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Effect of Perlite as Lightweight Aggregate on Seawater-Fly Ash Concrete Compressive Strength and Water Absorption

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Abstract: Concrete production increased and give negative impact to the environment. In this study, the lightweight concrete was designed using eco-friendly materials such as seawater, fly ash (FA), and perlite aggregate. The objective of this study is to determine the compressive strength and the water absorption of the seawater-FA concrete containing perlite as lightweight coarse aggregate. There two (2) stages of mixing process. First stage was the trial mix, where minimum strength of 50 MPa need to be achieved by replacing OPC with FA by 10%, 20% and 30% by weight. Second stage was the mixture with FA obtained in stage 1 and perlite as coarse aggregate replacement at 10%, 20% and 30% by volume, at target strength of 30MPa. Compressive strength test was conducted on 36 samples at 7 and 28 days, while water absorption test was conducted at 28 days of curing ages on 18 samples. From the result of the trial mix concrete, it was found that the compressive strength test achieved 50 MPa with 30% of FA replacement, meanwhile all FA-seawater mixture with perlite up to 30% replacement achieved 30 MPa. Water absorption, on the other hand, increased as the proportion of perlite increased.

Keywords: Fly Ash (FA), Perlite Concrete, Compressive Strength, Water Absorption

1. Introduction

Lightweight concrete is a type of concrete that the mixture has been altered with some material which has capability to decrease the self-weight of the concrete. Nowadays, the lightweight concrete is a flexible material that has sparked a lot of interest and a lot of industrial demand in a variety of construction projects because it is obviously lighter than the conventional concrete [2]. The density of lightweight concrete is more significant that its strength in structural applications. This is because the lower the density of the concrete, the lower the self-weight of the structure, the smaller the foundation size, the lower the construction cost [7]. One of the important mixtures that need to alter to produce lightweight concrete are coarse aggregate. The coarse aggregate gives the major impact of the weight

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of the concrete. By using the lightweight aggregate can reduce the dry density of the concrete compared to normal aggregate [9].

From the previous study by [8], the strength of the lightweight concrete is lower than the conventional concrete since its density is much lower. Since the strength is low, the lightweight concrete can only be used as roof slab, slab, surface rendered for external wall of small house, reinforced concrete, and others. In Malaysia, lightweight concrete has been used along with the Industrialised Building System (IBS) technology. Construction Industry Development Board (CIDB) has stated that the lightweight concrete has been used with the interlocking precast concrete block in construction of bungalow [13]. According to Public Work Department Malaysia (JKR), the lightweight concrete is used in the implementation of IBS in government project as lightweight block in construction of column component and load-bearing wall [15].

2. Literature Review

In this study, the usage of seawater in the concrete production is an alternative to reduce the consumption of fresh water in construction industries. This is because the fresh water nowadays has turn out to be limited for daily used. Seawater has become a medium to combine with cement in water-cement ratio as a binder in concrete mix. This study will obtain the result that shows that if the seawater can be a suitable alternative component in design mix or not. Furthermore, the usage of FA as partial replacement of Portland cement is going to be studied in this project. From the various of previous studies stated that the partial replacement of Portland cement with FA are giving many positives result since the FA are one of the pozzolanic material due to high silica and aluminum composition. Perlite is one of the common materials that had been used in construction industries due to its unique characteristic which is low density, heat insulator and sound insulator. Even perlite become the major component in lightweight concrete because of its density, it also decreased the strength.

2.1 Seawater

The previous research from [10] stated that the usage of seawater in concrete design mix produced higher strength compared to concrete that used fresh water as the concrete design mix, but the long-term strength of the concrete is expected to be lower. Another research that had been studied from [11] stated that the compressive strength of seawater-concrete for 3 and 7 days are 12.9% and 9.66% is higher than fresh water-concrete. For water absorption test on seawater concrete from the past report, there are two mixture of concrete which is mix A (freshwater concrete) and mix B (seawater concrete). From the test, water absorption for seawater concrete which is mix B is lower than conventional concrete which is mix A [12].

