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A Study on the Labor Productivity Analysis of Underground and Ground Levels in Reinforcement Work of Apartment

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Abstract

In Korea, there is no index to measure labor productivity, thus, there is a need for such to measure the labor productivity of rebar construction for apartment houses. In this study, in order to analyze the difference in labor productivity between the basement and the ground floor in the rebar construction of an apartment house, the number of people input and the amount of rebar carried in for about 6 months were summarized based on the actual construction daily report. Based on this, assuming a cycle, labor productivity was calculated and tested at a confidence level of 95% using the T-test method. Labor productivity was calculated as the average productivity for each cycle based on the amount of rebars brought in. The cycle was assumed to be 1 cycle, with 7 days of 'rebar loading period' and 7 days of 'rebar exhaustion period' for each person. Only cycles with 200 or more people were summarized to obtain 16 cycles. In addition, according to the ratio of the input personnel, it was classified into A when it was 60% or more, and Group B when it was 40% or less. The difference in productivity was analyzed through the average of the productivity data values of each group. This study has investigated and revealed the difference in productivity between the sub-ground-floor and above-ground-floor rebar work in high-rise communal housing not with predictions but with numerical data. The method of measuring labor productivity in this study is expected to be used as a more objective data value in construction sites. It is necessary to check the efficiency by applying it to various sites later.

Keywords: Apartment, Re-bar Work, Labor Productivity, T-test, Basement floor.

1. Introduction

In construction, productivity is an index that can measure the manpower and resources that are injected. Productivity is also a factor that can influence whether or not the construction project will become successful[1]. However, in Korea the concept of productivity measurement methodology is not clear and due to its low awareness and understanding it is difficult for the efforts to increase productivity to become effective[2]. In fact, due to poor management of data on construction productivity in construction sites, it becomes extremely difficult to find the causes of lowered productivity[3]. As shown above productivity information is an index for measuring project results and thus becomes an important factor in making decisions[4]. Alongside form work, reinforcing bar work is the work that influences most greatly on a building's structural safety, durability and construction period[5]. However, there is difficulty in determining the rational cost on construction and heavy dependence on labor. Therefore, information on labor productivity is essential also in reinforcing bar work[6].

In this study, the focus was set on the factors affecting the labor productivity in reinforcing bar work in Korean communal housing. Among the many factors, the differences between the sub-ground level floors and above ground level floors were analyzed. In the sub-ground level floors much more time is needed compared to the above ground level floors[7]. What this means is that there is higher labor productivity. However, these values are merely anticipated values of the foremen on site with years of experience and

traditional practices, not exact values measured with indexes[8]. Furthermore, there is not a standardized definition on labor productivity in the construction industry, which leads to a situation where there are no indexes to be measured[9]. Hence, the need to produce an index to make productivity analysis possible is paramount.

In this study, labor productivity in reinforcing bar work in Korean communal housing was calculated by the amount of reinforcing bar injected per person in set periods, and it was done in 4 stages. The object of the study was a Communal Housing 2BL located in the Yongsan district, Gwangju, Korea. The construction period was from December 5, 2016 to May 21, 2019. Of the period, daily reports taken for about 6 months from August 2017 to February 2018 were defined as the period of this study.

2. Preliminary study

Productivity is an index showing the efficiency in producing, and there are many kinds such as labor productivity, capital productivity, productivity of material, etc. Most frequently used among them is labor productivity[10,11]. Labor productivity generally refers to the amount of products or added value that can be produced by one worker during a set time[12]. It is a representative figure that serves as a standard in economic development[13]. It is further divided into physical labor productivity which shows the amount of output against the injected amount of labor, and value added labor productivity which shows the rate of added value against the injected labor. Physical labor productivity is appropriate for determining production efficiency or technology level, and value added labor productivity is appropriate for evaluating the effectiveness of creating value, such as distribution basis or the ability to pay wages, and is therefore closer to the profit of the company[14].

