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The effects of seaweed powder to the properties of polymer modified concrete

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Abstract. *Eucheuma Cottonii* is a sea plant that commonly known as seaweed grows abundantly and part of the products in agricultural industries. The effects of alginate from seaweed benefited the properties of composites due to its advantage as a hydrophilic gelling material. This paper investigates the effects of *Eucheuma Cottonii* in polymer modified concrete. The investigations covers on the physical properties and mechanical properties of the polymer modified concrete based on different percentages of seaweed powder. The percentages chosen are 10%, 20%, 30%, 40% and 50% cement replacement inside polymer modified concrete. The effects on the seaweed powder percentage to the properties of polymer modified concrete are determined through microstructural, water absorption, pulse velocity, compressive strength and indirect tensile strength. Findings from the experimental works show that an optimum seaweed powder percentage into polymer modified concrete is 20% with improvement shows from the mechanical properties. It can be concluded that, seaweed powder potentially acted as a binder in polymer modified concrete and suitably chosen as a sustainable material inside polymer modified concrete.

1. Introduction

Sea plant, seaweed is seen could be integrated with Portland cement in concrete to form modified-polymer concrete [1-4]. This is due to the potential properties of seaweed as an admixture to modified polymer concrete properties [5-9]. This alternative material initially produce from a natural material will definitely increase the concrete value as it is possibly promoted green material, less energy consumption and less carbon emission due to its cement replacement ability. In this current research, *Eucheuma Cottonii* (seaweed powder) is introduced as an admixture to modified concrete compositions. This innovation is a breakthrough of conventional polymer concrete that used typical polymers such as potassium silicate, epoxy or vinyl ester [10]. This type of sea plant is a carbohydrate polymer that normally being used in a food and pharmaceutical industries. Currently, the seaweed agricultural industry can produce a millions of tonnes to support the food industries in making sushi wrapping and fillings, and to the cosmetic industries as well. In general, sea plant contains agarose which characterized by thickening agents under the polysaccharide polymeric carbohydrate molecules. It may belong to three division which are; red algae (Rhodophyta), brown algae (Phaeophyta) and green algae (Chlorophyta). The success in integrating seaweed as a new binding material inside concrete would significantly contributes to environmental friendly material and could benefit the construction industry. Currently, there are limited works that was reported on the potential of seaweed

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modified concrete. Retno Susilorini *et al.* (2014) have used two types of seaweed known as Eucheuma Cottonii (seaweed gel) and Gracilaria Sp. (seaweed powder) in mortar to investigate the mechanical properties of modified mortar [2]. It was found that an addition of seaweed powder increased the compressive strength up to 20% as compared to the plain mortar. While, up to 80% tensile strength enhancement is expected to the modified mortar. This is a good sign of seaweed potential as construction material as the improvement to the strength is mainly contributed from an excellent bonding mechanism of seaweed modified mortar. On the other hand, Praveena and Muthadi (2016) have highlighted the benefits of seaweed as construction materials on better water retention, high density, excellent fire and alkaline resistance, and good thermal insulation material [3]. Kulkarni and Muthadi (2017) also raised an advantage of seaweed in carbon dioxide fixation from cement and durability improvement in terms of the water absorption and permeability [1]. To that, seaweed is best alternative to the polymer concrete as its ability beyond the purpose of polymer concrete, filler and water repellent. An experimental work that is conducted by Ramasubramani *et al.* (2016) also found the benefits of seaweed addition into concrete which shows an improvement to the tensile and flexural strength at 8% seaweed addition [4]. Other previous works also found the benefits of seaweed addition with improvement to the chemical and mechanical properties [5-9]. Considering all the related previous works, this current research work focused on investigates the optimum percentage of seaweed powder modified concrete in a scope of microstructural and mechanical behaviours.

2. Materials and Methods

2.1 Materials

The *Eucheuma Cottonii* is obtained from Sabah, a northern portion of Borneo. The seaweed powder is creamy in colour, and is a raw powder product of marine algae. This seaweed powder is considered as an admixture and replacing cement at certain proportions as a binder. At the same time, Portland cement is also used as a control binder material. The mix proportion of the cement to fine aggregate ratio is 1:1.6 with water to cement ratio of 50%. The seaweed proportions varied from 10, 20, 30, 40 and 50% of cement replacement. The design strength for control specimen is 35 N/mm^2. The concrete mixing process is conducted in a laboratory with room temperature of 28 ± 2 ºC. Table 1 shows the specimens prepared for this research work with related material compositions. The specimens for seaweed modified concrete (SMC) are prepared for 150 x 150 x 150 mm cubes and 150 mm diameter x 300 mm height cylinders. The specimens are cured in water until test day at 1 day, 3 days, 7 days and 28 days aged. There are a total of 90 cubes prepared for compressive strength test, ultrasonic pulse velocity test and water absorption test, and 18 cylinders prepared for the splitting tensile strength test.

