

Comparative Analysis of Cost, Quality, and Time on the Productivity of Deep Cement Mixing Work Between Subcontractors in the Probolinggo-Banyuwangi Toll Road Construction Project Section 2**Muhammad Yusuf Sholihin, Kartono Wibowo, Rifqi Brilyant Arief**Magister Teknik Sipil, Fakultas Teknik, Universitas Islam Sultan Agung Semarang,
IndonesiaEmail: sholihin.st27@gmail.com

Keywords	Abstract
Toll Roads, Deep Cement Mixing, Unconfined Compression Test/UCS, Cost of Work, Productivity of Work	The eastern segment of the Trans Java toll road project, spanning 171.516 km from Probolinggo to Banyuwangi (Probowangi), is a critical infrastructure initiative aimed at enhancing regional connectivity. This study focuses on Phase 1 of the Gending-Besuki section, particularly Section 2 (STA 09+000 to STA 20+200), where deep cement mixing (DCM) was employed for soil stabilization prior to landfilling. The objective is to evaluate the differences in performance among four subcontractors based on time, cost, and quality metrics. A quantitative comparative approach was applied using recorded data from the respective contractors. The results indicate that PT Geotekindo completed the project in the shortest time (31 days) with the highest productivity (428.63 m ³ /day) and the lowest cost (IDR 681,296/m ³). In contrast, PT Leekang Jaya Konstruksi took 116 days with 277.53 m ³ /day productivity, while PT Keller Ground Indonesia finished in 85 days but at the highest cost of IDR 788,437/m ³ . Despite the differences in performance, all subcontractors met the quality standard with unconfined compressive strength (UCS) values ≥ 1 MPa. The findings highlight that higher productivity correlates with lower costs and faster completion, without compromising quality. These insights are crucial for future project planning and subcontractor selection strategies in large-scale infrastructure developments.

**INTRODUCTION**

The Trans Java toll road is a large-scale national infrastructure project stretching approximately 1132 kilometers from Merak to Banyuwangi. This development is part of the Indonesian government's strategic efforts to improve connectivity between regions, support national logistics, and stimulate economic growth and social welfare (Alfisyahri et al., 2023; Darmawan & Prastyanto, 2020; Gado et al., 2024; Zebua, 2022). As one of the final sections of the corridor, the Probolinggo-Banyuwangi toll road (commonly known as Probowangi) plays a crucial role in linking East Java to major logistics routes. The project is being executed by PT Jasamarga Probolinggo Banyuwangi (PT JPB), a subsidiary of PT Jasa Marga (Persero) Tbk, through multiple joint operation (KSO) schemes involving nine contractors divided into three consortiums (Andary & Adriati, 2024a; Fadilla & Pradiptiya, 2022).

The construction of Section 2 (STA 09+000 – STA 20+200) of the Probowangi toll road involves complex geotechnical conditions, which required ground improvement before the landfilling stage. The method selected for this was deep cement mixing (DCM), which aims to

increase soil bearing capacity by injecting and mixing cement with in-situ soil (Liu et al., 2019; Vu et al., 2023). All subcontractors involved in this section, namely PT Keller Ground Indonesia, PT Leekang Jaya Konstruksi, and PT Geotekindo, used Ordinary Portland Cement (OPC) Type I sourced from PT Anugrah Prima Energi and groundwater from local bore wells for the cement slurry (Muhrozi, 2022). While the materials used are standardized, the time, cost, and quality outcomes of the DCM work vary across the subcontractors, raising questions regarding efficiency and performance differences (Andary & Adriati, 2024b; Kwandy et al., 2019).

Previous studies have focused on either the technical or economic aspects of soil improvement. For instance, Demissew (2022) examined the mechanical behavior of cement deep mixing columns in soft clay conditions, highlighting the influence of soil type and cement content on compressive strength. Sudarma et al. (2019), on the other hand, investigated the cost-effectiveness of various soil stabilization techniques in highway construction. However, few studies have adopted an integrative approach that compares the performance of different DCM subcontractors in terms of time, cost, and quality within the same project environment (Chompoorat et al., 2022; Lenz-Alcayaga et al., 2025; Rashid et al., 2015; Sánchez-Garrido et al., 2022). This study offers a novel contribution by addressing that gap, providing a comprehensive evaluation of subcontractor efficiency in DCM work (Ahmed et al., 2016; Hendarti, 2023; Pooranampillai et al., 2012).

