Civil Engineering and Architecture 8(3): 305-311, 2020
DOI: 10.13189/cea.2020.080314 http://www.hrpub.org

Performance Evaluation of Woven Polyethylene Formwork on Tie Beam and Pile Cap Structure in Terms of Cost and Time

Novena Ulimandalany Barus, Jessica Sjah*, Ayomi Dita Rarasati

Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Depok, West Java, Indonesia

Received February 25, 2020; Revised May 19, 2020; Accepted May 27, 2020

Abstract One of the most important components in the construction execution is concrete works. Therefore, we need formworks to form the structural elements that are planned in a construction process. In the process, an economical alternative needs to be taken regarding choosing formwork material to get more benefits, both in terms of cost and time. Fabric formwork can be an alternative solution for formwork material. An example of a feasible formwork material alternative is woven polyethylene-based formwork. The purpose of this research is to evaluate the performance value of woven polyethylene formwork and compare it with the conventional formworks such as wood and brick in terms of cost and time. Field observations and literature reviews have been done to answer these questions. By using woven polyethylene formwork on tie beam and pile cap structure, it was found that the average time and the investment cost of installation are consecutively 344.23 s/m^2 and IDR75000 which is faster and cheaper than using conventional ones.

Keywords Fabric Formwork, Woven Polyethylene, Concrete Structure, Construction, Performance Evaluation

1. Introduction

Concrete work is one of the most important components of the construction project. Concrete is a material that can reduce building maintenance costs, give the fire resistance to the building, is able to reduce noise, so it can provide a longer life to a building (Hanna, 1999). Therefore, concrete needs a mould to form the structural elements in the construction projects, which is usually called formwork. Formwork is defined as a temporary structure whose purpose is to provide support and resistance until the concrete can support its own weight. In terms of cost, formwork contributes 40-60% of total concrete work and about 10% of total building costs (Hanna, 1999). Based on this research, the construction team should make an economical decision from the material selection to the formwork installation, so it can provide a benefit both in terms of cost and time (Jones, 2003; Umit Dikmen & Sonmez, 2011).

Along with the times, there is a new type of formwork called fabric formwork (Hurd, 1995; Veenendaal & Block, 2012; West & Araya, 2012; Chandler, 2015; Hawkins et al., 2016; West, 2016). Fabric formwork has actually begun to be used in concrete construction since the early 1900s. In the 1960s, this formwork started to widely be used, triggered by the availability of high-strength and low-cost fabric materials (Lamberton, 1989). At this time, fabric formwork was used as a concrete mould for foundation, underwater and other concrete works (West, 1994; Van Mele & Block, 2011 ; Orr et al., 2011; Seracino et al, 2012; Veenendaal & Block, 2014; Pedreschi & Lee, 2015). The interest of fabric formwork is coming from an architect named Miguel Fisac, who has a patent about the construction method for prefabricated fabric wall panels (Orr et al., 2011). Since then, various design and construction methods for fabric formwork have been developed, including the zero waste system, to the recording of significant savings in material and labour costs due to the use of fabric formwork (Sutherland, 2005; Chang, 2007).

The use of fabric formwork can save up to 40% of the use of concrete compared to the use of other formwork materials. In addition, the use of fabric formwork also gives a better concrete surface finish compared to other formwork materials. This will reduce the maintenance and repair of printed fabric formwork (Orr et al., 2011). Nevertheless, the use of fabric formwork in Indonesia is

still minim when compared to other types of formwork.

Factors that Affect the Performance of Fabric Formwork

Formwork is a part of concrete construction that requires careful planning, both from the selection of material to the selection of the installation method itself. This is done to anticipate the failure of casting due to broken formwork. Therefore, it is necessary to pay attention to the performance of formwork itself. Factors that affect the selection of formwork systems include cost, quality, safety, cycle time, building design, location constraints, available resources, contractor experience, workforce capability, total reputation for capital availability, and methods of implementation (Asadi & Praneth, 2017). This study will examine more about the costs and time of installing formwork

Installation Time of Formwork

Project scheduling is the result of planning, which can provide information about the planned schedule and project progress in terms of resource performance in the form of costs, labour, equipment, and materials as well as the project duration plan and the progress of time for project completion. Scheduling is the allocation of time in order to complete a project to achieve optimal results by considering the existing limitations. The preparation of project activities is intended to help carry out project evaluations (Wijayanto, 2014).