Jeong Jae-ho analyzed potential factors lowering labor productivity so as to increase labor productivity in the construction sites[15]. Using IPA analysis method, the significance level and the performance rate of countermeasures for the hindrance factors were measured. Actual construction sites were selected and, upon performing comparative analysis, management solutions appropriate and realistic for on site management were provided to the field supervisors. Sumanth divided management of productivity into measurement, evaluation, planning and improvement Sink divided it into measurement and evaluation, planning, constrol and improvement, and measurement of effect and evaluation[16,17]. Productivity from two studies was divided into four stages. In the measurement stage an objective record of the current process was taken. Evaluation is the stage that analyzes it and planning is the stage where the production process is adjusted taking consideration for the problems found in the analysis stage. Once such stages are applied, productivity sees improvement.

3. Methodology

Based on the daily reports, the actual figures of people and reinforcing bar injected for about six months were collected. Reinforcing bar is injected from Monday (Day1) to Sunday (Day7). It was assumed that the injected manpower is exhausted from Thursday(Day4) to Wednesday(Day10) the following week. Defining that as 1 Cycle periodic average productivity was calculated. A period when manpower of more than two hundred workers, which is a number showing the peak in construction activity, was selected. Such a Cycle was organized with 16 periods, in the order of descending errors. The periods when the manpower injected in the sub ground-level floors was above 60% were categorized as Group A. Periods wherein less than 40% of manpower was injected were categorized as Group B. Productivity values for periods totalling 7 Cycles were purposely calculated one week later in order to increase reliability. In order to verify the results, the productivity differences between sub-ground-level and above ground-level floors were tested using the T-test, at a confidence level of 95%.

4. Average Labor Productivity

With data from on-site daily reports for about six months, labor productivity was calculated. Using data from the daily reports the number of persons was the actual number and the unit for the amount of injected reinforcing bar, based on the different kinds of rebars, was Ton. The collected data for the injected manpower and reinforcing bar for each week is shown in [Table 1]. Injected manpower is based on the total sum of injected manpower in the reinforcing bar work from the framing construction on the day from Construction Company B and Construction Company C. The amount of injected rebar in [Table 2] shows the total sum of injected rebar of various types from the previous day.

Table 1: Daily Worker Number

Classification	Company Name	Type of construction	One day	Cumulative
Framing	B construction	Rebar	33	2594
	C construction		2	644

Table 2: Injected Rebar Amount

Name of Item	Standard	Unit	Previous Day	Cumulative
Rebar	HD10	Ton	1.3	225
	SHD13		7.2	561
	UHD16		9.4	606
	UHD19		2.9	159
	UHD22		10.3	301
	UHD25			33

Total	31.13	1884.30

Using methodology from [Table 1] and [Table 2], data was collected for six months. One Cycle was from Monday through Sunday, and it is as shown in [Table 3].

Table 3: Injected Rebar Amount and Manpower

Injected Rebar Amount	28 (Mon)	29 (Tue)	30 (Wed)	31 (Thu)	1 (Fri)	2 (Sat)	3 (Sun)	Total
HD10	0	0	0	13.7	16.5	0	14.8	45
SHD13	0	0	0	2.9	13.7	0	4.3	20.9
UHD16	0	0	0	0.4	56.1	0	0.4	56.9
UHD19	0	0	0	0	27.1	0	0	27.1
UHD22	0	0	0	0	7.7	0	0	7.7
UHD25	0	0	0	0	4.7	0	0	4.7
Manpower	34	34	37	37	35	32	31	240 (Person)

Labor productivity is defined by the amount of exhausted reinforcing bar, which is the amount of labor by the number of injected workers. The exact labor productivity can be determined by calculating the amount of exhausted rebar per worker on a particular day. However, as there is no practice of recording the amount of exhausted rebar on a daily basis all the time, the exact calculation of labor productivity is not possible. Therefore, rather than calcualting the amount of exhausted rebar per injected worker one has to get figures for productivity by calculating the previously-mentioned injected rebar divided by the number of workers. However, the problem with this method lies in the fact that the exact calculation is not possible if there is no record of how much of the injected rebar was actually exhausted and on what day.