The objectives of this study are fourfold: (1) to determine the average daily productivity of DCM work for each subcontractor, (2) to compare the cost efficiency of the DCM work, (3) to analyze the compressive strength quality of the DCM columns using the Unconfined Compression Test (UCS), and (4) to explore the interrelationship between time, cost, and quality in assessing overall efficiency. The findings are expected to offer valuable insights for construction managers and policymakers by aiding in evidence-based subcontractor selection, improving cost-time planning accuracy, and reinforcing quality assurance in infrastructure development.

RESEARCH METHODS

Deep Cement Mixing Jobs

Deep cement mixing (DCM) is a direct soil improvement method (field treatment technology) in which cement additives are added to the soil. Stabilization using a mixture of these materials can be done dry or liquid (slurry). This method can be used to reduce settlement and optimize soil stability. In addition, DCM can act as vertical drainage, speeding up the settlement process. The process begins by using a drill to drill holes all the way to the hard ground. Once the machine reaches the desired depth, the binding material, usually cement, is injected to fill the space and mixed with soft sludge. After the cement hardens, it forms embedded columns (Suwarno & Wicaksono, 2021). The DCM method is briefly presented in Figure 1.

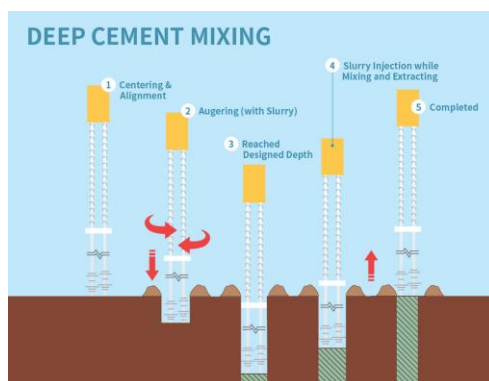


Figure 1. deep cement mixing (DCM)
(source: Suwarno & Wicaksono, 2021)

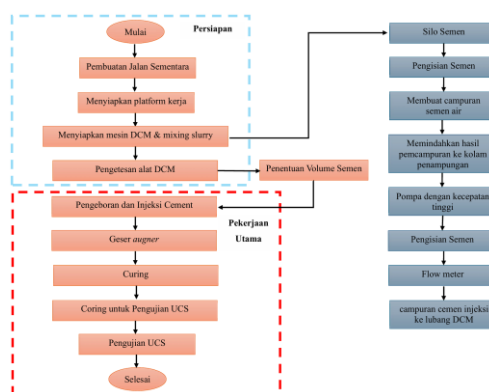


Figure 2. deep cement mixing
(Source: (PT Acset Pondasi Indonusa, 2024)

Job Productivity

Productivity is the relationship between the real results obtained and the inputs that have been used in a single unit of time. Meanwhile, according to Sinungan (1995) in (Wiroso & Hendarti, 2023) it is stated that productivity is a comparison of the size of the price of input and output and also as a comparison between the amount of expenditure and input expressed in general units. Productivity is greatly influenced by factors such as wage level, experience and skills, education and expertise, age of workers, procurement of goods, weather, distance of materials to location, cooperative relationships and managerial factors.

The factor that affects productivity is labor. In general, it can be said that it can be formulated as follows :

$$P = \frac{O}{I}$$

Information

P = Productivity (unit volume of work/unit of time)

O = Output (unit of work volume)

I = Input (unit of time)

Work productivity has a large effect on the implementation of the project or in other words, if the productivity of workers is high, the project will also be completed faster. In general, it can be said that labor productivity is the large volume of work produced by a worker or team of workers over a certain period of time

$$\text{Productivity} = \frac{\text{work volume}}{\text{work time}}$$

Cost of Work

Wage unit price analysis is a multiplication process between the labor index and wage prices so that the unit wage price is obtained. Meanwhile, the value of the unit price of work can be obtained through the sum of the unit price of materials and the price of the unit of wages (Wirosa & Hendarti, 2023). The analysis of the unit price of materials of a job is to calculate the number of materials needed, as well as the amount of material cost needed to complete the work, the formula to determine the cost of materials needed is

