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APPRAISAL OF RELATED RISKS WITH LOCALLY MADE BLOCK MAKING MACHINE: A MULTI-SITE CASE STUDY OF NIGERIA BLOCK MAKING INDUSTRY

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ABSTRACT

Non-movement accidents usually arise from the use of machinery and it accounted for more than 10% of all accidents reported yearly. This study evaluated the common risks related to using locally made Block Making Machine (BMM) in 55 block making factories (BMF) located in the Southwest, Nigeria. The objective was to measure the level of exposures of workers to the machine related hazards. Questionnaire, involving 170 workers, and observation methods were used to obtain the safety conditions attached to operating the machines. The hazards prevention program checked by Safety Professionals (SaPro) included machine guarding, environmental hazards control and the use of Personal Protective Equipment (PPE) among others. Non-parametric Chi-Square tests and the independent sample t-test at p<0.05 were used to analyze the data. More than 87% of the total workers suffered injury on the job. Fingers, legs and low-back injuries were mostly reported by 80%, 68.5% and 63.3% workers respectively. Unguarded machinery (78.6%), awkward postures (75%), manual lifting (67%) and carelessness (60%) were the reported risk factors. The Chi-Square test showed that there was significant relationship between the ratings of the operators and the SaPro, on poor machine guarding, access to machine control and environmental control (Chi Square (272) = 8.741E2a, p = .000). The study asserted a need for a redesign of the locally made block making machine for inclusion of safety elements to enhance safety using the machine.

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1. INTRODUCTION

There are thousands of accidents and cases of ill health reported every year. Almost two-thirds of all such accidents arise from the movement of people, goods and vehicles. ‘Non-movement’ accidents usually arise from the use of machinery; and it accounted for between 10 and 15% of all accidents. The most common occupational diseases are deafness, asthma, vibration, white finger, back, hand, arm, shoulder, and neck problems. Those likely to be of most concern include: machinery safeguarding, hazardous substances, dust, noise, and vibration. On manually operated machines,
Hands are most frequently injured. Broken bones and dislocations, amputations of fingers and hands, and eye injuries, are numerous every year (Health and Safety Executive, 2004). Ineffective machine safeguards, inadvertent activation of equipment, and shifting work materials were identified as some of the major contributing factors in the majority of amputations (Boyle et al., 2000). As stated by Umeokafor et al. (2014), when inadequate intervention patterns are adopted, accidents increase rapidly. Hence, there is a consensus that occupational health and safety is poor in the developing countries (Diugwu, 2012). A study conducted to document the causes of hand injuries in Nigeria, road traffic collisions and machine accidents were showed to be the leading causes (Ogemdi, 2010). In the pattern of occupational accidents, injuries, accident causal factors and intervention study conducted by Umeokafor et al. (2014) in Nigerian factories, management factors accounted for 91.3% of the remote or contributory accident causal factors in which 90% were due to lack of training. Adeyemi et al. (2013) also emphasized lack of ergonomics trainings among workers in most industries in Nigeria and related this to one of the major reasons for a high level of injury, most especially, in lifting related jobs.

Hazard is anything that can cause harm with mechanical and non-mechanical hazards reported to be common (Canadian Centre for Occupational Health and Safety (CCOHS), 2001). Possible types of machine hazards are; drawing-in, crushing, impact and entanglement among others. In order to ensure that people do not operate or pass close to the moving parts of machinery, safeguarding is widely recommended to reduce the risks as far as practicable. Ideally, a guard should be custom designed for the machine and the work process (Commission for Occupational Safety and Health, 2009). The employer should consider safeguarding when purchasing machinery and should be designed with the machine operator in mind and suit the operation to ensure effective and safe operators’ use. As reported, commonly used guard include; permanently fixed physical barriers, physical barriers, interlocked guards and safe by position (Ministry of Business, Innovation and Employment, 2013).

According to CCOHS (2001), hazard analysis is a technique that focuses on the relationship between the employee, the task, the tools, and the environment. When evaluating work activities for potential hazards, the entire machine modes of operation, individual activities associated with the operation, maintenance of the machine, and the potential for injury to employees are considered. Torstensson (2012) reported hazards analysis as one of the techniques used as the key for safe machinery.

