included the following:

- date
- number of crews and their composition
- number of the crew working hours
- crew productivity
- weather condition data (mean temperature, humidity, and wind speed).

The weather data was provided by the Weather Authority in Qatar.

A data analysis was also conducted on the variation of trade labour productivities during the year. Finally, multiple linear regression equations were developed to relate trade labour productivity to weather condition variables, namely, temperature, wind speed, and humidity.

4 Result analysis

A regression analysis was performed using Minitab software to find the relationship between the trade productivity and weather condition variables namely, temperature, wind speed, and humidity. Mallows’ $C_p$ was used first to choose between multiple regression models by balancing their number of predictors. Mallows’ $C_p$ compared the precision and bias of the full regression model to models with a subset of the predictors. The selected models were those that had small Mallows’ $C_p$ and close to the number of predictors in the model plus the constant. A model with a small Mallows’ $C_p$ value is relatively precise and has a small variance in estimating the true regression coefficients and predicting future responses. Moreover, a model with a Mallows’ $C_p$ value close to the number of predictors plus the constant is relatively unbiased in estimating the true regression coefficients and predicting future responses.

The regression models were selected herein that satisfy the following conditions:

- a Mallows’ $C_p$ value very close to the number of predictors plus the constant
- lowest mean square error (S) value
- highest adjusted $R^2$ value.
4.1 Plaster work productivity

Four labour crews were chosen for the study. After collecting the productivity data for the plastering trade, the results were analysed to determine the variation of the plastering work productivity over time. As shown Figure 1, the productivity was low in the summer months. It started to increase after the summer months until it reached its maximum value in the middle of February.

A regression analysis was performed using Minitab software to find the relationship between the plastering work productivity and weather parameters. The regression analysis gave the following equation:

\[ PP = 38.81 - 0.597 \times MT + 0.052 \times MS - 0.074 \times MH, \]

where

- PP: daily crew plaster work productivity (m²/crew/day)
- MT: mean temperature (degrees Celsius)
- MH: mean relative humidity (%)
- MS: mean wind speed (km/h).

Figure 1 Daily plaster work productivity variation over time

Table 1 summarises the Mallows’ \( C_p \) and adjusted \( R^2 \) results for several regression models. The results show that the selected regression model (3) is the best one that can represent the variation of plaster work productivity with time. The selected regression model satisfies the following conditions:

- a Mallows’ \( C_p \) value of 4, which is equal to the number of predictors plus the constant (4 = 3 + 1).
- the lowest mean square error (S) value of 1.903
- the highest adjusted \( R^2 \) value of 91.5.

The regression analysis exhibited an adjusted \( R^2 \) of 91.5% which means the regression equation will give the productivity of plaster with 91.5% accuracy.
4.2 Block work productivity

As shown in Figure 2, the block productivity shows a similar to that of plastering work. In other words, the productivity started low in the summer period then it increased to reach a maximum value in the winter, and then it started to get stable and tended to decrease at the end of winter.

Figure 2 Daily block work productivity variation over time

A regression analysis of the productivity results, which was performed using Minitab, gave the following equation for the productivity of block work:

\[
\text{Block Work Productivity} = 63.87 - 1.42 \text{MT} - 0.023 \text{MH}
\]

(4)

where

\begin{itemize}
  \item MT: mean temperature
  \item MH: mean of relative humidity.
\end{itemize}

Table 2 summarises the Mallows’ \(C_p\) and adjusted \(R^2\) results for several regression models. The results show that the selected regression model (4) is the best one that can represent the variation of block work productivity over time. The selected regression model satisfies the following conditions:

- a Mallows’ \(C_p\) value of 2.7, which is very close to the number of predictors plus the constant (2.7 \(\equiv 2 + 1\))
• the lowest mean square error (S) value of 2.625
• the highest adjusted $R^2$ value of 94.7.

The regression analysis exhibited an adjusted $R^2$ of 94.7%, which means the regression equation will give the productivity of plaster with 94.7% accuracy.