2.2 Fly Ash (FA)

FA has a wide range of physical and chemical properties depending on the type of coal used in the power plant and the equipment used. FA are collected by the mechanical dust collector from the fuel gases of the thermal power plants. Same as Portland cement, FA chemical composition are silicon, calcium, and aluminum. The compressive strength of the FA concrete from the experiment that run by [5] stated that the concrete with 30% FA replacement has maximum strength compared to other replacement rate in 7, 14 and 28 days of concrete age. This result proved that the most suitable percentage of FA replacement is 30% compared to normal concrete. The water absorption test of FA concrete was determined by [3]. From the results, it is shows that the water absorption of conventional concrete is 4.1% same as the concrete with 30% of FA.

2.3 Perlite

Perlite aggregate that replaced coarse aggregate in the production of lightweight concrete is due to it physical and chemical properties. The density that stated by [1] is 150 kg/m3 to 300 kg/m3 which make it is one of the most suitable materials that can replace coarse aggregate in lightweight concrete production. The testing of compressive on concrete with 0%, 5%, 10%, 15%, 20%, and 25% of perlite replacement for 7 and 28 days of curing. 10% of perlite replacement yield the highest compressive strength compared to other percentage of perlite replacement [6]. The research from [4] stated that the durability of the concrete can be determine by water absorption test. The test was conduct after 28 days and 90 days of curing. the normal concrete which is 0% of perlite obtained the lowest water absorption percentage which can be considered as good to be compared to all the lightweight concrete with perlite aggregate.

3. Materials and Methods

The gradation of sample can be determined through dry-sieve analysis of aggregate sample which is perlite and gravel. 42 of cubes of 100 mm x 100 mm x 100 mm are casted and curing with different series of mixture at 7 days and 28 days and then, the testing of hardened concrete is done to obtain the compressive strength for each sample. In addition, another 18 of cubes of 100 mm x 100 mm x 100 mm are casted and curing with different percentage of mixture at 28 days. Then, the water absorption test has be done on the concrete cube to measure the amount of water that penetrate the concrete cubes. Next, the data and analysis of lab test result were discussed, and a conclusion gathers all the project's output. Then, recommendations are provided in order to improve the results and create a comparison for future research.

3.1 Material

The materials that have been used in this study to produce seawater-FA concrete contain perlite aggregate are seawater, Ordinary Portland cement (OPC), fly ash (FA), gravels, and perlite aggregate. The materials for the lightweight concrete must be prepared first before the concrete cube of (100 mm x 100 mm x 100 mm).

3.2 Trial Mix and Actual Mix

The trial mix design purpose is to find the optimum ratio of FA replacement for OPC which is 10%, 20% and 30%. Thus, the quantities of seawater, coarse aggregate and fine aggregate will be same for each sample. After the optimum ratio of FA has been obtained, the actual mix has been performed with different quantities of perlite which is 10%, 20% and 30% to be replace with coarse aggregate.

3.3 Methodology Flow Chart

Methodology flow chart was shown in Figure 3.1.