Table 1. Mix proportions for polymer modified concrete (kg/m^3)

Specimen	Aggregate		Binder		Water
	Coarse	Fine	Portland cement	Seaweed powder	
PMC	1097	673	420	-	210
PMC-1	1097	673	378	42	210
PMC-2	1097	673	336	84	210
PMC-3	1097	673	294	126	210
PMC-4	1097	673	252	168	210
PMC-5	1097	673	210	210	210

2.2. Testing Procedures

The elemental compositions of seaweed powder are investigated using Energy dispersive X-ray Analysis (EDX). The EDX is an attachment to the electron microscope equipment to identify the elemental compositions. The elemental compositions are showing by peak of spectra of the true compositions of the sample. The compressive strength test is conducted based on standard BS EN 12390-3 testing of hardened concrete, while BS EN 12390-6 for the tensile splitting strength of concrete [11-12]. BS 1881-122:2011 standard is used for the water absorption test of the specimens. BS EN 12504-4:2004 is used for the ultrasonic pulse velocity test [13-14]. Figure 1 shows the compressive strength test using Matest 3000 kN compression testing machine and ultrasonic pulse velocity equipment.

(a) Compressive strength test (b) Ultrasonic pulse velocity test equipment

Figure 1. Mechanical properties and Pulse Velocity tests

3. Results and discussions

3.1 Physical Properties and Elemental Compositions of Eucheuma Cottonii

The physical properties of *Eucheuma Cottonii* is investigated in this research using seaweed powder samples. It was found that the moisture content of the seaweed powder is 12% with water gel strength of 700 g/mm^2. This gel strength is much more higher compared to normal strength of 6 g/mm^2. The higher gel strength strengthen the properties of *Eucheuma Cottonii* as a Carrageenan polysaccharides to promote excellent binding element [15-16]. It has a pH value of 12 that shows it properties as an alkaline material. As compared to the pH of Portland cement of 11, the *Eucheuma Cottonii* has a bit higher value. Even though, this pH value is believe could still introduced an alkaline environment to the composite. The order of twelve chemical elements found from the EDX is C > O > K > S > Cu > Ca > Na > Mg > Cl > Si > Al > Fe. The main chemical elements that contributed to the polysaccharides are Potassium (K), Calcium (Ca), Sodium (Na) and Magnesium (Mg). It was found from the EDX results that the contents of Potassium is higher compared to other elements and thus concludes the excellent gel strength for the *Eucheuma Cottonii.*

3.2 Water Absorption of Seaweed Modified Concrete

The water absorption of SMC is given in Figure 2. The water absorption of control concrete is 7.2%. Whereas, further addition of seaweed at 10% and 20% in replacing the Portland cement have reduced the water absorption at 6.4% and 5.6%, respectively. Further replacement of Portland cement with seaweed powders has increased the water absorption to 6% and up to 6.9% at 50% replacement. These shows that the seaweed powder have the ability to produce a commercial quality of modified concrete with values of water absorption that less than 7%. Furthermore, the SMC at 20% seaweed percentage shows a very good quality of modified concrete based on the water absorption. It was believed that a low water absorption of the SMC capable in producing a better quality of modified concrete considering its excellent behaviour in water absorption.

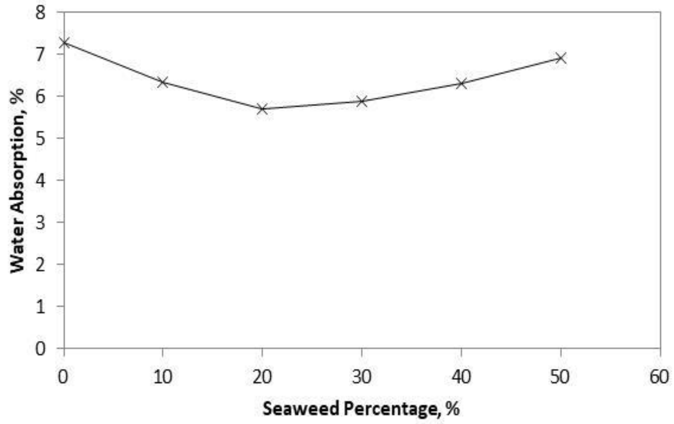

Figure 2. Relationship between water absorption and seaweed percentages of modified concrete