**Table 2** Block work Mallows’ $C_p$ statistical analysis

<table>
<thead>
<tr>
<th>Number of Variables</th>
<th>Adjusted $R^2$</th>
<th>(S)</th>
<th>Mallows’ $C_p$</th>
<th>Variable (1)</th>
<th>Variable (2)</th>
<th>Variable (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td>94.2</td>
<td>2.629</td>
<td>2.30</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>humidity</td>
<td>94.7</td>
<td>2.625</td>
<td>2.7</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>humidity</td>
<td>94.2</td>
<td>2.626</td>
<td>2.9</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>humidity</td>
<td>94.2</td>
<td>2.6270</td>
<td>4.0</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

4.3 Ceramic tile work productivity

The impact of weather conditions on the productivity of ceramic work crews is lower than that of plaster and block work crews. This is due to the fact that ceramic work crews are always working in the shadow of buildings and by consequent they are not exposed directly to the sun.

As shown in Figure 3, the ceramic work productivity shows a trend similar to those of plastering and block work. In other words, the productivity started low in the summer period, increased to reach a maximum value in the winter, and then started to decrease at the end of winter.

**Figure 3** Ceramic work daily productivity variation with time

A regression analysis of the productivity results, which was performed using Minitab, gave the following equation for the productivity of block work:

$$\text{Productivity for Ceramic Work} = 39.6 - 0.581 MT - 0.0163 MH$$  \hfill (5)
Table 3 summarises the Mallows’ $C_p$ and adjusted $R^2$ results for several regression models. The results show that the selected regression model (5) is the best one that can represent the variation of block work productivity over time. The selected regression model satisfies the following conditions:

- a Mallows’ $C_p$ value of 2.4, which is very close to the number of predictors plus the constant ($2.4 \approx 2 + 1$)
- the lowest mean square error (S) value of 1.205
- the highest adjusted $R^2$ value of 93.9.

The regression analysis exhibited an adjusted $R^2$ of 93.9% which means the regression equation will give the productivity of a ceramic work crew with 93.9% accuracy.

### 4.4 Formwork (shuttering) work productivity

During the analysis of the formwork analysis, a significant difference in productivity results was found between vertical (i.e., columns, core walls, and shear walls) and horizontal (i.e., slabs and beams) formwork. That’s why a separate analysis was performed for horizontal and vertical formwork. One important point to mention here is that formwork crews are composed of one carpenter only because the shuttering work can be done without the help of labourers. Therefore, the number of crews in the shuttering trade is usually equal to the number of carpenters working on the site. Another point is that the formwork productivity can’t be recorded every day unless all wood moulds are ready for concrete casting.

### 4.5 Horizontal formwork productivity

The shuttering productivity is computed at the end of each shuttering period using the following equation:

$$
\text{Crew Daily Productivity} = \frac{\text{Total volume of concrete shuttering}}{\text{Number of crews} \times \text{Number of days}}
$$

(6)
A regression analysis of the productivity results, which was performed using Minitab, gave the following equation for the productivity of horizontal shuttering work:

\[
\text{Horizontal Shuttering Productivity} = 9.44 - 0.142 \text{MT} - 0.0094 \text{MH}
\]

where

- MT: maximum temperature
- MH: mean of relative humidity.

As shown in Figure 4, the horizontal formwork productivity started low in the summer period and increased to reach a maximum value in the winter.

Table 4 summarises the Mallows’ $C_p$ and adjusted $R^2$ results for several regression models. The results show that the selected regression model (7) is the best one that represents the variation of horizontal shuttering productivity over time. The selected regression model satisfies the following conditions:

- a Mallows’ $C_p$ value of 2.2, which is very close to the number of predictors plus the constant ($2.2 \approx 2 + 1$)
- the lowest mean square error (S) value of 0.357
- the highest adjusted $R^2$ value of 92.59.

The regression analysis exhibited an adjusted $R^2$ of 92.59% which means the regression equation will give the productivity of a horizontal shuttering crew with 92.59% accuracy.
4.6 Vertical formwork productivity

The productivity of vertical shuttering is lower than that of a horizontal one. This is due to the nature of vertical concrete structures. The formwork productivity of columns has a lower productivity than that of shear walls and reinforced cores. Thus, the productivity data for columns, shear walls, and reinforced cores in each floor was collected in this study.

As shown in Figure 5, the vertical formwork productivity started low in the summer period and increased to reach a maximum value in the winter.

Figure 5  Daily vertical shuttering productivity variation with time

A regression analysis of the productivity results, which was performed using Minitab, gave the following equation for the productivity of block work:

\[
\text{Vertical Shuttering Productivity} = 9.03 - 0.113 \text{MT} - 0.0133 \text{MH}
\]

where
- MT: mean temperature
- MH: mean of relative humidity.