1.1. Block Moulding Machine

Sand Crete block is an important building material in Africa used for construction of buildings. Sand Crete blocks comprise natural sand, water and cement (Adejugbe, 2014) which are mass-produced in Nigeria using mostly locally fabricated block making machine (BMM). Palmer, in 1900, developed the first commercial machine for producing Sand Crete blocks (Asafa, 2006) which has been improved on since then. Olusegun and Ajiboye (2015) designed and constructed a more efficient Sand Crete block compactor machine of which water absorption was found to be less than 10%. Adejugbe et al. (2014) designed and constructed a low cost and easy to maintain vibration-compaction block moulding machine that can accommodate two different sizes of mould.

The BMM major parts includes; the mould box compartments, the linkage mechanisms that transmit motion to the mould boxes for the ejection of the wet bricks, the machine frame that support the bulk of the entire structure and the lever arm that lifts the ejector mechanism (Kolawole and Odusote, 2013). The machine has simple operational procedures. The wet sand cote mix is shoveled into the mould on a wooden pallet. The top is levelled with a scraper and the cover of the mould is applied to effect initial compacting. The cover is opened and additional mix is applied to refill the mould. The mould cover is then applied and properly secured with the hook lock. The motor is activated and vibration caused by the eccentric weight is transmitted via the bottom plate through springs, the lower platform, through the moving bottom plate of the mould to the wet Sand Crete mix. The top covers plate of the mould
ensures a complete compacting which took place within a time of one minute. The top cover of the mould is opened. The ejector lever is compressed downward to lift the compacted wet block out of the mould (Olusegun and Ajiboye, 2009).

Workers in BMF are of three categories. They include the operators that handle the machine operations, the mixers which are responsible for mixing Sand Crete with shovel and the carriers who carry the moulded blocks to the dry land for curing. The operators who are directly faced with hazards in machine operations may be exposed to the highest machinery related risks (Mccall and Horwitz, 2006). Three types of mechanical components having potential for hazards were reported; point of operation, power-transmission apparatus and other moving parts of the machine (OSHA, 2004). The mixers are directly faced with shoveling-related hazards and cement substance skin contacts. Shoveling can be physically demanding to the cardiovascular system when done at fast rates. Improper shoveling can also cause severe back pain. Ideally, shovel handle should come up to the user’s chest in order to reduce forward bending (Occupational Health Clinic, 2010). Exposure to cement pollution also was linked to a number of different health outcomes, starting from changes in the respiratory tract and impaired pulmonary function, to reduction of performance, and to mortality (Schuhmacher et al., 2004; Aydin et al., 2010; Zeleke et al., 2013). Syed (2013) investigated the health risks associated with workers working with cement, 89%-91% of the workers were found to be suffering from skin allergies. According to HSE (2004), the most common health effects from hazardous substances are: skin diseases, lung problems, skin cancer. The prevention of skin contact by adequate personal protection was mentioned as one way to minimize risks of adverse health effects. Where prevention or control is insufficient on its own, personal protective equipment are to be provided.

The aim of this study was to conduct hazard analysis of the operation of locally fabricated BMM used in most Nigeria block making factories. The objectives were to find out the hazards associated with the operations of the machine and how it affects the handlers and other workers in the industry.

2. MATERIALS AND METHODS

Cross sectional studies design was adopted in this study which included, studies to examine the hazards in operations of the locally fabricated BMM and workplace safety and, surveys with the use of questionnaires to measure various effects of the operation-related hazards on the group of workers.

2.1. Machinery Hazard Check

The machine hazard checklist had been reported by Gorge Manson University, (2011) and that of machine safety checklist highlighted by Industrial Accident Prevention Association (IAPA) (2008) were modified and used by Safety Professionals (SaPro) to carry out workplace inspections and assessment of hazards level of all machineries in 55 BMF in South Western Nigeria. SaPro focused attention, using observation, on the risk involved in the performance of task on the BMM, the safety-related situations of the machines and the working environment. Scores (5 = strongly prevalence, 3= prevalence, 1 = limited, 0 = insignificant) were used to rate workers’ exposures to risks of four improperly installed Machinery Safety Elements (MSE) of the BMM which included unsecured machine guards, poor access to machine control (on and off), poor machinery set-up (installations and layout) and poor environmental control (noise, vibration, oil spillages). Observation method is reported crucial to any efforts to use it as a method of research (Dana, 2011; Trent, 1998). With this technique, methods at which workers performed their tasks and safety practices adopted were critically followed.

