Working posture analysis of wall building activities in construction works using the OWAS method

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Abstract. Activities of construction works are carried out manually and continuously with critical and repetitive working postures. The poor working condition causes fatigue, musculoskeletal disorder, in the worst case could lead to working accident. The paper discussed critical working postures of construction works of house construction project in Indonesia. Three mains activities have been identified to be studied, namely building up the brick wall, plastering the wall, and casting the concrete column. The activities were video recorded, the dimension of the work place and its component were measured and further analyzed in ergonomics laboratory. The postures were studied using Ovako Working Posture Analysis System (OWAS) method to identify their critical levels. The improvements were proposed to remove the critical posture and reduce the risk of injury. Result of the study showed that building up the brick wall was the most critical task since it has 2 critical postures, while plastering the wall and casting the concrete column have 1 critical posture respectively. The propose improvement has successfully removed the critical posture and reduce the risk of injury.

1. Introduction

Construction works consist of many groups of activities. According to parts of the building, generally the activities starts from foundation works, wall building and roof installation. The foundation is the most important part of the building. As the base of the building, the foundation must be able to receive the load of the hole construction. With regard to this function, the foundation is the strongest part of the building. The wall protects the building from outside disturbance, such as wind, rain, snow, sun light and hot or cold temperature. The wall also plays important role for the access from outside to the inside of the building or the other way rounds. The windows and doors are installed in the wall for access purpose. The wall contributes to the esthetic of the building most among all component of the building. That is why the construction of the wall takes serious attention by the contractor, workers, consultant and the owner of the building. The roof is the top cover of the building. Similar to the wall, the roof protects the building from the outside disturbance, especially that come from the above of the
building, such as wind, rain, snow and sun light. The roof must be strong enough to resist from the load of outside disturbance. The roof also contributes to the esthetic of the building. That is why the design of the roof must meet the strength and appearance requirement [1, 2].

Managing the construction works is a unique task. Most of the work activities are depend one each other. Many activities could be started only after the other activities are completed. Dealing with this problem, the project manager usually manages the works according to the part of the building, starts from foundation, continue to the wall and finish with the roof. However, in some works, the activities take a shorter time compare to the completing non-activity process. For example, in the concrete casting process, after only 3 hours working to prepare the cement and cast it into the mold, the workers have to wait up to 12 hours for natural curing process of the concrete. In this case, in order to maintain the efficiency, the activities are managed according the nature of the task, such as concrete work, iron work, wood work, roof installation and painting. The workers could continue to the other part of the building while the non-activity natural finish process to be completed [3, 4].

The unique management described above make the construction works a difficult task to the workers. They have to move from one location to the other location of the construction area during the work. They have to return to the previous location frequently, to check whether the non-activity process have been completed and the following tasks could be started. Walking in a construction area put the worker in a risk of accident since many harmful materials are presented. The construction works are considered as heavy works as well. The workers need to carry heavy tools, equipment and material, as well as to control/ drive heavy machineries. Most of the activities are provided outside in the open space, where the workers are exposed to the hot temperature (from the machines and sun light), cold temperature (at night or snow) and extreme weather (wind or rain). All of this working condition requires a serious safety consideration for the construction workers. The working environment as well as the working task need to be improved in order to increase the safety and ergonomics level for the construction workers [5, 6].

Many researches have been conducted to study and improve the safety and ergonomics level of construction work. Lee and Han [7] studied the critical working posture provided by the worker when tying beams with steel bars, assembling column templates, and cement grouting. They identified that bent and twisted trunk posture was the major poor posture for construction workers. Construction workers were required to handle heavy load as reported by Lunde et al [8]. Handling a heavy load during a long duration of industrial working led to muscle injury and decreases the working productivity and injury [9]. Lunde et al [8] evaluated the level of cardiovascular load in relation to individual factors, work ability, musculoskeletal pain and subjective general health. They concluded that the cardiovascular load at work was significantly associated with age and oxygen consumption, but not with workability, musculoskeletal pain or subjective general health.