Table 5 summarises the Mallows’ $C_p$ and adjusted $R^2$ results for several regression models. The results show that the selected regression model (Eq. 8) is the best one that represents the variation of vertical shuttering productivity over time. The selected regression model satisfies the following conditions:

- a Mallows’ $C_p$ value of 2.0, which is very close to the number of predictors plus the constant ($2.2 \approx 2 + 1$)
Impact of weather conditions on construction labour productivity in Qatar

- the lowest mean square error (S) value of 0.302
- the highest adjusted $R^2$ value of 90.01.

For vertical shuttering, the basic criteria’s values are:

The regression analysis exhibited an adjusted $R^2$ of 90.01% which means the regression equation will give the productivity of plaster work crews with 90.01% accuracy.

<table>
<thead>
<tr>
<th>Number of variables</th>
<th>Adjusted $R^2$</th>
<th>(S)</th>
<th>Mallows’ $C_p$</th>
<th>$\text{Variable (1) temperature}$</th>
<th>$\text{Variable (2) wind. speed}$</th>
<th>$\text{Variable (3) humidity}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>88.3</td>
<td>0.30158</td>
<td>0.7</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1</td>
<td>6.9</td>
<td>0.84897</td>
<td>573.7</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>90.01</td>
<td>0.30202</td>
<td>2.0</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>88.1</td>
<td>0.30334</td>
<td>2.7</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

5 Discussion

The results show that the labour productivity was the lowest during the summer months and increased to reach a maximum value by the end of the winter months. It is worth noting that the construction productivity is not only affected by the weather conditions, but also by other factors such as labour mental state, sudden accidents, and a shortage of materials. However, this study dealt only with the impact of weather conditions on the construction productivity on Qatari construction sites.

5.1 Labour productivity over time

The labour productivity in Qatar increases in winter and decreases in the summer. For example, the plastering work productivity reached the minimum value of 18.13 m²/crew/day on 14 July, 2013 and the maximum value of 35 m²/crew/day during the month of February. The percent difference between the minimum and maximum productivity values is equal to 48.2% as shown below:

$$\text{Plastering productivity Difference (\%) } = \frac{35 - 18.13}{35} \times 100 = 48.2\%.$$ (9)

This shows the large decrease in plaster work productivity during the summer months. This productivity decrease should be considered by Qatari construction companies when preparing project schedules.

The block work productivity had the same pattern as that of the plastering trade. Its productivity reached a minimum value of 11.5 m²/crew/day on 1 July, 2013, and a maximum value of 40 m²/crew/day on 13 February, 2014. The percent difference between the minimum and maximum productivities is equal to 71.3%.
On the other hand, the weather impact on ceramic work productivity is as much as those of block and plaster works. This is due to the fact that ceramic work is usually done inside the facility, which protects workers from the direct exposure to the sun and hot weather. The productivity of ceramic work reached a minimum value of 16 m²/crew/day during the month of July and a maximum value of 30.7 m²/crew/day during the month of February. The percent difference of both productivity values is equal to 52.2%.

The productivity of concrete shuttering for vertical and horizontal structures follows a similar trend. The minimum and maximum productivity values for vertical concrete shuttering were 3.95 m³/crew/day and 5.93 m³/crew/day, respectively. The percent difference between the two productivities is 66.6%. On the other hand, the minimum and maximum productivity values for horizontal concrete shuttering were 3.77 m³/crew/day and 6.21 m³/crew/day, respectively. The percent difference between the two productivities is 60.7%.

5.2 Temperature impact on productivity

Construction labour productivity is affected by weather conditions. It is worth investigating which of the weather variables (i.e., temperature, wind, and humidity) has the most impact on construction labour productivity. A correlation was used herein to determine the strength of the relationship between construction labour productivity and temperature. It is used to find the correlation between two sets of data (data X, data Y) using the following equation:

\[
\text{Correlation for } (X,Y) = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2(Y_i - \bar{Y})^2}} \tag{10}
\]

The correlation result values vary between the values of 1 and –1 (i.e., \(-1 \leq \text{Correlation} \leq 1\)). The two sets of data are closer to each other when the correlation is closer to the values of 1 and –1.

The correlation results of the labour productivity of plaster, block, ceramic, vertical shuttering, and vertical shuttering are summarised in Tables 6–10, respectively. The correlation between the trade productivities and temperature is very strong. This shows that the temperature has the strongest impact on trade productivities. On the other hand, the correlations between the trade productivities and wind speed and humidity (shown in grey colour) are substantially lower compared to that of temperature. This indicates that the wind speed and humidity have a lower impact on trade productivities.

