Manual Handling Process on Concrete Panel Lifting Using Ergonomic Approach

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ABSTRACT: Precast concrete panel is one of the Industrial Building System (IBS) components currently used in modern construction industry, especially, in a highly populated urban area in Malaysia, owing to its cost and time efficiency in a project completion. However, the constraints lie in Musculoskeletal Disorders (MSDs) when IBS workers manually lift the concrete panel repeatedly. The aim of this study is to analyze the recommended weight limit (RWL), lifting index (LI) and physiological experience among workers while lifting precast concrete panel with 3300mm x 600mm size and compressive strength of 40MPa. The methods involved include a survey through the Nordic questionnaires, interview sessions, NIOSH lifting index calculation, recommended work limit calculation, Rapid Upper Limb Assessment (RULA) and video recording. The results yielded the MSDs problem. The guidelines of recommended weight limit and lifting index are produced. They benefit workers and increase their awareness on the MSDs issues.

Keywords - Industrialized Building System, Lifting index, Musculoskeletal Disorders, Precast Concrete Panel, Recommended Weight Limit

1.0 INTRODUCTION

IBS is defined as an implementation of construction manufacturing through components prefabricated in building construction (Mohd Nawi, Othman Mydin, Abdul Nifâ, Osman, & Anuar, 2015). IBS can also be defined as a construction technique in which components are manufactured in a controlled factory environment, transported within a logistic area, modular and assembled into a structure with minimal supplementary site work (Oleiwi, Mustapha, & Al-Mattarneh, 2010). IBS comprises innovative mould systems, precast component systems, modular block systems, and fabricated steel and lumber structures as construction parts (Badir, Kadir, & Hashim, 2002). In order to reduce the dependency on unskilled workers from neighbouring countries, the government set up the IBS Strategic Plan in 1999 to promote IBS by initially introducing the blueprints of industrialized construction in 2015, followed by the IBS Roadmap 2003-2010 and IBS Roadmap 2011-2015. The roadmaps have been developed based on the direction provided by supplier development scheme, education and training, quality control and research, awareness programmes, and development programmes (CIDB, 2010). The viewpoint for IBS execution in Malaysia still needs to be encouraged with essential initiatives from the government by encouraging manufacturers, contractors and suppliers to absorb the IBS system (Nurul Azam Harun, 2017). According to M.R. Yusof, Musa, Samsudin, Mohammad, & Baharuddin (2016) the construction can be clarified based on material, process and system. M.R. Yusof et al., (2016) asserted that the weight relation of components must be used for building categorization and weight has played a significant role, impacting the mobility and production technique of the components and their erection method on site. The organization by weight also has the benefit of differentiating between various basic materials used in the production of components which in turn determines the characteristics of the building system.

Construction workers are always exposed to the hazard at the workplace. A study showed (Zerguine, Tamrin, & Jalaludin, 2018) that six large construction projects in Malaysia involved 323 foreign construction workers, the results shows that the workers (31.5%) have experienced falling from a great height (6 feet or more above lower level), followed by handing and lifting components (24.7%). According to Luttmann, Matthias, Caffier, & Lieber (2003), illnesses in the workplace are divided by two fragments namely in-site disease and long-term disease. In-site diseases are related to pathophysiological response to internal or external factors where immediate injury is caused by 4 main factors; fallen from high level, dropped objects, tucked between objects and tripping. The Department of Safety and Health (DOSH) Malaysia reported that 160 workers died onsite in 2017 due to high level falls (41.4%), dropped objects (15.7%), tucked between objects (14.3%) and tripping (11.4%) (DOSH, 2017). Meanwhile, long-term disease is related to the disorder or
disruption to a regular bodily structure and function. A syndrome is a collection of signs and symptoms associated with a specific health-related cause (Health and Safety Executive, 2017). One of the issues in construction in advance to long-term disease are Musculoskeletal Disorders (MSDs), caused by carrying out tasks or handling materials repeatedly beyond the limits (Adnan & Aziruddin Ressang, 2014). MSDs are injuries and disorders that affect the human body’s movement or musculoskeletal system especially in the joint part which occurs while workers are performing repetitive motions (Choi & Rajendran, 2014).

