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Research Paper

Efficiency of Ferocement Construction on Riverside Stone Masking in Irrigation Channels in Pasuruan City, East Java

MahfulUmaryadi Akhmad[1], Lalu Mulyadi[2], Lies Kurniawati Wulandari*[3].
[23]*Lecturer National Institute of Technology, Malang-Indonesia*
[2]*PostgraduatestudentsNational Institute of Technology, Malang-Indonesia*
**Corresponding Author*

ABSTRACT: *Ferrocement is a mortar made from a homogeneous mixture of cement, sand, and water reinforced with reinforcement covered with continuous and tightly woven wire. The specification aspect is carried out by testing the mortar compressive strength at the ages of (3, 7, 14, 21, and 28 days) and water absorption testing at the age of 28 days after curing. Water loss testing is carried out by observing the ferrocement irrigation channel on a laboratory scale at the age of 28 days. The cost and time aspects of the work implementation are analyzed based on the Circular Letter of the Directorate General of Construction Development Number 33 of 2023.*
The results of the compressive strength study of stone masonry mortar at the age of 28 days for Type N were 107.41 kg/cm2; Type M was 263.77 kg/cm2; and ferrocement was 361.66 kg/cm2. The water absorption value of Type N mortar was 17.62%; Type M was 16.71%; and ferrocement was 16.26%. This means that the mortar mixture plan for Type N, Type M, and Ferrocement met the required specifications and criteria. The water loss of the laboratory-scale ferrocement channel was 3.66% and there was no seepage or water droplets on the surface of the test object. These results indicate that ferrocement is watertight. The cost of implementing the irrigation channel work using river stone masonry is Rp. 454,577,440.00 and ferrocement Rp. 410,802,000.00. The implementation time for the irrigation channel work using river stone masonry is 65 working days and 55 working days for ferrocement. These results show that ferrocement construction is more efficient than river stone masonry in terms of specifications, costs and time.

Keywords: *efficient, ferrocement, irrigation channels.*

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I. Introduction

Irrigation channel construction in Pasuruan City often uses river stone masonry. Unfortunately, the use of river stone masonry is not able to securely protect the irrigation channels from various natural damages, such as landslides and sediment buildup [1]. As a result, irrigation water does not reach the irrigation plots that need it. The impact is a shortage of irrigation water supply in some areas, resulting in agricultural land not being able to produce optimally, thus harming farmers. In addition to being susceptible to damage, river stone masonry requires a longer time to complete and is expensive [2].

The Pasuruan City Government is striving to develop irrigation water supply services. The challenge faced is the high cost of constructing irrigation channels. Therefore, innovative construction technologies are needed to support an irrigation water supply that is efficient, strong, easy to construct, economical, and competitive [3]. This study analyzes ferrocement as an alternative irrigation construction method to increase irrigation water supply, which is expected to be able to channel irrigation water to the irrigation plots that need it.

II. Materials And Methods

2.1. Conceptual Framework

The results of the efficiency analysis of ferrocement irrigation channel construction on river stone masonry demonstrate the development of ferrocement as an alternative irrigation channel construction method to improve agricultural irrigation services. Ferrocement is easy to apply, strong, durable, and more economical.

To provide a clear picture of how the parameters in this study were analyzed, a conceptual framework was developed based on the background, problems, and objectives of the study.
The parameters in this study refer to Circular Letter of the Directorate General of Construction Development Number 33 of 2023 [4], which includes the following:
1) Technical specifications for river stone and ferrocement mortar.
The tests conducted were the compressive strength of the mortar at 3, 7, 14, 21, and 28 days [5] and the water absorption of the mortar [6].
2) Cost of implementing the river stone and ferrocement channel work.The volume of work is multiplied by the unit price of the work [7].
3) Time to implement the river stone and ferrocement channel work.
The volume of work is divided by labor productivity.

2.2 Research Hypothesis
The hypothesis to be proven in this research is that ferrocement irrigation channels are more efficient than river stone masonry in terms of technical specifications, cost, and time.

2.3. Operational Definition
– Mortar technical specifications include material composition, mix ratio, compressive strength, and other properties that affect the mortar's performance in construction;
– Job implementation cost is the total budget required to complete a project from start to finish;
– Job implementation time is the time required to complete the entire project from the preparation stage to completion;

2.4. Channel Model Design
The ferrocement channel model design is a prototype of a river stone irrigation channel in the field, based on its net cross-sectional capacity. The channel's net cross-sectional capacity is 2.70 meters at the bottom; 2.90 meters at the top; and 1.00 meters high. The irrigation channel is 400 meters long.