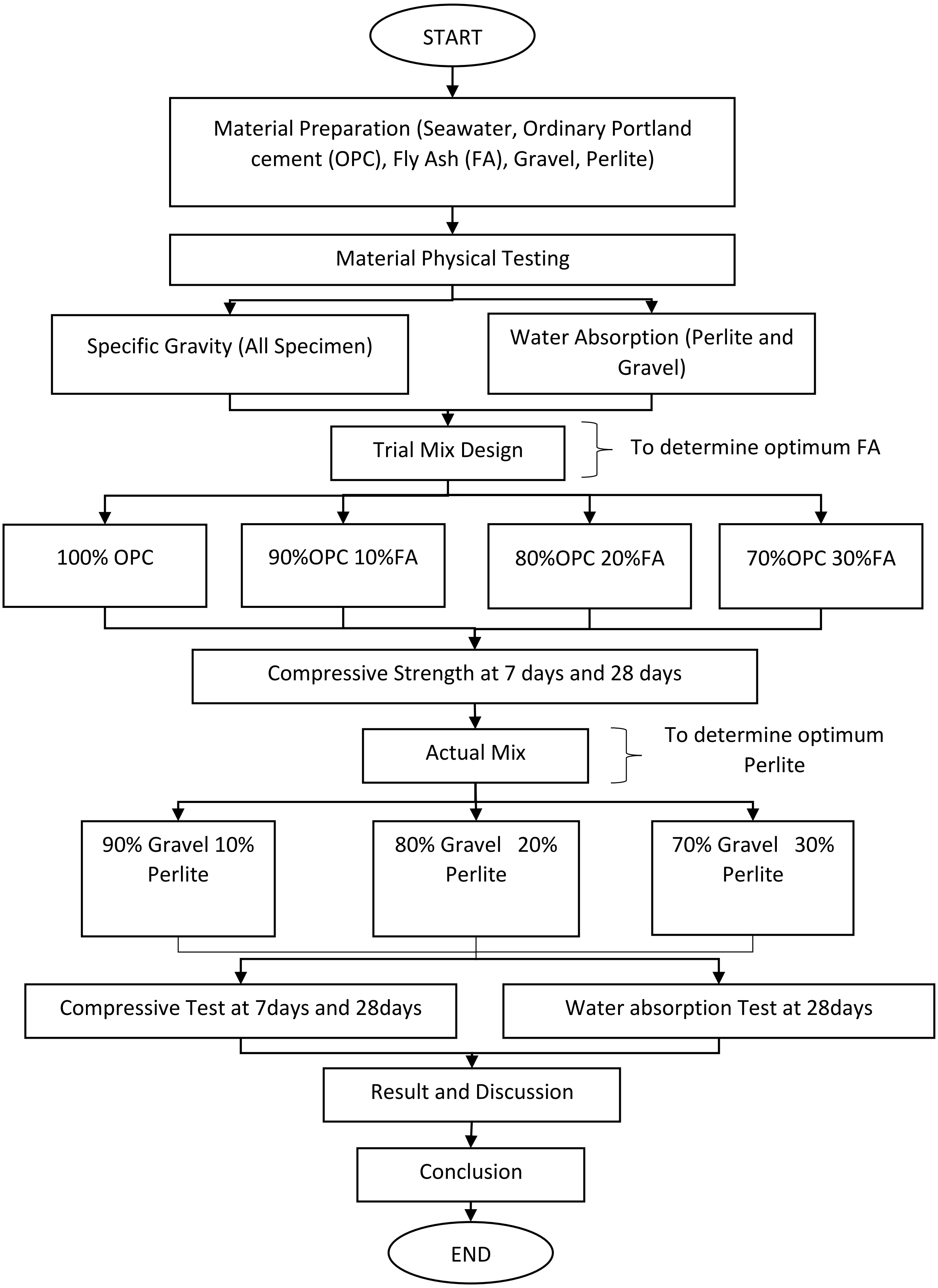

Figure 3.1: Methodology flowchart

4. Results and Discussion

All the data and analysis of the result that have been obtained from the project are showed. There are several tests that have been done to achieve the project objectives such as specific gravity test, dry sieve analysis, water absorption test for gravel and perlite, slump test, compressive strength test and water absorption test on concrete. All of this test is needed to be completed in order to achieve the objective of this project.

4.1 Specific Gravity Test and Water Absorption Test

Specific gravity test and water absorption test are test that have been carried out to obtain the physical properties of the material that have be used in the mix design. The result of the tests was shown in Table 4.1 and Table 4.2.

Table 4.1: Density of the materials

Material	Density (g/cm^3)
Tap water	1
Seawater	1.04
OPC	2.81
Fly Ash	2.28
Sand	2.52
CA	2.58
Perlite	0.44

Table 4.2: Water absorption of the materials

Material	Water absorption (%)
Fine aggregate	7
Coarse aggregate	1
Perlite	40

4.2 Dry Sieve Analysis

To determine the grading curve for coarse aggregate and fine aggregate, the dry sieve analysis test was performed. The result of the tests was shown in Figure 4.3 and Figure 4.4.