Unit price of material / wage / tool = coefficient of material x unit price

The material coefficient indicates the amount of material needed to complete 1 m³, 1 m² or 1 m³ of work volume. The unit price of wages is an analytical calculation of the amount of labor needed to complete the work. The unit price of labor wages varies from region to region, so in the preparation of the project cost budget, it must refer to the wage price that corresponds to the price at the project site. In general, it can be concluded with the following equation:

Unit Price of Work = Price of Materials + Price of Wages + Price of Tools

Unconfined Compression Test (UCS Test) on Deep Cement Mixing Jobs

The Unconfined Compression Test is the value of the axial stress at the maximum force that an object can sustain before it suffers damage caused by compressive force. The cohesive soil free compressive strength test method is intended to determine the free compressive strength of soil samples that have cohesion, both disturbed, remolded soils and compacted soil samples. And it is used to determine an approximate value of cohesive soil strength expressed in total voltage. This applies to cohesive materials, such as clay and cemented soil, which remain upright without rotational resistance and do not release water during loading (water comes out of the ground due to deformation/deformation) (Sudarma et al., 2019). The formula for finding the value of the free compressive strength can be seen in the equation

$$Q_u = \frac{P}{A}$$

Qu= Free compressive strength (N/mm² or MPa)

P = Load (N)

A= Sample cross-section area (mm²)

A. Data

The data used as an analysis can be seen in table 1 and table 2.

Table 1. Use of drill tools in deep cement mixing work

No	Subcontractor Name	Number of Deep Mixing Rig Tools	Number of Drills per tool (Axis)
1	PT Keller Ground Indonesia	2	1 and 2
2	PT Leekang Jaya Konstruksi	1	4
3	PT Geotekindo	2	2

Table 2. Deep cement mixing job site

No	Subcontractor Name	Job Location (STA)
1	PT Keller Ground Indonesia	17+250 – 17+350
		17+450 – 17+550
		19+150 – 19+250
		19+650 – 19+670
		Ramp 4+250 – 4+300
2	PT Leekang Jaya Konstruksi	16+550 – 16+750
		18+600 – 18+950
		19+050 – 19+150
3	PT Geotekindo	19+670 – 19+850

RESULT AND DISCUSSION

Job Productivity

Based on the realization of DCM work carried out by PT. Keller Ground Indonesia in 5 locations starting from October 18, 2024 to January 11, 2025 with a total of 85 working days. PT Keller Ground Indonesia was able to complete the work volume of 23,826,992 m³ which was carried out with 2 drill tools, namely with the first tool with 1 axis and the second tool with 2 axes in table 3.

Table 3. The realization of deep cement mixing work carried out by PT. Keller Ground Indonesia

Job Location	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
	18-24 Oct	25-31 Oct	1-7 Nov	8-14 Nov	15-21 Nov	22-28 Nov	29 Nov - 5 Nov
Sta. 17+450 - Sta. 17+550	86.205	794.759	1,324.798	1,245.636	1,396.988	1,868.084	-
Sta. 17+250 - Sta. 17+350	-	-	-	-	609.575	1,097.821	4,502.688
Sta. 19+150 - Sta. 19+250	-	-	-	-	-	-	-
Sta. 19+650 - Sta. 19+670	-	-	-	-	-	-	-
Ramp 4+250 - Ramp 4+300	-	-	-	-	-	-	-
Job Location	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Number of Volumes (m ³)
	6-12 Dec	13-19 Dec	20-26 Dec	27 Dec - 2 Jan	3-9 Jan	10-11 Jan	
Sta. 17+450 - Sta. 17+550	-	-	-	-	-	-	6,716.471
Sta. 17+250 - Sta. 17+350	1,338.083	-	-	-	-	-	7,548.167
Sta. 19+150 - Sta. 19+250	-	-	2,537.138	3,405.109	-	-	5,942.247
Sta. 19+650 - Sta. 19+670	-	-	-	-	1,199.986	-	1,199.986
Ramp 4+250 - Ramp 4+300	-	-	-	-	1,416.445	1,003.676	2,420.122
Total Volume of Work							23,826.992

$$\begin{aligned} \text{Productivity} &= (\text{Work Volume})/(\text{Work Time}) \\ &= 23.826,992/85 \\ &= 280.32 \text{ m}^3 / \text{day} \end{aligned}$$