Musculoskeletal Disorders (MSDs) are a common disease related to handling and lifting components, especially by sudden force beyond human limitation or by repetitive work. Activities involving heavy loads can result in acute injury, but most occupation-related MSDs are from motions that are repetitive, or from maintaining a static position (Barzideh, Chooobineh, & Tabatabaee, 2014). MSDs can ascend from making the same motions repeatedly or from repeated exposure to vibration, force, and awkward posture (Choi & Rajendran, 2014). MSDs are triggered by biomechanical burden which must be applied in executing jobs, energy period, and frequency with which tasks are done. MSDs can affect joints and tendons in all parts of the body and muscles (Luttmann et al., 2003). Upper and lower back, neck, shoulders and extremities (arms, legs, feet, and hands) were the most affected on MSDs (Rwamamara, Lagerqvist, Olofsson, Johansson, & Kaminskas, 2010). According to Sang D. Choi & Lu Yuan (2016), MSDs are injuries and disorders of a certain tissue especially in the joints of body parts and nervous system. Examples of MSDs include epicondylitis, tendinitis, back pain, carpal tunnel syndrome, hand-arm vibration syndrome and tension neck syndrome (Lop, Kamar, Aziz, Abdullah, & Akhir, 2017).

Precast concrete panel which is categorized as a light and medium weight panel or heavy weight panel has been prefabricated in factory and is still uses manpower during its installation process (Shapie et al., 2018). Consumption of precast panel is to be the main issue for this study due to favourite choices of IBS component application among the IBS industry players. The issues occur in ergonomic term when the workers at construction site do the lifting process manually using full human energy which results in serious injuries to the muscles, tendons, ligaments and joints and in turn, reduces productivity (Azman, Ahamad, Majid, & Shah, 2012). The current technique is unhealthy and dangerous when being performed repeatedly by workers. Due to this issue, the objectives of this study are to analyse the recommended weight limit (RWL), lifting index (LI) and physiological experience among workers while lifting precast concrete panels which are 3300mm x 600mm size.

The sizes of the precast concrete panel depend on certain models produced by the manufacturer, and this study focused on a model produced by Yang Sulong (M) Sdn. Bhd. in Melaka. The specifications of the precast concrete are 100mm thick, 600mm width and 3300mm length with weight distribution of 135 kg/m². The mass range of precast concrete is between 240 kg to 260 kg with a compressive strength of 40 MPa. Generally, this precast concrete comes in a bulk of 5 units for each pallet in a horizontal position of y.

2.0 METHOD

This pilot study focused on a construction site which uses a manual handling process to lift the concrete panel using an ergonomic approach. The analysis included the recommended weight limit (RWL), lifting index (LI) and physiological experience among workers while lifting precast concrete panel with a size of 3300mm x 600mm. In addition, the approaches used in this study included recommended work limit (RWL) calculation, NIOSH lifting index (LI) calculation, interview sessions (Nordic Questionnaire), Rapid Upper Limb Assessment (RULA), and video recording.

2.1 Rapid Upper Limb Assessment (RULA)

Firstly, the data was evaluated using the Rapid Upper Limb Assessment (RULA) through the CATIA software. A basic RULA was designed to assess the workers’ exposure in ergonomics risk factors related to the upper extremity of MSDs. The RULA ergonomics evaluated the biomechanical and postural load requirements of the task demands on the upper extremities, trunk and neck. The data for every body part was collected and scored; then the risk factor variables were accumulated, generating a particular score that represented the stage of MSDs risk as outlined in Table 1.

<table>
<thead>
<tr>
<th>Score</th>
<th>Level of MSD Risk</th>
</tr>
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<tbody>
<tr>
<td>1-2</td>
<td>negligible risk, no action required</td>
</tr>
<tr>
<td>3-4</td>
<td>low risk, change may be needed</td>
</tr>
<tr>
<td>5-6</td>
<td>medium risk, further investigation, change soon</td>
</tr>
<tr>
<td>7+</td>
<td>very high risk, implement change now</td>
</tr>
</tbody>
</table>
2.2 Recommended Work Limit (RWL) and Lifting Index (LI)

In the second step, parameters such as weight of the concrete panel, horizontal location (H), vertical location (V), vertical travel distance (D), asymmetry angle (A), frequency rate (F), the lifting duration, and coupling component (C) were measured for every worker. Based on the results of the first step, horizontal multiplier (HM), vertical multiplier (VM), distance multiplier (DM), asymmetry multiplier (AM), coupling multiplier (CM), and load constant (LC) were calculated. The data for RWL were collected from 3 different types of Body Mass Index (BMI); underweight, normal and overweight. Then, these RWL results was analysed using Lifting Index according to (below than 1.0) nominal or (more than 1.0) high risk.