Therefore, rather than using daily labor productivity periodic productivity is used for predicting productivity. As for the period, as can be seen in [Table 4], 1 Cycle was defined by assuming the amount of rebar injected from Monday through Sunday being exhausted by the injected manpower from Thursday that week to the following Wednesday. Reliability cannot be guaranteed if one assumes that the injected rebar in one week is exhausted entirely by the injected manpower that week. Therefore, in order to increase reliability there was a 3-day gap between the starting days of the two injections. As such, the average productivity was determined by taking the total sum of the injected rebar amount against the total injected manpower.

Table 4: Period Average Productivity

Injected Rebar Amount	28 (Mon)	29 (Tue)	30 (Wed)	31 (Thu)	1 (Fri)	2 (Sat)	3 (Sun)	Total
HD10	0	0	0	13.7	16.5	0	14.8	45
SHD13	0	0	0	2.9	13.7	0	4.3	20.9
UHD16	0	0	0	0.4	56.1	0	0.4	56.9
UHD19	0	0	0	0	27.1	0	0	27.1
UHD22	0	0	0	0	7.7	0	0	7.7
UHD25	0	0	0	0	4.7	0	0	4.7
								162.3 (ton)
	31 (Thu)	1 (Fri)	2 (Sat)	3 (Sun)	4 (Mon)	5 (Tue)	6 (Wed)	
Manpower	37	35	32	31	35	44	0	214 (Person)
Period Average Productivity		Injected Rebar Amount / Manpower					0.758411(ton/person)	

The data from six months were collected in the previously-explained methodology. In order to lower the errors of the data only the periods where more than 200 workers were active were considered. That is because the minimum number of workers is two hundred when construction is vibrant. Data for the said 16 periods is found in [Table 5].

Table 5: Periods Involving Over 200 Workers, Productivity

Cycle	Mon ~ Sun Injected Rebar Amount (ton)	Thu ~ Wed Manpower (Person)	Productivity(ton/person)
1	(7.31~8.6) 102.1	(8.3~8.9) 235	0.434468
2	(8.14~8.20) 98.4	(8.17~8.23) 283	0.347703

3	(8.28~9.3) 162.3	(8.31~9.6) 214	0.758411
4	(9.4~9.10) 178.2	(9.7~9.13) 260	0.685385
5	(9.11~9.17) 213.6	(9.14~9.20) 309	0.691262
6	(9.18~9.24) 304.4	(9.21~9.27) 270	1.127407
7	(10.9~10.15) 106.2	(10.12~10.18) 255	0.416471
8	(10.16~10.22) 214.1	(10.19~10.25) 289	0.74083
9	(10.23~10.29) 123.4	(10.26~11.1) 245	0.503673
10	(10.30~11.5) 190	(11.2~11.8) 206	0.92233
11	(11.6~11.12) 157.9	(11.9~11.15) 217	0.72765
12	(11.20~11.26) 403.4	(11.23~11.29) 362	1.114365
13	(11.27~12.3) 155	(11.30~12.6) 262	0.591603
14	(12.11~12.17) 90.17	(12.14~12.20) 214	0.421355
15	(1.15~1.21) 115.4	(1.18~1.24) 238	0.484874
16	(2.19~2.25) 182.8	(2.22~2.28) 239	0.764854

5. Analysis of the Difference in Average Labor Productivity Between Sub-Ground-Level and Above-Ground-Level Floors

Injected manpower was organized in order to analyze the differences in average labor productivity during work in the sub-ground-level and above-ground-level floors in the previously-mentioned 16 periods. As for the injected manpower, only the workers injected into the rebar work per each day as per operation status were counted. The ratio of injected workers to the entire number of injected workers is shown in [Table 6]. Only the workers that took part in actual work are counted towards the number of injected workers. The field supervisor and those whose job is merely to carry rebars are excluded. A slight discrepancy in numbers arises in the total number of injected workers but it is minimal in terms of affecting the value of data. Sub-ground-floor construction work includes work in areas such as foundation, septic tank, electrical room, and water reservoirs, and the total number of workers is 10. Above-ground-floor workers number 9, including work in the ceiling and flooring of parking garages.