3.3 Ultrasonic Pulse Velocity Test Results

The ultrasonic pulse velocity test is conducted for cube specimen for all SMCs to evaluate the concrete quality and to proof the investigations obtained for experimental tests. The UPV test is conducted at 1 day, 3 days, 7 days and 28 days cube aged. It was conducted for three cube specimens for each seaweed powder percentages. The pulse velocity is calculated based on a ratio between specimen width and the time taken of the pulse to go through the other side of the cube specimen. The UPV test results are plotted in Figure 3 for all test ages. It was found that the higher velocities exhibited by SMC at 20% seaweed percentage for all specimen test ages. Further additions of seaweed percentage to the modified concrete have reduced the velocities lower than control cube at 40% and 50% addition, at 28 days. This is somehow proof the observations got in the water absorption section. The SMC with 20% seaweed percentage replacement shows a very good quality of modified concrete and is proven through the higher velocity in the UPV test.

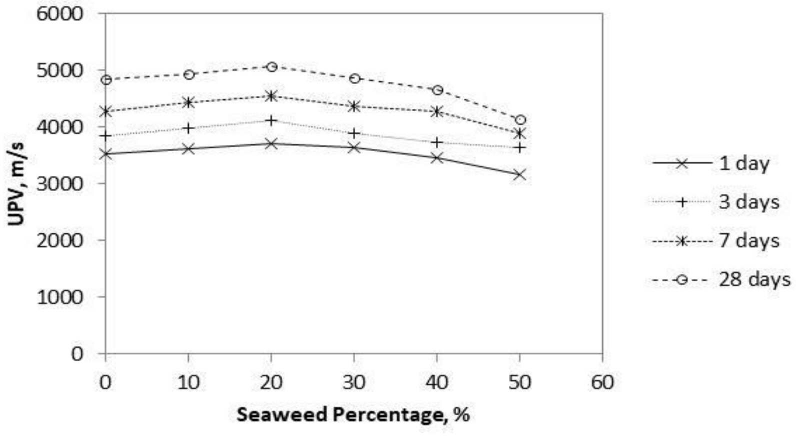

Figure 3. Relationship UPV and seaweed percentages of modified concrete

3.4 Mechanical Properties of Seaweed Modified Concrete

The mechanical properties tests of seaweed modified concrete are carried out for the compressive strength and tensile strength. Figure 4 and 5 show the compressive strength and the strength contributions, respectively. From the findings, it shows that the higher contribution of the compressive strength is obtained at 20% seaweed percentage. The enhancement can be obtained as high as at 25% as compared to the control at 28 days aged. Besides, as early as at 7 days aged, the 20% seaweed percentage capable of meeting the design strength for 35 ± 5 N/mm^2 compressive strength. This is in agreed with findings obtained from previous research which shows that an alginate that contains in the seaweed able to stabilize a composite with higher compressive strength (Leon-Martinez et al., 2013 and Heidari et al., 2015). The stabilization process is obtained from the hydrophilic gelling material in seaweed.

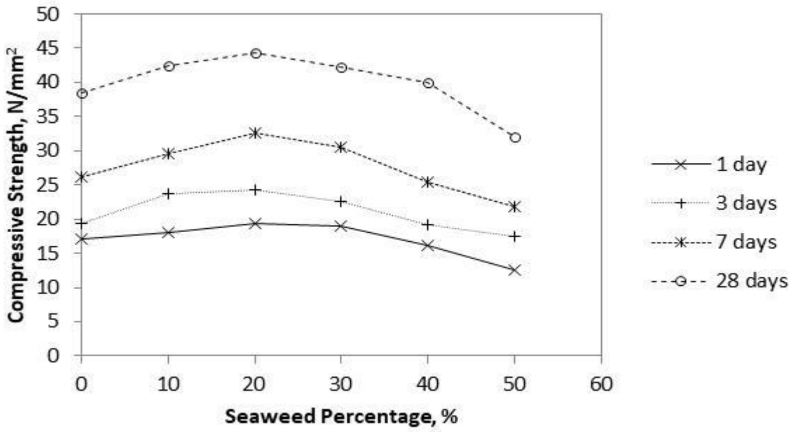

Figure 4. Relationship between compressive strength and seaweed percentages of modified concrete