2.3 Nordic Musculoskeletal Questionnaire

The last step for this study was a signification study between RULA and LI using Nordic Musculoskeletal Questionnaire (NMQ)(Kuorinka et al., 1987). Nordic Questionnaire was designed as a standardized questionnaire allowing the evaluation of the neck, lower back, shoulder and general complaints for epidemiological research use.

The NMQ can be distributed as a survey through structured interviews or questionnaires. Reliability is an important feature of this study as it determines whether the data collection instrument used is consistent or not and it will affect the results of the study. In order to determine reliability, the internal consistency method used was translated into the Alpha - Cronbach score. This score became an induction for the correlation stage for each item submitted in the questionnaire. 19 respondents were involved in this study, they were divided into 3 categories according to weight; (6) underweight, (7) normal and (6) overweight. Six people interpreted the Alpha - Cronbach validity test score representing each category as shown in Table 2. Based on the results, the developed questionnaire had a good reliability based on the score of 0.86 and the instrument was deemed fit for the survey.

<table>
<thead>
<tr>
<th>Table 2 Interpretation Alpha - Cronbach score</th>
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<tbody>
<tr>
<td>Alpha - Cronbach score</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>0.9 – 1.0</td>
</tr>
<tr>
<td>0.7 – 0.9</td>
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<tr>
<td>0.6 – 0.7</td>
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3.0 RESULT AND DISCUSSION

The results were beneficial to improve the manual handling process of the concrete panel lifting in the IBS system. This study focused on the psychophysical (i.e., horizontal distance, vertical travel distance, precast concrete panel size, etc.) and biomechanical ergonomics factor in the form of the recommended assisting devices and appropriate body posture.

3.1 Samples

19 male participants completed the study. The distribution is summarized in Table 3.

<table>
<thead>
<tr>
<th>Table 3 Personal Characteristics</th>
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<tbody>
<tr>
<td>Percentages of participants</td>
</tr>
<tr>
<td>Experience</td>
</tr>
<tr>
<td>&gt;10 years</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Percentage of BMI Index Respondent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 18.5 (Underweight)</td>
</tr>
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</table>

Table 3 show details the respondents’ work experience and distribution of BMI Index. The majority of subjects (37 %) have working experience of more than 5 years. These findings showed that the higher result might be affected by the high salary. 21% of respondents were underweight according to the Body Mass Index (BMI) while 32% and 47% of respondents belong to the normal and overweight category respectively.
3.2 Rapid Upper Limb Assessment (RULA)

From the observation, three techniques pattern must be done by workers to lift the precast concrete into the vertical position manually; combined hip hinge and squat technique, shoulder pack technique and neutral spine technique.

3.2.1 Combined Hip Hinge and Squat Technique

In the first technique, the workers had to combine hip hinge and squat technique to lift up to the shoulder level. Hip hinge is a sagittal flat effort where the hips are the axis of rotation sandwiched between a neutral lumber pelvic segment and a femur (upper thigh bone). The results in Fig. 1(a) showed the first technique of hip hinge and squat that was used by workers during the onsite lifting process.

![Onsite hip hinge and squat technique done by worker and the simulated results](image)

An analysis on RULA resulted in a score of 7 in red colour, indicating that the technique imposed a very high risk to the workers and change was needed as shown in Fig. 1(b). However, it can be quite difficult when the body and the movement would affect multiple joint through balancing—especially job demanding to stabilize a column of many joints (the spine), although moving at the hip combined. The capability for a hip hinge effort mechanism is tremendously important for optimum mechanics throughout the lifting of the precast concrete. It involves an organization between essential stabilizers and gluteal musculature, as well as a high level of body awareness and motor control. The inability to disassociate hip effort from spine effort can lead to reduced performance and increased MSDs. The best position techniques are shown in Fig. 2.

![Comparing the hip hinge and squat technique between the poor technique and the best practice](image)

(a) Poor technique: the lower spine rounds forward as motions occur at the back instead of only at the hips joints. This will create stress on the lower back.