Table 6: Total Number of Workers in Sub-Ground-Floor

Injected Rebar Amount	14 (Mon)	15 (Tue)	16 (Wed)	17 (Thu)	18 (Fri)	19 (Sat)	20 (Sun)	Total
HD10	0	0	9.7	0	2.1	10.3	0	25.1
SHD13	0	0	8.2	0	21.1	17.3	0	46.6
UHD16	0	0	2.5	0	0.7	1.9	0	5.1
UHD19	0	0	0	0	0.4	0.2	0	0.6
UHD22	0	0	1.7	0	16.2	0	2	19.9
UHD25	0	0	0	0	0.7	0	0.4	1.1
								98.4 (ton)
	17 (Thu)	18 (Fri)	19 (Sat)	20 (Sun)	21 (Mon)	22 (Tue)	23 (Wed)	Total
Total Injected Manpower	41	46	57	33	0	44	44	265
Total Sub-ground-floor Injected Manpower	12	13	51	28	0	0	0	104
Total Above-ground-floor Injected Manpower	29	33	6	5	0	44	44	161
Periodic Average Productivity		Injected Rebar Amount / Manpower					0.758411(ton/person)	
Sub-ground-floor Injected Manpower Ratio		(Total Sub-ground-floor Injected Manpower / Total Above-ground-floor Injected Manpower) *100					0.39245(%)	

During the 16 periods, the total rebar amount, total injected manpower, sub-ground-floor injected manpower, sub-ground-floor manpower ratio, productivity data values are in [Table 7]. In order to compare the difference between the data value of Injected Manpower Ratio and Productivity, the periods whose total injected manpower ratio was above 60% were labelled Group A, and those whose total injected

manpower ratio was below 40% were labelled Group B.

Table 7: Total Number of Workers in Sub-Ground-Floor

Cycle	Injected Rebar Amount (ton)	Manpower (person)	Total Sub-ground-floor Injected Manpower (person)	Productivity (ton/person)	Rate (%)	More than 60%	Less than 40%
1	102.1	225	168	0.453778	74.67	A	
2	98.4	265	104	0.371321	39.25		B
3	162.3	206	144	0.787864	69.90	A	
4	178.2	240	151	0.787864	62.92	A	
5	213.6	266	160	0.7425	60.15	A	
6	304.4	256	129	0.803008	50.39		
7	106.2	227	117	1.189063	51.54		
8	214.1	259	122	0.467841	47.10		
9	102.1	225	168	0.826641	62.21	A	
10	98.4	265	104	0.568664	56.77		
11	162.3	206	144	0.872376	66.30	A	
12	178.2	240	151	1.179532	55.85		
13	155.1	242	79	0.640909	32.64463		B
14	90.17	198	28	0.455404	14.14141		B
15	115.4	201	5	0.565686	2.45098		B
16	182.8	222	63	0.823423	28.37838		B

The classified data values show that Group A is made up of 6 Periods, namely, 1, 3, 4, 5, 9, and 11. Group B is made up of 5 Periods, namely, 2, 13, 14, 15 and 16 that yielded productivity data. As a measure of increasing reliability productivity data was gathered one Cycle later from the first Cycle to the seventh Cycle. Results from Group A yielded 42 data values and those from Group B yielded 35 data values, which are shown in [Table 8].

