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I. INTRODUCTION

Productivity is an important issue in the construction industry. Productivity significantly affect the completion schedule of the project, as well as the effect on the budget. Low productivity let the project completed behind the schedule, the cost increase and the budget overrun. This situation lead the construction company lose the profit and reduce the competitiveness in construction industry.

Materials, equipment, and labor are three aspects of construction projects that affect productivity. Labor intensiveness is the most important factor that should be getting attention for improving productivity (Chan, 2014). Labor account for up to forty percent of the direct capital cost of large construction projects, and there is a need to maximize the productivity of labour resources (Ng, S.T. *et al*, 2004).

D'Onofrio (2003) indicated that there are numerous factors affect labor productivity, such as (1) location, (2) site restriction, (3) weather conditions, (4) project size, (5) height, (6) the complexity of the work, (7) experience in management and supervision, and (8) skill of craft labor. In line with that, Thomas & Herman (2006) claimed that labor productivity affected by (1) ineffective utilization of resources (labor, materials, equipment, and information), (2) unfavorable working conditions (congestion and out-of-sequence work), and (3) adverse weather.

In a different side, Oglesby *et al* (1989) cited numerous factors affect labor productivity, such as (1) capability, (2) physical fatigue, (3) mental fatigue, (4) stress fatigue, (5) boredom, and (6) environmental aspects of on-site construction. Individual capability is different from people to people, therefore the employers have to implement standardized test to qualify applicants on the basis of strength, lifting ability, agility, or similar characteristic. On the job, the employers have to pay careful attention to work assignment to avoid excessive fatigue or overtaxing an individual's physical capabilities. Physical fatigue largely result from an overuse of energy from

short-term overexertion and the long-term requirements of the body.

Managers and supervisors in construction project often have deadline that demand high energy input. They are often faced with conflicting demand from workers on the one hand and from higher-level management on the other. For workers, there may be cramped work space, noise, and heat. In such situation the heartbeat increases and those affected fell fatigued, that suffer productivity (Oglesby *et al*, 1989).

Manuaba and Vanwonterghem (1996) classified physical fatigue by measure the differences between work pulse (heartbeat) and rest pulse, compare to the differences between maximum pulse and rest pulse, as cardiovasculair load (CVL). Maximum pulse for male is (220 – age) heartbeats per minute. The percentage of CVL is presented in this formula :

$$\%\,CVL = \frac{100 \times (\text{Work Pulse} - \text{Rest Pulse})}{\text{Maximum Pulse} - \text{Rest Pulse}}$$

It is difficult to measure mental work load as a first step toward assessing its effect on fatigue and productivity. One study found that mental loads increased the respiration rate and heartbeat by 15% and that substansial decrement in efficiency occurred (Oglesby *et al*, 1989). Much construction is carried on the open, so productivity can be strongly affected by adverse environmental conditions such as heat, rain, humidity, and noise.

Physical fatigue, mental fatigue, and environmental aspects mentioned by Oglesby *etal* (1989), and the other side, location, weather conditions, and ineffective utilization of resources cited by D'Onofrio (2003), Thomas and Horman (2006), carried the thought of attempt to improve labor productivity by pay sufficient attention on the method of work. In this way, ergonomics is an important aspect that must be considered to improve labor performance.

Labor productivity is the most difficult aspect to predict (D'Onofrio, 2003), because it is influenced by many factors and there is no standard of work method is applied. Labor doing the work in various ways. Some of the methods indicate inefficient movement and inefficient work time, consume a lot of energy. The work methods also not respect to the convenience condition to the labor, often cause muscle fatigue even musculosceletal disorders. Such working methods led the labor productivity is not optimum. To improve labor productivity due to the work method, application of the ergonomics principles and motion economics principles must be considered.

Ergonomics is the ability to apply information regarding human characters, capacities, and limitation to the design of human task, machine system, living spaces, and environment so that people can live and work safely, comfortably and efficiently (Mittal et al, 2013; Shoubi et al, 2013). Motion economics principles is a set of rules and suggestions to improve manual work and reduce fatigueand unnecessary movements do by worker. It can lead reduction in the work related trauma.

Ergonomics can be defined as "the branch of science that concern with the achievement of optimal relationship between workers and their work environment" (Tayyari and Smith, 1997). It deals with the assessment of the human's capabilities and limitation (biomechanics and anthropometry), work and environmental stresses (work physiology and industrial psychology), static and dynamic forces on the human body structure (biomechanics), fatigue (work physiology and industrial psychology), and design of workstations and tools (anthropometry and engineering).