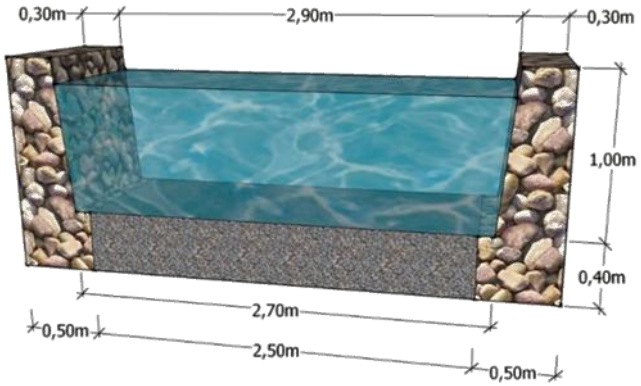

Figure 1. Cross-section of a river stone channel in the field

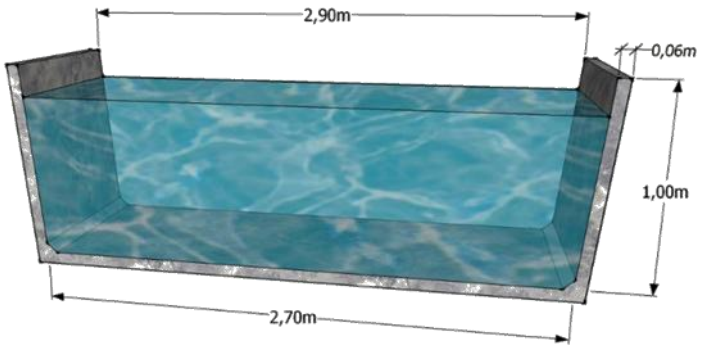

Figure 2. Ferrocement channel prototype

Water loss testing for ferrocement channels was carried out using a laboratory-scale irrigation channel model.
The technical specifications for river stone masonry mortar use Type N with a compressive strength of 5.2 MPa and Type M with a compressive strength of 17.2 MPa. The compressive strength of the ferrocement mortar is 30

MPa.
Model technical specifications (materials):
- Stone masonry mortar uses Type I Gresik Portland cement and Pasuruan sand;
- Ferrocement mortar uses Type I Gresik Portland cement and Lumajang concrete sand;
- Ferrocement reinforcement uses M6 wire mesh.

Figure 3. Cube mortar test specimen

Figure 4. Reinforcement of the frame and making of the laboratory scale ferrocement mold

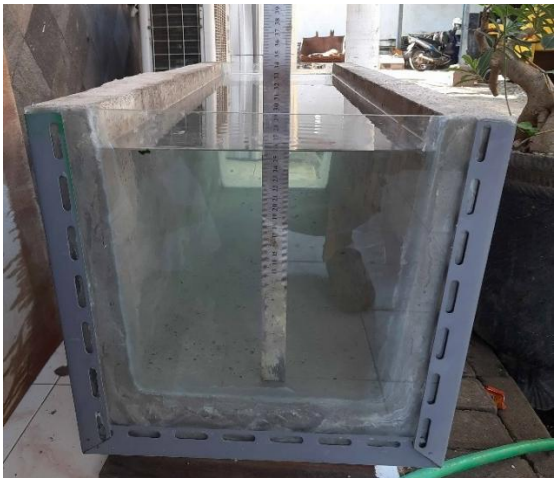

Figure 5. Observation of laboratory scale ferrocement water loss test

III. Results And Discussion

3.1. Mortar Technical Specifications

In this study, the technical specifications for the river stone and ferrocement channel work focused on the mortar's compressive strength and water absorption.

Mortar Compressive Strength

Table 1. Results of mortar compressive strength testing

Age (days)	Compressive strength of mortar (kg/cm2)		
	Type N	Type M	Ferrocement
3	43,51	108,77	150,92
7	67,98	205,30	235,22
14	96,53	237,93	324,95
21	99,25	251,53	343,98
28	107,41	263,77	361,66