Table 8: Total Number of Workers in Sub-Ground-Floor

Group A Cycle	1	3	4	5	9	11
1	0.4538	0.7879	0.7425	0.803	0.5687	0.8724
2	0.5801	0.7766	0.7615	0.7574	0.5933	1.3295
3	0.7293	0.7549	0.7333	1.019	0.4242	1.659
4	0.7735	0.6966	0.9472	0.9681	0.7223	1.6311
5	0.9137	0.5931	1.0192	1.1031	0.9762	1.3634
6	1.388	0.607	0.9958	0.6237	1.0343	1.1903
7	1.5402	0.889	0.7835	0.8495	1.1487	1.2856

Group B Cycle	2	13	14	15	16
1	0.3713	0.6409	0.4554	0.5657	0.8234
2	0.377	0.6714	0.5066	0.5294	0.9374
3	0.4493	0.8262	0.3427	0.7441	0.9141
4	0.499	1.0872	0.2224	0.8611	0.7119
5	0.6957	1.4926	0.3769	1.0503	1.0626
6	0.5383	1.4049	0.3617	1.4567	1.2543
7	0.4552	1.3114	0.3702	1.6735	1.6711

The difference in productivity was analyzed using the averages of data values collected from the previously-explained processes. However, since the values are extracted from a portion of the collected samples reliability testing is needed. Thus, T-testing is done at confidence level of 95%. The following hypothesis is posited for the difference in labor productivity between sub-ground-level and above-ground-level work. H0 is 'there is no difference in labor productivity between sub-ground-floor and above-ground-floor high-rise communal housing reinforcing bar work,' and H1 is 'there exists a difference in labor productivity between sub-ground-floor and above-ground-floor labor productivity in high-rise communal housing reinforcing bar work.' The collected data for testing, as shown in the technical statistics in [Table 9], shows average labor productivity as 0.99(ton/person) for sub-ground-floor and 0.79(ton/peson) for above labor productivity, with standard deviation for each being 0.34 and

0.41.

Table 9: Technical statistics

Location		N	Mean	Std. Deviation	Std. Error Mean
Productivity	A	40	0.9857	0.33623	0.05316
	B	35	0.7918	0.41209	0.06966

In order to test the difference between the two groups, an independent samples T-test is done. Since one cannot know the population variance of the two groups, analyses with the assumption that the variation value is different, and those with the assumption that common variation is used are both performed. Upon testing the differences between the two groups the T value was 2.243 with the P value at 0.028, as shown in [Table 10], and confirmed falling in the boundary of level of significance as set by this study. Also, when common variance was not used T value was at 2.213 and testing from both sides yielded a P value of 0.03, which fell in the level of significance. Therefore, the null hypothesis on the difference in labor productivity of this study can be rejected. Analysis results of the rebar work in high-rise communal housing showed that there is a difference in labor productivity between sub-ground-floor and above-ground-floor rebar work, and as a result they showed that the difference in the average values of the total productivity data are reliable data.

Table 10: T-Test Results

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	T	df	Sig.(2-tailed)
Productivity	Equal variances assumed	1.961	0.166	2.243	73	0.028
	Equal variances not assumed			2.213	65.709	0.030

		t-test for Equality of Means			
		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
				Lower	Upper
Productivity	Equal variances assumed	0.1939	0.0865	0.0216	0.3662
	Equal variances not assumed	0.1939	0.0876	0.0190	0.3689