1. Installation Time with Wood Formwork

The installation of wood formwork does not affect the volume of work. The duration only changes at significant volume differences. In other words, the shape of the structure determines the duration of the installation of wood formwork (Hesna & Alfalah, 2013). Through the research, Tedja, et al (2015) gets the results of the installation of assistance to 1 m^2, as shown in Table 1.

Table 1. Installation Time of Wood Formwork.

No	Job Description	Time (Minute)
1	Formwork Installation	44.375
2	Formwork Dismantling	7.500
	Total Time	51.875

2. Installation Time with Brick Formwork

The installation time of brick formwork is influenced by the volume of the structure. At the smaller structure sizes, the installation time will be faster compared to wood formwork. However, if the size is large enough, there is a possibility that the installation time will be longer compared to wood formwork (Hesna & Alfalah, 2013). Through the research, Tedja, et al (2015) gets the results of the installation of assistance to 1 m^2, as seen in Table 2.

Table 2. Installation Time of Bricks Formwork.

No	Job Description	Time (Minute)
1	Formwork Installation	7.500
	Total Time	7.500

Installation Cost of Formwork

According to Wijayanto (2014), the unit price analysis is the preliminary guideline for calculating the cost of a building plan in which numbers are showing the amount of material, work wages, and the cost per unit of work that will later be needed in planning the budget.

1. Installation Cost of Wood Formwork

The analysis of the unit price of 1 m^2 formwork installation in IDR for tie beam and pile cap according to SNI 7394-2008 is shown in Table 3 and Table 4.

Table 3. Installation Time of Tie Beam Wood Formwork.

Installation needs		Unit	Index	Unit Price (IDR)	Total Cost (IDR)
Material	Wood gradeIII	m^3	0.040	2 600 000	104 000
	5 cm – 10 cm nail	kg	0.300	24 600	7 380
	Formwork oil	L	0.100	15 500	1 550
Total cost of material / m^2					112 930
Labour	Worker	OH	0.520	130 200	67 704
	Wood worker	OH	0.260	149 730	38 930
	Head of worker	OH	0.026	164 052	4 266
	Foreman	OH	0.026	174 468	4 537
Total cost of Labour / m^2					115 437
Total cost of Installation / m^2					228 367

Table 4. Installation Cost of Pile Cap Wood Formwork.

Installation needs		Unit	Index	Unit Price (IDR)	Total Cost (IDR)
Material	Wood gradeIII	m^3	0.045	2 600 000	117 000
	5 cm – 10 cm nail	kg	0.300	24 600	7 380
	Formrok oil	L	0.100	15 500	1 550
Total cost of material / m^2					125 930
Labour	Worker	OH	0.520	130 200	67 704
	Wood worker	OH	0.260	149 730	38 930
	Head of worker	OH	0.026	164 052	4 266
	Foreman	OH	0.026	174 468	4 537
Total cost of Labour / m^2					115 437
Total cost of Installation / m^2					241 367

Table 5. Installation Cost of Brick Formwork.

Installation needs		Unit	Index	Unit Price (IDR)	Total Cost (IDR)
Material	Bricks	pcs	25	2 300	57 500
	Portland Cement	Zak	0.300	53 000	15 900
	Sand	m^3	0.03	185 000	5 550
Total cost of material / m^2					78 950
Labour	Brick worker	OH	0.20	149 730	29 946
	Head of worker	OH	0.020	164 052	3 281
Total cost of Labour / m^2					33 227
Additional tools	Kaso Profil 5/7, borneo	m^3	0.003	3 500 000	10 500
	Flax yarn	m^3	0.065	2 000	130
	Bucket	pcs	0.025	6 000	150
	Pacul Adk	pcs	0.015	35 000	525
Total cost of Additional Tools / m^2					11 305
Total cost of installation / m^2					123 482

2. Installation Cost of Brick Formwork

The analysis of the unit price of 1 m^2 formwork installation in IDR for tie beam and pile cap according to SNI 7394-2008 can be seen in Table 5.