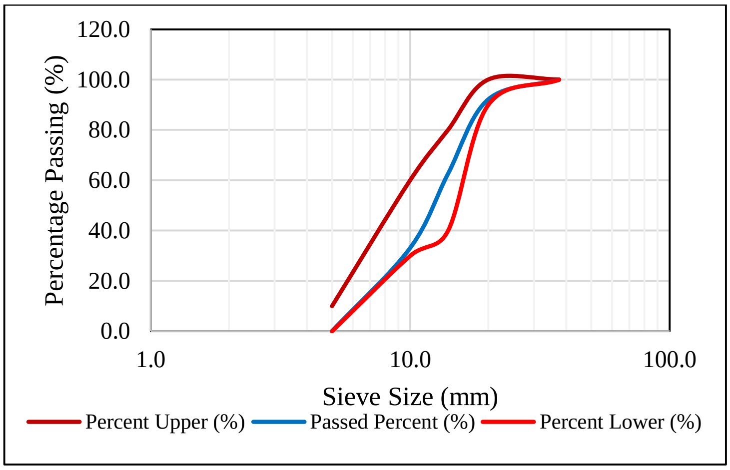

Figure 4.1: Grading curve of coarse aggregate semi-log graph

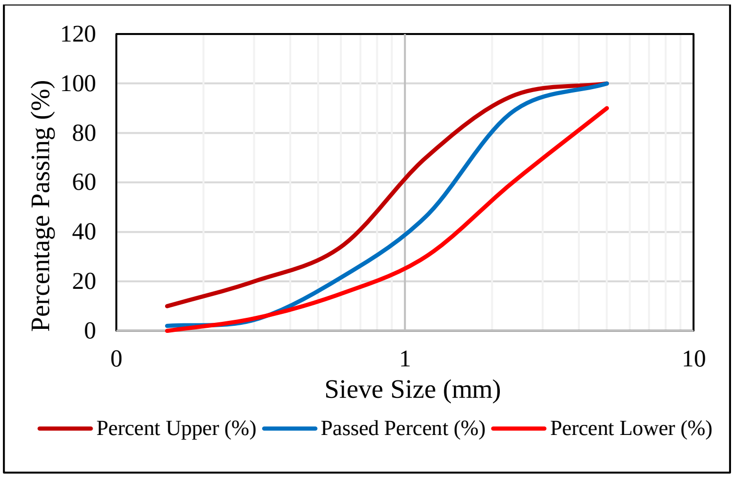

Figure 4.2: Grading curve of fine aggregate semi-log graph

4.3 Slump and Hardened Density

The workability of concrete can be determined by carried out the slump test. The slump range from the mix design by DOE method are 60 mm to 180 mm with verbal time 0s to 3s which mean the concrete are high workability. The result of the slump test for trial mix and actual mix are shown in Table 4.3 and Table 4.4. Other than that, the normal concrete density is within range 2300 kg/m^3 to 2500 kg/m^3. From the data that have shown in Figure 4.3, the density of FA concrete is within the range of normal weight concrete since the FA is a replacement material of OPC. While the data in Figure 4.4 show that the density of the perlite concrete are lower than 2300 kg/m3 since the perlite is a lightweight aggregate.