PT Leekang Jaya Konstruksi carried out DCM work using one tool with 4 axes (4 drilling rigs). All DCM work carried out by PT Leekang Jaya Konstruksi is done within 24 hours with a worker shifting system. DCM's work to support progress, of course, there are other supporting work including tool mobdemob, preliminary work, coring, and UCS testing. PT Leekang Jaya Konstruksi carried out DCM work at 6 work sites from September 9, 2024 to January 3, 2025 with a total work duration of 116 days and a work volume of 32,193,436 m³ can be seen in table 4.

$$\begin{aligned} \text{Productivity} &= (\text{Work Volume})/(\text{Work Time}) \\ &= (32.193,436)/116 \\ &= 277.53 \text{ m}^3 / \text{day} \end{aligned}$$

Comparative Analysis of Cost, Quality, and Time on the Productivity of Deep Cement Mixing Work Between Subcontractors in the Probolinggo-Banyuwangi Toll Road Construction Project Section 2

Table 4. Realization of deep cement mixing work

Job Location	Progress of Realization of Deep Cement Mixing Work (m3)						
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
	9-15 Sep	16-22 Sep	23-29 Sep	30 Sep - 6 Oct	7-13 Oct	14-20 Oct	21-27 Oct
STA 16+550 - STA 16+650	10.006	81.264	473.806	-	1,240.433	2,113.846	1,950.249
STA 16+650 - STA 16+750	-	-	-	3,067.154	1,570.926	-	-
STA 18+600 - STA 18+700	-	-	-	-	-	-	-
STA 18+700 - STA 18+800	-	-	-	-	-	-	-
STA 18+825 - STA 18+950	-	-	-	-	-	-	-
STA 19+050 - STA 19+150	-	-	-	-	-	-	-
Job Location	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
	28 Oct - 3 Nov	4-10 Nov	11-17 Nov	18-24 Oct	25 Oct - 1 Dec	2-8 Dec	9-15 Dec
STA 16+550 - STA 16+650	-	-	-	-	-	-	-
STA 16+650 - STA 16+750	-	-	-	-	-	-	-
STA 18+600 - STA 18+700	-	2,085.537	3,313.409	-	-	-	-
STA 18+700 - STA 18+800	-	-	397.329	3,708.098	1,067.245	-	-
STA 18+825 - STA 18+950	-	-	-	-	2,107.897	2,638.521	2,798.732
STA 19+050 - STA 19+150	-	-	-	-	-	-	-
Job Location	Week 15	Week 16	Week 17	Number of Volumes (m3)			
	16-22 Dec	23-29 Dec	30 Dec -3 Jan				
STA 16+550 - STA 16+650	-	-	-	5,869.604			
WED 16+650 - STA 16+750	-	-	-	4,638.080			
STA 18+600 - STA 18+700	-	-	-	5,398.946			
WED 18+700 - STA 18+800	-	-	-	5,172.672			
WED 18+825 - WED 18+950	-	-	-	7,545.150			
STED 19+050 - STED 19+150	1,116.590	1,396.049	1,056.346	3,568.984			
Total Work Volume (m3)				32,193.436			

The DCM work carried out by PT Geotekindo uses 2 deep mixing rigs with 2 axes each (2 drilling rigs). This work was completed within 31 working days from December 7, 2024 to January 7, 2025 by producing a work volume of 13,287,547 m3 as shown in table 5.

Table 5. Realization of DCM work by PT Geotekindo

Job Location	Progress of Realization of Deep Cement Mixing Work (m3)					
	Week 1	Week 2	Week 3	Week 4	Week 5	Number of Volumes (m3)
	7-13 Dec	14-20 Dec	21-27 Dec	28 Dec-3 Jan	4-7 Jan	
STA 19+800 - STA 19+850	428.333	3,448.212	979.046	-	-	4,855.591
STA 19+750 - STA 19+800	-	-	2,210.550	-	-	2,210.550
STA 19+700 - STA 19+750	-	-	1,249.977	3,389.716	-	4,639.693
STA 19+670 - STA 19+700	-	-	-	-	1,581.713	1,581.713
Total Work Volume (m3)						13,287.547

$$\begin{aligned} \text{Productivity} &= (\text{Work Volume}) / (\text{Work Time}) \\ &= (13,287,547) / 31 \\ &= 428.63 \text{ m}^3 / \text{day} \end{aligned}$$