Handling heavy load during the work must be minimized, either by minimizing the load weight, shorten the handling time or reducing the handling frequency. The individual load weight could be reduced by increasing the number of the workers [10]. The load that previously handled by one worker was shared among several workers, made the load lighter for each worker. The load could be minimized using supporting equipment such as developed by Salam et al [11]. They proposed a new design and prototype of artificial skeleton that fit user’s anthropometry. The mechanism of the skeleton reduces the bio-mechanic load up to 20% of the handling load.

Working environment has been studied by researcher since it effects the worker health and working performances [12]. The study by Iskandar et al [13] found that a poor working environment, i.e. heavy dust, poor lighting and high temperature, significantly decrease the workers motivation, productivity and product quality. Social environment has been considered as significant factor that effect the worker’s performances [14]. Erwan et al [15, 16] studied the burnout syndrome among the workers caused by long shift time, poor working environment and unmanageable extra works. They proposed a better working management in order to decrease the stress among the workers.
Productivity and product quality were the main concern of modern industry [17, 18]. Related production parameters need to be controlled all the time to maintain production efficiency and to reduce production cost [19, 20]. It was proven that safety and ergonomic factors are among important parameters that significantly affect workers performance that contribute directly to productivity, product quality and production cost [21]. Ergonomics research developed many new methods or adopted successful methods from other research area to increase the safety and ergonomic level in working environment. Iqbal et al [22] used factorial design and response surface methodology to optimize the design parameters of workplace in order to increase the working performance. As the result of the study, they found the optimum value of design parameters that decreased working time, decreased critical posture, increased the lifting weight limit and decreased metabolic energy of the workers while providing the work tasks. The study has been further developed using virtual engineering for easier workplace design process and better experimental result [23].

This paper reports the research on critical working posture provided by the workers in construction project. Even though such a study has been explored by many researchers around the world, construction work is a unique working activity. Unsimilar to manufacturing works, that mostly have been standard and conducted uniformly in the factories, many construction works were not yet standard. The same job, could be provided by many different ways and very much depends on the available equipment, tools, technology and cost as well as affected by gender, social level and culture [24]. This research study the wall building activities in a common house building in Indonesia. Three main activities were considered, namely building up the brick wall, plastering the wall, and casting the concrete column. All of the activities were provided manually. The critical posture of the workers was investigated and analyzed using Ovako Working Posture Analysis System (OWAS) method. The recommendation was provided to improve the workplace and/ or the work task to eliminate or reduce the critical working posture.

| Body part | OWAS score | Description                        |
|-----------|------------|------------------------------------|
| Back      | 1          | Straight                           |
|           | 2          | Bent                              |
|           | 3          | Twisted or bent to one side        |
|           | 4          | Bent and twisted or bent and bent to one side |
| Arms      | 1          | Both arms below shoulder level     |
|           | 2          | One arm at or above shoulder level |
|           | 3          | Both arm at or above shoulder level |
| Legs      | 1          | Sitting, legs below seat level     |
|           | 2          | Standing, legs straight            |
|           | 3          | Standing on one leg, legs straight |
|           | 4          | Standing on both leg, legs bent    |
|           | 5          | Standing on one leg, legs bent     |
|           | 6          | Kneeling on one or both knees      |
|           | 7          | Walking or moving                  |
| Load      | 1          | Less or equal to 10 Kg             |
|           | 2          | Greater than 10 Kg and less or equal to 20 Kg |
|           | 3          | Greater than 20 Kg                 |
2. Method
The working activities were observed directly in the construction area and recorded by video tape. The dimension of the work place’s component were measured and photo recorded. The video and photograph were brough to the ergonomics laboratory for further investigation. The working postures were analysed by using OWAS method. OWAS is a working posture analysis technique which was developed by a steel company named Ovako [25]. OWAS gives a score for the position of three main body parts (i.e. back, arm and leg) and load that handled by the subject, as shown in Table 1.