2. Method

This research was conducted by field observation in a project using formwork made from woven polyethylene. The equipment needed is forms for data retrieval, stationery, stopwatch, and camera for the documentation process at the project site. Observation is needed to obtain primary data in research which will be compared with secondary data obtained from the results of literature studies.

The results of measurements of mobilization from the warehouse to the installation area until the installation of spacers on the formwork are needed to the time parameter. For investment cost parameters, it is necessary to have data regarding the calculation of costs both from the material used to the wages of workers per unit area of woven polyethylene formwork.

The field observation has been done in the three different projects. The first project is in the Shop-House Project (Figure 1.). The second project is in the Road Pavement Project (Figure 2.). The last project is Showroom Project (Figure 3.). The observed structural elements are tie beam and pile cap.

Figure 1. Shop-House Project using woven polyethylene formwork

Figure 2. Road Pavement Project using woven polyethylene formwork

(a) (b)

Figure 3. Showroom Project using woven polyethylene formwork for: (a) pile cap structure, (b) tie beam structure

3. Result and Discussion

Installation Time for Woven Polyethylene Formwork

Time parameters are measured based on several activities that take place when installing formwork in the related project. The installation activities in the field include the mobilization of formwork from temporary storage areas, the process of cutting formwork (if carried out), the formwork joining process which consists of laying down formwork in accordance with the axles, and linking the wire between the continuous formwork. Thus, the installation time can be defined by the total time needed until the formwork is installed perfectly on a predetermined axle. The following is the formula for the duration used. The duration obtained will be divided by the observed surface area formwork.

Installation Time of Tie Beam Formwork in Shop-House Project

The area of formwork observed in this project is 249.95 m^2, which is 73 observation points observed. The type of structure observed is the tie beam structure. The average installation time for Shop-House Project can be seen in Table 6.

Installation Time of Tie Beam Formwork in Road Pavement Project

The area of formwork observed in this project is 100,64 m^2, which is 18 observation points observed. The type of structure observed is the tie beam structure. The average installation time for Road Pavement Project is shown in Table 7.

Installation Time of Tie Beam Formwork in Showroom Project

The area of formwork observed in this project is 90,9 m^2, which is 29 observation points observed. The type of structure observed is the tie beam structure. The average installation time for Road Pavement Project is shown in Table 8.

It was found that the average installation time for tie beam structure using woven polyethylene formwork was 214.65 s/m^2, which is the shortest time needed for formwork installation compared to other materials such as wood and brick.

Installation Time of Pile Cap Formwork in Showroom Project

The duration of installation of pile cap structure will be discussed. The observation was done in Showroom Project for 3 observation points. The average installation time for Road Pavement Project can be seen in Table 9.

Table 6. Average Installation time for Shop-House Project using Woven Polyethylene Formwork

	Mobilization Time s/m^2	**Cutting Time s/m^2**	**Connection time s/m^2**	**Installation Time s/m^2**
Shop-House Project	17.83	54.62	104.95	177.40

Table 7. Average Installation time for Road Pavement Project using Woven Polyethylene Formwork

	Mobilization Time s/m^2	**Cutting Time s/m^2**	**Connection Time s/m^2**	**Installation Time s/m^2**
Road Pavement Project	24.73	27.44	182.86	235.04

Table 8. Average Installation time for Showroom Project using Woven Polyethylene Formwork

	Mobilization Time s/m^2	**Cutting Time s/m^2**	**Connection Time s/m^2**	**Installation Time s/m^2**
Showroom Project	41.16	22.67	167.67	231.50

Table 9. Total Time of Pile Cap Installation in Showroom Project using Woven Polyethylene Formwork

Observation Point	**Mobilization Time s/m^2**	**Tyding & Nailing s/m^2**	**Addition of Stir s/m^2**
1	130	289	338
2	157	310	235
3	61	428	440

However, the authors classify the duration again so that it can be compared according to the installation activity in the tie beam structure. Adjustments made including the duration of tidying and nailing the formwork will be combined with the duration of the addition of the mortar on the formwork. In connection with this, there was no cutting in the pile cap structure because the formwork had already been formed. Therefore, the results of this observations can be concluded, as shown in Table 10.