Source: Test results

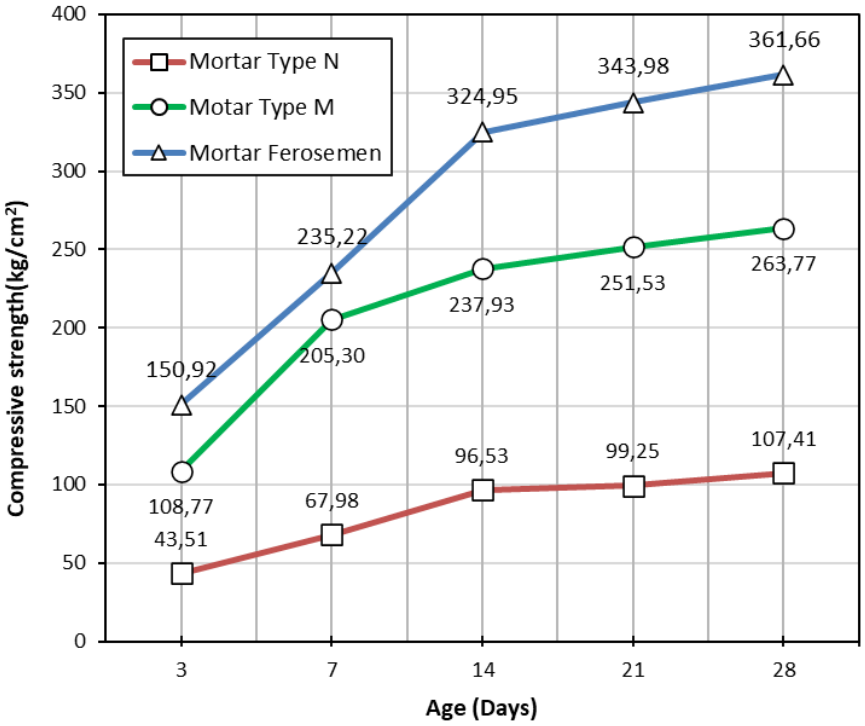

Figure 6. Graph of mortar compressive strength based on age

The results of the description of the compressive strength test parameters show that the compressive strength value of mortar at the age of 28 days for Type N is 107.41 kg/cm2; Type M is 263.77 kg/cm2 and Ferrocement is 361.66 kg/cm2.

Mortar Water Infiltration

Table 2. Results of mortar water absorption tests

Mortar type	Mortar water seepage (%)
Type N	17,62
Type M	16,71
Ferrocement	16,26

Source: Test results

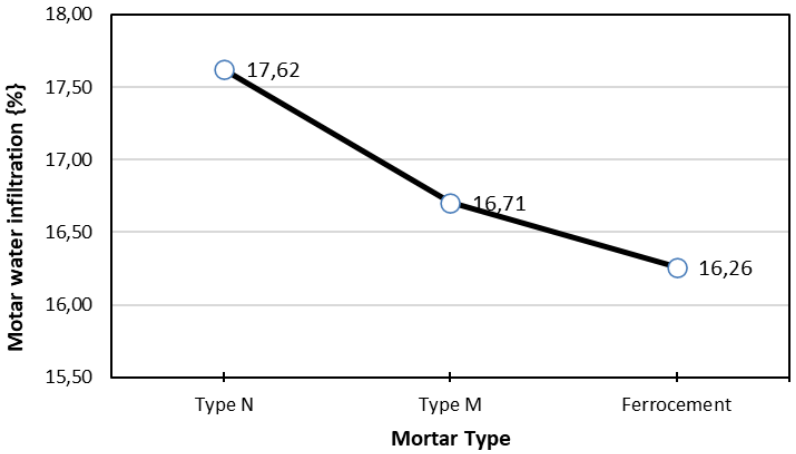

Figure 7. Graph of mortar water absorption based on mortar type

The results of the description of the mortar water absorption test parameters indicate that the higher the mortar's compressive strength, the lower its water absorption value.
Observations after 24 hours in the laboratory-scale ferrocement channel showed a decrease in water level of 9 mm, with a water loss of 3.66%. No seepage or water droplets were observed on the surface of the laboratory-scale ferrocement channel.

3.2. Cost of Drainage Work

Table 3. Cost of drainage work using river stone masonry

No.	Job description/type	Volume	Unit	Unit price (Rp.)	Total price (Rp.)
1	Stone masonry with type N mortar (5.2 MPa), semi-mechanical, with demolition stone	81,40	m^3	611.100,00	49.743.540,00
2	Stone masonry with N type mortar (5.2 MPa), semi-mechanical	358,60	m^3	921.500,00	330.449.900,00
3	1.5 cm thick plaster, with type N mortar (5.2 MPa)	400,00	m^2	57.800,00	23.120.000,00
4	Broadcast work with PC-PP type M mortar (17.2 MPa) on 1 m2 of masonry wall	720,00	m^2	71.200,00	51.264.000,00
				Amount	**454.577.440,00**

Source: Calculation results
The results of the description of the cost parameters for implementing the river stone channel work are Rp. 454,577,440.00.

Table 4. Cost of implementing ferrocement channel work

No.	Job description/type	Volume	Unit	Unit price (Rp.)	Total price (Rp.)
1	Ferrocement concrete quality fc' = 30 MPa	116,00	m^3	1.200.500,00	139.258.000,00
2	Ferrocement concrete formwork with 12 mm or 18 mm multiflex	1.656,00	m^2	96.600,00	159.969.600,00
3	Ferrocement reinforcement with Wiremess M6 (square wire mesh)	1.904,00	m^2	58.600,00	111.574.400,00
				Amount	410.802.000,00

Source: Calculation results

The results of the description of the cost parameters for implementing the ferrocement channel work are Rp. 410,802,000.00.