(b) Correct technique: The spine maintains as a neutral posture and movement occurs from the hip joints.

(c) Hip hinge squat technique: torque focuses on the hip, resulting in the majority of the load at the gluteal and hamstring musculature (posterior chain) as opposed to the quadriceps.

Figure 1 Onsite hip hinge and squat technique done by worker and the simulated results

Figure 2 Comparing the hip hinge and squat technique between the poor technique and the best practice
3.2.2 Shoulder Pack Technique

The second technique involved a shoulder pack technique which essentially used all the upper body parts where the shoulder was pulled into the body. This technique used the optimal pressing and pulling movement, like firing a canon out of canoe. Shoulder packing is a matter of confirming that the shoulder is retained in the appropriate position to be at its safest and strongest position when lifting the object. This state ensures the accurate muscles to become energetic and engaged in a precise arrangement. Based on Fig. 3(a), the workers used their arm and their spine strength to lift and resist the concrete panel.

![Poor Technique](image1)
![Simulated Result](image2)
![Shoulder pack technique](image3)

**Figure 3** Onsite shoulder pack technique done by worker and simulated result

A simulated result from RULA in Fig. 3(b) showed the final score of 6 in orange colour, indicating that it has a medium risk to workers and a further investigation for a change was needed in the work techniques. However, the highest score of 10 at the wrist and arm should be considered through appropriate technique applications. A poor technique might affect the four muscles surrounding the shoulder joint namely infraspinatus, supraspinatus, teres minor, and subscapular which made up the rotator cuff. It need tolerated the movement and steadiness otherwise it will loosen ball and socket shoulder joint. Any damage to these tendons or muscles can cause constraint in movement, pain, and weakness in the shoulder and arm. Surgery is often suggested for serious rotator cuff tears. Fig. 3(c) shows the recommend techniques when straightening their spine by using their shoulder to push the concrete panel weight. An appropriate technique of shoulder pack will stabilize shoulder and reduce the unintended injury as well as give lift more weight.

3.2.3 Neutral Spine Technique

Lastly, the neutral spine technique denotes the perfect spinal position to maintain, when applies during bow down and picking off the ground. A neutral spine is the optimal position to handle stress and weighty loads. The vertebrae are aligned to handle forces without placing abnormal stress on the cartilaginous discs between them.
Figure 4 Onsite neutral spine technique done by worker and simulated result instead of the right technique

In Fig. 4(a), a poor technique was used by the workers and the result from the simulation as shown in Fig. 4(b) yielded the value of 6 in orange colour, indicating that it has a medium risk for workers and further investigation is needed to change the work techniques. As shown in Fig. 4(c), the best practices were recommended where the neutral spine technique considered the degree of wrist, wrist twist and arm of workers during the task. Realistically, an operator should maintain a neutral spine in performing the weight lifting task especially heavy weights or else a disc injury might occur which is one of the primary causes of back pain.

3.3 Recommended Work Limit (RWL) and Lifting Index (LI) and Physiological Experience among Workers

The results show that workers fully experience prolonged standing, manual lifting, pushing and pulling respectively. They are never exposed to the knowledge or training of ergonomics or ergonomic studies. Level of pain and discomfort is a qualitative measure and empirical studies testing for psycho-physical are well-known methods for screening the musculoskeletal disorders (Jagannath & Adalarasu, n.d.). The outcomes from the study can best be described in Table 4. The interpretation of the mean value reflects the high level, medium level and low level involving the use of Likert scale. Estimated mean value can best be described based on Landell (1997). As illustrated in Fig. 5, they are different of body parts are related to work discomfort or pain.
Table 4 Work related discomfort/ pain perceived in different parts of body.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>2.55</td>
</tr>
<tr>
<td>Shoulder</td>
<td>3.45</td>
</tr>
<tr>
<td>Upper back</td>
<td>3.75</td>
</tr>
<tr>
<td>Lower back</td>
<td>3.90</td>
</tr>
<tr>
<td>Upper arm</td>
<td>3.30</td>
</tr>
<tr>
<td>Lower arm</td>
<td>3.25</td>
</tr>
<tr>
<td>Hand</td>
<td>3.77</td>
</tr>
<tr>
<td>Thigh</td>
<td>3.55</td>
</tr>
<tr>
<td>Calf</td>
<td>2.45</td>
</tr>
<tr>
<td>Feet</td>
<td>2.35</td>
</tr>
</tbody>
</table>

1.00 - 2.49 - Strongly disagree ; 2.50 - 3.49 - Medium
3.50 - 5.00 Strongly agree (Landell, 1997)

Figure 5: Work related discomfort/ pain perceived in different parts of body (Jagannath & Adalarasu, 2011).