2.2. Semi-Structured Interviews

A set of questionnaire was completed among 170 workers (operators, cement mixers and carriers) using a modified version of Nordic Questionnaire as reported by Kuorinka et al. (1987) to measure subjective injury (past or present) on their different body regions by written response. The operators handling operations of the machine were interviewed on the events and semi
previous events related with hazards prevalence on the job. The subjects, properly informed on how to allocate ratings (5 = strongly agree, 3 = agree, 1 = disagree, 0 = strongly disagree) to report prevalence of various injuries as experienced on the job and the risk factors opined to have contributed to the reported injuries. They were also asked to provide ratings (5 = strongly prevalence, 3= prevalence, 1 = limited, 0 = insignificant) on their opinions regarding the improperly fixed MSE of the BMM. All the potential volunteers agreed, and consents were taken in written form, to have the interview conducted after they were adequately informed by the SaPro and that their participation in the study was voluntary. The purpose of the study and the confidentiality of the information provided were emphasized. The interview however lasted approximately 15 minutes for each subject during their break periods.

2.3. Data Analysis
Non-parametric Chi-Square tests and the independent sample t-test at p<0.05 were conducted to test the significant relationship and to analyses the means difference respectively between the general ratings of the operators, and the SaPro, on MSE. Descriptive statistical procedure was also used for data presentations.

3. RESULT AND DISCUSSION
3.1. Workers’ response to interviews
One hundred and fifty-four (90.6%) of the one hundred and seventy (170) workers that participated in the study completed the questionnaire. This included 55 operators, 45 mixers and 53 carriers, all of which have spent not less than one and half (1.5) years on the current job. The demographics of the workers are presented in Table 1. Average age of the workers is about 32 years most of which were 29 years of age and of 2 years on the current job.

Table 1: Demographic information of workers studied in fifty five block making industry.

<table>
<thead>
<tr>
<th>Descriptions</th>
<th>Age</th>
<th>Years of Working Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>32.2</td>
<td>2.3</td>
</tr>
</tbody>
</table>

3.2. Workers’ self-reported on-the-job experienced injuries
The workers were grouped into two; the operators who were directly engaged in the running of the machinery and the co-workers which included the mixers and the carriers. More than 87% of the two groups reported to have sustained one injury or another on the job. Among this category, 78.6% mentioned that the injury kept them away from their normal duties for several days with self-incurred medical bill. As noted in Figure 1, and among the operators’ group, finger injury was mostly reported by 80%. This was followed by leg pains (68.5%), low back pain (63.3%). Other reported commonly sustained injuries included leg region (68.5%) (cuts, pains and irritation), hearing loss (56.2%) and at their base of thumb region (54%). However, among the co-workers’ category, low back pains (72.5%), leg pains (68.5%), feet injury (55%) and skin irritation (56%) were the highly reported injuries. Others include eyes irritation (52%), palm injury (42.2%), finger cut/pain (40.2%) and upper arm pains (35.8%) among others.

3.3. Workers’ reported injury risk factors
As reported among the operators’ category (Figure 2), 67% stated that the long standing postures characterized by their work may have contributed to most of the pains
suffered. Unguarded dangerous parts of the machine, awkward postures at lifting, manual lifting, carelessness, fast work pace were also mentioned by, 78.6%, 75%, 67%, 60% and 58% respectively of, the group of workers. Other reported risk factors included; forceful gripping (55%), wrist twisting (55%), cement substances (45.5%) and poor work tools (36.2%). By the mixers and the lifters group of workers, manual lifting (95%), repetitive movement (78%), awkward posture while lifting (75%), fast work pace (72%), forceful gripping (71%), and cement substance (68%) were among the highly reported. Others included carelessness (65%), wrist twisting (57%), unguarded dangerous parts of the machinery (56%), handling of harmful objects (58%) and poor work environment (45%).

3.4 Safety professionals’ ratings and observations to workers’ work methods, exposures to machine related injuries and safety practices

As observed by SaPro (Fig. 3), within the highest mark of 5 (100% or strongly prevalent) and the lowest score of 0 (0% or insignificant) attached to the presence of different job hazards possible areas and inadequacies in the design of BMM, seven major observations were documented and rated. Among the operators’ group, caught in moving parts risk scored the highest of 4.6 (92% or strongly prevalent), environmental risk was averagely rated 4.5 (90% or strongly prevalent), exposure to unguarded dangerous parts of the machine was allocated 4.2 marks (84% or strongly prevalent) as wrong/improper usage of PPE was scored 4.1 (82% or strongly prevalent).