Ergonomics is the study of work laws. Its goal is to fit work to individuals, as opposed to fitting workers to the work, through developing knowledge that results in efficient adaption of work methods to the individual's physiological and psychological characteristic. Therefore, the objective of ergonomics applied is to identify and alleviate those work stresses that adversely affect the health, safety and efficiency of workers (Tayyari and Smith, 1997). In other words, the ergonomist's task is first to determine the capabilities of the workers and then to attempt to build a workable system around these capabilities (Oborne, 1987; Musidah and Syakhroni, 2010).

Occupation ergonomics strive to review work systems and modify them to minimize occupational stresses. Ergonomics principles can be used in the following industrial applications (Tayyari and Smith, 1997):

a. Design, modification, replacement and maintenance of equipment for enhanced productivity, the work-life and product quality.
b. Design and modification of work spaces and workplace layout for ease and speed of operation, service and maintenance.
c. Design and modification of work methods, including automation and task allocation between human operators and machine.
d. Controlling physical factors (e.g., heat, cold, noise, vibration, and light) in the workplace for the best productivity and safety of employees.

II. MATERIAL AND METHODS

This study is part of a dissertation research in the Doctoral Program in Civil Engineering Diponegoro University of Semarang, Indonesia. The objectives of this research is to study how the implementation of ergonomics and motion economics principles can improve construction labor productivity. Brick masonry and plaster worker, wall painter, and ceramic installation worker in building construction were chosen as samples, since the productivity of these tasks are dominantly based on labor capability. Brick masonry work was choosen by consideration that almost housing in Jawa, a most densely populated area in Indonesia, is build of brick masonry. Painting and ceramic installation were choosen since the tasks must be done by people work that can not be replaced by machine.

The method of this research is field base experience. Exist labor work method was documented by digital camera recorder, and then the pictures analyzed by ergonomics and motion economics principles. The next step is design work method by applied ergonomics and motion economics principles to improve productivity. The labor productivity by exist work method then compared to the labor productivity resulted by improved work method. Standard productivity of construction work formulated in SNI (Standar Nasional

Indonesia) is used as benchmark. The test of work load is done by investigated the level of cardio vasculair load (CVL) of labor on exist work condition and the CVL on improved work method to be compared.

The research was held in Yogyakarta included 10 construction projects, involved 30 labor of brick masonry work, 22 labor of ceramic installation work, and 24 labor of wall painting work. All of them are men, age of 25 – 40 years old, at least 2 years experienced, normal posture of Indonesian people (160 -170 cm height, 60 – 70 kg weight), and good performance referred by foreman. Several assumptions were taken in this research, such as:

(1) The labor physical and psychological condition in the exist work method is relatively similar to the labor physical and psychological condition in the improved work method.
(2) The work quality of exist work method is relatively similar to the work quality of improved work method.
(3) Labor productivity observed in this research reflect average productivity of labor in general.

III. RESULT AND DISCUSSIONS

In this research ergonomics analysis was done on labor work method in three aspects:

(1) Position of the body at work
(2) Environment of workplace
(3) Work device support

Labor work in different position of the body, depend on the height of the work area to be done. There are four body positions of the labor at work : squat, bent, stand up, and sit down. Each of these positions consume different energy and causes musculosceletal fatigue in different level. Regarding to ergonomic principle, squat position and bent position are bad positions, because these positions consume much energy and causes severe musculosceletal fatigue. The modification of work method to alleviate squat position is done by arrange labor worked by sitting on low bench (Figure 1 and Figure 2), and placed material on the table to avoid bent position. Placing material on the table eliminate unnecessary movement as well, therefore meet the principle of motion economic (Figure 3 and Figure 4).

Figure 1. Squat Position

Figure 2. Sitting on low bench

Figure 3. Bent Position

Figure 4. Material Placed on Table

The environment of workplace varies between hot condition by sun rise exposure and shady condition under the roof. The exposure of heat will increase heart beat, decrease breath, and cause labor motion slow down. Labor work on the scaffolding will slow down the motion also, as there is limited workplace that make labor fell not so save and not so convenience.

The three aspects (position of the body, environment of workplace, and work device support) influence labor productivity. Observation was done in two conditions: exist work method and improved work method. Table 1 shows observation of Labor 1 on brick masonry in exist work method. Tabel 2 shows observation of Labor 1 in improved work method.