Table 4.3: Slump test data of FA concrete

Series	Fly Ash	Perlite	Workability (mm)	Sp (ml)
Series 1	0%	0%	160	8.06
Series 2	10%	0%	150	6.26
Series 3	20%	0%	140	3.92
Series 4	30%	0%	165	6.18

Table 4.4: Slump test data of perlite concrete

Series	Fly Ash	Perlite	Workability (mm)	Sp (ml)
Series 5	30%	10%	170	7.98
Series 6	30%	20%	170	9.58
Series 7	30%	30%	110	7.78

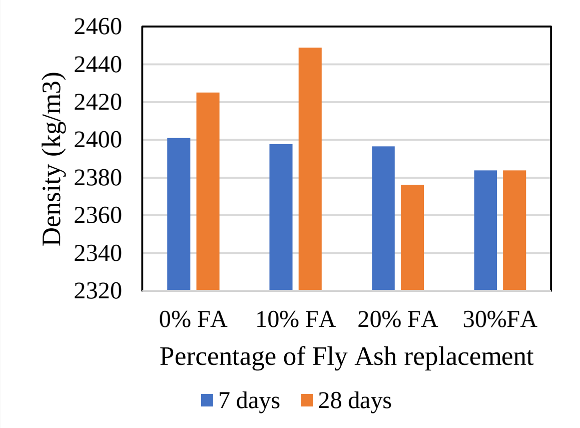

Figure 4.3: Density of trial mix concrete (with FA only)

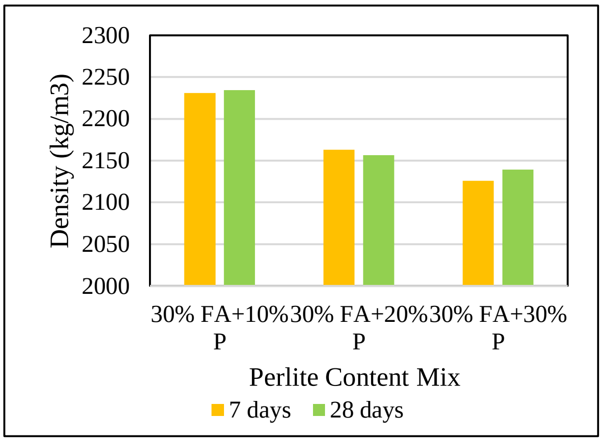

Figure 4.4: Density of actual mix concrete (with 30% FA and perlite)

4.5 Compressive Strength Test

To determine the optimum percentage of FA replacement, the compressive strength test is caried out to obtain the compressive strength of the concrete. From the data shows in Figure 4.5, 30% of FA replacement recorded the highest strength in both 7 days and 28 days of curing which is 41.9 MPa and 57.3 MPa respectively. While the compressive strength test data that have been obtained for perlite concrete as shown in Figure 4.6. The optimum percentage of perlite as lightweight aggregate is 10% because it achieves the highest compressive strength in both 7 days and 28 days of curing which is 31.4 MPa and 43.8 MPa respectively.

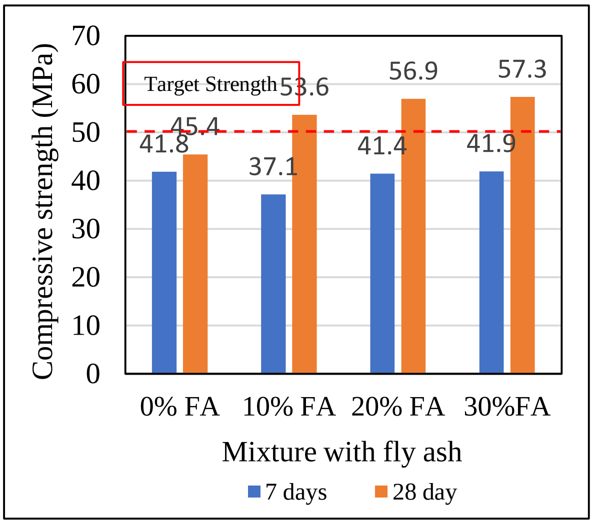

Figure 4.5: Compressive strength test of fly ash concrete (10%, 20% and 30%)