The score depends on the level of critical, difficulties, risk of injury and weight of the load. Higher score represents the higher level of critical posture. Accordingly, each of individual posture during the task has 4 digit OWAS score. Based on the combination of the 4 digit OWAS score, the class of posture category is given, as shown in Table 2. The class represent the critical level as posture, start from class 1 (normal) until class 4 (the most critical posture). Because of its simplicity and usefulness, OWAS method has been used in many cases for decades, i.e. perchery system [26], automotive [27], medical [28] and musculoskeletal problem [29].

3. Result and discussion
The construction process of building a brick-cement wall requires three main activities, which is casting, arranging bricks and cement, and plastering. Activities carried out by construction worker involves critical working postures, such as scooping cement, laying bricks, sweeping cement on bricks, plastering and casting. The critical postures lead to the risk of injury of the musculoskeletal system, or in the worst-case lead to dangerous working position and probably continue to working accident.

| Tabel 2. OWAS class for body posture and load |
|---|---|---|---|---|---|---|
| Back | Arms | Legs | Load 1 | Load 2 | Load 3 | Load 4 | Load 5 | Load 6 | Load 7 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 |
| 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 4 | 1 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 4 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

INTERNASIONAL OF THE RESULT
1- No action required
2- Corrective actions required in the near future
3- Corrective actions should be done as soon as possible
4- Corrective actions for improvement required immediately
3.1. Building up the brick wall

The brick-cement wall is one of the important parts of a building. Arranging brick-cement was conducted manually by the worker starts with laying the bricks horizontally with approximately 5 cm gap in between. The gap was then filled with the cement mix. Five cm cement mix was applied on the top of the brick row, and the task continue with next row until the wall was complete. Based on the early investigation, four critical posture could be identified during the building of brick wall, i.e when the worker scooped the cement from the container, applied cement on the top surface of the wall, took the brick, and put the bricks on the wall.

When the worker scooped cement from the container located on the floor level at his right side, as shown in figure 1(a), he needed to bent and twist his back. Referring to Table 1, the OWAS score for this back position was 4. However, both of the arms were under the shoulder level, which was considered as normal position (OWAS score for arms = 1). Since the location of the cement container was too low for the worker, he needed to bend his legs, made the OWAS score for legs = 4. The weight of the cement was less then 10 kg, made the OWAS score for the load = 1. The total OWAS score for the said posture was 4-1-4-1. According to Tabel 2, it felt in class 4, which was considered as extremely critical posture and corrective actions for improvement was required immediately.

Figure 1. Building the brick wall, (a) scoop the cement from the container, (b) apply the cement on the wall, (c) reach the brick from the floor level and (d) position the bricks on the wall.
In order to remove the critical posture, a table was provided in the right side of the worker with the high approximately similar to the worker’s elbow level. The cement container was put on the table. Now the worker did not need to bent, neither to twits his back as well as to bent his legs when scooping the cement from the container. The total OWAS score for new posture was 1-1-2-1, which felt in class 1 and considered as normal and safe position.

When the worker applied cement on the top surface of the wall, as shown in Figure 1 (b), he needed to bend his back because the surface was lower than his elbow high and according to the task requirement, he needed to put his lower arm in horizontal position. The OWAS back score for this position was 2. The total OWAS score for the position was 2-1-2-1 (both of the arms were below shoulder level, standing position with legs straight, and the weight of the load was less than 10 Kg), made the position felt in class 2, which was considered as a safe position but the corrective action was required in the near future. According to Table 2, the posture could be improved if the OWAS back score changes from 2 to 1. However, the current standing position could not be changed to sitting position because of the nature of the task. As the conclusion, the working posture reminded in class 2.

When the worker took the brick from the floor level (Figure 1.c), he provided the same position as he scooped the cement (Figure 1.a). Accordingly, the similar analysis and the improvement were conducted to reduce the critical level of the working posture from class 4 (extremely critical posture) to class 1 (normal posture). Similarly, when the worker put the bricks on the wall (Figure 1.d), he provided the same position as he applied cement on the top surface of the wall (Figure 1.b). Accordingly, the similar analysis was conducted, and no improvement could be provided due to the nature of the working task and the working posture reminded in class 2.