Among the other workers, awkward posture at lifting (84%), lack of/improper usage of PPE (74%), manual handling of harmful materials (70%), manual material lifting (70%), exposures to unguarded dangerous machine parts (66%) were among the highly rated. Figure 4 to 6 show some level of safety practices observed adopted among the workers. In the case of Figure 4, the locations of ‘stop’ and ‘on’ machine control was too close to the running flywheel and accessing this point exposed operators to the risks of caught in moving parts. Figure 5 shows how an operator of BMM positioned shovel closed to the running flywheel after it was used to scope wet sand cote mix into the mould. This practice exposed the subjects to danger as the flywheel may throw the shovel to hit any region of the body. Figure 6 describes a PPE commonly adopted by the two categories of the workers. Cement sack were used to improvise for safety booth. This was noted in almost all the studied subjects (92.8%) in all the factories.

Table 2 shows the SaPro ratings for hazard point elements in 4 possible areas of mechanical hazards noted with the operations of block moulding machine. From the table, only machine layout was allocated an average score above 50% (good) mark. Operators’ access to ‘On’ and ‘Off’ control and guards on point of operation, were rated 32% to 21.6% (below fair) marks respectively. Accessibility to, or availability of, emergency stop, noise control measure and vibration control measures were all allocated zero (0%) (very poor) mark.
### Table 2: Block moulding machinery hazard checklist as observed and rated by SaPro in 55 block making factories

<table>
<thead>
<tr>
<th>HAZARDS CHECKLIST</th>
<th>RATINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVERAGE (Safe) Mark</td>
</tr>
<tr>
<td><strong>A. MACHINE GUARDS</strong></td>
<td></td>
</tr>
<tr>
<td>Point of operation</td>
<td>1.5</td>
</tr>
<tr>
<td>Pulleys/ flywheels</td>
<td>0.62</td>
</tr>
<tr>
<td>Belts or chain drives</td>
<td>0.46</td>
</tr>
<tr>
<td>Key ways, nut and bolts</td>
<td>1.08</td>
</tr>
<tr>
<td><strong>B. OPERATOR’S ACCESS TO CONTROLS</strong></td>
<td></td>
</tr>
<tr>
<td>Start and stop controls</td>
<td>1.6</td>
</tr>
<tr>
<td>Emergency stop controls</td>
<td>0</td>
</tr>
<tr>
<td><strong>C. MACHINERY SET-UP</strong></td>
<td></td>
</tr>
<tr>
<td>Installations</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Figure 7, summarized the SaPro ratings on 4 specific areas of the machine checklist - environmental, machinery set-up, access to machine control and machine guards as presented in Table 2.

Figure 7: Safety professionals’ average ratings to block making machine hazards checklist.

Among all the four areas, machinery set-up was allocated 42% good. However all others were rated below 20% (poor) mark and the least awarded mark (8%) (very poor) was noted with environmental hazards control.

3.5 Statistic test
The result of Chi square test conducted shows that there was significant relationship between the ratings of the operators, and the SaPro, on poor machine guarding, access to machine control, machinery set-up and environmental control (Chi Square (272) = 8.741E2, p = .000). In a further statistic test, independent-samples t-test (Table 3), indicate that the two independent groups (Operators and SaPro) in machine guards, found that SaPro ratings had statistically significant lower level of means values (mean=.5800, SED=0.0530) compared to the Operators’ self-ratings (mean = .6727, SED = 0.0595), with t(108) = 1.558, p = .797. Hence, the groups’ means are significantly not different. Meaning that both the two groups rated the state of machine guard very low (poor). In a similar trend, the ratings of the two groups were not also different on ‘access to machine control’ (p=.110), which was averagely rated 16% safe as and ‘environmental control’ (p=.097) which was averagely rated 8% safe by the SaPro and as shown in Table 2. However in the case of machinery set-up, the groups difference were not significant. The operators had a different opinions to SaPro ratings. While the average SaPro rating was 42% safe, the operators had a lower rating opinions which was less than 42%. Other results are as shown in Table 3.