(a) PT Keller Ground Indonesia



(b) PT Leekang Jaya Konstruksi



(c) PT Geotekindo

Figure 3. deep cement mixing

Cost of Work

The deep cement mixing work carried out by PT Keller Ground Indonesia includes mobilization and demobilization of drilling tools from Malaysia, site management, local mobilization of cement tools and silos, DCM work, coring work, and UCS testing work.

$$\begin{aligned} \text{Cost per m}^3 &= (\text{Total Work Cost}) / (\text{Work Volume}) \quad (\text{Rp} / \text{m}^3) \\ &= 18.786.086.075 / 23.826,992 \end{aligned}$$

$$= \text{IDR } 788,437$$

The deep cement mixing work carried out by PT Leekang Jaya Konstruksi includes mobilization and demobilization of drilling tools from Malaysia and Korea, Preliminaries Work, DCM work, coring work, and UCS testing work.

$$\begin{aligned} \text{Cost per } m^3 &= (\text{Total Work Cost}) / (\text{Work Volume}) \quad (\text{Rp} / m^3) \\ &= 22,760,102,360 / 32,193,436 \\ &= \text{IDR } 706,980 \end{aligned}$$

The deep cement mixing work carried out by PT Geotekindo includes mobilization and demobilization work of drilling equipment, site management, DCM work, coring work, and UCS testing work.

$$\begin{aligned} \text{Cost per } m^3 &= (\text{Total Work Cost}) / (\text{Work Volume}) \quad (\text{Rp} / m^3) \\ &= 9,052,748,970 / 13,287,547 \\ &= \text{IDR } 681,296 \end{aligned}$$

Table 6. Realization of the cost of deep cement mixing work

Job Items	PT Keller Ground Indonesia			PT Leekang Jaya Konstruksi			PT Geotekindo		
	Volume	Unit Price (Rp)	Total (Rp)	Volume	Unit Price (Rp)	Total	Volume	Unit Price (Rp)	Total
Mob demob	2.00	1,580,000,000	3,160,000,000	1.00	2,400,000,000	2,400,000,000	2.00	760,000,000	1,520,000,000
Site Management	1.00	2,800,000,000	2,800,000,000	1.00	2,000,000,000	2,000,000,000	1.00	350,000,000	350,000,000
Local Mobilization	1.00	380,000,000	380,000,000						
DCM Jobs	23,826.99	470,000	11,198,686,240	32,193.44	510,000	16,418,652,360	13,287.55	510,000	6,776,648,970
Coring Cost	1,092.00	950,000	1,037,400,000	1,746.00	925,000	1,615,050,000	422.00	750,000	316,500,000
UCS Fees	600.00	350,000	210,000,000	1,020.00	320,000	326,400,000	280.00	320,000	89,600,000
Total Job Price			18,786,086,240			22,760,102,360			9,052,748,970

Unconfined Compression Test (UCS)

Each sub-contractor for the use of cement materials is all the same, which is 175 kg/m³. The use of water is by making a drilled well in the work area of the cement silo mix site. So that this is no different from the use of materials for the achievement of good work quality. Each subcontractor uses a penetration speed reference of 1 m/min and a lifting speed of 2 m/min as shown in figures 4 and 5.

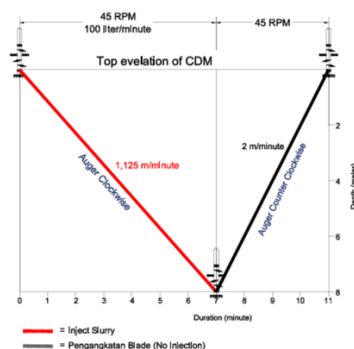


Figure 4. Drilling scheme of 8 meters depth cement mixing work

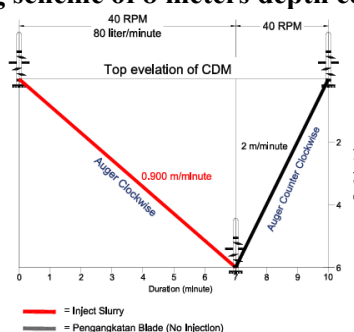


Figure 5. Drilling scheme of 6 meters depth cement mixing work

Comparative Analysis of Cost, Quality, and Time on the Productivity of Deep Cement Mixing Work Between Subcontractors in the Probolinggo-Banyuwangi Toll Road Construction Project Section 2

Each process of taking the test specimen for free compressive strength is cored as deep as the deep cement mixing column according to figure 4.10. The results of coring sampling were taken from 5 test specimens each at depths of 20%, 40%, 60%, 80% and 100% can be seen in figure 6. The results of the test specimen will later be tested for free compressive strength at the age of 28 days as shown in figure 7. It can be seen in figures 8, 9, 10 that the results of the UCS test for all coring points have met the requirements of ≥ 1 Mpa, so that in terms of the quality of work, all subcontractors have met the requirements for safety and accepted work by PT Jasa Marga Probolinggo Banyuwangi.