3.2. Plastering the wall

Plastering is the process to cover the brick wall surface with cement. It was conducting manually by the worker. The cement mix was put in a container. The worker took the cement mix from the container and applied it to the surface of the wall. The task was provided during standing and kneeling depend on the location of the plastering. Changing the position from standing to kneeling frequently gave a stress to the worker’s body. The working posture analysis was required to reduce the stress and remove the critical posture.

When the worker plastered the higher part of the wall (as shown in figure 2.a), his back was in normal straight position (Back = 1), but both of his arms are above his shoulder level (Arms = 3). He
works in standing position with both legs straight (Legs = 2). The weight of the load (cement mix and scoop) was less than 10 Kg (Load = 1). The total OWAS score for the posture was 1-3-2-1, making a high wall plaster position in category/class = 1 which is a normal category and no improvement was required. When the worker plastered the lower part of the wall (as shown in Figure 2.b), his back was bent (Back = 2), and both arms above shoulder level (Arm = 3). He provided the task with kneeling position (Legs = 6). The weight of the load was less than 10 Kg (Load = 1). The total OWAS score obtained was 1-3-6-1, making the lower wall plaster posture in category/class = 4 which was an extremely critical posture and corrective actions for improvement required immediately. Considering the situation, a sit support could be provided to change the working position from kneeling to sitting (Legs = 1). The total OWAS score became 2-3-1-1, which felt in class 2 that much safer for the worker compare to the previous posture.

3.3. Casting of concrete column
The casting activity studied here was conducted in making the vertical concrete column. The casting process was carried out manually by the worker, starts with taking the bucket containing concrete mix
(cement mixed with sand, gravel and water) as shown in Figure 3.a, continue with lifting the bucket (Figure 3.b), and finally pouring the concrete mix into the column mould (Figure 3.c). The process continued until the mould was completely full of the concrete mix. However, based on the analysis, only one critical posture were identified during the casting cycle task.

The critical posture was occurred when the worker took the bucket from the flatform, as shown in Figure 3(a). The worker needed to bent and twist his back to reach to the bucket located on the floor level at his right side. The OWAS back score for this position was 4 (refer to Table 1). However, both of the hands were under shoulder level, which was considered as normal/safe position (Arms score = 1). Since the bucket was too low, the worker needed to bent his leg (Legs score = 4) when he reached the bucket on the floor level. The weight of the bucket with material is lower than 10 Kg, made the Load score =1. The total OWAS score was 4-1-4-1. Referring to Table 2, the working position was considered as class 4 (a dangerous critical posture and corrective actions for improvement was required immediately).

Based on the observation, the critical posture occurred because of the location of the concrete mix bucket that too low for the worker. A table could be provided in the wright side of the worker and the bucket was put on the table, made it in the same level of the worker’s hand high while standing. The new position made the worker worked with his back straight and his legs straight. The new total OWAS score was 1-1-2-1, made the position felt in class 1 (normal posture).

4. Conclusion
The ergonomics assessment for construction works have been conducted. Four critical postures were found during the investigation. According to OWAS method, they were categorized as extremely critical posture and the improvement need to be provided immediately. The critical tasks have been conducted by the workers for a long time and they have been a routine daily work activity. The propose improvement has successfully remove the critical postures and reduce the risk of injury. The fact that the improvement was a simple action and did not need any significant additional cost, time and manpower, showed that the ergonomics and safety awareness in the construction project was very low. The socialization and training need to be conducted regularly for the workers and the contractor to update their understanding on Occupational Safety and Health in construction work. The law enforcement also needs to be implemented as well as direct inspection to make sure that the ergonomics and safety were seriously considered. For future work, the anthropometry of the worker will be considered to study whether the equipment used during the works match the body size of the worker. It was an important ergonomic factor since the anthropometry of the local workers was unique [30] and many equipment was imported from other countries.

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