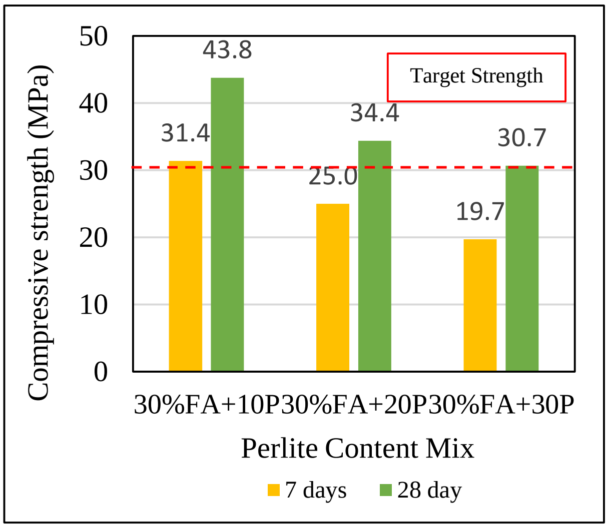

Figure 4.6: Compressive strength test of fly ash concrete with perlite at 10%, 20% and 30% coarse aggregate replacement

4.6 Water Absorption Test

The lower the water absorption percent, the better the quality of the concrete. As for the trial mix concrete, the water absorption value is shown in Figure 4.7 while for perlite lightweight concrete water absorption data is shown in Figure 4.8. From the data obtained, water absorption of perlite concrete was higher than FA concrete. This is because the perlite aggregate has excessive air void and will make it an absorptive material. However, 10% of perlite replacement indicate 2.3% water absorption which are not so much different with FA concrete and can be considered as good quality of concrete. So, the higher the percentage of perlite replacement, the higher the water absorption of the concrete.

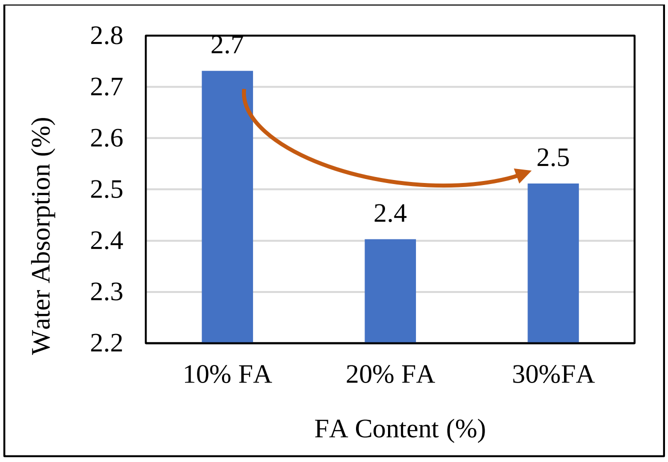

Figure 4.7: Water absorption of FA concrete

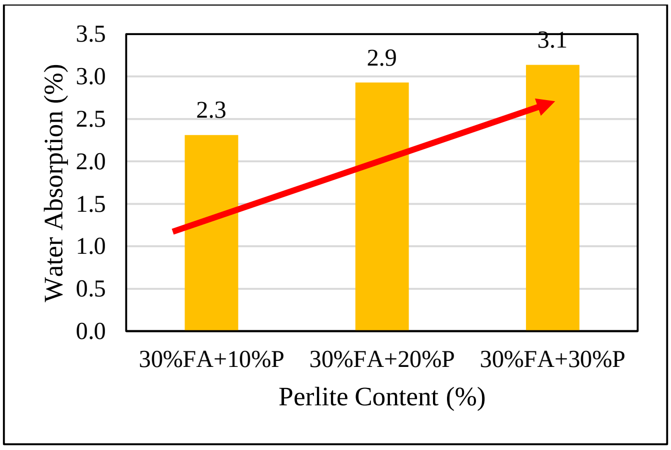

Figure 4.8: Water absorption of perlite concrete

5. Conclusion

The following conclusion have been made:

1. The optimum ratio of FA in the trial mix was 30 % because it achieved the highest compressive strength compared to other percentage of replacement.
2. The optimum ratio of perlite in the actual mix was 10 % because it achieved the highest compressive strength compared to other percentage of replacement.
3. When the perlite content is increased, the compressive strength will be decreased.
4. The percentage of water absorption is lower when the perlite content is lower.