The findings showed that respondents strongly agreed that they experienced discomfort or pain in the upper back, lower back, hand and thigh with mean a of 3.75, 3.90, 3.77 and 3.55 respectively. Meanwhile, respondents showed a moderate level of pain or discomfort in the shoulder, neck, upper arm and lower arm. For calf and feet parts, respondents strongly disagreed with the statement. These values corresponded fairly well with RULA analysis; correlating well with the feelings of discomfort or pain in the upper back, lower back and thigh.

To determine the RWL from the NIOSH lifting equation, the task conditions manipulated in the psychophysical and biomechanical experiments, the six multipliers must be calculated first. The measurements and data needed are shown in Fig. 6. In general, all the respondents were classified to three groups based on the Body Mass Index (BMI) namely Normal, Underweight and Overweight.

Figure 6 Psychophysical and biomechanical determination of respondents.

The mean of Recommended Weight Limit (WRL) by the BMI group is illustrated in Table 5. In addition, Lifting Index (LI), calculated using NIOSH lifting equation, can be observed in Fig. 6 for each group.

Table 5 The Mean of Recommended Work Limit of the BMI groups.

<table>
<thead>
<tr>
<th>BMI</th>
<th>Average Concrete panel per person (kg) (MAWL)</th>
<th>RWL (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Less than 18.5 (Underweight)</td>
<td>18.5 - 24.99 (Normal)</td>
</tr>
<tr>
<td>83</td>
<td>83</td>
<td>83</td>
</tr>
<tr>
<td>26.81 kg</td>
<td>27.91 kg</td>
<td>28.96 kg</td>
</tr>
</tbody>
</table>

Note: MAWL – Maximum Acceptable Weight of Limit, RWL – Recommended Weight Limit
The results on the maximum safe weight for lifting concrete panel revealed that the RWL for Overweight BMI group was the highest with only 3.8% more than the Normal group and 8% for Underweight group. The RWL of these groups showed only a slight difference. The Mass load in this study was 250kg which was divided to 3 or 4 workers responsible for lifting activities, was more than the “Load constant” itself which was 23kg based on NIOSH, a load considered to be ideal conditions and safe for 75% of females and 90% of males. Surprisingly, the results show a clear trend that the RWL for each group of BMI is more than the baseline weight or load constant (LC), creating high risk for workers to experience back injuries later. These RWL results strongly suggest that employers should consider a possible solution in depleting the risk injury factors in the workplace.

According to Fig. 7, the LI analysis demonstrated that all groups of respondents scored more than 1; ranging between 2.80 and 3.10; an overall mean of 3.10 for Underweight group, 2.98 for the Normal group and 2.88 for the Underweight group. Most of the LI values were greater than 2, indicating a potential high risk for the respondents performing such tasks of experiencing Low Back Pain (LBP). Further analysis was carried out with LI values, resulting values more than the baseline 1, verifying that RWL values which also exceeded the baseline of LC. Those values reinforce the facts that workers were imposed a higher risk of LBP for each respondent.

4.0 CONCLUSION

Recommended Weight Limit (RWL), Lifting Index (LI) and physiological experience among workers when lifting the precast concrete panel with 3300mm x 600mm sizes yield that IBS workers have been exposed with higher risk of LBP and will eventually suffer MSDs especially in the spine and waist. All results and analysis gained in this study led to MSDs problem suggesting a lot of improvement and recommendation must be considered in terms of appropriate techniques assisted by the right design equipment or machine in elevating workers’ productivity during lifting the precast concrete panel and still achieve the best health during and after performing the tasks. This scenario needs an action to be taken by multiple parties such as a government in terms of constructing a safety and healthy realms in terms of ergonomic courses or legislation for the site workers, developer as employer, union, NGOs and workers themselves in raising an awareness mutually along with an educational effort. This study produces a guideline of recommended weight limit and lifting index that can be used by employees to increase the awareness of the workers on the (MSDs) issue as well.

REFERENCES