Figure 6. Coring work for test specimen sampling

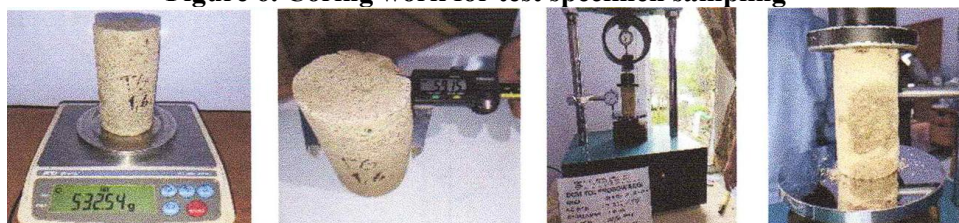


Figure 7. UCS Testing

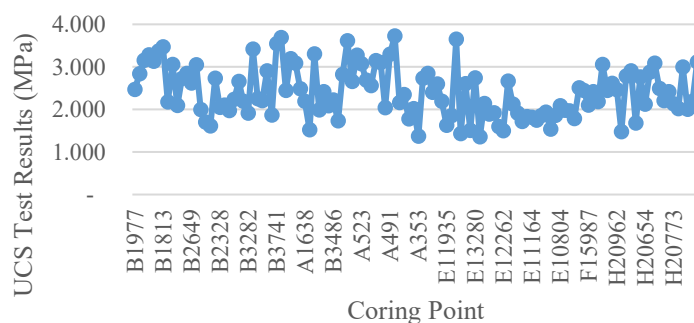


Figure 8. PT Keller Ground Indonesia UCS test results

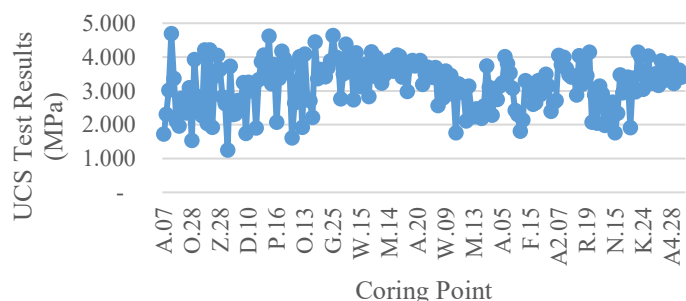


Figure 9. PT Leekang Jaya Konstruksi UCS test results

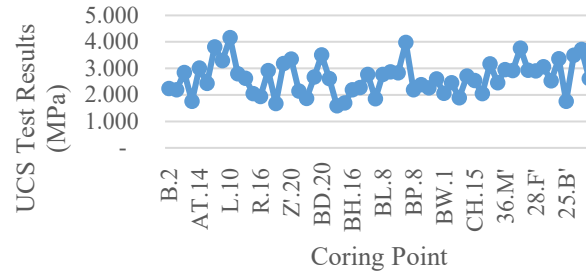


Figure 10. PT Geotekindo's UCS test results

The relationship between time, cost and quality on the productivity of deep cement mixing work

The subcontractors on the deep cement mixing work have their respective work areas in accordance with the work contract with KSO HKi-Acset-NK for the construction of the Probolinggo Banyuwangi toll road package 2. Each subcontractor has completed the work with 24 hours of work per day. PT Keller Ground Indonesia has completed the dcm work using 2 drill tools (1 axis and 2 axis) with a volume of 23,826,992 m³ for 85 days with a work productivity of 280.32 m³/day and a work cost of IDR 788,437. PT Leekang Jaya Konstruksi has completed the dcm work using 1 drill tool (4 axis) with an achievement volume of 32,193,436 m³ for 116 days with a work productivity of 277.53 m³/day and a work cost of Rp 706,980. PT Geotekindo has completed the dcm work using 2 drilling tools each with 2 axes with a volume of 13,287,547 m³ for 31 days with a work productivity of 428.63 m³/day and a work cost of IDR 681,296. All subcontractors for work quality control have met the requirements, namely ≥ 1 MPa.