6. Conclusion

In construction, productivity is an index that can measure the manpower and resources that are injected. Productivity is also a factor that can influence whether or not the construction project will become successful. However, in Korea the concept of productivity measurement methodology is not clear and due to its low awareness and understanding it is difficult for the efforts to increase productivity to become effective. This study sought to analyze the labor productivity of communal housing reinforcing bar in the sub-ground-floor and above-ground-floor levels. However, the assessment method of labor productivity in the Korean construction industry was done not by accurate indices but by the experience of the field supervisor. As such a method cannot yield accurate data a measurable index is needed. Furthermore, there is not a standardized definition on labor productivity in the construction industry, which leads to a situation where there are no indexes to be measured. Hence, the need to produce an index to make productivity analysis possible is paramount. Therefore, an analysis was made on the labor productivity of sub-ground-floor and above-ground-floor work using accurate data from construction daily reports of six months. This study has investigated and revealed the difference in productivity between the sub-ground-floor and above-ground-floor rebar work in high-rise communal housing not with predictions but with numerical data. It is anticipated that the results of this study can be used for analyzing productivity in the future. In addition, this study has limitations in its scope because it analyzed the reinforcing bar work productivity of the multi-unit housing project. As a future study, it is necessary to analyze the rebar work productivity of various types and projects of various sizes.

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8. References

1. Son CB, Lee DC. An Analysis on the Factors Decreasing Productivity of Building Construction. Architectural Institute of Korea. 2002;18(12):125-132.
2. Kim YS. Analysis of the Factors Influencing

Construction Productivity. Architectural Institute of Korea. 1994;10(10):267-272.
3. Moon WK, Han SH, Kim YS, Kim YS, Kim SB. Analysis on the Factors Influencing Construction Productivity for Management of Construction Productivity Information. Korea Institute of Construction Engineering and Management. 2006;():422-426.
4. Yu JH, Lee HS. Productivity Management System for Construction Projects. Architectural Institute of Korea. 2002;18(7):103-113.
5. Mun JM, Kim CD. Productivity Improvement through the Waste Elimination of Construction Process. Korea Institute of Construction Engineering and Management. 2002;3(4):93-103.
6. Kim MJ, Lee KH, Shin WS, Son CB. An Analysis of Productivity on the Reinforced Concrete in the Apartment Construction Site. The Korea Institute of Building Construction, 2014, 14.1: 34-35.
7. Won JS, Lee G. An Analysis of the International Competitiveness of Productivity in the Korean Construction Industry. Korea Institute of Construction Engineering and Management. 2008;9(4):75-83.
8. Jeong IH, Son CB, Bang JD, Kim JO, Ahn YS, Shin HS. Productivity and Work Analysis of Frame Work in Apartment Construction. Architectural Institute of Korea.1995;11(4):269-276.
9. Jang HM, Kim, KH, Kim JJ. Labor Productivity Model on Construction Industry Using System Thinking. The Korea Institute of Building Construction.2009;9(3):79-85.
10. Son JW, Yoon JS, Paek JH. A Study on Construction Productivity Measurement Method. Architectural Institute of Korea.2003;19(10):101-108.
11. Pyo YM, Bae SY, Ryu HH, Lee SB. The Study on the Analysis of Factors Decreasing Construction Labor-Productivity Using AHP Method. The Korea Institute of Building Construction. 2005;():141-147.
12. ARDITI, D. Construction productivity improvement. Journal of Construction Engineering and Management, 1985, 111.1: 1-14.
13. Won JS, Lee G. An Analysis of the Ability of the Korean Construction Industry based on the Labor Productivity of Specialty Contractors. Architectural Institute of Korea. 2007;27(1):705-708.
14. Park HP. A Fundamental Study on International Comparison of Labor Productivity in Construction Industry. In: Proceedings of the Korean Institute of Building Construction Conference. The Korean Institute of Building Construction, 2018. p. 310-311.
15. Jones DL. The role of physical activity on the need for revision total knee arthroplasty in individuals with osteoarthritis of the knee. [Hanyang]: University of Pittsburgh; 2001. 436 p
16. SUMANTH, David J. Productivity Engineering and Management: Productivity Measurement, Eveluation, Planning, and Improvement in Manufacturing and Service Organizations. 1984.
17. Sink, D. Scott. Productivity Management: Planning, Maesurement and Evaluation, Control and Improvement. John Wiley & Sons, 1985.