Flexural Behavior of Ferrocement on Coastal Infrastructure

B. Bayzoni[1*] and H. R. Husni[2]

[1] Department of Civil Engineering, Faculty of Engineering, Lampung University, Gedong Meneng, Rajabasa, Bandar Lampung, Indonesia. 35141
[2] Department of Civil Engineering, Faculty of Engineering, Lampung University, Gedong Meneng, Rajabasa, Bandar Lampung, Indonesia. 35141
*bayzoni.1973@eng.unila.ac.id

Abstract. Coastal buildings and infrastructure, especially piers or barges, definitely interact with sea water which has salinity, this will affect the physical and mechanical properties of ferrocement which will affect the life use of the building. So it is necessary to conduct research on the influence of the coastal environment on the physical and mechanical properties of ferrocement. The research was carried out by making ferrocement panels 25mm x 100mm x 500mm size, then the panels were placed in the coastal environment of Bandar Lampung City. The research results showed that the modulus of rupture/first crack of ferrocement decreased by 27.19% after being soaked for 8 weeks. The flexural strength of ferrocement decreased by 14.13% after being soaked for 8 weeks. Anomalies occurred at 1 and 2 weeks of immersion that showed an increase which indicated that cement hydration reactions were still occurring for up to 6 weeks. So, it is deemed necessary to carry out further studies regarding the increase in compressive strength of PCC cement mortar over time (effective age of the PCC cement hydration process). Another study needs to be carried out using a reinforcement ratio greater than 1% to study the level of durability and ductility.

Keywords: coastal environment, ferrocement, portland cement composite.

1 Introduction

Indonesia is a maritime country with many islands and a very wide coastal area. Lampung province has a total coastline length of up to 1,105 km, this is also because apart from land, Lampung also has 137 small islands on the edge of the Indian Ocean. The fairly high length of the coastline is of course related to the need for quite large infrastructure and coastal buildings, such as the need for small and medium-sized piers which are needed to support community transportation, fishing boat traffic, and marine tourism traffic which is increasing day by day.

Several small piers have been created to support tourism activities, such as the Grand Elty pier and Pahawang Island Pier (see Fig 1 and Fig 2).

A. Zakaria et al. (eds.), *Proceedings of the 1st International Conference on Industry Science Technology and Sustainability (IConISTS 2023)*, Advances in Engineering Research 235,
https://doi.org/10.2991/978-94-6463-475-4_32

Fig. 1. Puhawang Island Pier.

Fig. 2. Grand Elty's Pier.

The precast method is one of the solutions used in relation to construction methods for remote areas, and to reduce transportation costs, light materials can be used. One material that is quite light due to its relatively small volume that has been used in the construction of piers is ferrocement, as seen in Fig. 1 and Fig. 2. Ferrocement has also been used for shipbuilding in Indonesia [Alrasyid et al, 2023]. Ferrocement is a type of thin reinforced concrete construction, where usually hydraulic cement is reinforced with layers of mesh with a small and continuous diameter. The mesh layer may be made of metal or other suitable material (ACI Committee 549). Cement mortar, which is a ferrocement material/component, has very strong mechanical properties to withstand compression. This compressive strength is the basis for planning all structural elements of ferrocement. Research on concrete in general tensile strength shows a tendency to increase with compressive strength in old concrete in the marine environment. These two parameters have a close relationship [Yao et al, 2017]. The compressive strength of concrete with fly ash has also been studied [Hygrive et al, 2017].

Beach buildings and infrastructure, especially piers, definitely interact with sea water which has salinity, this will of course affect the physical and mechanical properties of ferrocement which will affect the life of the building. Studies on ferrocement on the marine environment have been carried out [Kowalski, 1977].

2 Research Method

2.1 Speciment

The test object (specimen) was made in the form of a ferrocement plate with dimensions of 25 mm x 100 mm x 500 mm. Making the test object begins with making formwork using 25 mm x 25 mm hollow aluminum frame and 19 mm multiplex coated with plastic (Fig. 3.) so that it is easy to disassemble so that it can be used repeatedly.