Table 3: Comparison between the SaPro ratings and the machine operators scores on four possible risk factors to BMM hazards

<table>
<thead>
<tr>
<th>Assessed machinery hazards elements</th>
<th>SED</th>
<th>t-value</th>
<th>p-value</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine guards</td>
<td>.0595</td>
<td>-1.558</td>
<td>.797</td>
<td>Significant</td>
</tr>
</tbody>
</table>
As confirmed by the statistic tests, inadequate safeguard on the dangerous parts of the locally fabricated block making machines may be among the major contributing factors to the reported work-related injuries among all the three categories of the studied block making factory workers. The pulley, belt and other dangerous parts of the machine were left exposed and not properly guarded to restrict workers from getting close to the rotating points. Several hazards, one of which may be caused by carelessness as displayed in Figure 5, may be minimized if guards are adequately provided at such a dangerous point. Such an improper ergonomics practice as adjustment of belts while running on the pulley, as commonly observed among the operators, will be eliminated.

In the studied block making machine operations, the operators and the mixers groups of workers used shovel. Using the right size of shovel for feeding the mould cavity and in mixing Sand Crete mix will be helpful. As noted, the level of awkward posture during the shoveling activity was noted to be frequent with operators’ body getting too close, and hands too near, to the machine nip points. According to OHC (2010) the handle of a shovel for such a task, should come up to the user’s chest (about the height of the breast bone) in order to reduce forward bending that may stress the lower back muscles and keep hands far from the hazard points. Most of the shovels used by these categories of workers were however found to be lesser than this recommendation.

Scrapers is a common tool use by the operators to level the Sand Crete mix on the top of mould before the mould is covered for compaction. This point of operation is a nip point and should be redesigned to be wide enough to be easily assessed by the shovel contents. It was also noted that most of the scrapers used were too short. It may pull body regions, such as fingers or hands, into the pinch point.

Placement of wooden pallet at the bottom of the mould and the lifting of same with the compacted wet block, is a task assigned to carriers. When the ejector lever is not properly handled by the operator, during the short time of lifting the pallet, the upper part of the mould and/or the mould cover may injure the carriers’ hands or fingers. The tasks, however, required right usage of personal protective equipment (PPE) such as hand gloves. It also calls for vigilance on the part of the two groups of workers.

The lower platform of the block mould moves upwards along the inside of the mould to enhance the ejection of moulded block. This can be linked with one level of hazard or the other. The lever can lead to head injury which may occur if operators shift eyes off the machine and/or when they try to lift the lever with one hand. Appropriate usage of PPE such as helmet could reduce such an injury.

It was reported by the National Institute on deafness and other communication Disorder (2014) that noise at a certain level can cause hearing loss. In almost all the block factories studied, operating sounds of the machines generated a high level of mechanical noise, most especially during compaction. Further studies to measure the extent to which the noise pollution can affect the workers may be required. However, continuous exposure to machine noise may result into hearing loss. Other environmental hazards notable with the operation of the machine were oil leakages and spilages. Proper lubrication and checking of gaskets / oil seals, can help to reduce the noise and other environmental hazards.

Commonly observed among the operators and mixers group of the workers, was the improvising of safety booth with the use of cement sacks. This practice signals a non-availability of safety booth (PPE) for the group of workers and the residual knowledge of the group of workers on the possible negative effects of cement substance on their skin. The potentials for this measure at protecting skin from harmful substance may attract future studies. However, this measure may not be a
perfect match with safety booths. Workers’ feet may still be exposed to injury as the sack may not be strong enough to prevent sharp objects from pinching the foot region. It may not also prevent penetration of liquid Sand Crete mixtures.

With the statistic tests conducted, the study confirmed that, machine guards and operators’ access to ‘On’ and ‘Off’ control need some level of redesign. Environmental hazards, most especially noise, oil spillages and vibrations, are on the high level and required a better ergonomics measure at controlling them. There is generally an insufficient PPE provision for workers and these demands for urgent provisions by the various administrators in the block making factories. These measures will enhance safety in the operation of the machine and improve safety and health of all the categories of workers in the industry.

4. CONCLUSION

This study analyzed hazards associated with the use of locally made block making machine in Nigeria’s block making factories. It can therefore be concluded from the study that the level of safety in the operation of the machine is very low. The reported hazards associated with the operations of the machine include among others finger cuts, leg pains, low back pain, hearing loss, feet injury and skin irritation. The injuries kept most of the workers away from their normal duties for several days with huge self-incurred medical bills. The authors suggested the need for a redesign of the block making machine to incorporate machine guards, improve operators’ safe access to machine control and develop ergonomics measures at controlling environmental hazards associated with the machine. This will enhance safety and prevent disability among the group of workers.

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