Measurement Analysis of Box Girder Production Cycle Times in Indonesia Infrastructure Projects

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ABSTRACT
Infrastructure is one of the important elements in the development of a country. The number of bridge infrastructure projects that can increase the growth of the construction industry in Indonesia must be supported by construction technology as well as the use of precast box girders. Problems arise due to inaccurate planning and production scheduling of box girders which cause the project delay. For this reason, it is necessary to carry out an analysis of the measurement of the box girder production cycle times as soon as possible hence it can provide an overview and reference in planning and scheduling elevated infrastructure projects. The purpose of this research is to measure the box girder production cycle times in Indonesian infrastructure projects. The main variable is the box girder production cycle time. The projects observed were projects in the last 3 years from 2016 to 2020. And the production of the box girder segments chosen were box girder segments with straight alignment. The average analysis is used to know the average of the cycle times. Based on descriptive analysis, the average production cycle time is 38.95 hours with an average delay time of 6.28 hours. The average production cycle time can be used as a reference for planning and developing schedules for elevated infrastructure projects.

Keywords: *Box Girder, Cycle Times, Production, Scheduling.*

1. INTRODUCTION

Infrastructure is one of the important elements in the development of a country. Infrastructure has an important role in economic development [1]. Nowadays, the Indonesian government has focused on developing construction infrastructures such as roads and bridges. The number of bridge infrastructure projects that can increase the growth of the construction industry in Indonesia must be supported by construction technology as well as the use of precast box girders.

Precast box girder is a type of girder used for segmental bridges. A segmental box girder is used because it has several advantages, such as lighter segment weight, no structural cracks when opening dry joints, damaged segments can be recycled, and less traffic disruption. Additionally, Box girder is used because it is more efficient and resistant in structure especially in earthquake situations [2]. Box girders are designed as the most efficient and economical cross-section of the segmental bridge [3]. Precast box girders are produced at the precast plant or outside the project site but in a controlled environment, delivered to the site, and installed according to a schedule determined by the customer. Fabrication of the bridge segment in a separate area also eliminates casting activities from the critical construction path and reduces the overall construction time [4].

Nowadays, precast fabricators face many challenges as they strive for their business success. Precast fabricators are involved in the construction project team as suppliers or subcontractors who produce, ship, and select precast components [5]. For the precast fabricators, customer satisfaction is measured by the timeliness of delivery [6]. Construction projects rely on the timely delivery of products manufactured by the precast fabricator [7]. Because delivery time has a significant impact on construction project performance [8]. Delivery delays can cause low profits and construction delays which will damage the profits of precast fabricators and construction contractors. Delay in delivery can interfere with the progress of an erection and therefore cause a delay. Also, the consequences of late delivery include penalties or breach of contract, decreased business reputation [9], and also higher labor costs [10],

The production schedule plays an important role in the successful completion of a project [11]. The schedule is one of the main performance criteria used for the evaluation of construction projects and, as a result, gives significant attention to the industry. The purpose of production scheduling in precast plants is to ensure timely manufacturing of components with the most efficient utilization of production resources [9]. Production scheduling is based on production planning and under the constraints of production equipment, technology processes, and capabilities. The purpose is to plan schedule and optimize production resources from a time and space perspective, define production lines, hence it can achieve production goals. The majority of scheduling problem is a combination of optimal problems [12]. Production time variability is one of the obstacles for one of the precast fabricators in Indonesia so that it can affect scheduling. Improper box girder production scheduling can cause delays in delivery to the site, which can delay work in the field, increase execution time and increase construction costs [11]. Sometimes the uncertainty of the execution completion date causes unexpected fluctuations in the production schedule, making it difficult to plan for efficient production [5].

Good production planning is the main key in precast production. Production planning is a process that collects the information needed to analyze and issue a production schedule, and control progress [5]. Several efforts have been done to improve precast production planning and control activities [9] such as estimation of productivity. Estimation of the productivity of precast manufacturing is needed to set the production schedule [13]. It means that measuring box girder production cycle times is very important for planning production schedule until delivery schedule. The purpose of this research is to measure the box girder production cycle times in Indonesian infrastructure projects by observing each box girder production process and calculating the average value. The average production cycle time can be used as a reference for planning and developing schedules for elevated infrastructure projects.

2. METHOD

This is quantitative research. This research made observations on variable box girder production cycle times. The sampling technique was used is accidental sampling which means the selection of the sample base on the ease in obtaining data. The project samples taken are elevated infrastructure projects between 2016 and 2020. The infrastructure projects observed were representative of railway projects and toll road projects. The number of project samples is 5 projects with a total of 125 segment samples to be observed as in Table 1.