A very significant difference can be seen in Figure 11 of PT Geotekindo with the work using 2 drill tools with 2 axes each, showing that the productivity of the work is high and has a fairly low price.

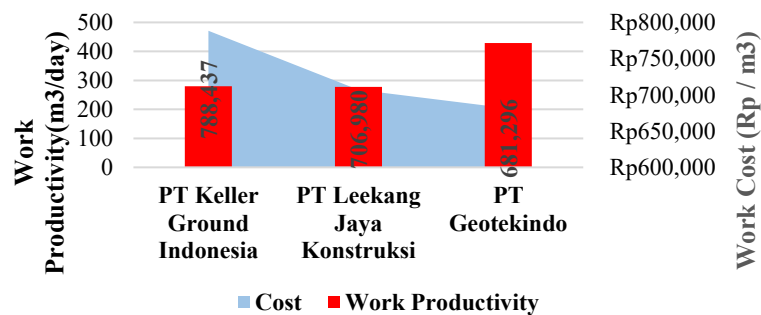


Figure 11. Comparison of DCM productivity and job prices

CONCLUSION

Based on the results and discussion of the research regarding "Comparative analysis of time, cost, and quality between subcontractors on the productivity of deep cement mixing work in the Probolinggo-Banyuwangi toll road construction project of the Kraksaan-Paiton section", it can be concluded as follows: (1) The average daily productivity of deep cement mixing work is in the order of the most, namely PT Geotekindo with an average productivity of 428.63 m³/day, PT Keller Ground Indonesia with an average of 280.32 m³/day, PT Keller Ground Indonesia with an average of 280.32 m³/day. the productivity is 280.32 m³/day, and PT Leekang Jaya Konstruksi with an average productivity of 277.53 m³/day; (2) the price of deep cement mixing work based on the lowest order, namely PT Geotekindo with a price of IDR 681,296 /m³, PT Leekang Jaya Konstruksi with a price of IDR 706,980 /m³, and PT Keller

Ground Indonesia with the highest price of IDR 788,437 /m³; (3) the quality of work with the Unconfined Compression Test (UCS) test of each subcontractor has met the standard, namely ≥ 1 MPa; and (4) the relationship between time, cost, and quality regarding efficiency in deep cement mixing work between subcontractors, namely subcontractors who have high productivity capacity so that they accelerate work time have lower work prices and in terms of quality of work, the results have met standards.