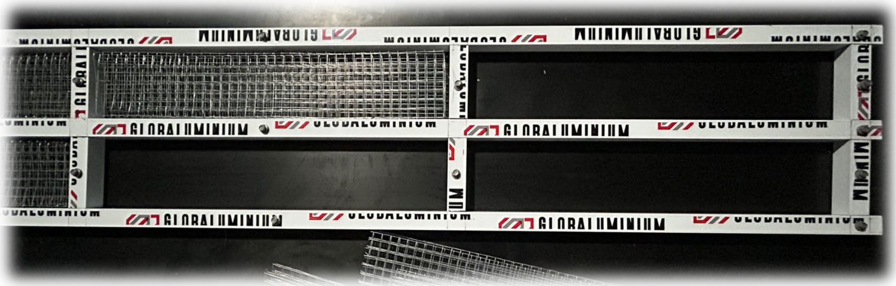

Fig. 3. Formwork and reinforcement.

Reinforcement uses welded mesh wire with an opening size of ½" and a wire diameter of 0.67 mm, made in 5 layers. After the formwork and reinforcement are ready, the next work is to prepare the mortar mixture consisting of sand, cement, water and retarder, and the pouring process is carried out in stages (Fig. 4.).

Fig. 4. Formwork and reinforcement.

Releasing the test object from the formwork was carried out after the mortar had hardened (for 1 day), which then carried out a curing process for 28 days by immersing it in a water bath (Fig. 5.).

Fig. 5. Curing process.

The immersion process in coastal environments is carried out at a depth of 0.5 m – 2 m which is influenced by tidal conditions (Fig. 6.). During the immersion process, it is estimated that the test object experiences changes in mechanical behavior caused by the influence of sea water containing salt or other sulfate influences.

Fig. 6. Implementation of the immersion process.

The test objects that have been soaked on the coast will then be lifted to be tested according to the time group that has been previously determined.

2.2 Testing

The test method used is a bending test with a 2-point load system (Fig. 7.). This method is used to obtain the first crack behavior and flexural strength of ferrocement plates. With a configuration like in the picture, it is hoped that a pure bending mechanism will occur in the mid-span area and no shear mechanism will occur.

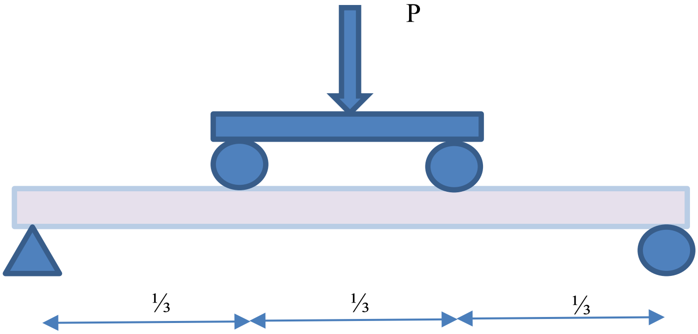

Fig. 7. Two Point Load System.

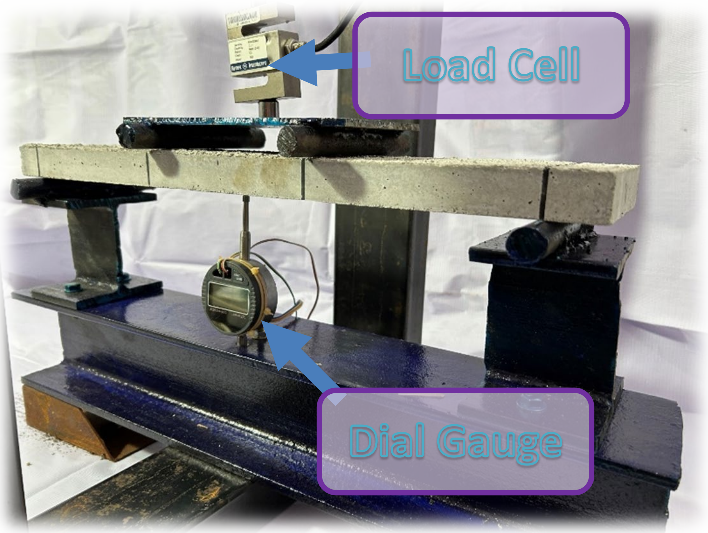

Fig. 8. Two Point Load System.

The arrangement of test objects and measuring instruments is shown in Fig. 8. The Load Cell is used to measure the amount of load applied and the Dial Gauge is used to obtain the amount of deflection. The testing process is carried out by applying the load in slow increments with additions of around 10 N per second. During the loading process, pay attention to when cracks occur which can be observed by the decrease in load that occurs. The loading was stopped after the test object failure (Fig. 9.).