Table 1. Box Girder sample calculation

No	Project	Year	Description Line	Production Volume m^3	Production Volume Segment	Sample Segment
1	Mass Rapid Transit (MRT) Package CP 101 - 102	2016-2017	Straight Alignment	18,812	1,421	25
2	Mass Rapid Transit (MRT) Package CP 103	2016-2017	Straight Alignment	7,223	683	25
3	Bogor Outering Ring Road 2B	2017	Straight Alignment	25,872	1,848	25
4	Light Rail Transit Kelapa Gading - Velodrome	2017	Straight Alignment	17,220	1,230	25
5	Bogor Outering Ring Road 3A	2019 - 2020	Straight Alignment	31,040	2,140	25
Production Total 2016 – 2020				**100,167**	**7,322**	**125**

After the data was collected, the descriptive analysis is applied to get a descriptive result such as mean, median, modus, minimum and maximum. The results of the descriptive analysis will be validated by experts in box girder segment production. According to PMI, this is called expert judgment and it is a tool and technique in project time management planning [14]. The number of experts who were asked to validated the results were 5 peoples. The expert requirements are as follows:

1. Respondent is an expert in box girder production and construction
2. The minimum education of respondent is a bachelor degree in civil engineering
3. The respondent can be an academician, professional engineer, or practitioner which has a minimum of 10 years of working experience.

Based on the expert requirements, Table 2 shows profiles of the experts.

Table 2. Expert profile for validation

No	Expert	Position	Working Experience	Education
1	Expert 1	Plant Manager	15 Years	Master Degree
2	Expert 2	Project Manager	13 Years	Master Degree
3	Expert 3	Site Engineer	10 Years	Master Degree
4	Expert 4	Site Engineer	18 Years	Bachelor Degree
5	Expert 5	Senior Foreman	20 Years	Bachelor Degree

3. RESULT AND DISCUSSION

3.1. Results

There are 10 activities in the box girder production process which observed, namely geometric control data setting (A), formwork setting (B), installation rebar cage to formwork (C), installation embedded items (D), elevation setting before concrete pouring (E), concrete pouring (F), concrete curing (G), product geometric control data retrieval before product release (H), product setting as match cast (I), and product placement on the stockyard (J). Table 3 shows the results of observation and analysis of the box girder production cycle times and delay time that occurs at each activity or stage of the process.

Table 3. Box Girder production cycle times calculation results

No	Activity Code	Production Activity	Production Cycle Time (Hours)			
			Mean	Median	Max	Min
1	A	Geometric Control Data Setting	0.55	0.50	1.50	0.17
2		Delay Time	0.61	0.58	1.08	0.33
3	B	Formwork Setting	9.07	10.00	11.33	3.67
4		Delay Time	1.77	1.67	2.50	0.50
5	C	Installation Rebar Cage to Formwork	2.00	2.17	2.50	0.83
6		Delay Time	0.53	0.50	1.00	0.17
7	D	Installation Embedded Items	6.63	7.50	9.17	3.83
8		Delay Time	0.40	0.00	1.25	0.00
9	E	Elevation Setting Before Concrete Pouring	0.81	0.83	1.25	0.33
10		Delay Time	0.53	0.00	1.50	0.00
11	F	Concrete Pouring	1.48	1.33	2.50	1.00
12		Delay Time	0.00	0.00	0.00	0.00
13	G	Concrete Curing	10.13	9.50	13.17	7.00
14		Delay Time	0.46	0.00	1.33	0.00
15	H	Product Geometric Control Data Retrieval Before Product Release	0.54	0.50	1.17	0.00
16		Delay Time	1.22	1.00	2.50	0.67
17	I	Product Setting as Match Cast	0.78	0.67	1.50	0.33
18		Delay Time	0.75	0.75	1.25	0.33
19	J	Product Placement on Stock Yard	0.69	0.50	1.58	0.25
Total Production Process (Hours)			**32.67**	**33.50**	**45.67**	**17.42**
Total Delay Time (Hours)			**6.28**	**4.50**	**12.42**	**2.00**
Total Production Cycle Times (Hours)			**38.95**	**38.00**	**58.08**	**19.42**

Base on the results of the analysis, the longest process is concrete curing with a total time is 10.13 hours, formwork setting with a total time is 9.07 hours, and installation of embedded items with a total time is 6.63 hours. The total production process rate is 32.67 hours per box girder segment. And this research found that there is a delay time for each process and it is significantly contributed to the addition of box girder production cycle times. The total delay time is 6.28 hours. This means that the total production cycle times are equal to the total production process plus the total delay time or 38.95 hours per box girder segment. To facilitate the calculation, the total production cycle time can be said to be 1.62 days.