Tabel 1. Ergonomic Observation and Productivity Level on Improved Work Method

OBSERVATION 1

Work job : Brick Masonry — Worker : Labor 1
Location : Privat House, Prambanan – Bantul — Age : 36 th

Date	Time of Observation	Observation			Rest Pulse	Work Pulse	% CVL	Productivity (m^2/30 mnt)
		Body Position	Environment Of Workplace	Supporting Device				
1	09.00 - 09.35	Sit on bench	Shady	On Ground	63	87	19,83	0,750
	11.15 - 11.45	Sit on bench Stand up	Shady	On Ground	62	86	19,83	0,815
	13.30 - 14.00	Stand Up Stand Up	Shady	On Ground	63	87	19,89	0,775
2	08.45 - 09.15	Sit on scaff Stand up on Scaffolding	Shady	Scaffolding	63	88	20,66	0,710
	10.30 - 11.00	Sit on scaff Stand Up	Shady	Scaffolding	63	89	21,48	0,770
	14.00 - 14.30	Stand Up Stand Up	Low Hot	Scaffolding	64	90	21,48	0,760
Average					63	88,5	20,52	0,763

Table 2. Ergonomic Observation and Productivity Level on Exist Work Method

OBSERVATION 1

Work job : Brick Masonry — Worker : Labor 1
Location : Bantul General Hospital — Age : 36 th

Date	Time of Observation	Observation			Rest Pulse	Work Pulse	% CVL	Productivity (m^2/30 mnt)
		Body Position	Environment Of Workplace	Supporting Device				
1	08.30 - 09.00	Squat	Shady	Scaffolding	62	85	19,66	0,675
	10.45 - 11.15	Squat Back Bend	Shady	Scaffolding	63	85	18,18	0,615
	14.30 - 15.00	Stand Up Back Bend	Hot	Scaffolding	63	88	20,66	0,655
2	08.45 - 09.15	Back Bend Stand Up	Shady	Scaffolding	63	82	15,70	0,610
	10.30 - 11.00	Back Bend Stand Up	Shady	Scaffolding	63	86	19,00	0,665
	14.15 - 14.45	Back Bend Stand Up	Low Hot	Scaffolding	64	86	18,33	0,650
3	08.50 - 09.20	Squat	Shady	Scaffolding	62	86	20,57	0,680
	10.45 - 11.15	Squat	Low Hot	Scaffolding	63	87	21,70	0,710
	14.10 - 14.40	Back Bend Stand Up	Hot	Scaffolding	63	95	26,45	0,715
Average					62,89	86,66	20,03	0,664

It can be seen from Table 1 and Table 2, the percentage of CVL increase from 20,03 in exist work method to 20,52 in improved work method, while the productivity increase from 0,664 m2/30 minutes to 0,763 m2/30 minutes. The increase of productivity is reached as labor worked more rapidly as they felt more convenient with the improved work method. The complete observation result and analysis is presented in Table 3 .

Table 3. The Increase of Labor Productivity Lead by Applied Ergonomic Principle on Work Method

No	Work Observed	Productivity (m^2/hour)		Increase Productivity (%)
		Exist Work Methode	Improved Work Method	
1	Brick Masonry	1,3796	1,7727	28,49
2	Plaster	1,3766	1,5999	16,22
3	Wall painting	2,1185	2,8735	21,47
4	Ceramic Fixing	0,4901	0,6225	26,18
No	Work Observed	Productivity (m^2/hour)		Increase Productivity (%)
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The productivity of improved work methods on Table 3 was obtained from selected labor with prime condition. To find the average productivity that meet general condition of all construction labor, these productivity is corrected by 10%. The comparison between observed labor productivity to the SNI (Indonesian National Standardization) as the benchmark of this research is presented in Table 4.

Table 4 The Comparison of Labor Productivity to the SNI

No	Work Observed	Productivity (m^2/hour)		Productivity Differences from SNI	
		Observed	SNI	m^2/hour	%
1	Brick Masonry	1,60	1,45	0,15	10,34
2	Plaster	1,45	0,95	0,55	57,89
3	Wall painting	2,57	2,28	0,29	12,72
4	Ceramic Fixing	0,56	0,42	0,14	33,33

The differences between observed productivity in this research to the SNI occurs because SNI is the standard for labor productivity in all region of Indonesia that have large skill variation, so SNI has to accommodate labor in regions with low skill, while labor observed in this research come from Yogyakarta that have high level productivity compare to the other region.

V. CONCLUSION

At this time the implementation of ergonomic principles have not been seriously considered in construction project, though the ergonomic way of work will increase productivity and improve worker health as well. The result of this research prove that labor productivity achieved by the application of ergonomic work method increased significantly, especially for job that rely on skill and physical capability of labor.

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