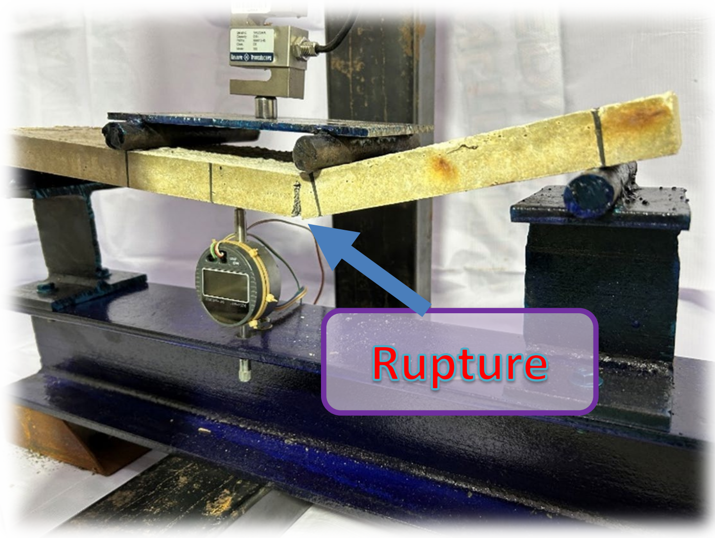

Fig. 9. Test Set-Up.

3 Result and Descussion

3.1 Analytical Study

To be able to estimate the test loading to be carried out, it is necessary to carry out theoretical calculations to obtain the ferrocement cross-sectional properties of the test object.

Data on cross-sectional properties are then used to create stress-strain diagrams of ferrocement in compression (Fig. 10.) and in tension (Fig. 11.). The stress-strain curve of ferrocement in compression is depicted in a bi-linear model, while the stress-strain curve of ferrocement in tension is depicted in a tri-linear model.

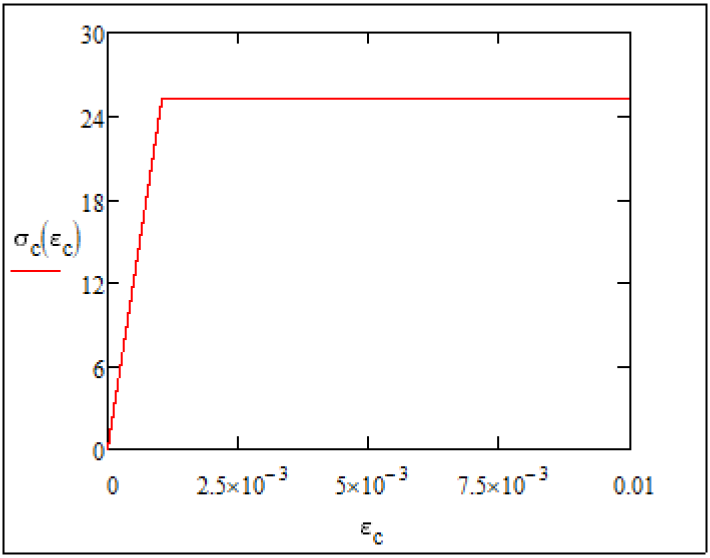

Fig. 10. Stress strain curve of ferrocement in compression.

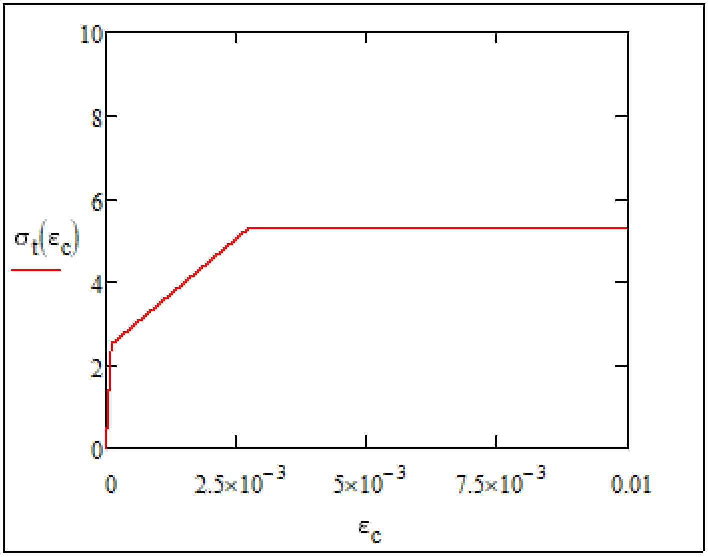

Fig. 11. Stress strain curve of ferrocement in tension,

3.2 Initial Condition Test Results

The bending test of a plate that does not experience the influence of the coastal environment is shown in Fig. 12.