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References

[1] Atila Gurhan Celik. (2013). *Expanded Perlite Aggregate Characterization for Use As a Lightweight*. *49*(2), 689–700.

[2] Hamad Mohammed, J., & Hamad, A. J. (2014). Materials, Properties and Application Review of Lightweight Concrete. *Revista Tecnica de La Facultad de Ingenieria Universidad Del Zulia*, *37*(2), 10–15.

[3] Hatungimana, D., Taşköprü, C., İçhedef, M., Saç, M. M., & Yazıcı, Ş. (2019). Compressive strength, water absorption, water sorptivity and surface radon exhalation rate of silica fume and fly ash based mortar. *Journal of Building Engineering*, *23*(October 2018), 369–376. https://doi.org/10.1016/j.jobe.2019.01.011

[4] Ibrahim, M., Ahmad, A., Barry, M. S., Alhems, L. M., & Mohamed Suhoothi, A. C. (2020). Durability of Structural Lightweight Concrete Containing Expanded Perlite Aggregate. *International Journal of Concrete Structures and Materials*, *14*(1). https://doi.org/10.1186/s40069-020-00425-w

[5] Joel, S. (2020). Compressive strength of concrete using fly ash and rice husk ash: A review. *Civil Engineering Journal (Iran)*, *6*(7), 1400–1410. https://doi.org/10.28991/cej-2020-03091556

[6] Karthika, R. B., Vidyapriya, V., Nandhini Sri, K. V., Merlin Grace Beaula, K., Harini, R., & Sriram, M. (2020). Experimental study on lightweight concrete using pumice aggregate. *Materials Today: Proceedings*, *43*, 1606–1613. https://doi.org/10.1016/j.matpr.2020.09.762

[7] Kumar, S. M., Kirti, C., & Kumar, S. A. (2020). *Experimental Study of Light Weight Concrete*. *3*(Ii), 90–95.

[8] Law Yim Wan, D. S., Aslani, F., & Ma, G. (2018). Lightweight Self-Compacting Concrete Incorporating Perlite, Scoria, and Polystyrene Aggregates. *Journal of Materials in Civil Engineering*, *30*(8), 04018178. https://doi.org/10.1061/(asce)mt.1943-5533.0002350

[9] Naveen Kumar, K., Vijayan, D. S., Divahar, R., Abirami, R., & Nivetha, C. (2020). An experimental investigation on light-weight concrete blocks using vermiculite. *Materials Today: Proceedings*, *22*(xxxx), 987–991. https://doi.org/10.1016/j.matpr.2019.11.237

[10] Tiwari, P., Chandak, R., & Yadav, R. K. (2014). “Effect Of Salt Water On Compressive Strength Of Concrete.” *Journal of Engineering Research and Applications Www.Ijera.Com*, *4*(4), 38–42. www.ijera.com

[11] Vafaei, D., Hassanli, R., Ma, X., Duan, J., & Zhuge, Y. (2021). Sorptivity and mechanical properties of fiber-reinforced concrete made with seawater and dredged sea-sand. *Construction and Building Materials*, *270*(xxxx), 121436. https://doi.org/10.1016/j.conbuildmat.2020.121436

[12] Younis, A., Ebead, U., Suraneni, P., & Nanni, A. (2018). Fresh and hardened properties of seawater-mixed concrete. *Construction and Building Materials*, *190*(September), 276–286. https://doi.org/10.1016/j.conbuildmat.2018.09.126

[13] CIDB. (2021, April 19). *CIDB Malaysia*. Retrieved from CIDB.gov.my: https://www.cidb.gov.my

[14] DOSM, D. o. (2019, May 10). *Departmen of Statistics Malaysia Official Portal*. Retrieved from Departmen of Statistics Malaysia Official Portal Web Site: https://www.dosm.gov.my

[15] JKR. (2020). *PELAKSANAAN SISTEM BINAAN BERINDUSTRI (IBS) DALAM.* Kuala Lumpur: Perbendaharaan Malaysia.