3.2. Discussion

Production planning is a precast segmental box girder production key. Production planning is a way to find out the complete information to be able to develop a good schedule for production and control the progress of production [5]. Measuring the box girder production cycle time is one of the efforts to make a good precast production planning [9]. Because box girder production cycle time is showing an estimation of productivity and it can be a basis to set a production schedule [13].

Base on the results of this research, the rate of the box girder production cycle time is 38.95 hours or 1.62 days. This value can give us reference and overview in calculating the productivity of precast plant and developing a good production schedule. This research also found total delay time in between activity or stage of the process is 6.28 hours. And it should be done further analysis on the factors that affect the delay time and perform the optimization.

According to the result of the analysis, setting formwork, curing, and installing embedded items are the longest process. The cycle time of production is also able to be made shorter by identifying the type of formwork that has a faster period to set up, conducting materials engineering, changing curing methods, and adding human and material resources to increase the speed of installing embedded items. These efforts are expected to optimize production cycle times hence the optimum production planning and production schedule could be achieved.

Box girder precast production schedule is very important because it is a determinant of a successful project [11]. The precast production schedule is used to ensure the production is on time [9]. So that the box girder delivery process is also on time. Because delivery time has a significant impact on construction project performance [8] and success of construction project [7].

The production schedule is also a basis to develop a master construction schedule. Meaning, inaccurate planning and production schedule, the construction process will be disrupted and delay, such as a delay in box girder erection. Delay will damage the profits of precast fabricators and construction contractors, and also increase labor costs [10]. In the end, the consequences of delay are paying penalties and decreasing company business reputation [9].

4. CONCLUSION

We can conclude that the results of measurement analysis of box girder production cycle time are 38.95 hours or 1.62 days. The Box girder production cycle time is not only consisting of a production process time of 32.67 hours but also a delay time of 6.28 hours. The results of this study are expected to provide an overview and reference in planning the scheduling of an infrastructure project and have implications for the development of construction project management science. Further research is necessary to analyze the factors that affect the box girder production cycle time and it is necessary to calculate the optimization of the box girder production cycle time so that the cycle time is truly optimum, effective, and efficient.

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REFERENCES

[1] M. Yılmaz and R. Kanıt, “A practical tool for estimating compulsory OHS costs of residential building construction projects in Turkey,” *Safety Science*, 101, p 326–331, 2018.

[2] J. B. B. P. Sitanggang, "Jembatan Box Girder Segmental," Jurnal Karya Teknik Sipil S1 Undip, vol. 2, no. 3, pp. 1-6, 2013.

[3] P. Bujnakova, “Construction of precast segmental box girder bridge” IOP Conference Series: Materials Science and Engineering, 385, 012007, 2018.

[4] J. Moreton and H. H. Janssen, “Casting Box Girder Segments. Following Basic Casting Yard Procedures Will Assure Quality Concrete Bridge Segments” The Aberdeen Group, 1995.

[5] P. Pawar and A. A. Warudkar, “Precast Factory Management,” Journal of Advances and Scholarly Researches in Allied Education Vol. XV, Issue No. 2, 2018.

[6] M. Bilec, R. Ries, S. Matthews & A.L. Sharrard, “Example of a hybrid life-cycle assessment of construction processes,” Journal of Infrastructure System 12(4): 207– 215, 2006.

[7] G. Ballard and R. Arbulu, “Taking Prefabrication Lean,” Proceedings of the 12th Annual Conference of the International Group for Lean Construction, Elsinore, Denmark, 2004.

[8] L. S. Pheng and C. J. Chuan, “Just-in-time management in precast concrete construction: a survey of the readiness of main contractors in Singapore,” Integrated Manufacturing Systems, vol. 12, no. 6, pp. 416–429, 2001.

[9] Ko, “An integrated framework for reducing precast fabrication inventory,” Journal of Civil Engineering and Management, 16(3), 418–427, 2010.

[10] Z. Wang and H. Hu, “Improved Precast Production–Scheduling Model Considering the Whole Supply Chain,” Journal of Computing in Civil Engineering, 31(4), 04017013, 2017.

[11] T. Kim, Y. Kim, and H. Cho, “Dynamic production scheduling model under due date uncertainty in precast concrete construction,” Journal of Cleaner Production, 120527, 2020.

[12] Qingxue Liang and H Hu, “Optimization of precast production scheduling for rail track slab.” IEEE Technology & Engineering Management Conference (TEMSCON), 2017.

[13] V. Benjaoran, N Dawood and D. Scott, “Bespoke precast productivity estimation with neural network model," In Khosrowshahi, F (Ed.), 20th Annual ARCOM Conference, 1-3 September 2004, Heriot-Watt University. Association of Researchers in Construction Management, Vol. 2, 1063-74, 2004.

[14] PMI, “Project Management Body of Knowledge” Pennsylvania: Project Management Institut, Inc., 2017.