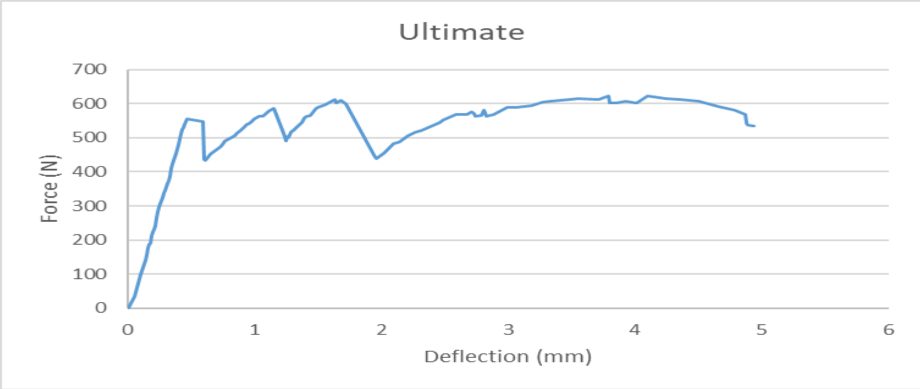

Fig. 12. P-Δ diagram of 0-week plate test.

In the P-Δ diagram Fig. 12. shows several peak loads, the first peak occurs at a load of 555N with a deflection of 0.47mm, the second peak occurs at a load of 585N with a deflection of 1.15mm, the third peak occurs at a load of 610N with a deflection of 1.68mm and the last peak occurs at load 623N 3.79mm. The behaviour above shows that the first crack occurs at the first peak when the load is 585N, the occurrence of the crack causes a reduction in plate thickness so that the stiffness decreases suddenly which is shown by a sudden decrease in load. Because the reinforcement in ferrocement is layered (in this specimen there are 5 layers), the process of cracking is also gradual. After the first crack occurs, the second layer of reinforcement provides greater resistance so that the strength again increases to 585N and the deflection is 1.15mm. At this point additional cracks occur in the ferrocement layer so that the layer-by-layer cracking process gives a P-Δ diagram that fluctuates along with the crack propagation pattern towards the inner side fibers of the plate.

3.3 First Crack

The results of observations regarding the occurrence of the first crack in each group of test objects are given in Fig. 13.

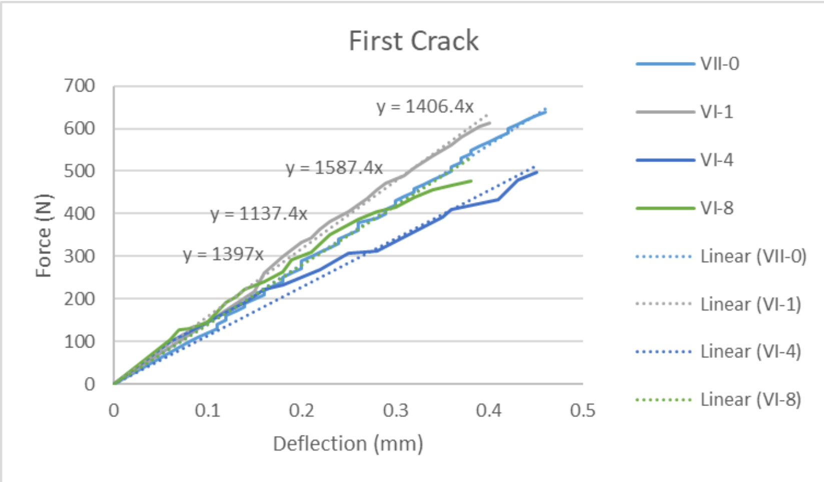

Fig. 13. First Crack Test Result.

Table 1. Crack Stress.