Table 10. Time of Installation for Pile Cap Structure using Woven Polyethylene Formwork

Area of Formwork (m^2)	Mobilization Time s/m^2	Tyding, Nailing & Addition of Stir s/m^2	Installation Time s/m^2
1.68	77.38	373.21	450.60
1.68	93.45	324.40	417.86
1.68	36.31	516.67	552.98

The comparison of time of installation of formwork for tie beam and pile cap structures is shown in Table 11.

Table 11. The Average of Time Installation for Tie Beam and Pile Cap Structure using Woven Polyethylene Formwork

Type of Structure	Installation Time s/m^2	Average Installation Time s/m^2
Tie Beam	214.65	344.23
Pile Cap	473.81	

From the table, it can be concluded that the installation time for pile cap structure is 2.2 times longer than for tie beam structure. That is because there are additional activities needed for the pile cap installation process, namely the process of tidying and nailing, and the addition of stir. In addition, the pile cap is at an elevation of -1.5 m, therefore the formwork material mobilization process takes longer than the mobilization process in the tie beam structure.

From the results above, it was found that the average installation time for woven polyethylene formwork was 344.23 s/m^2. When compared with other materials, the installation time using woven polyethylene formwork is 500 times faster than using wood material and 80 faster than using brick material.

Installation Cost for Woven Polyethylene Formwork

The cost required to make 1 m^2 formwork made from woven polyethylene is IDR 75 000. These costs include material and labour costs.

From the unit price analysis table for tie beam and pile cap, the total installation price/m^2 is IDR 125 000 with brick material and IDR 240 000 with wood material. From the data obtained, it can be concluded that the total installation cost for woven polyethylene formwork is IDR 75,000/m^2 which is 1.7 times cheaper than using brick material and 3.2 times cheaper than using wood material.

4. Conclusion

Based on the results of the research, in terms of time, woven polyethylene formwork has a faster installation time compared to other materials such as woods and bricks, which has an average installation time of 344.23 s/m^2. In terms of cost, woven polyethylene formwork is cheaper compared to other materials such as wood and brick, which has an installation cost of IDR 75 000/m^2. It can be concluded that in its installation, the use of formwork made from woven polyethylene is quite effective as a substitute for conventional materials such as wood and brick. But for woven polyethylene formwork, it is possible to have the additional costs for spacers if the height of the formwork is more than 60 cm.

Table 12. Installation Cost of Woven Polyethylene Formwork

Installation needs		Unit	Index	Unit Price (IDR)	Total Cost (IDR)
Material	Woven polyethylene	m^2	1	45 000	45 000
	Wire mesh m4	zak	1	13 977	13 977
Total cost of material / m^2					58 977
Labour	Worker	OH	0.3	34 750	10 425
	Foreman	OH	0.133	47 140	6 269
Total cost of Labour / m^2					16 694
Total cost of Installation / m^2					75 671

Acknowledgement

This research is funded and supported by DRPM Universitas Indonesia through Indexed International Publication Grant for Student Final Project (Hibah Pitta 2019). The number of Contract is: 0743/UN2.R3.1/HKP.05.00/2019.

REFERENCES

[1] Asadi, S., & Praneth, P. (2017). A Comparative Study for Evaluation of Different Formwork Systems Utilization in Construction Projects. *International Journal of Mechanical Engineering and Technology (IJMET)*, 21-29.

[2] Chandler, A. (2015). Fabric Formwork - Prototype to Typology. *The Journal of Architecture*, 20(3), 420-429.

[3] Chang, H. C. (2007). *Productivity Analysis of Construction Formwork in Residential Building*, MS Thesis. Department of Civil engineering, National Taiwan University, Taiwan (in Chinese).

[4] Hanna, A. S. (1999). *Concrete formwork systems*. New York: Marcel Dekker, Inc.