3.3. Channel Work Implementation Time

Table 5. Timeframe for carrying out the river stone channel work

Stone masonry with N type mortar (5.2 MPa), semi-mechanical				
	Number of teams	1	Teams	
	Volume of work	440,00	m^3	
Labor	Coefficient(people of the day)	person	Productivity	Duration (days)
Worker	1,0000	10,00	10,00	44,00
Bricklayer	0,5000	5,00	10,00	44,00
Foreman	0,1000	1,00	10,00	44,00
	Amount	16,00		44,00
1.5 cm thick plaster, with type N mortar (5.2 MPa)				
	Number of teams	1	Teams	
	Volume of work	400,00	m^2	
Labor	Coefficient (people of the day)	person	Productivity	Duration (days)
Worker	0,130	10,00	76,92	5,20
Bricklayer	0,130	10,00	76,92	5,20
head craftsman	0,013	1,00	76,92	5,20
Foreman	0,013	1,00	76,92	5,20
	Amount	22,00		6,00
Broadcast work with PC-PP type M mortar (17.2 MPa) on 1 m2 of masonry wall				
	Number of teams	1	Teams	
	Volume of work	720,00	m^2	
Labor	Coefficient (people of the day)	person	Productivity	Duration (days)
Worker	0,200	10,00	50,00	14,40
Bricklayer	0,200	10,00	50,00	14,40
head craftsman	0,020	1,00	50,00	14,40
Foreman	0,020	1,00	50,00	14,40
	Amount	22,00		15,00

The results of the description of the theoretical time parameters for carrying out the river stone masonry channel work, assuming 1 foreman for each work unit, is 65 working days.

Table 6. Time for implementation of ferrocement channel work

Ferrocement concrete quality fc' = 30 MPa				
	Number of teams	1	Teams	
	Volume of work	116,00	m^3	
Labor	Coefficient (people of the day)	person	Productivity	Duration (days)
Worker	1,650	10,00	6,06	19,14
Bricklayer	0,275	1,67	6,06	19,14
head craftsman	0,028	0,17	6,06	19,14
Foreman	0,165	1,00	6,06	19,14
	Amount	12,84		20,00
Ferrocement concrete formwork with 12 mm or 18 mm multiflex				
	Number of teams	1	Teams	
	Volume of work	1.656,00	m^2	
Labor	Coefficient (people of the day)	person	Productivity	Duration (days)
Worker	0,200	10,00	50,00	33,12
Bricklayer	0,100	5,00	50,00	33,12
head craftsman	0,010	0,50	50,00	33,12
Foreman	0,020	1,00	50,00	33,12
	Amount	16,50		34,00
Ferrocement reinforcement with Wiremess M6 (square wire mesh)				
	Number of teams	1	Tim	
	Volume of work	1.904,00	m^2	
Labor	Coefficient (people of the day)	person	Productivity	Duration (days)
Worker	0,00360	10,00	2.777,78	0,69
Bricklayer	0,00120	3,33	2.777,78	0,69
head craftsman	0,00012	0,33	2.777,78	0,69
Foreman	0,00036	1,00	2.777,78	0,69
	Amount	14,67		1,00

The results of the description of the time parameters for the implementation of the ferrocement channel work theoretically, assuming 1 foreman for each work unit, is 55 working days.

Efficiency Analysis

This section presents the results of an efficiency analysis of the river stone and ferrocement channel work against specifications, costs, and implementation time.

Table 7. Summary of analysis results of the river stone and ferrocement channel work

No.	Parameter description	River stone pairs	Ferrocement
1	Technical specifications:		
	- Mortar compressive strength (kg/cm2)	Type N = 107,41 Type M = 263,77	361,66
	- Mortar water absorption (%)	Type N = 17,62 Type M = 16,71	16,26
2	Cost of work implementation (Rupiah)	454.577.440,00	410.802.000,00
3	Work execution time (Days)	65	55

Ferrocement mortar has higher compressive strength and lower water absorption than stone masonry, meaning that, technically, ferrocement mortar is more efficient than river stone masonry.

The cost efficiency of implementing ferrocement drainage is 9.63% lower than river stone masonry.

The time efficiency of the ferrocement channel work is 15.38% faster than the river stone masonry.

IV. Conclusion

Based on the research results, it can be concluded that the ferrocement construction irrigation channel is more efficient than river stone masonry in terms of technical specifications, costs, and time. Although thin, ferrocement construction has higher compressive strength and lower mortar absorption than river stone masonry. The cost of implementing ferrocement construction is 9.63% cheaper than river stone masonry, and the construction time, ferrocement construction is 15.38% faster than river stone masonry due to the simple construction process.

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