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Plaster work productivity correlation results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Productivity/crew/hour</td>
</tr>
<tr>
<td>Productivity/crew/hour</td>
<td>1</td>
</tr>
<tr>
<td>Mean temperature</td>
<td>–0.93</td>
</tr>
<tr>
<td>Mean wind speed</td>
<td>0.42</td>
</tr>
<tr>
<td>Mean humidity</td>
<td>–0.35</td>
</tr>
</tbody>
</table>
The correlation analysis shows that the temperature has the largest impact on construction trade productivities. Therefore, to increase trade productivity, contractors need to find some ways to decrease temperature on construction sites such as, securing temporary, preventing labours from being directly exposed to the sun, and using fans to increase air ventilation and reduce air humidity.

**Table 7**  Block work productivity correlation results

<table>
<thead>
<tr>
<th>Productivity/day/crew</th>
<th>Mean temperature</th>
<th>Mean wind speed</th>
<th>Mean humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity/day/crew</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean temperature</td>
<td>–0.97</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Mean wind speed</td>
<td>–0.02</td>
<td>0.04</td>
<td>–0.33</td>
</tr>
<tr>
<td>Mean humidity</td>
<td>0.27</td>
<td>–0.29</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 8**  Ceramic tile work productivity correlation results

<table>
<thead>
<tr>
<th>Productivity/day/crew</th>
<th>Mean temperature</th>
<th>Mean wind speed</th>
<th>Mean humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity/day/crew</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean temperature</td>
<td>–0.97</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Mean wind speed</td>
<td>–0.04</td>
<td>0.04</td>
<td>1</td>
</tr>
<tr>
<td>Mean humidity</td>
<td>0.31</td>
<td>–0.29</td>
<td>–0.34</td>
</tr>
</tbody>
</table>

**Table 9**  Vertical shuttering work productivity correlation results

<table>
<thead>
<tr>
<th>Productivity/day/crew</th>
<th>Mean temperature</th>
<th>Mean wind speed</th>
<th>Mean humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity/day/crew</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean temperature</td>
<td>–0.94</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Mean wind speed</td>
<td>0.18</td>
<td>0.07</td>
<td>1</td>
</tr>
<tr>
<td>Mean humidity</td>
<td>0.28</td>
<td>–0.28</td>
<td>–0.35</td>
</tr>
</tbody>
</table>

**Table 10**  Horizontal shuttering work productivity correlation results

<table>
<thead>
<tr>
<th>Productivity/day/crew</th>
<th>Mean temperature</th>
<th>Mean wind speed</th>
<th>Mean humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity/day/crew</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean temperature</td>
<td>–0.94</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Mean wind speed</td>
<td>–0.12</td>
<td>0.06</td>
<td>1</td>
</tr>
<tr>
<td>Mean humidity</td>
<td>0.17</td>
<td>–0.29</td>
<td>–0.32</td>
</tr>
</tbody>
</table>
6 Conclusions

This study focused on investigating the impact of weather conditions on the productivity of several construction trades in Qatar. A full data of specific weather components (i.e., temperature, wind speed, and humidity) were recorded. The labour productivity of four trades (plaster work, block work, ceramic tile work, and concrete shuttering work) was also recorded between the months of July, 2013 and February, 2014. The analysis of the results has shown that the weather conditions have a high impact on construction labour productivity. The construction labour productivity during the summer months can be as low as half of that during the winter months. A linear regression equation was developed for each construction trade to represent the variation of its productivity with respect to weather components, namely, temperature, wind speed, and humidity. This equation can be used to predict the labour productivity for the four construction trades over time. The study showed that the temperature has the highest impact on construction labour productivity. Therefore, there is a need for construction managers to find ways to reduce the impact of temperature on the job site such as using temporary shades or spreading cold water.

This study has the potential of reducing Qatari construction project delays due to weather conditions. It allows taking into account the effects of weather conditions on activity durations during the scheduling of Qatar in project scheduling. This allows project schedulers and managers to have a more realistic project schedules.

For future work, the impact of weather conditions on labour productivity for other constructions should be studied such as plumbing, drainage, mechanical work, HVAC, excavation, painting, excavation, … etc.

References