[5] Hawkins, W.J., Herrmann, H., Ibell, T.J., Kromoser, B., Michaelski, A., Orr, J. J., Pedreschi, A., Pronk, A., Schipper, R., Shepherd, P., Veenendaal, R., Wansdronk, R. and West, M. (2016). Flexible Formwork Technologies: A State of the Art Review. *Structural Concrete*, 17, 6. https://doi.org/10.1002/suco.201600117

[6] Hesna, Y., & Alfalah, R. (2013). Variasi Penggunaan Jenis Material Bekisting Pada Pekerjaan Struktur Pile Cap dan Pengaruhnya Terhadap Biaya dan Durasi Pelaksanaan Proyek. *KoNTeks 7*, 197-203.

[7] Hurd, M. K., (1995). Formwork for Concrete.

[8] Jones, Ed. (2003). Estimating cost for wood formwork fabricated onsite. *Concrete Construction-World of Concrete*, 48(4), 54-55.

[9] Lamberton, B. (1989). Fabric forms for concrete. *Conc. int*, 58-67.

[10] NOrr, J. J., Darby, A. P., Ibell, T., & Evernden, M. C. (2011). Concrete Structures Using Fabric Formwork. *The Strustural Engineer*, 20-16.

[11] Seracino, D., Rudi, Cauberg, N., Tysmand, T., Adriaenssens, S., Wastiels, J., Mollaert, M., Belkassem, B. (2012). Shell Elements of Textile Reinforced Concrete using Fabric Formwork: a Case Study. *Advances in Structural Engineering*, 15(4), 677-690.

[12] SNI 7394:2008. (2008). The procedure for calculating the unit price of concrete work for construction of buildings and housing. *Badan Standarisasi Nasional*.

[13] Sutherland, M. (2005). Formwork Economics, *Concrete Engineering International*, 9(4), 18-19.

[14] Orr, J.J., Darby, A., Ibell, T. J., Evernden, M.C., Otlet, M. Concrete Structures using Fabric Formwork. *Structural Engineer*, 89(8), 20-26.

[15] Pedreschi, R. & Lee, D. S. H. (2014). Structure, Form and Construction. Fabric Formwork for Concrete. *In Proceedings of Across: Architectural Research through to Practice. 48th International Conference of the Architectural Science Association*.

[16] Tedja, M., Halim, H., Divaninta, K., & Hidayat, V. (2015). Comparison Formwork Wood Sloof to Batako Viewed from the Aspect of Time and Cost. *ComTech*, 499-504.

[17] Umit Dikmen, S. & Sonmez, M. (2011). An artificial neural networks model for the estimation of formwork labour. *Journal of Civil Engineering and Management*, 17(3), 340-347. http://dx.doi.org/10.3846/13923730.2011.594154.

[18] Van Mele, T. & Block, P. (2011). A Novel Form Finding Method for Fabric Formwork for Concrete Shells. *J. Int. Assoc. Shell and Spatial Structures*, 52, 217-224.

[19] Veenendaal, D. & Block, P. (2012). Computational Form Finding for Fabric Forworks: An Overview and Discussion. *In Proceedings of the 2nd International Conference on Flexible Formwork*, J. et al. Ohr (ed.) Bath, UK, 368-378.

[20] Veenendaal, D. & Block, P. (2014). Design Process Prototype Concrete Shells using a Hybrid Cable Net and Fabric Formwork. *Engineering Structures*, 75, 39-50.

[21] West, M. (1994). Fabric Formwork. *Progressive Architechture*, 88.

[22] West, M & Araya. (2012). R. Recent Fabric Formwork Construction Projects. *In Proceedings of the Second International Conference on Flexible Formwork*, University of Bath, UK.

[23] West, M. (2016). *The Fabric Formwork Book: Methods for Building New Architectural and Structural Forms in Concrete*. Routledge.

[24] Wijayanto, B. R. (2014). Metode Pelaksanaan dan Analisa Biaya Bekisting pada Pekerjaan Struktur. *Jurnal Karya Teknik Sipil*, 773-784.