	P (N)	Δ (mm)	σ (Mpa)	Settlement (%)
0WK	640	0.46	4.61	0.00%
1WK	614	0.40	4.42	4.06%
4WK	498	0.45	3.59	22.19%
8WK	466	0.36	3.36	29.19%

Observing the graphs in Fig. 13 and Table 1, it can be seen that there is a decrease in cross-sectional crack strength along with the length of soaking. In the 8th week, a decrease in crack strength was seen up to 27.19%. The crack strength of ferrocement greatly affects the durability/resistance of ferrocement because cracks can cause the intrusion of minerals or substances which can disrupt the stability of the reinforcing wire, especially in the form of corrosion, which can cause a decrease in the overall strength of the ferrocement section.

3.4 Phased Condition Test Results

The next evaluation is to study the ultimate behavior of the ferrocement cross section after undergoing the soaking stage from 1 week to 8 weeks. Several test groups are given in Fig. 14. to Fig. 16.

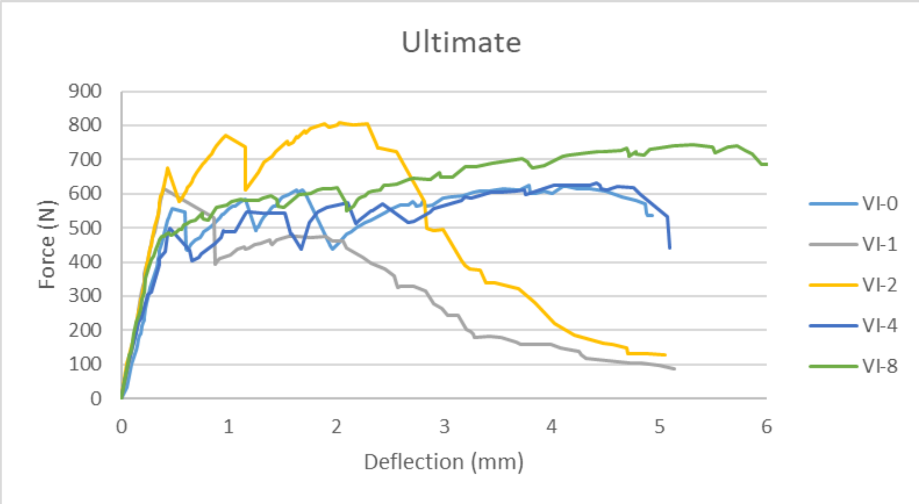

Fig. 14. Group VI loading stage test results.

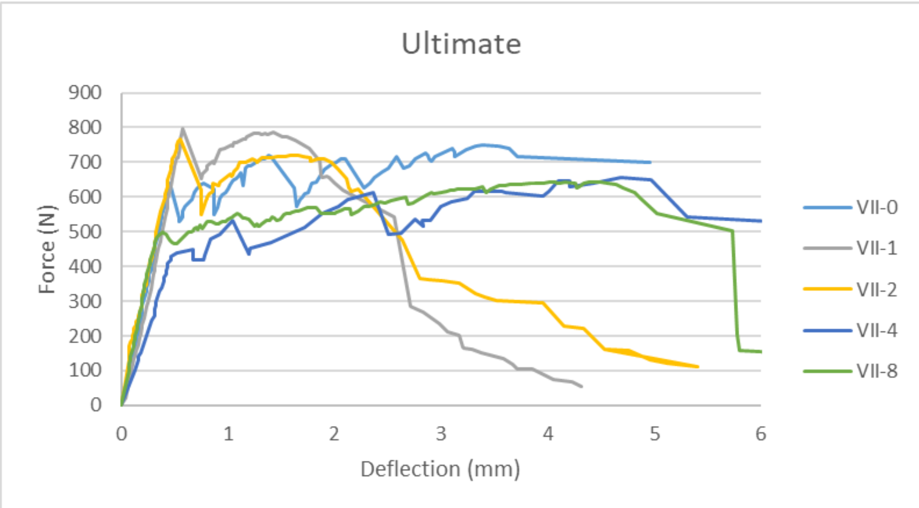

Fig. 15. Group VII loading stage test results.