REFERENCE

- Ahmed, M., Islam, S., Nazar, S., & Khan, R. A. (2016). A comparative study of popular concrete mix design methods from qualitative and cost-effective point of view for extreme environment. *Arabian Journal for Science and Engineering*, *41*, 1403–1412.
- Alfisyahri, F., Fadli, A., Sihombing, E. H., Septiani, R., & Adab, S. C. (2023). *Relevansi antara Kualitas Pelayanan dan Fasilitas Produk dengan Tarif (Biaya Tol) Sebagai Alternatif pendukung untuk kepuasan pengguna jalan tol*. Penerbit Adab.
- Andary, C., & Adriati, F. (2024a). Analisis Perkuatan Tanah Dasar di Jalan Tol Indralaya-Bengkulu Menggunakan Metode Geotextile Woven. *Spirit of Civil Engineering (SPRING) JOURNAL*, *5*(01), 26–34.
- Andary, C., & Adriati, F. (2024b). Analisis Perkuatan Tanah Dasar di Jalan Tol Indralaya-Bengkulu Menggunakan Metode Geotextile Woven. *Spirit of Civil Engineering (SPRING) JOURNAL*, *5*(01), 26–34.
- Chompoorat, T., Thepumong, T., Khampod, A., & Likitlersuang, S. (2022). Improving mechanical properties and shrinkage cracking characteristics of soft clay in deep soil mixing. *Construction and Building Materials*, *316*, 125858.
- Darmawan, I. R., & Prastyanto, C. A. (2020). Perancangan Geometrik dan Perkerasan Jalan Tol Probolinggo-Banyuwangi Segmen Probolinggo-Paiton dengan Menggunakan Perkerasan Kaku. *Jurnal Teknik ITS*, *8*(2), E44–E50.
- Demissew, A. (2022). Comparative Analysis of Selected Concrete Mix Design Methods Based on Cost-Effectiveness. *Advances in Civil Engineering*, *2022*(1), 4240774.
- Fadilla, R. N., & Pradiptiya, A. (2022). Analisis Daya Dukung Pondasi Spun Pile Dievaluasi Dengan Kalendering Dan PDA. *Journal of Applied Civil Engineering and Infrastructure Technology*, *3*(2), 18–25.
- Gado, A., Tan, V., & Gare, M. (2024). Analisis Pengaruh Konektivitas Jaringan Jalan Terhadap Peningkatan Jumlah Kendaraan Di Kabupaten Sikka. *TEKNOSIAR*, *18*(2), 65–73.
- Hendarti, L. (2023). 5. Perbandingan Indeks Pemasangan Pondasi Batu Kali dengan Menggunakan Analisa Harga Satuan Pekerjaan dan Kondisi Aktual:(Studi Kasus Pembangunan Kantor Kecamatan Gladagsari, Kabupaten Boyolali). *Surakarta Civil Engineering Review (SCER)*, *3*(1), 53–65.
- Kwandy, R., Sentosa, G. S., & Iskandar, A. (2019). Prediksi Penurunan Gedung dan Daya Dukung Menggunakan Hasil Uji Plate Bearing di Labuan Bajo, NTT. *Jurnal Mitra Teknik Sipil*, *2*(2), 75–84.
- Lenz-Alcayaga, R., Paredes-Fernández, D., Verdejo, F. G., Páez-Pizarro, L., & Hernández-Sánchez, K. (2025). Economic evaluation: Impact on costs, time, and productivity of the incorporation of integrative digital pathology (IDP) in the anatomopathological analysis of breast cancer in a national reference public provider in Chile. *Journal of Pathology Informatics*, *16*, 100417. <https://doi.org/https://doi.org/10.1016/j.jpi.2024.100417>
- Liu, Y., He, L. Q., Jiang, Y. J., Sun, M. M., Chen, E. J., & Lee, F.-H. (2019). Effect of in situ water content variation on the spatial variation of strength of deep cement-mixed clay. *Géotechnique*, *69*(5), 391–405.

- Pooranampillai, S., Parmantier, D., Dawson, K., & Shin, S. (2012). A case history on the design, construction, and field quality control of cement Deep Soil Mixing. *37th Annual Conference on Deep Foundations*, 135–145.
- PT Acset Pondasi Indonusa. (2024). *Metode Kerja Cdm (Cement Deep Mixing)*.
- Rashid, A. S. A., Black, J. A., Kueh, A. B. H., & Noor, N. M. (2015). Behaviour of weak soils reinforced with soil cement columns formed by the deep mixing method: rigid and flexible footings. *Measurement*, 68, 262–279.
- Sánchez-Garrido, A. J., Navarro, I. J., & Yepes, V. (2022). Evaluating the sustainability of soil improvement techniques in foundation substructures. *Journal of Cleaner Production*, 351, 131463.
- Sudarma, I. M., Indramanik, I. B. G., & Satriawan, I. G. A. (2019). Analisa Nilai Kuat Tekan Bebas Campuran Semen dan Tanah Lempung Ex. Tabanan dengan Berbagai Variasi Kadar Air. *Jurnal Teknik Gradien*, 11(2), 80–89.
- Suwarno, & Wicaksono, L. A. (2021). Sistem Perbaikan Tanah Deep Cement Mixing Di Lokasi Stock Yard Stasiun Kereta Api Garungkong Kabupaten Barru, Sulawesi Selatan. *Civil Engineering, Environmental, Disaster & Risk Management Symposium (Ceedrims) Proceeding 2021*, 387–394. <https://publikasiilmiah.ums.ac.id/handle/11617/12733>
- Vu, T. B., Dang, V. Q., Ngo, Q. A., & Ho, L. S. (2023). Influence of some factors on the mechanical properties of cement-treated clay for shallow mixing in Vietnam: A comparative study. *Results in Engineering*, 17, 101011.
- Zebua, H. F. (2022). Analisa penurunan akibat beban timbunan pada tanah gambut dengan perkuatan. *Jurnal Ilmiah Desain & Konstruksi*, 21(1), 50–64.