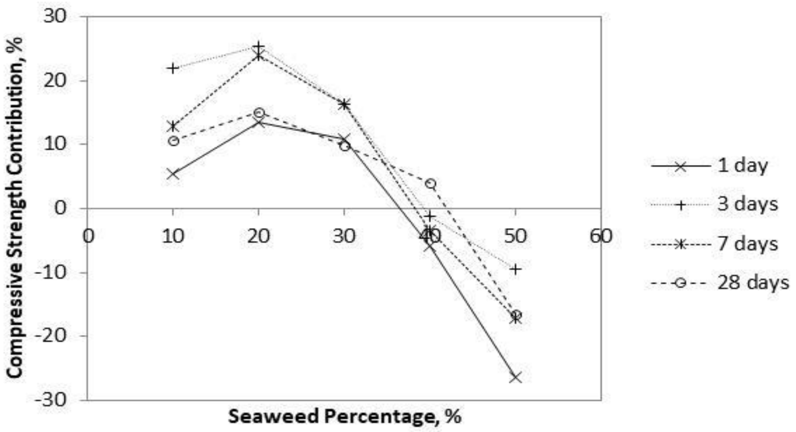

Figure 5. Relationship between the compressive strength contributions as compared to the control

The tensile strength of a SMC is obtained from indirect tensile splitting strength of a cylinder. The tensile strength test results are shown in Figure 6. While, Figure 7 shows the contributions of every seaweed percentage to the tensile strength of the modified concrete. It was found that the positives contribution can be seen at 10% and 20% seaweed powder additions. Further addition at 40% and 50% addition have no significant contribution to the modified concrete. This is a good sign of seaweed modified concrete as improvement to the tensile strength is a new breakthrough of modifying the concrete properties. This significant finding is believed due to the improvement to the binding properties in between the composite constituents. Seaweed powder has the ability to promote an excellent adhesion to the aggregates surrounding it. It has the capability to fill in the gaps in between the aggregates and succeeding improves the tensile performance.

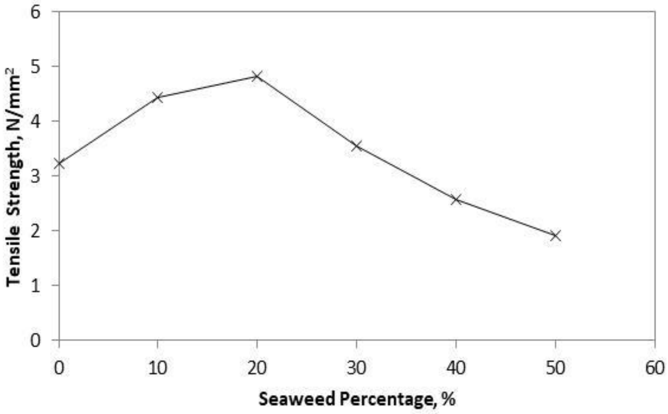

Figure 6. Relationship between tensile strength and seaweed percentages of modified concrete

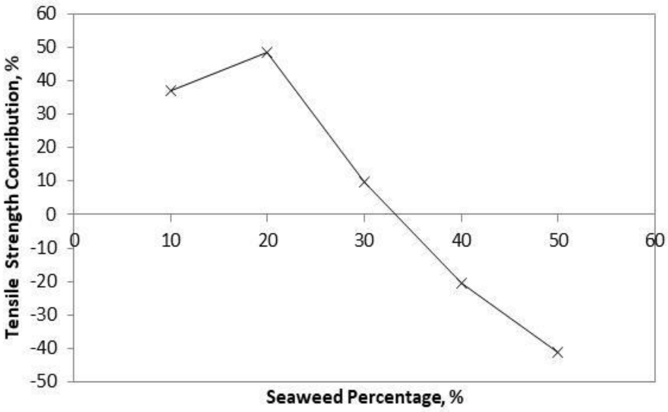

Figure 7. Relationship between the tensile strength contributions as compared to the control

4. Conclusions

In conclusions, *Eucheuma Cottonii.* observed as a potential cement replacement in polymer modified concrete. It will act with cement to form a strong and excellent binding agent for all constituents inside the polymer modified concrete. An optimum percentage of the seaweed powder is at 20% cement replacement. As further percentage addition, will cause a less significant to the properties and strength of the modified concrete. The observed potential of seaweed polymer modified concrete is determined through test results shows from the physical properties and mechanical properties of the composite which are water absorption, pulse velocity, compressive strength and tensile strength.

Acknowledgments

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