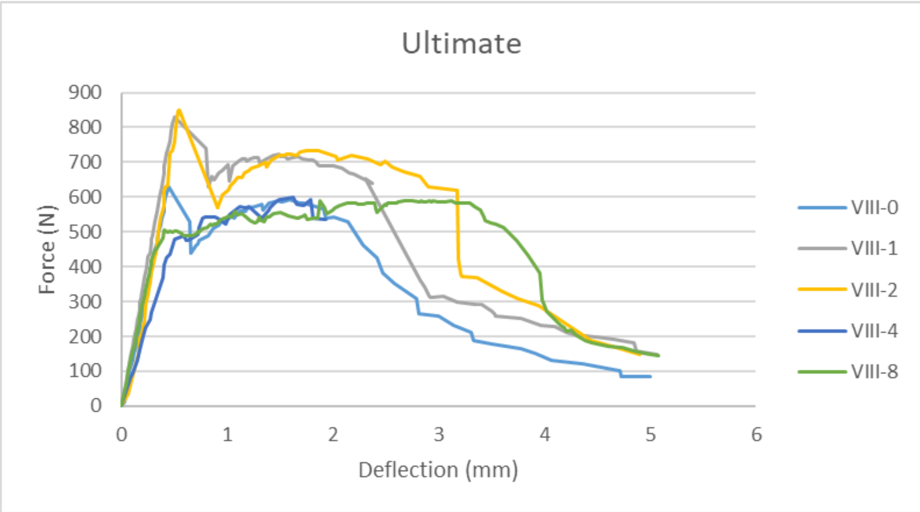

Fig. 16. Group VIII loading stage test results.

The graph of the test results shows the behavior of decreasing strength after the ferrocement cross-section was soaked for more than 4 weeks. Soaking for 1 week and 2 weeks showed an increase in strength compared to the initial condition without soaking, but then it decreased again. This behavior is indicated because the test specimens were immersed in a coastal location after 28 days, so it is possible that in the next 2 weeks there will still be an increase in strength caused by the hydration process of Portland Cement Composite (PCC) cement which is different from Ordinary Portland Cement (OPC).

A summary of the maximum load test results is shown in Table. In the table it can be seen that in 4 and 8 weeks of immersion there was a reduction in the maximum load at the ultimate condition of up to 14.13%. Meanwhile, 1 and 2 weeks of immersion showed an increase in load of up to 6.13%, but this peak load condition was reached when the deflection was 0.58mm, which indicated that it was still in first crack condition.

Table 2. Maximum Load.

	P (N)	Δ (mm)	Settlement (%)
0WK	750	3.39	0.00%
1WK	796	0.58	-6.13%
2WK	766	0.55	-2.13%
4WK	657	4.68	12.40%
8WK	644	5.01	14.13%

4 Conclusion and Recommendation

From the results and discussions carried out several conclusions and suggestions can be drawn.

1. The crack strength/modulus of rupture of ferrocement decreased by 27.19% after being soaked for 8 weeks.
2. The flexural strength of ferrocement decreased by 14.13% after being soaked for 8 weeks.
3. There is an increase in strength when the ferrocement is 4 – 6 weeks old.
4. Further research needs to be carried out using a reinforcement ratio higher than 1% so that significant strength reduction behavior at each cracking stage does not occur.
5. The soaking process in coastal environments can be carried out for a longer time so that a further level of strength reduction can be obtained.

Acknowledgments. Authors wishing to acknjournowledge to the University of Lampung for supporting the research team through BLU 2023 funds, and also thank to the Unila Civil Engineering Department for providing the opportunity to carry out this activity. As well as technicians and students who took part in this research..

References

1. ACI Committee 549, 1982 State of The Art on Ferrocement
2. ASTM E178-02 2002 *Standard practice for dealing with outlying observation* American Society for Testing and Materials, p 1-18
3. Yao, W., Jiang, S., Fei, W, Cai, T. 2017 Correlation between the compressive, tensile strength of old concrete under marine environment and prediction of long-term strength. *Advance and Material Sciences and Engineering* vol 2017 12 pages. http://doi.org/10.1155/2017/8251842
4. Ambroziak, A., Haustein, E., Kondrat, J. 2019 Chemical and mechanical properties of 70-years- old concrete *Journal of Materials in Civil Engineering*, Vol. 31.8
5. Kowalski T.G. 1977 Desirable Properties Of Fine Grained Concrete for Marine Ferrocement Uses *Journal of Ferrocement* Vol. 7 No. 2 pp 96-98
6. Alrasyid, H., Nulhakim, F., Ayu, V.K., Jupriyanto 2023 Ferrocement for Maritime Security and Safety Platforms *International Journal of Social Science Research and Review* Vol. 6.1 pp 186-192